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Review

6G Mobile Networks: Key Technologies, Directions, and Advances

Ramraj Dangi [1], Gaurav Choudhary [2,3,*], Nicola Dragoni [3], Praveen Lalwani [1], Utkarsh Khare [1] and Souradeep Kundu [1]

1 School of Computing Science and Engineering, VIT Bhopal University, Sehore 466114, India; ramrajdangi@vitbhopal.ac.in (R.D.); praveen.lalwani@vitbhopal.ac.in (P.L.); utkarsh.khare2021@vitbhopal.ac.in (U.K.); souradeep.kundu2021@vitbhopal.ac.in (S.K.)
2 Center for Industrial Software, The Mærsk Mc-Kinney Møller Institute, University of Southern Denmark, DK-6400 Sønderborg, Denmark
3 DTU Compute, Department of Applied Mathematics and Computer Science, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark; ndra@dtu.dk
* Correspondence: gac@mmmi.sdu.dk

Abstract: The exponential growth of the fifth-generation (5G) network gives businesses and universities a chance to turn their attention to the next-generation network. It is widely acknowledged that many IoT devices require more than 5G to send various types of data in real-time. In addition to 5G, several research centres are currently concentrating on 6G, which is expected to produce networks with great quality of service (QoS) and energy efficiency. Future application requirements will necessitate a significant upgrade in mobile network architecture. 6G technologies offer larger networks with lower latency and faster data transmission than 5G networks. This review presents a comprehensive overview of 6G networks which includes the novel architectural changes within 6G networks, recent research insights from diverse institutions, applications within the realm of 6G networks, and the key features associated with them. We also explored various technologies of 6G networks encompassing terahertz, visible light connectivity, blockchain, and symbiotic broadcasting, all of which contribute to the establishment of robust and socially integrated network structures. In this survey, we have focused on 6G network slices and discussed a detailed exploration of security and privacy concerns regarding the potential 6G technologies at the levels of physical infrastructure, connecting protocols, and service provisions, alongside an evaluation of current security strategies.

Keywords: 6G network; network slicing; security; threats; machine learning

Citation: Dangi, R.; Choudhary, G.; Dragoni, N.; Lalwani, P.; Khare, U.; Kundu, S. 6G Mobile Networks: Key Technologies, Directions, and Advances. *Telecom* **2023**, *4*, 836–876. https://doi.org/10.3390/telecom4040037

Academic Editor: Christos Volos

Received: 1 September 2023
Revised: 26 October 2023
Accepted: 20 November 2023
Published: 1 December 2023

1. Introduction

The foundation for the next 6G wireless network standard is already starting to take shape, whereas the 5G mobile network standard is still in its early phases. It's quite okay to start thinking about 6G's possible features even though the technology won't be ready for a while. A gigabit wireless network with service areas segmented into distinct geographic areas known as cells. Since 6G networks are expected to be more diverse than older mobile networks, they will be able to support applications that go beyond what people usually do with their phones. As a result of the Internet of Everything (IoE), many new vertical services and applications have been created to make our lives, society, and industrial processes better. These include mass production, smart transportation systems, smart homes, and virtual reality (VR) technology. There are many different Quality of Service (QoS) requirements for these vertical solutions, which have a wide range of effects. On the other hand, what current fifth-generation (5G) networks can do is not nearly enough to support new vertical applications. Because of this, academics are interested in new ways to design and run 6G networks [1].

Through a shift in service and technology development, integration, and usage, the 6G network seeks to redefine how people view communication networks. The 6G network may address network issues in the future. Future services and applications will leverage complex networks and bio-inspired technologies to meet performance goals and meet rising resource needs [2].

6G networks will replace 5G cellular technology. 6G networks can work at higher frequencies than 5G networks and have a lot more capacity and less latency. The goal of the 6G network is to make it easier for people to talk to each other by making latency as low as one microsecond. This is 1000 times faster than the throughput of one millisecond. 6G will employ even shorter wavelengths in the terahertz (THz) spectrum, which covers the frequency range of 100 GHz to 3 THz, as opposed to 5G, which employs mmWave in the microwave frequency range. While 5G has a significant impact on Radio Access Networks (RAN), the impact of 6G networks will be considerably higher due to a significant increase in frequency that will minimize the need for antennas almost everywhere.

1.1. Problem Statement and Motivation

The existing literature survey primarily covers architecture, technical requirements of 6G, and the challenges and problems related to implementation. Some surveys also explored various aspects of 6G technologies, each with its unique set of parameters. However, these studies did not offer comprehensive coverage of all 6G technologies, focusing on network slicing and security. Some researchers deep-dived into Terahertz communication and IoT technologies, while others concentrated on spectrum sharing and RF technology. So, our main aim is to give a detailed study of all the technologies working on the 6G network with security challenges and network slicing in 6G networks. The need for surveying recent advancements in 6G mobile networks and technologies is essential for staying at the forefront of technological progress, guiding research and development efforts, informing policy decisions, and boosting innovation and collaboration in the 6G domain.

The primary motivation of this survey is to cover the state-of-the-art techniques and recent novel 6G communication and technological developments by researchers. The recent advancement study on 6G will help to accelerate the development and production of the 6G network. This survey provides an umbrella approach to bring multiple solutions and recent improvements in a single place to accelerate the 6G research with the latest key enabling solutions and reviews.

1.2. Research Methodology

In order to prepare the literature on the 6G network, we use a search approach and a snowballing approach. However, because of the broad area, we only include research on 6G technologies, security, and network slicing. By comparing the security criteria indicated by various research, we can see how many studies have mentioned them, which risks they are connected to, and what solutions have been suggested. We include the 6G technologies that have been identified together with the characteristics, allowing us to discuss which technologies need more investigation. We have created the following keywords with these requirements: 6G network technology, security, and network slicing. We used the following databases as sources: Elsevier/ScienceDirect, IEEE Xplore, and the ACM Digital Library. Combining these three sources offers a reliable depiction of international research in this field. The search was divided into three phases. First, we searched databases for papers about 6G technology based on their titles. This gave a general summary of the volume of research done in this area. We then restricted our search to include papers addressing 6G security. Finally, we look at research papers on network slicing.

1.3. Key Contributions

This article's primary objective is to present the key findings of 6G technologies, network slicing, and security of the 6G network. It also aims to help readers assess how well recent training addressed 6G issues and produced solutions to deal with those issues, i.e., what new approaches need to be used and how they can solve issues? The following are some of the highlights of the exploratory composition.

- This survey covers the most recent advances & progress in the 6G age, as well as new benefits received by the experimental group and crucial elements of the 6G evolution.
- The evolution of mobile network technology is the topic of this research. The growth of mobile communications and its many facets are also explored.
- With a comprehensive classification, this study explores the emerging operational and research groups working on 6G and the many exploration domains in 6G wireless communication systems.
- This analysis considers the benefits, features, key technologies, and fundamental concepts of a 6G network. The potential for network slicing and security in the 6G network is also investigated with an eye to future use cases. The 6G IoT-based approaches and optimisation techniques were also highlighted in the survey.
- We provide a thorough overview and a summary of recent developments in the emerging technologies of the 6G cellular connection, including Wireless Communication Technology and Systems, which also covers Terahertz (THz), Next-Generation Antenna and RF Technology, Channel Coding and Modulation Technique, Spectrum Sharing, Internet-of-Things, and Blockchain Technology. By stressing the surroundings of current techniques and accompanying obstacles, a specialised overview is also circulated.
- The improvements in softwarization, agile control, and deterministic services over the 6G armature are explored, and an architectural perspective for Network Slicing for the 6G network is presented.
- In this study, we examine the potential difficulties and opportunities presented by Network Security throughout the development of 6G technology. This survey also includes discussions on security considerations, focusing on data processing, threat detection, network monitoring, and data encryption.

1.4. Outline of the Survey

The remaining article is structured as follows: A state-of-the-art comparison of current surveys and road maps may be found in Section 2. 6G market overview and current status has been covered in Section 3. The numerous 6G network technologies are covered in Section 4. The role of network slicing in 6G technology is explored in Section 5. Section 6 explores the new dangers and security issues with 6G networks, and Section 7 brings the article to a conclusion. The arrangement of the article is shown graphically in Figure 1. Table 1 contains a list of acronyms along with their definitions.

Table 1. List of Acronyms.

Abbreviations	Full Forms	Abbreviations	Full Forms
3GPP	Third Generation Partnership Project	**MNO**	Mobile network operator
5G	Fifth Generation Wireless Network	**MSITM**	Metasurface-in-the-middle Attack
6G	Sixth Generation Wireless Network	**NASOR**	Network And Slice Orchestrator
AI	Artificial Intelligence	**NFV**	Network function virtualization
AMPS	Advanced Mobile Phone Service	**NOMA**	Non-orthogonal Multiple Access
AR	Augmented Reality	**NS**	Network Slicing
BDMA	Beam Division Multiple Access	**OAM**	Operations, Administration and Maintenance
CN	Core Network	**OCC**	Optical Communication Channel
DDoS	Distributed Denial-of-Service Attack	**OFDM**	Orthogonal Frequency Division Multiplexing
DLT	Distributed ledger technology	**OMA**	Orthogonal Multiple Access

Table 1. *Cont.*

Abbreviations	Full Forms	Abbreviations	Full Forms
D-OMA	Delta-Orthogonal Multiple Access	**ORAN**	Open Radio Access Network
DoS	Denial-of-Service	**OWC**	Optical wireless communication
DRL	Deep Reinforcement Learning	**PKI**	Public Key Infrastructure
DRM	Digital Rights Management	**RAN**	Radio access network
DSCM	Digital Sub-Carrier Multiplexing	**QOS**	Quality of Service
DTTCM	Distributed Turbo Trellis Coded Modulation	**RF**	Radio Frequency
E2E	End to End	**RIS**	Reconfigurable intelligent surfaces
ECC	Elliptic Curve Encryption	**RL**	Reinforcement Learning
eMBB	Enhanced Mobile Broadband	**RSMA**	Resource Spread Multiple Access
eMTC	Enhanced Machine Type Communication	**RTD**	Real Time Difference
ETSI	European Telecommunications Standards Institute	**RTIE**	Real-time intelligent edge
eURLLC	Enhanced Ultra-Reliable Low Latency Communications	**SDN**	Software-Defined Networking
FBMC	Filterbank Multicarrier	**SLA**	Service-Level Agreement
FDMA	Frequency Division Multiplex Access	**TDMA**	Time Division Multiple Access
feUMBB	Further Enhance Ultra-Mobile Broadband	**THz**	Terahertz
FSO	Free-space optical communication	**TLS**	Transport Layer Security
FTN	Faster-than-Nyquist	**TPG**	Test Pattern Generator
HAP	High-Altitude Platform	**TTCM**	Turbo Trellis enCiphered Modulation
IIoT	Industrial Internet of things	**UAV**	Unmanned Aerial Vehicle
IoE	Internet of Everything	**UHDD**	ultra-High Density Data services
IoT	Internet of Things	**uHEE**	ultra-High Energy Efficiency
IPsec	Internet Protocol Security	**uHRS**	ultra-High Reliability and Sensing
IR	Infrared radiation	**uHRUx**	ultra-High Reliability and User experience
JWT	JSON Web Token	**uHS**	ultra-High Security
KPIs	Key Programmable Interface	**uHSLLC**	ultra High Sensing Low Latency Communications
LAP	Link Access Protocol	**uHSLo**	ultra-High Sensing and Localization
LDPC	Low-Density Parity-Check	**uLLRS**	ultra-Low Latency Reliability and Secure
LiFi	Light-Fidelity	**UMTS**	Universal Mobile Telecommunications Service
LMDS	Local Multipoint Distribution Service	**uRLLC**	Ultra-Reliable Low Latency Communication
LoS	Line of sight	**V2X**	Vehicle to Everything
LTE-A	Long Term Evolution-Advance	**VLC**	Visible light communication
MIMO	Multiple-Input Multiple-Output	**VNF**	Virtualized Network Functions
MITM	Man In The Middle Attack	**VR**	Virtual Reality
ML	Machine Learning	**WCDMA**	Wideband Code Division Multiple Access
mMTC	Massive Machine Type Communication	**WiMAX**	Worldwide Interoperability for Microwave Access
mmWave	millimeter Wave	**XR**	Extended Reality

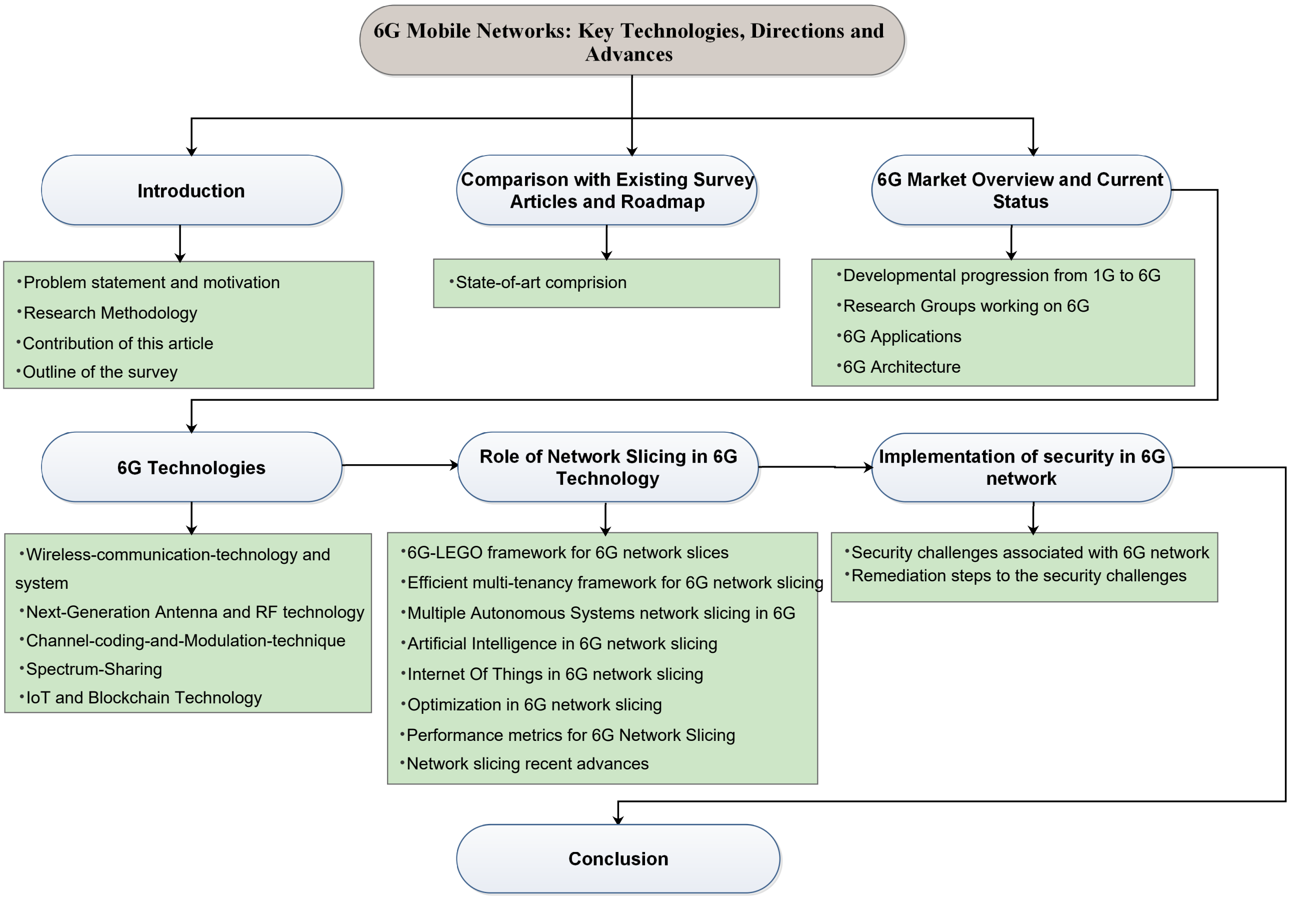

Figure 1. Outline of the survey.

2. Comparison with Existing Survey Articles and Roadmap

Certain research puts importance on certain features such as Network Security, Wireless Communication Technology and Systems, IoT and Blockchain Technology, Channel coding, and Modulation Techniques. Table 2 includes an overview of previous studies on the slice of the network, network security, and technological aspects of the network. Some surveys focus on network slicing, Next-generation antenna and RF technology, and Spectrum Sharing.

Soon Xin Ng et al. [3], proposed a cooperative communication scheme (DSCM) using channel coding and modulation technique. Marco Giordani et al. [4] explore the 6G scenarios and requirements from a full-stack, system-level perspective, and choose 6G technologies that can meet them. Sudeep Bhattarai et al. [5] provides an overview of major recent technological and legal developments that are facilitating a fundamental change toward 'radio-spectrum' assets should be managed and distributed using adaptable, flexible, business methods internationally. Ramesh Sekaran et al. [6] gives a review that assesses the key difficulties in combining Blockchain and IoT technologies to achieve cutting-edge solutions in 6G networks. MostafaZaman Chowdhury et al. [7] outlines the network architecture for 6G wireless communication in the future exploring NS, wireless communication technology, blockchain and next-generation antenna & RF technology. Walid Saad et al. [8] explained the fundamentals of a 6G system, proposed a new range of service categories, and revealed their envisioned 6G performance criteria. Haitham Hassan H. Mahmoud et al. [9] outlined the system requirements, possible trends, technologies, services, applications, and research advancements in order to conceptualise the 6G cellular Haitham Hassan H. Mahmoud et al. [9] outlined the system requirements, potential developments, techniques, applications, deployments, and research achievements In order to conceptualize the 6G cellular system. Samar Elmeadawy et al. [10] provides a study on network security, wireless communication technology along with IOT and blockchain technological concepts. Ashish Kr. Gupta et al. [11] explore technological advancements, their benefits, and how to address customer needs for the 6G mobile network. Yang Lu et al. [12] explore the possibilities, key technologies, and network scenarios for 6G networks thereby, a conceptual framework for 6G is also suggested [13].

Anutusha Dogra et al. [1] suggest some newer NS solutions, Wireless communication technology, spectrum sharing, and IOT concepts proposing a virtualized 6G network architecture. Wen Wu et al. [14] covers domains such as NS in 6G networks. Hao Xu et al. [15] focuses the topics like network security, NS, wireless communication, spectrum sharing, and IoT technologies to implement efficient resource management in 6G network architecture. Rodrigo Moreira et al. [16] explored the concepts of NS and blockchain technology to build a recursive network slicing between several Autonomous Systems using the NASOR approach. Slawomir Kuklinski et al. [17] explored self-managed and self-orchestrated network slices sustained using 6G-LEGO. Finally, Maansa Krovvidi [18] provided a study on an AI-based NS framework encompassing wireless communication and IoT technology.

All of these surveys emphasized only a few of the components as described in Table 2. All aspects of network slicing, network security, and 6G network technologies are the primary emphasis and scope of our study.

Table 2. Comparison with Existing Survey Articles and Roadmap (Discussed: Yes; Never Mentioned: -; Partially Mentioned: Partially).

Authors & References	Network Security	Network Slicing	Wireless Communication Technology and System	Next-Generation Antenna and RF Technology	Channel Coding and Modulation-Technique	Spectrum Sharing	IoT & Blockchain Technology
Soon Xin Ng et al. [3]	-	-	-	-	Yes	-	-
Marco Giordani et al. [4]	-	-	Yes	Yes	-	-	-
Sudeep Bhattarai et al. [5]	-	-	-	-	-	Yes	-
RAMESH SEKARAN et al. [6]	-	-	-	-	-	-	Yes
MostafaZaman Chowdhury et al. [7]	-	Yes	Yes	Yes	-	-	Partially (only For Blockchain)
Walid Saad et al. [8]	-	-	Yes	Yes	-	-	-
Haitham Hassan H. Mahmoud et al. [9]	-	Yes	Yes	Yes	-	-	-
Samar Elmeadawy et al. [10]	Yes	-	Yes	-	-	-	Yes
Ashish Kr. Gupta et al. [11]	-	-	Yes	-	-	-	-
Yang Lu et al. [12]	-	-	Yes	Yes	Yes	Yes	Yes
Anutusha Dogra et al. [1]	-	Yes	Yes	-	-	Yes	Partially (only For IoT)
Wen Wu et al. [14]	-	Yes	-	-	-	-	-
Hao Xu et al. [15]	Yes	Yes	Yes	-	-	Yes	Yes
Rodrigo Moreira et al. [16]	-	Yes	-	-	-	-	Partially (only For Blockchain)
Slawomir Kuklinski et al. [17]	-	Yes	-	-	-	-	-
Maansa Krovvidi [18]	-	Yes	Yes	-	-	-	Partially (only For IoT)
Our paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes

3. 6G Market Overview and Current Status

The market for 6G networks is expected to lead to new ideas in imaging, presence technologies, and knowing where you are. 6G is expected to come by 2030. The COVID-19 outbreak has had a complex impact on the industry and has created numerous growth hurdles for the global 6G market. Companies that are focusing on the development of 6G networks are—Apple Inc., Nokia Corporation, AT&T Inc., Verizon Communications Inc., Google LLC, Intel Corporation, Samsung Electronics Co. Ltd., Cisco Systems Inc., LG Corporation, Sony Corporation, etc. While the rest of the world waits for the new 5G technology to catch on, China and the United States are already hard at work creating 6G networks, the next development in the field of quick communication. The widespread development and use of 6G technology around the world is a big reason why the industry is moving forward. According to the South China Morning Post, China claimed to have made progress in 6G mobile technology by January 2022. In order to maintain its focus on cloud computing, digital platforms, and the development of 6G, Verizon has concentrated on creating 6G. In addition to what has already been said, telecom experts from Finland and Japan have suggested working together to improve 6G technologies. The development of 6G is a priority for many firms, governments, and businesses. Such massive new developments are expected to increase the global 6G market's overall growth. Due to a large number of businesses, government programs, and other factors, it is expected that North America will have the largest share of the global 6G market. When it comes to promoting the next generation of communication technology, the United States is behind the curve. AT&T and Ericsson's executives were elected to spearhead the campaign to position North America as a pioneer in 6G networks for the US industry. The Next G Alliance, which comprises Ericsson, AT&T, Verizon, Samsung, Microsoft, and other companies, was announced by the Alliance for Telecommunications Industry Solutions in October 2020. Over the next ten years, the alliance wants to strengthen North America's position as a global leader in mobile communications. China just sent the first 6G test satellite into space, which has caused a rush of interest in the field. For instance, China successfully launched a test satellite for 6G networks and about 12 other satellites into orbit on 6 November 2020, using a Long March 6 launch system rocket. The Minister of Communication in India also said that 6G technology would be used by 2024. However, by building a higher frequency spectrum, 6G networks are able to give high-speed access to the network; additionally, higher-throughput satellite communication services are used to provide extensive coverage in remote and isolated places [19].

For the 6G network, innovative service classes are identified and explained in the following sections:

1. Massive URLLC: The acronym URLLC stands for communications with increased availability, reduced delay, and reliability for critical applications like the industrial internet of things and remote surgery. Massive-URLLC is a new service class that combines traditional mMTC with 5G-URLLC. It will come about because 6G will need to make the 5G URLLC service huge. One of the applications for huge URLLC that some want to deploy is autonomous intelligent driving (AID). AID necessitates juggling many priorities at once, including obstacle detection, automatic driving, motion planning, and others. Interesting alternatives to Massive-URLLC include multiple access techniques like OMA, NOMA, and assertion of multiple access. By using OMA techniques like massive-URLLC, the amount of bandwidth required for 6G might grow exponentially as more devices are added. Other multiple access techniques, such as NOMA, can be used to strike the ideal balance between scalability, reliability, and latency. Massive-URLLC demands the delivery of a lot of little data packets for "time-critical" 6G applications to ensure high resource efficiency and low latency [20].
2. eMBB: Applications like holographic meetings, AR, and VR often require fast transmission speeds, minimal latency, and great reliability. Additionally, these demands must be met in situations demanding a great deal of mobility, including sea and air travel. As a result, the following new service class for 6G has proposed an enhanced mobile broadband URLLC. For this service class, the importance of energy-efficiency is a priority. In comparison to the URLLC along with eMBB in 5G networks, this new network class should be extremely skilled in improving mobile communications networks, with regard to handover, interference, and huge data transmission and processing. Additionally, the improved mobile broadband URLLC communication service's security and privacy issues need to be considered [20].

3. Massive eMBB—The link frequency will be quite high in Industry 4.0-based scenarios in order to acquire tactile perceptions and convert them into digital data. As a result, big eMBB will be a hot topic in the 6G network as a way to improve large-scale IIoT operations and functionalities by enabling the vast connection between worker, sensor, and an actuator that has low-latency[20].

As a result of technological advancements and intelligent autonomous driving novel key service classes will emerge the network of the future. There are several advantages of 6G network over 5G network[21] as explored below:

1. Frequency Bands—For fixed access, 5G provides millimeter wave and sub-5GHz frequency bands. While 6G enables sub-6 GHz frequency bands, millimeter waves for mobile communication investigation of THz bands, non-RF bands, etc.
2. Data Rate—20 Gbps downlink and 10 Gbps uplink data rates are provided by 5G. On the other hand, 6G offers 1 Tbps for both the uplink and the downlink.
3. Latency—5G offers a latency of around 1 ms, whereas 6G aims to achieve a latency of less than 1 µs.
4. Architectural Style—The 5G architecture uses Mmwave tiny cells with a range of roughly 100 metres and dense sub-6 GHz smaller BSs with umbrella macro BSs. While 6G design comprises cell-free smart surfaces operating at higher frequencies, transient hotspots generated by BSs placed on drones, and tests with miniature THz cells.
5. Device Type—5G comprises devices like Smartphones, Sensors and Drones. 6G consists of gadgets including smart implants, CRAS, XR, and BCI technology, as well as DLT gadgets.
6. Reliability—5G has a reliability of 10–5 and 6G has 10 to 9.
7. Accuracy in localization—For 5G networks, 10 cm on 2D, and 1 cm on 3D for 6G based networks.
8. Customer engagement—50 Mbps 2D anywhere for 5G and for 6G network it is 10 Gbps 3D everywhere.

3.1. Developmental Progression from 1G to 6G

First generation (1G): 1G wireless mobile communication emerged in the late 1970s to early 1980s. It utilized analog technologies and the Advanced Mobile Phone System (AMPS) for voice services. Operating in the 824–894 MHz frequency range, it employed FDMA technology with 30 kHz channel capacity, achieving a maximum speed of 2.4 kbps. In 1988, AMPS expanded its capacity by 10 MHz through spectrum broadening. The United States introduced 1G AMPS in 1982 [22].

Second Generation (2G): 2G wireless mobile communication introduced in the early 1990s, marked a shift to digital technologies. It brought improvements over 1G by enabling both voice and basic data services. 2G networks employed technologies like GSM (Global System for Mobile Communications) and CDMA (Code Division Multiple Access). These networks allowed for clearer voice quality, text messaging, and limited data capabilities. Data transfer speeds were typically around 9.6 kbps, paving the way for simple internet access and services like SMS. The 2G era laid the foundation for more advanced mobile communication technologies [22].

Third Generation (3G): 3G wireless mobile communication introduced around the early 2000s, marked a significant advancement from 2G. It provided faster data speeds, enabling more robust internet access, multimedia services, and video calling. Technologies like UMTS (Universal Mobile Telecommunications System) and CDMA2000 improved data rates, offering speeds up to several megabits per second. This era saw the widespread adoption of smartphones and the growth of mobile internet usage. 3G networks laid the groundwork for the expansion of mobile data services and the evolution towards more advanced generations of wireless communication [22].

Fourth Generation (4G): 4G wireless mobile communication introduced in the late 2000s, brought substantial enhancements over 3G. It provided significantly faster data speeds, allowing for high-quality video streaming, online gaming, and improved internet browsing. Technologies like LTE (Long-Term Evolution) and WiMAX offered data rates reaching tens of megabits per second. 4G networks facilitated the rise of mobile apps, video sharing, and connected devices, driving the smartphone revolution and enabling a more connected digital lifestyle. This era marked a significant step toward achieving seamless high-speed mobile internet experiences [22].

Fourth Generation LTE-A (4.5G): A more sophisticated 4G-LTE model. In LTE-A, multiple antennas are combined for both broadcasters and receivers using MIMO technology. With MIMO, several signals and antennas may operate simultaneously, enabling LTE-A 3 times faster than traditional 4G. Wireless accessibility to triad traffic (data, voice, and video) out of any location in the globe was made possible by LTE-A, which also offered a greater system limit and less application server delay. LTE-A provides an upload rate of up to 90 Mbps and download speeds of over 42 Mbps [23].

Fifth Generation (5G): 5G wireless mobile communication introduced in the late 2010s, represents a transformative leap in connectivity. It offers ultra-fast data speeds, extremely low latency, and the capacity to connect a vast number of devices simultaneously. 5G enables advancements like augmented reality, virtual reality, autonomous vehicles, and the Internet of Things (IoT). Utilizing technologies like millimeter wave frequencies and massive MIMO, 5G networks provide multi-gigabit speeds and near-instantaneous communication, revolutionizing how we interact with technology and paving the way for new applications and innovations [23].

Sixth Generation (6G): Users will benefit from various 6G services like Massive-URLLC, eMBB, and Massive-eMBB. Massive URLLC includes approaches like OMA, with NOMA and assertion multiple access, the amount of bandwidth required might rise linearly as the quantity of devices increases. Other multiple access strategies may be employed to provide the optimum latency, reliability, and scalability trade-offs. The main objective of eMBB will be energy efficiency. Mobile communication networks should be able to considerably benefit from this envisioned service class in terms of handover, interference, and massive data transmission/processing. The underlying privacy and security considerations must also be taken into account. Massive-eMBB would demand a high link density to acquire tactile impressions and transform them into digital information. Massive eMBB will thus be a hot topic in the 6G future, enabling vast low-latency communication among personnel, sensors, and actuators to improve large-scale IIoT operations and capabilities. 6G also includes other services like uHSLLC, UHDD, uHRS, feUMBB, eURLLC, etc. 6G offers a latency of 1 microsecond. This is 1000 times faster than the throughput of one millisecond. 6G will employ even shorter wavelengths in the Terahertz (THz) band, which spans 100 GHz to 3 THz, than 5G, which uses mmWave in the microwave frequency range [13].

Figure 2 shows the Evolution of Mobile generations and is depicted in a detailed way as per Table 3.

Table 3. Summary of Mobile Technology.

Generations	Access Techniques	Switching Techniques	Error Correction Mechanism	Data Rate	Frequency Band	Bandwidth	Application	Description
1G	FDMA	Circuit Switching	NA	2.4 kbps	800 MHz	30 KHz	Voice	Let us to have a conversation.
2G	TDMA, CDMA	Circuit Switching	NA	10 kbps	800 MHz, 900 MHz, 1800 MHz, 1900 MHz	200 kHz	Voice and Data	Allow us to send messages and travel with better data services.
3G	CDMA, WCDMA	Circuit and Packet Switching	Turbo Codes	384 kbps to 5 Mbps	800 MHz, 850 MHz, 900 MHz, 1800 MHz, 1900 MHz, 2100 MHz	5 MHz	Voice, Data, and Video Calling	Allow us to experiment by surfing the internet and using mobile applications.

Table 3. *Cont.*

Generations	Access Techniques	Switching Techniques	Error Correction Mechanism	Data Rate	Frequency Band	Bandwidth	Application	Description
4G	OFDMA	Packet switching	Turbo Codes	100 Mbps to 200 Mbps	2.3 GHz, 2.5 GHz and 3.5 GHz initially	15 MHz	Voice, Data, Video Calling, HD Television, and Online Gaming.	Allow us to use unified network topologies and IP protocols to communicate voice and data via fast broadband internet.
5G	NOMA	Packet Switching	LDPC	10 Gbps to 50 Gbps	1.8 GHz, 2.6 GHz and 30–300 GHz	5–100 MHz	Voice, Data, Video Calling, Ultra HD video, Virtual Reality applications	IoT and V2Xhave broadened the scope of broadband wireless services beyond mobile internet.
6G	D-OMA, RSMA	Packet Switching	LDPC with improved encoder and decoder(TPG decoder)	Up to 1 Tbps	90 GHz-140 GHz, 110 GHz to 170 GHz, 140 GHz to 220 GHz, 170 GHz to 260 GHz, 220 GHz to 325 GHz, 325 GHz to 500 GHz, 500 GHz to 750 GHz, 750 GHz to 1100 GHz, up to 3000 GHz	7–20 GHz	Voice, Data, Video Calling, AI, optical wireless communication (OWC), 3D networking, unmanned aerial vehicles (UAV), and wireless power transfer	End-users will be ableto smoothly and rapidly access a variety of high-end servicesthrough 6G. End-users, on the other hand, will require devices with powerful batteries in order to access high-end services without delayor disruption. The goal of 6G is to double the battery life of gadgets.

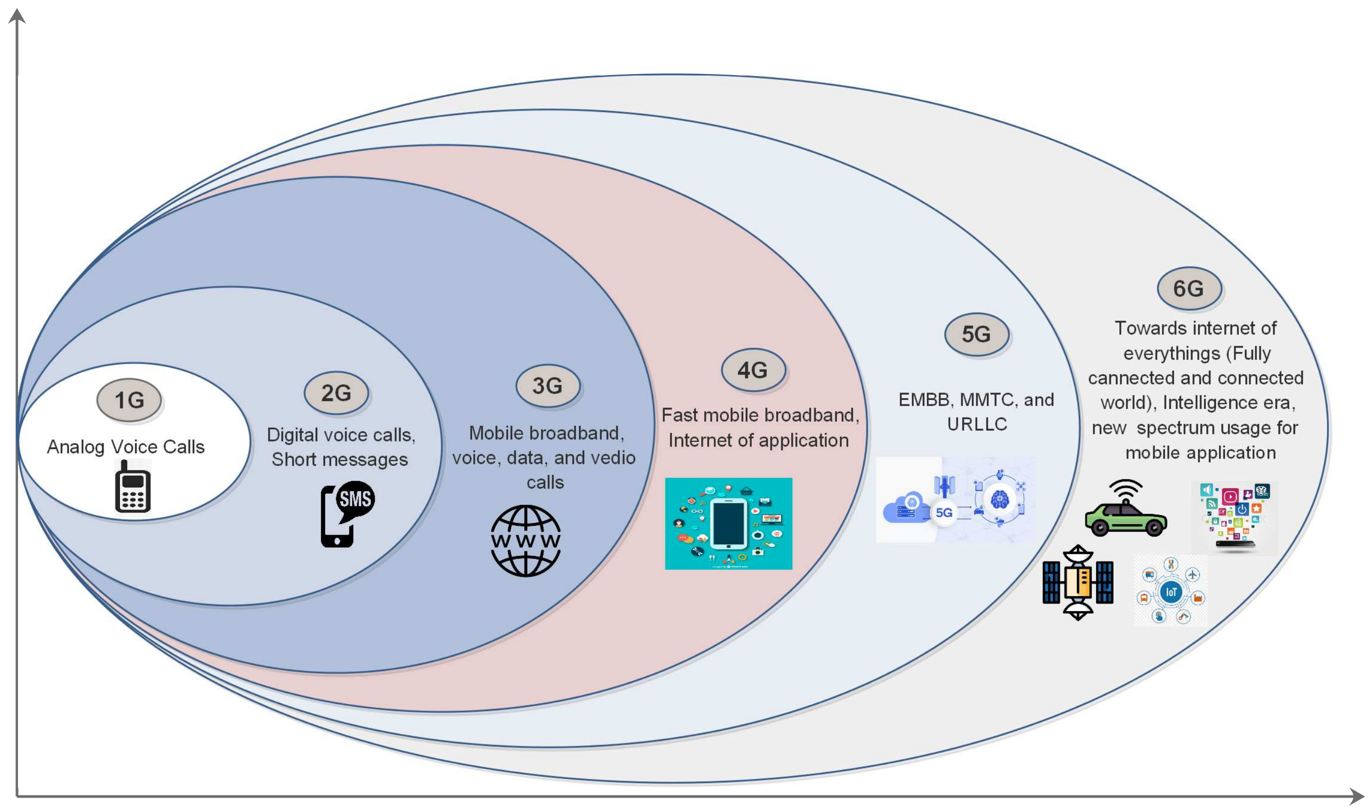

Figure 2. Evolution of mobile generations.

3.2. Research Groups Working on 6G

There are several companies and universities that are researching the upcoming next-gen 6G network, so as to provide sustainable future development. Some of them can be classified as below:

- NTT Docomo: NTT Docomo released a journal paper in January 2020, following the distribution of its first white paper discussed above in September 2019. An intriguing viewpoint presented in this study for new remote transmission advancements that could be used in 6G proposes that faster-than-Nyquist (FTN) flagging, which folds up and sends signals non-symmetrically using an evaluation rate faster than that of the recurrence data transfer capacity in the space-time, would be used in place of OFDM approaches. Additionally, it recommends employing virtual massive MIMO technology to fulfil the specifications for receiving wire gains [24].
- Rohde and Schwarz: Rohde and Schwarz create, deliver, and market a large number of electronic capital products for industry, foundation administrators, and government clients. All the free gathering is among the innovation and market pioneers in its business fields, including remote correspondences and RF test and estimation, broadcast and media, airport regulation and military radiocommunications, online protection, and organization technology. Around March 2020, Rohde and Schwarz distributed a study. The ideas and details mentioned in the article are very comparable with NTT Docomo's article [25].
- The Finnish 6G Flagship: 6G Flagship is the world's most memorable 6G exploration program. We are a piece of the Finnish government's public exploration lead program from 2018 to 2026. We want to make the fundamental 6G mechanical parts, the instruments, and the hardware to construct a 6G Test Network, foster picked vertical applications for 6G to speed up cultural digitization, and keep on being a perceived vision pioneer and pursue research accomplice in overall 6G exploration. In June 2020, they delivered eleven further 6G White papers, resulting in a total of documents from Flagship to twelve. Later, in July 2020, Samsung's white paper was released as one of the most recent upgrades [26].
- Samsung Corp.: The University of Oulu white paper appears to be technologically superior to Samsung's research, which was published in July 2020 [26]. Here are a few recent events that have been determined to be important.
    1. A clearer explanation of the Novel Antenna Technologies needed for THz parallelism is provided. Here two specialized advancements have indeed been explored:
        - RF-front ends and antennas based on metamaterials: A metamaterial is frequently built by assembling a multitude of movable components in various ways on scales smaller than the frequencies. Despite the fact that research on terahertz communication has been done in this area since 2002, 2012, and 2015, Samsung's work specifically looks at 3 different ways to use metamaterials. The employment of a meta-area focal point to refine a shaft form may be advantageous. The operation of a receiving wire for metadata is comparable to that of a radio wire used only for sending commands. Modifiable smart surfaces could be used for a proliferating path in cases when there is no LoS connectivity.
        - Orbital Angular Momentum: OAM enables high-request spatial multiplexing in environments where it would have been impossible to do so using conventional MIMO advances, such as LOS channels. In whatever instance, it seems like its realistic implementation ain't perfectly possible.
    2. Range Sharing: An effect of area utilisation was examined in such a trial of distinctive range sharing. The study suggests using AI to foresee use from various aspects and so help minimise accidents with minimum overhead. By using split computing, devices may delegate complex computation tasks to other computing resources available within the company.
- Bharti Airtel & Vodafone India: An ambitious start into nearby 6G enhancement will result in licensed innovation (IP) creation for the Indian telecom biological system, according to 0.79% and Vodafone Idea NSE 2.60%. They stated that the Indian telecom

sector and the academic community needed to work together with the telecom office and contribute to the 6G standard structure in accordance with international regulations. They stated that it was necessary for the Indian telecom sector and the academic community to collaborate with the telecom office and contribute to the 6G standard framework in accordance with global standards endorsed by the Third Generation Partnership Project (3GPP).

- Huawei Technologies Co. Ltd.: The most advanced mobile communications system available now is 6G, but it will do much more than just support exchanges. The introduction of 6G will truly usher in a time when everything will be sensed, connected, and clever. 6G will function as a circulated brain network that provides correspondence links to join the physical, digital, and natural universes. This will provide the eventual concept of Intelligence of Everything with a solid foundation to build upon. According to this CNET article, the Chinese corporation is reportedly looking into 6G at its research and development facility in Ottawa, Canada [27].
- LG Corp.: The 6G innovation would be displayed during LG's participation in the 2021 Korea Science and Technology Exhibition from 22–24 December 2021, according to the tech titan from South Korea. During the Exhibition being held at Kintex, Ilsan, the organisation will highlight its efforts in 6G remote transmission and gathering. Interestingly, LG will announce a powered speaker for 6G in partnership with the German Fraunhofer Research Institute. In August 2021, LG aggressively tested the 6G power speaker in Berlin. Using the 6G recurrent frequency, the company had the possibility to efficiently communicate and obtain remote information within a 100-meter direct distance outside. The race for the business sending of 6G innovation is on and LG is focusing on 2029 for the commercialization of its 6G innovation. We'll see whether LG will be pipped to the diadem by different organizations. LG, a regional rival of Samsung, launched a 6G testing facility in January 2019 in collaboration with the Korea Advanced Institute of Science and Technology (KAIST) [28].
- ZTE Corp.: Incorporating RIS, one of the core innovations of 5G-Advanced and 6G, into the 5G organisation, and understanding the co-location and co-inclusion of mmWave and Sub-6GHz in densely populated metropolitan areas, the organisation begins to take the lead in this area. This effectively lowers the cost of the arrangement, shortens the sending time, uses less network energy, and aids in the growth of green, low-carbon, and high-efficiency businesses. The RIS system from ZTE is the result of cross-disciplinary collaboration between electromagnetic meta-materials and contemporary distant correspondence technology. It's a cutting-edge innovation in the area of distant communication and has become one of the key advancements of 5G-Advanced and 6G. ZTE's RIS arrangement has some control over the bar shape through the control data sent by the base station to achieve precise beamforming, unlike the diffuse reflection or specular impression of normal materials. As a result, it is able to comprehend programmable remote channels and transform the latent versatile remote channels of traditional distant correspondence innovation into versatile reconfigurable remote channels. On 17 May 2020, Chinese telecom equipment provider ZTE and big transporter Chinese Unicom came to an agreement to jointly explore 6G possibilities and innovation patterns as well as to look into crucial innovation and standard collaborations [26].
- Beijing University of Posts and Telecommunications: Beijing Post and Telecommunications made a significant leap forward, lauded by CCTV, and held onto track assets. Be that as it may, the improvement of Chinese innovation organizations in the 6G field is certainly not clear. In actuality, according to the advancement of Chinese innovation organizations in the 6G organization, the United States is probably going to lose 6G once more. To "go with the run"! In the field of 6G organizations, Huawei Ren Zhengfei said before that Huawei's 6G organization innovation is done at the same time as 5G, which likewise shows that Huawei has for quite some time been sent in the 6G field, and Huawei has additionally sent off a satellite client's 6G innovation

innovative work. This likewise shows that Huawei has proactively begun to create in the 6G field. We found two licenses by the school, which are unequivocally associated with Beyond 5th Generation and 6G advancements. The licenses, which guarantee require the beginning of August 2019, are CN110392350A & CN110430550A [29].

- College of Padova, Italy: This specific 6G White Paper is one of the twelve fresh, thematic 6G White Papers that the 6G Flagship initiative supports. It was funded by more than 50 professionals and supporters of impending 6G innovations. Here, it is anticipated that cutting-edge systems administration features will be explored in detail. These features will eventually influence the development of the 6G mobile network beyond the current 5G standard. Therefore, our focus is on the advancements and recommendations provided by the development of software and administration-based design. We also explore the major advancements that serve as the pillars for the advancement of 6G systems administration, taking into account the advancement of a cloud-based local mobile communication system and the adoption of a new IP design that supports high-accuracy services. In this white paper, we investigate the different examinations that can be acquired from the various sections engaged with the conveyance of a specific correspondence administration. We additionally examine the utility of high-accuracy start-to-finish telemetry and cross-portion examination. In a report titled Towards 6G Networks: Use Cases and Technologies, published by the University of Padova, the college's specialists identify the major difficulties, chances, and use cases of 6G advancements that they feel will define 6G firms [26].
- College of Aveiro, Portugal: The necessity for 6G research is also made evident by such a test paper dated March 2019. The paper examines the major factors that are expected to propel the development of 6G. Additionally, it explores how applications for AI and machine learning can be effective in 6G technology. It introduces brand-new elements which are typical to find within the 6G range, including quantum correspondence and satellite coordination. Colleges are probably getting ignored or just not receiving much attention at a certain time, but they nevertheless seem to have played a pioneering role in setting the groundwork of 6G and selecting how that basis and development would be [30].

3.3. 6G Applications

There will be full AI integration in the 6G communication networks. All networks would make use of AI for monitoring, management, physical layer signal analysis, strategic planning, provider connections, etc. This ought to facilitate the sector's digital transformation as it moves toward Industry 4.0, the industrial production revolution.

The various application of the 6G network is as follows:

1. Ultra smart cities: Potential scenarios in an ultra-smart city would call for data rates around 1 Tbps, 3D connectivity, localization within 1 cm, and the reliability of 99.99%, for example, for autonomous vehicles, e-health, or smart industries. The measurements required for such apps in a smart city cannot be managed by 5G networks. Most 6G users will need mobility assistance between 240 and 1200 km/h. In order to coordinate while moving at high speeds, a self-driving car needs to interact with other vehicles and roadside sensors. In a different situation, drones would be needed to track the cars and act as information relays or hover ground stations for cross-communication. Extremely diminished-delay connectivity is among the essential criteria for autonomous cars and judgement, and under the aforementioned scenarios, 6G ought to be able to provide it [31].
2. Multi-dimension Materiality: Online games that incorporate user-machine interaction with extremely high-quality graphics data and use AR or VR technologies generate a lot of data. Soon, 3D games and other cross-media will combine VR and AR to create totally immersive gaming experiences that reproduce reality utilising all five senses. The remarkable capacity, reliability, and information rate we need to convey enhanced information across a wireless medium will be made available by 6G. To put it another

way, we want a great customer experience, low latency, excellent reliability, and high information density [31].

3. Haptic communication: Imagine a healthcare system where an injured patient can only express their feelings verbally. In this case, a headband with intelligence may reconstruct brain signals and display them as a 3D video of a person's vision, which a carer can view in real time using mobile networks. These haptic communication approaches will enable them to transmit information through touch. This situation is one of the planned applications of 6G technology, in which the network can support significantly higher data rates than 5G. Brain-controlled computer interfaces are another haptic network that is frequently used. In these networks, users use haptics to interact with their surroundings and control them using digital devices like a wireless chip installed in the brain that responds to emotions [31].
4. Healthcare and remote-surgeries: Critical applications can benefit from ultra-low latency of less than 1 millisecond in 5G networks. Remote surgeries, on the other hand, are exceedingly sensitive, requiring a latency of less than 1 ms. The introduction of 6G networks will revolutionise telemedicine and remote medical care since it will eliminate time and location constraints [32]. The 6G vision calls for a data throughput of 1 Tbps and data reliability of at least 99.99%. In contrast to past networking technologies, 6G must strive to meet simultaneously the lowest and highest latency requirements. This is necessary for remote surgery because certain data streams should be received at the destination within a given minimal delay and other data streams should arrive within a specified maximum delay [31].
5. Holographic communication: We will rapidly discover that the virtual world doesn't really give us access to every aspect of reality as AR/VR apps develop. Telepresence has just exceeded in-person gatherings due to the current COVID-19 pandemic epidemic. For this project to remotely show an object or a person in actual, advanced virtual reality technology, bandwidth, and computations are required. To put it another way, a visual during a virtual conference might be a multi-dimensional, real-time projection that communicates the audio-visual impact of a person or thing. For a fully immersive VR experience, movies with 16 K resolution, 240 Hz scanning rate, and 3600 circular coverage must be delivered as a hologram. For example, in a social performance, a faraway musician may be introduced as a virtual presence to entertain those present. The same is true for remote and difficult-to-access regions such as mines and deep-ocean ports, where holographic communication might be employed for excavation and crew training. These transfers entail significant amounts of data, which 6G networks can handle [31].
6. Tactile internet: Several devices are expected to communicate with each other instantly and interactively over 6G networks, allowing for data transmission, control, and real-time touch feedback. The sensations of touch and taste are combined with voice, video, and other forms of communication in tactile internetworking. For instance, employing virtualized holographic representations to access subsea boats and containers, perform remote operations, and educate astronauts in space stations calls for just a feeling of contact to do maintenance & perform distant instruction with incredibly reduced delay. Additionally, as the food industry aims to digitise users' food access experiences, a key focus will be on the conveyance of taste and smell to improve users' experiences. The 6G network can satisfy the requirements because of its increased data capacity and low latency [31].
7. Internet-of-Things: The Internet of Things (IoT) is evolving into a crucial component of such future Internet and also is generating a significant amount of interest both from academics and businesses because of its enormous potential to provide services to customers in many facets of modernity. The introduction of 6G is expected to lead to new IoT apps. The most recent 6G applications in a variety of significant IoT fields, including Healthcare Internet of Things (H-IoT), Vehicular-Internet-of-Things (V-IoT),

Autonomous Driving, Unmanned-Aerial-Vehicles (UAVs), Social Internet of Things (S-IoT), and IIoT, are extensively evaluated and assessed. They are briefed as below:

- 6G for Healthcare-Internet-of-Things (HIoT): By utilizing its technological solutions, 6G connectivity will transform the Internet of Things. In reality, to accomplish virtually significant health service with a quick and accurate remote medical, healthcare areas like remote patient monitoring demand reduced delay communications with the consistency requirement of over 99% [33]. It's worth noting that with such a milliseconds latency and high reliability, 6G-robotics may indeed be utilised to do remote operations, enabling doctors who are located elsewhere to direct the process using robotic tools. Specifically, agreements are being implemented that really can take power over the exchange of health information throughout the operation and automated verification for demands for health information [34].
- 6G for Vehicular-Internet-of-Things (VIoT) and Autonomous-Driving (AD): The development of 6G technology has drastically altered vehicle IoT networks, which has revolutionised smart transportation systems. The study uses mMTCs in VIoT networks on 6G to enable V2X communication for the transmission of brief automotive data payloads by a large number of vehicles without the need for human interaction. In order to arrange available radio resources for V2X data connections within the specified frequency budget, signature features like time frames and hashing techniques are updated to reduce the likelihood of false positives. To fully utilise the potential of vehicle intelligence in VIoT, cutting-edge intelligence features with machine learning are integrated alongside the road components, which are responsible for evaluating traffic volume and weather forecasts relying on the accumulation of measurements from automobiles [34].
- 6G for Unmanned-Aerial-Vehicles (UAVs): UAVs network enables 6G-based broad IoT with simply a focus on UAV aviation process optimization. To do this, the issue of maximising the effectiveness of sending data must be addressed, taking into account large-scale channel status, onboard energy, and interfering temperature limitations. The appeal of clustered IoT stations led to the creation of a station grouping technique based on intra-cluster NOMA communication, which allows UAVs to broadcast radio transmissions to IoT terminals [35]. A synergistically optimal outcome of UAV path prediction and subplot allocation is reached by splitting the down-link transfer of energy and up-link data transfer subplots. A three-dimensional non-stationarity geometrical probabilistic model based on AV elevation, spatial consistency, and three-dimensional random UAV motion routes is constructed in order to accomplish this, and it makes use of a variety of channel arrangements [34].
- 6G for Satellite-Internet-of-Things (SIoT): It is essential to integrate satellite technology into current wireless connections if widespread IoT connectivity is to be achieved with 6G. Theoretically, satellites consist of three main network levels, namely LEO, MEO, and GEO, to provide global operations to terrestrial Internet of Things (IoT) customers. But in the 6G network, several satellites might be deployed in hundreds of orbits just above the earth, enabling LEO systems to truly achieve global reach and improved efficiency through frequency reuse. In addition, inter-satellite linkages will be constructed to enable interactions between satellites using THz bands, which have a much wider bandwidth than their mmWave and optical equivalents and can accommodate more satellites while attaining higher link stability. Every IoT device actually has to develop an asynchronous procedure by choosing one accessible preface from the offered preface collection for transmitting data in order to interact with the ground station through the uplink ports. In order to conduct yet another fractional time advance estimate and minimise extra signalling complexity and energy costs, an improved preface sequencing method is provided [34].

- 6G for Industrial-Internet-of-Things (IIoT): The Industrial IoT area has recently looked at the functions of 6G. Given the scarcity of IIoT devices, sensors are frequently deployed at random, which adds needless energy expenditures. Big data, prediction based on neural training algorithms, and engagement during the learning phase with historical datasets are all effective methods for doing smart sensor grouping using Convolutions. Much improved resource management with less energy use and much less complexity is confirmed by simulation analysis. By considering block size, CPU and memory utilisation, and network latency, a unified fog cloud computing architecture is used to manage blockchain information analytics. The 6G-IIoT apps that may use information learning to explain their very complicated design and extraordinarily large data quantities should pay special attention to this. Additionally, using UAVs for space-to-terrestrial communication has the significant potential to increase smart farming by enabling aerial-based soil measuring using their sensor system across a wide area of coverage. So, in order to give a comprehensive picture of a farm for automated development of land output, UAVs may also be used to assist crop photography from a low height. While 6G offers the IIoT previously unheard-of advantages, privacy and security pose serious obstacles that must be overcome [36].

3.4. 6G Architecture

The journey to the 6G chained people has begun, and research into the 6G architecture has essentially started. With the majority of demands worldwide, a financially sustainable and fast 5G rollout is currently ongoing or will begin soon. The creation of the 5G architecture is still happening and will probably continue for another eight or more cycles. Additionally, real-time dispatching and synchronisation between natural, digital, and physical individuals are used to portray the future as spontaneous occurrences that produce artificially replaced mortality experiences. From the viewpoint of the network, tangible could in fact be extravagantly associated with intercept and system-on-chip architecture, digital would stand for next-generation software architecture as well as binary-digital representation, and natural would collaborate with the-bio-sensors as well as the novel mortal-machine integrations. To achieve the rigidity, implicit, belief, protection, efficiency, and automation robots needed to realise the wide range of operational goals, they might be intimately connected in tandem. This Het-Pall system, which has more Pall computational resources, serves as the foundation for the 6G network. Simplicity can be achieved by using concurrent RAN-CORE imposed microservices, innovative cell-liberated architectures, and trap architectures. A new information and data framework would be a key element of 6G given the importance of information with AI/ML optimization in the construction and maintenance of a 6G network. The networks can be modified for specific needs, much like sub-networks but also optimised slices, thanks to the 6G armature's stiffness. Robotisation and connectivity with an orchestrating framework and purpose would be key components for many industries. The secure armature, particular protocols options, charge and policy enforcement, plus network visibility are a few additional elements that were not covered in this piece but are still topics for future study that will be required to describe the whole 6G armature [37].

This section outlines the architectural changes required for 6G on the basis of three components, as shown in Figure 3.

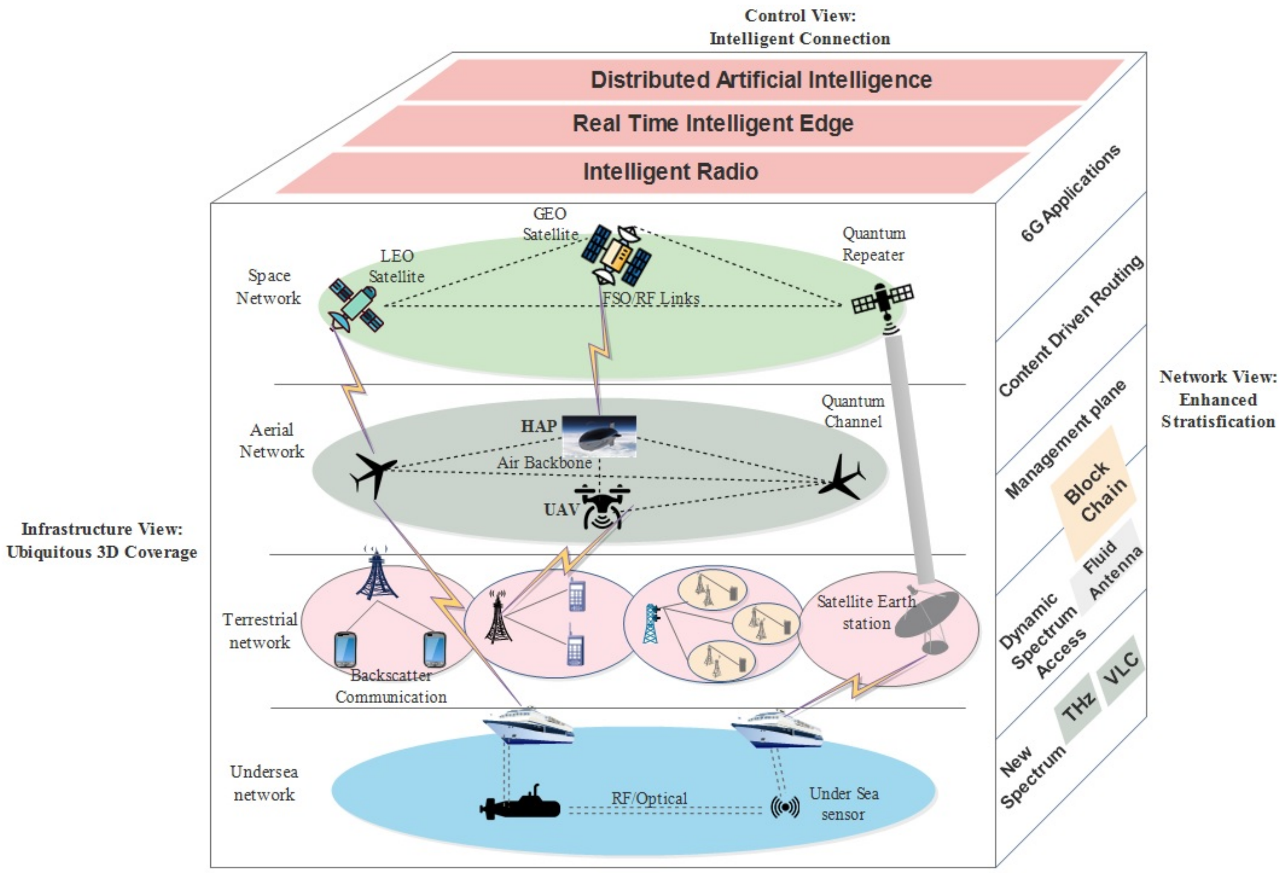

Figure 3. 6G Architecture.

3.4.1. From Terrestrial to Ubiquitous 3D Coverage

Increasing the comprehensiveness of communication coverage becomes a goal of the next-generation network design. The prevailing network design is built upon ageing terrestrial cellular infrastructures. Non-terrestrial networks would be integrated into 6G to offer complete wireless connectivity.

- Space-Network: High throughput satellite (HTS) devices are known to provide broadband Internet solutions with prices and capacity that are equivalent to terrestrial offerings. Geostationary orbit (GEO), where the majority of communications satellites are located, is at a height of 35,786 km, which inevitably causes significant latency and makes connectivity with terrestrial mobile networks impossible. A non-geostationary orbit (NGSO) satellite system is proposed, and multiple satellite constellations are about to begin making a lot of money to provide low-latency, extremely high Internet connectivity. compared to a network of terrestrial optical fibres. Reduced latency connectivity may be available with an LEO system using co-routing radio-frequency and laser technologies.
- Aerial-Network: High altitude platforms (HAP), which normally work the stratosphere, and low altitude platforms (LAP), which are usually at a height little and over a few kilometres, can be generally categorised as two types of aerial networks. HAP networks can provide more coverage and can last longer than LAP networks. Unmanned aerial vehicle (UAV)-based LAP networks, on either hand, could be deployed faster, more easily modified to properly serve the communication system, and function great narrow communication. When facilities are severely damaged or absent altogether, such as in disaster emergency circumstances, UAV networks offer mobile communication. The suggested new trajectory optimisation & path guidance techniques considerably help save energy.

- Undersea-Network: The three main categories of underwater wireless networks are radio frequency, acoustical, and optical communications. Due to the unexpected and complex undersea setting, which results in challenging network coverage, severe signal attenuation, and mechanical damage to the equipment. There are numerous issues to be solved.

3.4.2. Direction to Smart Network Connectivity

Businesses and academics have recently focused a strong emphasis on ML, a subset of artificial intelligence. Additionally, edge computing and artificial intelligence work together to lower budgets while improving customer satisfaction. The development of the 6G framework should take into account the potential applications of AI in networks in great detail and adopt an AI-driven strategy wherein intellect will become an inherent feature of the 6G architecture [38]. A small and remote network object can alter the design in a smart way depending on a number of preset choices in a unique but predictable way, according to the baseline knowledge. The autonomous development of networks is what smart networks are ultimately expected to do.

- Real-time intelligent edge: The provision of engaging Intelligence applications will be necessary for the next-generation network, as well as a few services, notably autonomous cars, particularly susceptible to response delay and hence take real-time, intelligent interaction with their surroundings. These services cannot be provided by centralised cloud AI using static data; instead, the RTIE, which makes intelligent predictions, inferences, and decisions based on real-time information, is urgently needed.
- Intelligent-radio: IR is a richer and larger idea that distinguishes computational techniques and hardware. It runs as a single-entity methodology for estimating hardware resources Transceiver methods are capable of dynamic configuration in accordance with the hardware data. From this viewpoint, IR can utilise the spectrum available. Thanks to the physical layer. IR also can modify transmission methods and signal strength.
- Distributed-AI: The networking of the future would be a sizable decentralised framework where smart choices will be taken at many bitwise steps. Distributed AI uses shared resources in the system via a parallel procedure which necessitates separating the information and models in a suitable way to speed up understanding and increase inference consistency.

3.4.3. Novel Infrastructure

TCP/IP was indeed the foundation of the current Network protocol design, which has been extremely successful. Recent internet lacks ensure the delivery of future-oriented applications due to several new problems. Some TCP/IP-based protocols, including QUIC (Quick UDP Internet Connections), have somewhat lowered such difficulties. Unfortunately, these patch-like protocols just add to the complexity of the Internet and do little to address its fundamental flaws. The header-payload mode that is currently followed by network layer packets is static and separate from the demands of higher applications. Meta-data and instructions set by the app designer could play a significant role within forthcoming IP protocol in order to enable a wide range of potential developments and offer customised internet connectivity. Comparable to this, the transport layer requires additional improvement to address future communication requirements.

4. 6G Technologies

This section describes recent advances in the 6G next-generation antenna, 6G scaling, basic synthetic fabrics, modulation techniques, coding scheme, and other integrated emerging techniques are all examples of wireless communication technology [12,39]. Numerous important 6G network technologies are displayed in Figure 4.

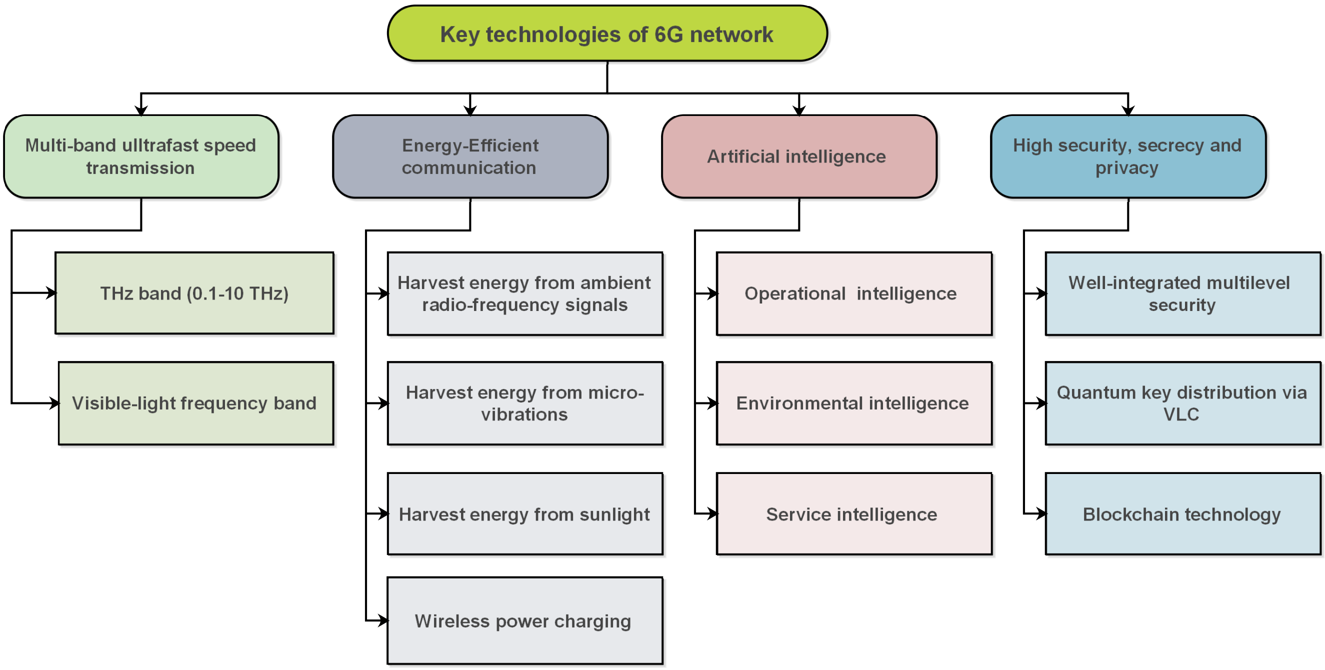

Figure 4. Key technologies of 6G network.

4.1. Wireless-Communication-Technology and System

Each every generation of communication networks introduces novel and captivating characteristics. The use of 6G technology is now imminent. Given its early level of development and ongoing research, 6G technology is now in the phase of investigation. This study explores the speculation around the possibilities and tactics for the implementation of 6G communication.

In [7], the possible operations and the technologies are to be stationed for 6G communication. They also described the potential obstacles and research trajectories needed to achieve 6G aspirations. In addition to describing the innovative technology that may be used in 6G, they also explained the idea of 6G transmissions. This article provides a viewpoint on the network infrastructure and new wireless 6G networks. In this article, new technologies such as machine learning, broadband, free-space optic systems, blockchain, 3D networking, communication systems, autonomous drones, mobile free communication, incorporation of wireless energy, the transmission of information, associated networks, switching network slicing, hologram beamforming, and scattering are explored.

In [40], gaining an understanding of research done in various optical wireless systems is highly anticipated for the establishment of future networks. Implementing IoT and 5G/6G expectations on a tactile internet foundation is difficult. The supply of high capacity, huge connection, low quiescence, extreme safety, a minimal energy footprint, high quality of experience, and the most dependable connection for 5G communications networks are the most crucial and challenging concerns. Only RF-grounded systems are unable to fulfil the significant demands of future 5G/6G and IoT networks. RF networks' chic equivalent outcome is OWC technology. The cohabitation of RF and optical wireless communication technologies can enable the creation of similar networks. This study included a complete analysis of how OWC technologies including VLC, LiFi, OCC, and FSO will support the successful rollout of the next 5G/6G and IoT networks. The properties of 5G, 6G, and IoT systems as well as the features of OWC technologies have been consolidated here for that purpose. Here, the performance advantages of OWC systems over characteristics of a similar kind are explored for each of the 3 standards.

Future communications beyond 5G and 6G will heavily rely on reconfigurable intelligent surfaces (RIS). The RIS is expected to be used to help establish a smart wireless environment for forthcoming communications, but it can also be used to construct the transmitter and receiver, creating a smart and intelligent transmitter and receiver. As a result, and this is a very crucial aspect, the latency of forthcoming communications may be greatly decreased by utilizing RIS. The next generation of networks will largely embrace artificial intelligence since it facilitates communication.

Terahertz-Communication

Terahertz waves are electromagnetic waves with wavelengths between 0.1 mm and 10 mm, and frequencies ranging from 0.1 to 10 THz. The intermediate and very far infrared light are separated by frequency. Between macro and microelectronics, THz swells in real time. Terahertz communication offers the dual benefits of a strong transmission rate and an abundance of diapason coffers [12]. This is a successful wireless broadband access (Tb/s communications) technology for future mobile dispatching. The Federal Dispatches Commission was there in September 2018 at the World Mobile Congress (FCC) of the United States stated that 6G can utilise THz diapason-grounded networking and spatial multiplexing technology. Terahertz technology is a frequently emerging technology that will alter the future of the planet. Terahertz technology's widespread use is a key aspect of 6G. The ultra-wideband technologies include the following, depending on the 6G technology network and business conditions:

1. Proposals for transmission channels for terahertz space & terrestrial communications that are comparable in terms of channel size, modeling, and algorithms.
2. THz Straight transmission, terahertz mongrel modulation, waveforms, multichannel coding, and terahertz broadcast modulation are a few examples of terahertz signal coding and modulation techniques.
3. Synchronous THz transmission, essential transmitter architecture, increased baseband, signal technology computation, and design of integrated circuits methodologies are some examples of the research and development that goes into Radio wave system and THz tower architecture [12].
4. Trials and error with the terahertz communication network and outfit developmental progress.

In comparison to wireless optic and fryer transmissions, terahertz swells offer additional benefits. Broad application possibilities exist for terahertz surges in space dispatches, broadband wireless security access, and high-speed and short-distance wireless dispatches:

1. The air's humidity readily absorbs the terahertz spike as it travels through it. Additionally, it is appropriate for wireless high-speed and close-range communication.
2. The beam is more focused, has greater directionality, and is more capable of interfering.
3. Wider bandwidth and an advanced frequency characterise terahertz swells. They are able to satisfy the need for dB of wireless broadband transmission. The potential diapason bandwidth is knockouts of GHz, and the terahertz surge diapason has a frequency between 108 and 1013 GHz. It is capable of communicating at speeds more than Tb/s.
4. The frequency of terahertz waves is a clear window in the atmosphere itself around bands of 350 μm, 450 μm, 620 μm, 735 μm, and 870 μm for communication in outer space. They are able to communicate across great distances with less power and reduced transmission rates.
5. The Terahertz wavelengths, which have a limited spectrum, can also be used for Massive MIMO with extra antenna rudiments.
6. Despite having a better energy efficiency than wireless optical communications, terahertz swells photon energy is very low—roughly 10^{-3} eV. There is just 1/40th of visible light. It has an exceptionally high energy efficiency while carrying information.
7. Robust penetration Matter may be accessed by terahertz waves with less attenuation. In certain unique instances, they're appropriate for communication requirements [12].

In [41], the goal is stated, and it offers various key technologies encountered in THz wireless communication systems as well as a thorough literature analysis on the advancement of THz dispatches. THz solid-state superheterodyne receivers, high-speed THz modulators, and THz antennas still need to be developed despite the considerable difficulties. Additionally, two different kinds of lab-position THz communication systems are provided roundly, separately: a solid-state THz communication system and a spatial direct modulation THz communication system. In contrast to the direct modulation THz system, which permits high-power THz sources to be input for the purpose of authorising relatively long-distance dispatches, the solid-state THz system transforms intermediate frequency (IF) modulated signals to THz frequency. Finally, we explore a number of implicit operation scripts as well as some crucial technical difficulties that will be faced in upcoming THz dispatches.

In [42], it has summarised the state of THz dispatches investigation, spectrum management, and standardised conditioning at the moment. In all three sectors, encouraging progress has recently been made on the route to 100 Gbit/ s of wireless transmission. These discoveries will serve as the foundation for the creation, standardisation, and ultimately the use of ultra-rapid THz communication networks. According to recent developments, the business launch of THz dispatches may be anticipated in the near future and will assist in handling the continuous demand for cellular data rates is rising.

In [43], it is summed up that:

- The bit rate may be raised by using high frequency carriers like millimetre and terahertz waves.
- Perfect connectivity between wired and wireless networks is made possible by the grounded signal generation and modulation techniques of photonics.
- The wireless connection in the 300 GHz band using the direct discovery approach has attained 30 Gbit/s error-free. The 600 GHz band guarantees advanced.
- Coherent discovery strategy has been investigated in order to boost bit rate and receiver perceptivity; a proof-of-conception experiment has been shown in the 100 GHz range.
- The usage of RTDs in 300 GHz band, in addition to Si grounded Tx/Rx, has been shown. Electronics grounded technique is crucial for low cost and/or consumer operations.

In [44], the current state of the development of upcoming THz broadcasts have been examined and presented. The initial propagation properties of the most probable operations and scripts in this frequency range are well known. Modern semiconductor technology advancements have made it possible to build up demos that indicate the possibility of achieving data speeds of several hundred Gbit/s. One of the most important challenges for unborn tasks is the development of intelligent antenna generalities to overcome the high path loss in confluence with dynamic shadowing events caused, for illustration, by moving humans. In order to enable the operation of several knockouts of GHz, diapason sharing generalities with unresistant services will have to be developed.

In [45], The frequency band between 0.1 and 30 THz is practically uncharted territory, it dispatches. This terahertz gap has recently received the most attention from researchers since the high carrier frequency suggests unknown channel capacities1. In fact, predictions for 2015 were for data speeds of 100 Gbit/s. Then, we provide a single-input, single-output, 100 Gbit/s wireless communication system operating at 237.5 GHz for the first time, capable of sending data over a distance of 20 m. A narrow-band terahertz carrier is photonically created by merging the comb lines of a mode-locked ray in an unravelling-carrier photodiode in this development, which combines terahertz photonics with electronics. Additionally, the single-traveling-carrier photodiode system is transmitted through a ray-fastening antenna. A millimeter-surge monolithic interwoven circuit with new terahertz mixers and amplifiers enters the signal. This method, in our opinion, offers a way to assess wireless dispatches to Tbit/s rates across distances greater than 1 km.

4.2. Next-Generation Antenna and RF Technology

One of the major innovations that will enhance the diapason efficacy of wireless networking communication systems is multi-antenna technology, particularly veritably large-scale antenna technology. A really large-scale antenna is a crucial tool for improving the communication system's diapason efficacy. Understanding new large-scale antenna array layout assertion and techniques, largely entwined RF power circuit modification, and breaking the proposition and the highly specialised implementation issues of the crossband, high-effective, full-space content antenna RF field are some of the objectives of this study of adaptable big antenna arrays and RF technologies [12].

Introductory synthetic accouterments. It is necessary for the To adapt, RF front-end of data transmission, increased communication bandwidths, enhanced effectiveness, and inlet and outlet signal power with excellent predictability. The novel liquid emulsion compound substance may provide communication gear with an extraordinarily powerful electromagnetic surge immersion capacity by being made from colourful essence accessories. It is the preferred option for wave absorption accessories in future RF instruments because of its distinctive electrical and optical properties [12]

In [46], the associated technological means are required to realise the overall RF system vision of a digitally controlled, analog RF system that is frequency agile, bandwidth scalable, and biddable with other request conditions. These technological tools include switch-mode power amplifiers that are frequency-nimble, antennae and pollutants made of tuneable metamaterials, powerful low-noise amplifiers, and adaptable active pollutants.

Colourful cooperative exploration systems have been introduced, supported by the BMBF and the Framework Programs of the European Commission. The system environment for this joint issue is provided by Bell Labs Europe, together with a number of artificial and academic partners that provide a wide variety of new specialised skills. A palm-to-palm bid describes cooperative exploration. System providers like Alcatel-Lucent may be certain that the tools created satisfy their needs from a system viewpoint, and technology suppliers can be certain that their tools flawlessly satisfy request criteria, icing marketing success.

In [47], the literature on flexible substrates for electromagnetic activities, especially patch antenna technology, was the epitome. For patch antennal operations, a variety of flexible, bending, and foldable substrates are urged. The current review study will assist the experimenters of the concerned exploration sector in planning for future advancements in wireless communication technology as the need for flexible substrates grows daily in the era of ultramodern throwaway technology.

It examines the research that has been done on flexible substrates, which are used in high-tech radio frequency and antenna design activities. Natural fibrils grounded substrates are regarded as the most promising candidates as substrates for next-generation electronic operations, regardless of conventional operations, because of their abundance, low profile, lightweight, flexibility, and terrain safety properties. A thorough analysis of the designs and aesthetics used to employ the aforementioned accessories in radio frequency operations is also presented here. The large-scale production and implementation of these technologies in actual systems face a number of difficulties [47].

4.3. Channel Coding for the Next Generation

With an information throughput of 100 Gbps, a THz band that is advanced above the 275 GHz band, and GHz-wide channels capacity, the 6G technology will create a full-region perfect network platform. This creates additional difficulties for basic modulation and channel coding techniques. Channel coding for the next generation. The latest generation of channel rendering technology, which serves as the basis for wireless network communication, could improve the output of 6G networks to Tb/s. The representation of the being stoner channel may be improved based on the complexity of the obstruction, taking into account the features of how information is transmitted multiuser/more-complex scripts in 6G architecture [12].

Communication technology's primary objective is to transmit individual signals regardless of their complexity. The square surge aligned with the Sinc function is crucial for conveying sign information. In environments with multiple paths and frequencies, wireless signals must combat interference and swiftly transmit data. Dynamic spectrum allocation, like OFDM, is widely used in wireless communication for multipath utilization. However, OFDM's orthogonality hampers addressing Gabor's proposal limitations in mobile communication. OFDM's square surge has challenges like long side waves and susceptibility to baseband shifts, hindering baseline frequency control and carrier synchronization. Consequently, OFDM struggles to adapt to the forthcoming mobile transmission phase [12].

In [48], the benefits of using a system called Orthogonal Frequency Division multiplexing to overcome the adverse goods of severe multipath propagation, similar to what occurs in the mobile event is explained. The signal is demodulated with the aid of a Fast Fourier Transform fashion. Consideration is given to the digital rendering arrangement, and it's concluded that a consecution of a convolutional law and a Reed-Solomon law gives excellent results. The feasibility of enforcing such a system for domestic requests is compactly bandied.

Associated with an applicable interleaving system, the convolutional canons guarantee in this environment excellent performance for a reasonable decoding complexity (64-state Viterbi decoder, in the exemplifications chosen). Consecution with a Reed-Solomon law improves the performance yet further. Nonetheless, the complexity of enforcing the decoding of Reed-Solomon canons leads us to reject this result. We propose to use CSRS canons, which have similar parcels while offering a lesser decoding simplicity.

The principles of modulation and channel rendering explained above permit the description of a digital sound broadcasting system having a performance with respect to Eb/ N0 and spectral effectiveness close to the Shannon limit. Analysis of the complexity of the demodulation and associated decoding functions leads to the conclusion that the corresponding receivers in a domestic mass-product environment are doable.

In [3], the proposed DSCM system is intended to be decoded combined with the Variable Length Law (VLC), two coded modulation schemes, and fundamental principles. The source knots encode the original signals with a sequential concatenated VLC and a Turbo Trellis Coded Modulation (TTCM) scheme. The decrypted TTCM-VLC codes are transmitted to the recipient knot and a relay knot during the initial transmission process. The relay knot estimates the decoded bit sequence using a critical iterative TTCM-VLC decoder. This decoded bit stream is assure encoded with the use of a simple Trellis Coded Modulation (TCM) method before being sent to the destination knot. A new four-element iterative decoding arrangement is used at the destination knot to retrieve the original source symbols. The DSCM scheme is proven to perform noticeably better than the TTCM-VLC benchmarked method allocated with relaying.

The serially concatenated TTCM-VLC is a source-coding, channel-coding, and modulation method that is jointly optimised. In this contribution, we've shown that using a simple TCM-backed relay knot to support the TTCM-VLC scheme can save an additional 8.5 dB of transmit power. The collaborative DTTCM system is likewise outperformed by the suggested DSCM-O strategy by around 2 dB, and the proposed scheme is just 1.47 dB below the bottom limit of the related relay channel capacity. Since it requires less transmitting power, the distributed source-coding, channel-coding, and modulation system that has been shown can reduce the position of blockage in the mobile network. More mobile drug users may be supported on sophisticated, rich mobile networks if the recommended technique is put into action [3].

4.4. Spectrum-Sharing

In order to handle the issue of variable spectrum demand across various networks, spectrum sharing is widely adopted. On the one hand, it's crucial to expand the spectrum that is presently usable, including the terahertz and visible light spectrums. On the other side, it's also necessary to alter the guidelines for spectrum operation. The majority of permitted carriers used by cellular networks are spectrum resource owners, who also have the only right to utilise the spectrum. In fact, if spectrum coffers are momentarily unused, no one else has a reason to utilise them. Strict limitations and criteria apply to users' customised pointers and operating ranges within the alone approved spectrum. It may be utilised for a long period and successfully prevents interference between systems. Despite the high level of stability and reliability of this system, there are still problems, such as inefficient bandwidth utilization and idle applications caused by the allocated frequency spectrum of authenticated persons. The conflict between forces and demands on the spectrum is exacerbated as a result [12].

The 6G's terahertz-frequency features raise the viscosity of its network. Dynamic diapason sharing has emerged as a key tool for improving spectrum efficiency and streamlining network construction. In order to comply with the requirements of the 6G system's spectrum resource operation, dynamic spectrum participation makes use of a knowledgeable dispersed diapason sharing access medium that can dynamically increase the available spectrum range and optimise spectrum operating regulations. The advancement of blockchain, variable spectrum allocation, machine learning, as well as other techniques in order to achieve intelligent spectrum sharing and 6G network security is another advantage [12].

In [49], the reshaping of the spectrum by customised innovation has been demonstrated. The commons and property models are advocated by lawyers, but there are additional systems to consider as well, each with their own advantages. In different bands, many models might be used. Models should be given names based on practical concerns for perpetration. The activities must come first and foremost. Should unlicensed spectrum bands be used instead of certified primary spectrum druggies? It varies. With its stringent QoS requirements, licensing works well for television broadcasting [50]. Due to their irregular transmissions and ability to retransmit, wireless connections between computers and string modems perform better across unlicensed airwaves. Should secondary bias coordinate via a dynamic secondary request or employ spectrum opportunistically? It varies. Technically speaking, opportunistic access is easier if agent broadcasts are predictable, as they are with broadcasters [51]. Although there are no QoS assurances for secondary bias, this is acceptable for certain (but not all) processes [52]. On the other hand, if agents are cellular carriers, the dynamic secondary Request would be more appropriate since, with a little cooperation, several secondary biases can transmit while still protecting the QoS of both cellular visitors and secondary bias [49].

In [5], in relation to the ongoing purposeful effort to adopt successful changes towards how they managed and utilised radio spectrum, it has provided a complete overview of major trends, unplanned reform activities, and research issues. It is difficult to use spectrum properly and to its full capacity since the majority of the traditional spectrum administrations now in use are highly strict and inflexible. Devoted exclusive-use contracts, based on outmoded radio-technological accessories, reduced the drive to use spectrum efficiently and caused problems with artificial failure, impeding the creation of innovative wireless technology and services. The future should accept more system dynamics of spectrum sharing, or Dynamic Spectrum Access (DSA), in which frequency bands may be communicated across various operation contexts, including marketable/government, heritage/new, licensed/unlicensed, or numerous classes of spectrum right holders, along various specialized confines, such as frequency, time, space, and direction.

4.5. IoT and Blockchain Technology

6G Internet of Things: Perception The Internet of Effects is at an advanced stage of development. It is an intelligent network that has detectors that can send and receive data via various networks, much like the tactile and visual internet. The view of the Internet and older networks has changed over the 6G era. The interesting, clever topics are teachable [12]. To build an expert system and accumulate experience that matches their perceptions, they may feed back and regulate the knowledge they have gleaned. The control data for the return journey that relates to the information's substance is also sent together with the pure information content. It belongs to a new wave of information technology that mixes computer and control systems. It has the ability to transform the conventional internet of effects into the IoT [53].

Blockchain engineering: In order to regulate and reuse businesses and provide differentiated stoner services, 5G network drivers employ network slicing and other technologies. The 6G network will keep improving the personalised services it provides to drug users and will use further practical methods to provide each stoner with intelligently tailored services via business operations and edge computing. The network will become flatter and employ an automated distribution scheme throughout. The distributed blockchain registry software's ledger can ensure that user information won't be stolen by third parties thanks to the oneness of blockchain, including its decentralisation, obscurity, accountability, failure to intervene, and confidentiality. It can be taken by outsiders also continuously enhance network cooperation effectiveness and ability to withstand service hiccups on networks, increase new info and security mechanisms, and enhance security and seclusion of the involved real estate [12,54].

Numerous barriers are put in place to reduce the IoT's relinquishment across various processes as the number of linked IoT devices grows quickly. Many businesses worry about interoperability because it forces the creation of new data silos. The owners of IoT devices must trust the associations to keep their data secure for the centralised IoT result to work. A promotional technology that aided IoT systems is blockchain. Through its features, a distributed tally avoids centralised armature problems and maintains data. Blockchain creates confidence between Internet of Things bias and reduced risk of manipulation using Blockchain cryptography. By preventing the mediators and conciliators from leaving the room, it reduced costs. Blockchain has the ability to address many IoT issues, but every combination of two mature technologies comes with its own set of challenges. The qualities of blockchain are evolving as a result of IoT conditions including protection, information confinement, agreement protocol, and smart contracts. Numerous exploratory studies on the combination of blockchain with IoT are researched in order to assess security problems. Due to increased energy use, process time, and communication output, our investigation demonstrates that the blockchain technology developed for IoT networks performs poorly. The attitude toward data integrity and confidentiality is still weak in certain living workshops. Analyzed are the exploratory difficulties and unresolved problems in the objectification of blockchain with a 6G communication network. Also included are the future exploration criteria for 6G-enabled IoT that is blockchain-enabled. The composition's unwritten compass is to combine blockchain and IoT 6G technologies to cut down on computing costs. Depending on demand and circumstances, 5G technology security and sequestration risks should be mitigated [6].

In [55], the author carefully and painstakingly analyses the IoT-envisioned sustainable, intelligent metropolises built on 6G communication networks. Three blockchain-based infrastructures were put forward by our team for use in healthcare 5.0, ITS, and other smart operation vantage points. They began by outlining the background of blockchain, IoT, and smart cities. They also talked about the application of blockchain in the IoT-envisioned smart cities and intriguing issues like single points of failure, information security, and austerity issues. To address these issues, we also suggested application-wise infrastructures. Additionally, cutting-edge methods were dissected in-depth for each operation in relation to the terrain of the IoT-enabled smart megacity and compared with the suggested system. We explore the limitations as well as the potential of blockchain for every intelligent activity separately. Finally, the significant future research direction is solidified to support the growth of smart megacities. Our debate and disquisition are intended to pave the way for further research on decentralised smart metropolises.

In Table 4, several authors explored the technological aspects of 6G related to throughput, latency, coverage, cost, transmission rate, etc. Various technological taxonomies of sixth-generation networks are shown in the form of the mind-tree diagram as per Figure 5.

Table 4. Summary of 6G Technology (Discussed: ✓; Never Mentioned: X; Partially Mentioned: *).

Authors	Throughput	Latency	Energy Efficiency	Spectral Efficiency	Transmission Rate	Coverage	Cost
Yang Lu et al. [12]	✓	✓	✓	*	*	✓	*
MostafaZaman Chowdhury et al. [7]	*	✓	✓	✓	*	*	✓
MostafaZaman Chowdhury et al. [40]	*	✓	*	*	*	*	X
Chen, Z. et al. [41]	*	X	X	*	✓	X	*
Kürner, T. [44]	*	X	X	*	*	X	X
Song [43]	X	X	X	X	✓	X	X
Kürner, T. [42]	X	X	X	*	X	X	X
Fischer, G. [46]	X	X	X	X	X	X	✓
Razaq, A et al. [47]	X	X	X	X	*	*	✓
Lassalle, R. et al. [48]	X	X	X	*	✓	X	X
Ng, S.X. et al. [3]	✓	X	X	X	X	X	X
Peha, J.M. [49]	X	X	X	✓	*	X	X
Bhattarai, S. et al. [5]	X	*	X	*	X	*	✓
Sekaran, R. et al. [6]	*	✓	X	X	X	*	✓
Kumari, A. et al. [55]	✓	✓	X	X	X	X	✓

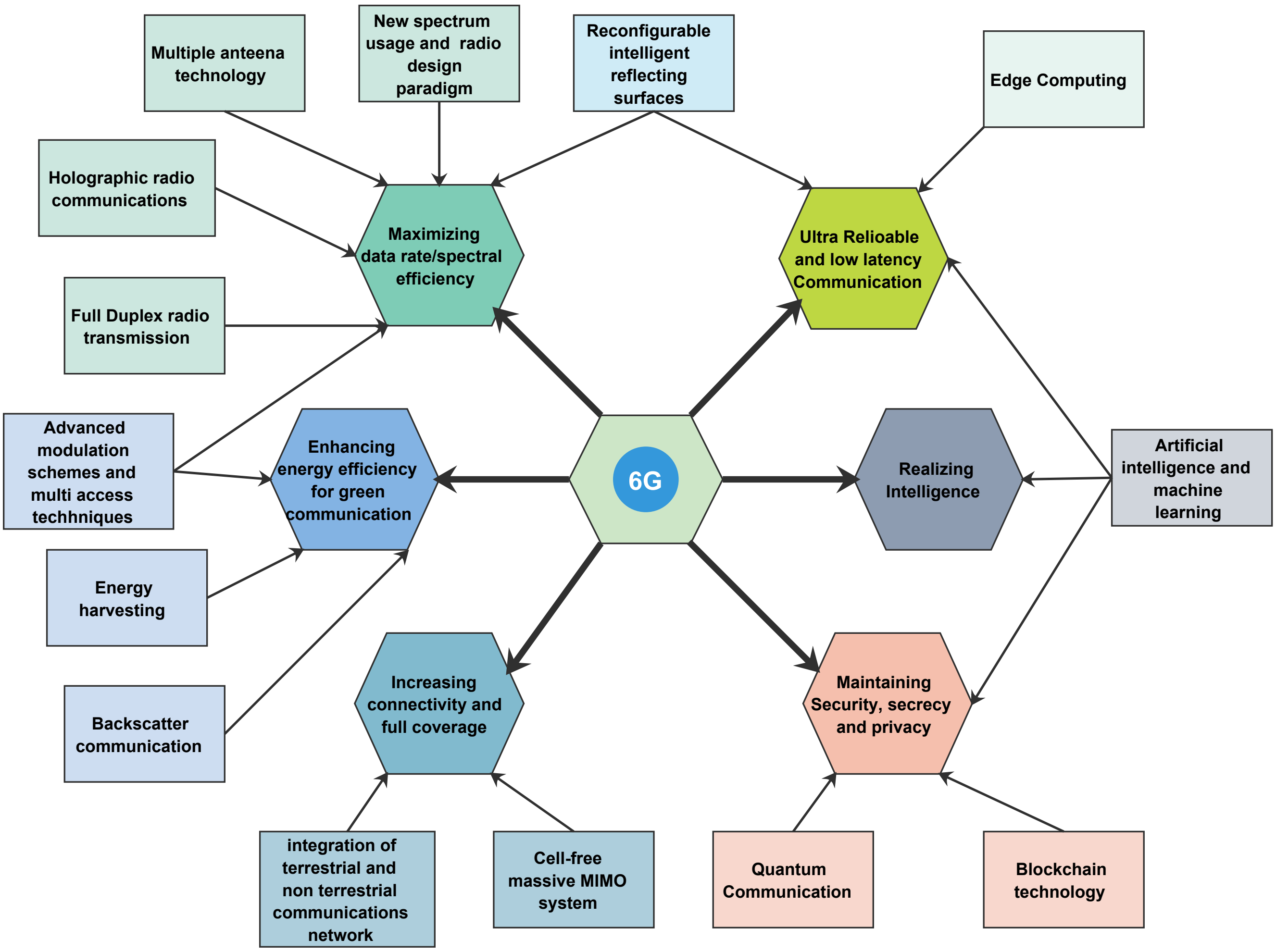

Figure 5. 6G network taxonomy.

5. Role of Network Slicing in 6G Technology

Network slicing is a technique for partitioning a physical or virtualized multi-domain network into smaller, more manageable subnetworks. Mobile network operators may easily design network slices that serve a certain application, service, group of customers, or network by using SDN, NFV, orchestration, analytics, and automation. Slices of a network may span several operators and span many network layers, including the access, core, and transport layers. By slicing a network, each piece may support a particular use case with its own design, administration, and security. Although functional elements and resources may be shared across different network slices, aspects like data speed, capacity, connection, quality, latency, reliability, and services can be customised to a particular service-level agreement (SLA) for each slice. Automation will play a big role in network slicing since MNOs are expected to build and manage hundreds or even thousands of network slices. MNOs can't manually handle this quantity of slicing at the speeds that their customers want. Instead, end-to-end automation should be used to execute the zero-slice lifecycle flexibly at scale and in real-time when traffic loads, service needs, and network resources change. However, once this technology is operational, it will open up a wealth of new income opportunities for MNOs. 6G network architectures will open up new revenue streams and allow for the sharing of network and spectrum resources for a variety of different enterprises with varying needs. 6G networks will provide unparalleled openness, customization, automation, and softwarization based on the evolving ORAN (Open Radio Access Network) paradigm. 6G networks will be a reality in the not-too-distant future, and they will be used for a variety of purposes in many walks of life. Network slicing enables service providers and significant consumers to make the most efficient use of network resources. An analysis of the current slicing approaches provides a better and more efficient artificial intelligence-based network slicing framework, which will be used in the next 6G communication network [56]. Figure 6, discusses the network slicing in 6G networks.

5.1. 6G-LEGO Framework for 6G Network Slices

In [17], the ETSI-NFV-MANO paradigm is used by most modern network slicing technologies, with some modifications like multi-domain slicing, slice choice, etc. The architecture is a component of the independent 5G network that adheres to 3GPP standards. Nevertheless, there are substantial disadvantages to the current network slicing for 5G implementation, especially in terms of management and orchestration: Slice management isolation is not completely handled, slice tenant management capabilities are constrained, and centralization poses major scalability and reliability concerns. Because there is an insufficient separation of concerns, slice-level activities are also not properly separated from other processes. As a consequence, several 5G network elements communicate with the overall network-slicing architecture. In this research, a novel architecture for the 6G network is presented that uses a method to maintain identity and self-orchestrated slices. To achieve this, a modular architecture called 6G-LEGO is proposed, in which single-domain slices rely on different slice-agnostic orchestrators, whereas slices with multiple domains have built-in management and orchestration abilities. The framework enables the very easy and innovative creation of additional slices by joining single domain slices.

5.2. Efficient Multi-Tenancy Framework for 6G Network Slicing

In [18], 6G networks will be a reality soon and will be utilised for a variety of applications in many sectors of life. The current slicing approaches were examined in this paper, and a more effective and efficient artificial intelligence-based network slicing framework was provided to be used in future 6G communication network technologies. A network slicing framework with clearly measurable metrics has been suggested. The architecture intelligently considers the valuable physical resources accessible from the end device to the network, control, and data centers. The framework makes it simple to create intelligent 6G networks.

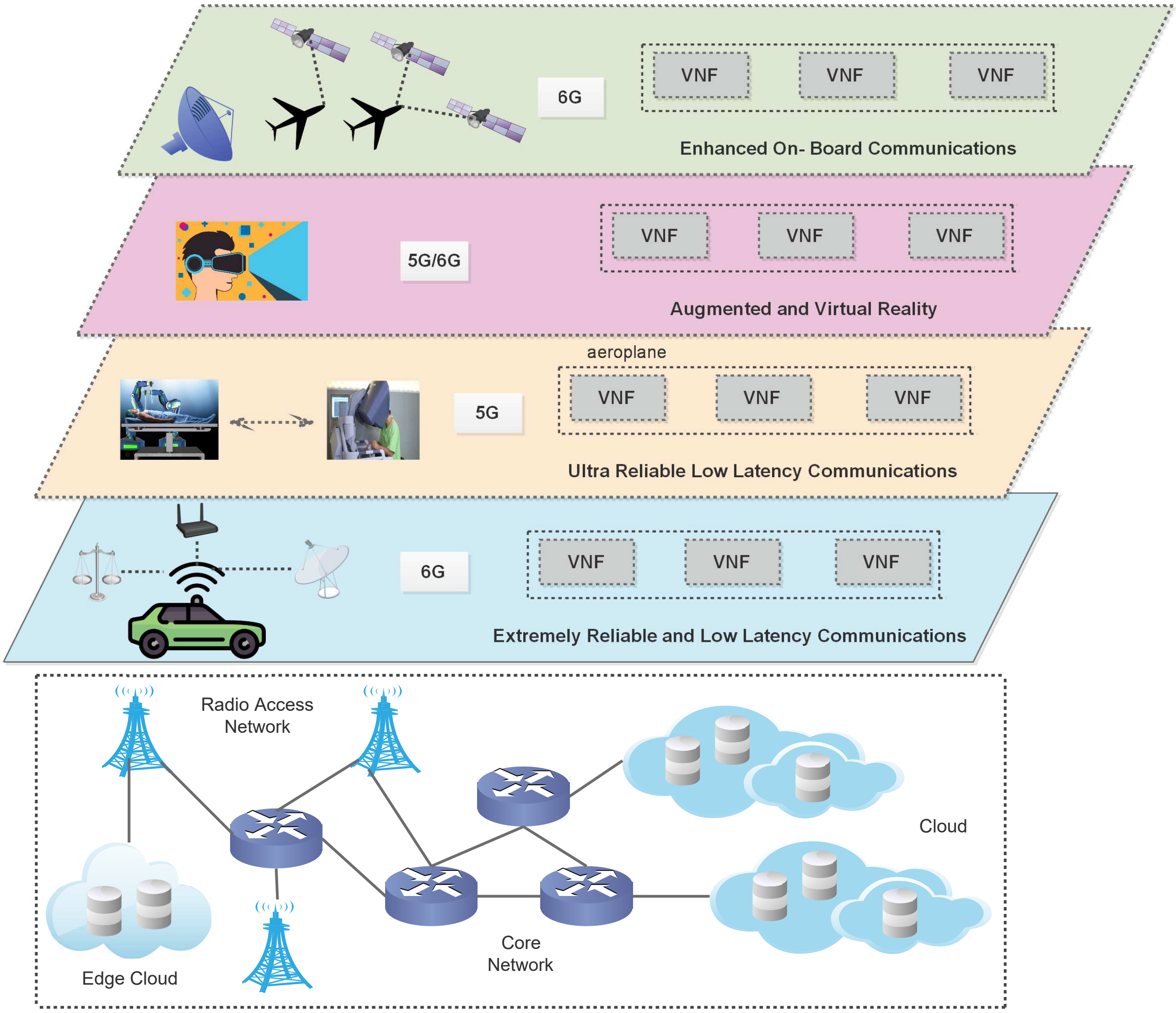

Figure 6. Network Slicing in 6G network.

5.3. Multiple Autonomous Systems' Network Slicing in 6G through NASOR

In [16], networks should connect communicative peers to meet the needs of vertical services. Native network slicing solutions are required as networks evolve towards 6G. The existing 6G network slicing environment is examined using the NASOR technique in order to spot numerous deficiencies and suggests the idea for recurrent networking slices across several self-governed systems. This innovative concept helps build the additional network infrastructure needed to realise our 6G ambition. The network could not spread cutting-edge applications and corporate sectors due to its one-size-fits-all design. NASOR is indeed a component that performs transit-level recursive slices in conjunction with the 3GPP Management Platform. The NASOR-enabled recursive slicing is a novel approach for supporting the creation of new network services required by the 6G vision.

5.4. Artificial Intelligence in 6G Network Slicing

The rapid rise of sophisticated terminals and infrastructures, as well as a wide range of applications with various needs, pose a threat to the ability of current networks to fully satisfy the demands of the quickly growing traffic. Using a novel paradigm known as artificial intelligence, 6G elevated networks have been developed and optimized. Data retrieval, smart strategy and planning, automatic network adjustment, and growth are all made possible by AI-enabled intelligent architecture for 6G networks, which is divided into 4 layers: an intelligent-sensing layer, an analytic and data mining layer, an intelligent control layer, and an intelligent application layer [57].

1. Deep Learning: Network slicing and deep reinforcement learning are essential 6G network technologies. Multiple network slices from various tenants may be present in a 6G network. To enable intelligent and effective resource management, network providers must provide slices that fulfil the 6G use cases and quality of service and experience standards.
   Intelligent and efficient resource management necessitates anticipating tenant demand for services and achieving autonomous slice behavior. DRL allows for the analysis of techniques based on the optimization objective, network emphasis (core, edge, and end-to-end networks, for example), state space, action space, algorithms, and network architecture [58].
2. ML: ML-based algorithms make it feasible for app-based traffic direction between networking devices, dynamic network segmentation for addressing various situations with variable quality of service needs, and pervasive connection across diverse 6G communication channels [59].
   In 6G wireless communication networks, machine learning technologies are used. Supervised, unsupervised, and reinforcement strategies are among these methods:
   - Supervised learning: A labelled data set is used to train supervised learning algorithms. The system is aware of both the desired output data and the input data needed to make a supervised prediction. To be effective in any application, supervised learning requires a sufficient amount of data [60].
   - Unsupervised learning: Unsupervised-learning algorithms must correctly anticipate the output from a set of unlabeled inputs, which is the main difference between supervised and unsupervised learning algorithms. These methods are most commonly employed for grouping and aggregation problems, but they can also be utilised to solve regression problems with excellent results [60].
   - Reinforcement Learning: A performance indicator obtained from the model's environment is used to accomplish RL. The model maximises the reward indication in an effort to produce the best performance level. Combining supervised and unsupervised learning techniques is what is known as RL [60].

5.5. Internet of Things in 6G Network Slicing

New services with entirely different requirements and features are developing with the expansion of the Internet of Things (IoT), which the current fifth generation of mobile cellular networks cannot support. 6G networks are designed to be capable of enabling novel services with ever-evolving technical specifications. Based on a review of the new 6G service standards, this includes advanced methods for a smart 6G network. Network self-evolution, wireless distributed computing, radio channel development, latency-sensitive transmissions, and 3C-based spectrum management are some of the technologies included in this [61].

In URLLC, latency has become a major performance parameter that is not attainable with conventional communication protocols. Future service needs may not all be satisfied by 5G, though. IoT has increased the need for communication between objects, such as linking all of the machinery in a plant. Things demand quite different types of communication. To create a smart and flexible 6G network, each node has to have adequate communication, processing, and caching resources to enable smart operations and self-evolution. All of the network's 3C components may be used jointly by several distinct technologies to enable a smart and open 6G network [62].

5.6. Optimization in 6G Network Slicing

Next-generation wireless networks are planned to support a wide range of vertical industries and provide a plethora of new applications. Network-slicing, which divides the infrastructure into several logical networks to enable service-oriented resource allocation, was created to fulfil the stringent specifications of various services. A hierarchical resource management system introduces the application of deep reinforcement learning in processing requests for resource requirements from various tenants and resource management within authorised slices for each tenant. The E2E slice, which consists of numerous connected VNFs from the transport network, core network, and RAN, presents a challenge for the optimization of diverse resources. When compared to conventional model-based optimization techniques, ML systems can find the best solution more rapidly by repeatedly learning from the reward feedback of the surrounding environment. To function at its best, RL incorporates long-term system growth into its decision-making process and modifies choice strategies in response to feedback from earlier choices. In order to boost revenue, resource providers must control multi-domain resources efficiently and allot the right number of resources to E2E slice instances. RL has been extensively utilised to address a variety of resource management issues, including voltage regulation, spectral efficiency, and computing resource management, because of its ability to develop an optimal strategy fast. In terms of providing excellent networking choice optimization and satisfying constantly changing quality of service needs, the proposed strategy seeks to implement a global resource manager (GRM) to standardise the method differentiable towards resource demands from tenants and several local-resource-managers (LRM) to deal with fluctuating resource needs for separate tenants [63].

5.7. Performance Metrics for 6G Network Slicing

5.7.1. Resource Allocation

The 6G network will need to perform significantly better than earlier generations of networks in order to serve apps and services that need multi-gigabit data rates, low latency, and ubiquitous access for the Internet of Everything. But in order to achieve every one of these challenging objectives, efficient resource administration and distribution are essential due to the scarcity of available spectrum resources. The blockchain is one technology that could help with all of this. The blockchain has lately earned a significant position as a result of its intrinsic qualities, which are critical to the 6G network and other networks. The network would be capable of efficiently tracking, regulating resource consumption, and facilitating resource sharing due to the integration of blockchain technology, particularly in the context of 6G [15].

5.7.2. Load Balancing

High-speed wireless access technologies, millimeter wave LANs, and 6G networks each need higher levels of security, lower delay, better reliable protocols, and larger communications capacities. Effective congestion management, which enables carriers to operate several network cases within a similar architecture for a higher quality of service, is among the key components of 6G technology. AI technology and machine learning (ML) are essential for redesigning and maximising the overall effectiveness of the 6G wireless network because of the enormous amount of information available. For sustained load balancing, avoid network slice breakdown and provide more slicing in the case of any slice failings or overload. Inbound network traffic necessitates a deft choice procedure. To solve those problems, a hybrid deep learning-enable effective congestion-managed architecture is given. The hybrid deep learning approach makes use of support vector machines and long short-term memories [64].

5.7.3. Slice Failure Management

Network Functions Virtualization and software-defined networking are two techniques that give telecommunications networks a new level of flexibility in deployment, operation, and maintenance [65]. They also allow several virtual networks (multi-tenancy) to be realised on a single network infrastructure. A mathematical model that first addresses the broad network slice design issue is then expanded to include traffic uncertainty [66].

The model is more durable since the network slice is shielded from failures of a single substrate network element.

5.8. Network Slicing Recent Advances

In [67], network slicing enables the move from a network-as-infrastructure to a network-as-a-service architecture, enabling a variety of smart services with varying requirements. The paper describes and examines major recent breakthroughs in network slicing to enable a variety of Internet of Things (IoT) smart applications. The following factors are used to create a taxonomy for network slicing: essential design principles, enablers, resource designs for tiers, infrastructure facilities, protection, and server application linking are all cut into different pieces. For the purpose of facilitating Internet-of-things smart environments, recent developments in network slicing, taxonomies, objectives, use applications, & ongoing research areas are examined. It takes network slicing to create a variety of possible 6G systems. Network slicing would also be a vital technique for converting modern-day cities into smart environments that use technological advances to significantly raise the standard of living for citizens [68].

Table 5 indicates the contributions made by several authors with respect to network slicing in terms of the Core or RAN network, the performance metrics of the slices, as well as the applicable security associated with them.

Table 5. State of art studies of network slicing in 6G network (R1: Core network, R2: RAN network, LB: Load balancing, RA: Resource allocation, SFM: Slice failure management, Z1: AI in network slicing, Z2: Optimization in network slicing, Z3: IoT in network slicing, SEC: Security). Discussed: ✓; Never Mentioned: X.

Authors	Key Contribution	R1	R2	LB	RA	SFM	Z1	Z2	Z3	SEC
[14]	(AI)-native network slicing architecture	✓	X	X	✓	X	✓	✓	X	X
[69]	Implementation of intelligent D2D in future 6G.	✓	X	X	✓	X	✓	✓	✓	✓
[67]	Artificial Intelligence-based Network slicing framework for future 6G.	X	✓	X	✓	X	✓	✓	✓	✓
[15]	Blockchain's potential for resource management and sharing in 6G.	X	X	X	✓	X	✓	X	✓	✓
[64]	Hybrid deep learning-enabled efficient congestion control technique.	X	X	✓	✓	✓	✓	X	✓	✓
[70]	Mathematical model for the generic network slice design.	X	X	X	✓	✓	X	X	X	✓
[63]	Resource management paradigm employing deep reinforcement learning.	✓	✓	X	✓	X	✓	✓	X	X
[1]	6G Network Architecture based on virtualized network slicing	✓	✓	X	✓	X	✓	✓	✓	✓
[17]	Self-managed and self-orchestrated slices sustained using 6G-LEGO.	✓	✓	X	✓	X	X	X	✓	✓
[16]	Recursive network slicing between several Autonomous Systems using NASOR.	X	X	X	X	X	✓	X	X	✓
[58]	Deep Reinforcement Learning for network slicing resource management.	✓	✓	X	✓	X	X	✓	✓	✓
[57]	Smart 6G Networks with AI.	X	✓	X	✓	X	✓	✓	X	✓
[59]	Algorithms for Machine Learning in 6G Wireless Networks	X	X	X	✓	X	✓	✓	✓	✓
[62]	A smart and open 6G network.	✓	X	X	X	X	X	✓	✓	✓
[71]	For 6G, an intelligent self-sustaining RAN slicing framework has been developed.	X	✓	X	✓	X	✓	✓	✓	X
[2]	6G Cognitive Load Balancing Methodology	X	✓	✓	X	X	✓	✓	✓	X
[20]	The report discusses potential 6G requirements and trends.	X	X	X	✓	X	✓	✓	✓	✓

6. Implementation of Security in 6G Network

In this section, we talked about the implementation of security in the 6G network—the state of being free from danger or threat. Here we talked about the need for changes required in the security of 6G compared to the era of 5G [72]. The security challenges and solutions are also discussed with the changing technologies. The developers of a sixth generation (6G) of wireless connections have already entered the conversation, even if the fifth generation (5G) wireless networks have yet to be fully explored. Consequently, we examine whether privacy might affect the anticipated 6G connectivity and potential difficulties involving various 6G technologies, as well as the underlying outcomes, in order to unite and strengthen overall safety in 6G networks. With the supplied 6G network framework as the foundation, we present our concept for 6G security and safety key performance indicators (KPIs). Additionally, we discuss the privacy issues that might arise with the 6G circumstances and implied 6G procedures that are currently accessible [73]. We additionally provide the audience with a few insightful details regarding exploratory devices and standardised standards pertinent to 6G protection. In this article, we specifically address security problems related to 6G enablers such as distributed tally technology (DLT), physical layer security, distributed AI/ML, visible light communications (VLC), THz, and quantity computing. This study aims to provide informative assistance for such later investigation of 6G secure during this initial stage of sight toward actuality, one by one [74].

Additionally, 6G processes have certain weaknesses. Generally, linked robotic & autonomous devices use VLC technology and artificial intelligence to compute, which could be troublesome for savage behaviour, cryptography, and data transfer. The molecular communication network, the THz technology, and the quantity communication network are all used in multi-sensory XR activities, making them vulnerable to user access assaults and violent behaviour, including data transfer exposures. Multisensory XR operations are used in a similar manner as wireless brain-computer relationships, although they have different security issues. The two primary faults are cruel conduct and encryption. The distributed tallying and block-chain techniques, which are the last 6G network activities, are quite secure, although they may continue to be the subject of malicious activity [75,76].

In order to allow entirely autonomous networks, 6G uses AI calculations. As a result, 6G would be impacted by assaults on AI technologies, particularly Machine Learning (ML) systems. Underlying security vulnerabilities against ML systems include poisoning attacks, data injection, modification of data, sensing corruption, modelling elusion, modelling inversion, modelling birth, and category conclusion assaults. Additional characteristics enable AI systems to function more effectively. Due to the fact that drug addicts are typically not able to see how their information is processed, assaults on acquired data and the inadvertent use of private information can cause severe problems. Blockchain is another crucial technology to enable 6G systems in the future. Blockchain is appropriate for decentralised resource management, distributed information sharing, and the provision of services in 6G networks that are primarily big and dispersed. With enough machines, it is possible to launch 51 assaults and bring down the blockchain. Sequester maintenance is difficult since blockchain networks retain data closely. The present 5G specification relies on classical encryption, such as elliptical wind cryptography, instead of addressing security challenges brought on by quantum computing. The 6G network will witness the existence of a significant number of computers, making the current security methods based on asymmetrical critical cryptography susceptible to assaults based on large numbers of machines. Without the development of amount-safe encryption protocols, the secured 5G dispatch offered by asymmetrical critical cryptography could no longer be suitable for post-quantum security. The technique known as visible light communication (VLC) is also appropriate for indoor ground equipment like positioning systems and outdoor systems like vehicle-to-vehicle communication. Similarly to typical assaults against wiretapping, jamming, and knot-breaking systems, VLC systems really aren't safe to use [77].

Conventional SIM cards use symmetrical critical encryption that has been demonstrated to work effectively for billions of drug addicts. However, it uses the Internet of

Things, sequester, network identification, and bogus ground stations as examples. This had never been deployed at a similar size previously. 5G aims to provide authentication using a public-key infrastructure in addition to SIM (PKI). A collection of microservices interacting via HTTPS is the basis of 5G. Transport Layer Security (TLS), which employs elliptical wave encryption, provides authentication, secrecy, and integrity for comparable communication (ECC). However, since it hasn't been deployed yet, it may be kept for 6G [78].

Several innovations and developments in areas of structure, operation, technology, programs, and standards go into the conception of 6G networks. Similar to the overall 6G goal, which builds just on cloudified plus softwarized 5G networks with greater intelligence, the 6G security view also closely resembles AI, which promotes security robotisation. The enemies also get increasingly powerful, sophisticated, & capable of developing novel varieties of security traps while at a similar timeline [79]. For instance, it is difficult to identify zero-day assaults, although it is possible to stop their spread. Incorporating smart and adaptable security methods will be more necessary than ever before for anticipating, identifying, deterring, or preventing security threats, as well as preventing the spread of comparable weaknesses in 6G networks. Assuring trust and security across the various professions and between the participants is also crucial. In particular, security and safety are two closely associated themes where security refers to the protection of verifiable facts and safety provides the concealment of the individual qualities linked to such facts. Security is distinct from other things; however, the opposite is really not true. In order to ensure security, data protection mechanisms must constantly be present. We discuss whether security complements one another for various features of 6G in the following sections [80].

6.1. Security Challenges Associated with 6G Network

Although 5G specs remain in development and 5G connectivity isn't yet completely available, 6G cellular communications have been anticipated. In several instances, the partnership between 6G and AI might have opposing ends when it comes to preserving or violating privacy and security concerns. Because 6G's standardised features & standards have not yet been established, there's a dearth of material that explains how secure and private 6G networks will be [81]. Here are a few security issues that the 6G network has to deal with:

- Based on Artificial Intelligence: AI technologies have a stronger influence on privacy. In certain ways, the proper use of AI could safeguard privacy in 6G; however, in other ways, privacy breaches may happen. AI models are vulnerable to privacy threats throughout the development & training stages.
    1. Poisonous attacks: false regression results and misclassification due to the modification of training data using malicious samples that have been purposefully created (e.g., inadequate flagging or alteration of annotated data).
    2. Evasion attacks: by adding problems to the test cases, one might try to go past the learned model during the testing stage.
    3. ML API-based Attacks: Whenever a malicious party makes API requests and attacks a machine learning model to get predictions on feature vector inputs, model inverting (recovering data for training), model extract (revealing architectures while jeopardising model confidentiality), & membership inferences (using the model output to make predictions based upon training examples and ML models) could all be part of it.
    4. Physical assaults upon infrastructure and communications disruption choices and data management are hampered by deliberate interruptions & deficiencies in communication and computing infrastructure, which may even bring down whole AI systems.
    5. AI framework infringement: The majority of AI remedies make use of current AI/ML frameworks. The legitimacy of AI/ML functionalities is targeted by flaws in such artifacts or conventional attack vectors against its software, firmware, and hardware environment (particularly cloud-centric operations).

- Based on Distributed Ledger Technology: It's probable that now the security concerns in Blockchain and smart contracts will have an implied impact on 6G networks as a consequence of the planned collaboration among DLT and 6G. The bulk of these attacks are the consequence of issues with software development, limitations imposed by programming languages, and vulnerabilities in network access protection. Additionally, both corporate and commercial blockchain systems could face similar security issues [82].

    1. The potential for an eclipse attack: blockchain nodes might receive misleading information that might lead to the validation of bogus transactions whenever connections are interrupted or dispersed.
    2. 51% Attack: Cyber attackers can dominate the blockchain if they corrupt open-source blockchain apps and get or control at least 51% of the mining power.
    3. End-user vulnerabilities: People may overlook or lose their private keys, which might compromise their blockchain-stored resources (e.g., identity theft, malware, phishing attacks).
    4. Software Vulnerability: The decentralised paradigm of several blockchains may be permanently damaged when such DLT initiatives attempt to deploy shakily specific responses on operational blockchains.

- Based on Quantum Communication: It's really anticipated that quantum-safe encryption will be implemented in the post-quantum era as a result of the development of quantum computing. Due to its propensity to exploit the quantum characteristics of data, quantum computing might already be able to provide total randomization & security to enhance overall transmission quality. Physical layer security and post-quantum cryptography integration might lead to safe 6G lines of communication. Quantum security procedures have the ability to be used in prospective 6G app scenarios. Well, with quantum gains for supervised and unsupervised learning for clustering and classification jobs, quantum machine learning algorithms may increase confidentiality and security in communications systems [83].

    1. Quantum replication attack: making a perfect clone of a piece of data in a randomised quantum state without changing the data's initial condition.
    2. Quantum collisions attack: Whenever 2 distinct inputs to a hashing algorithm deliver alike outputs in a quantum context, this is known as a quantum collision attack.

- Based on Terahertz: THz communications have been anticipated to play a crucial role in 6G technology. With enhanced security at the physical layer, the THz frequencies have improved signal directivity that prevents unauthorised parties from being in the same direct relationship as the authorised user to capture signals. Nevertheless, by positioning an item in the route of transmission to deflect radiation toward himself, an eavesdropper could also capture a signal in line-of-sight (LoS) broadcasts [84].

    1. Access control attacks For gaining entry to restricted resources or changing system settings, parties violate access rules, steal information, or kidnap users.
    2. Eavesdropping attack: Despite being resistant to intercepting assaults, broadcasts with strong polarity in small ranges are nevertheless vulnerable to hostile nodes capturing the signals.

- Based on Visible Light Communication: Owing to the benefits of radio frequency (RF) systems, like fast data speeds, a broad accessible spectrum, resilience over interference, & intrinsic security, VLC is indeed an optical wireless technology that has gained significant attention. Contrary to RF systems, VLC mechanisms can provide a better protection level since light cannot pass through solid objects like walls. The broadcasting format & LoS propagation of VLC systems, make them open to eavesdropping by unauthorised nodes present within the transmitters' broadcasting area. For such construction of useful VLC systems, the confidentiality of the systems is an essential concern [85].

1. Data-tampering or jamming attacks: Unauthorized transmissions can go unnoticed in VLC or hybrid VLC-RF systems. The likelihood of an effective assault is increased via a finely focused transmitter, such as those created by optical beamforming methods [86].
2. Eavesdropping attack: Whenever node terminals are placed in public spaces, wide screens are present in the covering zones, & there are cooperative eavesdroppers, they become just as susceptible as RF.

- Metasurface-in-the-Middle Attack: Experts claim that 6G would potentially be greatly secured over wireless technology having greater beamwidths since it uses highly directional antennas. The idea is that by tightly focusing communication between the receiver and transmitter, the possibility of an eavesdropper intercepting a channel is reduced. Scientists at Rice University reported a man-in-the-middle attack targeted at 6G frequencies to highlight genuine security issues in an effort to verify that 6G is secured while technologies are being explored [87]. A well constructed metasurface may be used by an attacker to capture communication at 6G frequency, according to the experts, who refer to their assault as a metasurface-in-the-middle attack (MSITM). Through creating a metasurface & positioning it exactly in the path of vision between transmitter and receiver, the attacker can divert some part of sensitive communication. The resultant programmable scattering radiation patterns may create a diffraction-based eavesdropping route for the enemy. This could cause a phasing mismatch at the surface interface [88].
- Parameter attack: Injection assaults against cross-domain data services might result from improperly vetted parameters. Logic corruption, data manipulation, & data injection all happen. Data on the topology of the network is changed to introduce hostile nodes and fictitious linkages. Fake parameter injection that is ongoing might result in a denial-of-service assault that leaves data services unusable [89].
- Identity attack: Using vulnerabilities in identification & authorisation procedures for gain Harvested API keys are utilized as credentials. Unprotected E2E domain orchestration services are taken advantage of to alter settings in such an effort to violate service level agreements as well as to launch new instances that consume a lot of network resources [90].
- Man-in-the-middle attack: Through starting false failure occurrences & intercepting domain control messages, MITM assaults can redirect traffic through rogue endpoints [91].
- DDoS attacks: For 6G, DDoS assaults are anticipated to be significantly severe. Numerous vulnerable Internet of Things (IoT) devices might send enormous amounts of harmful traffic toward intruders. Edge servers that are frequently accessed, though, have less effective DDoS mitigation features. DDoS assaults can potentially be harmful to end devices [92].
- Deception attack: The 6G network's transmitted data will be manipulated on purpose [93].
- Data leakage: Obtaining data about unauthorised parties' intentions to undermine system security goals such as privacy and confidentiality, etc. Additional assaults might start as a result of all this.
- Improper configurations: Intent-based links, which are comparable to Zero-touch Ntworks & Service Management (ZSM) in that they may be open to data uncovering, may be used by 6G networks, opening them up to assaults including unwanted configurations & strange behavior. Unwanted setup of intent-based interfaces, like switching the security level from high to low or altering the linking of intent to action, might risk the security of the entire management architecture [94].

6.2. Remediation Steps to the Security Challenges

Due to the ever-increasing and large-scale challenges associated with 6G technology, there have to be some steps taken in order to remediate the issues and occurrences as a result of the assaults by malicious intruders. Some of the resolution steps are described below:

- Distributed and Scalable AI/ML security: Self-X (self-configuration, self-monitoring, self-healing, and self-optimization) tasks would be carried out by autonomous networks in 6G with little to no user intervention. Distributed AI/ML approaches should impose quick controls & analytics on the enormous quantity of data obtained in 6G networks because the ubiquitous usage of AI/ML would be implemented in such a distributed and large-scale system across multiple use cases, including network management. Distributed AI/ML may be used for security at many stages of 6G cybersecurity defence & prevention. The benefits of autonomous operation, improved precision, and predictive capabilities for security analytics are where AI/ML-driven cybersecurity finds its usefulness.
- Security for Quantum Communication: Quantum communication rules like quantum key distribution have the ability to be used in a variety of 6G scenarios, including those for ocean communication, satellite communication, terrestrial wireless networks, and THz communications systems. Quantum key distribution (QKD) uses quantum theory to create a private key and distribute it among two lawful parties, making it suitable for traditional key distribution systems. Quantum-safe encryption is expected to be implemented in the post-quantum period as a result of the development of quantum computing. The advent of quantum algorithms might enable the polynomial-time solution of the discrete logarithmic issue, the fundamental difficulty in existing asymmetric cryptography.
- Physical Layer Security: At each level, the network has security methods that may be employed individually to build an additional defence or collectively throughout levels for applications with low resources. 6G will make use of physical-level security techniques to offer an adaptable extra layer of security in an environment of novel enabling technologies. Classifying the channel's backscatter as a protective measure against this eavesdropping method can help certain eavesdroppers be found, but not everyone of them. Molecular communication (MC) is a potential technology for 6G in several healthcare systems since bionanomachines interact using chemical signals or molecules in an aqueous environment. While dealing with a number of privacy and safety concerns relating to the communication, authentication, and encryption processes, MC manages to provide security for extremely confidential material.
- Solution to Parameter attack: Input validation, user authentication, access control, and rate restriction are ways to stop parameter assaults.
- Identity security: Identity assaults may be avoided by implementing authenticating (Signed JWT tokens, OpenID connect), authorising (role-based access control, attribute-based access control, and access control lists), and both.
- Prevention against Man-in-the-middle attack: Utilization of VPNs and safe secured communications (e.g., IPsec, SSLffLS & HIP).
- Prevention against DDoS attacks: Throttling or rate-limiting the use of APIs, deploying API gateways and micro gateways, and using AI-based API security to conduct continuous monitoring can all help avoid assaults that direct distributed denial of service.
- Resolution against Data leakage: The following methods can be used to prevent data exposure: authenticating the relationship among the intent producer and consumer, like signed JWT tokens and OpenID Connect; limiting access through access control measures like role-based access control and OAuth 2.0; and further utilising communication security through TCP/IP protocols (TLS 1.2).

7. Conclusions

Typical features include AI-driven wireless communication technologies, individualised network experiences, and a concentration on machines as important workers all contributing to increased network dependability and accuracy. The 6G network intends to improve inter-device connectivity. The advantages of using AI algorithms and security mechanisms exceeded the advantages of using 6G networks, which offered higher data speeds. We have a smart and secure network backbone due to 1G to 5G and 6G research. The expanding application of AI, IoT, and blockchain boosted researchers' excitement for 6G. Such a 6G network will benefit from technological advancements, including the use of the terahertz band, artificial intelligence, wireless optical communications, three-dimensional connection, unmanned aerial vehicles, and wireless transmission. High levels of security and privacy should be a primary priority of wireless research in order to assure the viability of 6G networks. The continued development of technology suggests that 6G networks will be much more diverse than their predecessors.

Technology moves quickly and rules take time to create, so we've always marched towards 6G. The notion of 6G shows how quickly technology progresses. Given how swiftly we went from 1G to 5G, 6G is the next natural step in a faster, more reliable wireless connection. According to projections, 6G smartphones and high-level antennas may penetrate obstacles by reproducing images from diverse local settings with different densities. To enable future technology, 6G covers several applications. 5G networks cannot handle smart city app metrics, which 6G mobility assistance can do. Autonomous vehicles need low-delay connection, which 6G should supply. 6G will give the capacity, dependability, and information rate needed to carry enhanced data wirelessly, making it ideal for AR/VR technology. 3D games and cross-media using all five senses are conceivable with a 6G connection. In other words, we want high information density, low latency, excellent dependability, and great customer service. Haptic communication utilising 6G can reconstruct brain impulses and portray them as a 3D movie of a person's view. People use haptics to interact with their surroundings and control them with digital devices like a wireless chip in the brain that responds to emotions. In contrast, remote procedures are sensitive and need less than 1 ms of delay. Telemedicine and remote healthcare will alter with 6G networks' space and time savings. Holographic communication may be utilised for excavation and personnel training at distant mines and deep-ocean ports. These huge data transfers are handled by 6G networks. Tactile internetworking combines speech, video, and touch and taste. Due to its high data capacity and low latency, 6G can meet the needs. IoT is becoming an important aspect of the future Internet and gaining academic and industrial attention. Introducing 6G should lead to new IoT applications. During 6G, the digital, physical, and social worlds will seamlessly merge, resulting in enhanced sensory experiences. Human efficiency, living, operating, and environmental care would be rethought using intelligent information platforms and high computer capacity. 6G would improve 5G in various technical and use-case areas, reducing costs and boosting adoption. New use cases will be feasible with 6G. As AI and machine intelligence learn to recognise people and objects, wireless cameras will become all-purpose sensors. Using radio and acoustics, users will learn about their environment. Electronic cash and credentials may become prevalent. We may even control machines using brain sensors. The proposed architecture might handle 6G network applications and technology. AI-based network slicing reduces network administration effort and adapts to changing network circumstances. However, understanding actual vertical demands and circumstances would help 6G advancement. Such ecosystems must appropriately examine such aspects so standardisation groups can produce the right resolutions and service, device, and technology vendors can implement the outcomes in the real world. Thus, employing new methods for communicating, gathering, and analysing demands supports development in the industry.

Author Contributions: Conceptualization, U.K., R.D., G.C., S.K. and N.D.; methodology, R.D., G.C. and P.L.; validation, U.K., R.D., G.C., S.K., N.D. and P.L.; investigation, U.K., R.D., G.C., N.D., S.K and P.L.; resources, G.C. and N.D.; Data curation, S.K., U.K., R.D. and G.C.; writing—original draft preparation, R.D. and G.C.; writing—review and editing, G.C., R.D. and N.D.; visualization, N.D., R.D., G.C., U.K., S.K. and P.L.; supervision, G.C., R.D., N.D. and P.L.; project administration, G.C. and

N.D.; funding acquisition, G.C. and N.D. All authors have read and agreed to the published version of the manuscript.

Funding: This work has been supported by project TRANSACT funded under H2020-EU.2.1.1.—INDUSTRIAL LEADERSHIP—Leadership in enabling and industrial technologies—Information and Communication Technologies (grant agreement ID: 101007260).

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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