Guest Editorial: Special Section on 5G Edge Computing-Enabled Internet of Medical Things

***Abstract*—The relationship between computing and healthcare has a long history, but adoption of telemedicine is gradual due to political resistance, lack of infrastructure development frameworks, and lack of resources. One of the most rapid technological advancements will be the Internet of Medical Things (IoMT), which is predicted to bring about the greatest technological delivery ever. Edge computing in conjunction with 5G speed is the solution to achieve the requirements of quality of service metrics metrics during the analysis of clinical data. Artificial intelligence with edge computing has made significant contributions to the smart healthcare system's network for ultra-reliable communication in the areas of less delay, widespread device connectivity, and enhanced speed of data transmission. Since the edge-enabled IoMT-based system in the healthcare system offers a number of extraordinary potential, this Special Issue explores those areas of applicability. The aim of Special Issue is to cover the research difficulties associated with the implementation of edge computing-based IoMT systems in the healthcare system and suggests a framework for such a system.**

***Index Terms*—5G, edge computing, Internet of Medical Things (IoMT), Internet of Things (IoT).**

I. Introduction

With the growth of edge computing and 5G, the technologies of healthcare are drifted away from the local hospitals for monitoring the patients remotely who need it utmost especially in pandemic scenario. The edge computing architecture generates and consumes the data easier by Internet of Medical Things (IoMT), such as nurses' mobile phones, physician's notebooks, patient-monitoring tools, and other medical related technologies. Numerous developments in forthcoming accessibility for more remote healthcare facilities has been increased with 5G edge computing. Advanced artificial intelligence (AI) technologies has also accelerated the growth in various applications, such as safety of patients, management of chronic diseases, safety of drug supply chain, and so on [A1]. For the safety and monitoring of patient health, sensors and cameras are utilized to notify risk management schemes by following observance with the clinic sanitation strategies. The IoMT devices and sensors that facilitate the persistent monitoring of patients are used to give alerts to the caretakers of clinically significant variants as well as prospects for early interventions. Those same devices could be employed to lessen the hazards in the drug supply chain by providing alerts to caretakers of issues, such as temperature variations in vaccines during transportation. The IoMT has brought together the people (patients, clinicians, and caregivers), processes (patient care and support), enablers (mobile applications and connected medical devices), and data (patient performance and data) for delivering outcome of patients effectively and efficiently. IoMT has infused the 5G edge computing high-speed wireless technologies of medical care like with connected solutions for real-time remote monitoring and analysis. With this, IoMT is capable of improving the patient's outcomes by boosting accessibility, empowering the patients to take control of their health, driving efficiencies and streamlines communication, preventing the spread of disease with solutions for in-home care, allowing for convenience and bringing expertise to remote areas, enhancing collaboration across healthcare teams, and providing more holistic view to providers. A further favorable frontier is where edge computing and AI intersect is edge AI which shifts AI-enabled decision-making by empowering the devices for the processing of data faster than the centralized IoMT models. It enable real time, more secure and automated user experience for patients and healthcare providers. Healthcare 5.0 is a boon in the medical domain as it provides various functions, such as remotely monitoring of the patient health, reducing the inventory to store the patient data digitally, and providing awareness about the next stage of diseases, as well as providing automated detection and diagnosis of diseases from the multi-modality images, controlling complex surgeries and analyzing the patient data for effective diagnosis and treatment. Now a days, IoMT is a growing trend for the potential delivery of fast and precise medical services. Various body sensors in Internet of Things (IoT)-based systems are integrated with AI, cloud computing, machine learning, and wearable devices for providing promising solutions in healthcare. However, IoT in healthcare faces various challenging issues, including scarcity of accurate and cost-effective smart healthcare sensors, the trust concerns related to the security and privacy of healthcare data, scarcity of interoperability and uniform standards across the eHealthcare appliances, heterogeneous and multidimensional healthcare data. 5G-enabled IoeHT to provide faster connectivity as compared with the traditional 4G networks. Telehealth tools with 5G and edge computing technology can also attain accessible routine checkups. Patients in rural and remote areas can connect over videos with their physicians for routine care and consultation. The IoMT-enabled 5G and edge computing technology provides various services through an infrastructure

Date of current version 30 September 2022.
Digital Object Identifier 10.1109/TII.2022.3193708

of connected medical devices, software applications, and health systems. This Special Issue (SI) invites original research in the field of IoMT for eHealth. In this issue, a cutting-edge progression in the area of 5G edge computing-enabled IoMT would be discussed by introducing efficient and innovative solutions. Further, future directions of research and developments in Healthcare 5.0 would be considered to handle the various issues and challenges in this field.

II. An Intelligent Trust Cloud Management Method for Secure Clustering in 5G Enabled Internet of Medical Things [A2]

Communication through device-to-device is a viable exemplar for 5G networks in future. It is a 5G edge computing-enabled technology that helps the IoMT in an effective way for providing decentralized clinical services. This research introduces an intelligent trust cloud management strategy to ensure reliable and secure communication in 5G edge-enabled IoMT systems. In this, a mechanism for active training has been suggested to build the common trust clouds by using fuzzy trust by concluding and acclaiming specific trust cloud is created, and a trust categorization system is suggested to identify malicious IoMT devices. A trust cloud updating method is described to make the suggested trust management technique intelligent and adaptable under wireless medium. The outcomes of the simulations show that the suggested approach can successfully handle the problem of trust uncertainty and increase the effectiveness of malicious device detection.

III. Secure Data Transmission in Internet of Medical Things Using RES-256 Algorithm [A3]

The idea of cryptographic algorithms is employed in this research as an effective access control scheme for a healthcare system powered by the IoMT. Elliptic curve digital signature algorithm is employed for encrypting the key from Rivest Cipher (RC6), and the encrypted output is then sent to secure hash algorithm (SHA256) based on cypher value for hashing, thus improving the data integrity. Rivest Cipher (RC6) is utilized for the generation of key value [A2]. in addition, these high-secure schemes are employed to ensure confidentiality and availability to safeguard private data from implantable devices for improving the quality of services (QoS) offered by the healthcare systems. The results of extensive experiment analysis and modeling show that the suggested approach is more resistant to a variety of known assaults, including denial of service, sensor attacks, and Router, according to thorough experiment analysis and simulation results. Better resistance protocols are used in this system's analysis of patient safety.

IV. A Multi-Watermarking Scheme for Verifying Medical Image Integrity and Authenticity in the Internet of Medical Things [A4]

Smart healthcare systems are proliferating in daily lives due to the development of the IoMT, 5G mobile network, and other technologies. For accurate diagnosis, treatment, and management of various illnesses, patients, physicians, and other medical professionals rely on effective and safe storage of electronic health records, and its transmission and analysis, particularly, medical images. In this article, a multiwatermarking method based on brain storm optimization algorithm and quantum random walk is suggested for use with medical photos. Text data are embedded to hide patient and private hospital information in regions of noninterest, while a logo picture used to validate the integrity of medical images is placed in regions of interest. This method helps to assure authenticity and increases the accuracy of medical picture verification. The suggested multiwatermarking scheme's capacity, security, robustness, and imperceptibility were verified by a number of experiments.

V. A Novel Resource Oriented DMA Framework for Internet of Medical Things Devices in 5G Network [A5]

While moving the IoMT devices, such as ambulance, medical devices, and emergency clinical equipment's, sometimes, experience critical distortions of signals due to handoff delays, packet loss, reduced throughput, and interference. These problems have been addressed utilizing the IP-based WiFi solution and the Network Mobility Basic Support Protocol (NBSP) [A3]. However, due to the patients' increased requirements, the handover revealed the weak signal, additional signaling overhead, and larger delays, which led to radio connection failure. In order to improve the functionality of the mobility entities and centralized network entities, this study offers a unique, resource-efficient flow-enabled distributed mobility anchoring. The performance of the proposed framework is assessed and compared with the traditional Proxy NEMO and NBSP approach in terms of the mobile routers and variable number of cell residence.

VI. FairHealth: Long-Term Proportional Fairness-Driven 5G Edge Healthcare in Internet of Medical Things [A6]

Recently, 5G edge IoMT was able to offload medical services for reducing latency. Although, several previous publications used the assumption that altruistic patients would forego QoS in favor of the overall ideal. This adequate and oversimplified assumption will undercut the engagement enthusiasm, which is unjust for healthcare that is deadline-conscious and priority-aware. Authors suggest a long-term proportional fairness-driven 5G edge-based healthcare system, called FairHealth, to overcome this problem. To begin, they set up a long-term Nash bargaining game, taking into account stochastic demand and a dynamic environment, to represent the service offloading. Then, understanding a tradeoff between service and fairness stability, a new resource scheduling method has been developed that decoupled the long-term fairness problem to subproblems. Moreover, a block-coordinate descent approach has been suggested for iteratively resolving the nonconvex fair subproblems. According to the simulation results, when compared with the traditional global time-optimal scheme, their method can increase the fairness index (also known as the Nash product) by 74.44% [A4].

VII. In the Digital Age of 5G Networks: Seamless Privacy-Preserving Authentication for Cognitive-Inspired Internet of Medical Things [A7]

AI and cognitive science are combined in the cognitive-inspired IoMT for interaction with people and pervasive digital environments. Massive amounts of data are produced by IoT devices, which are then processed by cognitive computing for the effective analysis at the edge. The IoMT designed the intelligent communication systems for enabling the ubiquitous services using the aforementioned analysis. The protocols utilized in IoMT, however, rely on quantum-computer attack-prone conventional number theory systems. Therefore, handling access privacy, preservation, and trust assurance requires an effective CI-IoMT approach. In order to approve connections between smart devices, this study introduced an identity-based seamless privacy preservation. To reduce access times in an emergency, it solely relies on quick user verification [A5]. The simulation research demonstrates that, in comparison to other current systems, the suggested IB-SPP approach used the less data volume and minimal reaction time.

VIII. DCA-IoMT: Knowledge Graph Embedding-Enhanced Deep Collaborative Alerts-Recommendation Against COVID19 [A8]

Since there are so many options available online, filtering to the highest degree of accuracy is essential. Although knowledge graph embedding has a significant impact on recommendations, current knowledge graph (KG)-based schemes only utilized the correlations between stand-alone entities and preferences, not the tendencies and cocurricular characteristics of the environment. Another crucial use of the present and future IoMT is to recommend the region-aware preventive alerts to the specific persons, which necessitates the association of recent location-based COVID-19 data into KG. In order to deal with the dilemma, a revolutionary deep collaborative alerts (DCA) recommendation technique has been provided. In particular, DCA gathered up-to-date web information on COVID-19, cleaned it, and converted it to KG. To determine probable connections, matrix factorization is used to compute the biend hidden factors. In addition, cross transistor and relevance estimator are set up for improving the model's capacity for generalization. Two datasets are used in experiments for the testing of DCA efficacy. Analysis of results demonstrated that the suggested strategy has done better than the state-of-art methods while still offering the necessary recommendations [A8].

IX. ANAF-IoMT: A Novel Architectural Framework for IoMT Enabled Smart Healthcare System by Enhancing Security Based on RECC-VC [A9]

The IoMT is a new trend that offers a variety of efficient and effective services but security remains a problem that must be overcome. The adoption of IoMT is seriously jeopardized by novice users' lack of security awareness as well as the possibility of various attacks for getting health-related information. In this article, a security improvement to the IoMT that is centered on RECC-VC is proposed. First, this method preserved the privacy by using the exponential K-anonymity algorithm Second, an improved Elman neural network (IENN) has been suggested for examining the data sensitivity degree. In this IENN, weight update is done via the GMCO. In order to securely upload the data to the cloud server, a novel RECC-VC is suggested. In addition, blockchain technology is used to store the data on the cloud server. The suggested procedures perform better than the standard ones in experimental analysis. The suggested IENN model is validated using cutting-edge techniques and achieves accuracy of 96%. In addition, the RECC-VC proposal achieves a 98% security level.

X. Conclusion

In this SI, main focus is on 5G-enabled edge computing for IoMT. Different methodologies for secure IoMT, watermarking scheme, resource-oriented framework, long-term resource scheduling for 5G in IoMT, and recommendation for COVID-19, are parented in this SI, which are exploratory in nature.

Syed Hassan Ahmed Shah, *Guest Editor*
Department of Computer Science
California State University
Fullerton, CA 92831 USA

Deepika Koundal, *Guest Editor*
Department of Systematic, School of Computer Science
University of Petroleum Energy Studies
Dehradun 248007, India

Vyasa Sai, *Guest Editor*
Intel Corp.
Folsom, CA 95630 USA

Shalli Rani, *Guest Editor*
Institute of Engineering and Technology
Chitkara University
Rajpura, Punjab 140401, India

Appendix
Related Articles

[A1] L. Sun, X. Jiang, H. Ren, and Y. Guo, "Edge-cloud computing and artificial intelligence in Internet of Medical Things: Architecture, technology and application," *IEEE Access*, vol. 8, pp. 101079–101092, 2020.

[A2] L. Yang, K. Yu, S. X. Yang, C. Chakraborty, Y. Lu, and T. Guo, "An intelligent trust cloud management method for secure clustering in 5G enabled Internet of Medical Things," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2021.3128954.

[A3] S. M. Nagarajan, G. G. Deverajan, K. U, T. M, M. D. Alshehri, and S. Alkhalaf, "Secure data transmission in Internet of Medical Things using RES-256 algorithm," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2021.3126119.

[A4] F. Yan, H. Huang, and X. Yu, "A multi-watermarking scheme for verifying medical image integrity and authenticity in the Internet of Medical Things," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2022.3159863.

[A5] M. K. Hasan et al., "A novel resource oriented DMA framework for Internet of Medical Things devices in 5G network," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2022.3148250.

[A6] X. Lin, J. Wu, A. K. Bashir, W. Yang, A. Singh, and A. A. AlZubi, "FairHealth: Long-term proportional fairness-driven 5G edge healthcare in Internet of Medical Things," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2022.3183000.

[A7] B. D. Deebak, F. H. Memon, S. A. Khowaja, K. Dev, W. Wang, and N. M. F. Qureshi, "In the digital age of 5G networks: Seamless privacy-preserving authentication for cognitive-inspired Internet of Medical Things," *IEEE Trans. Ind. Informat.*, May 3, 2022, doi: 10.1109/TII.2022.3172139.

[A8] N. Khan, Z. Ma, A. Ullah and K. Polat, "DCA-IoMT: Knowledge graph embedding-enhanced deep collaborative alerts-recommendation against COVID19," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2022.3159710.

[A9] M. Kumar, Kavita, S. Verma, A. Kumar, M. F. Ijaz, and D. B. Rawat, "ANAF-IoMT: A novel architectural framework for IoMT enabled smart healthcare system by enhancing security based on RECC-VC," *IEEE Trans. Ind. Informat.*, to be published, doi: 10.1109/TII.2022.3181614.