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RESEARCH ARTICLE

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Leveraging AI-enabled 6G-driven IoT for sustainable smart cities

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Summary

Many scholastic researches have begun around the globe about the competitive technological interventions like 5G communication networks and its challenges. The incipient technology of 6G networks has emerged to facilitate ultrareliable and low-latency applications for sustainable smart cities which are infeasible with the existing 4G/5G standards. Therefore, the advanced technologies like machine learning (ML), block chain, and Internet of Things (IoT) utilizing 6G network are leveraged to develop cost-efficient mechanisms to address the issues of excess communication overhead in the present state of the art. Initially, the authors discussed the key vision of 6G communication technologies, its core technologies (such as visible light communication [VLC] and THz), and the existing issues with the existing network generations (such as 5G and 4G). A detailed analysis of benefits, challenges, and applications of blockchain-enabled IoT devices with application verticals like Smart city, smart factory plus, automation, and XR that form the key highlights for 6G wireless communication network is also presented. In addition, the key applications and latest research of artificial intelligence (AI) in 6G are discussed facilitating the dynamic spectrum allocation mechanism and mobile edge computing. Lastly, an in-depth study of the existing open issues and challenges in green 6G communication network technology, as well as review of solutions and potential research recommendations are also presented.

KEYWORDS

artificial intelligence, blockchain, green 6G, internet of things, smart city, spectrum technologies

1 | INTRODUCTION

1.1 | 6G background study

The 6G is the upcoming generation in the evolution of wireless network technology. The 6G network technology will explore and improvise new architectures, mechanisms, concepts, and protocols to the current network technology. An architectural shift in paradigm is observed with the advancement from 1G to 5G with new generations coming in a gap of every 10 years known as the 10-year rule. The current 5G network technology has major challenges relating to security and privacy which makes it very limited in usage. Also, quality of experience (QoE) optimization is needed in the 5G network technology which will be reinforced in 6G.[1] 6G will offer support and a potential improvement to newer spectrum technologies like visible light communication (VLC) and THz communication. The 6G is benefitted further by using sub-THz wireless transceivers and imaging circuits involving modeling system and communication network theory. New materials and matter being less lossy can provide better system performance. These spectrum technologies have been discussed in depth in our survey explaining the differences and developmental details leading to the upgrade in network communication.

1.2 | Technological developments in network generations

Before the birth of 1G, in the 1980s, analogous systems were introduced for communication having only speech transmission. The wireless generations were first developed in late 1980s.[2] 1G network generation used analog signals for transmission and provided a data rate to a maximum of 2.4 Kbps.[3] The main problems of the first-generation (1G) technology were its inadequate security and transmission power. In response to these challenges, the second-generation (2G) technology was developed, aiming to address the issue of low transmission efficiency. This was achieved by implementing digital modulation mechanisms such as code division multiple access (CDMA) and time division multiple access (TDMA) in 2G. 2G supported MMS, SMS, speech services, and peer-to-peer networking (P2P),[4,5] but it failed in processing video streams efficiently. 3G was introduced to increase data transmission rate to a maximum of downlink 64 and uplink 25 Mbps.[6] The 4th generation network saw IP (Internet protocol) integration and improvement in service quality and security.[6] 4G saw an increase in data rate to 1 Gbps. 4G supported video chats and high definition (HD) TV. 4G saw the usage and introduction of orthogonal frequency division multiplexing (OFDM) and multiple input multiple output (MIMO).[7] 5G increased the energy and spectral efficiency.[6,8] There exist three important scenarios in 5G being massive machine-type communications (mMTC), ultra reliable low latency communications (URLLC), and enhanced mobile broadband (eMBB).[9–11] The mMTC framework used in 5G supports a huge number of connected devices increasing the scalability.[10] The eMBB provides high data rates to a maximum of 1 Gbps and operates in spectrum frequency bands having high bandwidth of over 6 GHz.[10] In and after 5G, the major change in comparison to 4G and 3G would be URLLC. The most important part is the focus of URLLC on Internet of Things (IoT) which would lead to development in automotive traffic, Industry 4.0, and robotics. Due to the URLLC advantage of requiring low latency, the need for flat architecture is critical. 6G will have integrations with many upcoming technologies like Blockchain, IoT, and artificial intelligence (AI). Figure 1 shows the transformational technologies in 6G and their overlaps.

1.3 | Blockchain and IoT technologies in 6G

Blockchain is used for providing security mechanisms in 6G. Blockchain uses decentralization to overcome various IoT challenges. Blockchain and IoT are upcoming technologies for creation and integration of the applications to share the inherent attributes. Blockchain's transparency and decentralization make the processing robust in 6G wireless systems. Systematic resource allocation is also an advantage of blockchain. In 6G network technology, the security offered by blockchain will need to be more enhanced and be adaptive based on the location, nature, and capability of the application. Mobile edge access and cloud storage systems are the cutting-edge technologies that are benefitted from blockchain. The issues related to latency need to be taken care in blockchain. In the future, latency-related issues need to be taken care in blockchain. IoT system includes huge volumes of data associated with power, network connection, and storage requirements to deduce meaningful information from the data. As the number of IoT devices and pairables increases, there are higher demands for an information security system. Hence, blockchain and IoT systems go hand in hand by ensuring holistic security and privacy approaches for more than 50 billion devices connected through IoT systems and 6G. Also, integration of AI with IoT devices introduces new concept of Internet of Intelligent Things (IoIT). There exist several existing works on the development and the integration of blockchain with IoT. In the previous works, blockchain protocols with IoT did not typically consider the challenges involving delays and bandwidth overheads. This survey analyzes the main challenges in integration of Blockchain with the IoT technologies in network communication by explaining the major issues and limitations of the IoT and Blockchain technologies.

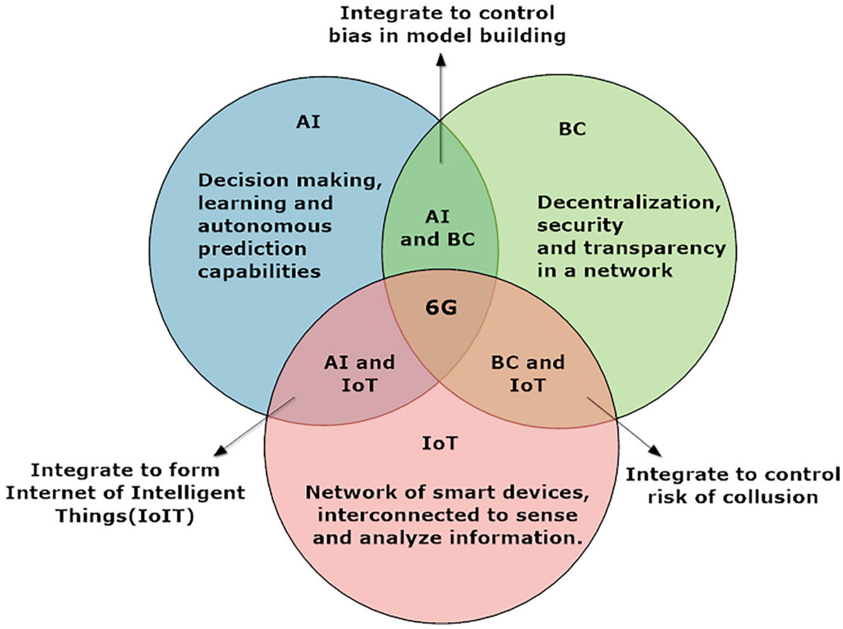


FIGURE 1 Transformational technologies in 6G.

1.4 | Smart city and home infrastructure with IoIT in 6G

Smart city infrastructure refers to a design of the quality of life of the people by using the optimization techniques for operations and resources to make the city prosperous by analyzing and integrating core components. In 5G, the everyday necessities and activities are individually intelligent, but they are not completely integrated as a smart unit. These activities and utilities include transportation, water, waste management, and healthcare. The 6G will have a complete integration with these smart activities and utilities to make it a smart city. The infrastructure of the IoIT will enable the creation of a smart home environment, where the entire home functions as a comprehensive and interconnected smart system. Various components within the home possess computational capabilities that allow real-time monitoring and assessment of necessities such as water, heating, and other resources. The waste and leakages will also be avoided by intelligent mechanism in a smart home. Additionally, the smart home also behaves as an automated ecosystem by controlling and integrating the working of a huge number of devices. The controlling is done through various protocols like Wi-Fi or Bluetooth. Also, chips designed to think like a human brain are especially attractive solution. These chips combine lot of nanosensors and data to take a decision with the help of AI. Hence, IoIT will be an important feature for smart home and smart city infrastructure benefiting from speech and other sensory communications.

1.5 | AI's evolution through network generations

AI has become a highly researched technology. It is extensively used to overcome many real-time challenges in network communication like congestion control, routing, and in safeguarding the privacy over a network. Traditionally, AI has been used for network diagnosis and monitoring networks.[20] Recently, AI has been used to optimize topology of networks using many heuristic algorithms. AI was first integrated in the 5G wireless network technology paving the way and has been used in planning, optimizing, provisioning, and securing networks. In 5G, AI was only partially supported but lead to the emergence of many applications such as[21–24] in communication technology. There has been a major interest in the research of integration of AI with 6G. In 6G, AI will improve the performance of resource allocation tasks by lowering the latency and delay. Integration of AI with BC and the usage of deep reinforcement learning will lead to an increase in the quality of service (QoS) making resource sharing over the network more flexible and scalable.[25] Figure 2 illustrates the blockchain-based 6G architecture for P2P trading to depict the integration of AI with BC. This survey explores the concepts of 6G and AI together, integration of AI with 6G, and future challenges and open

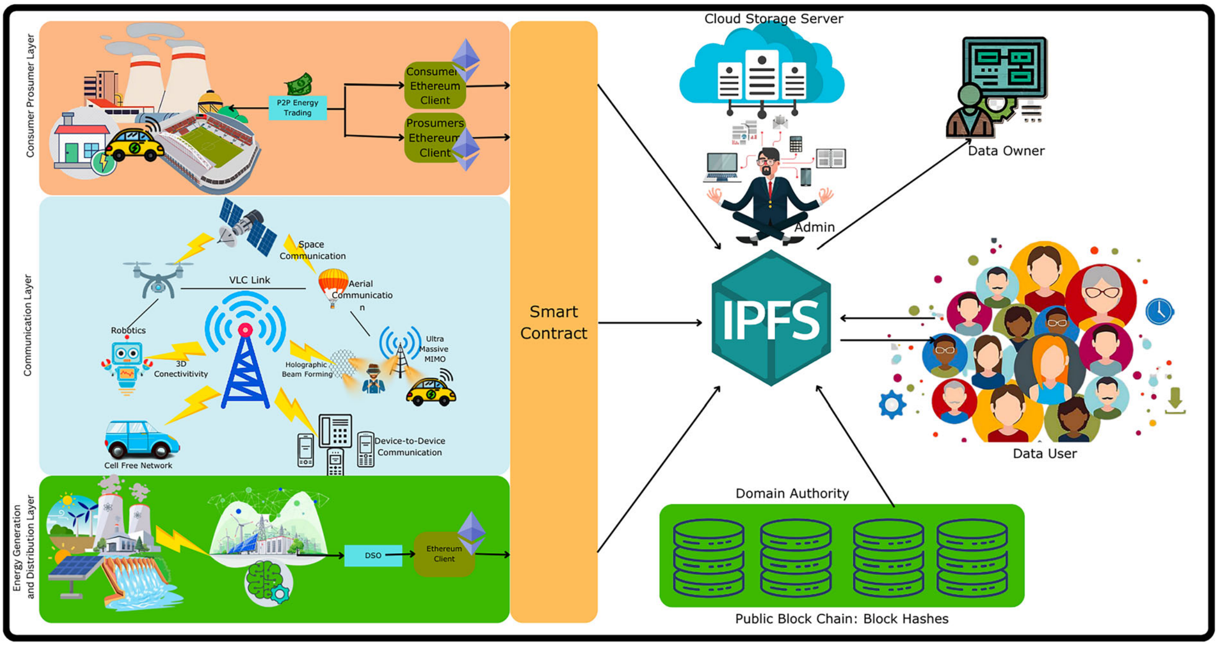


FIGURE 2 Blockchain-based SG architecture for P2P trading.

issues in AI and 6G network technology. Tables 1 and 2 give the details of the comparison of the surveys and the upcoming technologies introduced in them.

There are two types of challenges in 6G network, that is, technical and nontechnical, and the major open issues in 6G will exist because of the characteristics and inherent limitations of the internet. (Table 3) Newer internet protocols and architectures are expected to overcome these challenges in 6G technology. The list of abbreviations for the major jargons used in this survey is presented in Table 4. This survey explains the various challenges and limitations of 6G and also solutions to overcome them by the use of cell-less architecture, secure model, and smart energy harvesting. A total of 150 research papers and technical articles were selected pertaining to 6G and AI, blockchain and IoT from Springer, IEEE Xplore, ACM Digital Library, Science Direct, Elsevier,[29,30] and so on. The structural and organizational roadmap of the sections of this review paper is presented in Figure 3.

1.6 | Objectives and contributions of this survey study

Currently, several survey papers are being examined on 6G. However, 6G and its integration with upcoming technologies like blockchain, AI, and IoT are not addressed anywhere together in one review paper. Our review paper provides a comprehensive study that integrates the state-of-the-art research work in the literature. The key contributions of this review paper are as follows:

- Description and comparison of the evolution and development of wireless network technologies from 1G to 5G with the modulation mechanisms and technologies in each generation.
- Explanation of the architectural paradigm shift by the development of 6G network technology and analysis of core technologies in 6G like spectrum technologies, that is, VLC and THz communication.
- Detailed analysis of contributions and limitations of blockchain-enabled IoT with 6G wireless communication network.
- Comprehensive analysis of the applications and research challenges of Blockchain in IoT-enabled 6G devices especially for smart grid and manufacturing.
- In-depth study of AI network enabled with 6G technology, techniques, and applications of AI and state-of-the-art research in AI with 6G.
- Exploration of the major open issues and challenges in 6G and analysis of the solutions and future research guidelines in green 6G communication network technology.

TABLE 1 Comparison of our survey with existing papers.

State of the art	Year	Aim	Key features	Demerits	6G focused	AI focused	BC focused
Giordani et al. [12]	2020	Described the innovations which might transform upcoming 6G networks	It went through several scenarios in which 6G could be extremely useful.	The use of AI to increase the dependence in the 6G wireless network has not been addressed.	√	x	x
Yang et al. [13]	2019	Demonstrated the AI-enabled smart 6G framework as well as its functionality.	In-depth discussion of AI-enabling 6G design and its utility in 6G scenarios.	The taxonomical study is absent, as is the application of AI in dynamic spectrum allocation.	√	√	x
Zong et al. [14]	2019	To demonstrate a novel 6G device architecture.	The shortcomings of 5G were explored, and new 6G application scenarios were introduced.	AI and design focused solely on photonics are covered.	√	√	x
Saad et al. [15]	2019	To promote more innovative 6G study topics	Future 6g implementations and their associated technology are the emphasis.	The design, workings, and structure of the 6G network are not emphasized.	√	√	x
Yastrebova et al. [16]	2018	Potential problems and applications that can be addressed by a 6G network are presented.	It demonstrated how 6G network proposed framework could be in the future.	The function of AI in 6G is not discussed.	√	x	x
Strinati et al. [17]	2019	To give a detailed overview of 6G.	Detailed discussion of the shortcomings of 5G and the necessity for 6G.	There was no thorough evaluation of Ai techniques in 6G.	√	x	x
Zhang et al. [18]	2019	To clarify main 6G innovations and look at how 6G networks could be used in the future.	Stated role of mobile ultra-broadband, AI, and IoT could aid 6G networks in meeting their objectives.	Architecture and hardware design are not listed.	√	√	x
Zhao et al. [19]	2019	To show the results of a survey study on 6G Smart Reflecting Surfaces.	Analyzed latest feedback and summarized potential issues in IRS area for 6G	Absence of a clear 6G design focused on IRS, as well as AI participation in their research	√	√	x
Proposed Survey	2021	To provide detailed survey of 6G architecture, its applications and role of Blockchain, AI, and IoT in 6G scenarios.	Analyzed BC, IoT, AI, Big Data Analytics for 6G Network Systems in Smart City and offered Green 6G solutions.	In depth analysis of techniques like Reinforcement Learning and Q-Learning needed	√	√	√

TABLE 2 Comparison of recent existing methods.

Technique	Features	Challenges	Prospectives
DEHM[26]	Due to its effectiveness and resilience, it has the potential to be utilized in edge/cloud cyberspace for achieving an optimal solution.	Premature convergence and search stagnation	The adaptive mutation factor can be adopted for catering variable workload
IADE[27]	Employed to discover an optimized solution in real-world multidimensional applications such as 5G/6G devices. Highly efficient, robust, and facilitates seamless connectivity for terrestrial networks.	Slow convergence during later iterations, heavy reliance on parameters, and susceptibility to getting stuck in local optima	Can be implemented in extensive network intelligence, along with a networked data center, to enhance network sustainability and enhance service quality for various resource-constrained devices.
AFED-EF[28]	Tackles the problem of load fluctuations and enhance energy efficiency in the provisioning of virtual machines (VMs) by simultaneously redirecting incoming traffic to suitable resources for optimizing the QoSs.	Does not cater to the nonuniform traffic patterns.	Network bandwidth allocation can be done and incorporating microservices for variable spatio-temporal IoT demands.

TABLE 3 Comparison among 4G, 5G, and 6G network technology.

	4G	5G	6G
Network specific characteristics	Flat and all-IP	• Virtualization • Slicing • Network cloudization • Softwarization	• Virtualization • Slicing • Intelligentization • Network cloudization • Softwarization
Service focus	Users	Connectivity	Interaction among humans and world
Usage structure	• MBB	• eMBB • URLLC • mMTC	• FeMBB • ERLLC • LDHMC • umMTC • ELPC
Technological advancements	• D2D communications • Unlicensed spectrum technology • Carrier type aggregation • Turbo Code • ICIC • OFDM • MIMO	• LDPC and polar codes • NOMA • mm-wave communication technology • Massive MIMO • Edge/fog/cloud computing • SDN and Network Slicing • Flexible Frame Structure	• OAM multiplexing • VLC and laser Communication • ML/AI • THz communication Technology • Blockchain-assisted spectrum sharing • Quantum computing and communications • SM-MIMO • HBF and LIS
Network energy efficiency	1 time	1 time	10-100 times that of 5G
Maximum rate of data	102 Mb/s	2x101 Gb/s	=1 Tb/s

TABLE 3 (Continued)

		4G	5G	6G
	Spectrum efficiency	1 time	3 times that of 4G	5 to10 times that of 5G
	Latency	101 ms	1 ms	101 to 102 μs
KPI	Mobility	3.5 * 102 kmh-1	5*102 kmh-1	= 103 kmh-1
	Area wise traffic capacity	10-1 Mb per second per square meter	101 Mb per second per square meter	101 Gb per second per square meter
	Connectivity density	105 Devices per square km	106 Devices per square km	107 Devices per square km
	Experienced rate of data	10 Mb per second	10-1 Gb per second	1 Gb per second
Applications		• Speech services • Mobile internet • Mobile-specific payment methods • Mobile television • HD videos	• VR/AR/UHD type videos • IoT • Smart city and smart homes • Smart wearables • V2X	• Industrial internet • Space travel • Holographic verticals and society • IoV and UAV • Deep-sea networking • Internet of nanothings • Digital sensing and reality in full-sensory mode

TABLE 4 List of used abbreviations.

ASR	Automatic speech recognition
BC	Blockchain
CDMA	Code division multiple access
CNN	Convolutional neural network
DNN	Deep neural networks
DQN	Deep Q-network
eMBB	Enhanced mobile broadband
FDD	Frequency division duplex
FL	Federated learning
HOG	Histogram of oriented gradients
IoE	Internet of everything
IoT	Internet of things
KCF	Kernelized correlation filters
KNN	k-nearest neighbors
L-SVM	Linear support vector machine
LSTM	Long short-term memory
MAC	Medium access control
MDP	Markov decision process
MEC	Mobile edge computing
MIMO	Multiple input multiple output
ML	Machine learning
mMTC	Massive machine-type communications
MMS	Multimedia messaging service

(Continues)

TABLE 4 (Continued)

MRA	Multi-radio access
NOMA	Non-orthogonal multiple access
OFDM	Orthogonal frequency division multiplexing
OWC	Optical wireless communications
PCA	Principal component analysis
QoE	Quality of experience
RF	Radio frequency
RIP	Routing information protocol
RL	Reinforcement learning
RNN	Recurrent neural network
SCF	Spectral correlation function
SCMA	Sparse code multiple access
SDN	Software defined networks
SE	Spectrum efficiency
SMS	Short message service
SVM	Support vector machines
TDD	Time division duplex
TDMA	Time division multiple access
THz	Terahertz
UAV	Unmanned aerial vehicles
VLC	Visible light communication

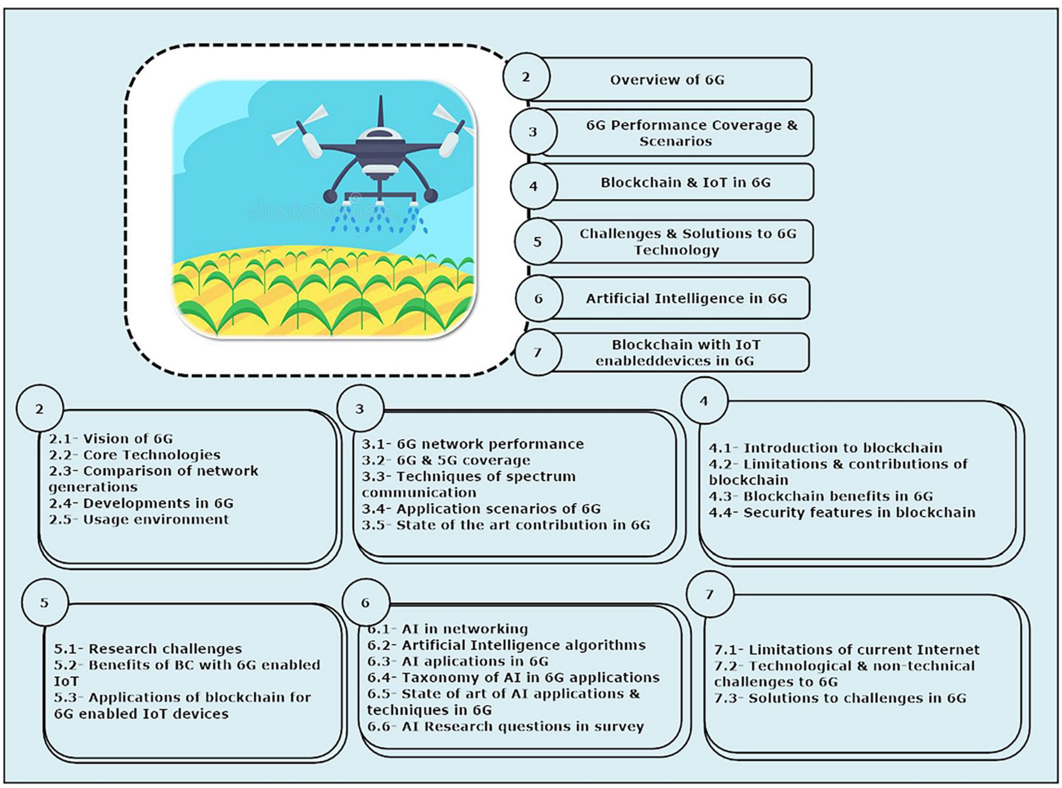


FIGURE 3 Structural organization of the paper.

1.7 | Structure of the survey

The review paper is divided into eight main sections. Section 1 gives the introduction to the main topics discussed in our survey paper which include blockchain, IoT, AI, smart city, and spectrum technologies. Section 2 is the overview to 6G communication network. Section 3 involves the performance, coverage, and scenarios in 6G. This section includes many state-of-the-art contributions in 6G and 6G/5G coverage. Section 4 gives the details of blockchain and IoT in 6G communication network. The next section which is Section 5 involves the integration of blockchain with IoT devices in 6G. Section 6 gives the details of AI in 6G which includes applications, taxonomy, and research questions in the survey. Section 7 focuses on the challenges and solutions to the problems in through green 6G features in 6G wireless communication network. The survey paper is finally concluded with the future research work proposed by the authors. Figure 3 gives the outline structure of the review paper.

2 | ABRIDGEMENT OF DEVELOPMENTS IN 6G ENVIRONMENT

2.1 | Vision of 6G communication

Microwave communications were majorly used over the sub-6G bands, prior to 6G.[31] For the 6G wireless communications terahertz (THz) bands will be the main player.[15,31,32] THz would be utilized for short range and high bit rate communication due to low propagation loss.[33] The exploitation of sub-THz spectrum will also lead to greater wireless network capacity for radio wireless communications.

6G system in the future is expected to support newer services and features like 3D mapping,[34] robust sensing, autonomous vehicular networks, smart wearables and implants, and reality computational devices. This shift is owed to the inception of sub-terahertz (sub-THz), VLC to support 6G applications and devices.[35] Hence, 6G architecture is envisioned to have lower latency and higher data speed.[15] 6G network is also expected to achieve global coverage through the integration of celestial-aerial-terrestrial-aquatic regional networks.[36] AI and Big Data facilitated Vision of 6G comprising of security, coverage, application fields, and spectral technologies is shown in Figure 4.

2.2 | Core technologies of 6G

6G's core technologies and their technical performance are discussed in this subsection. The potential core technologies comprise of wireless communication technology which includes THz communication and VLC; antenna technology

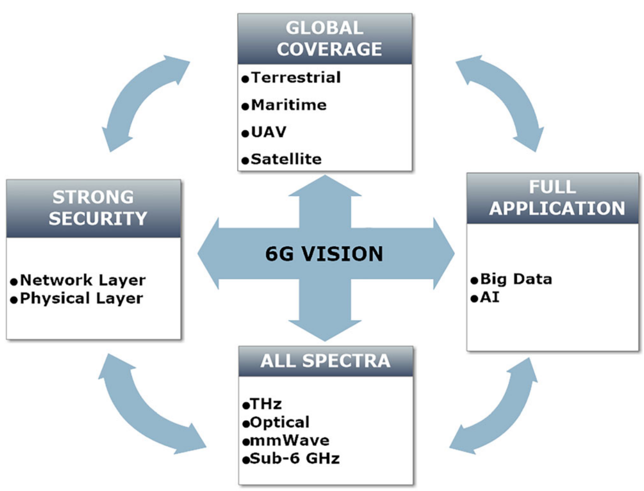


FIGURE 4 Artificial intelligence (AI) and big data facilitated vision of 6G.

and RF technology which includes antenna technology and synthetic materials; channel coding and modulative technologies which includes channel coding, nonorthogonal waves, and multiple access system; spectrum sharing which includes free/full duplex; and dynamic spectrum sharing mechanism and additional integrated new technologies. Figure 5 depicts the core technologies of 6G along with their components.

2.2.1 | Wireless communication technology

THz communication

The THz communication involves the electromagnetic THz waves having frequency in the range from 10–1 to 101 THz. This spectrum lies in-between the microwave light region and the far infrared light region. The advantages of using THz communication in 6G are that it has firstly a high transmission rate and secondly abundant resources in the spectrum. This is in contrast to the previous generations which used microwaves having resource constraints. The increased (Tb/s communication) makes THz communication a suitable choice in future mobile communications owing to the increased wireless broadband access. Owing to the numerous advantages, THz communication technology has become among the top technologies which will enhance the upcoming living. A crucial characteristic of 6G is the suitable application of THz technology over a large number of use cases.[37–40] The THz technologies included in accordance to 6G network and business are as follows:

1. Channel transmission theory, like channel measuring, algorithms, and modeling in THz ground and space communication networks.
2. THz direct, hybrid, and broadcast modulation techniques, signal encoding and advanced modulation techniques, like high- accuracy and high-speed acquisition mechanisms.
3. THz waves have their distinctive characteristics in communication systems and have a lot of benefits than microwave communication and wireless optical communications which were used in the previous network generations. THz waves have wide application prospective in space communication and short-distance and high-speed wireless broadband communication technology[41–44]:
4. THz waves can involve less transmission costs and have a low-power long-distance communication characteristic.
5. THz waves have a greater frequency and a broader information measure that is, bandwidth. Hence, THz will meet the spectrum information measure in wireless broadband transmission providing a communication rate surpassing Tb/s. The THz wave spectrum is between the range 108 and 1013 GHz.

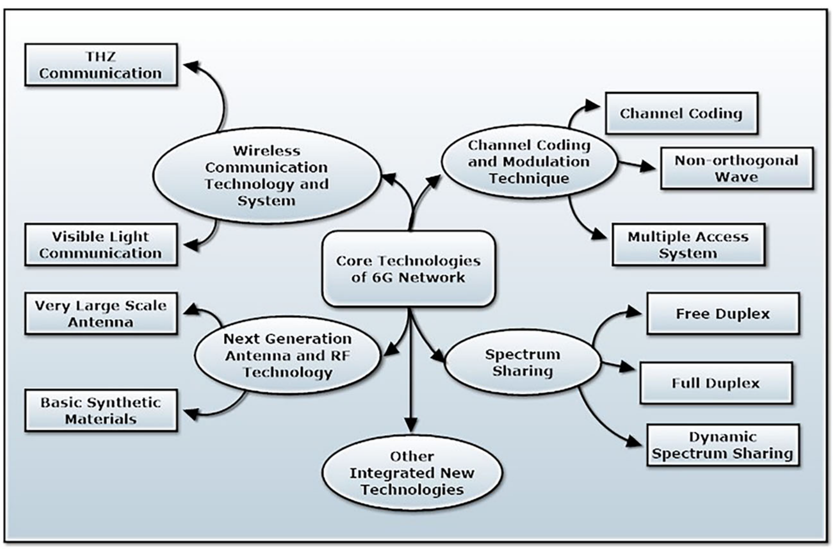


FIGURE 5 Core technologies of 6G along with their components.

6. The short wavelengths within the THz band are appropriate for enormous MIMO with a lot of antenna parts.
7. THz waves will penetrate with less attenuation in matter and are appropriate for communication needs in some selective scenarios.
8. THz waves are highly energy efficient as compared with wireless optical communication, owing to its extremely low photon energy.

VLC

Optical wireless communications (OWC) frequency band includes the major three types of rays which are infrared, visible, and ultraviolet which lie in the RF wireless communication technology. VLC refers to the visible band in the OWC system ranging from 390 to 700 nanometers.[45,46] As compared with radio communication, the advantages of VLC are numerous as follows:

1. VLC technology can offer several potential THz-level bandwidth spectrums.
2. VLC technology is not dependent and affected by external electromagnetic radiation interference effect. Hence, it can be used to eliminate electromagnetic effect and also in areas sensitive to the same like neuro-hospitals, chemical plants, airports, and fuel stations.
3. Visible light cannot pass through obstacles, walls, and other similar objects. Hence, the network is a lot of secure owing to this property of the VLC technology.
4. VLC technology aids the fast growth of upcoming wireless networks by reducing usage and maintenance costs.

2.2.2 | Antenna technology and synthetic material

Antenna technology

Antenna technology is an important technology for wireless communication system having advantage of the spectral efficiency in the world of wireless communication system. In addition to this advantage, it solves technical problems related to the radio frequency fields and cross-bands. It is also a highly efficient, gives complete coverage, and highly integrates to the radio frequency field technology.[14,47–49]

Synthetic material

Metals are used to extract crystalline compounds which have a variety of optical, thermal, and electric properties. These compounds can be used for electromagnetic absorption and prove as a blocker for the same in radio frequency technology. Owing to the advent of meta-surfaces, these materials can be used to leverage space, time, and frequency domains to change the electromagnetic fields. This can be extended to complex imagery tasks and space and satellite communications.[50,51]

2.2.3 | Channel coding and modulative technologies

Channel coding

Channel coding and modulation technologies are used to counter the growing data bands, bandwidth spread and increasing data rates. These technologies are also used to increase the throughput in communication technology. This can further be optimized viewing the complexity of user scenario in the networks.[52–54]

Nonorthogonal type waves and multiple access system

Nonorthogonal communication technology is a new technology which is spectrum efficient and has supreme frequency domain and time domain properties. This technology is highly usable in mobile communications owing to its synchronization between spectrum and carrier and data differentiability using NOMA (nonorthogonal multiple access). The advantages are achieved by combining intermediate carrier data with nonorthogonal waves in 6G network technology. The two important divisions of NOMA are code and power domain NOMA. The future implementations include polarized decomposition and design optimality in the architecture and features of NOMA.[46,48,55]

2.2.4 | Spectrum sharing

Spectrum sharing is an important concept to avoid spectrum resources wastage and adequately dividing resources based on the user networks needs and demands. The spectrum sharing rules are reliable and also stable but can lead to utilization and insufficiency problems. Hence, there is a need to expand and increase the spectral resources and prioritizing demand constrains for the networks. Secondary technologies comprising of database resources and spectral sensing sharing the resources with primary users having spectrum usage rights will lead to dynamic sharing without interference problems.[56]

Free/full duplex spectrum and dynamic spectrum sharing technology

A free duplex mode is a nearly true full duplex mode. These modes are used to tackle spectrum requirements problem. Free duplex mode does not differentiate between the FDD (frequency division duplex) and TDD (time division duplex) architecture in 6G wireless network generation. These architectures are used in the duplex mode; the former is dynamic, whereas the latter comprises most of the frequency band above 2 GHz and is configured only in special scenarios. The full duplex mode has the advantages of lessened transmission delays and improved throughput owing to better and efficient spectral resource sharing.[11,57,58] Dynamic spectrum sharing technology is an intelligent distributed feature to improvise efficiency of spectrum. Integrating this technology with blockchain and AI provides many use cases for its application in 6G networks.

2.2.5 | Additional newer technologies

AI assisted wireless communication network technology

AI has become an important key area for research and applications in real life. The use of high-density data, networks, antennas, and electromagnetic absorbing materials has shaped the integration of AI with wireless communication technology especially 6G.[17,59–61] The deep learning (DL) domain of AI especially has proved to benefit other related areas like bio-informatics, machine learning (ML), and computer vision. Hence, AI can be used to have stable and reliable connections among air, land, and satellite communications. These communications leverage the increasing data supply from multiple users and over multiple networks using different learning techniques. There are various technologies which make use of DL like self-organizing and DL network technology and signal estimation and detection technology which are primarily deployed on DL framework.[19,62,63]

IoT in 6G

IoT in 6G- Intelligent networks like internet perception is a highly developed feature of the IoT. The 6G wireless communication technology involves perception internet with characteristics like obtaining experience, information control, and learning ability. In the recent time, new technology has combined AI with IoT to develop AIotT.[64]

Blockchain and ledger technology

6G network technology can benefit from the blockchain and ledger technology in improving the security and preserving the privacy within the network. Also, network efficiency and improved stability and reliability of network services make integration of 6G and blockchain advantageous. These advantages can be attributed to the fact that blockchain and ledger technology employ anonymity, transparency, decentralization, and information security control against multiple unknown parties.

2.3 | Comparison and collation of network generations

6G network technology will combine a lot of geographically separated networks like mobile, satellite, local, and ocean.[65] New features, protocols, and architecture will lead to solving the existing problems in the current network generation and provide useful solutions by deep, holographic, and intelligent connectivity. DL forms an important part of deep connectivity in addition to deep sensing. Augmented reality, virtual reality, and extended reality (XR) constitute the holographic connectivity. The trends in 6G are as follows.

2.3.1 | Catfish effect

With every network generation, the application domain grows and also includes the previous generations' application areas. In 5G, IoT-related industries are targeted. In the future generations, more industries and application areas are expected to be incorporated with the coverage growing further leading to the so called "Catfish-effect".

2.3.2 | 10-year cycle rules

It has been observed that the previous network generations from 1G to 5G each took about 10 years to develop from the previous generation. Hence, it can be concluded that in 10 years, there is adequate research and development is done to accommodate and move to a new network generation. The 6G is now expected to be introduced and accepted as 5G has been in use for about 10 years. Figure 6 shows the timeline of network generations.

2.3.3 | IoT-based 6G envisioned business potential

5G network generation is the foundation for IoT models applications. The 6G and future generations will see even further expansion and upgradation of 5G networks in various aspects.[14,51,54] 6G will also incorporate improvement in spectrum efficiency, transmission rate, reliability, and latencies. The 6G is also expected to improve IoT-related industries and diversify into multiple network industries. The integration of various networks across air, space, satellite, and land with increased network coverage will also be seen in 6G.[3,66]

2.4 | Technological augmentations in 6G

The previous generations like 4G witnessed main focus on separate network markets; 5G has seen major achievement from improved technology deployment. 6G will see further improvement and development using communication and information technology majorly in three scenarios mMTC (massive machine type communications), eMBB, and URLLC.[10,11,67]

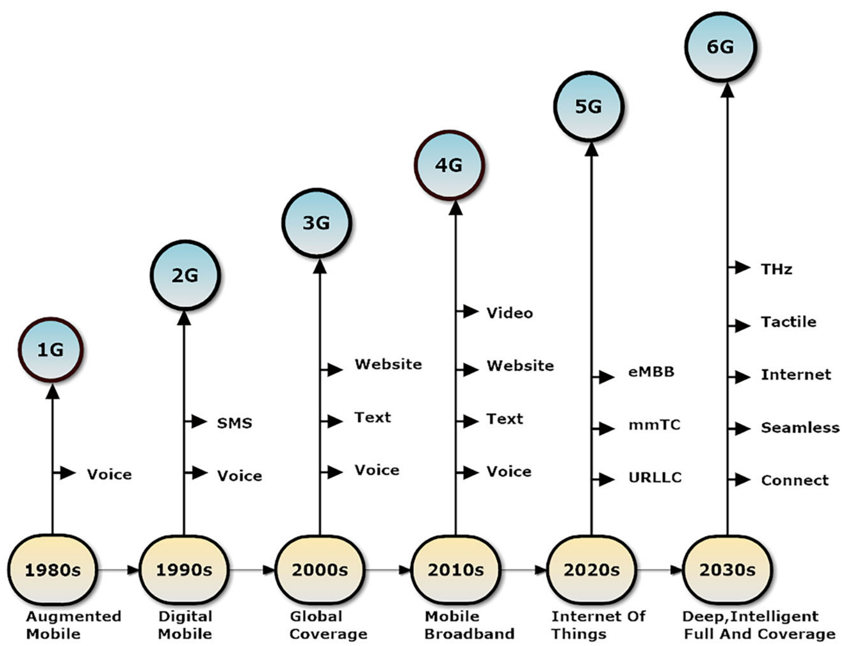


FIGURE 6 Timeline and features of network generations.

6G network technology will witness robust technological improvement using WTI (wireless tactile internet), VLC, and HPC (high performance computing).[36,37] The table below lists the comparisons among 4G, 5G, and 6G network technology. From the table, it can be noted that owing to improvements and augmentations over network efficiency, mobility rate and reliability among other metrics that 6G has better and improved performance over technical metrics.

2.5 | 6G assisted usage environment

6G will support holographic (augmented reality [AR]/virtual reality [VR]/XR) and high precise communications for various application networks like tactile internet. The key drivers leading to increased data volume and transactions are Internet of Everything (IoE) and the mobile Internet. The 6G is also expected to have lower latencies and increased throughput. The following are more features to be supported by 6G.

1. 6G will support high-definition videos like extremely high-definition (EHD) and the super-high-definition (SHD) videos.
2. 6G will have ultralow latencies in Internet and related industries.
3. 6G in addition to IoT will support the Internet of Bodies and Internet of Nanothings using smart wearable devices.
4. 6G will expand network coverage and human reach by supporting deep water and space communication.
5. 6G will enhance and upgrade 5G applications and areas like autonomous vehicular networks.[47]

2.6 | Role of ML in 6G

Figure 7 depicts the role of ML in 6G communications. ML algorithms should be implemented and trained across various levels of the network infrastructure, including the management layer, radio base stations, mobile devices, and core systems. The network itself can assist in this process through device programmability and configurations. At the same time, ML agents can be strategically deployed to optimize physical layer algorithms such as link adaptation, and also, ML agents optimize higher layer algorithms, for instance, mobility. These agents can be deployed in a controlled and probable manner to achieve maximum efficiency. To achieve significant improvements in real-world scenarios, it is crucial to utilize ML tools to enhance the MAC scheduler. Reinforcement learning frameworks prove particularly effective for problems where the network needs to adapt to variable user conditions, such as conditions of channel, and

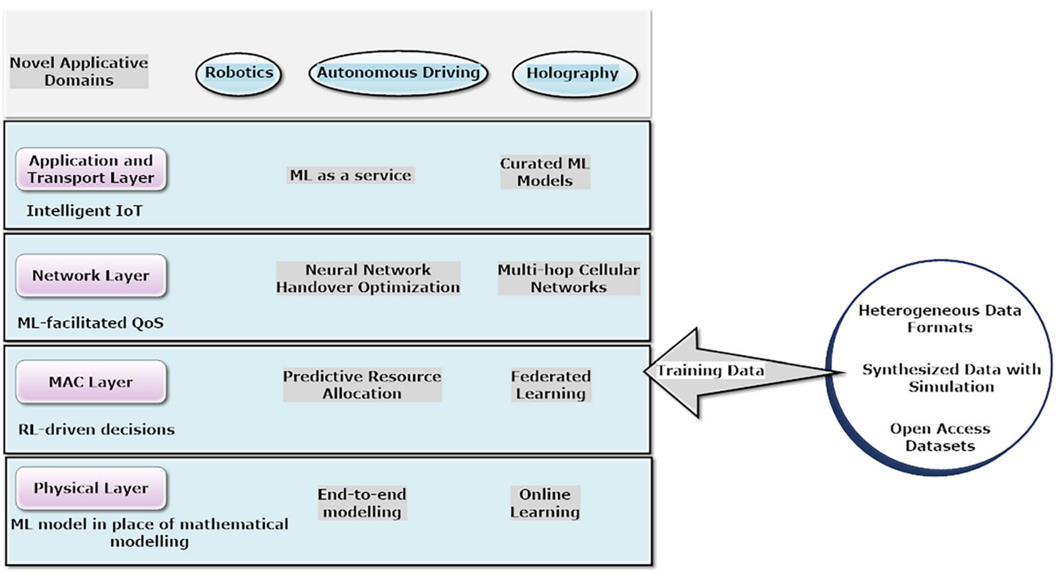


FIGURE 7 Role of machine learning (ML) in 6G networks.

accordingly adjust the optimal strategies. Incorporating sensor fusion techniques and enabling ML as a service with the integration of embedded ML solutions into wireless communication nodes at the transport layer or the application layer enriches the overall experience of sharing, enhances capabilities of remote control, and provides seamless connectivity.

3 | 6G PERFORMANCE, COVERAGE AND SCENARIOS

3.1 | 6G network performance

6G network technology will witness robust technological improvement using WTI, VLC, and HPC.[2,64,68,69] The table below shows the differences between the 5G and the 6G networks. It can be identified that with regard to improvements in the network efficiency, mobility rate, and reliability among other metrics that 6G has better and improved performance over technical metrics. Table 3 shows the differences between 4G, 5G, and 6G, and Table 5 gives the detailed comparison of 5G and 6G.

3.2 | 6G and 5G facilitated coverage

One of the most significant aspects of upcoming network generation is spatial features. Outer space, geographical location, microworld, and biological world are all limitations that network communication can overcome.

The network interconnection is not limited to only two dimensions but will be expanded to cover land, air, space, and to the depths of seas and oceans. The 6G network coverage will include the whole world. Using technique of spatial multiplexing, the 6G land mobile communication system will collaborate to create a network that combines terrestrial communication, satellite, and maritime internet to provide increased and full bandwidth spectrum universal coverage as shown in Figure 8. Thus, the upcoming network generation will leave no area in this world uncovered, reflecting the traits of universal interconnected networks.[37,43,70,71]

To realize the 6G network coverage, there will be a requirement to set constellations of orbit satellite communication. It will merge different networks for maritime internet communications (sea/ocean-based) and terrestrial mobile

TABLE 5 5G and 6G network performance and potential core technologies.

	Performance metrics	5G	6G
Rate	Peak rate	101 Gbps to 2 × 101 Gbps	102 Gbps to 103 Gbps
	User experience rate	Less than 1Gbps	In Gbps
	Mobility rate	5 × 102 km/h	More than 103 km/h
	Reliability rate	Less than 10-5	Less than 10-6
Delay	Latency delay	1 ms	10-1 ms
	Processing delay	102 ns	10
Density	Traffic density	10 Tbps/m^2	102 to 104 Tbps/m^2
	Connection density	106 connections/m^2	Up to 108 connections/m^2
Efficiency	Network efficiency	102 bits/J	2 × 102 bits/J
	Spectrum efficiency	102 bps/Hz	2 × 102 to 3 x 102 bps/Hz
Positioning	Outdoor position	10 m	1 m
	Indoor position	About 1 m	10–1 m
Frequency	Regular-carrier spectral frequency	2 × 102 GHz	20 GHz
	Multi-carrier spectral frequency	2 × 102 GHz	102 GHz
	Operation frequency	3 to 3 × 102 GHz	Up to 103 GHz
Integration	AI-XR integration	Partly integrated	Fully integrated
	Satellite integration	Not integrated	Fully integrated

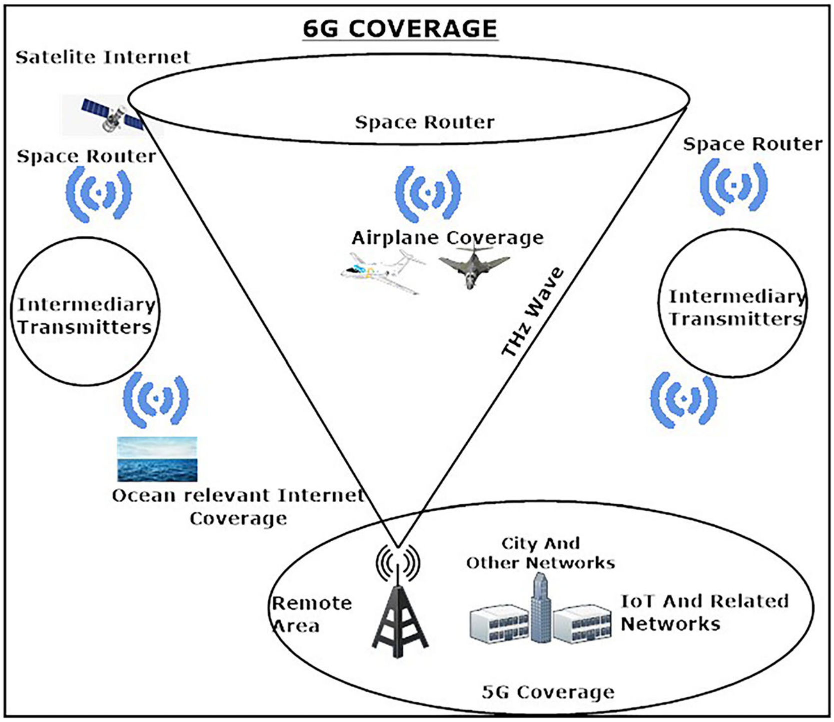


FIGURE 8 6G and 5G facilitated area coverage.

communications (land-based) to create a high-accuracy, high-stability network that will cover the entire planet. Satellites will be able to move freely and even move between any two satellites thanks to 6G.

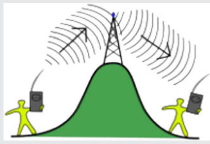
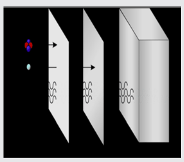
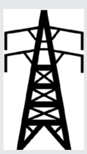
3.3 | Techniques of spectrum communication

The backbone of mobile communications is spectrum, and since the first network generation, we have seen a massive expansion of spectrum capital with each new generation due to the never-ending chase of higher rates of data. Subject to the current spectrum and bandwidth constraints, it is not possible to achieve the aggregated bit rate in the order of Tbps. Thus, requirement of new spectrums is necessary. The current viable options are THz and visible light spectrums (VLC).[17]

3.3.1 | THz communication

The THz band is a spectral band which is sandwiched inside the microwave and the optical bands. In the 6G wireless networks, higher frequencies in the THz band (10-1-10 THz) would be important for pervasive wireless communications. There are several distinct advantages to using the THz band for upcoming communication networks[72]: THz transmission networks are supposed to accept data rates of 102 Gbps or greater, with 10s of GHz usable bands in the THz range, while the mm-Wave band has just 9 GHz bandwidth.[73] THz waves can also penetrate certain materials with less attenuation, which might be useful in some cases. Its characteristics like short pulse duration and narrow beam make it a more secure way of communication. THz waves have a wide variety of uses in the ultrahigh-speed wireless networking and space communication due to these characteristics, and standard agencies and global regulatory bodies are now working to speed up the implementation of novel communications technologies in the THz spectrum. Table 5 highlights the characteristics of THz and VLC bands, simultaneously comparing the key differences. The upcoming THz wireless communication infrastructure faces immense challenges. However, significant advances have been made in global studies (Table 6).

TABLE 6 Comparison of THz and VLC.

Parameter	Image	THz	VLC
Available bandwidth		10–100 GHz	100 s of GHz
Transmission distance		NLOS	LOS
Data rate achieved		100 Gbps	10 Gbps
EM radiation		Yes	No
Spectrum regulatory		Licensed	Unlicensed
Penetration ability		Special opaque materials	Transparent materials
Cost		High	Low
Transmission power		High	Low

3.3.2 | VLC

OWC is a form of optical communication where a signal is transmitted using unguided visible, ultraviolet (UV) or infrared (IR) light, often utilized for short-range communication. VLC refers to OWC systems that run in the visible band (430–790 THz). It has a widespread usage of LEDs. LEDs can very easily switch among different intensity levels, thus creating more ways to encode data in the emitted light.[74] VLC has its own set of merits which include it being unlicensed, low construction, and maintenance costs, not generating electromagnetic radiation and many more.[75] VLC cannot penetrate opaque objects and thus confines the transmission of network information within a building. This adds to the information transmission security and minimizes inter cell interference. The maximum data rate that is attainable is primarily determined by lighting color or technology. There is considerable difference in the data rates of a RGB LED and a phosphor coated blue LED. The former's data rates are in the range of multi-Gb/s, whereas the latter are only up to 1Gb/s. VLC is expected to reach greater heights of data rates in the upcoming future research works. Figure ? highlights the key differences between THz and VLC.

3.4 | Applications scenarios of 6G

Along with following along the lines of previous generations of network, 6G will explore new horizons and will expand into virtual and augmented reality. Figure 9 summarizes the potential scenarios of 6G which include the human digital twin, smart factory plus, high-speed internet access in the air, XR based on holographic communication, smart city, worldwide emergency communication rescue system, and the tactile and wireless Internet, among other things.

3.4.1 | Human digital twin

Human digital twins can be helpful in the medical or the pharmaceutical industry. Within the current network technology, the identification of human anatomy by the scientific digital technology is primarily deployed for the identification of key tests and the avoidance of some known diseases. Its accuracy and availability in real-time scenarios must be enhanced. It is not possible to make human digital representations in the current network constraints because of their complexity. Human digital twins can be created using a mix of interdisciplinary sciences like bioscience, materials science, and bioelectronic medicine, as well as the emerging groundbreaking 6G technology. Every biological system within the human body, be it respiratory system, cardiovascular system, urinary system could be

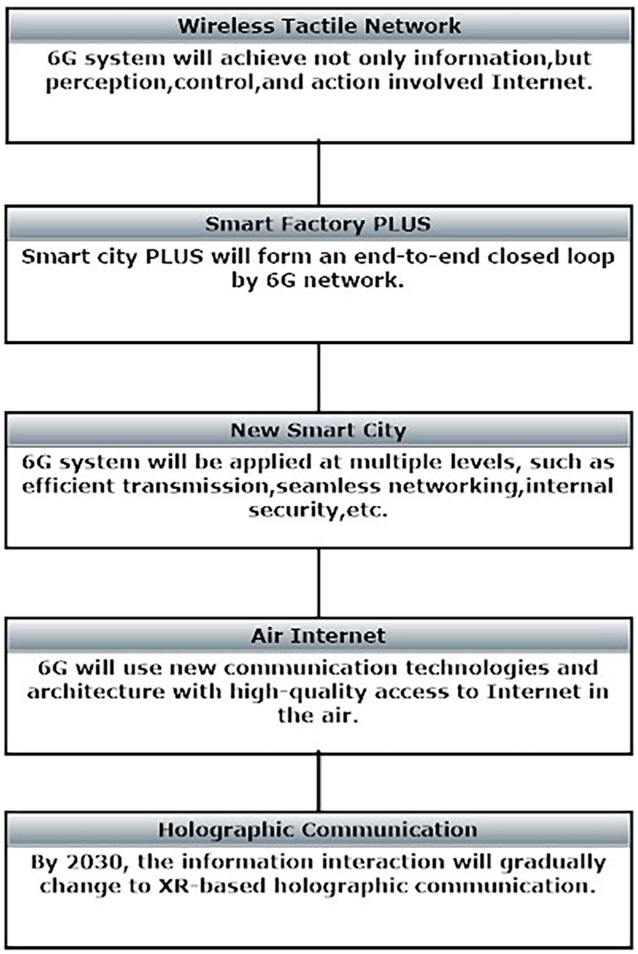


FIGURE 9 Potential scenarios of 6G.

assessed accurately with intelligent sensors and could be taken well care of. In specialized healthcare facilities, AI could also be used to include efficient and effective diagnostics and sources for conducting a customized surgical operation.[76,77]

3.4.2 | High-speed air-based internet access

It was hard to construct a high-quality air network infrastructure in existing network generations. Land base stations and satellite delivery are the two primary types of air communication networks. If the ground base station model is used, the air network will face some difficulties due to the frequent and fast movement of airplanes and the broad cross-border range. The efficiency of the air network can be reasonably assured if satellite communication is used, but it would be expensive (Tariq et al., 2019;[78]).

3.4.3 | XR based on holographic communication

In recent years, the VR, mixed reality (MR), and AR have garnered great attention in academia and industry. The industry also refers to these three technologies collectively XR. Features of 6G, such as high rate of transmission and low delay, can make XR application scenarios better. The large bandwidth characteristic of 6G network can meet the development demand of XR. There is even scope of holographic communication being accomplished which will make games, sports, concerts, and education more interactive.[15,79]

3.4.4 | 6G and AI assisted smart city

A smart city consists of smart/intelligent homes, roadside infrastructure, factories, apartments among many other deliverables. A smart city is one in which traditional networks and utilities are rendered progressively efficient by the application of telecommunication and digital technology, to the benefit of its residents and businesses. Integrated AI and 6G together can realize this potential scenario. A novel smart city can be brought into existence with the help of 6 G ([80,81]; Carter, et al., 2018;[82,83]).

3.4.5 | Worldwide emergency communication rescue system

In all areas, 6G can have a consistent network coverage system. By 2030, universal communication is supposed to be one of the primary features of 6G networks. Current blind spots of network will also be addressed, such as deep valleys, deep oceans, deserts, and mountains. Broad coverage, versatile implementation, ultra-low energy usage, and high accuracy would all be features of the upcoming 6G communication network. The 6G network could be used for dynamic and real-time surveillance of areas vulnerable to natural disasters (such as mountains, seas, and coastal areas), as well as providing emergency alert services in events like earthquakes, cyclones, and floods to help mitigate loss of life and property.[16,42]

3.4.6 | 6G and blockchain-based smart factory plus

The 6G device gathers real-time relevant data from factories, machine tools, and peripheral components using ultralow-level latencies, high bandwidth, and high precision. To process orders in real time, edge computing and latest technology of AI directly track and transfer data in the terminal.[66,84] 6G's blockchain technology allows data to be exchanged directly among terminals in a smart factory, bypassing the need for a transportation hub, resulting in decentralization of operations and increased performance. The 6G will not only be limited to the factory but will be the key point for the whole production process. Using the 6G network and related technologies, smart factory PLUS will build a deeply connected network, from specific demand side consumer requirements to factory delivery network.[16,65,85,86]

3.4.7 | ML- and DL-based automation

Network robots and automated vehicles can be implemented more easily with 6G using ML and DL technologies. Self-driving vehicles made on 6G wireless connectivity have the potential to drastically alter people's lives. The 6G framework would encourage the widespread introduction and use of self-driving vehicles. Self-driving cars sense and identify their surroundings using a range of sensors (like GPS, sonar, odometer, light detectors, radar, and inertial calculating instrument). Vehicle-to-server services and V2X will be provided by the 6G framework. Now coming to UAVs which are commonly called as drones, 6G will efficiently support UAVs by leveraging their advanced features and using new AI, DL, and ML technologies. Package distribution, media processing, real-time monitoring, food and agriculture, disaster mitigation, and logistics are all examples of UAV applications.[12,67]

3.4.8 | Tactile and wireless network

The tactile network's identity will be defined by extremely low latency combined with high accessibility, consistency, and security. Major impact on the industry and society will be casted, thereby opening up a slew of new possibilities for digital technology markets and public service delivery. 5G network's IoT network focuses primarily on awareness and connection. A 6G network link would be a possible shared smart target in the near future. The traditional internet can only be used for exchanging data and knowledge. It would be so much greater than that with the tactile internet. It will cover remote digital data transfer, remote control, and data transfer-related response activities. It will make the shift from content delivery to remote capability delivery smooth.[54,87]

3.4.9 | Big data analytics-based healthcare

As the reasons pertaining to low level data rate and waiting time, previous network generations and communication technologies were unable to provide adequate digital healthcare. The 6G would provide secure connectivity, enhanced availability, ultralow-level latencies, increased rate of data, and dependability through XR, robotics systems, AI which comprise of the big data analytics enabling the possibility of digital and remote surgeries. Figure 10 shows key applications, trends, and technologies of AI in 6G systems.

3.5 | State-of-the-art study contributions in 6G

Table 7 summarizes the state-of-the-art advancements that have contributed to 6G in this segment. Nawaz et al. suggested a quantum ML vision for 6G.[34] The authors looked at cutting-edge ML methods that could be applied to upcoming-generation of communication networks. They also addressed existing quantum communication strategies and a few active research challenges, as well as introducing a quantum computational-based ML system for 6G wireless networks. Lastly, they addressed open research concerns related to quantum ML applications in 6G. Mozaffari et al[88] pioneered the idea of three-dimensional mobile networks, which are primarily based on UAVs/drones. They took into account the two main concerns of 3D cell association and network preparation, when integrating cellular technology-based drone users with drone ground stations. They devised a new method for calculating the least number of drone base stations and their realistic positions in three-dimensional space, using truncated octahedron cells. They also came up with a frequency modeling analytical expression. Ultimately, they proposed a 3D cell association scheme that takes into account optimum latency. Mumtaz et al[89] presented a summary of THz communication possibilities in vehicular networks. They addressed the numerous THz communications bands that are available and standardization activities.

Nevertheless, 6G is still in its initial stages, and significant efforts will be needed to bring the vision of 6G using the THz band to realization. To allow smart medical applications, Salem et al. analyzed a nanosensor network using the blood as a channel for THz communication.[90] Using efficient medium theory, they suggested an electromagnetic design for blood. The suggested model has the advantage of being efficient in terms of specifying RBC volume percentage and the particulate form. An additional benefit of their research is the discovery of a connection between molecular noise and propagation loss and RBC concentration. With an increase in RBC concentration, molecule specific noise and propagation loss decrease, and vice versa.

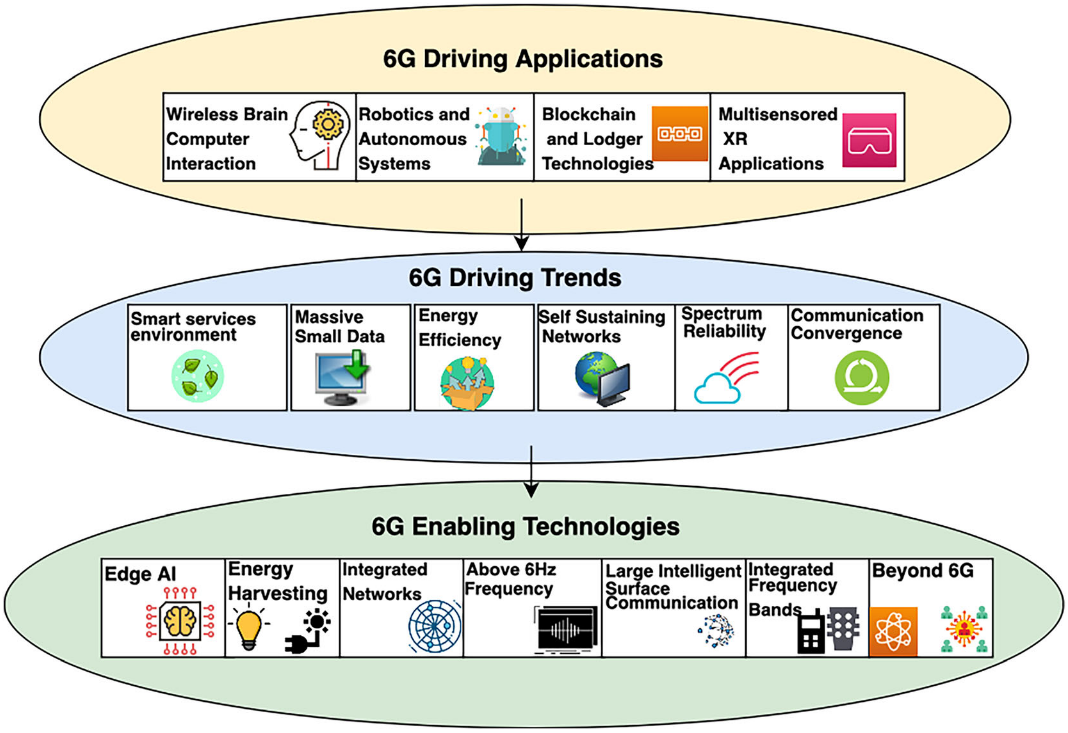


FIGURE 10 AI aided 6G and green 6G applications, trends, and technologies.

TABLE 7 Summary of state-of-the-art in big data analytics-based network technology.

State of the art	Central topic	Key features	Merit
Nawaz et at [34]	Quantum ML	Quantum ML was examined for 6G cellular networks.They described a new architecture for 6g communication networks based on Quantum ML and assisted by QC	A thorough summary of the relevant state of the art is discussed in the domains of ML, quality control, and QML. Raised significant challenges for Quantum ML implementation in 6G communication networks.
Mozaffari et at [88]	Three-dimensional networking	A new three-dimensional cellular network model is proposed, which integrates cellular technology-based drone users and drone ground stations.	Presented a reliable strategy for reducing latency between the drone-BS and drone-UEs.Relative to old cellular association schemes, the provided 3D association scheme greatly reduces latency, which benefits drone users.
Mumtaz et at [89]	THz communication	The possibilities and challenges of THz communications for vehicular networks are discussed. A bandwidth study of usable THz communication bands is presented.	Provide first-time solutions to some of these challenges
Salem et al. [90]	THz communication	Usage of THz communication for medical and health care related applications. An EM model related to effective medium theory was developed for blood.	The presented model allows for a wide range of RBC volume fractions and particle shapes to be defined. A relation was discovered between path loss, molecular noise, and RBC concentration in blood.

(Continues)

TABLE 7 (Continued)

State of the art	Central topic	Key features	Merit
Carrasco et al. [[91]]	THz Communication	A hierarchical body area nanonetwork framework was proposed. Using easily accessible electronic components, nano devices like nanonodes and nanorouters are systemically used for the presented design.	In the THz band, a basic communication structure for the sharing of information among nanodevices is introduced. The effects of loss of path and absorptive mechanism of molecular noise on the propagation of EM waves are minimized.
Khan et at [[92]]	Edge AI	They were able to motivate user engagement in the federated learning process by using a Stackelberg game to simulate the incentive-based interaction between a central server and participant devices for federated learning.	The core aspects of federated learning and possible study recommendations are discussed. New open research challenges are also raised, along with potential solutions.

Canovas-Carrasco et al[91] suggested a hierarchical body region nanonetwork architecture based on THz communication. For the proposed architecture, they conceived two types of devices: nanonodes and nanorouters. They suggested a new communication scheme that would allow nanonodes to communicate using the THz band of communication. They used the hand of a human being to communicate and minimized molecular absorptive noise and propagation loss. Another benefit of the new design is that it addresses the problem of transmission rate reductions due to energy constraints. At the edge devices, Khan et al. surveyed federated learning.[92] For federated learning especially at the site of network edge, quality enhancement and system design were considered. The first part of the presentation covered main design elements for allowing federated learning at the edge of the network. New open research challenges are also raised, along with potential solutions.

4 | BLOCKCHAIN AND IOT IN 6G NETWORK SYSTEMS

4.1 | Introduction to blockchain

The blockchain is a decentralized ledger that stores and shares records of all virtual events or transactions that have occurred. Each transaction is double-checked by the majority of the system's members. It holds every single transaction's record. As a safety feature for all communication networks, blockchain is majorly used to create the large-scale index and functions as a common, shared and collective ledger. Blockchain technology has been called disruptive technology as a result of the growth of crypto currencies and has made the shift to a secured network from a client-server network. It is a decentralized database that can be used to execute monetary operations and allows users to allocate a P2P network inside which nontrusted participants exchange data without the need for an intermediary. The respective computed hash of the prior block is used to generate the corresponding block, which is why trust is so important in the block chain.

4.2 | Limitations and contributions of blockchain and IoT for 5G/6G

Table 8 explains the summary of relevant existing surveys on integration of blockchain with IoT for 5G/6G. As defined in Jesus et al[93] the emerging technology has a significant effect on many technological fields, including the IoT, in terms of transaction models, communications, decentralization, and independent system communication. The aim was to provide ideas about how to use blockchain to improve privacy in IoT by examining the structure and functioning of the technology. However, the proposed algorithm's cost was not reduced. In Qu et al,[94] a new layer-based architecture called blockchain structures (BCS) was implemented to define IoT and BC connections for authentication. But there

TABLE 8 Challenges in blockchain integration with IoT for 6G network.

State of the art	Name of technology	Methodology	I[a]	B[b]	G[c]	C[d]	T[e]	Constraints
93	Transaction models	It offers suggestions for the layout and operation of BC in order to explore how technology is helpful in improving the privacy in the IoT. Also, sheds light on prevention of the publication of node blocks to the main linkage	×	√	×	×	√	No reduction in computational cost and consensus models
94	BC structures (BCS)	For authentication, BCS determines the relationship between IoT and BC. The security analysis and features are also discussed in this paper.	×	√	×	×	√	No improvement in security level and complete decentralization not achieved
95	BC and IoT technologies	It offered high-level strategies for dealing with the flaws.	√	√	×	√	√	With designed technologies, the exact problem could not be found.
96	BC and IoT integration	Identified the various obstacles that the research community is facing in incorporating BC and IoT in a seamless manner.	√	√	×	√	√	No reduction in complexity level size of BC is also a limitation.
97	Centralized architecture	This article fills in the gaps in scaling, inter - operability, as well as other research issues.	√	√	√	√	√	Problem of energy consumption remains unsolved. But computational overhead was reduced.
98	CSI-free strategies	As the number of powered devices grows, CSI decreases. The energy coverage area was expanded with high reliability thanks to CSI-free plans.	×	×	√	×	√	No reduction in execution time
33	QC- and QML-based framework	In 50 networks, it defined possible benefits and problems for applications.	√	×	√	√	×	No improvement in reliability level. Large scale reliable quantum devices are not available.
64	OWC technology	For 5G/6G and IoT implementations, OWC met networking device demands.	√	×	√	√	×	Overhead of communication was not reduced by technology of OWC.
18	THz communication	Mobile ultra-broadband, SACs and symbiotic radio were all maintained by THz communications. It presented the fundamental theory, main problems, and the recent features and solutions for every technology.	√	×	√	√	√	No improvement in data integrity
99	Integration of IoT with BC	BC assured sensing integrity of data on an integrated and optimized IoT platform. Also it includes features of generic IoT systems, and also real-time tracking and management among the users and the device.	√	√	×	√	√	Communication overhead and cost was not minimized

(Continues)

TABLE 8 (Continued)

State of the art	Name of technology	Methodology	I[a]	B[b]	G[c]	C[d]	T[e]	Constraints
25	Intelligent and secure type architecture	The integration of AI and blockchain into a stable and intelligent architecture for next-generation wireless networks is suggested.	√	√	√	√	×	No major success in the improvement of level of privacy
100	Security module in IoT device	Hacking and data infringement is limited using BC technology. By creating a new approach, they are able to help to resolving the security issues that IoT-based application and services face.	√	√	×	√	√	Security level not improved as it lacked authentication. Constraints existed in the depiction of the main design, which needs to be improved further
12	System-level viewpoint and fullstack technology	Provided a comprehensive, system-level view of 6G applications and specifications, and identified 6G technologies that can be met by enhancing 5G architecture or by implementing entirely new communication designs.	√	×	√	√	×	Lack of central authority for improvement of security
101	Cryptography strong and decentralized platform	With this type of decentralized network, the use of a central authority for authorization and communication is avoided.	×	√	×	×	√	The level of data protection and security did not alter

[a]Issues.
[b]Blockchain.
[c]5/6G.
[d]Challenges.
[e]IoT technology.

was no improvement in security level and complete decentralization was not achieved. Maroufi et al[95] merged Blockchain and IoT technologies with high-level strategies for coping with Blockchain and IoT technologies' disadvantages and weaknesses. The explicit challenge in Blockchain and IoT technology was not identified. Panarello et al[96] conducted a systematic analysis that included blockchain technology and integration of IoT. The aim was to examine study in BC-related technology in IoT context. It looked at a wide range of domains and used classification to structure the literature, but it could not address the complexity issues. [fn1]This is the first author footnote but is common to [fn2]This is the first author footnote but is common to. The centralized architecture in Mistry et al[97] was designed to reduce computational complexity. In the devices interaction in IoT-enabled computer technology, a distributed access control method was created. In centralized architecture, privacy preservation and security were critical issues. However, it consumed more resources. With a multitude of devices, channel state information (CSI)-free strategies were implemented in López et al.[98] As the cardinality of powered devices increases, CSI decreases. The CSI-free plans are spread across the region which improves the energy coverage while retaining a greater validity; however, the runtime increases as a result. To recognize possible advantages and issues for applications in 5G networks, a systematic analysis of ML was performed; Nawaz et al[33] implemented a QC- and QML-based architecture for 6G wireless networks via resolving problems. However, it did not succeed in increasing the degree of reliability. In Chowdhury et al.,[64] OWC met the needs of the 5G communication network. OWC technologies had been used to manipulate 5G/6G and IoT. No reduction in communication overhead was detected. To recognize every function, the main technologies were examined in Zhang et al.[18] Communication assisted by satellites, symbiotic radio, and mobile ultra-broadband were all maintained using THz communications. Data integrity, on the other hand, was lower. To ensure the integrity of sensing data, an IoT-enabled platform with blockchain was implemented in.[99] The main objective was to reward device owners for providing quick access to their devices in different locations. It addressed how IoT systems can be used to track and manage end users. However, the cost of communication remains unsolved. In Dai et al,[25] a stable and intelligent framework for wireless networks was created by combining AI and blockchain to allow for reliable and safe sharing of resources. DL algorithm was used to fix blockchain-enabled content caching issues in order to boost the system's efficacy and create a caching scheme but low level of privacy of data served as a drawback. To prevent hacking and data infringement, an IoT device protection module based on blockchain technology was implemented in Choi et al.[100] The developed technology resulted in a blockchain framework with several levels of authentication for user and IoT devices; however, the standard of protection did not change.

For several instances, new innovations were implemented in Giordani et al[12] with wireless networks moving toward 6G. We created a complete, system-level view of 6G scenarios and specifications and identified 6G network technologies that can be met by enhancing 5G architecture or by implementing entirely new communication designs. However, no central authority was formed to strengthen security. In Biswal et al,[101] a decentralization-based and cryptographically sound platform with immutability was implemented to prevent the use of central authorities for security and communication. Still, the level of data protection did not change. The blockchain technology resolved the issues by introducing new features such as distributed ledgers to boost security.

4.3 | Blockchain benefits in 6G

The main challenges in blockchain for 6G are as follows.

4.3.1 | Increased connectivity

a. Reliability and scalability: Considering higher traffic and huge data transactions, the scalability performance is of paramount importance in 6G systems. Higher reliability, accuracy, and zero delay are essentially needed in 6G communication systems. This is usually achieved through M2M and D2D communication and in the future using mMTC.
b. Synchronization: Power allocation stations and networks need to be in sync in a real time scenario. In 6G generation, blockchain will be used extensively to counter these challenges which were previously tackled by decisive systems in 5G.
c. Increased throughput: Blockchain can be used to increase the connectivity of devices over a network. This leads to huge amount of data being sent and received, and as the transactions and communications increase, higher throughput forms a key advantage.

4.3.2 | Integrated safety measures

a. Data integrity and confidentiality: Newer technologies deploy light weight algorithms in order to be processed on small IoT devices. These light weight cryptographic algorithms encounter data integrity breaches and privacy risks especially eavesdropping. Hence, it is important that in future generations, data integrity and confidentiality are adopted by secure technologies.
b. Authentication: Authentication methods and access controls have to incorporate the increase demands in 6G. Resource efficiency and associated bottlenecks are of prime concern in 6G environment and future network generations.
c. Availability: As the volume of data and devices over the network increase, service accessibility becomes tremendously important. And in 6G environment, vulnerable attacks like DDoS are more probable so, better security is needed.
d. Auditing measures: In a network system, it is important to limit the threat and take constructive actions. Deep packet level audits help to identify these scenarios with paramount security features. The number of tenants in a network poses a challenge regarding to privacy.

To leverage the full potential of 6G network communication technology and overcome the major challenges in 6G, blockchain is a very useful technology adoption. In telecommunication ecosystems, there is a big need to control the connection demands in the network resource organization through a smart automated mechanism. Decentralized evaluation and spectrum allocation are needed to capture the adequate resource management especially in resource constrained domains. Blockchain technology is integrated in a smart network framework having a large infrastructure of users and operators. Spectrum allocation and sharing also involve use of game theory. Figures 11 and 12 show the challenges, opportunities, benefits, and blockchain applications in 6G.

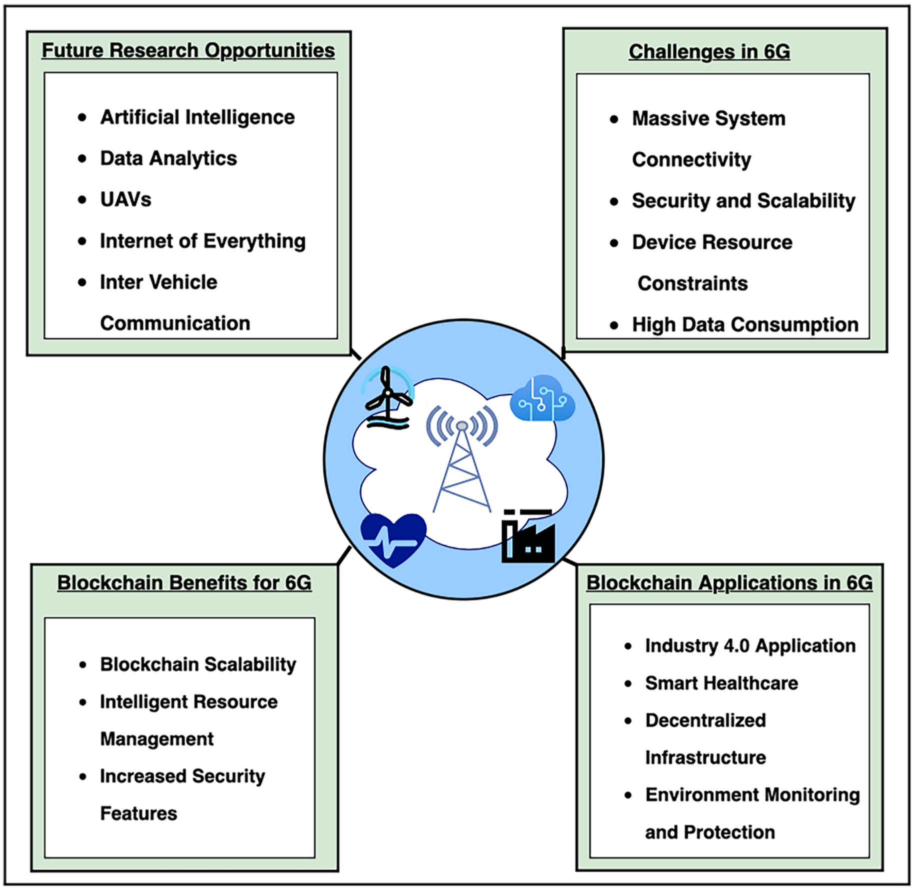


FIGURE 11 Blockchain technology significance and opportunities in 6G.

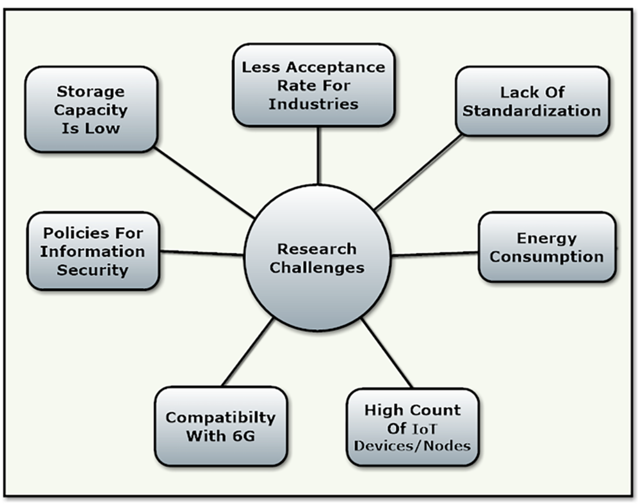


FIGURE 12 Research challenges of blockchain with IoT in 6G systems.

4.4 | Security oriented features in blockchain

4.4.1 | Privacy

Privacy is an important and one of the prime security features. The 6G network system involves complex and high-level security needs among which diverse data privacy applications are varied. Content-centric 6G networks have their privacy mechanisms improved by the integration of blockchain.

4.4.2 | Access control mechanism

Stability and reliability issues are faced in the centralized systems involving access control. There is a huge demand in the communications networks for centralized access control mechanisms especially in the near future. Blockchain technology is implemented dependent on access control mechanism and verification in 6G network technology for cloud radio.

4.4.3 | Accountability

Accountability plays a major role as an important security characteristic in 6G communication network. Dispersed ledger technology and blockchain technology combined improve the accountability and security of the network.

5 | BLOCKCHAIN WITH IOT-ENABLED DEVICES IN 6G

The integration of blockchain and IoT involves concern with regard to the industry and academic domains. For IoT scenarios, blockchain depends on PoW designs being itself styled in bitcoin features. Energy requirements get limited with the fast integration of IoT devices. In a network, the systems are changed by the use of blockchain and the information stored in their nodes is known as IoT devices. This transformation leads to less storage needs and computational requirements and helps in faster technology adoption with less constraints. Figure 13 shows the merits of integrating BC with 6G-enabled IoT devices.

5.1 | Research challenges

As the IoT devices and subsequent node count increases, the blockchain gets increased. Interoperability and equivalence decrease in a scenario where ledgers do not communicate with others. The full interoperability is achieved primarily by the stakeholders. In order to overcome breach of trust and security, there is a requirement for various international strategies. Uncertainty may lead to difficulty in carrying out the business cases. It is difficult for the providers to use blockchain technology in varied firm business cases. There is also a need for the integration of high-speed network connection as the IoT devices are made to be compatible with the upgrade.

5.2 | Benefits of BC with 6G-enabled IoT

IoT designs have been adopted according to the requirements and constraints. In-depth analysis and feature selection have not been achieved to integrate with suitable blockchain platform. Blockchain requirement in IoT devices stems from the underlying needs of the state accumulation and protection from third party. The appropriate blockchain platform is described by IoT devices through gained knowledge about the needs like transactions, resources, and time efficiency. The main benefits arising from integration of blockchain with IoT devices are the characteristics in the network like security, privacy, reliability and scalability. IoT has an important role for in-service digitization by using access mechanisms to distribute network information in order to increase the quality of life. As a result of this combination, a strong decentralized network with developer technologies of smart contracts and safety that meets high dependability and scalability requirements is created.

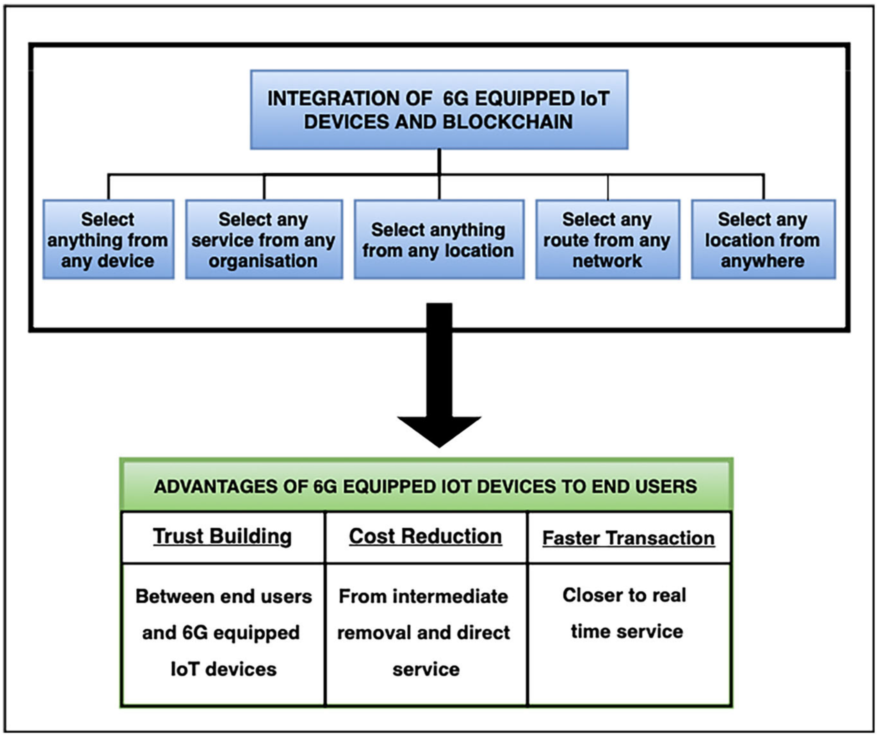


FIGURE 13 Integration and advantages of blockchain structure (BC) with 6G-enabled IoT devices.

1. Decentralization and fault tolerance: Decentralization and fault tolerance go hand in hand in a network system. As centralized systems take a shift to decentralized systems, the fault tolerance performance improves considerably. The clustering of resources is adequately managed by to improve the data processing.
2. Identity: Identification of IoT devices is provided by blockchain for an improved identification process.
3. Autonomy: IoT-driven industrial applications are implemented by the integration of blockchain in mobile devices.
4. Security: In order to secure interdevice communication, new protective mechanisms and agreements are used for data transactions.
5. Reliability: Incorporation of blockchain and IoT leads to the user validation to approve the transparency and reliability of data transactions with utmost confidence. Figure ? depicts the challenges faced in blockchain with IoT-enabled 6G devices.

5.3 | Applications of blockchain for 6G-enabled IoT devices

In 6G-enabled IoT, a classification of blockchain-industrial applications is defined. Smart manufacturing, smart grid, multimedia, agriculture, healthcare, unmanned aerial vehicles, and internet of vehicles were among the traditional areas of focus for diverse reasons. With limited capital and operational expense, blockchain and 6G improved security and bandwidth. Figure 14 depicts the blockchain applications for 6G-enabled IoT. The following subsections provide a more detailed summary.

5.4 | BC is a nice tool for 6G

Blockchain is claimed as a promising tool to unlock the 6G potentials by facilitating the management of distributed network resources. These resources include spectrum, computation systems, and caching. In the context of 6G, blockchain can be employed for various purposes, including sharing and managing of resources, storing of data, spectrum regulation, and more. Few research works have been carried out where benefits of blockchain technology in 6G has been

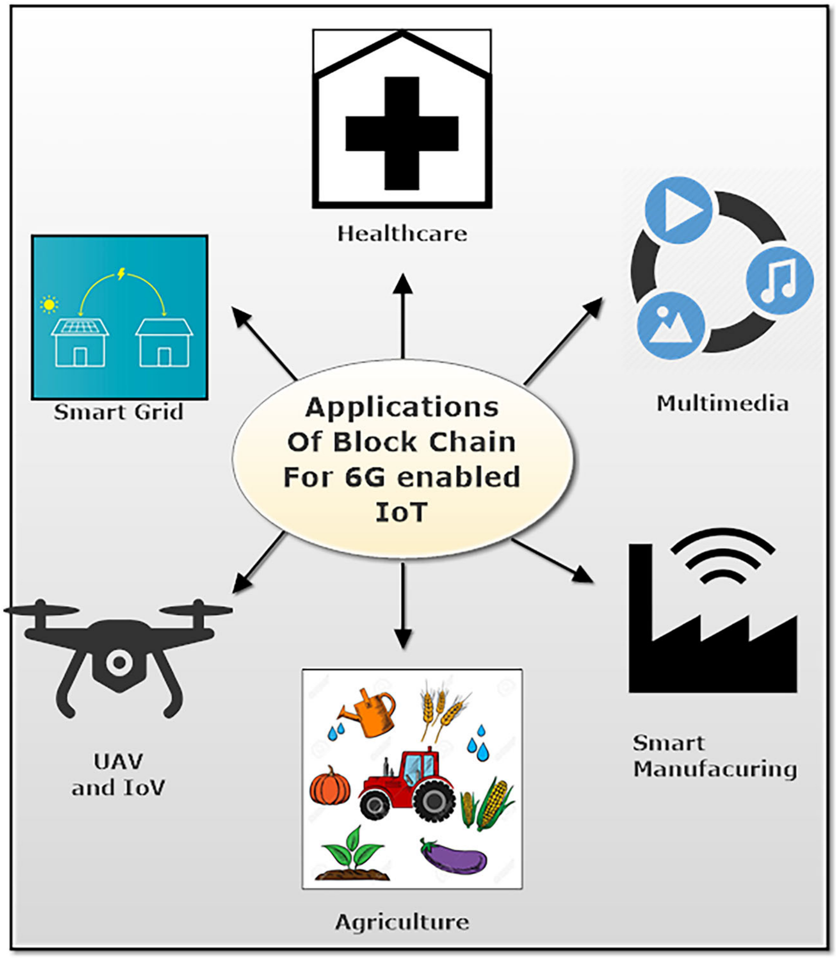


FIGURE 14 Blockchain structure (BC)-based smart applications for 6G-based Internet of Things (IoT)

witnessed. This involves resource and infrastructure management, access control, authentication, local area wireless networks and cloud/edge computing.

Blockchain technology offers multiple solutions to overcome infrastructure-sharing challenges among various operators of mobile network. Traditionally, mobile users rely on SIM cards in existing mobile networks. When switching mobile network, changing the SIM card becomes necessary, either physically or electronically. However, blockchain introduces a unique wallet ID assigned to all users, enabling seamless identification across all multiple networks. This promotes a user experience that is independent of the specific operator, driven by the competitive mobile network environment. Moreover, blockchain employs a distributed ledger technology (DLT) that ensures authority, inspection, and robust security for content-oriented wireless network of 6G. The events recorded on the blockchain remain immutable and transparent, making them useful for auditing purposes. Smart contracts on the blockchain address the real-time allocation of local spectrum, allowing smaller mobile networks to take over the frequency bands from larger operators which are not used within specific coverage areas and time frames.

Trustworthiness and security are critical concerns, particularly when sensitive information is involved in offloading computations. Blockchain technology establishes the required trust between the smart devices and edge servers thereby promising the integrity of offloaded computations and remote resources.

5.4.1 | BC-enabled smart manufacturing

The industrial sector is transitioning from automatic to emerging intelligent technologies. Each development process generates a huge amount of data, including product creation, allocation, sale, and operation. The data are divided, which makes data collection and analysis challenging. Interoperability problems are addressed by connecting IoT systems via a peer-to-peer network for data sharing in industrial sectors. Smart manufacturing is now more secure thanks to BCoT.

5.4.2 | Big data analytics assisted agriculture

To increase the quantity of agricultural commodities, smart agriculture used emerging technologies such as GPS, IoT, and Big data analytics. Information is stored in a control unit and processed by AI. Smart agriculture uses a mix of information technology to build the agriculture-dependent supply chain as cost-effective as possible. In agricultural supply chains, DLTs improved performance, quality control, and usability. Two related structures must be built to avoid the repetitive complexities of accumulating data on blockchain. Information on Planting: Information about particular supply chain processes such as development and collection is obtained. Information about agricultural operations is contained in the provenance record.

5.4.3 | BC leveraged smart grid

The appearance of variable renewable energy resources changes as energy users shifts from pure shoppers to both producers and consumers. Additional energy is sold by energy prosumers to other consumers. Energy trading between producer and customer is known as peer-to-peer (P2P) energy trading. It is difficult to ensure safe energy dealing in a distributed environment. But BC technology made it possible to ensure safe peer-to-peer energy exchange. Through blockchain agreement, an energy trading system based on conglomerate blockchains was presented to save costs without the use of a broker. For maintaining the confidentiality of smart grid transactions, a decentralized energy-trading framework based on blockchain was implemented.

5.4.4 | BC- and cloud-based healthcare

Due to the enormous population, healthcare is one of the most important societal issues that includes the increased demand for healthcare facilities as a result of poorly funded hospitals. The advancement of smart wearable healthcare technology has created opportunities for remote monitoring facilities to be offered at home. With pulse, diabetes, and pressure analysis, wearable devices assess and collect healthcare data. Doctors can analyze the data of a particular patient at any specific time and from any location thanks to networks. The limitation in security of healthcare devices poses a number of challenges in terms of maintaining privacy while increasing data protection. To solve the security and privacy issue of healthcare data, blockchains were incorporated into healthcare systems. Healthcare data stored on cloud databases are maintained thanks to block chain. Medical sensors capture healthcare systems' data, which is then transferred to a device for patient tracking. The protection of privacy is done effectively.

5.4.5 | Internet of vehicles and unmanned aerial vehicles

The IoV includes vehicle-to-vehicle networks, vehicle-to-infrastructure networks, vehicle-to-road networks, and vehicle-to-pedestrian networks (IoV). To fix security issues, the blockchain is combined with IoV. In IoV, a confidence policy was applied to blockchains. RSUs are used to enforce PoW/PoS consensus, which authorizes their message obligation. Blockchains are being used in smart grids to save electricity and communicate data between electric and hybrid vehicles.

5.4.6 | BC centered multimedia and digital right management

The media distribution refers to the distribution /delivery of digital multimedia material such as sound, picture, and video. The advantages of traditional online content distribution included improving access, lowering costs, and delivering better efficiency. The cloud-based content delivery networks (CDNs) are selected due to their low housing costs. The developed systems contained a number of difficult-to-resolve issues. Centered on the blockchain BRIGHT is a rights management framework for blockchain video files. Current multimedia did not save any information about ownership or multimedia adaptation documents. For particular purposes, the original media were fiddled with in order to share false information on social media. The watermark included data on two distinct specifications: Image Hash, which is used to protect the actual media content so that it can be recovered when needed, and Cryptographic Hash, which consisted of a transaction record that represented any changes in the original sought media.

6 | AI IN 6G

6.1 | AI in networking

Several problematic issues are there in the communication system, such as topology management, congestion management, route management, privacy, and confidentiality, that have become possible to solve with AI. Centered on the blockchain BRIGHT is a rights management framework for blockchain video files. Current multimedia did not save any information about ownership or multimedia adaptation documents. The original media is interfered with for specific reasons in order to spread misleading content on social media. During the pre-2000 period, above mentioned AI implementations were considered its initial applications. However, a vast number of Graphics Processing Units have easily affordable computing possible since its conception. AI's position has been diversified thanks to Compute Unified Device Architecture cores. AI can also be used to track and protect networks in addition to developing and optimizing network topologies. For rising IT networks, AI is becoming highly significant in taming complexities. IT infrastructures are more complicated than ever to maintain due to the prevalence of devices, information, and individuals. Ongoing advancements in AI such as ML and DL technologies have made it possible to complete previously thought-to-be-impossible challenges. These advanced techniques leverage a deep understanding of the network and can accurately predict a variety of parameters in order to perform different tasks. They are capable of a variety of functions, including traffic classification, management of resources, and information identification. They conduct network rerouting mechanism, congestion control management, and QoE optimization automatically to improve network adaptation.[1] AI has aided the creation of new network architectures such as intent-driven networking, which is an automated method for creating network models based on consumer needs. It helps teams to communicate their needs or intentions to the network, which then adjusts all of the machines automatically. Previously, teams had to apply their network specifications to expert network engineers for installation of the whole network, which was a lengthy and tedious operation. Improved flexibility and operational performance are two benefits of intent-based networking in IT networks which are one of the main advantages.

AI simulates certain human cognition and intelligent actions to provide information for wireless networks. The 6G would allow further intelligent applications, such as smart cities, wireless networks, vehicular communications, and unlicensed spectrum access, by integrating AI.[14,17,35,37,51,102–106] AI, which will be housed in new local "clouds" and "fog" settings, will aid in the development of a large number of novel applications based on sensors which would be incorporated in each and every aspect of our lives.[12] We will go through some main AI techniques and their implementations for 6G in the following sections.

6.2 | AI aided big data analytics algorithms

We will go through some potential AI learning techniques in this section. The techniques are listed below.

6.2.1 | Model-driven DL

An artificial neural network (ANN) is trained with already known and stored data on the basis of professional experience in the model-driven method.[104,105] The model-driven methodology is better suited with many communication systems than the data-driven method as it does not necessitate as much processing power or duration to train as the data-driven approach does.[107] Zappone et al[107] suggest a two-step method to applying model-driven DL: First, established technical skills, such as mathematical frameworks, developed from wireless communication issues, should be put to use. Then, even if initial theoretical approaches are incorrect, we can fine-tune the features in an ANN with real datasets in the future.

6.2.2 | Deep reinforcement learning

It uses Markov decision models to determine the next coming "move" governed by models of state transition.[108] This is considered to be among the most effective approaches for optimizing an aggregate reward method by step-by-step decision making.[102] It is a strategy for resolving resource distribution issues in 6G.[103] The radio resource will become increasingly inadequate as 6G wireless networks support a larger range of network users in the upcoming times. As a result, effective radio-resource allotment mechanism is both necessary and complex.[103]

6.2.3 | Supervised learning

This method uses labeled training data to train the computer model.[102] Logistic and linear regression, LDA, KNNs, naïve Bayes, and decision trees are some of the well-known techniques that could be made use of, in the 6G network. The network and physical layers both may benefit from supervised learning methods. We can use it in the physical layer to estimate channel states, decode channels, and so on. In the network layer, these techniques can be used for traffic categorization management, caching mechanism, and latency reduction, among other things.

6.2.4 | Unsupervised learning

Without using identifiers, this learning technique is utilized for identifying unidentified trends in a dataset. Clustering, anomaly tracking, auto-encoders, deep belief nets, and the expectation-maximization techniques are all examples of unsupervised learning techniques. It can be used at the physical layer for things like optimum modulation and channel-aware attribute extraction. It can also be used in the network layer for routing, traffic management, and parameter estimation, among other things.

6.2.5 | Federated learning

To maintain system owners' confidentiality, it focuses to train a ML model with the help of training data spread across various clients.[109] FL technologies will help enable the transfer of AI from a centralization-based cloud-based model to a decentralization-based device assisted model as 6G moves toward a distributed system.[32,68,110] Furthermore, as edge computing technology and edge devices become more common, AI computational roles can be distributed through a main central node to many decentralized nodes at the edge. As a result, it is an important ML tool for deploying accurate generalized models across various devices.[111]

6.2.6 | Explainable AI

Because the 6G age will usher in a slew of new technologies such as remote surgery and self-driving cars, it is critical to make AI understandable in order to foster confidence between humans and computers. Many AI strategies in 5G wireless networks' PHY and MAC layers are still unexplained.[112] In 6G, AI technologies like autonomous cars and remote surgery are expected to be extensively used, necessitating interpretability in order to build confidence. To be considered trustworthy, AI decision making mechanism must be understandable and explainable by professionals. DL explainability can be further improved using current approaches such as visualization of research papers, hypothesis analysis, and didactic claims.

6.3 | AI applications in 6G

This subsection will look at few of the numerous possible applications of AI in 6G, like network management and autonomy. The 6G scenarios of AI in network management and in autonomy are depicted in Figure 15.

6.3.1 | AI in network management

With the 6G network communication system getting larger and more compound, DL might be used in lieu of humans to increase network management flexibility and productivity.[102] Both the physical and network layers will benefit from AI technologies. In wireless communications, AI techniques and mechanisms have been used in architecture and resources distribution at the physical layer.[113] Scheduling, preservation of link and optimization of transmission, on-request beamforming, and harvest of energy are all possible applications of deep reinforcement learning.[68,102] Furthermore, AI techniques can be applied to the network layer. Resource distribution, fault detection, and other problems can be addressed using supervised learning methods.[102] Unsupervised type learning techniques can also assist with routing mechanism, traffic management, estimation of parameters, resource allocation, and other tasks. Traffic estimation, packet management, multi-objective routing, safety, and classification, among other things, can all benefit from reinforcement learning.

6.3.2 | AI in autonomy

AI could make 6G wireless systems self-contained.[51,59,105] Intelligent agents can actively and independently identify and fix network issues. AI-based network management facilitates the real-time tracking of network status and the maintenance of network health. Additionally, edge computing and edge devices may benefit from AI techniques, allowing them to learn to tackle security issues on their own.[59,114,115] Furthermore, 6G is expected to support autonomous applications like fully autonomous vehicles and robots.[113]

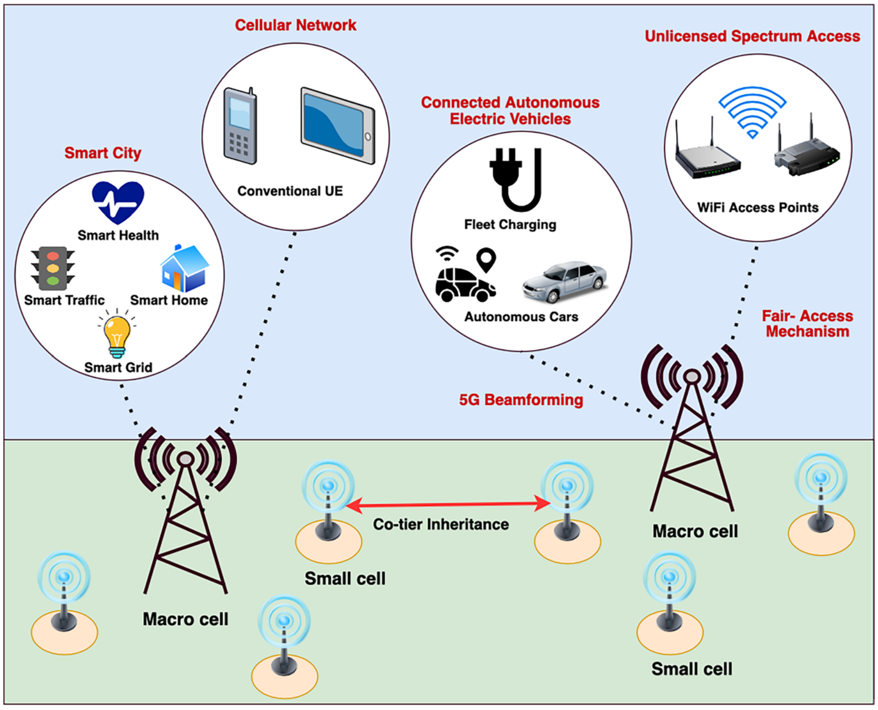


FIGURE 15 Smart city-based 6G applications of AI in network and autonomy.

6.4 | Taxonomy of AI in 6G applications

The AI taxonomy for 6G application scenarios is discussed in this section. The proposed approach considers the two main possible taxonomical applications of 6G where AI has a significant role. Dynamic spectrum allocation and mobile edge computing are examples of such application areas. The following is a brief summary of these applications.

6.4.1 | Dynamic spectrum allocation

Since there are so many users on 6G network systems, the bandwidth should be distributed constructively for the most optimum possible use. Elevated frequency bands could be assigned to large-volume data, while low-frequency bands could be used for short posts and messages. A further strategy is to use dynamic spectrum sharing mechanism, where the secondary users use the primary users' unused space. Secondary users have lower priority than primary users, and secondary user signals do not compete with primary user signals. The following is a list of AI strategies which could be used for dynamic spectrum allocation mechanism along with detailed description:

a. K nearest neighbor (KNN) After measuring the distance using a procedure like calculating the Euclidean distance, the nearest k neighbors are used to allocate a new data value to a class. The class chosen is the one with the most members among the k neighbors. To have a simple majority each time, the k value is usually an odd number. KNN is often leveraged to distribute the spectrum resources in a manner to lead to a minimal overlap among various signals which can are low-ranged and also low-power. The signal sources are listed in this system to ensure that there is minimal signal interaction between them.[116]
b. Support vector machine It can be leveraged in the binary categorization to optimize the distance among samples from different groups. As the secondary users use the spectrum resources while the primary users are inactive, SVM can be used to forecast the traffic corresponding to primary users and then assign the spectrum to a secondary user who has the most future inactivity time. The LSVM (linear support vector machine) was identified to outperform other approaches such as ANNs, RNNs, and GSVM (Gaussian Support Vector Machine) in terms of detecting traffic.[117]
c. Deep reinforcement learning integrated with reservoir computing mechanism The reservoir computing feature is an exclusive RNN architecture which transforms input signals to higher-dimensional spaces in a black-box fashion. This learning is leveraged to scour the spectrum for optimum bandwidth utilization and the feature of reservoir computing that produces the QValue by loading the resources at the spectrum data into the deep Q-network. Once the network has been properly trained, each secondary user will make smart choices about spectrum access based on the least amount of broadcasting data from the users who are primary. This integration of RC and DQN outperforms methods that depend solely on spectrum figures.[118]
d. Recurrent neural networks The authors Maksymyuk et al. presented an RNN-based model architecture for continuously managing the spectrum, taking into consideration cell efficiency and collisions, as well as long and short traffic methodologies. This model had a 90% accuracy rate and was able to double the network's strengths.[119]

6.4.2 | Mobile edge computing

It is a key enabler for 6G technology, since it allows processes to be done as near to the devices and systems. The edge computing systems that are capable of both computational power and communications characteristic must be held close to IoT devices that produce data. This would minimize the quantity of information transferred to the central servers, resulting in reduced latency and better performance for applications in real-time. The model may be able to provide an increased level of protection because it will deliver transient services via edge devices in the event of a network outage. AI technologies, instead of conventional algorithms, may provide better outcomes in complicated networks like MEC. In MEC,[120] AI techniques may study and analyze the data, assisting in forecasting, optimizing, and decision making. These AI methods can help provide high QoE in intelligent dynamic applications for edge contexts.

6.5 | State of the art AI applications and techniques in 6G

6.5.1 | Video analytics in real-time

A wide variety of edge computation technologies, like road safety and planning, VR, and security, depend on real-time-video streaming processing.[121] Real-time video applications stream data at 30 frames per second, which is significantly faster than earlier devices that used stored data at 3 frames per second.[137] AI combined with edge computing and IoT cameras can solve a variety of problems and potentially boost real-time analytics services.[138] In recent times, a number of studies have been conducted in this area. Ananthanarayanan et al,[121] for example, created an implementation called Rocket which yields higher throughput and high-precision results having few inputs and at a lower cost. Their software gathers and stores video from different cameras, then decrypts it using vision processing modules. Modules include already built frameworks and implementation-level improvements for data processing and analysis data. In recent years, it has been discovered that searching the appropriate video inside a huge set of data is difficult, time-taking, and costly. As a result, Hsieh et al[122] established Focus, a less-costly reduced-latent video querying method. In actual-time video streaming, they used a GT-CNN for labeling things and labeling groups of it, which is a less costly and a better CNN framework having a small cardinality of convolutional layers.

6.5.2 | Automatic speech recognition technology

Usage of this ASR sector in everyday living has risen steadily. Offline speech recognition systems that support voice activated assistants without relying on the cloud are also becoming increasingly popular. Among the most widely used techniques for offline voice recognition is keyword spotting.[139] ASR is made up of three major components:

i. Data collection: It selects the most relevant data for speech recognition from a wide volume of audio files.
ii. Feature extraction technique: This technique collects essential and useful features from a dataset.
iii. Neural network classification model: This model uses taken-out speech features as the input data and outputs a probability score for each keyword.

In recent years, a number of researches were also integrated in this area. Lin et al[126] developed edge-speech-nets, an effective deep neural network (DNN) framework for placing DL models on communication systems for speech identification. This model was found to be very stable regarding its results (having accuracy of around 97%) and computation time using the Google Speech Commands dataset.

6.5.3 | Autonomous driving vehicles

When we move closer to automated transportation, we should expect safer travel and better traffic control. Cardinality of sensors needed to construct automated driving vehicles is big, and the data produced from them should be analyzed in actual-time in order to take fast choices having good precision (>99.999%) and reduced latency (below 1 ms). Transferring large amounts of data to far located servers and receiving real-time feedback is challenging. As a result, edge computing will be needed in autonomous driving vehicles. Navarro et al[140] suggested a design for identification of pedestrians on the streets for autonomous vehicles. The motion of the target, stereoscopic details, and the presence of a pedestrian were all extracted using a LIDAR sensor, resulting in an n-dimensional vector. This vector was used to train a ML model for autonomous cars, which resulted in a 96.8% accuracy in detecting pedestrians.

6.5.4 | AI aided healthcare

AI are aiding doctors and healthcare experts to provide patient-centered care while keeping costs low and reliability high. It can be used in almost every area of healthcare, including interpreting medical images and medicating the disease, using NLP for speech-to-text and automated recording, and developing better customized medications that are tailored to the patient's bodily needs rather than applying the same known medicine on everyone. Li et al[128] suggested the Edge Care architecture, which is a three-layer hierarchy. The user layer, which is in charge of data processing, is at the bottom of the stack. The sample data are made up of actual data and the client's electronic medical record (EMR), which is then transferred to edge servers for review. The next layer is the edge layer that separates the network system into several small sections, each having its own local control. The highest-level layer, the core layer's role, is to protect data and security across the whole network structure. Additionally, it manages the efforts of different local authorities in variable networking areas. The existence of a core layer improves the overall system's performance and ensures improved teamwork.[141]

6.5.5 | ML- and DL-assisted smart cities and homes

Intelligent systems such as intelligent lighting, intelligent doorbells, home devices, and smart protection systems will evolve as IoT devices become more prevalent. Numerous wireless featured IoT controllers and sensors are needed for accomplishing this. Data analysis in smart home applications must depend on the edge computation mechanism to ensure security and prevent sensitive data from being misused. A fall recognition system was created to ensure user protection by generating warning alerts and notifying users whenever something fell. For actual-time monitoring, the Raspberry Pi2 is utilized as an edge computation interface to scan and compress images.[135] ML type models are used to remove features from the cloud in order to identify the fall of an object and alert users as needed.[142] This model can be enhanced by incorporating a DL model that only considers the picture in the foreground when detecting falls. It would reduce traffic and connectivity costs over time. A DL model for smart city load management, called DRUMS, was suggested, in which CNN was used to analyze usage data generated by smart homes. The key goal was to close the gap between supply and demand for load.[143]

6.5.6 | ML facilitated user data privacy and security

Quite a few applications and sites make use of a user's personal data. If significant amount of personal data is leaked, it can be exploited. Multiple security features can be executed and altered with the help of AI to guarantee that the personal information of the user would not be compromised and exploited. For ensuring data protection, Osia et al[132] created an integrated architecture which is made up of edge computing and cloud computing in synchronization. After the data have been compiled, it is transferred to remote servers for analyzing the user's personal data. After that, the remaining unimportant data are moved to the virtual storage.[132] Serious attacks and abnormal data should be detected by the network. To detect abnormal behavior, Pajouh et al[131] suggested using the naive Bayes and KNN algorithms. They used the NSL-KDD database to build the model and proved that an edge system can identify these conducts. Hussain et al[134] created a deep architecture CNN-based structure that achieved 96% precision. The volume of data in the network will exhaust a core abnormality detection system, causing it to fare badly. To get around this, the network was made up of 100 nonoverlapping areas, one with its own edge server devoted specifically to anomaly identification. Table 9 shows a comparative analysis of different AI techniques for developing mobile edge-based applications.

6.6 | AI in 6G specific research questions in survey

6.6.1 | Review section

This section explains the objectives, methodology, and criteria used during the conduction of our survey. We include the most essential research questions and answers and the advantages associated with the AI and networking topic in depth. The relevant information was identified and extracted; secondly, quality checking was carried with the addition of new and recent information and the citation of the references.

6.6.2 | Research objectives

This survey identifies important research questions and the literature and background research work related to 6G communication networks and AI techniques. In addition to the question, the objectives, important details, and challenges faced are explained in every section.

TABLE 9 AI-, ML-, and DL-based applications and techniques.

I[a]	SA[b]	Aim	AI-T[c]	Advantages	Disadvantages
VAR[d]	121	Implemented a large-scale video analytics in real-time for planning mechanisms and safety purposes	DNNs	Gave highly accurate outputs with less costs addressing latency and bandwidth issues using the “Rocket” software	Less use-cases given by the framework
VAR[d]	122	Presented a framework to deal with the input queries on bulk video type datasets efficiently	Ground-Truth CNNs	Gave a low-cost involving and less-latency query mechanism with less expensive CNN adaptation using compression and video-specific specialization of CNNs than rest methods like NoScope	The system is only usable for video type dataset only and cannot be applied to audio or other datasets
VAR[d]	123	Proposed a smart surveillance architecture for human object tracking at the edge with real-time video processing	HOG and SVM and KCF for tracking	Output results were better than rest of the approaches leveraging detection at edge and HOG-SVM algorithms	The detection algorithms are very costly and system performance isn't very efficient which is needed for video processing in real time
VAR[d]	124	Developed an efficient framework for smart surveillance system and leveraging the depth-wise separated convolutions for low computational resources in detecting humans	Light-Weight CNNs	Developed a memory efficient system for human detection with satisfactory results	Safety and security related challenges were not fulfilled
VAR[d]	125	Improved version of the framework than the previous of real-time video surveillance	CNN	More use-cases and efficient approach than the previous framework	Challenges in usability and efficiency for the general use
ASR[e]	126	Proposed low level footprint in DNN-based architectures for voice recognition through a feature network driven by humans	DNN	Used low-cost mathematical operations efficiently which is outputted into low level prediction latency and smaller memory footprint	The framework is yet not tested on important datasets to validate the results on speech recognition
ASR[e]	127	Presented a framework using electroencephalography (EEG) for efficient voice recognition	Dl with EEG	First EEG features were leveraged in deep learning to successfully overcome loss in presence of noise	Performance improvement in general case is needed.
HS[f]	128	Presented an efficient system using edge computing for mobile specific healthcare systems	EdgeCare Hierarchical model	The framework offers effectiveness with security features and fast data trading	Some use cases and issues were compromised
HS[f]	129	Proposed a framework for remote health monitoring using AI with Edge and Fog computing	LSTM-RNN	Resulted in better precision and recall using the framework than previous approaches	Improvements needed to deliver a high extensive performance
AV[g]	130	Proposed system to detect pedestrians for autonomous vehicles using image enhancement	YOLOv3	Model trained by image enhancement framework has more accurate detection rate than the one without	The detection rate is not good in case of more than 25 number of single pedestrian image

(Continues)

TABLE 9 (Continued)

I[a]	SA[b]	Aim	AI-T[c]	Advantages	Disadvantages
DS[h]	131	Presented a system to identify malicious attacks and behavior using component analysis	Naïve Bayes and KNN	Better performance in comparison to earlier methods to identify the Remote to Local (R2L) and User to Root (U2R) type of attacks	Attacks are only detected in the backbone layer
DS[h]	132	Proposed a hybrid approach to split deep neural networks	DL	Privacy was improved using Siamese fine-tuning	Optimization of hyper-parameters is required for better results
DS[h]	133	Designed a novel distributed privacy infrastructure to give the users a full control for the collection of data through cameras	Computer Vision and DNN	Selective notification is provided to users to choose to leave data collection procedure to ensure privacy	Application requirements are critical for ensuring better accuracy
DS[h]	134	Presented a novel system to inhibit the network from cellular outages	CNN	High detection accuracy is achieved in addition to the scalability of the framework	Overhead costs are increased in deploying an edge server to each region
SCH[i]	135	Presented a framework for fall detection system using feature extraction in the smart homes	DL	Increased performance with decreased traffic and computational resources	The framework has not been implemented and is still being developed
SCH[i]	136	Presented an algorithm for pipelining-based monitoring mechanism for smart cities	SVM	The framework results in high computational performance and low latency	Better results can be achieved using LSTMs

[a]Implementation.
[b]State of the art.
[c]AI technique.
[d]Video analytics in real-time.
[e]Automatic speech recognition technology.
[f]AI aided healthcare.
[g]Autonomous driving vehicles.
[h]Data privacy and security.
[i]ML- and DL-assisted smart cities and homes.

6.6.3 | Data collection and selection criteria

We have included recent research papers from the year 2015 and onwards. The research papers include survey papers, journal and conferences papers, and technical articles from Springer, IEEE Xplore, ACM Digital Library, Science Direct, Elsevier,[29,30] and so on. This makes it a comprehensive and up-to date survey using peer-reviewed research papers and databases. The final research information was filtered and pruned for selection and incorporation in our survey to make it more systematic. The specific research questions are summarized in Table 10.

7 | CHALLENGES AND SOLUTIONS TO 6G TECHNOLOGY

7.1 | Limitations of current internet

The current Internet features and protocols have been in the use for 40 years, with the internet architecture (TCP/IP) achieving huge success regarding data delivery and transmission. Also, QUIC (quick UDP internet connections) protocol which is built on the same architectures has also brought many advantages. Despite the huge success of these

TABLE 10 AI research query summary.

Serial no.	Research query	Aim
1	What is 6G technology and why is there a need for it?	Major benefits, important details and architecture of 6G are explained alongside.
2	What are AI techniques and their role in 6G networking?	Importance and use of AI techniques are analyzed with advantages in communication.
3	Discuss, compare and analyze AI techniques in 6G	he survey gives details and solutions to the background of AI used in 6G.
4	How is AI incorporated in 6G?	This survey explores 6G shortcoming and the solutions offered by AI and its application in 6G.
5	What are various challenges in 6G?	Open challenges and issues faced in 6G oriented areas are discussed.
6	How is the research applicable in the current scenario?	Incorporation of AI in 6G and its real-life advantages are provided in the survey.

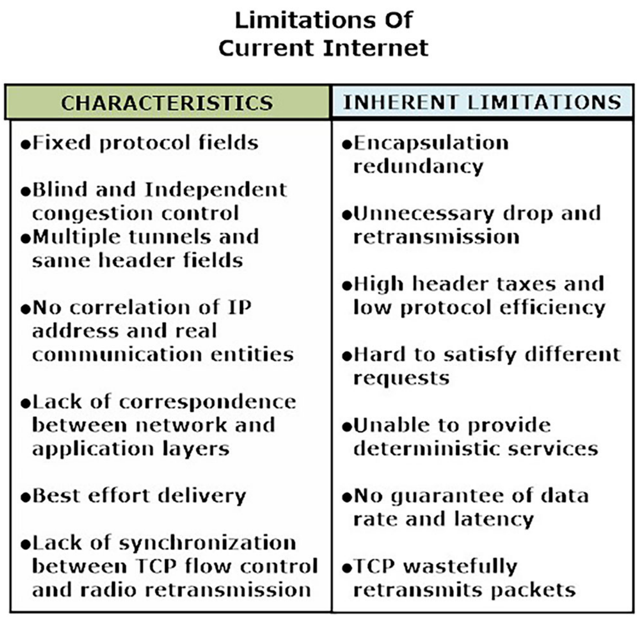


FIGURE 16 Limitations and characteristics of current internet.

protocols, there are multiple delivery and transmission challenges like throughput, data rates, and latency constraints, and they also make Internet architecture very complicated.[144] Hence, there is a need of new services and protocols expected to counter the constraints in the future. The characteristics and inherent limitations of the current Internet are presented in detail in Figure 16.

7.2 | Technological and nontechnical challenges to 6G

There are various technological and nontechnical challenges to 6G networks. Figure 17 summarizes the major challenges to 6G networks.

7.2.1 | Technical challenges to 6G

a. THz waves. THz waves prove to be very advantageous in 6G networks and also mobile communication. But this frequency band also has a lot of constraints and poses challenges as discussed below.[42–44,70,145]

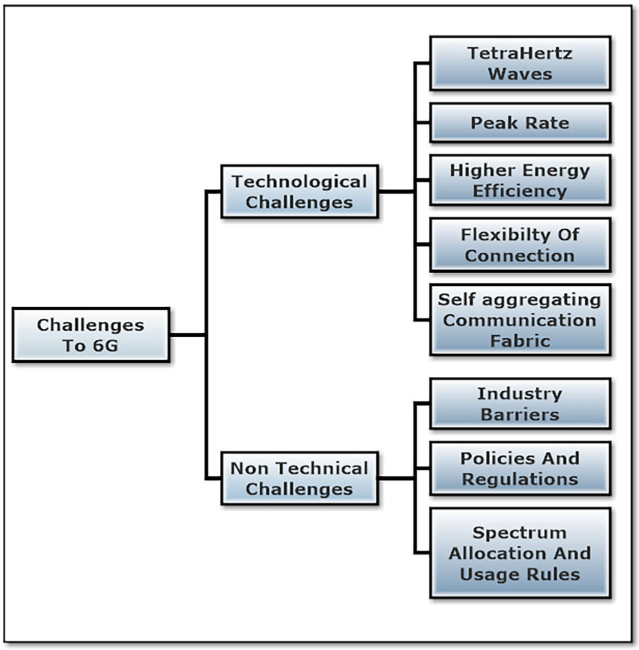


FIGURE 17 Technical and nontechnical challenges to 6G.

i. Coverage and communication: The low-frequency part of the band has larger space attenuation as frequency squared is proportional to free space fading. This makes THz frequency band highly directional propagation signal. Hence, there is a need to optimize the mechanism and update the methods of this signal function.
ii. High fading characteristics: The THz frequency band is highly dependent on coverage and shadows. The effect of rain and humidity fading on THz frequency communication is very small as above 100 GHz this fading is relatively flat. Hence, frequency bands with low attenuation can be selected for THz communication in the future like 140 and 220 GHz.
iii. Irregular connection and fluctuations: The high attenuation of THz frequency waves to shadows causes the propagation to fluctuate very much. Also, as THz frequency waves are highly directional signal, the propagation path becomes very weak over time. The cells compose THz system which also change their association over the propagation path. Hence, a fast and reliable mechanism is required to provide a solution to the irregular connection problem.

b. Peak rate. Peak rate is a key measure and metric while comparing the mobile communication and network technologies. Over the years, network generations have focused to increase the peak rate and 6G will increase the peak rate further. The applications and devices that will be benefited by the increased peak rate in 6G are as follows.

i. Big data smart applications for general purpose which require transmission mechanism for large amount of data. This will also lead to further development of mobile communication systems in future generations.
ii. Holographic communications and AR, VR, XR will be greatly benefitted by the 6G peak rate as the data rate requirements are very high for these applications as compared with rest of the wireless applications.[40,51,146]

c. Increased energy efficiency. In future 6G generations, increased bandwidth, throughput, and data rates with multiple large number of wireless nodes can lead to large energy requirements and consumptions. The increased throughput at the cost of high-energy requirements can be grave and hence bitwise energy consumption (J/bit) has to be decreased. The effective division of energy for deployment and large number of network sensors requiring tremendous energy are the major challenges. Also, in 6G network, power consumption for antenna processing and data transmission are the top challenges in future. Hence, green energy communications are very vital to handle and overcome the high-energy requirements.[51,64]

d. Robust connection. Human activity is evolving and expanding due to the growth in science and technology. Human activity has reached to the outer space, deep seas, and high-altitude mountains and increased the communication needs. Communication network technology becomes extremely paramount as humans try to broaden their reach of activities. Communication modules and segments are exactly relating to the IoT are being utilized and distributed largely over different areas. To fulfil the future requirement, the IoT will see an upgrade in the number of sensors and expansion of DL networks for robust communications. This also forms the future goal and challenge of 6G to have exchange of information and communicate with multiple devices over a wide area coverage.[40]
e. Communication fabrics. The 6G is expected to aggregate multiple networks dynamically. Despite every network generation aiming to accommodate top technical 3GPP standards, a closed standard system is formed. The integration of multiple, complicated, and different techniques and standards emerge when network connection for devices is increased. With the advent of IoT and IoE, 6G is expected to provide highly integrated dynamic technology system deliverables. In addition, dynamic, intelligent, and robust aggregation of network technology will be seen. The 5G in comparison to 6G accommodates network technologies semistatically or statically and also the accommodation is up to a limited extent. The 6G will be required to diversify the implementation of aggregation of networks in an intelligent, flexible, dynamic, and robust fashion to handle complex and largely different user demands in the future.[79]

7.2.2 | Tactile internet-based challenges

Integration of computational systems, controller systems, and the communications systems are a major challenge for tactile Internet. Software and virtual network entities are integrated over mobile communication framework to increase efficiency in real time. As the tactile internet is a new concept, it has underlying challenges. Scalable and robust routing algorithms are required to decrease end to end delays. In addition, user plane separation/coordination techniques and intelligent control plane are also important techniques to reduce overheads and interface delay. Secure mechanisms through authorization are required for privacy preservation in tactile internet against malicious users.[54,87,147]

7.2.3 | Nontechnical challenges

There are many nontechnical problems in addition to the technical problems that will be faced by 6G. The nontechnical challenges range from spectrum usage and allocation rules, industry barriers, and policies.[56] Mobile communication will be working closely and will be integrated to other diverse industries and domains due to the active penetration of 6G in social production. Traditional industries may pose to be a challenge to the entry and usage of 6G owing to their traditional benefits and behaviors. Geographic coordination is required in order to ensure coordination of allocation THz frequency in 6G. Allocation of a unified frequency band is essential in spectrum allocation and usage rules. Strict rules are imposed on satellite communication as well. Spectrum and orbit resources need to be distributed, and share must be consulted by numerous countries. Satellite communication systems and policies are being discussed and mediated by major countries and companies.[15,148]

7.3 | Solutions to challenges in 6G

7.3.1 | RL-based smart energy harvesting

Sustainability is paramount in 6G network applications with the use of renewable energy and resources and energy efficient devices. Wireless energy harvesting ensures sustainability in 6G. Ambient sunlight, interference-aware, and dedicated radio frequency harvesting sources are some of the scenarios being covered by wireless energy harvesting mechanism. Smart power control systems are crucial as harvested energy is majorly diverse for the wireless energy harvesting sources. Wireless channel and incoming harvesting channel popularly known as system state is assumed in the historical power control which is not widely available and has many practicality challenges. Reinforcement learning is one of a possible solution to the energy harvesting channel which can observe the system state but limited to a cap in the number of system states. Online learning schemes will be needed to improvise this solution like the use of Lyapunov opportunistic optimization.

7.3.2 | BC aided secure business model systems

Decentralization is a key technology for communication among large number of different and widely placed devices within a secure architecture and in a cost-efficient mechanism. The cost effectiveness in addition to the secure system provides a novel solution economically to the devices using different schemes. In case of a centralization specific business model system, increased latencies are observed. High latency is a potential danger to high-speed 6G communication services. Hence, newer distribution-based business models like blockchain and cryptographic-based secure and private services prove to be useful to provide secure solutions.

7.3.3 | ML-assisted smart cell-less architecture

Multiple communication technologies need to be managed efficiently in 6G wireless network systems. A cell-less architecture helps to provide a quality experience to users offering seamless transmission and communication. Communication technologies like millimeter-wave, THz, and VLC are provided the quality interaction by this novel 6G architecture. Smart cognitive radio having adaptive features can be used in 6G operations. A cognitive radio which is software defined can perform several smart operations using ML algorithms. These operations involve self-optimization, self-management, and self-error recovery. ML models can be equipped with fast learning using Quantum ML.[33]

7.3.4 | Distributed and secure model systems through BC

Distributed computing has becoming exceedingly popular nowadays especially distributed ML. The integration of these concepts to 6G also involves maintaining privacy intact for the systems. AI will become essential in a 6G wireless communication system for multiple intelligent applications. Data transfer for training is done on cloud or edge server to improve time and cost of training a ML model. To maintain the privacy, encrypted data rather than unencrypted data can be used in 6G. The 6G will be greatly benefitted by using this technique and following a distributed authentication scheme like involving blockchain in DLT for a secure model.

7.3.5 | Intelligent reflecting surfaces in 6G

Reconfigurable intelligent reflecting surfaces can be deployed in the 6G wireless network systems to improvise energy efficiency and increase throughput. MIMO can be used with THz communication waves and antenna arrays to leverage the increasing data needs. High-frequency waves reduce diffraction and scattering effects.[149] High-frequency waves have disadvantage in suffering from blockage of electromagnetic waves by obstacles and having measurable path loss. Reconfigurable intelligent reflecting surfaces help to overcome these challenges as the reflecting elements comprising the surface reflect the electromagnetic radiations.[150] This helps in greatly improving communication performance over wireless network. Access points-based reflecting surfaces also prove to be a viable solution. This scheme involves unmodulated carrier signal to pass on the surface resulting in minimal fading by radio frequency generator.[151] All the discussed solutions to challenges in 6g are summarized in Table 11.

8 | RESEARCH DIRECTIONS

The potential research directions against several challenges in 6G-based IoT are discussed a follows:

- To address the *security and privacy in 6G-IoT*, many perturbation methods can be utilized for securing the training datasets against any kind of data intrusion in the edge paradigm-based 6G IoT networks.
- Further, to take care of *energy efficiency*, QoS and energy consumption can be optimized by using a 6G-based multimedia data structure.

TABLE 11 Challenges, causes, and solutions aiding green 6G.

Challenges	Causes	Solutions
Adaptive transceivers based on AI	*A large number of parameter settings	*Intelligent transceiver built on ML and deep Q-learning. ML techniques can be used to dynamically tune certain parameters.
	*Physical layer specifications for different applications vary significantly.	*Transceiver focused on federated learning. It accomplishes this effectively by limiting the use of wireless resources by sending only model updates to the edge/cloud server (which are far smaller than the entire training data).
Smart cell-less architecture	*Managing a variety of communication technologies of varying capabilities	*Cognitive radio focused on deep Q-learning. It can conduct self-protection from intrusion, self-fault restoration, self-optimization, and self-management, among other intelligent activities.
	*Various bands of communication, each having its own set of features	*Quantum ML can then be used to learn ML models quickly.
Secure business model systems	*At the network edge, ML models are being educated.	*A few of the solutions for 6G-distributed security could be authentication strategies focused on DLT (using blockchain).
	*Decentralized security with low delay is necessary for intelligent systems.	*Homomorphic encryption
Smart energy harvesting	*Using energy-efficient equipment and renewable sources to enable 6G applications in a sustainable manner is needed.	*The use Lyapunov opportunistic enhancement and strategies focused on online education
	*Existence of a huge number of different types of interference signals	*A few of the proposed options is reinforcement learning.
Distributed and secure model systems	*ML model training at the site of network edge	*New decentralized, secure architecture business models should be built to leverage cost-effective communication across different widely distant players in 6G.
	*For smart applications, distribution-based authentication with low level of latencies are required.	*Safe service brokering among distributors and suppliers using blockchain technology
Intelligent reflecting surfaces in 6G	*For mm wave and THz communication, there is high path loss.	*Tunable smart reflective deep learning-based surface. It boosts the efficiency of wireless communication.
		*Other choice is by using smart reflecting surface-based access points that can be reconfigured.

- There are also some *hardware constraints* present in the IoT Devices. This can be solved using a software-oriented DL accelerator to aid the training process of AI/DL models on sensor hardware.
- Also, the consolidation of 6G-IoT systems needs *strict policies and standardized specifications* for which a collaborative association of all business stakeholders like customers and services providers can be done.

8.1 | Future scope and analysis

Blockchain is a reliable solution for developing trust and aiding in distributed communications for 6G IoT networks, especially in untrusted wireless environments. Moreover, methods of energy harvesting can be leveraged where exploitation of renewable energy resources can be done to build green 6G-IoT systems. In addition, for developing lightweight hardware platforms in order to meet the service needs, edge-intelligent devices in 6G networks are required. Lastly, multi-access edge computing initiative is proposed to enable the seamless utilization of edge computing and communication resources in different IoT applications.

8.1.1 | Analysis

The amalgamation of blockchain with IoT and 6G has displayed significant potential. BCT encompasses essential characteristics such as immutability, transparency, security, and anonymity. By eliminating the need for trusted intermediaries, BCT reduces processing time and costs in peer-to-peer transactions. This shift toward a digitized distributed economy facilitated by blockchain technology holds the promise of intelligent living with enhanced integrity. By incorporating blockchain into next-generation 6G networks and massive IoT systems, high-performance services are ensured, leading to a mutually reinforcing cycle of improvement. Blockchain-facilitated 6G networks will create a conducive environment for intelligent analysis of large-scale data, supporting sustainable high-quality products and services tailored to meet specific consumer needs. A shared blockchain ledger marketplace can simplify asset transactions between many customers, enabling sharing of network resources, roaming, network slicing, and so on. In the realm of Industry 4.0 and industrial IoT applications, blockchain-powered maintainable business models offer reliability, secure communication mindful of privacy, and environmentally conscious technologies.

9 | CONCLUSION

As 5G technology becomes deployed widely, it raises concern to the requirements related to network security and to the huge increase in the number of network users. The 6G is expected to overcome these challenges as well as to fully leverage all the underlying features and functionalities. Recently, there is a lot of research about 6G and its integration with other upcoming technologies. These technologies and mechanisms comprise of new spectral technologies like VLC and THz communication, Blockchain, IoT, ML, DL, and AI. The 6G has revealed its capabilities for enhancing the smart city/home, smart grid, smart manufacturing, and the network communication sector by these technologies. In this review paper, the authors have provided a systematic and comprehensive survey of upcoming technologies in 6G by initially describing the evolution of network generations and their comparisons on various factors like latency and efficiency and listing the improvements and shortcomings. The authors explain the numerous technologies integrated with 6G in detail. Blockchain provides security features using decentralization and systematic resource allocation. IoT systems help to transform data to meaningful information with the help of network and power resources. AI optimizes the topology of networks using many heuristic algorithms and helps in congestion control, safeguarding the privacy over a network. The challenges faced by these technologies are also facilitated with a detailed discussion. The taxonomy of core technologies and applications in 6G (edge AI and autonomous systems etc.) throwing light to their characteristics and the real-world scenarios and applications is also discussed in addition to a detailed comparative analysis. The authors of the paper also explain characteristics and inherent limitations of the current internet. The current security issues and key performance challenges of 6G systems is also discussed in this article. Several emerging techniques in green 6G like smart energy harvesting and smart cell-less architecture are presented in this review paper. Finally, the authors summarize the solutions and causes to the challenges in the 6G technology which will improve the wireless 6G network systems. The authors look forward to improve and widen their research in the future on the topics of newer solutions to 6G challenges and more details of reinforcement learning and Q-learning as they are newly developed technologies to improve the real-world challenges in 6G communication technology.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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