Chapter 13: 6G: Technology, Advancement, Barriers and the Future

Author(s):

Meghna Manoj Nair (Vellore Institute of Technology, Chennai
mnairmeghna@gmail.com)

*Amit Kumar Tyagi (National Institute of Fashion Technology, New Delhi,
amitkrtyagi025@gmail.com)

13.1 Introduction

Cellular networks, as very commonly known, is a data communication network which facilitates effortless and robust roaming capabilities for complementing the cellular devices. In the initial days, when mobile phones connected to such networks were used potentially for sending bare minimum texts and making calls, in the present day, almost every other task and digital chore can be done through the smart phones connected to these networks. In fact, they've taken up a primary role of communication in relation to almost every other aspect of human daily life [1]. The world has reached a point wherein a minor mishap or glitch in the cellular network has multiple and drastic adverse effects starting from massive losses in the economic sector all the way to disturbances in the financial transactions, inability to attend to emergencies during accidents and attacks, and what not. There are also sufficient cases that throw light on the significance to be given to the security of these cellular networks because of the high dependencies' humans have on it [2]. The one thing that can be noticed despite the huge growth and revolution of cellular networks is that there's hardly any importance or initiative taken to accurately and precisely safeguard these networks so as to support and extend the concept to creative and innovative integrations, increased subscribers, more speed/bandwidth, etc. with ease and efficiency.

The 5^{th} generation (5G) network technology is one of the recent and latest works that has been on the rise in last few years and has been very recently launched in India too. Despite

this fact, it's essential to continue looking forward to the communication needs of the future and hence, this work on 6G technology. The main purpose of this paper is to idealize and provide the foundational aspects of 6G and how it could prove to be revolutionary in the coming years [3]. The main motive of 6G networks is to deliver fast and efficient speed transmission, maximize the capacity and non-proximity, etc. Even though it may be a little early to accurately define this technology, it is very often considered to be the ultimate successor of the 5G networks and cellular technology with a possibility of expanded data rates and increased capacity in terms of bandwidth [4]. This in turn points to very low levels of latency being a necessary requirement for the upcoming wireless technology of networks. In a few more years, it's highly likely that users of such cellular technology are going to be impacted by the huge inflow of data and communication, as a result of which, 6G technology must definitely emphasize on the continue development of wireless technology featuring advanced frequency spectrum in comparison to the previous generations of communication technology [5]. On the whole, it is likely that 6G systems would enable data transmission of around hundreds of GB per second with a combined usage of a millimeter wave and a terahertz wave band. The evolution of cellular communication from its first generation all the way to its fifth generation and proceeding towards the sixth generation, is truly astounding. The 1G technology in analog which led to the incorporation of the very first mobile phones in the 1980s supported speed limits of up to 2.8 Kbps with the help of a circuit switch through an analog phone service [6]. With the help of a frequency division multiplexing, it was able to carry out the basic operations and functionalities of a cell phone but offered very little quality for voice calls and consumed large amounts of energy. Then came the 2G digital technology which built its foundation on the global system for mobile communication which was brought about in Finland in the initial 1990's. In fact, it was the very first cellular network that attempted to replace the inefficiencies of the previous analog technology such as

increased standard of safety and slightly better quality. It also provided features that supported text and media/photo messaging. With this, the third-generation technology was developed with much higher speeds of up to 144 Kbps along with global roaming facilities [7]. Further, it also provided the advantage of connecting to the internet through mobile data or other internet protocol-based networks along with multimedia transmission features. In the late 2000's came the 4G technology with the main goal of achieving excellent quality, maximal capacity, and fantastic user experience with a bandwidth expansion of up to 1 Gbps.

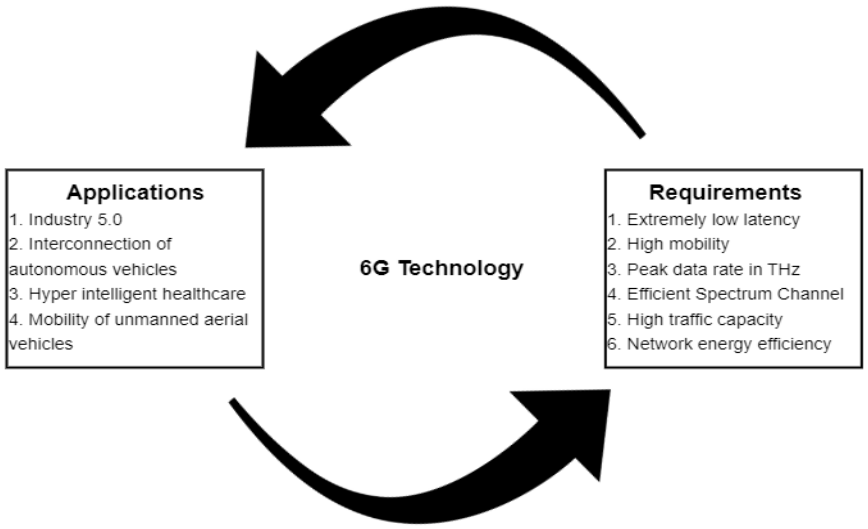

Figure 13.1 Major requirements and applications of 6G

The utilization of this network is done using terminal portability which has a great influence in this level of cellular network. Following the surge of 4G, came the 5G technology with a focus on the growing nature of the world wide web and dynamic wireless networks that are ad-hoc in nature. The fact that it provides the opportunity for artificial intelligence-based integrations is what propelled this concept the furthest. The next up and coming technological concepts, considering that 5G would be economically available across the world in the next few years, is the sixth-generation technology which is the area of focus of this paper [8]. The major requirements of 6G are as shown in Figure 13.1 above.

13.2 Background Work

The current works in the field of 6G mainly focus on the prospective technology of 6G in mobile communications, its possible applications, advantages, and so on. The work put forth by the authors of [9] focuses on the possible framework of sixth generation technology, it's architecture and the communication scenario regarding the same. It also highlights the comparison between 5G and 6G along with the possible issues of the prospective communication technology such as the limited flexibility access to radio, issues regarding network security, the non-uniformity in high frequency band, and problems in tactile communications. In [10], the work throws light on the vision, requirements, and technological trend of 6G.

The authors believe that the main vision of this revolutionizing concept is to solve the limitations and drawbacks of 5G which consists of system coverage and internet of everything. They've also mentioned the future roadmap of standardization for 6G which dates all the way to 2030's. The authors of [11] emphasizes on the initial point of 6G evolution and the possibility of integrating Artificial Intelligence (AI) with the same. They've also elucidated on how the three main components of 6G not just focus on human society, information space, and physical world, but also incorporates the fourth dimension of the virtual communication enabling technology. In [d], the research work throws lights on the use of 6G communication technology with respect to intelligent healthcare systems. It elucidates and elaborates on the major aspect of this network of communication such as holographic interaction, haptic internet connectivity, and the intelligent framework of medical things/wearables. The works of authors in [12] highlights the future of wireless technology and discusses the networks of 6G as well as 7G, its comparison with the conventional broadband networks, and the major aspects of 7G. The technology has advanced to such an extent that it's helped in evolving from times of using 2G all the way to robotics and

automation in 5G. Every subsequent generation of technology in terms of communication would empower major changes and modifications by correcting the various issues in the previous generations.

5G is still noble and in its rudimentary stages but 6G will definitely take over in the coming years. It is touted to drive the adoption of 5G use cases at scale through optimizations and cost-reduction, especially at the enterprise level. At the same time, it will enable new use cases. Moreover, 6G will bring together the human, physical, and virtual environments. Take the concept of 'Metaverse', for example. It is one of the 5G use cases, which promises to disrupt both traditional and digital spaces. With 6G, the 'Metaverse' would not just evolve into a final model but is also likely to unify with the physical world with the help of artificial intelligence and machine learning. This is because the most notable aspect of 6G would be its ability to sense the environment, people and objects -- according to telecom gear maker Nokia Bell Labs. The network's sensing ability combined with artificial intelligence and machine learning will make the network more cognitive. India is running behind schedule on the rollout of 5G, but tables may turn with 6G. This is because the country has already begun the development of 6G. According to Minister of Communication Ashwini Vaishnaw, work towards developing the next generation of communication technology has begun using indigenously developed 6G infrastructure with the aim to launch it either by 2023-end or early 2024.

13.3 Problem Definition

6G, being one of the technologies that's yet to be brought out to the world has quite a few bottlenecks and challenges including those of system coverage, capacity requirements, movement speed of data and its transmission rate, energy efficiency, etc. One of the other pressing concerns is that of the security aspect which is often neglected even though it needs to be given significant important in scenarios where there's large influx of data and

information. This sixth generation of cellular network technology is likely to take roots by the 2030's and is expected to provide communication efficacies through hyperconnectivity [13]. However, through research, it's essential to highlight the major security aspects of this empowering network technology in order to address the difficulties in relation to privacy preservation, security aspects, and the trust factor of 6G networks. This paper addresses the security and privacy preservation aspect of 6G technology. The pressing reason for addressing the security aspect of 6G is because of the following four features. First of all, it is likely to provide an opportunity to initiate a platform that offers integrated air, ground, space, and sea-based communication networks. Secondly, this conceptual implementation would give rise to a novel generation of intelligent and smart services and amenities through AI, big data, etc. Thirdly, the combination of terahertz, millimeter wave, and optical communications would help in improving the capacity in terms of network traffic and data speed. Last but not the least, the security and privacy have to be strengthened to ensure that this network of communication technology is easily scalable and preventable from external attacks or breaches. The fourth and most important point is the problem this paper addresses [14].

13.4 Motivation

Security is of prime concern in the world today especially with the growing dependency of humans on technological devices and equipment that extract so much of information knowingly or unknowingly. Right from the first-generation analog technology, all the way to the fifth generation of network communication technology, there have been quite a few mishaps and glitches in the security and privacy aspects and this has been the motivation for addressing this issue through this paper. In the early 1980's, with the launch of 1G which mainly used modulations from analog for data transfer, there was absolutely no guarantee or commitment in the field of security and this exposed the system to numerous unencrypted

services which were prone to attacks [12, 15]. Similarly, with the initiation of 2G which heavily relied on digital modulations and its protocols along with the GSM standard, there was an added feature of authenticating users for the network service providers to ensure protected transmission and information. However, there was still a number of vulnerability issues in terms of security with 2G because of its linear authentical service instead of the two secure services. With the introduction of 3G in the late 2000s, though there was a hike in terms of the data transmission rate and speed along with internet connectivity facilities, it also made sure to address the security issues faced in 2G by incorporating a two-way validation and key agreement system to stabilize the security. This too did have loopholes that resulted in channel attacks and network threats. For the following fourth generation technology, there were many security concerns which levered sever damage to the terminal devices or the end nodes in the network leading to tampered hardware, viruses, and operating systems. With regards to the 5G networks which consist of core, backhaul, and access networks, there are chances of connection outages leading to major security concerns. The fact that all generations of network communications possess some or the other security and privacy vulnerability is the motivation for addressing this very issue through this paper [16, 17].

13.5 Progressed work and Implementation towards Security

With the evolution of communication network technologies, each advanced level of respective tech generations has tried to address and eradicate the limitations of the previous levels. However, the one bottleneck that has remained consistent throughout is that of the security issue. The following figure, Figure 13.2, gives a detailed analysis of the security vulnerabilities have grown or evolved along with the advancement in the respective communication networks [18].

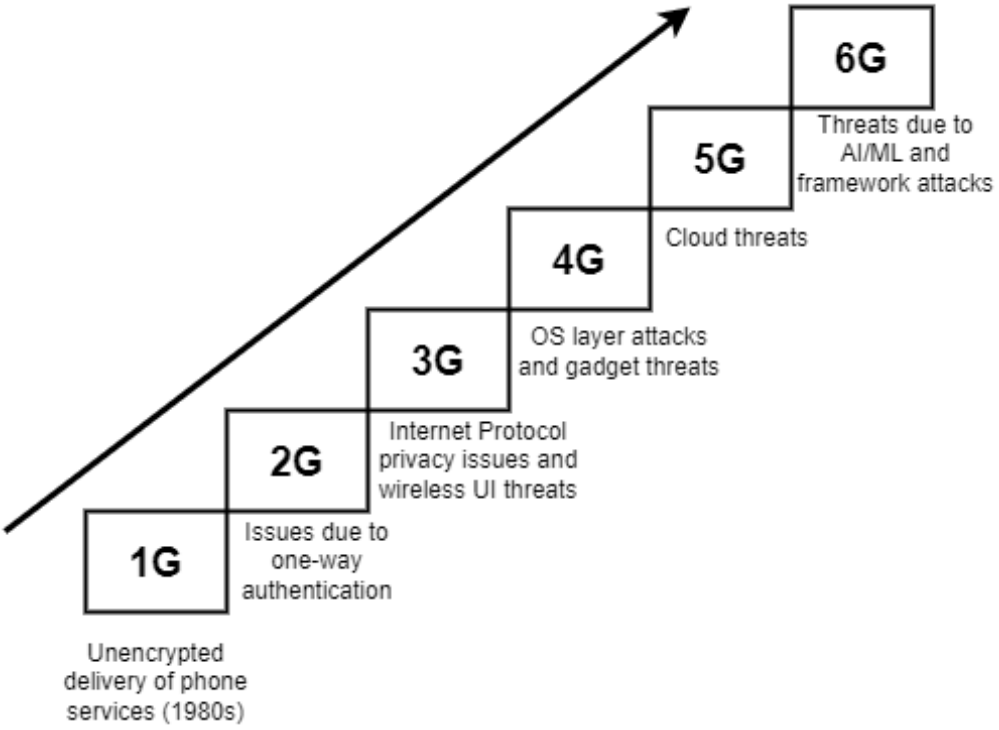

Figure 13.2 Security vulnerabilities from 1G to 6G

The implementation of 6G technology in the world would call for strict and stringent measures in the field of security and extended network services. However, the most important and highly impactful factor among all belongs to that of the privacy or security preservation aspect due to the involvement and integration of advanced framework designs, standardization, policies, etc. Considering the fact that 6G has the capability of being integrated with AI, its security aspect can also be strengthened using the same phenomena. Moreover, it also has the added advantage of the cloud based and software compatible base from the previous fifth generation network. The one thing to be noted is that even though these technologies are being enhanced and evolving to be intelligent over the years, the possible attacks and adversaries are also becoming smarter by the day making it even more challenging to combat the security vulnerabilities. It is equally necessary and important to ensure a trustworthy, reliable, and privacy preserving environment to safeguard the data during data transmission and to prevent attacks. Though security and privacy are two

completely different terms with meanings that lie along different realms, both of them are complimentary to each other and are always interlinked. The two parameters that are likely to be useful in terms of casting an impact and measuring the level of security are the Key Performance Indicators (KPI) and the Key Value Indicators (KVI) [19].

One possible way to combat this issue is to utilize one of the growing phenomenon's of blockchain. Blockchain, a distributed ledger-based system to store and record data in in a list of blocks which are securely linked and encrypted using hash pointer techniques. The integration of this highly secure and publicly reliable ledger technique could not only ensure security, but also simplify management of network services as well as spectrum features. The possibility of developing a safely curated system of a blockchain based radio access network framework that can handle and deal with the authentication and validation process is the ideal solution. Furthermore, since blockchain is not a centralized system which has its power vested in the hands of a single individual, and since it follows the 51% rule, tampering or breaching the data being transmitted is not practically possible. The major areas and aspects that blockchain would cover in terms of its security safeguarding feature with 6G is efficient and dynamic solutions for resource and spectrum management, compute power and data storage services, and infrastructural handling [18, 19 and 20].

The convergence of communications and sensing is the goal of 6G, which builds on the success of 5G. 6G should be able to train automation systems that cover a wide range of devices, various types of network and communication technologies, and humans through sensing the physical world and human beings. Users should promptly receive the networking services they expect from 6G. Emerging technologies will be embraced, including Internet of Everything, real-time intelligent edges, quantum communication, molecule communication, etc. As a result, network and information security will be crucial to both individual and societal safety. However, perceiving people and the physical world raises important privacy

preservation concerns, which is in tension with trust. Another view of 6G is it is a large-scale heterogeneous network (LS-HetNet) by integrating terrestrial networks, space satellite networks, and marine networks. Such an integrated network can seamlessly support anywhere and anytime networking. But high Quality-of-Trust should be offered by LS-HetNets to meet mobile user expectations.

Network resources can be efficiently allocated with high flexibility across different domains in accordance with user demands by integrating with cloud computing and edge computing. However, this calls for trustworthy virtual cooperation between several network operators while maintaining user and operator privacy. ITU-T stipulates that Trustworthy networking should be offered in order to prepare for future development. In 6G, reliable networking should provide security and address privacy leakage holistically. In conclusion, it is anticipated that 6G will have appealing features such reliable and autonomous networking based on efficient sensing to automatically meet user requests by integrating diverse communication and networking technologies. However, these encouraging characteristics present fresh problems with privacy, security, and trust that drive practice and study.

13.6 Popular Critical Challenges and Future Research Directions

This paper focuses on the main possible issue of 6G in the future which is that of the security aspect. However, there are a number of other challenges and issues apart from security that can be further discussed and researched upon. The very first challenge the use of terahertz frequency band [21]. Though it would provide expansive bandwidth and speed, its going to be a herculean challenge to maintain and consistently service. The generations of THz signal is quite difficult as it has stringent requirements in terms of its size, sophistication, and transmission. One of the other possible challenges is the friction faced during underwater communication which is one of the specialty features of 6G [22]. The fact that water currents and waves are ever so dynamic that leads to completely unpredictable environments, leaving

behind the only option of acoustic communication in such situations. The 6G technology also calls for heavily designed and efficient transmitter and receiver antenna and it should also have very high integrations [23][24]. This again is an added challenge as it requires extensive research and development techniques to curate the same. Furthermore, one of the prevailing and predictable issues is that of latency in end-to-end transmissions and reliability factor. In order to perform consistently and seamlessly, robust forward error correction standards and procedures are required along with a parallelized array of channels to distribute the process so as to reduce the latency. High energy consumptions, overloadable capacity, global coverage, high density or number of nodes in the network per kilometer, overwhelming costs, and non-uniformity are some of the other major challenges that need to be positively overcome in the field of 6G. The figure, Figure 13.3, given below gives a brief overview of the possible issues and challenges in this field. This provides a massive scope for researchers to carry out surveys and develop frameworks to overcome the same through their publications [25].

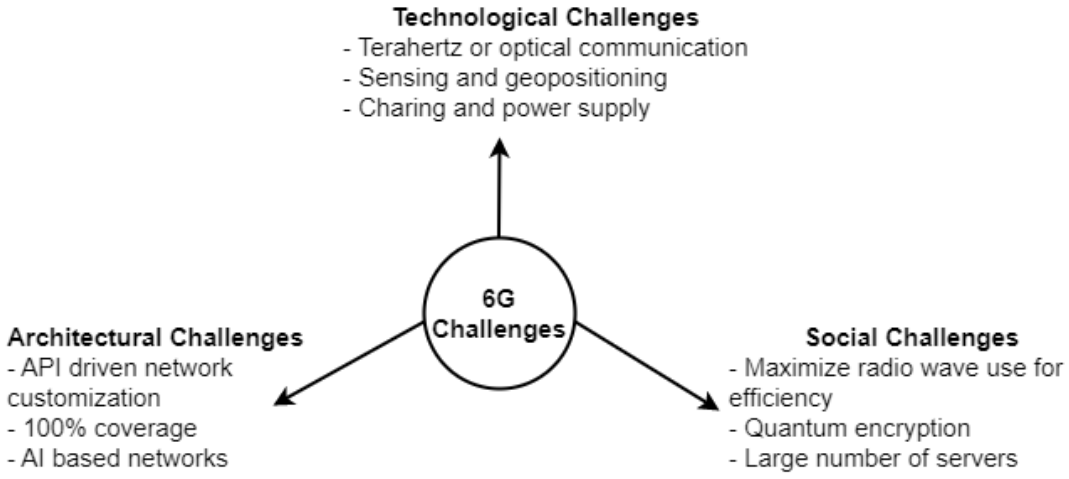

Figure 13.3 Challenges of 6G

• From the possibility to the certainty: Due to the unique characteristics of Internet Protocol, the services offered by mobile internet in the past were rife with ambiguities and instability.

These services can readily please subscribers in the 4G age. After all, a little bit of packet loss and network latency won't interfere with customers' ability to watch movies and shop online. However, the expansion of the 5G and 6G networks into all sectors of the economy and across all devices necessitates the provision of low latency and great dependability. This is the rationale behind the introduction of network slicing, MEC, and related technologies in 5G to provide the end-to-end network services capabilities ensured by SLA (Service-level agreement). According to expectations, network services will be more reliable in the 6G era and better able to respond to a variety of scenarios across a wide range of sectors [26].

• Openness and customization: On the one hand, as we are all aware, the openness and sharing that characterizes the Internet is what helps it grow. On the other hand, the ecosystem of mobile communication networks restrains its expansion to some extent by using unique technologies. Moving into the 5G era, mobile networks should actively encourage the integration of CT and IT to support the exploration of more cutting-edge applications in all industries. This will allow many industries to participate in the digital revolution. The 6G era will see an evolution in the ability to be open and customizable, supporting flexible and agile services with API interfaces for industrial clients to fulfil the demands of creating specialized networks and specialized applications [27].

• Artificial intelligence network: Artificial intelligence (AI) is currently being used in a number of fields, including automated translation, picture and speech recognition, and many others. For starters, better standards for network latency, stability, and user experience are required as network services evolve. Another factor is that maintaining and improving network KPIs through standard operation becomes more difficult the more complex the network is. Operators and equipment suppliers are attempting to integrate AI into the network to support network automation and intelligent transformation in an effort to overcome these difficulties. However, in order to maximize the usefulness of an AI engine, significant

amounts of data and computational power are needed. As a result, the interaction between AI is necessary for the future artificial intelligence network in the 5G and 6G era.

• 100% Coverage: With a cell phone nowadays, you can live a convenient and simple life, but more than three billion people globally still do not have access to the Internet. The high cost of installing base stations and optical fibre cables as well as the geographical situation contribute to the failure of network construction in remote places. The deployment of the space-earth integration network is required in the 6G era to reach the target of 100% coverage worldwide. Base stations should be placed on platforms in the high stratosphere and on LEO satellites, which can fully deliver network signal to some remote places, in order to establish a space-Earth integration network. Generally speaking, this solution investigates the potential of numerous new applications [29].

• Terahertz communication: The frequency range between 100GHz and 10THz is referred to as the terahertz frequency band and will be used in the 6G era. Despite having a large bandwidth, it has never been used. It can therefore be used without restrictions. However, it is predicted that terahertz in the 6G era will experience many of the same issues as millimeter wave today, including poor coverage, expensive network deployment, an undeveloped ecosystem of terminals, and other issues that must be addressed by the entire telecom sector [30].

• Perception and location: Mobile operators are currently using the radio spectrum for telecommunication purposes. However, in the 6G era, radio spectrum may be utilized for more than just communications; it can also serve as a sensor and a location-based service, enabling more novel applications by offering services like communication and location tracing. For instance, to improve and enrich the user experience, radio signals can recognize posture, gesture, and the surrounding environment. By observing the surrounding environments for moisture, temperature, vibrancy, and other elements, you can maintain the

steady operation of Smart City and all enterprises. Locate new services for exploration [31].

• Make the best use of spectrum: Radio spectrum is an important carrier of innovation in the digital age since it is a valuable resource. Countries design the authorization and distribution systems for spectrum in the era of mobile networks. In the past, this arrangement encouraged network growth, but over time, it led to spectrum waste. As a result, in the 6G future, dynamic spectrum sharing technology will be researched. The wireless sector is attempting to regulate and distribute the spectrum more intelligently and flexibly by introducing AI, block chain, and relevant technologies. Massive MIMO is advancing to increase spectrum use efficiency in the meanwhile [32].

• Network security: Network security is essential to the development of the digital economy. Low latency, excellent dependability, wide bandwidth, and network security in particular are components of the 5G value [33–38].

13.7 Conclusion

This section concludes the paper which talks about the technology of 6th Generation network, the security aspect of 6G, and the other possible barriers. We have represented a brief elucidation of the major features that align and showcase 6G communication systems and have proposed a possible solution for the security through Blockchain technology. Towards the end of the paper, we also highlight the various possible issues in the field of 6G apart from the security aspect which span across areas of architectural, technological, and social fields of 6G. In a world that is continuously evolving and improving its technological developments, 6G is just an arm's reach away as we have already entered the phase of 5G technology. It is highly expected that 6G would expand massively and is likely to develop a huge base of users both theoretically and practically. From the networking point of view, 6G would deploy novel architectural frameworks that are intelligent and capable of decision making. On the whole, 6G would definitely be a leap into the next generation of

communication networks.

References

[1]. Chowdhury MZ, Shahjalal M, Ahmed S, Jang YM. 6G wireless communication systems: Applications, requirements, technologies, challenges, and research directions. IEEE Open Journal of the Communications Society. 2020 Jul 20;1:957-75.

[2]. Jiang W, Han B, Habibi MA, Schotten HD. The road towards 6G: A comprehensive survey. IEEE Open Journal of the Communications Society. 2021 Feb 8;2:334-66.

[3]. Saad W, Bennis M, Chen M. A vision of 6G wireless systems: Applications, trends, technologies, and open research problems. IEEE network. 2019 Oct 15;34(3):134-42.

[4]. Letaief KB, Chen W, Shi Y, Zhang J, Zhang YJ. The roadmap to 6G: AI empowered wireless networks. IEEE communications magazine. 2019 Aug 21;57(8):84-90.

[5]. Zhang Z, Xiao Y, Ma Z, Xiao M, Ding Z, Lei X, Karagiannidis GK, Fan P. 6G wireless networks: Vision, requirements, architecture, and key technologies. IEEE Vehicular Technology Magazine. 2019 Jul 18;14(3):28-41.

[6]. Giordani M, Polese M, Mezzavilla M, Rangan S, Zorzi M. Toward 6G networks: Use cases and technologies. IEEE Communications Magazine. 2020 Mar 18;58(3):55-61.

[7]. Rappaport TS, Xing Y, Kanhere O, Ju S, Madanayake A, Mandal S, Alkhateeb A, Trichopoulos GC. Wireless communications and applications above 100 GHz: Opportunities and challenges for 6G and beyond. IEEE access. 2019 Jun 6;7:78729-57.

[8]. Huang T, Yang W, Wu J, Ma J, Zhang X, Zhang D. A survey on green 6G network: Architecture and technologies. IEEE access. 2019 Dec 4;7:175758-68.

[9]. Nawaz F, Ibrahim J, Muhammad AA, Junaid M, Kousar S, Parveen T. A review of vision and challenges of 6G technology. International Journal of Advanced Computer Science and Applications. 2020;11(2).

[10]. Chen, S., Liang, Y.C., Sun, S., Kang, S., Cheng, W. and Peng, M., 2020. Vision, requirements, and technology trend of 6G: How to tackle the challenges of system coverage, capacity, user data-rate and movement speed. IEEE Wireless Communications, 27(2), pp.218-228.

[11]. Zhang, P., Niu, K., Tian, H., Nie, G., Qin, X., QI, Q. and ZHANG, J., 2019. Technology prospect of 6G mobile communications. Journal on Communications, 40(1), pp.141-148.

[12]. Nayak, S. and Patgiri, R., 2021. 6G communication technology: A vision on intelligent healthcare. In Health informatics: A computational perspective in healthcare (pp. 1-18). Springer, Singapore.

[13]. Wang M, Zhu T, Zhang T, Zhang J, Yu S, Zhou W. Security and privacy in 6G networks: New areas and new challenges. Digital Communications and Networks. 2020 Aug 1;6(3):281-91.

[14]. Porambage P, Gür G, Osorio DP, Livanage M, Ylianttila M. 6G security challenges and potential solutions. In2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit) 2021 Jun 8 (pp. 622-627). IEEE.

[15]. Nguyen VL, Lin PC, Cheng BC, Hwang RH, Lin YD. Security and privacy for 6G: A survey on prospective technologies and challenges. IEEE Communications Surveys & Tutorials. 2021 Aug 30;23(4):2384-428.

[16]. Lu Y. Security in 6G: The prospects and the relevant technologies. Journal of Industrial Integration and Management. 2020 Sep 4;5(03):271-89.

[17]. Abdel Hakeem SA, Hussein HH, Kim H. Security Requirements and Challenges of 6G Technologies and Applications. Sensors. 2022 Mar 2;22(5):1969.

[18]. Hewa T, Gür G, Kalla A, Ylianttila M, Bracken A, Liyanage M. The role of blockchain in 6G: Challenges, opportunities and research directions. 2020 2nd 6G

Wireless Summit (6G SUMMIT). 2020 Mar 17:1-5.

[19]. Nguyen T, Tran N, Loven L, Partala J, Kechadi MT, Pirttikangas S. Privacy-aware blockchain innovation for 6G: Challenges and opportunities. 2020 2nd 6G Wireless Summit (6G SUMMIT). 2020 Mar 17:1-5.

[20]. Maksymyuk T, Gazda J, Volosin M, Bugar G, Horvath D, Klymash M, Dohler M. Blockchain-empowered framework for decentralized network management in 6G. IEEE Communications Magazine. 2020 Oct 6;58(9):86-92.

[21]. Elmeadawy S, Shubair RM. 6G wireless communications: future technologies and research challenges. In2019 international conference on electrical and computing technologies and applications (ICECTA) 2019 Nov 19 (pp. 1-5). IEEE.

[22]. Akyildiz IF, Kak A, Nie S. 6G and beyond: The future of wireless communications systems. IEEE access. 2020 Jul 21;8:133995-4030.

[23]. De Alwis C, Kalla A, Pham QV, Kumar P, Dev K, Hwang WJ, Liyanage M. Survey on 6G frontiers: Trends, applications, requirements, technologies and future research. IEEE Open Journal of the Communications Society. 2021 Apr 7;2:836-86.

[24]. Shahzadi S, Iqbal M, Chaudhry NR. 6g vision: Toward future collaborative cognitive communication (3c) systems. IEEE Communications Standards Magazine. 2021 Jun 25;5(2):60-7.

[25]. Latva-aho M, Leppänen K, Clazzer F, Munari A. Key drivers and research challenges for 6G ubiquitous wireless intelligence.

[26]. T. Arunkumar and L. Kalaiselvi, ―Latest Technology of Mobile Communication and Future Scope of 7.5 G‖, International Journal of Engineering & Technology Research, Volume 2, Issue 4, pp. 23-31, July 2014

[27]. Gawas, A. U. (2015). An overview on evolution of mobile wireless communication networks: 1G-6G. International Journal on Recent and Innovation Trends in Computing

and Communication, 3(5), 3130-3133.

[28]. Gill, J., & Singh, S. (2015). Future prospects of wireless generations in mobile communication. Asian J. Comp. Sci. Technol, 4(2), 18-22.

[29]. Zong, B., Fan, C., Wang, X., Duan, X., Wang, B., & Wang, J. (2019). 6G Technologies: Key Drivers, Core Requirements, System Architectures, and Enabling Technologies. IEEE Vehicular Technology Magazine, 14(3), 18-27.

[30]. Yang, P., Xiao, Y., Xiao, M., & Li, S. (2019). 6g wireless communications: Vision and potential techniques. IEEE Network, 33(4), 70-75.

[31]. Khutey, R., Rana, G., Dewangan, V., Tiwari, A., & Dewamngan, A. (2015). Future of wireless technology 6G & 7G. International Journal of Electrical and Electronics Research, 3(2), 583-585.

[32]. Kalbande, D., Haji, S., & Haji, R. (2019, June). 6G-Next Gen Mobile Wireless Communication Approach. In 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA) (pp. 1-6). IEEE.

[33]. M. M. Nair, A. K. Tyagi and N. Sreenath, "The Future with Industry 4.0 at the Core of Society 5.0: Open Issues, Future Opportunities and Challenges," 2021 International Conference on Computer Communication and Informatics (ICCCI), 2021, pp. 1-7, doi: 10.1109/ICCCI50826.2021.9402498.

[34]. Tyagi A.K., Fernandez T.F., Mishra S., Kumari S. (2021) Intelligent Automation Systems at the Core of Industry 4.0. In: Abraham A., Piuri V., Gandhi N., Siarry P., Kaklauskas A., Madureira A. (eds) Intelligent Systems Design and Applications. ISDA 2020. Advances in Intelligent Systems and Computing, vol 1351. Springer, Cham. https://doi.org/10.1007/978-3-030-71187-0_1

[35]. Goyal, Deepti & Tyagi, Amit. (2020). A Look at Top 35 Problems in the Computer Science Field for the Next Decade. 10.1201/9781003052098-40.

[36]. Tyagi, Amit Kumar; Nair, Meghna Manoj; Niladhuri, Sreenath; Abraham, Ajith, "Security, Privacy Research issues in Various Computing Platforms: A Survey and the Road Ahead", Journal of Information Assurance & Security . 2020, Vol. 15 Issue 1, p1-16. 16p.

[37]. Madhav A.V.S., Tyagi A.K. (2022) The World with Future Technologies (Post-COVID-19): Open Issues, Challenges, and the Road Ahead. In: Tyagi A.K., Abraham A., Kaklauskas A. (eds) Intelligent Interactive Multimedia Systems for e-Healthcare Applications. Springer, Singapore. https://doi.org/10.1007/978-981-16-6542-4_22

[38]. Mishra S., Tyagi A.K. (2022) The Role of Machine Learning Techniques in Internet of Things-Based Cloud Applications. In: Pal S., De D., Buyya R. (eds) Artificial Intelligence-based Internet of Things Systems. Internet of Things (Technology, Communications and Computing). Springer, Cham. https://doi.org/10.1007/978-3-030-87059-1_4