Türk Mühendislik Araştırma ve Eğitimi Dergisi
Turkish Journal of Engineering Research and Education

2(2), 104-112, (2023)

RESEARCH ARTICLE

Use of Artificial Intelligence in Next-Generation Wireless Network Infrastructures

Yeni Nesil Kablosuz Ağ Altyapılarında Yapay Zeka Kullanımı

Remzi Gürfidan [1*], Mevlüt Ersoy[2], Hilal Kartal[2]
[1] Isparta University of Applied Sciences, Yalvaç TBMYO, Computer Programming, Isparta, Türkiye.
[2] Süleyman Demirel University, Computer Engineering, Isparta, Türkiye.

Received / Geliş : 04.10.2023
Accepted / Kabul : 25.10.2023
***Sorumlu Yazar (Corresponding Author) Remzi Gürfidan** remzigurfidan@isparta.edu.tr

ABSTRACT: The diversity in service requirements, applications, devices, and networks that emerges with the development of technology transforms into complex systems in next-generation wireless networks. Wireless communication technologies and infrastructures, which play a critical role in communication and are becoming increasingly widespread, stand out as a highly favourable and productive area for research. In particular, the popularity of research areas such as artificial intelligence, cyber security, and signal intelligence, where wireless network technologies are specialized, is growing rapidly every day. Next-generation wireless networks are needed to meet and serve the requirements of the complex networks of the future. The systematic use of big data with next-generation wireless networks will be effective in making the system intelligent. The use of artificial intelligence with next generation wireless network infrastructures will make an effective contribution to artificial intelligence services. In this paper, the developments in wireless networks over the years are analysed in detail. The standards and limitations of wireless technologies are clearly compared. There are debates on how artificial intelligence, the technology of today and the future, will be used in next generation wireless network infrastructures. We hope that this paper will guide future researchers by providing a comprehensive review on the integration of wireless communication technologies and artificial intelligence. We also hope to inspire researchers by providing more information about the applications and limitations of wireless networks in different domains. We hope that this study will shed light on the gaps in the literature for future studies.

Keywords: Artificial intelligence, wireless networks, next-generation wireless networks, 6G wireless networks, network infrastructures.

ÖZ: Teknolojinin gelişmesiyle birlikte ortaya çıkan hizmet gereksinimleri, uygulamalar, cihazlar ve ağlardaki çeşitlilik, yeni nesil kablosuz ağlarda karmaşık sistemlere dönüşüyor. İletişimde kritik bir rol oynayan ve giderek yaygınlaşan kablosuz iletişim teknolojileri ve altyapıları, araştırmalar için oldukça elverişli ve verimli bir alan olarak öne çıkıyor. Özellikle kablosuz ağ teknolojilerinin uzmanlaştığı yapay zekâ, siber güvenlik ve sinyal zekâsı gibi araştırma alanlarının popüleritesi her geçen gün hızla artıyor. Geleceğin karmaşık ağlarının gereksinimlerini karşılamak ve bunlara hizmet etmek için yeni nesil kablosuz ağlara ihtiyaç duyulmaktadır. Yeni nesil kablosuz ağlar ile büyük verinin sistematik kullanımı, sistemin akıllı hale gelmesinde etkili olacaktır. Yapay zekanın yeni nesil kablosuz ağ altyapıları ile birlikte kullanılması yapay zeka hizmetlerine etkin bir katkı sağlayacaktır. Bu bildiride gerçekleştirilen çalışmada kablosuz ağlarda yıllar içinde yaşanan gelişmeler detaylı olarak analiz edilmiştir. Kablosuz teknolojilerin standartları ve sınırlılıkları açık bir şekilde karşılaştırılmıştır. Günümüzün ve geleceğin teknolojisi olan yapay zekânın yeni nesil kablosuz ağ altyapılarında nasıl kullanılacağı, yeri ve önemi üzerine tartışmalar yapılmaktadır. Bu bildirinin, kablosuz iletişim teknolojileri ve yapay zekanın entegrasyonu konusunda kapsamlı bir inceleme sunarak gelecekteki araştırmacılara yol göstereceğini umuyoruz. Ayrıca, kablosuz ağların farklı alanlardaki uygulamaları ve sınırlamaları hakkında daha fazla bilgi sağlayarak araştırmacılara ilham vermeyi umuyoruz. Bu çalışmanın gelecekte yapılacak çalışmalar için literatürdeki boşluklara ışık tutacağını umuyoruz.

Anahtar Kelimeler: Yapay zeka, kablosuz ağlar, yeni nesil kablosuz ağlar, 6G kablosuz ağlar, ağ altyapıları.

Remzi Gürfidan, Orcid: 0000-0002-4899-2219 / Mevlüt Ersoy Orcid: 0000-0003-2963-7729 / Hilal Kartal Orcid: 0000-0001-9161-8495

1. INTRODUCTION

In 1946, the world's first telephone call was made using a car radio telephone. Thus, the basic principles of the cellular network were first introduced in 1947. In 1959, a general wireless telephone service was introduced to customers in the United Kingdom and this service was controlled by two base stations. With the increase in users, these networks have had difficulty handling large search volumes. A portion of the radio spectrum frequency has been published to initiate a larger scale study. This allowed the development of AMPS (American Advanced Cell Phone System) in 1983. Thus, 824 – 849 MHz frequencies are used for transmission from mobile and 869 – 894 MHz frequencies for transmission from cell base station [1].

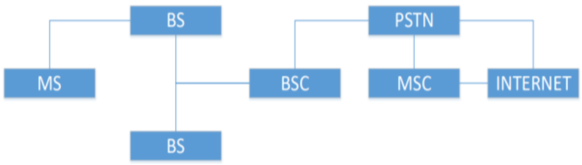

Figure 1: AMPS Architecture.

The 1G (First Generation) network model, which means first generation, was first introduced in 1980 as the first cellular network technology [2]. The 1G network model is also known as Enhanced Cell Phone Services (AMPS) [3]. Analog signal technology is used in the 1G network model. FDMA (Frequency Division Multiple Access) technique is used in the 1G network model. This technology is provided with radio antennas with a frequency of 150 Mhz for sound transmission. Because the FDMA technique has low capacity, it could not provide security in weak connections. At the same time, another limitation of this network is that it does not have a common standard [4]. In this model, it was not possible to service a device in motion. Voice call can be disabled when the user moves from one point to another base station.

Figure 2 shows the 1G cellular network design. Mobile Telephone Switching Office (MTSO) provides connectivity between Base Transceiver station (BTS) and design. MTSO provides connectivity between BTS and Public switched telephone network (PSTN). Manages circuit-switched (CS) networking relays, call forwarding, registration, and authentication [5]. The 1G network model has three cellular standards; AMPS, NMT and TACS. In 1990, the 2G network model was developed. With the 2G network model, the transmission rate has been increased from 150 MHz to 10Kbps (Kilobytes per second). The model, in which digital signal is used instead of analog signal, provides not only voice transmission but also data transmission. For audio transmission, unlike 1G, digital signals are used instead of analog signals [6]. In this network model, GSM (Global Systems for Mobile Communications) standard, SMS (Short Message Service) and e-mail services were used for the first time.

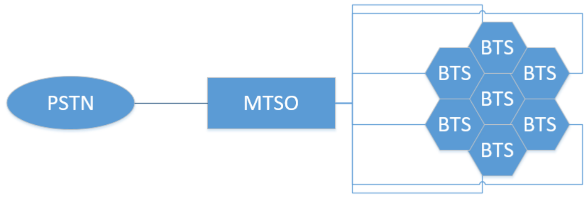

Figure 2: Network Architecture of 1G Technology.

With the 2G network model, data transmission also enabled short message and multimedia message (MMS) transmission. CDMA and TDMA are used as multiplexing technology in the 2G network model (Table 2) [7]. Another reason why 2G is more efficient compared to the 1G network model is that it provides two-pronged security for users. In this model, security is provided by both the sender and the receiver. Lack of video sharing facility and weakening of digital signals in case of network coverage loss are the shortcomings of this model [8]. At the beginning of the 2000s, 2.5G and 2.75G network models were put into use. With the use of GPRS (General Packet Radio Services) in the 2.5G network model, the transmission rate has been increased to 50 Kbps. It has different uses such as Wireless Application Protocol (WAP), Access Multimedia Messaging Services (AMMS), Email and World Wide Web Access services [9]. The increase in consumption of data services paved the way for the development of 2.75G and. The data transmission rate has been increased with Enhanced Data rates (EDGE) for GSM Evolution [10]. 3G technology was introduced as needs such as faster internet access came to the fore. With 3G technology, mobile devices have become able to accommodate the features of many devices. Services that can be provided from different devices such as cameras, computers, MP3 players, radios have become available on a single device [11]. 3G network technology consists of a radio core network and a radio access network. On the basis of 3G network technology, GSM (Global System for Mobile) is used to provide mobile communication. It also combines TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access) wireless principles in 3G network technology with GSM.

3G supported real-time application services to smartphone users with high-speed access. These applications include Video on Demand (VOD), Global Positioning System (GPS), Location-Based Services (LBS), Mobile TV (MTV) and Video Conferencing (VC) [12]. 4G (4th Generation) has developed after 2G and 3G. The 4G network model supports browsing and data transfer at much higher data rates compared to previous models and a supported transmission rate of up to 100 Mbps [7]. 4G networks are an IP-based heterogeneous network model that can be used regardless of the user's location, time and system. It has important features such as high availability (anytime, anywhere and with any technology), low transmission cost, multimedia support, personalization and integrated service. It also provides convenience for 4G integrated services. It allows users to use more than one service. Examples of these services are wireless services, GPS, CDMA. With 4G, such highly integrated services became possible in applications [13].

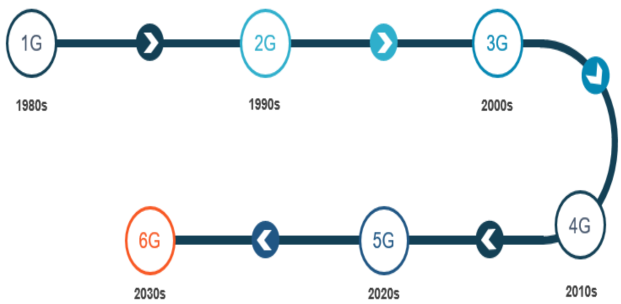

Figure 3: Mobile communication system evolution process.

2. 5G TECHNOLOGY

Technologies up to 5G had major shortcomings. Although each new network model tries to eliminate the deficiencies of the previous one, there are still deficiencies in 4G. The shortcomings of 1G; limited capacity, poor battery life, large phone size and poor sound quality. To address these, 2G was introduced, but when the network coverage weakened in 2G, digital signals were lost and data such as video was not processed. In 3G technology, although the deficiencies of the previous generations were eliminated, there was a lack of high bandwidth requirement with the developing technology, and the cost increased considerably as the phones supporting 3G supported wireless technology. Although 4G technology provided basic services such as MMS, wireless broadband access, HDTV content, voice and data, the 4G system required complex hardware and was difficult to implement. However, the battery usage was also high. To overcome these shortcomings, a new concept, 5G, was introduced [14]. 5G networks, which came to the fore at the beginning of 2015, have started to be used in some countries as of 2020, although they do not reach every part of the world. The 5G network model has been officially named International Mobile Telecommunications (IMT) - 2020 by ITU (International Telecommunication Union). At the same time, ITU has defined three application scenarios for the 5G network model [15]. These three broad categories are envisioned to support a wide variety of use cases/use cases: eMBB (Enhanced mobile broadband): In this usage scenario, large area, less coverage and high mobility are targeted. The need for high mobility is only required at pedestrian speeds. eMBB can also meet user requirements such as high-definition video broadcasting and artificial reality. URLLC (Ultra-reliable and low-latency communication): In this use case, the requirements are to ensure reliability, achieve low latency, and increase availability. Intelligent transportation systems, transportation security, smart networks, providing wireless control in industrial production, wireless and fast communication in the use of artificial intelligence are examples of the usage areas of these requirements [16]. mMTC (Large machine type communication): In cases where there is heavy data traffic, it is expected that the requirements will be met with mMTC. mMTC deployment may consist of many devices that are not latency sensitive. The cost of these devices should be low and the battery life should be long [17].

Compared to 4G, the 5G network model aims to keep the latency and battery consumption at a lower level and to implement the internet of things (IoT) better. 5G provides users with higher capacity, higher mobile broadband user density and reliable machine communication [18]. The 5G network model is a model designed for www. Cellular networks such as 4G and 5G use IPv6 as an internet protocol [19]. Table 1 shows the characteristics of cell communication in different generations.

Table 1: Characteristics of cell communication in different generations.

Generations	Audio	Data	SMS	E Mail	MMS	Video Call	Online Game	High-Definition TV	High-Definition Video	Virtual Reality App.
1G	+	-	-	-	-	-	-	-	-	-
2G	+	+	+	+	-	-	-	-	-	-
2.5G	+	+	+	+	+	-	-	-	-	-
2.75G	+	+	+	+	+	-	-	-	-	-
3G	+	+	+	+	+	+	-	-	-	-
3.5G	+	+	+	+	+	+	-	-	-	-
4G	+	+	+	+	+	+	+	+	-	-
4.5G	+	+	+	+	+	+	+	+	+	-
5G	+	+	+	+	+	+	+	+	+	+

Table 2: Different generations of cell communication.

Generations	Release Year	Standards	Multiplexing Technologies	Switching	Transmission Speed
1G	1980	AMPS	FDMA	CS	2.4Kbps
2G	1990	GSM	CDMA/TDMA	CS	10Kbps
2.5G	2000	GPRS	CDMA/TDMA	CS and PS	50Kbps
2.75G	2003	EDGE	CDMA/TDMA	CS and PS	144Kbps
3G	2001	UMTS	CDMA-2000 WCDMA	CS and PS	384Kbps
3.5G	2003	HSDPA	CDMA-2000 WCDMA	CS and PS	2Mbps
3.75G	2003	HSUPA	CDMA-2000 WCDMA	CS and PS	30Mbps
4G	2010	LTE M-WIWAX	OFDM SC-OFDM	CS ve PS	100Mbps
4.5G	2014	LTE-PRO	OFDM SC-OFDM	CS and PS	300Mbps
5G	2015	WWWW	BDMA	CS and PS	1Gbps+

3. PROSPECTS FOR 6G AND ITS FUTURE USES

The application of wireless communication has become an expanding technology from connecting people to connecting objects. With 6G technology, it is expected to meet the requirements that 5G cannot meet to a large extent [19]. The 5G cellular network model can provide reliable and low-latency (URLLC) communication.

However, the short packet limiting this situation causes the disadvantage of URLLC functions, making it a disadvantage in the 5G cellular network model. IoT (Internet of Things) applications have developed rapidly since the day they were defined and continue to develop. 5G network model is not enough to meet the communication, sensing, control and computing requirements in IoT applications.

This situation shows the lack of 5G in some issues and reveals the necessity of 6G technology for the developing technology. The need for 6G is not only due to the challenges and performance limits presented by 5G, but also to the continuous evolution of wireless networks. With the new generation wireless networks, the efficiency that can be obtained is maximized.

The evolution of artificial intelligence, intelligent driving, and industrial revolutions are creating key requirements for 6G that will lead to ubiquitous mobile ultra-broadband (uMUB), ultra-high-speed and low-latency communications (uHSLLC), and ultra-high data density (uHDD) service classes.

With the developments in artificial intelligence and industry, the need for new requirements in the 6G wireless network model has stopped. To meet these requirements, uMUB (mobile ultra-wideband), uHDD (ultra high data density) and uHSLLC (ultra high speed and low latency communication) services are needed. These services expose photonic-based cognitive radio technology and computational holographic painting technology for the 6G network model.

Technology-driven paradigm shift and network evolution provide clues about the design of 6G networks. As in Figure 4, 6G has three basic technologies; It demonstrates the logical beginning of 6G, which can generate several key technical requirements such as AI, photonic technology and RF holography [20].

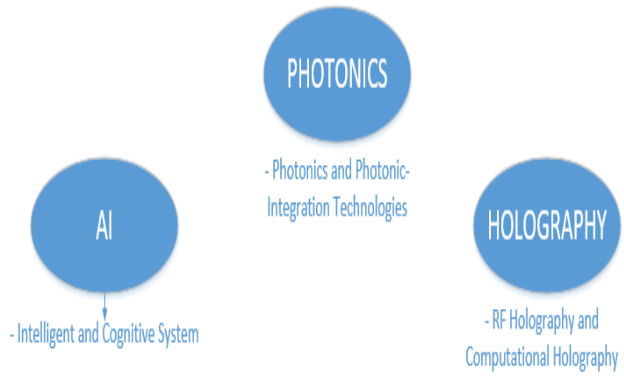

Figure 4: Three key technologies of 6G.

3.1 Performance Expectations for 6G

Unlike the 5G network model, the 6G network model is expected to have major performance improvement goals. Different use cases for 6G require the use of different KPI sets.

The 6G network model is expected to support smart networks, IoT applications, artificial intelligence-based decisions, along with developing applications such as distance education and smart tools [21].

Table 3: Comparison of 5G and 6G network model in terms of KPIs.

KPI'S	5G	6G
Peak Data Rate	20 Gb/s	1 Tb/s
User-experienced Data Rate	0.1 Gb/s	1 Gb/s
Peak Spectral Efficiency	30 b/s/Hz	60 b/s/Hz
User-experienced Spectral Efficiency	0.3 b/s/Hz	3 b/s/Hz
Maximum Bandwidth	1 GHz	100 GHz
Connection Density	106 devices/km^2	107 devices/km^2
Latent Period	1 ms	0.1 ms
Jitter	not specified	1 μs
Mobility	500 km/h	1000 km/h

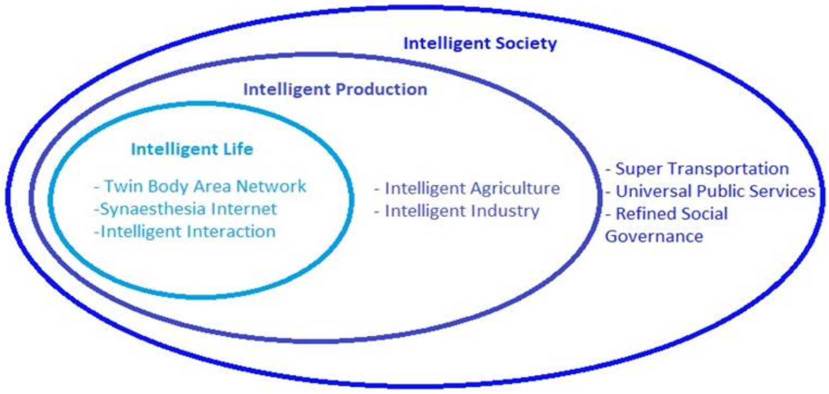

Figure 5: Scenario categories of 6G applications in 2030.

3.2 Security Protocols of 6G

Complex security infrastructures are required to meet the needs of the 6G network model. Security models designed for the 5G network model need to be developed separately for 6G. This security should be brought to the top by developing Software Defined Network (SDN) and Network Function Virtualization (NFV) [22].

3.3 6G Usage Areas

Although there are many application scenarios for 6G in 2030 and beyond, it is possible to examine all these in three main categories: smart life, smart production and smart society.

The twin body area network, synesthesia internet and smart interaction in the intelligent life category are expected to develop in areas such as learning, shopping, working and health. The concept of twin body area network refers to the digitization of the body and the smartening of treatments in the field of health, together with molecular communication. In this way, targeted therapy, pathological research and prevention of critical illness risks will be possible. With synesthesia, it is possible to have non-physical experiences of playing music and art with the internet. With the development of technology used in agriculture and industry, the development of the digital economy will accelerate. While the use of technology such as drones, VR and robots will increase efficiency with 5G, there will be better smart production with 6G. Technologies such as big data, IoT and cloud computing will play an important role in sectors such as agriculture, forestry and animal husbandry, and will provide a great efficiency for smart agriculture. It is expected that the transportation network consisting of land, sea, air and space vehicles will become multidimensional and fully autonomous driving will be in question. With the regular operation of multi-dimensional traffic vehicles, customized and safe transportation services will be provided and there will be an increase in initiatives for a smart society [1].

3.4 6G and Artificial Intelligence (AI)

With the 5G network model, NWDAF (Network Data Analytics Function) [23] has provided a network design convenient for artificial intelligence services. NWDAF is used to implement artificial intelligence-based network automation and optimize relevant network functions. Studies on the use of artificial intelligence and integrating mobile technologies are carried out by ITU (International Telecommunication Union). Technical features in areas such as the use of artificial intelligence and machine learning are also prepared for next-generation networks. These specifications include network architectures, protocols, algorithms and data formats [24].

In the new generation wireless networks, an alternative to many communication problems is offered by using artificial intelligence. Studies have been carried out to enable various applications with the use of artificial intelligence in new generation wireless networks [25]. There is a high level of interaction between mobile communication technology and artificial intelligence. By using AI technology, it is possible to optimize network resource usage and achieve better performance. At the radio link layer, radio resource scheduling or link customization can be better implemented via radio channel estimation. Or at the network layer, artificial intelligence can be used to solve the problem of self-driving network operation and management or mapping future networks [26][27]. There are also some challenges for AI-connected wireless networks. Depending on innovations such as artificial intelligence and machine learning, it is necessary to use big data analytics in wireless networks. Big data used for the control and optimization of new generation wireless networks is expected to cause some difficulties. Another challenge will be network operators losing direct control over the network. This situation can be caused by real-time operations and automations.

4. DISCUSSION AND CONCLUSION

In this section, a comparative discussion of 4G, 5G and 6G technologies in terms of pros and cons will be carried out. Afterwards, the results obtained from the discussion will be reported.

4G technology is a significant advancement that allows for high-speed data transfers and improves connection quality. More bandwidth, lower latency, better capacity, and higher energy efficiency are anticipated for 4G networks in the future. To meet these aspirations for faster and more dependable mobile internet access, 4G infrastructure must be continuously improved. 5G technology, which provides even faster speeds, lower latency, and more capacity, is acknowledged as a revolutionary stride forward in communications. Even more bandwidth, the capacity to link billions of devices simultaneously, ultra-low latency, enhanced security, and increased energy efficiency are some of 5G's potential future benefits. To meet these aspirations, 5G networks must continue to grow in order to support the creation of next-generation services and applications. 6G is still a developing technology with questionable future prospects. However, the following are some expectations and potential solutions:

- **Data transmission rates that are extremely fast**: 6G is anticipated to offer even faster data transfer rates. This will allow for the faster transmission of far greater data quantities and the creation of more sophisticated applications.

- **Lower latency:** The 6G network seeks to further lower latency. Real-time applications (like virtual reality and augmented reality) will function more effectively as a result.

- **Greater connection density:** 6G is anticipated to offer a greater connection density, enabling the simultaneous connectivity of billions of devices. This will improve the integration and communication of Internet of Things (IoT) devices.

- **Better energy efficiency:** 6G aims to use energy more efficiently. This will result in electronics with longer battery lives and a more environmentally friendly communications network.

- **Uses of the next generation:** As 6G technology develops, even more cutting-edge uses are anticipated. These might incorporate remote medical care, driverless cars, augmented reality, virtual reality, artificial intelligence, and other things. However, as 6G is still in the research and development stage, it is still uncertain exactly what kind of technology it will be and what it will deliver. With the advancement of technology, more details regarding potential outcomes and remedies will become more apparent in the years to come. As shown in Table 3, 4G speeds up to 300Mb can be accessed, while 6G data speeds are expected to reach 11 GB. This will eliminate the problem of data speed, which is one of the biggest requirements in developing technology.

Author Contributions: The current state of the art and research on security and artificial intelligence in the literature in this study was carried out by author Remzi Gürfidan. Future work and discussion sections were carried out by the author Mevlüt Ersoy. Comparison and benchmarking studies were carried out by the author Hilal Kartal.

Conflicts of Interest: As the authors of this study, I confirm that there is no conflict of interest with any institution/organization or person.

5. REFERENCES

[1] N. Linge and A. Sutton, "The road to 4G", J. Inst. Telecommun. Prof, vol. 8, no. 1, pp. 9-16. Jan. 2014.

[2] A.F.M.S. Shah, "A Survey From 1G to 5G Including the Advent of 6G: Architectures,

Multiple Access Techniques, and Emerging Technologies" IEEE 12th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, 2022, pp. 1117-1123.

[3] T.H. Kim, H. Adeli, “Advances in Computer Science and Information Technology AST/UCMA/ISA/ACN 2010 Miyazaki – Japan Conferences, vol. 6059, Berlin, Germany: Springer.

[4] V. Abramov, S. Li, M. Wang, E.W Wong and M. Zukerman, “Computation of blocking probability for large circuit switched networks”, IEEE Commun. Lett., vol.16, no. 11, pp. 1892-1895, Nov. 2012.

[5] R. Akkurt, “Wireless Mobile Communication Technologies from Past to Present”, Eur. J. Sci and Tech, vol. 28, pp 115-119, Nov. 2021.

[6] A.U. Gawas, “An overview on evolution of mobile wireless communication networks: 1G-6G”, Int. J. Recent Innov. Trends Comput. Commun., vol. 3, no. 5, pp. 3130-3133, May 2015.

[7] A. Chaturvedi, A.V. Dhuman, “A Future of 5G Wireless System”, J. Sci. Technol., vol. 6, special issue 01, pp. 47-52, Aug. 2021.

[8] R. Yadav, “Challenges and evolution of next generations wireless communication”, International Multi Conference of Engineers and Computer Scientists, (IMECS 2017), Hong Kong, 2017, pp. 1-5.

[9] A. Sutton and N. Linge, “Mobile network evolution within the UK”, J. Inst. Telecommun. Prof., vol. 9, no. 2, pp. 10-16, Jul. 2016.

[10] M. Karabulut, “Improvement of Internet/Network Based Applications”, M.Sc. Thesis, Institue of Science, Kahramanmaraş Sütçü İmam University, Kahramanmaraş, 2007.

[11] F.M. Asmare, F.M. Geremew and L. Getnet Ayalew, “A survey on 3G mobile network traffic performance and analysis in Ethiopia”, Cogent Eng., vol. 9, no. 1, pp. 1-12, Dec. 2021.

[12] M. Lin, H. Choi, T. Dawson and T. La Porta, “Network integration in 3G and 4G wireless networks”, 19th International Conference on Computer Communications and Networks, Zurich, Switzerland, Aug. 2010, pp. 1-8.

[13] S.Y. Hui and K.H. Yeung, “Challenges in the migration to 4G mobile systems”, IEEE Commun. Mag., vol. 41, no. 12, pp. 54-59, Dec. 2003.

[14] R. Khutey, G. Rana, V. Dewangan, A. Tiwari, A. Dewamngan, “Future of wireless technology 6G & 7G”, Int. J. Electr. Electron. Res., vol. 3, no. 2, pp. 583-585, April 2015.

[15] L. Dong, et al., “Introduction on IMT-2020 5G trials in China”, IEEE J. Sel. Areas Commun., vol. 35, no. 8, pp. 1849-1866, Aug. 2017.

[16] M. Simsek, A. Aijaz, M. Dohler, J. Sachs and G. Fettweis, "5G-Enabled Tactile Internet", IEEE J. Sel. Areas Commun., vol. 34, no. 3, pp. 460 – 473, March 2016.

[17] M. Shafi et al., "5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice", IEEE J. Sel. Areas Commun., vol. 35, no. 6, pp. 1201-1221, June 2017.

[18] Turkey Information and Communication Technologies Authority, “5G and Beyond, White Book”, (2021) [Online]. Available: https://btk.gov.tr/uploads/announcements/5g-ve-otesi-beyaz-kitap/5g-ve-otesi-beyaz-kitap.pdf

[19] Y. Zhao, G. Yu, H. Xu, “6G Mobile Communication Network: Vision, Challenges and Key Technologies”, Chinese Science: Information Science, Scientia Sinica Information, vol. 49, no. 8, pp. 963-987, May 2019.

[20] B. Zong, C. Fan, X. Wang, X. Duan, B. Wang and J. Wang, "6G Technologies: Key Drivers, Core Requirements, System Architectures, and Enabling Technologies”, IEEE Veh. Technol. Mag., vol. 14, no. 3, pp. 18-27, Sept. 2019.

[21] S. Kumar, “6G Mobile Communication Networks: Key Services and Enabling Technologies”, J. ICT Stand., vol. 10, no. 1, pp. 1-10, Feb. 2022.

[22] M. Ylianttila et al., “6g white paper: Research challenges for trust, security and privacy” arXiv preprint arXiv:2004.11665. 2020.

[23] G. Liu et al., "Vision, requirements and network architecture of 6G mobile network beyond 2030” China Commun., vol. 17, no. 9, pp. 92-104, Sept. 2020.

[24] FG-ML5G, I. Focus Group on Machine Learning for Future Networks Including 5G” (2019) [Online]. Available: https://www.itu.int/en/ITU-T/focusgroups/ml5g/Pages/default. aspx.

[25] M. Chen, U. Challita, W. Saad, C. Yin and M. Debbah, "Artificial Neural Networks-Based Machine Learning for Wireless Networks: A

Tutorial", IEEE Commun. Surv. Tutor., vol. 21, no. 4, pp. 3039-3071, July 2019.

[26] R. Li et al., "Intelligent 5G: When Cellular Networks Meet Artificial Intelligence", IEEE Wirel. Commun. vol. 24, no. 5, pp. 175-183, Oct. 2017.

[27] D. Bega, M. Gramaglia, R. Perez, M. Fiore, A. Banchs and X. Costa-Pérez, "AI-Based Autonomous Control, Management, and Orchestration in 5G: From Standards to Algorithms", IEEE Netw., vol. 34, no. 6, pp. 14-20, Nov. 2020.