Journal of Theoretical and Applied Information Technology
15th June 2023. Vol.101. No 11

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A FULL-SCALE ANALYSIS ON CHALLENGES AND ISSUES OF NEXT GENERATION (5G) COMMUNICATION IN HETEROGENEOUS WIRELESS NETWORK BASED ENTERPRISE APPLICATIONS

SUBHRA PROSUN PAUL[1], D. VETRITHANGAM[2]

[1]Research Scholar, Chandigarh University, Department of CSE, Mohali, Punjab, India

[2]Associate Professor, Chandigarh University, Department of CSE, Mohali, Punjab, India

E-mail: [1]subhra.phd.cu2021@gmail.com, [2]vetrigold@gmail.com

ABSTRACT

In today's globalized world, there is a continuously growing interest in next-generation (5G) communication of versatile wireless network services for its popularity. A great technological transformation has been made in next-generation (5G) communication in cellular phone services in terms of screen size, data processing capacity, resolution density, and cost. To develop network coverage area, proper energy and bandwidth utilization, and faster communication with a cheap rate, next- generation (5G) communication has been introduced at several interconnected communication levels. No doubt, we still have to handle some remarkable challenges like the cell internal interference problem of a heterogeneous network, appropriate implementation of software-defined network concept at network architecture stage, network storage, resource management, and security in this 5G communication area. Additionally, upgraded signal processing, perfect channel estimation, network optimization, and successful mobility management are the important challenges to be faced in this field. Our main aim is to identify the key challenges and issues that area related to 5G communications and to discuss how these issues and challenges can be handled effectively in various commercial applications. In our research paper, we will attempt to emphasize some particular challenges and issues of next-generation (5G) communication as well as introduce a specific strategy to manage those challenges in this field. Moreover, a comparative analysis will be presented which will evidently make a distinction between the existing research work and our research in next-generation (5G) communication in a wireless network application.

Keywords: *Challenges, Issues, Wireless Network, Next Generation (5G), Commercial Application.*

1. INTRODUCTION

5G is referred to as the fifth generation cellular telephonic network, which is the latest international wireless communication standard. This 5G technology provides a modern type of network which is developed to communicate with any person, anything, and anywhere virtually [1]. As compared to the traditional communication techniques, this next generation (5G) communication technology afford speeds up to 20000 Mbps (equivalent to 20Gbps), which is capable of transmitting various data like text, images, audio, and video simultaneously using optical fiber cable [2][3]. It is observed that fifth-generation technology remarkably develops the modern world's speeds of user-level experience. Additionally, recent research in this field indicates

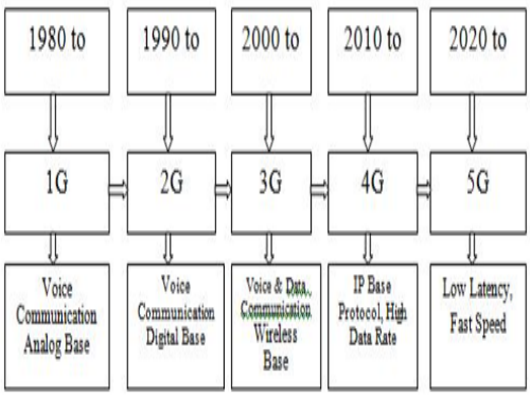

Figure 1: Evolution of Next Generation Communication (1G to 5G)

that 5G affords quicker download speeds in comparison to wifi [4][5].

Cellular telephonic wireless communication technology has passed through a number of evolution steps in the last thirty years after the first generation (1G) cellular network system was introduced in 1980 [6][7]. Due to the increasing popularity of cellular telephonic communication, its technological evolution is growing quickly to provide more connections to more users through next-generation communication (1G to 5G) [8][9].

The ultra-fast cellular internet system, lower latency network, IoT-based apps, security and monitoring system, HD multimedia data support, and versatile commercial application compatible system are the important features of today's next generation (5G) communication system [10][41]. It is a packet-based network that is used to provide a quality of service-oriented telecommunication related data transmission systems [11][12].

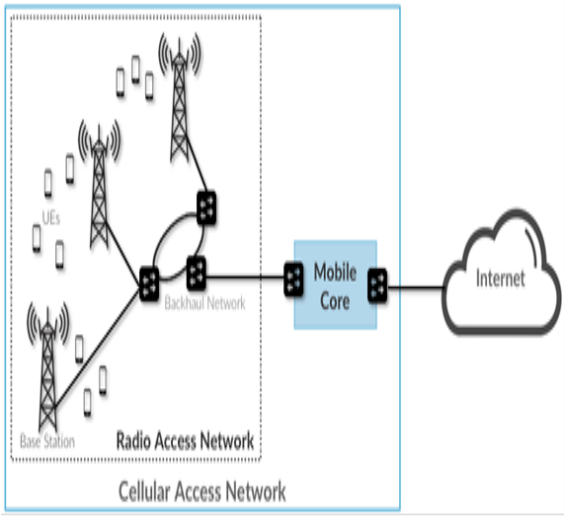

Figure 2: Next Generation (5G) Network Architecture

The We have observed that in recent years' next-generation (5G) communication has become a standard wireless communication technology, which brings a great revolution in data connectivity, speed, and compatibility of versatile inter-network communication [13]. High-level system capacity, maximum throughput, energy utilization, and cost-effectiveness features of 5G communication will have a positive impact on the telecommunication sector [14]. Not only in cellular telephonic communication but also in retail, entertainment, shipping, manufacturing, medical, agriculture, and infrastructure areas, next-generation (5G) communication is widely being implemented nowadays [15]. Apart from these remarkable advantageous features, 5G wireless communications still face some important challenges like insufficient accessibility, the latest hardware requirements, and maximum transmission antenna quantity [16].

We believe that this research work will be beneficial for efficient and effective enterprise application based wireless network fields. Specially, mobile ad hoc network where 5G can be implemented will be helpful. Various commercial fields like medical, agriculture, road transport sector can be developed successfully by considering major challenges and issues which are analyzed in this research work. Moreover, our research will open further research development of this field.

Although there are tremendous scopes of developing in this area of research, still some major challenges are there like security and connectivity to be handled very carefully. Resource availability and appropriate resource applicability in the proper field are still key issues in this area. Though there are some major commercial fields available to handle the challenges and issues of wireless network, but due to some technical and economic constraint, all major issues and challenges cannot be handled effectively in most commercial area.

2. BACKGROUNG STUDY

The essential elements of the next-generation (5G) communication system are high-level bandwidth spectrum, intricate modulation method, and advanced hardware unit [17]. With the help of the full duplex mode data transmission technique, cellular network Wi-Fi and Bluetooth with augmented reality (AR) and virtual reality (VR,) applications are implemented in next generation (5G) communication systems [18]. Low-band 5G, mid-band 5G, and high-band 5G are the three basic categories of 5G communication systems. In order to set up an efficient 5G communication system, high-level radio frequency, parallel connection to a number of access points, active radio topology, and malleable configuration of network function are required [19][20].

It is observed that the challenges of the next-generation (5G) communication systems are classified into two categories: technical challenges and common challenges [21]. Technical challenges include network traffic coordination, internal cell interference, and effective media access control, whereas common challenges include diversified networking service, infrastructure, communication, navigation, security, and protocol [22]. Additionally, we can mention that network

architecture, the data transfer processes of the faster channels, mobility maintenance and supervision are some of the significant challenges of next generation (5G) communication in various application areas [23].

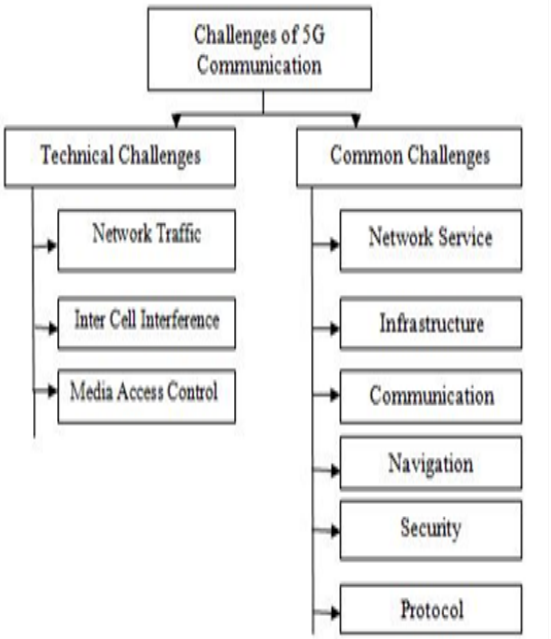

Figure 3: Taxonomy of Challenges of Next Generation (5G) Communication

3. OUTCOME OF THE LITERATURE GENESIS OVERVIEW

To identify different challenges of the 5G communication system properly, the multiple parameters and scenarios are taken into consideration and analyzed from different perspectives in versatile latest commercial applications like agricultural systems, medical sector, road transportation and traffic management, entertainment, industrial automation, and IoT based applications [24][25]. The fundamental goal of this next-generation (5G) network technology is not only to provide a faster inter-network wireless communication using lower latency in a cost-effective manner but also to develop existing network techniques and vertical solutions with the help of a modified service layers in various applications [26][27].

We have observed that elevated mobility organization is a prerequisite for user level satisfaction in next-generation (5G) communication services [28]. But in this case, still there are some challenges to be faced, like channel inference and pre-coding, mobility-based network expansion, signal quality, traffic load, disseminated antenna structure, and best deployment of the mobile relay [29].

Research shows that some promising techniques like multiple inputs multiple outputs (MIMO), software-defined networks, and heterogeneous networks have brought a revolutionary change and definition of the next-generation (5G) communication in the cellular networks through facing different challenges [30]. It is observed that millimeter wave (mm Wave) communication is a technology that can handle multiple challenges simultaneously, like maximum propagation thrashing, directivity, and obstacle sensitivity [31]. Research also shows that access point switching is a technique to obtain the highest level of data rate in the continuously increasing traffic jams during data transmission of the next-generation (5G) communication systems [32][33]. Additionally, network slicing in 5G communication is a reliable technique to handle mobility management challenges for comfortable customer service in the cellular telephone networks [34].

4. COMPARATIVE ANALYSIS

The noteworthy divergence between the on-hand research paper and our research paper on this next generation (5G) communication field is represented in the comparative analysis part, which is our main focus. To accomplish this work effectively and efficiently, over the last twenty years (2001-2021), research papers have been considered on this 5G communication field in different applications. For example, a thorough review on prospective elevated mobility-based wireless communication technology for 5G networks with its fundamental challenges is represented in one paper, whereas our paper tries to underline the generally facing challenges of 5G communication systems in various wireless network applications [35][36][40].

We can reflect on the following table where several existing original research articles on next generation (5G) communication systems are considered. We try to illustrate a comprehensible comparative analysis in this table by which our precise contributions to this area will be clear.

Table 1: Comparative Study between Our Research Contribution and Existing Research Work.

Serial No.	Year	Authors	Their Work	Strength of their work	Weakness of their work	Our Work
1.	2016	Stefano Buzzi and et al.	A survey on energy efficiency based wireless 5G communication as well as its related research challenges are discussed in this paper.	Strong and reliable data oriented survey.	Lack of network resources utilization	Our research article is a complete review based paper on challenges of next generation (5G) wireless communication.
2	2017	Haijun Zhang and et al.	Authors have explained network slicing technique based logical framework and mobility management scheme of 5G communication system in this paper.	Cluster network facility, energy usage.	Security issue, timing of resource availability.	We have tried to emphasize the regularly faced challenges in next generation (5G) wireless communication in our paper.
3.	2018	Haijian Sun and et al.	In this paper an edge communication framework of 5G network is proposed and some important challenges of wearable communication device of our daily life using 5G system.	Quality of service, network connectivity.	Complexity of routing algorithm	In our paper, some guidelines are introduced to manage the regular challenges on this area.
4.	2019	Hongji Huang and et al.	Authors have analyzed the improvement of deep learning based solution of 5G communication problem and have proposed a proficient deep learning based 5G communication scheme.	Bandwidth utilization, balanced load, and energy distribution	Security and resource management.	We have tried to represent a apparent study on all common challenges of next generation (5G) wireless communication in a variety of applications.
5.	2020	Cheng-Xiang Wang and et al.	Authors have illustrated how artificial intelligence and machine learning technique can be influenced in 5G communication in this paper.	Channel calculation, modeling, and network organization.	Addressing scheme of local data, large radio interface.	Our contribution reflects how dissimilar challenges are connected to versatile implementation field of this 5G communication.

From table 1, it is observed that there is a notable divergence between our research article and the related existing research work on next generation (5G) wireless communication in terms of a range of important challenges in versatile commercial applications in cellular networks.

Table 2: Comparative Analysis of Commonly Faced Challenges in Various Applications of 5G Wireless Communications.

Sr. No.	Field → Challenges ↓	Medical	Agriculture	Traffic / Road Transport	Entertainment	Iot Apps	Industrial Automation
1	Security	Yes	Yes	Yes	No	Yes	Yes
2	Energy	Yes	Yes	Yes	Yes	Yes	Yes
3	Latency	Yes	Yes	Yes	Yes	Yes	No
4	Bandwidth	Yes	No	Yes	No	No	No
5	Speed	No	Yes	Yes	No	No	Yes
6	Connectivity	Yes	Yes	No	Yes	No	Yes
7	Quality of Service	Yes	No	No	Yes	No	No
8	Protocol	No	No	Yes	No	No	Yes

From table 2, we have observed undoubtedly that even now there are many challenges to handle in next generation (5G) communication, but security, energy, latency, and connectivity are the key challenges to be faced regularly in various corporate sectors like medical, agriculture, traffic and road transport, industrial automation, entertainment, and IoT-based applications. Additionally, bandwidth, speed, quality of service, and protocol are also significant challenges in this field. In order to perform this task, the last twenty years of research papers on this field have been considered with the help of the Google scholar database.

Figure 4 is the pictographic demonstration of table 2 where in the X axis, various commonly faced challenges of next generation (5G) wireless communication are shown and in the Y axis, the number of application areas is shown.

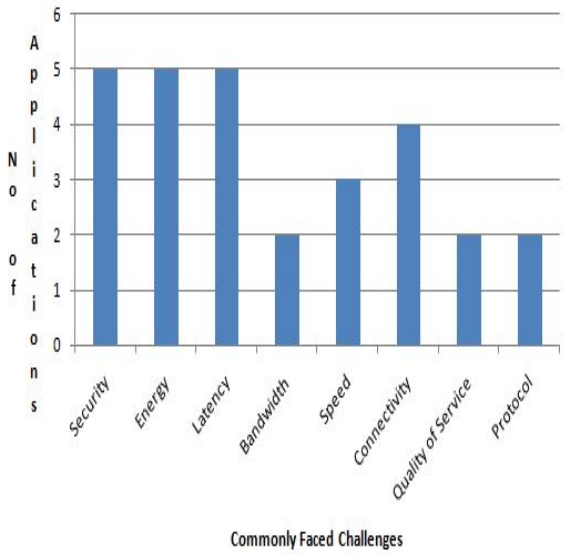

Figure 4: Common Challenges vs. No. of Application Areas in 5G Communication.

From the above figure, it is also noticed that latency, energy, and security are being faced in the highest number (04) of the application fields in the 5G wireless communication technology.

Table 3: Comparative Analysis of Commonly Issues in Versatile Application Fields of 5G.

Sr. No	Field → Challenges ↓	Medical	Agriculture	Traffic/ Road Transport	Entertainment	Iot Apps	Industrial Automation
1	Reliability	Yes	Yes	Yes	No	No	No
2	Scalability	Yes	No	No	No	Yes	No
3	Availability	No	Yes	Yes	No	Yes	No
4	Applicability	Yes	No	No	No	Yes	No
5	Flexibility	Yes	No	Yes	No	No	No
6	Productivity	No	Yes	No	No	No	No
7	Program Ability	No	No	Yes	No	No	No

It is clearly observed from the above table 3 that scalability and availability are two significant issues that are commonly managed in medical, agriculture, traffic/road transport, and IoT based applications in 5G wireless communication systems. Apart from this, reliability, applicability, and flexibility are also important issues to be faced in various application areas in 5G network. Programmability and productivity are two issues that are rarely faced in some specific application areas of 5G communication systems like agriculture

and road traffic & transportation systems. It is very interesting that there are no major issues to be handled in entertainment and industrial automation fields of the next-generation (5G) wireless communication system.

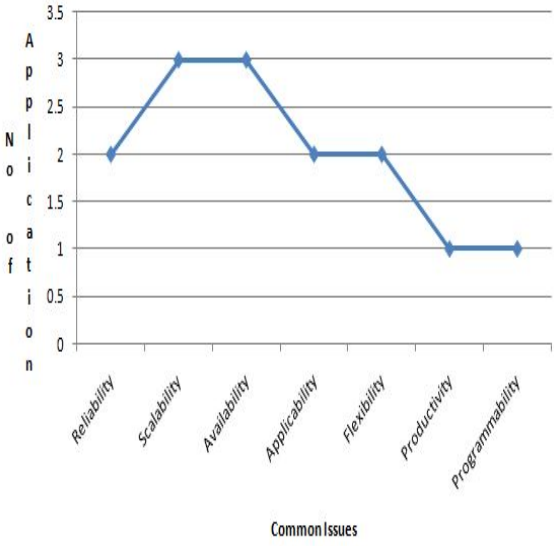

Figure 5: Various Common Issues Vs. No. of Application Fields of 5G Wireless Communication.

From figure 5 we have observed that different frequently faced issues in the 5G wireless communication networks are shown on the X axis, whereas the number of application fields is represented on the Y axis. We have also seen that scalability and availability are the most common issues that are regularly handled in the versatile commercial application field of 5G communication technology.

5. EMPIRICAL ANALYSIS

In this empirical analysis segment, some recently published research articles in the 5G wireless communication field of different applications are considered. We have tried to simplify the elementary concepts that are explained in these research articles by using a range of parameters and tools in the next generation (5G) wireless communication area like latency, security, bandwidth, energy, speed, connectivity, protocol, quality of service, etc. in versatile commercial applications at present. We have considered the following table 4, which evidently represents the proposed work and parameters/tools to implement the concept of a quantity of standard research paper. The research progress of the last twenty years in next-generation (5G) wireless communication systems in different application areas is also indicated in the following table 4.

Table 4: Outline of Last Twenty Years (2001-2021) Research Work on Next Generation (5G) Wireless Communications of Different Fields.

Sr. No	Year	Author	Proposed work	Tools/ Parameter Used
1	2020	Fenghe Hu and et al.	1. Authors have identified the key controller of virtual reality technique from the implementation and use case point of view. 2. The mapping between the insight prerequisite of human being and the consequent quality of service requirement of virtual reality technique are also discussed here.	In this article, connectivity, frequency, quality of service, reliability is taken as parameters
2	2020	Ishan Mistry and et al.	In this article, a high level review on challenges of 5G based IoT techniques for block chain oriented business automation system in different applications are accomplished.	Authors have connectivity, security, integrity, and availability as important parameter.
3	2020	Pal Varga and et al.	Authors have tried to summarize the challenges and research gap of 5G supported commercial IoT applications.	Reliability, latency, flexibility and security are considered remarkable parameter here.
4	2020	Tharaka Hewa and et al.	Authors have underlined the fundamental features of the block chain usability with the help of 5G communication and IoT technology.	In this paper energy, privacy, scalability, and availability are taken as parameters
5	2020	Yushan Siriwardhana and et al.	In this paper, authors have highlighted the methodologies to use 5G for e-health sector efficiently and its functions to	Security, scalability, and quality of service are used parameters in this paper.

			provide related digital service.	
6	2020	Leonardo Guevara and Fernanda Auat Cheein	Authors have introduced the impact of 5G techniques in smart city and road transport system as well as its technological, financial, and legislative challenges.	Security, capacity, and bandwidth are considered as tools in this article.
7	2020	Chengzhe Lai and et al.	In this article, authors have explained the major issues and challenges of 5G communication technology in vehicular network.	Authors have taken integrity and security as parameter in this paper.
8	2021	Yu Tang and et al.	A high level review on 5G technique and its functionalities in agricultural field are provided in this paper.	Energy, reliability, and security are taken as parameters here.
9	2022	Anusha Vangala and et al.	A thorough review on security related protocol for different sub areas of modern agricultural field and their IoT based present development is explained in this paper.	Security, integrity, and availability are taken as parameters here.
10	2022	Quy Vu Khanh and et al.	A complete analysis on technical evolution, development, and challenges of IoT based 5G communication systems are provided in this research paper.	Authors have considered latency, energy, and speed as key parameter in this article.

6. RESULTS AND DISCUSSION

With the help of the highest level of rationalization and discussion, which is mentioned in the comparative analysis and empirical analysis section, it is observed that next generation (5G) wireless communication technology is an increasingly popular communication technology day by day throughout the versatile business areas like industrial automation, entertainment, wearable communication devices, IoT based apps, agriculture, traffic & road transport, and medical, etc. We have earnestly tried to draw attention to several imperative issues and challenges that are frequently faced in various business fields of the next-generation (5G) wireless communication systems. To accomplish this task successfully, a number of the latest published typical research papers in this area are taken into consideration with the help of the goggle scholar database. After a thorough review of the existing research works, we can undoubtedly mention that there are some remarkable challenges like latency, speed, bandwidth, security, connectivity, energy, protocol, and quality of service that are commonly faced in the next-generation (5G) wireless communication whereas reliability, applicability, scalability, flexibility, availability, productivity, and programmability are notable issues that we cannot avoid in different commercial applications of 5G communication [37][38].

6.1 Proposal of the Solution Mechanism to Manage Challenges and Issues

In order to countenance, manage, and control all the noteworthy issues and challenges of next-generation (5G) wireless communication in various well-liked marketable implementations successfully and knowledgeably, we suggest some specific guidelines to be followed cautiously:

- As security is a vital challenge in IoT-based 5G communications, so to handle this challenge efficiently, the concept of the gateway device, edge computing, and cloud server are recommended. Apart from this, energy is another important challenge in 5G communication to be handled by the NB-IoT technique, which introduces a multi-objective fuzzy algorithm-based optimized scheduling mechanism.
- In the agricultural field of 5G communication technology, a cryptographic security mechanism should be implemented to handle the security and privacy challenges. In this case, we recommend various
- authentication protocols to be followed. Additionally, security-based block-chain techniques and consensus algorithms are recommended for IoT-based green and smart agricultural systems.
- In the medical sector of the 5G network, various access control mechanisms are recommended to

handle security and privacy issues. Simultaneously, we recommend the network slicing concept to manage scalability and quality of service issues effectively. Additionally, for the handling connectivity and availability issues and challenges, sharable spectrum bandwidth among various network operators is suggested for implementation.

- For the effective management of availability, integrity, energy issues, and challenges in the industrial automation field using a 5G network, we recommend the amalgamation of block-chain techniques with IoT devices be applied.
- For traffic management and vehicle road transportation field of next-generation (5G) wireless communication, we recommend the four-tier framework based on the concept of vehicle ad hoc network, mobile edge computing, 5G network, and software-defined network to handle latency, energy, and bandwidth challenges successfully.
- To handle the latency and energy challenges of entertainment and wearable communication devices field in the 5G network, it is recommended to implement the device-to-device communication, virtual reality, and cloud radio access network concept.

7. CONCLUSION

Nowadays, it is a matter of reality that the next-generation (5G) wireless communication techniques have an enormous effect on different latest cellular technology for various commercial applications [39]. All the way through our research paper, we truthfully try to emphasize the frequently faced issues and challenges in the 5G wireless cellular network applications and propose several precise solution mechanisms to manage those issues and challenges effectively and efficiently with the help of comparative analysis and empirical analysis. A number of particular technologies are suggested in precise applications for the regimented organization of issues and challenges in the 5G network system in the result and discussion segment. Through the background study, comparative analysis, and result & discussion section, we carefully try to identify and analyze the problem statement of this paper. So, it is no doubt that the outcome of our research article is key challenges and issues which is found out already and some guidelines that are proposed also to handle these issues and challenges in 5G communications accordingly. We are confident enough that by implementing these technologies, researchers can move about advance research in this area.

REFERENCES:

[1] H. Huang et al., "Deep learning for physical-layer 5g wireless techniques: Opportunities, challenges and solutions," IEEE Wirel. Commun, vol. 27, no. 1, pp. 214–222, 2020, doi: 10.1109/MWC.2019.1900027.

[2] C. X. Wang, M. Di Renzo, S. Stańczak, S. Wang, and E. G. Larsson, "Artificial Intelligence Enabled Wireless Networking for 5G and Beyond: Recent Advances and Future Challenges," IEEE Wirel. Commun, vol. 27, no. 1, pp. 16–23, 2020, doi: 10.1109/MWC.001.1900292.

[3] U. Siddique, H. Tabassum, E. Hossain, and D. I. Kim, "Wireless backhauling of 5G small cells: Challenges and solution approaches," IEEE Wirel. Commun, vol. 22, no. 5, pp. 22–31, 2015, doi: 10.1109/MWC.2015.7306534.

[4] M. Tehrani, M. Uysal, and H. Yanikomeroglu, "Device-to-device communication in 5G cellular networks: Challenges, solutions, and future directions," IEEE Commun. Mag., vol. 52, no. 5, pp. 86–92, 2014, doi: 10.1109/MCOM.2014.6815897.

[5] L. V. Liping, "An energy aware multipath routing algorithm for wireless sensor networks," Int. J. Online Eng., vol. 13, no. 4, pp. 45–56, 2017, doi: 10.3991/ijoe.v13i04.7061.

[6] Y. Xu, G. Gui, H. Gacanin, and F. Adachi, "A Survey on Resource Allocation for 5G Heterogeneous Networks: Current Research, Future Trends, and Challenges," IEEE Commun. Surv. Tutorials, vol. 23, no. 2, pp. 668–695, 2021, doi: 10.1109/COMST.2021.3059896.

[7] O. León, J. Hernández-Serrano, and M. Soriano, "Securing cognitive radio networks," Int. J. Commun. Syst., vol. 23, no. 5, pp. 633–652, 2010, doi: 10.1002/dac.

[8] Z. Xiong, Y. Zhang, D. Niyato, R. Deng, P. Wang, and L. C. Wang, "Deep reinforcement learning for mobile 5G and beyond: Fundamentals, applications, and challenges,"

IEEE Veh. Technol. Mag., vol. 14, no. 2, pp. 44–52, 2019, doi: 10.1109/MVT.2019.2903655.

[9] A. Aronsky and A. Segall, "A multipath routing algorithm for mobile wireless sensor networks," 2010 3rd Jt. IFIP Wirel. Mob. Netw. Conf. WMNC 2010, 2010, doi: 10.1109/WMNC.2010.5678765.

[10] Y. Fu, S. Wang, C. X. Wang, X. Hong, and S. McLaughlin, "Artificial Intelligence to Manage Network Traffic of 5G Wireless Networks," IEEE Netw., vol. 32, no. 6, pp. 58–64, 2018, doi: 10.1109/MNET.2018.1800115.

[11] S. K. Sharma, T. E. Bogale, L. B. Le, S. Chatzinotas, X. Wang, and B. Ottersten, "Dynamic Spectrum Sharing in 5G Wireless Networks with Full-Duplex Technology: Recent Advances and Research Challenges," IEEE Commun. Surv. Tutorials, vol. 20, no. 1, pp. 674–707, 2018, doi: 10.1109/COMST.2017.2773628.

[12] S. R. Heikalabad, H. Rasouli, F. Nematy, and N. Rahmani, "QEMPAR: QoS and Energy Aware Multi-Path Routing Algorithm for Real-Time Applications in Wireless Sensor Networks," arXiv Prepr. arXiv1104.1031, vol. 8, no. 1, pp. 466–471, 2011.

[13] Y. Niu, Y. Li, D. Jin, L. Su, and A. V. Vasilakos, "A survey of millimeter wave communications (mmWave) for 5G: opportunities and challenges," Wirel. Networks, vol. 21, no. 8, pp. 2657–2676, 2015, doi: 10.1007/s11276-015-0942-z.

[14] A. Kumar and M. Gupta, "A review on activities of fifth generation mobile communication system," Alexandria Eng. J., vol. 57, no. 2, pp. 1125–1135, 2018, doi: 10.1016/j.aej.2017.01.043.

[15] C. Simon, M. Maliosz, J. Biro, B. Gero, and A. Kern, "5G Exchange for inter-domain resource sharing," IEEE Work. Local Metrop. Area Networks, vol. 2016-Augus, 2016, doi: 10.1109/LANMAN.2016.7548842.

[16] T. E. Bogale and L. B. Le, "Massive MIMO and mmWave for 5G Wireless HetNet: Potential Benefits and Challenges," IEEE Veh. Technol. Mag., vol. 11, no. 1, pp. 64–75, 2016, doi: 10.1109/MVT.2015.2496240.

[17] M. J. MARCUS, "5G and 'Imt for 2020 and Beyond,'" IEEE Wirel. Commun, no. August, pp. 2–3, 2015.

[18] N. Wang, P. Wang, A. Alipour-Fanid, L. Jiao, and K. Zeng, "Physical-Layer Security of 5G Wireless Networks for IoT: Challenges and Opportunities," IEEE Internet Things J., vol. 6, no. 5, pp. 8169–8181, 2019, doi: 10.1109/JIOT.2019.2927379.

[19] Y. Tang, S. Dananjayan, C. Hou, Q. Guo, S. Luo, and Y. He, "A survey on the 5G network and its impact on agriculture: Challenges and opportunities," Comput. Electron. Agric., vol. 180, no. September 2020, p. 105895, 2021, doi: 10.1016/j.compag.2020.105895.

[20] I. Mistry, S. Tanwar, S. Tyagi, and N. Kumar, "Blockchain for 5G-enabled IoT for industrial automation: A systematic review, solutions, and challenges," Mech. Syst. Signal Process., vol. 135, p. 106382, 2020, doi: 10.1016/j.ymssp.2019.106382.

[21] P. Varga et al., "5G Support for Industrial Iot Applications – Challenges, Solutions, and Research Gaps," Sensors (Switzerland), vol. 20, no. 3, 2020, doi: 10.3390/s20030828.

[22] T. M. Hewa, A. Kalla, A. Nag, M. E. Ylianttila, and M. Liyanage, "Blockchain for 5G and IoT: Opportunities and Challenges," 2020 8th Int. Conf. Commun. Networking, ComNet2020 - Proc., no. March, 2020, doi: 10.1109/ComNet47917.2020.9306082.

[23] Q. V. Khanh, N. V. Hoai, L. D. Manh, A. N. Le, and G. Jeon, "Wireless Communication Technologies for IoT in 5G: Vision, Applications, and Challenges," Wirel. Commun. Mob. Comput, vol. 2022, 2022, doi: 10.1155/2022/3229294.

[24] M. Chen, J. Yang, Y. Hao, S. Mao, and K. Hwang, "A 5g cognitive system for healthcare," Big Data Cogn. Comput. vol. 1, no. 1, pp. 1–15, 2017, doi: 10.3390/bdcc1010002.

[25] A. Ahad, M. Tahir, and K. L. A. Yau, "5G-based smart healthcare network: Architecture, taxonomy, challenges and future research directions," IEEE Access, vol. 7, pp. 100747–100762, 2019, doi: 10.1109/ACCESS.2019.2930628.

[26] Y. Siriwardhana, G. Gür, M. Ylianttila, and M. Liyanage, "The role of 5G for digital healthcare against COVID-19 pandemic: Opportunities and challenges," ICT Express, vol. 7, no. 2, pp. 244–252, 2021, doi: 10.1016/j.icte.2020.10.002.

[27] F. Camacho, C. Cárdenas, and D. Muñoz, "Emerging technologies and research challenges for intelligent transportation systems: 5G, HetNets, and SDN," Int. J. Interact. Des. Manuf., vol. 12, no. 1, pp. 327–335, 2018, doi: 10.1007/s12008-017-0391-2.

[28] J. Liu et al., "High-Efficiency Urban Traffic Management in Context-Aware Computing and 5G Communication," IEEE Commun. Mag.,

vol. 55, no. 1, pp. 34–40, 2017, doi: 10.1109/MCOM.2017.1600371CM.

[29] L. Guevara and F. A. Cheein, "The role of 5G technologies: Challenges in smart cities and intelligent transportation systems," Sustain., vol. 12, no. 16, 2020, doi: 10.3390/su12166469.

[30] C. Lai, R. Lu, D. Zheng, and X. S. Shen, "Security and privacy challenges in 5g-enabled vehicular networks," IEEE Netw., vol. 34, no. 2, pp. 37–45, 2020, doi: 10.1109/MNET.001.1900220.

[31] R. Gupta, S. Tanwar, S. Tyagi, and N. Kumar, "Tactile-internet-based telesurgery system for healthcare 4.0: An architecture, research challenges, and future directions," IEEE Netw., vol. 33, no. 6, pp. 22–29, 2019, doi: 10.1109/MNET.001.1900063.

[32] R. Basir et al., "Fog computing enabling industrial internet of things: State-of-the-art and research challenges," Sensors (Switzerland), vol. 19, no. 21, pp. 1–38, 2019, doi: 10.3390/s19214807.

[33] E. I. Tamariz-Flores, K. A. García-Juárez, R. Torrealba-Meléndez, J. M. Muñoz-Pacheco, and M. Á. León-Chávez, An IoT-based urban infrastructure system for smart cities. 2018.

[34] F. Hu, Y. Deng, W. Saad, M. Bennis, and A. H. Aghvami, "Cellular-connected wireless virtual reality: Requirements, challenges, and solutions," IEEE Commun. Mag., vol. 58, no. 5, pp. 105–111, 2020, doi: 10.1109/MCOM.001.1900511.

[35] A. Vangala, A. K. Das, V. Chamola, V. Korotaev, and J. J. P. C. Rodrigues, "Security in IoT-enabled smart agriculture: architecture, security solutions and challenges," Cluster Comput., no. March, 2022, doi: 10.1007/s10586-022-03566-7.

[36] M. A. Ferrag, L. Shu, X. Yang, A. Derhab, and L. Maglaras, "Security and Privacy for Green IoT-Based Agriculture: Review, Blockchain Solutions, and Challenges," IEEE Access, vol. 8, pp. 32031–32053, 2020, doi: 10.1109/ACCESS.2020.2973178.

[37] P. Botsinis, S. X. Ng, and L. Hanzo, "Quantum search algorithms, quantum wireless, and a low-complexity maximum likelihood iterative quantum multi-user detector design," IEEE Access, vol. 1, pp. 94–122, 2013, doi: 10.1109/ACCESS.2013.2259536.

[38] Z. Zhang, K. Long, A. V. Vasilakos, and L. Hanzo, "Full-Duplex Wireless Communications: Challenges, Solutions, and Future Research Directions," Proc. IEEE, vol. 104, no. 7, pp. 1369–1409, 2016, doi: 10.1109/JPROC.2015.2497203.

[39] X. Yuan, Y. J. A. Zhang, Y. Shi, W. Yan, and H. Liu, "Reconfigurable-Intelligent-Surface Empowered Wireless Communications: Challenges and Opportunities," IEEE Wirel. Commun, vol. 28, no. 2, pp. 136–143, 2021, doi: 10.1109/MWC.001.2000256.

[40] Paul, S. P., & Vetrithangam, D. (2022, November). A Comprehensive Analysis on Issues and Challenges of Wireless Sensor Network Communication in Commercial Applications. In 2022 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS) (pp. 377-382). IEEE.

[41] Praveenchandar, J., Vetrithangam, D., Kaliappan, S., Karthick, M., Pegada, N. K., Patil, P. P., ... & Umar, S. (2022). IoT-Based Harmful Toxic Gases Monitoring and Fault Detection on the Sensor Dataset Using Deep Learning Techniques. Scientific Programming, 2022.