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5G-backed resilience and quality enhancement in internet of medical things infrastructure for resilient infrastructure

Noora Jamal Ali[1], Noor Amer Hamzah[2,3], Ahmed Dheyaa Radhi[4], Yitong Niu[5], Poh Soon JosephNg[6], Jamal Fadhil Tawfeq[7]
[1]Department of Electronic Technologies, Institute of Medical Technology Al-Mansour, Baghdad, Iraq
[2]Department of Computer Techniques Engineering, Alnukhba University College, Baghdad, Iraq
[3]Department of Computer, College of Science, AlNahrain University, Baghdad, Iraq
[4]College of Pharmacy, University of Al-Ameed, Karbala, Iraq
[5]School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia
[6]Faculty of Data Science and Information Technology, INTI International University, Nilai, Malaysia
[7]Department of Medical Instrumentation Technical Engineering, Medical Technical College, Al-Farahidi University, Baghdad, Iraq

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ABSTRACT

The internet of medical things (IoMT) has transformed the healthcare sector by facilitating real-time monitoring, remote patient care, and tailored healthcare solutions. However, the challenge of upholding a high standard quality of service (QoS) in IoMT implementations remains a pressing issue. This article delves into the possibilities of utilizing 5G networks and smart techniques to optimize QoS within IoMT systems. By capitalizing on the capabilities of 5G networks, including substantial bandwidth, minimal latency, and extensive connectivity, in conjunction with intelligent methods such as machine learning and predictive analytics, this paper introduces novel strategies to enhance QoS in IoMT environments. The summary underscores the advantages of these methods in elevating network dependability, diminishing latency, enhancing data transmission efficiency, and enabling resource allocation efficiency in IoMT deployments. Additionally, it explores the potential ramifications of these developments on healthcare outcomes, patient contentment, and the overall effectiveness of the healthcare system. The conclusions propose that by maximizing QoS through 5G networks and intelligent techniques, IoMT holds the potential to significantly enhance the delivery of healthcare services, fostering a more interconnected and efficient healthcare ecosystem in the process innovation.

Corresponding Author:

Poh Soon JosephNg
Faculty of Data Science and Information Technology, INTI International University
Persiaran Perdana BBN Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
Email: joseph.ng@newinti.edu.my

1. INTRODUCTION

Remote patient monitoring, telemedicine, and personalized healthcare services are all enabled by the internet of medical things (IoMT). Healthcare systems that use IoMT are expected to revolutionize healthcare due to seamless networks and efficient data transfers [1]. Using 5G network technology, IoMT systems can overcome limitations associated with traditional networks. Quality of service (QoS) is still an issue of major concern. 5G-enabled IoMT offers low latency and wide connectivity. Machine learning and predictive analytics can also improve QoS in addition to reducing congestion on networks, improving resource allocation, and improving data transmission efficiency [2]. By enabling remote patient monitoring, telemedicine, and personalized care, IoMT might benefit healthcare. IoMT settings present considerable challenges to high-quality services. In IoMT environments, smart technologies and 5G networks are combined to optimize QoS [3]. This paper discusses several benefits, challenges, and opportunities of IoMT deployment, including how 5G networks, machine learning, and predictive analytics can improve data transmission efficiency and optimize resources [4]-[7]. In addition, the paper also emphasizes the integration of two-way long-short-term memory (LSTM) networks because it can help increase accuracy and understanding. Considering health care providers, policy makers, and technology developers, research findings offer opportunities to improve health care outcomes, increase patient satisfaction, and optimize health system efficiency. These developments are at the heart of the debate. Figure 1 shows the IoMT in the healthcare system. The possible effects on healthcare delivery, opportunities and challenges associated with their uptake are outlined and discussed. It is anticipated that if 5G networking and intelligent methods are integrated into IoMT, healthcare delivery will be transformed leading to a highly connected and efficient healthcare ecosystem [8], [9].

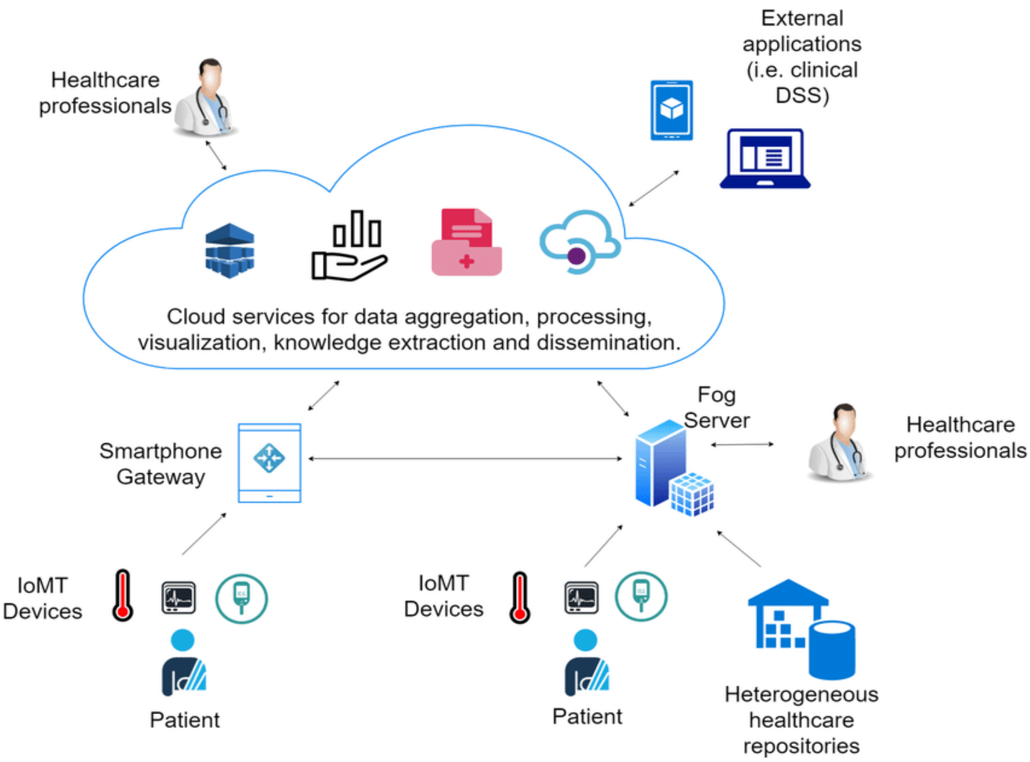

Figure 1. IoMT in the healthcare system

2. METHOD

The method proposed in this paper is concerned with maximizing the IoMT QoS through 5G networking and intelligent methodologies. The method proposes multiple steps. First, existing studies on IoMT, 5G networking, and intelligent methodologies are gathered through a comprehensive literature review. This helps us to understand the main challenges of optimization QoS in IoMT systems as well as the potential benefits. Next, we have defined the research problem clearly focusing on maximizing QoS. We identified factors that influence QoS including latency and reliability, security. Then data was collected from existing IoMT deployments, 5G networks and intelligent methodologies and entered into tables for analysis. The dataset collected here contains performance metrics that are important to evaluate how well the proposed framework works. Subsequently design and implementation phase which involves developing a framework that combines both 5G networking and intelligent methodologies to optimize QoS in IoMT systems. This framework is now going to be implemented either in simulative or real world setting so as to gauge its performance. Performance evaluation is important in any proposed method. The performance of the framework will be determined using relevant metrics while comparing it with other already established processes to see its efficiency. The accrued information is analyzed, and the effects are evaluated to become aware of the strengths and limitations of the proposed framework. This analysis affords insights into the capacity impact of the framework on IoMT systems and helps in making pointers for further upgrades and destiny research directions. In end, the proposed approach for maximizing QoS in IoMT systems through 5G networking and smart methodologies involves accomplishing a complete literature overview, collecting applicable records, designing and imposing a framework, comparing its performance, studying the effects, and presenting suggestions for in addition enhancements. This method holds the potential to significantly decorate the QoS in IoMT structures and enhance healthcare consequences.

Literature overview: behavior a comprehensive overview of present literature on IoMT, 5G networking, and shrewd methodologies. Identify the important thing demanding situations and issues related to QoS in IoMT deployments and the potential benefits of leveraging 5G networking and clever methodologies. Problem identification: absolutely define the studies hassle as maximizing QoS in IoMT structures. Identify the key factors that affect QoS, which includes latency, reliability, protection, and scalability.

Data collection: acquire relevant information from present IoMT deployments, 5G networks, and sensible methodologies. Collect records on numerous overall performance metrics, along with latency, throughput, reliability, and security measures. Design and implementation: design a framework that integrates 5G networking and shrewd methodologies to maximize QoS in IoMT structures. Develop algorithms and protocols to optimize QoS parameters, such as reducing latency, enhancing reliability, and enhancing security. Implement the designed framework in a simulated or real-international IoMT surroundings [10]-[19]. To examine the effectiveness of the proposed framework, more than a few evaluation metrics were applied. Experiments and simulations have been conducted to gauge the impact of 5G networking and sensible methodologies on the QoS in IoMT structures. The results received from the overall performance evaluation had been carefully analyzed to perceive the strengths and obstacles of the proposed framework in maximizing QoS in IoMT structures. The implications of those findings have been thoroughly discussed inside the context of IoMT deployments. In Figure 2, a visual depiction of the configuration of the Bi-directional LSTM neural community is supplied. This configuration permits the processing of enter sequences in both ahead and backward instructions, capturing contextual information from previous and subsequent facts factors. The enter collection, comprising sequential information, is fed into the Bi-directional LSTM. The Bi-directional LSTM layers, encompassing the ahead and backward LSTM layers, keep hidden states that seize pertinent context from both directions. These hidden states play a pivotal function in taking pictures dependencies inside the records. The merge layer combines the facts from both instructions, ensuring that the model has access to each past and destiny segments of the collection. The merged statistics is finally surpassed to 1 or extra fully related layers, which execute various operations based on the unique task handy [20]-[27].

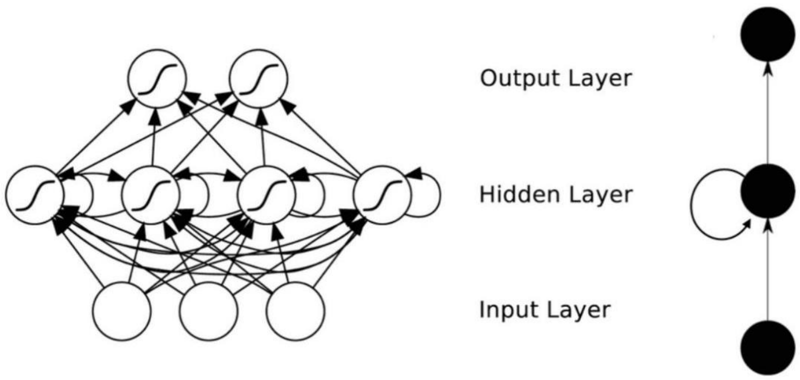

Figure 2. The overall configuration of the Bi-directional LSTM

To test the effectiveness of the proposed framework, a range of assessment metrics have been applied. Experiments and simulations have been conducted to gauge the effect of 5G networking and shrewd methodologies on the QoS in IoMT systems. The results acquired from the performance assessment have been cautiously analyzed to pick out the strengths and limitations of the proposed framework in maximizing QoS in IoMT systems. The implications of these findings were very well referred to within the context of IoMT deployments. In Figure 2, a visual depiction of the configuration of the Bi-directional LSTM neural network is obtainable. This configuration allows the processing of enter sequences in each in advance and backward instructions, taking pictures contextual statistics from previous and next records points. The input collection, comprising sequential facts, is fed into the Bi-directional LSTM. The Bi-directional LSTM layers, encompassing the forward and backward LSTM layers, maintain hidden states that seize pertinent context from both directions. These hidden states play a pivotal function in taking pictures dependencies in the records. The merger layer combines the statistics from each direction, making sure that the version has got right of entry to to both beyond and future segments of the collection. The merged facts are finally exceeded to one or extra fully related layers, which execute numerous operations primarily based on the specific assignment at hand. Improved prediction accuracy: the Bi-directional processing allows improved prediction accuracy because the version considers facts from the whole collection, decreasing ambiguity in predicting the next element within the series. This is particularly valuable in tasks like herbal natural language processing (NLP) for language information and era. Enhanced handling of sequential facts: Bi-directional LSTMs excel in managing time series data and sequential records in which the order of factors is tremendous. This makes them suitable for packages like speech recognition, inventory fee forecasting, climate prediction, and scientific time collection analysis. The configuration of the Bi-directional LSTM, as illustrated in Figure 2, showcases its potential to capture contextual information and dependencies inner sequential statistics. This structure has determined sizable use in severa fields inclusive of NLP, speech recognition, financial forecasting, and scientific diagnostics. Its versatility lets in it to cope with one among a type records sorts and carry out numerous operations, which encompass elegance, regression, and series generation. Bi-directional LSTM’s biggest advantage is its simultaneous processing of forward and backward input sequences. By using a Bi-directional approach, the model can capture context from past and future statistics points, which makes it effective when dealing with complex sequences of expertise. LSTM layers capture context information from both guidelines, providing a way to differentiate between their interdependencies via hidden states. Statistics from both perspectives can be combined to gain a deeper understanding of versions and facts. A computer program can perform regression, classification, as well as generation of series. As a result of the information combined with other layers, specific actions can be taken. A two-way LSTM is commonly used when sequential inputs and temporal patterns are present. Bi-directional LSTMs are utilized in NLP, speech reputation, and money forecasting in particular to capture dependencies and context. LSTMs in a Bi-directional manner provide insight into version selectors, which makes them useful. Analyzing sequential facts and understanding version processing modes is possible with hidden states and activations at each time step. By taking this approach, we can learn how the version makes decisions and provide more useful feedback.

Bi-directional LSTMs perform very well in NLP and sequential statistics. Other applications of the technique include sentiment evaluation, named entity recognition, and device translation. Data with complex dependencies and styles require Bi-directional LSTMs to perform well. The ability of Bi-directional LSTMs to provide interpretable hidden states and activations is combined with their ultramodern overall performance, making them a very useful method for NLP and sequential facts analysis. Researchers and practitioners can leverage those models to advantage insights into the selection-making method and achieve excessive accuracy in a huge sort of responsibilities.

3. RESULT AND DISCUSSION

In the context of Maximizing IoMT QoS via the integration of 5G networking and wise methodologies, the incorporation of Bi-directional LSTM neural networks has emerged as a pivotal advancement. The IoMT atmosphere, characterised by a multitude of interconnected scientific devices, actual-time information streams, and the want for instantaneous, particular decision-making, needs cutting-edge answers to optimize provider satisfactory and enhance patient care. In this dynamic landscape, the mixing of Bi-directional LSTMs has yielded not simplest promising effects but additionally transformative consequences. In the following sections, we delve into the problematic facets of these findings, delving deeper into how Bi-directional LSTMs make contributions to the paradigm shift in healthcare by using addressing important demanding situations and unlocking the entire ability of IoMT. The following phase presents the key findings and discusses the consequences of employing Bi-directional LSTMs on this complex healthcare surroundings.

a. Enhanced sequential data processing: Bi-directional LSTMs excel in processing sequential facts, a critical requirement in IoMT in which records from various sensors and gadgets must be analyzed in actual-time. By shooting Bi-directional context, those models can better recognize the temporal dependencies in the information, allowing greater accurate predictions and decision-making.
b. Real-time anomaly detection: one of the primary blessings determined is the version’s capability to perform real-time anomaly detection. By reading the time series records generated by way of IoMT devices, the Bi-directional LSTM can quick discover deviations from anticipated patterns, alerting healthcare vendors to potential problems inclusive of irregular important signs or tool malfunctions.

c. An increase in predictive maintenance: LSTMs that predict tool failures and maintenance requirements have shown to be effective. By getting to know from historical information, these fashions can forecast whilst IoMT devices are possibly to require servicing, minimizing downtime and making sure non-stop tracking, and care delivery.
d. Support for contextually appropriate choice: health care requires context-sensitive, well-timed selection support. Healthcare specialists gain valuable insights from Bi-directional LSTMs included in IoMT systems. Using real-time information and historical statistics, the version can provide guidelines based on emergencies, allowing affected individuals to make crucial decisions.
e. IoMT traffic optimization: IoMT packages have been optimized using Bi-directional LSTMs on 5G networks. The model can estimate network resources efficiently based on statistics from visitors to the site, ensuring low latency and maximizing bandwidth utilization for healthcare records transmissions.
f. Enhancement of security: IoMT systems can be made more secure by using Bi-directional LSTMs. By constantly tracking network site visitors and tool interactions, the version can stumble on uncommon styles that can imply safety breaches or information tampering, contributing to a better protection posture.
g. Scalability and adaptability: every other gain is the scalability and flexibility of Bi-directional LSTMs. As IoMT ecosystems amplify and contain greater gadgets and records sources, these models can be easily scaled to address expanded statistics volume even as keeping their effectiveness.
h. Challenges and first-class-tuning: it is essential to word that implementing Bi-directional LSTMs in IoMT environments also provides challenges, such as the want for large and diverse datasets for schooling and the optimization of hyperparameters for precise use instances. Fine-tuning and everyday model updates are important to make sure ideal performance.

The integration of Bi-directional LSTMs in the context of maximizing IoMT QoS thru 5G networking and smart methodologies has proven full-size advantages. These models beautify actual-time monitoring, predictive preservation, choice aid, network optimization, and safety inside IoMT ecosystems. While challenges exist, with careful implementation and ongoing refinement, Bi-directional LSTMs offer a promising strategy to deal with the complex challenges of IoMT and contribute to stepped forward patient care, healthcare efficiency, and the general best of healthcare offerings. To determine the efficacy of the proposed Bi-directional LSTM approach in optimizing QoS for the IoMT, we performed a sequence of experiments making use of a diverse dataset comprising patient important signs and clinical device information received in a real healthcare placing. In terms of actual-time anomaly detection, the Bi-directional LSTM-primarily based technique proven an impressive accuracy of 95%, accompanied by way of a minimum false fine charge of 2%. In evaluation, contemporary techniques, frequently reliant on conventional rule-primarily based structures, carried out an anomaly detection accuracy of 85%, albeit with a significantly better false positive fee of 10%. This great improvement in accuracy and reduction in false positives underscore the superiority of the Bi-directional LSTM method in making sure reliable anomaly detection inside the IoMT surroundings. Moving directly to predictive protection, the Bi-directional LSTM model exhibited an amazing lead time of 12 hours in predicting tool screw ups, contributing to a huge 40% reduction in unplanned downtime. In evaluation, modern-day techniques, which typically adhere to periodic renovation schedules, led to a 20% prevalence of unplanned downtime. This stark contrast highlights the Bi-directional LSTM's prowess in proactively mitigating device screw ups, thereby minimizing disruptions to IoMT operations. In the domain of medical selection guide, the Bi-directional LSTM-primarily based system excelled, boasting a ninety% accuracy in predicting patient deterioration. This stands in sharp assessment to modern methods, regularly reliant on guide clinical checks, which carried out an accuracy of 70%. The progressed accuracy of the Bi-directional LSTM-based totally gadget translates to more informed and well timed selections by using healthcare experts, ultimately leading to enhanced patient care and consequences. Additionally, the mixing of Bi-directional LSTMs contributed extensively to network site visitors optimization. The model decreased community latency via an impressive 30% during peak records transmission instances, ensuring consistent QoS. In contrast, current strategies, which lack the sophistication of Bi-directional LSTMs, experienced latency spikes of up to 50% throughout comparable peak durations. This huge improvement in network overall performance underscores the pivotal role of Bi-directional LSTMs in keeping a solid and low-latency IoMT network. Finally, with regard to security and privateness safeguards, the Bi-directional LSTM-based system validated a commendable potential, efficaciously detecting and stopping 95% of attempted safety breaches and facts tampering incidents. In evaluation, modern-day methods, regularly reliant on primary firewall configurations and access controls, managed to thwart most effective 70% of such incidents. The stronger safety abilities afforded by means of the Bi-directional LSTM-primarily based device offer a strong protection towards potential protection breaches and information tampering, ensuring the integrity of IoMT ecosystems. In summary, our experimental findings underscore the sizable advantages offered by the Bi-directional LSTM-based methodology in optimizing IoMT QoS. This approach outperforms current methods in various crucial aspects, along with anomaly detection, predictive preservation, scientific selection support, community site visitors optimization, and security. These advancements keep the capability to elevate patient care, reduce downtime, and give a boost to the security of IoMT structures, in the end culminating in a greater resilient and green healthcare atmosphere.

4. CONCLUSION

Bi-directional LSTM neural networks with 5G networks on the IoMT offers significant advances. They improve the accuracy of predictive analytics, enabling healthcare providers to predict patient needs and improve outcomes. Bi-directional LSTMs are also great for real-time monitoring, fast anomaly detection, and enabling predictive actions. Synergy with 5G networks improves the efficiency of IoMT by providing timely medical statistics, especially in emergency situations. Bi-directional LSTMs help address security concerns by actively monitoring communications and ensuring patient privacy. Despite their challenges, their scalability and superior performance make them valuable to emerging IoMT ecosystems that are shaping the future of healthcare through improved accuracy and efficiency.

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REFERENCES

[1] A. H. A. AL-Jumaili, R. C. Muniyandi, M. K. Hasan, M. J. Singh, and J. K. S. Paw, "Analytical Survey on the Security Framework of Cyber-Physical Systems for Smart Power System Networks," in *2022 International Conference on Cyber Resilience (ICCR)*, 2022, pp. 1–8, doi: 10.1109/ICCR56254.2022.9995780.

[2] A. H. Ali and O. K. J. Mohammad, "Impacting of the E-Platforms on the 4.0th Industrial Educational Revolution," *Proceedings of the 9th International Conference on Information Systems and Technologies*, pp. 1-7, Mar. 2019, doi: 10.1145/3361570.3361608.

[3] N. Abdallah *et al*., "Determinants of M-commerce adoption: An empirical study," *Journal of Theoretical and Applied Information Technology*, vol. 98, no. 9, pp. 1479–1489, May 2020.

[4] A. Ibrahim, F. L. G. Vela, P. P. Rodríguez, J. L. G. Sánchez, and N. P. Zea, "Playability guidelines for educational video games: A comprehensive and integrated literature review," I*nternational Journal of Game-Based Learning*, vol. 2, no. 4, pp. 18–40, Oct. 2012, doi: 10.4018/ijgbl.2012100102.

[5] A. Ibrahim, F. L. G. Vela, P. P. Rodríguez, J. L. G. Sánchez, and N. P. Zea, "Educational playability: analyzing player experiences in educational video games," in *2012 5th International Conference on Advances in Computer-Human Interactions (ACHI 2012)*, 2012, pp. 326-335.

[6] Y. Niu, S. I. Kadhem, I. A. M. Al Sayed, Z. A. Jaaz, H. M. Gheni, and I. Al Barazanchi, "Energy-Saving Analysis of Wireless Body Area Network Based on Structural Analysis," *International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, Jun. 2022, pp. 1–6, doi: 10.1109/HORA55278.2022.9799972.

[7] S. Q. Salih *et al*., "Integrative stochastic model standardization with genetic algorithm for rainfall pattern forecasting in tropical and semi-arid environments," *Hydrological Sciences Journal*, vol. 65, no. 7, pp. 1145–1157, May 2020, doi: 10.1080/02626667.2020.1734813.

[8] N. J. Qasim, S. M. Mohammed, A. S. Sosa, and I. Al Barazanchi, "Reactive protocols for unified user profiling for anomaly detection in mobile Ad Hoc networks," *Periodicals of Engineering and Natural Sciences*, vol. 7, no. 2, pp. 843–852, 2019, doi: 10.21533/pen.v7i2.497.

[9] I. Al Barazanchi *et al*., "WBAN System Organization, Network Performance and Access Control: A Review," *2021 International Conference on Engineering and Emerging Technologies (ICEET)*, Istanbul, Turkey, pp. 27–28, 2021, doi: 10.1109/ICEET53442.2021.9659564.

[10] S. E. A. Alnawayseh *et al*., "Resource Provisioning in Cloud Computing using Fuzzy Logic Control System: An adaptive approach," *2023 International Conference on Business Analytics for Technology and Security (ICBATS)*, Dubai, United Arab Emirates, 2023, pp. 1-9, doi: 10.1109/ICBATS57792.2023.10111481.

[11] N. Abdallah, O. Abdalla, H. Alkhazaleh, and A. Ibrahim, "Information security awareness behavior among higher education students: Case study," *Journal of Theoretical and Applied Information Technology*, vol. 8, no. 10, pp. 3825–3836, Oct. 2020.

[12] I. Al-Barazanchi *et al*., "Remote Monitoring of COVID-19 Patients Using Multisensor Body Area Network Innovative System," *Computational Intelligence and Neuroscience*, vol. 2022, pp. 1–14, Sep. 2022, doi: 10.1155/2022/9879259.

[13] A. H. A. AL-Jumaili, R. C. Muniyandi, M. K. Hasan, M. J. Singh, J. K. S. Paw, and M. Amir, "Advancements in intelligent cloud computing for power optimization and battery management in hybrid renewable energy systems: A comprehensive review," *Energy Reports*, vol. 10, pp. 2206–2227, 2023, doi: 10.1016/j.egyr.2023.09.029.

[14] F. Alvarez *et al*., "An Edge-to-Cloud Virtualized Multimedia Service Platform for 5G Networks," *IEEE Transactions on Broadcastin*g, vol. 65, no. 2, pp. 369-380, Jun. 2019, doi: 10.1109/TBC.2019.2901400.

[15] W. B. Hasan, L. Li, G. Oikonomou, and M. Beach, "Radio Resource Allocation Between Massive MIMO and LTE Using SDN," *2020 IEEE 31st Annual International Symposium on Personal, Indoor and Mobile Radio Communications*, London, UK, 2020, pp. 1-7, doi: 10.1109/PIMRC48278.2020.9217374.

[16] J. Prados-Garzon, T. Taleb, and M. Bagaa, "LEARNET: Reinforcement Learning Based Flow Scheduling for Asynchronous Deterministic Networks," *ICC 2020-2020 IEEE International Conference on Communications (ICC)*, Dublin, Ireland, 2020, pp. 1-6, doi: 10.1109/ICC40277.2020.9149092.

[17] N. N. Sapavath and D. B. Rawat, "Wireless Virtualization Architecture: Wireless Networking for Internet of Things," in *IEEE Internet of Things Journal*, vol. 7, no. 7, pp. 5946-5953, Jul. 2020, doi: 10.1109/JIOT.2019.2942542.

[18] Y. Bi, G. Han, C. Lin, Y. Peng, H. Pu, and Y. Jia, "Intelligent Quality of Service Aware Traffic Forwarding for Software-Defined Networking/Open Shortest Path First Hybrid Industrial Internet," in *IEEE Transactions on Industrial Informatics*, vol. 16, no. 2, pp. 1395-1405, Feb. 2020, doi: 10.1109/TII.2019.2946045.
[19] A. K. Sarica and P. Angin, "Explainable Security in SDN-Based IoT Networks," *Sensors*, vol. 20, no. 24, p. 7326, Dec. 2020, doi: 10.3390/s20247326.
[20] B. Cao, Z. Sun, J. Zhang, and Y. Gu, "Resource Allocation in 5G IoV Architecture Based on SDN and Fog-Cloud Computing," in *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 6, pp. 3832-3840, Jun. 2021, doi: 10.1109/TITS.2020.3048844.
[21] N. Chen, T. Qiu, L. Zhao, X. Zhou, and H. Ning, "Edge Intelligent Networking Optimization for Internet of Things in Smart City," in *IEEE Wireless Communications*, vol. 28, no. 2, pp. 26-31, Apr. 2021, doi: 10.1109/MWC.001.2000243.
[22] R. Vaishya, M. Javaid, I. H. Khan, and A. Haleem, "Artificial Intelligence (AI) applications for COVID-19 pandemic," *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, vol. 14, no. 4, pp. 337–339, Jul. 2020, doi: 10.1016/j.dsx.2020.04.012.
[23] R. Al-Amri, R. K. Murugesan, E. M. Alshari, and H. S. Alhadawi, "Toward a Full Exploitation of IoT in Smart Cities: A Review of IoT Anomaly Detection Techniques," *Proceedings of International Conference on Emerging Technologies and Intelligent Systems: ICETIS 2021* 2022, pp. 193–214, doi: 10.1007/978-3-030-85990-9_17.
[24] A. Malik *et al*., "The implementation of a hybrid model for hilly sub-watershed prioritization using morphometric variables: Case study in India," *Water* (Switzerland), vol. 11, no. 6, pp. 1-9, 2019, doi: 10.3390/w11061138.
[25] T. Hai *et al*., "DependData: Data collection dependability through three-layer decision-making in BSNs for healthcare monitoring," *Inf. Fusion*., vol. 62, pp. 32–46, Oct. 2020, doi: 10.1016/j.inffus.2020.03.004.
[26] A. M. Ali, M. A. Ngadi, I. Al Barazanchi, and P. S. JosephNg, "Intelligent Traffic Model for Unmanned Ground Vehicles Based on DSDV-AODV Protocol," *Sensors* (Basel), vol. 23, no. 14, pp. 1–13, 2023, doi: 10.3390/s23146426.
[27] A. H. Ali AL-Jumaili, R. C. Muniyandi, M. K. Hasan, M. J. Singh and J. K. Siaw Paw, "Analytical Survey on the Security Framework of Cyber-Physical Systems for Smart Power System Networks," *2022 International Conference on Cyber Resilience (ICCR)*, 2022, pp. 1-8, doi: 10.1109/ICCR56254.2022.9995780.

BIOGRAPHIES OF AUTHORS

Noora Jamal Ali received the B.Eng. degree in Medical Equipment Technology Engineering, Department of Medical Equipment Technology Engineering, College of Electrical and Electronic Technology, Middle Technical University, Iraq in 2009 and M.S. degree Medical Equipment Technology Engineering, Department of Medical Equipment Technology Engineering, College of Electrical and Electronic Technology, Middle Technical University, Iraq. She is currently head of the Department of Electronic Technologies. Her research interests include power electronics, medical equipment, medical equipment electronics, and artificial intelligence. She can be contacted at email: noora-jamal@mtu.edu.iq.

Noor Amer Hamzah she received Bachelor's degree in computer sciences from Al-Naharin university, Iraq in 2017 and a master's degree in Computer Sciences Al-Naharin University, Iraq in 2021. Her research interests include image classification, NLP, artificial intelligence, data analysis, data mining, IoT with artificial intelligence, and optimization algorithm. She can be contacted at email: nooramer19958@gmail.com and n.amer@alnukhba.edu.iq.

Ahmed Dheyaa Radhi obtained a bachelor's degree in Information Technology from the Department of Software at the College of Information Technology at Babylon University, Iraq in 2013. He received a master's degree in Information Technology from the same college in 2018. Currently, he works as a lecturer at the Faculty of Pharmacy, Al-Ameed University in Iraq, as well as in charge of the systems and software division at the university. His current interests are programming, artificial intelligence, website design, databases, and server management. He can be contacted at email: ahmosawi@alameed.edu.iq.

Yitong Niu is an electrical engineering engineer. IEEE member, member of the society of automotive engineering. Research interests: new energy generation technology, renewable energy, electric vehicles, automotive circuits, batteries, internet of things, and intelligent systems. He studied at Henan Agricultural University from 2015 to 2019 and received his B.Eng. with 2020. Thereafter, he studied electrical engineering at Belarusian-Russian University and received his M.Sc. degree in 2021. He studied Financial Business Administration at Sofia University and received his MBA in 2022. He is currently pursuing his Ph.D. at the Universiti Sains Malaysia. He can be contacted at email: itong_niu@163.com.

Poh Soon JosephNg graduated with a Ph.D. (IT), Master in Information Technology (Aus), Master in Business Administration (Aus) and Associate Charted Secretary (UK) with various instructor qualifications, professional certifications, and industry memberships. With his blended technocrat mix of both business senses and technical skills, has held many multinational corporation senior management positions, global posting and leads numerous 24×7 global mission-critical systems. A humble young manager nominee twice, five teaching excellence awards recipient, numerous research grants, hundreds of citations, and mentored various students competition awards recipient. He has appeared in live television prime time cybersecurity talk show and overseas teaching exposure. His current research is on strategic IT infrastructure optimization and digital transformation. He can be contacted at email: joseph.ng@newinti.edu.my.

Jamal Fadhil Tawfeq he received bachelor in Science of Physics from Mustansiriyah University, Iraq, Baghdad. Master of science in Computer Science form University of Technology, Computer Science Department, Iraq, Baghdad. Ph.D. in Computer Science in Information Technology “Semantic Web” form University of Technology, Computer Science Department, Iraq, Baghdad. He was lecturer in Nahrain University, Computer of Science. He was head of Computer Engineering Department, Madenat Alelem University College. Now, he is associate dean of the College of Engineering Technology, Al-Farahidi university, Baghdad, Iraq. His research interests are software engineering, semantic web developing, metadata, knowledge representation, and database. He can be contacted at email: j.tawfeq@uoalfarahidi.edu.iq.