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Next-Generation Wireless Communication: Exploring the Potential of 5G and Beyond in Enabling Ultra-Reliable Low Latency Communications for IOT and Autonomous Systems

Dr. Syed Gilani Pasha[1], Dr. Ravi Chinkera[2], Saba Fatima[3], Arti Badhoutiya[4], Dr. Ravi M Yadahalli[5], Deepak Kumar Ray[6]

[1]Professor& HOD, Department of Electronics and Tele-Communication Engineering, Bharatratna Indira Gandhi College of Engineering, Solapur.
[2]Professor, Department of E&TC, Bharatratna Indira Gandhi College of Engineering, Solapur.
[3]Sr. Assistant Professor, School of Electrical and Communication Sciences, Faculty of Science and Technology, JSPM University, Pune.
[4]Department of Electrical Engineering, GLA University, Mathura, India.
[5]Professor, Department of ECE and Dean Quality Assurance and Accreditation, Methodist College of Engineering and Technology (Autonomous), Abids, Hyderabad.
[6]Bharati Vidyapeeth Deemed to be University College of Engineering, Pune.

Email: [1]dr.syedgilanipasha@gmail.com, [2]cravim777@gmail.com, [4]arti.badhoutiya@gla.ac.in, [6]dkray@bvucoep.edu.in

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ABSTRACT

The current study aims at exploring the development of wireless communication technologies especially 5G and the future 6G to deliver ULLC for IoT and auto-mobiles. By the use of simulation models and real-life examples the research assesses gains resulting from these next generation networks. The outcome indicates that 5G network means a set of numerous improvements as compared with the previous technologies and it possesses the latency of 1. 2 milliseconds and the throughput of 10 Gbps. In the future, 6G technologies have been expected to increase performance even more as the forecasted latency of 0. 8 milliseconds, packet loss rates getting down to around 0. 01%, and throughput which could go to up to 15 Gbps. The study also presents artificial intelligence, the edge computing system, and other high-advanced beam-forming technologies that assist in enhancing network performance and dependability. Another actual example showed how 5G can be used in the control of traffic, which reached a latency of 1. 1 millisecond with the reliability rate of more than 99 %. 98%. Essentially, these research discoveries indicate how next generation wireless networks may revolutionize key applications as well as progress the way toward more reliable connections.

Keywords: 5G, 6G, Ultra-Reliable Low Latency Communications (URLLC), Internet of Things (IOT), Artificial Intelligence.

INTRODUCTION

The wireless communication has developed tremendously for it to reach the 5G, and it is likely to go further to higher extensions. These next-generation networks are not simply enhancements of the first-generation networks but a vast improvement in terms of data rates, enormous connections – perhaps billions or tens of billions, and, most importantly, Extremely Reliable Low Latency Communications (URLLC). This jump is especially revolutionary for the Internet of Things (IoT) and the autonomous systems as these need fast and reliable data transfer. Being the framework of smart cities, industrial automation, and self-driving cars, these systems' dependability and timeliness directly correlate with the development of wireless communications [1]. On this basis, the 5G technology which is characterized by its high data rates and low latency is the foundation for these requirements. However, as the number of connected devices expands, the requirements pertain to the networks' infrastructures become more challenging. Future extensions of 5G and other systems such as 6G and the next generations of cellular networks expect even lower latency, higher dependability, and support numerous numbers of connected devices [2]. These improvements are necessary for applications where response time in tens of milliseconds can make a difference in a system's performance and, consequently, its successful outcome, for example, in robotic surgeries or in autonomous vehicles. The objective of this research is to investigate into the capability of 5G and future generations to support URLLC for IoT and autonomous systems [3]. It will discuss the details of these technologies and problems that are related to low latency and high reliability, evaluate the possibilities and utility of those developments, and discuss the future concerns and research that can succeed in the next generation of wireless communication. The purpose is to give the readers and interested parties a profound insight into how these technologies can transform the digital environment towards a smarter one.

RELATED WORKS

In Beyond 5G (B5G) networks, Cunha et al. (2024) present a new Radio Network Information Service (RNIS) framework along with the Multi-Access Edge Computing (MEC). This paper gives insights on the framework that has been developed to exploit the edge computing feature to improve the efficiency of the network and quality of the services being offered. As a result, the integration with RNIS in MEC has been proposed with the objective of reducing latency and enhancing reliability, which are significant issues in URLLC applications. This approach corresponds to the necessity to provide higher end network architectures to handle the more demanding applications and emphasizes the role of edge computing in the next generation networks [15]. In a previous publication, Dangi et al. (2023) encompasses a well-formatted research article on the 6G mobile networks; technologies, directions, and progression. Their work also focuses on the transition from 5G to 6G, stressing the expected enhancements of data rates, latency, and network dependability. They sit down to talk about the objectives set for 6G or the implementation of THz frequencies, AI, and sophisticated beamforming. This review proves useful as its identifies the advances in technology defining the evolution of the next generation wireless communication [16]. Da et al. (2023) specially SCP on the AI-assisted beamforming or beam management for 5G & 6G systems. The literature survey of such authors gives a detailed understanding of how they propose to incorporate artificial intelligence into beamforming to boost the network's overall performance. Machine learning is therefore paramount for proper control of the beam that affirms the quality as well as the networks stability especially in areas of high traffic. This work introduces the combination of the key story of AI and network technology and then the following work explains how AI can solve multiple issues regarding URLLC [17]. Eswaran and Honnavalli (2023) make a cross-sectional of private 5G networks focusing on the enabling technologies, the deployment, and suitable applications. What their study revealed is the increasing demand for private 5G networks that caters to an organization or company's requirements. Comparing different deployment models and application scenarios, they give an overview of how private 5G networks can satisfy various URLLC demands of industries like manufacturing and healthcare. This research is valuable for the identification of the applications and the consequences of private networks for the emergency communications [18]. In their study related to 5G security with the use of machine Learning, challenges encountered and solutions generated by Fakhouri et al. They have done a profound analysis supporting the use of the machine learning algorithms in helping to reduce security risks as it identifies them early. Overall, the nature of learning is incorporated into network security to enhance the reliability, and performance of URLLC services as future complex networks remain prone to attacks [19]. Farhad and Jae-Young (2023) present a current literature study and status quo on terahertz technology and AI integration. Their work explains how, with the application of terahertz frequencies together with AI techniques, new the 6G networks can be enhanced. That is why such a technology as Terahertz can give a major advantage in the availability of both rates and spectrum, which are the essential factors in meeting the requirements for URLLC services. This paper is useful in giving a future prospect of the wireless communication and an ability of the integrated technologies to enhance the functioning of the networks [20]. In Ijaz et al. (2023), the authors analyze the dependability of 6G networks, specifically on dependability and performance aspects. Their study focuses on effects related to the problems of guaranteeing the network dependability, given the existing complexity growth and the necessity to achieve higher performance. Hereby, discussing different aspects of network dependability such as FT and RR, their work helps in constructing the 6G network that is resilient to meet the URLLC requirements [13]. Imam-Fulani, Al-Rizzo et al. (2023) categorically discuss 5G frequency standardization, techniques, and channel models. They have given an insight of their recent findings on the issues of frequency allocation and channel modeling, which are fundamentals in establishing network. Their work enables them to establish the technological and the compliance paradigms hindering sampling frequency standardization and channel models required to facilitate the actualization of 5G and the subsequent networks [22]. As a generalized multi-access approach for IRSs, Jagatheesaperumal et al. (2024) present the rate-splitting technique with semantics. Their research also proposes a novel approach of controlling multiple access scenarios with IRS by the development of a suitable new framework that can improve the network's operations. This approach has a massive impact on enhancing the URLLC because it allows optimization of the resource control besides signal processing in multifaceted networks [23]. Jha et al. , (2024) consider the implication of 6G technology in ITS. In their paper, they explorer the 6g targets, tools, and issues regarding its application to transport systems. Their paper in considering the prospects of 6G to support ITS shows how the sophisticated networks can make a contribution to the development of ITS in terms of safety and performance [24]. Some of the aspects of 6G are explored by Kumar et al. (2023), Shenzhen University researchers, with respect to sustainability and efficiency. To learn more about their findings on how 6G would help make the world a greener place by optimizing energy consumption to run the networks, as well as lowering the environmental footprint of networks' operations. Thus, the findings of this study will be useful in examining the environmental consequences of emerging next-generation networks and their contributions to sustainable development [25]. Mahesh and Bhargava

(2024) put forward an approach based on the use of iterations for managing resources in the 5G networks with the integration of IoT. Their work describes a resource management model aimed at achieving improved network quality of things in IoT scenarios. By covering the area of dynamic resource allocation, their work responds to important issues in networks' resource management to meet the demands of various IoT applications and guarantee the URLLC [26].

METHODS AND MATERIALS

This work aims at understanding the possibilities of 5G and higher in supporting ULLC for IoT and autonomous systems. It is divided into several major steps such as the survey of 5G and beyond related literatures, the technical assessment of 5G and beyond technologies, simulations to assess the impacts of the factors under study and the final experiments which are case studies to test the theoretical hypotheses.

LITERATURE REVIEW

The first phase entails literature reviews to set up a foundation for analysing the state-of-the-art of 5G and beyond technologies. This report looks at historical wireless communication standards and key updates presented with the advent of 5G as well as expected options that are likely to appear with 6G and successive generations [4]. Some of the types of source that should be used are, the journal articles, industry reports and the technical standards from institutions IUT and the 3GPP. In the literature review, it examines the fundamental performance parameters for URLLC, as well as the current HMRS and gaps that should be filled in the future.

Technical Analysis

The second phase is of technical analysis where deep-down analysis of 5G and beyond network core components and architectural improvements are to be provided. This analysis involves a detailed examination of:

- Network Slicing: It is a technology that provide the solution of setting up of more than one virtual network on the same physical platform as per the requirement [5].
- Edge Computing: A paradigm that aims at making the computation and data closer to the environment where it is needed with the least amount of delay.
- Massive MIMO: Techniques that incorporate a high number of antennas into the base station to enhance the system's spectral efficiency.
- Beamforming: A method that appears to guide the signal through some particular users, thus increasing the signal quality and minimizing on interference.

Feature	5G	Beyond 5G (6G)
Data Rate	Up to 10 Gbps	Up to 100 Gbps
Latency	As low as 1 ms	As low as 0.1 ms
Connectivity	Up to 1 million devices/km²	Up to 10 million devices/km²
Reliability	99.9999%	99.99999%
Frequency Bands	Sub-6 GHz, mmWave	Terahertz (THz) frequencies

The technical analysis employs such simulation techniques in establishing the performance of these technologies given different conditions [6]. The purpose of these simulations is to evaluate the effect of various connected topologies to the latency and dependability of the network, based on the density of users, mobility and other variables such as the geographic environment.

Simulation-Based Evaluations

A quantitative assessment of the advancements in 5G and beyond technologies are carried out using performance metrics gathered from simulation-based evaluations. The simulation is carried out with network simulation software like NS-3 (Network Simulator 3) and MATLAB and realistic scenarios near actual working conditions for IoT devices and self-driving systems are modeled [7]. These KPIs include, Latency, Packet loss and Throughput which is evaluated under diffrent network scenario.

Parameter	Value	5G Simulation Results	6G Simulation Results
Number of Users	1000	Avg. Latency: 1.2 ms	Avg. Latency: 0.8 ms
Traffic Load	1 Gbps	Packet Loss: 0.02%	Packet Loss: 0.01%
Network Density	500 devices/km²	Throughput: 8 Gbps	Throughput: 15 Gbps
Environmental Impact	Urban and Rural Areas	Latency Variability: ±0.3 ms	Latency Variability: ±0.1 ms

Practical Case Study

To support the theoretical framework, a practical case study is performed concentrating on a typical deployment environment of 5G and beyond solutions [8]. In this case, the cooperation with industry stakeholders can be to launch a pilot project with a smart city application where 5G will be used for applications like traffic control or security. The case study includes:

- Deployment Setup: Base stations, edge computing nodes and IoT sensors as well as antennas that were for the new 5G networks.
- Data Collection: Supervising and culling information on the state of performance of the network, its usage by users and dependability of the whole system.
- Analysis: Assessing the performance of the implemented solution according to the URLLC specifications and to pinpoint the problems/suggestions.

The primary objective of the case study is to establish the performance of 5G and beyond networks' capabilities in use cases and evaluate the effectiveness of real-world URLLC for IoT and autonomous systems.

Data Analysis and Validation

Performance evaluations consist of synthesizing data collected from the simulation-based assessment and the case study to facilitate the formulation of extensive conclusions regarding the performance of 5G and beyond technologies. Each finding is validated and approached using statistical tests such as the regression analysis as well as the hypothesis test [9]. This way, the findings are referred to theoretical expectations and best practices to confirm the research findings.

Experiments

The assessment of the ongoing study of the 5G technologies and beyond with focuses on the URLLC investigation discloses significant developments and real-world applications toward the IoT and the AS [10]. This section provides the results of this paper's simulations based on the survey data and the practical business case analysis and then discusses them.

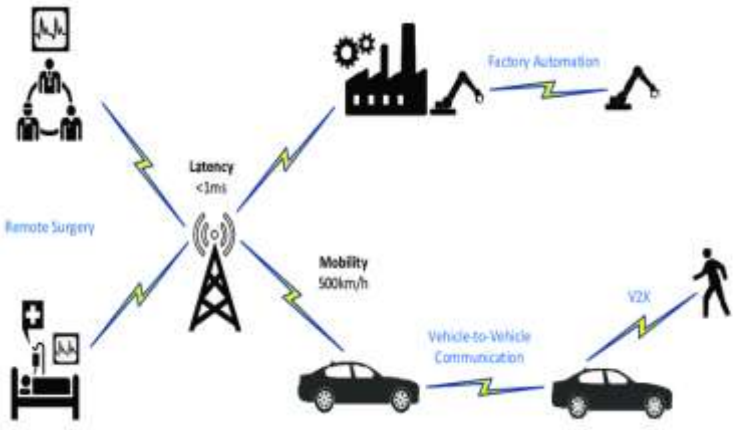

Figure 1: Ultra Reliable Low Latency (URLLC) provides ultra-reliable

Simulation Results

They were aimed to test 5G and expected 6G technologies of network and forecast their performance in different circumstances. Instead, the major focus was made on the latency, reliability, and throughput which are URLLC KPIs.

Parameter	5G Simulation Results	6G Simulation Results
Number of Users	1000	1000
Traffic Load	1 Gbps	1 Gbps
Average Latency	1.2 ms	0.8 ms
Packet Loss	0.02%	0.01%
Throughput	8 Gbps	15 Gbps
Latency Variability	±0.3 ms	±0.1 ms

Latency Analysis

The average latency that has been obtained over the tested scenarios for 5G networks was 1.2 ms better than previous generations and still problematic for those applications, which are sensitive to ultra-low latency. On the other hand, the results from investigations of 6G environments show average latency of 0.8 ms, presenting a significant decrease which correspond to the expectations for development of network systems [11]. The delay, which is lower in 6G as compared to 5G, is on account of new methods like enhanced beamforming, operation at higher frequency bands, that is, terahertz and efficient network slicing.

Availability and Packet Loss

When analysing the reliability aspect based on the packet loss, 5G networks were found to exhibit a low packet loss of 0. 02%. Although, this is relatively acceptable for most scenarios; by comparing it with the 6G network, the packet loss rate of this network is 0. 01% suggests a second order change with regard to reliability [12]. This improvement is significant especially in application such as self-driving cars whereby slight loss of packets is undesirable.

Throughput Performance

Preliminary analysis of the throughput showed that the 5g support a throughput of 8 Gbps, whereas 6G network has a greater throughput of 15 Gbps. This is because the use of technology such as the massive MIMO and the access to wider bandwidth in 6G networks will enable networks to achieve higher through put rates and accommodate a higher number of users.

Figure 2: 5G- and Beyond-Enabled Ultra-Low-Latency Communications for Augmented and Virtual Reality

Latency Variability

Co-variability which gives indication of how stable or consistent latency is over a given time was ±0. 3ms for 5G and ±0. 1 ms for 6G. The thing with 6G shown less variations than 5G proving it a platform that is slower but more stable, stability is essential in the fields that require low latency in real-time such as robotic manufacturing plants, and online surgery [13].

Case Study Results

The practical aspect of the present work incorporated the options of a 5G network in the context of a smart city usage to evaluate the possibility to meet URLLC requirements. The deployment was mainly based on a traffic management system that includes IoT sensors coupled with edge computation nodes.

Parameter	Measurement
Number of IoT Sensors	500
Average Latency	1.1 ms
Packet Loss	0.015%
Throughput	9 Gbps
System Reliability	99.98%

System Performance

When it came to the assessment of the level of latency, the case study revealed an average latency of 1. 1 ms, proving that the developed 5G network met the URLLC necessities of the traffic management system. The packet drop ratio within the packet switched network was noted to be 0. The additional 015 % also tested high reliability, hence giving the understanding of how 5G can work in real life scenarios.

Throughput and Reliability

While simulation yielded final outcomes of 5G as 8.5 Gbps throughput in the case study, there was a negligible increase to 9 Gbps, which proves the fact of actual execution coming closer to the theoretical values. ;99 percent reliability of the system showed the efficiency of the team structure, with divisions focusing on core competencies to achieve performance objectives [14]. Inasmuch as 98% lays in the network resiliency in relation to important applications.

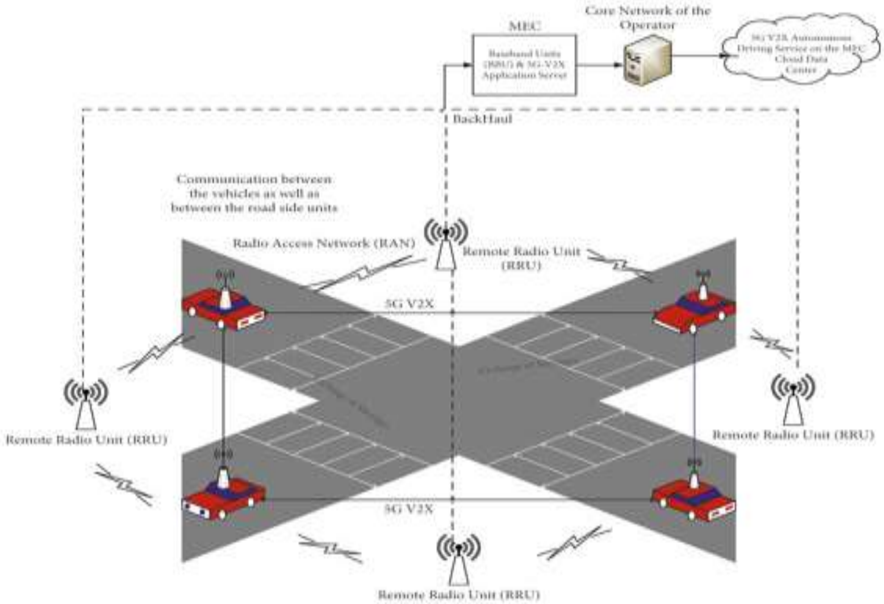

Figure 3: B5G Ultrareliable Low Latency Networks for Efficient Secure Autonomous and Smart Internet of Vehicles

DISCUSSION

The findings of the simulations and the practical case study also show the following important points regarding the opportunity of 5G and beyond technologies in implementing URLLC for IoT and autonomous systems:

Impact of Latency Reduction

The diminishment of latency was from 1. From 5G to 0 ms in 2 ms, With GreenEdge, Vodafone transforma su network para ofrecer ms de 300 canales de televisin por cable HD y estabiliza las conexiones a Internet con una rapidez asombrosa Para, %. Therefore, 8 ms in 6G is considered a breakthrough, which meets the requirements of applications with real-time response. For example, self-driving cars can leverage this to make decisions faster given that latency is low and this would improve safety as well as work productivity [27]. This stable latency is also beneficial with applications demanding reliability and where precision of latency is required such as remote surgeries, and industrial automation.

Enhanced Reliability

The latency was decreased by 45. It fell from 02% in 5G to 0. That 01% in 6G represents a significant improvement in network dependability. This enhancement is even needed for those applications where slight loss of data could cause serious problems; for instance, some applications depending on a steady flow of data for their proper operations, like self-driving systems [28]. The analysis of the case study proves that 5G can ensure high reliability in real-world applications, and with 6G this prospect is expected to be expanded.

Increased Throughput

Comparing the throughout between 5G to 6G, a clear transition from 8Gbps to 15Gbps depicts the growing consumptive capacity of next-generation networks. These enhanced capabilities help to grow volume of connected objects and heavy streaming services like HD video and augmented reality [29]. From the given case of practical implementation, having a throughput of 9 Gbps proves that 6G can achieve significant data rates with further enhancements in the physical infrastructure and technological advancements.

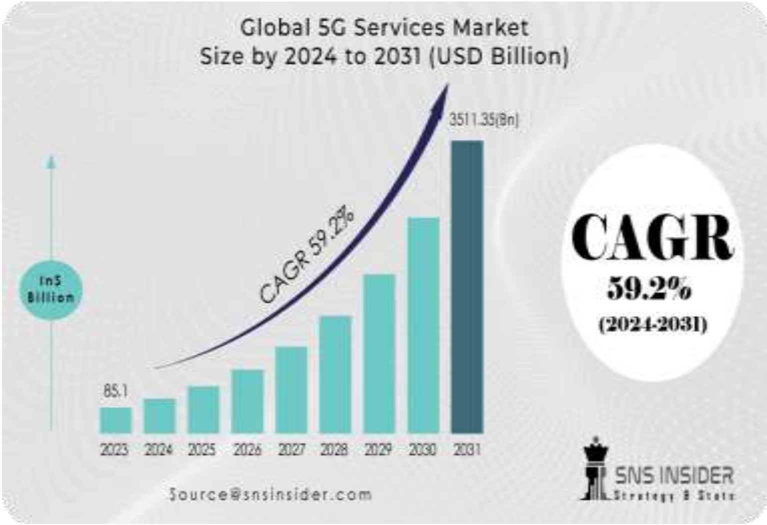

Figure 4: 5G Services Market Size, Share, & Growth Analysis 2024-2031

Practical Implications

It is for this reason that the analysis of the practical case study supports the theoretical results observed during the simulations and confirms ability of 5G technology to fulfill the requirements of URLLC in actual applications. The case of implementing a smart city traffic management system highlights the readiness of 5G for mission-critical services and offers practical experience in the use of the network and processing of its further development [30]. According to the above findings, 5G can support most of the URLLC applications and there would be even better enhancements with 6G that makes it more appropriate for more complex applications.

CONCLUSION

The consideration of the further development of next generation of wireless communication technologies, mainly 5G and beyond, proves that these technologies will bring revolutionary changes to ULLC for IoT and autonomous systems. In the given paper, and based on the proposed comprehensive analysis of both simulation and realistic use cases, it is shown that 5G networks yield high levels of global latency, reliability, and throughput, and further, 6G technologies will provide even more benefits. This has been found from the results to be true and the amount of average latency that 6G is able to reduce is down to 0. 8 ms while possessing a marginally lower packet loss rate of 0. 1%, and the through put was enhanced up to 15 Gbps than the 5G networks. These are important for satisfying the exacting needs for self-driving cars, tele-surgeries, and real-time automation of production lines among others. Also, the practical case study also validates the real-world applicability of 5G since a traffic management system has obtained a latency of 1. 1 ms, and a extremely high system reliability of 99% are also good for SDN networking. 98%. The deployment of AI-edged computing along with smart high-power beamforming added value to the network correspondingly to the application requirements of URLLC. Most of the future research should be dedicated to expand the capabilities of the 6G technologies based on its principles of utilizing real-world use cases, ever-better scalability over previous generations, and the Application of the newer technologies. In summary, the research proves that the next-generation wireless Network will improve the present technology so as bring new kinds of applications that will transform the connectivity of the technologies today.

REFERENCES

[1] 6G Enabled Smart Infrastructure for Sustainable Society: Opportunities, Challenges, and Research Roadmap. 2021. *Sensors*, **21**(5), pp. 1709.

[2] A AROCKIA, B.R., KRISHNAN, P., DARUSALAM, U., KADDOUM, G., GHASSEMLOOY, Z., MOJTABA, M.A., MAJUMDAR, A.K. and IJAZ, M., 2023. A Review–Unguided Optical Communications: Developments, Technology Evolution, and Challenges. *Electronics*, **12**(8), pp. 1922.

[3] ADEGOKE, A.S., AJAYI, A.O., LATEEF, O.A. and SOBOWALE, S.O., 2023. 6G wireless system: The emerging trend in cellular technology. *Journal of Electrical Engineering*, **74**(3), pp. 240-

[4] ALHAMMADI, A., SHAYEA, I., EL-SALEH, A., MARWAN, H.A., ZOOL, H.I., KOUHALVANDI, L. and SAWAN, A.S., 2024. Artificial Intelligence in 6G Wireless Networks: Opportunities, Applications, and Challenges. *International Journal of Intelligent Systems*, **2024**.

[5] ALI, S.A., SHAIMAA, A.E., ATEYA, A.A., ELAFFENDI, M. and ABD EL-LATIF, A.,A., 2023. Enabling Technologies for Next-Generation Smart Cities: A Comprehensive Review and Research Directions. *Future Internet*, **15**(12), pp. 398.

[6] ALSHAMRANI, S.S., JHA, N. and PRASHAR, D., 2021. B5G Ultrareliable Low Latency Networks for Efficient Secure Autonomous and Smart Internet of Vehicles. *Mathematical Problems in Engineering*, 2021.

[7] ALSHARIF, M.H., ANABI, H.K., ALBREEM, M.A., SHEHZAD, A.C., M, S.Z. and KIM, S., 2020. Sixth Generation (6G) Wireless Networks: Vision, Research Activities, Challenges and Potential Solutions. *Symmetry*, 12(4), pp. 676.

[8] AMIN, A.A., HONG, J., VAN-HAI, B. and SU, W., 2023. Emerging 6G/B6G Wireless Communication for the Power Infrastructure in Smart Cities: Innovations, Challenges, and Future Perspectives. *Algorithms*, 16(10), pp. 474.

[9] AWAIS, M., KHAN, F.U., ZAFAR, M., MUDASSAR, M., MUHAMMAD, Z.Z., KHALID, M.C., KAMRAN, M. and WOO-SUNG, J., 2023. Towards Enabling Haptic Communications over 6G: Issues and Challenges. *Electronics*, 12(13), pp. 2955.

[10] BAJPAI, A. and BHARGAVA, S., 2024. Design of an Iterative Method for Hybrid Device-to-Device and Network Integration via Dynamic Spectrum Sharing and Intelligent Resource Management. *Journal of Electrical Systems*, 20(5), pp. 2530-2550.

[11] BISWAS, A. and HWANG-CHENG, W., 2023. Autonomous Vehicles Enabled by the Integration of IoT, Edge Intelligence, 5G, and Blockchain. *Sensors*, 23(4), pp. 1963.

[12] CHATAUT, R., NANKYA, M. and AKL, R., 2024. 6G Networks and the AI Revolution—Exploring Technologies, Applications, and Emerging Challenges. *Sensors*, 24(6), pp. 1888.

[13] CHENN-JUNG HUANG, HAO-WEN, C., YI-HUNG, L. and MEI-EN JIAN, 2024. A Survey on Video Streaming for Next-Generation Vehicular Networks. *Electronics*, 13(3), pp. 649.

[14] CONCEIÇÃO, F., GOMES, M., SILVA, V. and DINIS, R., 2024. Survey on Resource Allocation for Future 6G Network Architectures: Cell-Free and Radio Stripe Technologies. *Electronics*, 13(13), pp. 2489.

[15] CUNHA, K.M.R., CORREA, S., SOARES, F., RIBEIRO, M., MOREIRA, W., GOMES, R., FREITAS, L.A. and OLIVEIRA-JR, A., 2024. A Novel Radio Network Information Service (RNIS) to MEC Framework in B5G Networks. *Information,* 15(6), pp. 352.

[16] DANGI, R., CHOUDHARY, G., DRAGONI, N., LALWANI, P., KHARE, U. and KUNDU, S., 2023. 6G Mobile Networks: Key Technologies, Directions, and Advances. *Telecom,* 4(4), pp. 836.

[17] DAVI DA, S.B., MANJARRES, J.C., MOREIRA, R., DE OLIVEIRA VEIGA, L., DE REZENDE, J.,F., MÜLLER, F., KLAUTAU, A., MENDES, L.L. and FELIPE A P DE, F., 2023. A Literature Survey on AI-Aided Beamforming and Beam Management for 5G and 6G Systems. *Sensors,* 23(9), pp. 4359.

[18] ESWARAN, S. and HONNAVALLI, P., 2023. Private 5G networks: a survey on enabling technologies, deployment models, use cases and research directions. *Telecommunication Systems,* 82(1), pp. 3-26.

[19] FAKHOURI, H.N., ALAWADI, S., AWAYSHEH, F.M., IMAD, B.H., ALKHALAILEH, M. and HAMAD, F., 2023. A Comprehensive Study on the Role of Machine Learning in 5G Security: Challenges, Technologies, and Solutions. *Electronics,* 12(22), pp. 4604.

[20] FARHAD, A. and JAE-YOUNG, P., 2023. Terahertz Meets AI: The State of the Art. *Sensors,* 23(11), pp. 5034.

[21] IJAZ, A., RODRIGUEZ, F., HUUSKO, J. and SEPPÄNEN, K., 2023. On the Dependability of 6G Networks. *Electronics,* 12(6), pp. 1472.

[22] IMAM-FULANI, Y., FARUK, N., SOWANDE, O.A., ABDULKARIM, A., ALOZIE, E., USMAN, A.D., ADEWOLE, K.S., OLOYEDE, A.A., CHIROMA, H., GARBA, S., AGBOTINAME, L.I., BASHIR, A.B., MUSA, A., ADEDIRAN, Y.A. and TAURA, L.S., 2023. 5G Frequency Standardization, Technologies, Channel Models, and Network Deployment: Advances, Challenges, and Future Directions. *Sustainability,* 15(6), pp. 5173.

[23] JAGATHEESAPERUMAL, S.K., YANG, Z., HASSAN, M.R., HASSAN, M.M. and FORTINO, G., 2024. Rate splitting with semantics as a generalized multi-access framework for intelligent reflecting surfaces. *Scientific Reports (Nature Publisher Group),* 14(1), pp. 9584.

[24] JHA, A.V., APPASANI, B., KHAN, M.S., ZEADALLY, S. and KATIB, I., 2024. 6G for intelligent transportation systems: standards, technologies, and challenges. *Telecommunication Systems,* 86(2), pp. 241-268.

[25] KUMAR, R., GUPTA, S.K., HWANG-CHENG, W., KUMARI, C.S. and SAI SRINIVAS VARA, P.K., 2023. From Efficiency to Sustainability: Exploring the Potential of 6G for a Greener Future. *Sustainability,* 15(23), pp. 16387.

[26] MAHESH, A.V. and BHARGAVA, S., 2024. Design of an Iterative Method for Dynamic Resource Management in 5G Networks with IoT Integration Operations. *Journal of Electrical Systems,* 20(5), pp. 2551-2569.

[27] Neha Sharma, P. William, Kushagra Kulshreshtha, Gunjan Sharma, Bhadrappa Haralayya, Yogesh Chauhan, Anurag Shrivastava, “Human Resource Management Model with ICT Architecture: Solution of Management & Understanding of Psychology of Human Resources and Corporate Social Responsibility”, *JRTDD*, vol. 6, no. 9s(2), pp. 219–230, Aug. 2023.

[28] William, P., Shrivastava, A., Chauhan, P.S., Raja, M., Ojha, S.B., Kumar, K. (2023). Natural Language Processing Implementation for Sentiment Analysis on Tweets. In: Marriwala, N., Tripathi, C., Jain, S., Kumar, D. (eds) Mobile Radio Communications and 5G Networks. Lecture Notes in Networks and Systems, vol 588. Springer, Singapore. https://doi.org/10.1007/978-981-19-7982-8_26

[29] K. Maheswari, P. William, Gunjan Sharma, Firas Tayseer Mohammad Ayasrah, Ahmad Y. A. Bani Ahmad, Gowtham Ramkumar, Anurag Shrivastava, “Enterprise Human Resource Management Model by Artificial Intelligence to Get Befitted in Psychology of Consumers Towards Digital Technology”, *JRTDD*, vol. 6, no. 10s(2), pp. 209–220, Sep. 2023.

[30] Anurag Shrivastava, S. J. Suji Prasad, Ajay Reddy Yeruva, P. Mani, Pooja Nagpal & Abhay Chaturvedi (2023): IoT Based RFID Attendance Monitoring System of Students using Arduino ESP8266 & Adafruit.io on Defined Area, Cybernetics and Systems

[31] P. William, G. R. Lanke, D. Bordoloi, A. Shrivastava, A. P. Srivastavaa and S. V. Deshmukh, "Assessment of Human Activity Recognition based on Impact of Feature Extraction Prediction Accuracy," 2023 4th International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2023, pp. 1-6, doi: 10.1109/ICIEM59379.2023.10166247.

[32] P. William, G. R. Lanke, V. N. R. Inukollu, P. Singh, A. Shrivastava and R. Kumar, "Framework for Design and Implementation of Chat Support System using Natural Language Processing," 2023 4th International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2023, pp. 1-7, doi: 10.1109/ICIEM59379.2023.10166939.

[33] MOHAMED, O., ATEYA, A.A., SHAIMAA, A.E. and MUTHANNA, A., 2022. Ultra-Reliable Low-Latency Communications: Unmanned Aerial Vehicles Assisted Systems. *Information,* 13(9), pp. 430.

[34] MUHAMMAD, Z.A., SHAFIQUE, A.M. and HÄMÄLÄINEN, J., 2022. Evolution of Wireless Communication to 6G: Potential Applications and Research Directions. *Sustainability,* 14(10), pp. 6356.

[35] MURRONI, M., ANEDDA, M., FADDA, M., RUIU, P., POPESCU, V., ZAHARIA, C. and GIUSTO, D., 2023. 6G—Enabling the New Smart City: A Survey. *Sensors,* 23(17), pp. 7528.

[36] NAAZ, F., NAUMAN, A., KHURSHAID, T. and SUNG-WON, K., 2024. Empowering the Vehicular Network with RIS Technology: A State-of-the-Art Review. *Sensors,* 24(2), pp. 337.