Chapter

Perspective Chapter: Internet of Things in Healthcare – New Trends, Challenges and Hurdles

Luis Muñoz-Saavedra, Francisco Luna-Perejón, Javier Civit-Masot and Elena Escobar-Linero

Abstract

Applied to health field, Internet of Things (IoT) systems provides continuous and ubiquitous monitoring and assistance, allowing the creation of valuable tools for diagnosis, health empowerment, and personalized treatment, among others. Advances in these systems follow different approaches, such as the integration of new protocols and standards, combination with artificial intelligence algorithms, application of big data processing methodologies, among others. These new systems and applications also should face different challenges when applying this kind of technology into health areas, such as the management of personal data sensed, integration with electronic health records, make sensing devices comfortable to wear, and achieve an accurate acquisition of the sensed data. The objective of this chapter is to present the state of the art, indicating the most current IoT trends applied to the health field, their contributions, technologies applied, and challenges faced.

Keywords: IoT systems, healthcare, eHealth, telehealth, medical support

1. Introduction

In recent years, the set of technologies encompassed under the name of the Internet of Things has experienced its greatest evolution and is currently approaching the slope of enlightenment of the hype cycle according to Gartner [1]. It has been applied in numerous areas, notably changing and improving the way in which different tasks and activities, both business and personal, are approached in daily life. Devices such as home assistants, home automation devices, and activity monitors are used more and more widely, providing information and functionalities that can be used quickly and easily.

One of the fields where there is more expectation about the application of this set of technologies is that related to healthcare and telehealth. Currently, there are several problems inherent in the health field that can be addressed thanks to the remote communication offered by the IoT. Advances in telehealth allow medical consultations and follow-up of patients in remote and isolated places, or with the limited mobility [2]. On the other hand, they enable the interconnection between health centers and remote systems that monitor elderly or disabled people who live alone or spend part of the time without company at all times, controlling vital signs or possible events such as falls that could endanger their lives [3].

Likewise, health services can be improved and optimized when health centers are provided with the capacity to integrate and interconnect devices that collect biomedical information with electronic health records [4]. Diagnosis, treatment, and follow-up in recovery from illnesses can be benefited in many cases by the continuous collection of these data [5], which complements the information obtained with specific observations that the medical professional can make during consultations, often limited in time. In addition, the data collected are a valuable source of information that can be used by Big Data and Artificial Intelligence applications to make new discoveries.

Although the advantages of these technologies applied to healthcare are clearly beneficial in many areas, there are also many aspects that make their implementation a challenging task. Due to the sensitive nature of the information, the technologies that must be implemented are those with characteristics that allow compliance with data privacy and security policies and standards [6]. On the other hand, they require health systems to have an appropriate infrastructure to accommodate these new technologies, as well as the adaptation of their protocols [7]. The training of health technicians, professionals, and patients to adapt them to these new systems is another relevant factor, and one that is related to usability and user experience [8].

Our purpose with this work is to analyze the evolution of IoT applied to healthcare and telehealth in recent years, the trends in application and what challenges currently exist. To address this objective, we will analyze the most relevant works in the recent years to draw conclusions about the global evolution of these technologies, check in more detail the problems they face, and identify whether there are standards, norms, or common complementary technologies to give a solution.

The rest of the article is divided as follows: In section two, the methodology of collection and analysis carried out are presented, detailing the aspects and characteristics on which we focus, in section three the results obtained are presented, and finally, the last section presents the conclusions.

2. Methodology

2.1 Search approach

The criteria established for the inclusion of studies in the analysis were that they had to be published in journals that appeared in the Journal Citation Reports (JCR) or in conferences included in prestigious journal editorials and digital libraries. The search engine used for the search engine was Google Scholar. The search was limited considering articles published in the last 5 completed years, that is, from January 2017 to December 2021 inclusive. The queries created to be used in the search engine consisted of the combinations of the term “IoT” with “healthcare,” “ehealth,” and “telehealth.” The search for these terms was established to be carried out on the full text of each work, not only on the title and abstract. Since the purpose is to collect current advances and trends, we exclude from the analysis those articles with a scoping review nature. Similarly, we exclude studies that were written in a language other than English.

Regarding the results obtained after carrying out the search, the first three hundred were taken for each year in order of relevance, and one hundred for each of the three keywords considered in combination with "IoT," that is, "healthcare," "telehealth," and "ehealth." It was established to do a sequential filtering on the set, checking on each result that it meets each of the established inclusion requirements; otherwise, it will be discarded from the final set of results to be considered in the analysis. In the first place, the character of a high-impact journal paper or publication presented at a conference contemplated in prestigious digital libraries was verified, for which those results that were books or book chapters were also discarded. Next, the discarding of articles that were not written in English was applied. We considered that, to have a meaningful sample of current trends, a sample of 25 results would be taken for each combination of keyword and year. The most cited articles were used as a selection criterion. On this sample, studies consisting of bibliographic reviews were discarded. This last-filtering process was carried out firstly by analyzing the title of each publication and secondly by analyzing the abstract. Additionally, it was observed whether any study was replicated in the set or belonged to the same authors and the purpose was the same, in which case the study with the latest publication date was discarded.

For the initial purpose of filtering, basic information about these works was collected, specifically the title of the article, abstract, authors, access link to the publication, the number of citations, and character of the document according to Google Scholar. All the analyses of the information and filtering process were carried out jointly by the authors and verified between them.

2.2 Extracted information

Once the filtering process was carried out, the next step was to extract the relevant information for the analysis of the current situation, limitations, challenges, solutions, and current trends of IoT applied to healthcare and telemedicine. Mainly, we focus on extracting the most used communication technologies to provide solutions or address current problems in this area of research. Other relevant characteristics extracted were the scope of application from the point of view of what aspect of healthcare is intended to address or what characteristics of the infrastructure are intended to be addressed in the study. Related to the field, we also extract information on the technological aspects of the solution provided. Additionally, the country of the institution that supports each investigation was taken, in order to identify those countries that have the greatest impact worldwide in IoT for ehealth and telehealth fields.

3. Results and discussion

3.1 Results obtained after filtering process

After the filtering process, 186 [9–194] results were obtained, 69 with healthcare and another 69 with ehealth. The article analysis screening process resulted in a greater elimination of works related to telehealth, obtaining 48 results. This is mainly associated with the fact that after analyzing the title and abstract, it was detected that several articles did not fit in the field of healthcare using IoT. However, the cause of the greatest impact on the screening of results was the nature of the scoping review of several studies. Around eight publications per keyword and year on average were removed for this reason. Analyzing by year, the appearance of reviews was greater in the most recent years, discarding approximately 35 of 75 results of the year 2021. This reveals the progress of previous years and the current trend in analyzing the actual scope of IoT and limitations, which is consistent with the status of this area on hype-cycle curve.

3.2 Countries with contribution with higher impact

Figure 1 illustrates the percentage of publications according to the country of the institution of the corresponding author. In those cases in which the corresponding author was not reflected, the institution of the main author was taken as reference. The graph shows that the institutions with the greatest impact in recent years are India (19.3%) and China (13.4%). The rest of Asian countries (including those located in the Persian Gulf and Russia) contribute 25.8% to this statistic. Approximately 21% corresponds to institutions in European countries, approximately 6% to entities in Africa (mainly Egypt and Tunisia), and 4% to countries in Central and South America. The United States and Canada add 7.5% and Australia and New Zealand approximately 4.8%.

3.2.1 Analysis of scopes of higher impact

With the term "scope," we refer to the topics on which each study focuses on contributing to the area of IoT systems applied to ehealth and telemedicine. After the analysis, we have found studies whose scope is related to the provision of a health service, proposing models, system designs, and/or implementations of a complete system or a component of an IoT system. On the other hand, scopes focused on improving some characteristic of IoT systems that are relevant when applied to healthcare have also been identified.

Figure 2 illustrates the scopes in the analysis. It can be seen that the majority of studies focus on providing solutions for the field of monitoring. The reader should know that a division has been made in this scope, distinguishing between studies that explicitly indicated or from which the character of real-time monitoring could be clearly inferred. The total number of studies that fit this domain was 83. These data

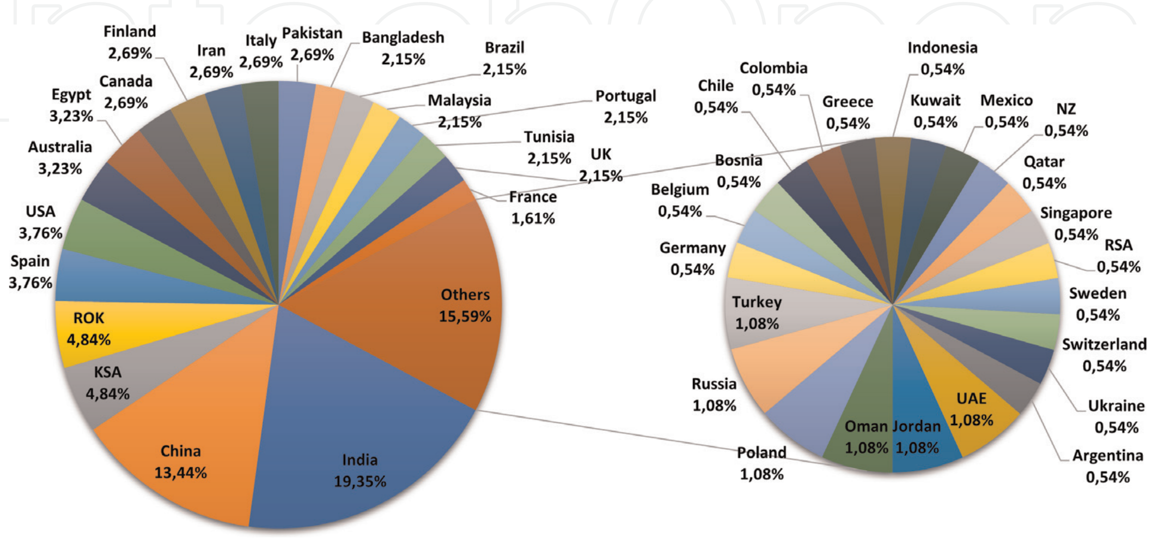

Figure 1.
Publications with more impact per country (N = 186).

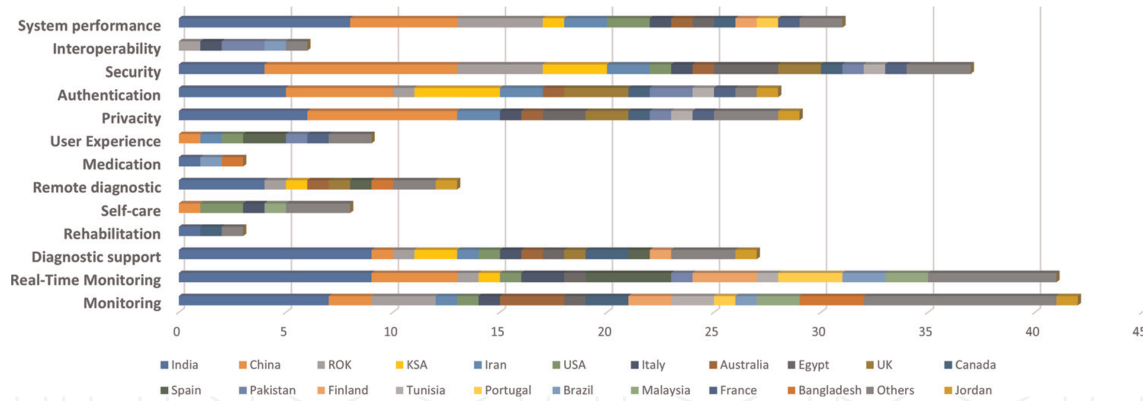

Figure 2.
Scope of the studies considered in the analysis.

show that the main purpose of the application of IoT to healthcare is to monitor patients, ubiquitously or integrated into rooms, for better control of vital signs or physiological parameters. This result is consistent with the main use for which IoT systems are used. Continuing with the analysis focused on areas of application, the next most common are those related to diagnosis. The creation of models that help the medical professional to give a diagnosis stands out mainly Machine Learning models that can be integrated into the system, sometimes complemented with architectures equipped with resources to apply Fog computing, as well as with the decentralization of processing with computing at the edge, trend that is currently increasing with the optimization of hardware and AI frameworks for model integration and consumption reduction [195]. Additionally, the applications are not restricted to the field of healthcare in the personal context, but also in the workplace [196]. To a lesser extent, we also find the use of IoT to facilitate the remote diagnosis of the patient. This last result may be related to the existing limitations to provide appropriate resources to remote centers or isolated areas that allow establishing reliable connections with sufficient transmission quality. The least relevant areas currently are self-care and remote rehabilitation. The first of these two areas mentioned was the one that had the greatest impact at the beginning of the use of IoT for healthcare, currently being on the slope of enlightenment or plateau of productivity in the hype-cycle curve. The low frequency of appearance of rehabilitation as a field of study may be due to the difficulty in carrying out rehabilitation tasks remotely.

Focusing on areas related to the improvement of system features, studies focused on maintaining the security of the IoT system are more frequent, that is, on avoiding transmission failures, network hacks, or data corruption. Additionally, we find studies focused on providing encryption protocols to ensure the authenticity and privacy of the patient. These last two scopes are often intrinsically related to system security. These results reveal the great challenges that exist in the integration of IoT systems in the Electronic Health Records of health systems: to be able to relate the data to the patient without compromising their privacy, as well as to manage the enormous amount of information collected avoiding losses, falsification information, and other security breaches. Very close in relevance we find the improvement of the performance of the system, that is, looking for better response times in the transmission and processing of information. Again, it is a challenging topic, especially in combination with equipping the system with authentication, privacy, and security protocols, which slows down IoT systems, which must be addressed for this type of system to be useful in terms of practicality.

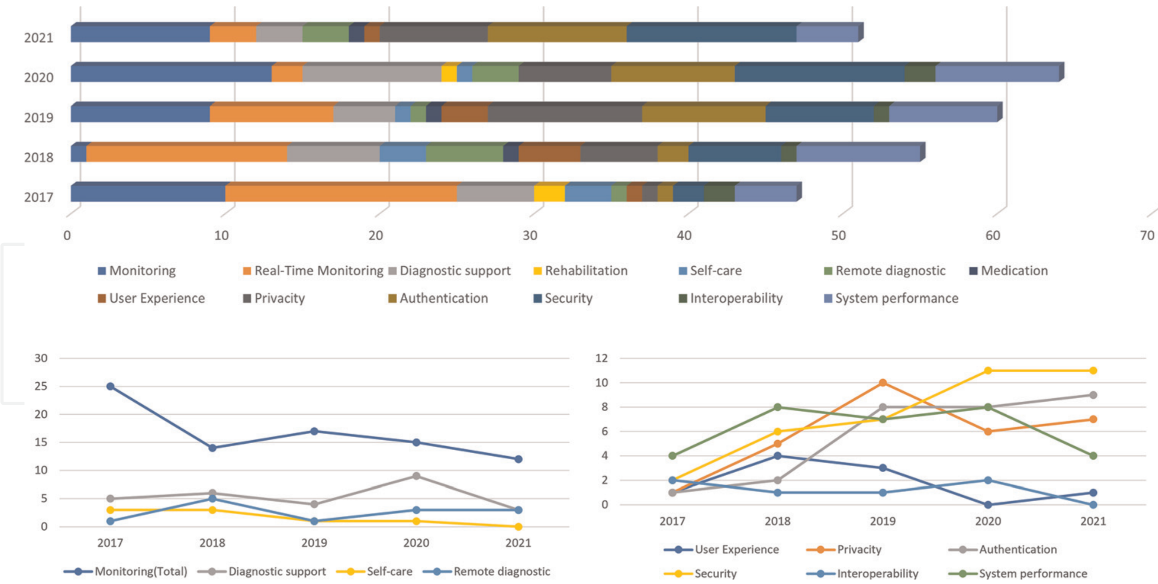

Figure 3.
Scope trends. At top, classification grouped by year analyzed in the study. At left, scopes related to the system's application approach. On the right, scopes focused on improving the characteristics of the IoT system.

In the results, we also observe that the studies related to the study of interoperability and the analysis of usability, user experience, and degree of acceptance have very little impact. These types of studies are not frequent, and yet, they address determining aspects in the adequacy of IoT systems to the health environment; its correct application depends on the fact that the implemented system is practical and perceived as useful. The little research on these issues may be the greatest limitation of these systems in the future.

Figure 3 shows the trend of these areas in the years considered for the analysis. Although a drop in the number of papers is perceived in 2021, this may be due to the fact that there has not yet been a stabilization in the number of citations on studies that contribute novelties to the field of research. Both graphs show how in recent years there has been a decrease in the impact of research aimed at providing solutions with IoT systems, and instead, there has been an increase in interest in research that focuses on improving some characteristics of the system architecture, mainly in security and privacy. This result again reveals indications of the situation of these systems in the hype-cycle curve, seeing reduced interest in deepen for new applications and consolidating their use by focusing on the greatest limitations that this set of technologies has, that is, aspects of security, privacy, and performance.

3.2.2 Interest in applied technologies

Paying attention to communication technologies, the charts in **Figure 4** reveal a varied set of alternatives. In these graphs, only those studies that have used and revealed the technologies applied in the implementation of IoT systems are taken into consideration. As a result, 87 articles were considered. The charts highlight the use of Bluetooth technology, in both its older versions and BLE, and Wi-Fi. Despite being a technology adapted to IoT, the use of LoRa is not frequent. GSM and GPRS technologies continue to be used, mainly because they have a greater network infrastructure for these technologies and because they are more in line with the user profile that

DOI: http://dx.doi.org/10.5772/intechopen.104946

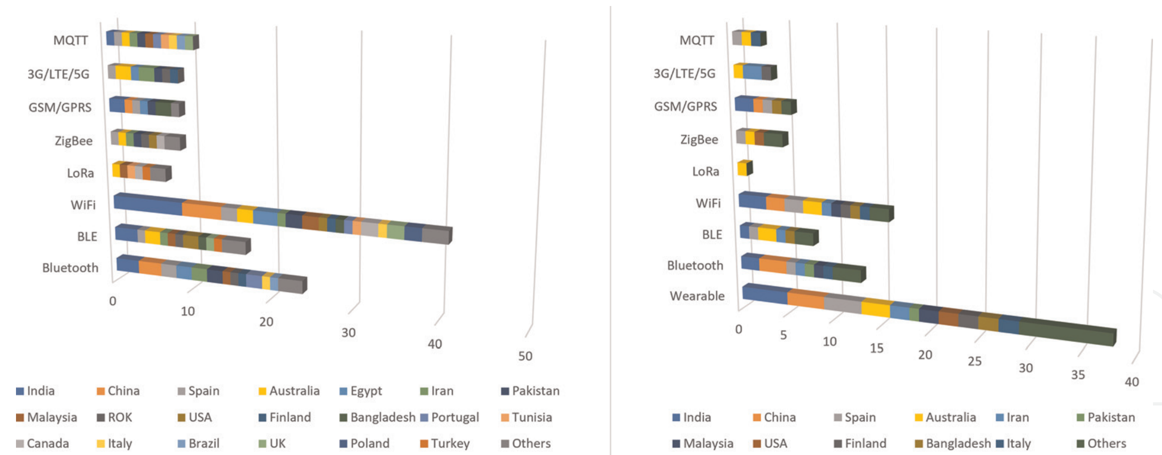

Figure 4.
Most common communication technologies in studies that carry out an implementation of an IoT system (N = 87). Top-right chart considers only those studies whose sensing acquisition devices are wearable (N = 36).

these systems are aimed at, mainly older people or those who are not familiar with new technologies.

Among the studies that reveal the communication technologies used, only 36 focus on the use of systems with exclusively wearable devices for data acquisition. In these studies, a lower use of MQTT is revealed in favor of the use of technologies such as Zigbee. Wi-Fi technology is still the most frequently used; however, there is a remarkable decrease.

The most frequent technologies identified in the analyzed studies include Machine Learning and Deep Learning for the fields of monitoring and diagnostic support. In the fields of security, privacy, and authentication, the use of Blockchain stands out. On the other hand, Fog computing and edge computing are the technologies for which the greatest interest is shown in the field of performance improvement. This is one of the most current trends, driven by systems equipped with more specialized hardware processing units [197].

4. Conclusions

The results obtained from the analysis of impact studies in recent years regarding IoT in healthcare show that Asian and Middle Eastern countries contribute to this area to a greater extent, especially India and China. With regard to the areas with the greatest impact today, we find the application to monitoring as the greatest representative. However, this type of study has reduced its relevance in recent years and instead has grown interest in the integration of security, privacy, and authentication measures to IoT systems, which gives indications of the stabilization of IoT technologies, and there is a tendency to investigate the improvement of the most important weaknesses. Infrequent and low-impact study topics are the analysis of the perceived usefulness of these systems, as well as interoperability, which may imply limitations and obstacles in the future in the implementation and use of these systems. The most used communication technologies are Bluetooth and Wi-Fi, with a smaller representation of technologies such as LoRa, Zigbee, and mobile data transfer technologies. The design and implementation of systems exclusively equipped with wearable acquisition devices is reduced. Machine Learning, Blockchain as well as edge and fog computing are the most trending technologies.

Acknowledgements

This work has been supported by "Fondo Europeo de Desarrollo Regional" (FEDER) and "Consejería de Economía, Conocimiento, Empresas y Universidad" of the Junta de Andalucía, under Programa Operativo FEDER 2014-2020 (Project US-1263715).

Conflict of interest

The authors declare no conflict of interest.

Author details

Luis Muñoz-Saavedra†, Francisco Luna-Perejón*†, Javier Civit-Masot† and Elena Escobar-Linero†
University of Seville, Seville, Spain

*Address all correspondence to: fluna1@us.es

† These authors contributed equally.

References

[1] Lheureux B, et al. Hype Cycle for the Internet of Things [Internet], Gartner; 2021. Available from: https://www.gartner.com/en/documents/4005498 [Accessed 2022-02-15]

[2] Al-Majeed SS, Al-Mejibli IS, Karam J. Home telehealth by internet of things (IoT). In: 2015 IEEE 28th Canadian Conference on Electrical and Computer Engineering (CCECE). Piscataway, New Jersey, US: IEEE; 2015. pp. 609-613

[3] Luna-Perejón F, Muñoz-Saavedra L, Castellano-Domnguez JM, Domnguez-Morales M. IoT garment for remote elderly care network. Biomedical Signal Processing and Control. 2021;**69**: 102848

[4] Ganzha M, Paprzycki M, Pawłowski W, Szmeja P, Wasielewska K. Semantic interoperability in the internet of things: An overview from the INTER-IoT perspective. Journal of Network and Computer Applications. 2017;**81**:111-124

[5] Saheb T, Izadi L. Paradigm of IoT big data analytics in the healthcare industry: A review of scientific literature and mapping of research trends. Telematics and Informatics. 2019;**41**:70-85

[6] Gong T, Huang H, Li P, Zhang K, Jiang H. A medical healthcare system for privacy protection based on IoT. In: 2015 Seventh International Symposium on Parallel Architectures, Algorithms and Programming (PAAP). Piscataway, New Jersey, US: IEEE; 2015. p. 217-222.

[7] Tortorella GL, Fogliatto FS, Espôsto KF, Mac Cawley Vergara A, Vassolo R, Tlapa Mendoza D, et al. Measuring the effect of healthcare 4.0 implementation on hospitals' performance. Production Planning & Control. 2022;**33**(4):386-401

[8] El-Haddadeh R, Weerakkody V, Osmani M, Thakker D, Kapoor KK. Examining citizens' perceived value of internet of things technologies in facilitating public sector services engagement. Government Information Quarterly. 2019;**36**(2):310-320

[9] Satija U et al. Real-time signal quality-aware ECG telemetry system for IoT-based health care monitoring. IEEE Internet of Things Journal. 2017;**4**(3): 815-823

[10] Azimi I et al. HiCH: Hierarchical fog-assisted computing architecture for healthcare IoT. ACM Transactions on Embedded Computing Systems (TECS). 2017;**16**(5s):1-20

[11] Yang G et al. IoT-based remote pain monitoring system: From device to cloud platform. IEEE Journal of Biomedical and Health Informatics. 2017;**22**(6):1711-1719

[12] Lomotey RK et al. Wearable IoT data stream traceability in a distributed health information system. Pervasive and Mobile Computing. 2017;**40**:692-707

[13] Dubey H et al. Fog computing in medical internet-of-things: Architecture, implementation, and applications. In: Handbook of Large-Scale Distributed Computing in Smart Healthcare. Cham, Switzerland: Springer; 2017. pp. 281-321

[14] Hayati N, Suryanegara M. The IoT LoRa system design for tracking and monitoring patient with mental disorder. In: 2017 IEEE International Conference on Communication, Networks and Satellite (Comnetsat). Piscataway, New Jersey, US: IEEE; 2017. pp. 135-139

[15] Vora J et al. Home-based exercise system for patients using IoT enabled

smart speaker. In: IEEE 19th International Conference on e-Health Networking, Applications and Services (Healthcom). Piscataway, New Jersey, US: IEEE; 2017;**2017**:1-6

[16] Park K et al. An IoT system for remote monitoring of patients at home. Applied Sciences. 2017;7(3):260

[17] Ara A, Ara A. Case study: Integrating IoT, streaming analytics and machine learning to improve intelligent diabetes management system. In: International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS). Piscataway, New Jersey, US: IEEE; 2017;**2017**:3179-3182

[18] Caporuscio M et al. Iot-enabled physical telerehabilitation platform. In: 2017 IEEE International Conference on Software Architecture Workshops (ICSAW). Piscataway, New Jersey, US: IEEE; 2017. pp. 112-119

[19] Antonio PO et al. Heat stroke detection system based in IoT. In: IEEE Second Ecuador Technical Chapters Meeting (ETCM). Piscataway, New Jersey, US: IEEE; 2017;**2017**:1-6

[20] Pham M et al. Delivering home healthcare through a cloud-based smart home environment (CoSHE). Future Generation Computer Systems. 2018;**81**: 129-140

[21] Liu C et al. Signal quality assessment and lightweight QRS detection for wearable ECG SmartVest system. IEEE Internet of Things Journal. 2018;**6**(2): 1363-1374

[22] Gurbeta L et al. A telehealth system for automated diagnosis of asthma and chronical obstructive pulmonary disease. Journal of the American Medical Informatics Association. 2018;**25**(9): 1213-1217

[23] Krishnan DSR et al. An IoT based patient health monitoring system. In: 2018 International Conference on Advances in Computing and Communication Engineering (ICACCE). Piscataway, New Jersey, US: IEEE; 2018. pp. 01-07

[24] Mulero R, Almeida A, Azkune G, Abril-Jiménez P, Waldmeyer MTA, Castrillo MP, et al. An IoT-aware approach for elderly-friendly cities. IEEE Access. 2018;**6**:7941-7957

[25] Stradolini F, et al. IoT for telemedicine practices enabled by an android™ application with cloud system integration. In: IEEE International Symposium on Circuits and Systems (ISCAS). Piscataway, New Jersey, US: IEEE; 2018;**2018**:1-5

[26] Ghosh D et al. Smart saline level monitoring system using ESP32 and MQTT-S. In: 2018 IEEE 20th International Conference on e-Health Networking, Applications and Services (Healthcom). Piscataway, New Jersey, US: IEEE; 2018. pp. 1-5

[27] Syed L et al. Telemammography: A novel approach for early detection of breast cancer through wavelets based image processing and machine learning techniques. In: Advances in Soft Computing and Machine Learning in Image Processing. Cham, Switzerland: Springer; 2018. pp. 149-183

[28] Stavrotheodoros S et al. A smart-home IoT infrastructure for the support of independent living of older adults. In: IFIP International Conference on Artificial Intelligence Applications and Innovations. Cham, Switzerland: Springer; 2018. pp. 238-249

[29] Manogaran G et al. Wearable IoT smart-log patch: An edge computing-based

Bayesian deep learning network system for multi access physical monitoring system. Sensors. 2019;**19**(13):3030

[30] Gia TN et al. Energy efficient fog-assisted IoT system for monitoring diabetic patients with cardiovascular disease. Future Generation Computer Systems. 2019;**93**:198-211

[31] Ozkan H et al. A portable wearable tele-ECG monitoring system. IEEE Transactions on Instrumentation and Measurement. 2019;**69**(1):173-182

[32] Saadeh W et al. A patient-specific single sensor IoT-based wearable fall prediction and detection system. IEEE Transactions on Neural Systems and Rehabilitation Engineering. 2019;**27**(5): 995-1003

[33] Gutiérrez-Madroñal L, La Blunda L, Wagner MF, Medina-Bulo I. Test event generation for a fall-detection IoT system. IEEE Internet of Things Journal. 2019;**6**(4):6642-6651

[34] Yee LM et al. Internet of things (IoT) fall detection using wearable sensor. Journal of Physics: Conference Series. 2019;**1372**:012048

[35] Islam MR et al. Design and implementation of low cost smart syringe pump for telemedicine and healthcare. In: 2019 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST). Piscataway, New Jersey, US: IEEE; 2019. pp. 440-444

[36] Al-Kababji A et al. IoT-based fall and ECG monitoring system: Wireless communication system based firebase realtime database. In: IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & big Data Computing, Internet of People and Smart City Innovation (Smart-World/SCALCOM/UIC/ATC/CBDCom/IOP/SCI). Piscataway, New Jersey, US: IEEE; 2019;**2019**:1480-1485

[37] Joseph S et al. IOT based remote heartbeat monitoring. In: 2019 International Conference on Advances in Computing, Communication and Control (ICAC3). Piscataway, New Jersey, US: IEEE; 2019. pp. 1-5

[38] Zhao P et al. Towards deep learning-based detection scheme with raw ECG signal for wearable telehealth systems. In: 2019 28th International Conference on Computer Communication and Networks (ICCCN). Piscataway, New Jersey, US: IEEE; 2019. pp. 1-9

[39] Shaik MS et al. Detection of FITS seizure by Alexa using IoT. In: 2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN). Piscataway, New Jersey, US: IEEE; 2019. pp. 1-4

[40] Singh RP et al. Internet of things (IoT) applications to fight against COVID-19 pandemic. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2020;**14**(4):521-524

[41] Rahman MS, Peeri NC, Shrestha N, Zaki R, Haque U, Ab Hamid SH. Defending against the novel coronavirus (COVID-19) outbreak: How can the internet of things (IoT) help to save the world? Health Policy and Technology. 2020;**9**(2):136

[42] Islam M et al. Development of smart healthcare monitoring system in IoT environment. SN Computer Science. 2020;**1**(3):1-11

[43] Otoom M et al. An IoT-based framework for early identification and

monitoring of COVID-19 cases. Biomedical Signal Processing and Control. 2020;**62**:102149

[44] Siriwardhana Y, De Alwis C, et al. The fight against the COVID-19 pandemic with 5G technologies. IEEE Engineering Management Review. 2020; **48**(3):72-84

[45] Hoffman DA. Increasing access to care: Telehealth during COVID-19. Journal of Law and the Biosciences. 2020;**7**(1):lsaa043

[46] Farahani B et al. Towards collaborative intelligent IoT eHealth: From device to fog, and cloud. Microprocessors and Microsystems. 2020;**72**:102938

[47] Abdelmoneem RM et al. Mobility-aware task scheduling in cloud-fog IoT-based healthcare architectures. Computer Networks. 2020;**179**:107348

[48] Muneer A et al. Smart health monitoring system using IoT based smart fitness mirror. Telkomnika. 2020; **18**(1):317-331

[49] Asadzadeh A et al. Information technology in emergency management of COVID-19 outbreak. Informatics in Medicine Unlocked. 2020;**21**:100475

[50] Gunasekeran DV et al. Digital health during COVID-19: Lessons from operationalising new models of care in ophthalmology. The Lancet Digital Health. 2021;**3**(2):e124-e134

[51] Ahmad RW et al. The role of blockchain technology in telehealth and telemedicine. International Journal of Medical Informatics. 2021; **148**:104399

[52] Arfi WB et al. Understanding acceptance of eHealthcare by IoT natives and IoT immigrants: An integrated model of UTAUT, perceived risk, and financial cost. Technological Forecasting and Social Change. 2021;**163**: 120437

[53] Honar Pajooh H et al. Hyperledger fabric blockchain for securing the edge internet of things. Sensors. 2021; **21**(2):359

[54] Ullah SMA et al. Scalable telehealth services to combat novel coronavirus (COVID-19) pandemic. SN Computer Science. 2021;**2**(1):1-8

[55] Wang W et al. Blockchain-assisted handover authentication for intelligent telehealth in multi-server edge computing environment. Journal of Systems Architecture. 2021;**115**: 102024

[56] Mukati N et al. Healthcare assistance to COVID-19 patient using internet of things (IoT) enabled technologies. Materials Today: Proceedings. 2021. Available from: https://doi.org/10.1016/j.matpr.2021.07.379

[57] Wu T et al. An autonomous wireless body area network implementation towards IoT connected healthcare applications. IEEE Access. 2017;**5**: 11413-11422

[58] Li C et al. The IoT-based heart disease monitoring system for pervasive healthcare service. Procedia Computer Science. 2017;**112**:2328-2334

[59] Mora H, Gil D, Terol RM, Azorín J, Szymanski J. An IoT-based computational framework for healthcare monitoring in mobile environments. Sensors. 2017;**17**(10):2302

[60] Jabbar S et al. Semantic interoperability in heterogeneous IoT

infrastructure for healthcare. Wireless Communications and Mobile Computing. 2017;**2017**:10

[61] Ullah F et al. Semantic interoperability for big-data in heterogeneous IoT infrastructure for healthcare. Sustainable Cities and Society. 2017;**34**:90-96

[62] Khan SF. Health care monitoring system in internet of things (IoT) by using RFID. In: 2017 6th International Conference on Industrial Technology and Management (ICITM). IEEE; 2017. pp. 198-204

[63] Sood SK, Mahajan I. Wearable IoT sensor based healthcare system for identifying and controlling chikungunya virus. Computers in Industry. 2017;**91**: 33-44

[64] Dziak D et al. IoT-based information system for healthcare application: Design methodology approach. Applied Sciences. 2017;**7**(6):596

[65] Laplante PA et al. Building caring healthcare systems in the internet of things. IEEE Systems Journal. 2017; **12**(3):3030-3037

[66] Mezghani E et al. A model-driven methodology for the design of autonomic and cognitive IoT-based systems: Application to healthcare. IEEE Transactions on Emerging Topics in Computational Intelligence. 2017;**1**(3): 224-234

[67] Bhatia M, Sood SK. A comprehensive health assessment framework to facilitate IoT-assisted smart workouts: A predictive healthcare perspective. Computers in Industry. 2017;**92**:50-66

[68] Strielkina A et al. Modelling of healthcare IoT using the queueing theory. In: 9th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS). Piscataway, New Jersey, US: IEEE; 2017;**2**:849-852

[69] He S et al. Proactive personalized services through fog-cloud computing in large-scale IoT-based healthcare application. China Communications. 2017;**14**(11):1-16

[70] Jaiswal K et al. IoT-cloud based framework for patient's data collection in smart healthcare system using raspberry-pi. In: International Conference on Electrical and Computing Technologies and Applications (ICECTA). Piscataway, New Jersey, US: IEEE; 2017;**2017**:1-4

[71] Elhoseny M, Ramrez-González G, Abu-Elnasr OM, Shawkat SA, Arunkumar N, Farouk A. Secure medical data transmission model for IoT-based healthcare systems. IEEE Access. 2018;**6**: 20596-20608

[72] Verma P, Sood SK. Fog assisted-IoT enabled patient health monitoring in smart homes. IEEE Internet of Things Journal. 2018;**5**(3):1789-1796

[73] Pace P et al. An edge-based architecture to support efficient applications for healthcare industry 4.0. IEEE Transactions on Industrial Informatics. 2018;**15**(1):481-489

[74] Kumar PM et al. Cloud and IoT based disease prediction and diagnosis system for healthcare using fuzzy neural classifier. Future Generation Computer Systems. 2018;**86**:527-534

[75] Luo E et al. Privacyprotector: Privacy-protected patient data collection in IoT-based healthcare systems. IEEE Communications Magazine. 2018;**56**(2): 163-168

[76] Mahmud R et al. Cloud-fog interoperability in IoT-enabled healthcare solutions. In: Proceedings of the 19th International Conference on Distributed Computing and Networking. New York, NY, USA: Association for Computing Machinery; 2018. pp. 1-10

[77] Verma P, Sood SK. Cloud-centric IoT based disease diagnosis healthcare framework. Journal of Parallel and Distributed Computing. 2018;**116**:27-38

[78] Woo MW et al. A reliable IoT system for personal healthcare devices. Future Generation Computer Systems. 2018;**78**: 626-640

[79] Min M et al. Learning-based privacy-aware offloading for healthcare IoT with energy harvesting. IEEE Internet of Things Journal. 2018;**6**(3): 4307-4316

[80] Tao H et al. Secured data collection with hardware-based ciphers for IoT-based healthcare. IEEE Internet of Things Journal. 2018;**6**(1):410-420

[81] Alhussein M et al. Cognitive IoT-cloud integration for smart healthcare: Case study for epileptic seizure detection and monitoring. Mobile Networks and Applications. 2018;**23**(6):1624-1635

[82] Catherwood PA et al. A community-based IoT personalized wireless healthcare solution trial. IEEE Journal of Translational Engineering in Health and Medicine. 2018;**6**:1-13

[83] Subasi A et al. IoT based mobile healthcare system for human activity recognition. In: 2018 15th Learning and Technology Conference (L&T). Piscataway, New Jersey, USA: IEEE; 2018;**2018**:29-34

[84] Srinivasa K et al. Data analytics assisted internet of things towards building intelligent healthcare monitoring systems: Iot for healthcare. Journal of Organizational and End User Computing (JOEUC). 2018;**30**(4): 83-103

[85] Badr S et al. Multi-tier blockchain framework for IoT-EHRs systems. Procedia Computer Science. 2018;**141**: 159-166

[86] Martínez-Caro E et al. Healthcare service evolution towards the internet of things: An end-user perspective. Technological Forecasting and Social Change. 2018;**136**:268-276

[87] Wang K et al. Adaptive and fault-tolerant data processing in healthcare IoT based on fog computing. IEEE Transactions on Network Science and Engineering. 2018;**7**(1):263-273

[88] Dwivedi AD et al. A decentralized privacy-preserving healthcare blockchain for IoT. Sensors. 2019;**19**(2):326

[89] Yang Y et al. Privacy-preserving smart IoT-based healthcare big data storage and self-adaptive access control system. Information Sciences. 2019;**479**: 567-592

[90] Kaur P et al. A healthcare monitoring system using random forest and internet of things (IoT). Multimedia Tools and Applications. 2019;**78**(14): 19905-19916

[91] Deebak BD, Al-Turjman F, et al. An authentic-based privacy preservation protocol for smart e-healthcare systems in IoT. IEEE Access. 2019;**7**:135632-135649

[92] Azimi I et al. Missing data resilient decision-making for healthcare IoT through personalization: A case study on maternal health. Future Generation Computer Systems. 2019;**96**:297-308

[93] Alraja MN et al. The effect of security, privacy, familiarity, and trust on users' attitudes toward the use of the IoT-based healthcare: The mediation role of risk perception. IEEE Access. 2019;**7**: 111341-111354

[94] Dautov R et al. Hierarchical data fusion for smart healthcare. Journal of Big Data. 2019;**6**(1):1-23

[95] Shahidul Islam M et al. Monitoring of the human body signal through the internet of things (IoT) based LoRa wireless network system. Applied Sciences. 2019;**9**(9):1884

[96] Sharma G, Kalra S. A lightweight user authentication scheme for cloud-IoT based healthcare services. Iranian Journal of Science and Technology, Transactions of Electrical Engineering. 2019;**43**(1):619-636

[97] Elmisery AM et al. A new computing environment for collective privacy protection from constrained healthcare devices to IoT cloud services. Cluster Computing. 2019;**22**(1):1611-1638

[98] Srivastava G et al. A light and secure healthcare blockchain for iot medical devices. In: IEEE Canadian Conference of Electrical and Computer Engineering (CCECE). Piscataway, New Jersey, US: IEEE; 2019;**2019**:1-5

[99] Tang W et al. Secure data aggregation of lightweight E-healthcare IoT devices with fair incentives. IEEE Internet of Things Journal. 2019;**6**(5): 8714-8726

[100] Abou-Nassar EM et al. DITrust chain: Towards blockchain-based trust models for sustainable healthcare IoT systems. IEEE Access. 2020;**8**: 111223-111238

[101] Rathee G et al. A hybrid framework for multimedia data processing in IoT-healthcare using blockchain technology. Multimedia Tools and Applications. 2020;**79**(15):9711-9733

[102] Muthu B, Sivaparthipan C, Manogaran G, Sundarasekar R, Kadry S, Shanthini A, et al. IOT based wearable sensor for diseases prediction and symptom analysis in healthcare sector. Peer-to-peer Networking and Applications. 2020;**13**(6):2123-2134

[103] Haghi M et al. A flexible and pervasive IoT-based healthcare platform for physiological and environmental parameters monitoring. IEEE Internet of Things Journal. 2020;**7**(6):5628-5647

[104] Celesti A et al. Blockchain-based healthcare workflow for tele-medical laboratory in federated hospital IoT clouds. Sensors. 2020;**20**(9):2590

[105] Bharathi R et al. Energy efficient clustering with disease diagnosis model for IoT based sustainable healthcare systems. Sustainable Computing: Informatics and Systems. 2020;**28**: 100453

[106] Wu T et al. A rigid-flex wearable health monitoring sensor patch for IoT-connected healthcare applications. IEEE Internet of Things Journal. 2020;**7**(8): 6932-6945

[107] Li J et al. A secured framework for sdn-based edge computing in IOT-enabled healthcare system. IEEE Access. 2020;**8**:135479-135490

[108] Ullah A et al. Fog-assisted secure healthcare data aggregation scheme in IoT-enabled WSN. Peer-to-Peer Networking and Applications. 2020; **13**(1):163-174

[109] Gope P et al. A secure IoT-based modern healthcare system with fault-

tolerant decision making process. IEEE Journal of Biomedical and Health Informatics. 2020;**25**(3):862-873

[110] Aujla GS, Jindal A. A decoupled blockchain approach for edge-envisioned IoT-based healthcare monitoring. IEEE Journal on Selected Areas in Communications. 2020;**39**(2): 491-499

[111] Wang X, Cai S. Secure healthcare monitoring framework integrating NDN-based IoT with edge cloud. Future Generation Computer Systems. 2020; **112**:320-329

[112] Guo X et al. A new data clustering strategy for enhancing mutual privacy in healthcare IoT systems. Future Generation Computer Systems. 2020; **113**:407-417

[113] Satpathy S et al. A new healthcare diagnosis system using an IoT-based fuzzy classifier with FPGA. The Journal of Supercomputing. 2020;**76**(8):5849-5861

[114] Sun Y et al. PMRSS: Privacy-preserving medical record searching scheme for intelligent diagnosis in IoT healthcare. IEEE Transactions on Industrial Informatics. 2021;**18**(3): 1981-1990

[115] Onasanya A, Elshakankiri M. Smart integrated IoT healthcare system for cancer care. Wireless Networks. 2021; **27**(6):4297-4312

[116] El Zouka HA, Hosni MM. Secure IoT communications for smart healthcare monitoring system. Internet of Things. 2021;**13**:100036

[117] Elayan H et al. Digital twin for intelligent context-aware iot healthcare systems. IEEE Internet of Things Journal. 2021;**8**(23): 16749-16757

[118] Alzubi JA. Blockchain-based Lamport Merkle digital signature: Authentication tool in IoT healthcare. Computer Communications. 2021;**170**: 200-208

[119] Wu TY et al. Improved authenticated key agreement scheme for fog-driven IoT healthcare system. Security and communication. Wireless and communication Networks. 2021;**2021**:19

[120] Mukherjee R et al. IoT-cloud based healthcare model for COVID-19 detection: An enhanced k-nearest neighbour classifier based approach. Computing. 2021;**1-21**

[121] Rajavel R et al. IoT-based smart healthcare video surveillance system using edge computing. Journal of Ambient Intelligence and Humanized Computing. 2021;**13**:3195-3207

[122] Wu F et al. Edge-based hybrid system implementation for long-range safety and healthcare IoT applications. IEEE Internet of Things Journal. 2021; **8**(12):9970-9980

[123] Poongodi M et al. Smart healthcare in smart cities: Wireless patient monitoring system using IoT. The Journal of Supercomputing. 2021;**77**(11): 12230-12255

[124] Magsi H et al. A novel adaptive battery-aware algorithm for data transmission in IoT-based healthcare applications. Electronics. 2021;**10**(4):367

[125] de Morais Barroca Filho I et al. An IoT-based healthcare platform for patients in ICU beds during the COVID-19 outbreak. IEEE Access. 2021;**9**: 27262-27277

[126] Rifi N et al. Towards using blockchain technology for eHealth data

access management. In: 2017 Fourth International Conference on Advances in Biomedical Engineering (ICABME). Piscataway, New Jersey, US: IEEE; 2017. pp. 1-4

[127] Al-Hamadi H, Chen R. Trust-based decision making for health IoT systems. IEEE Internet of Things Journal. 2017; **4**(5):1408-1419

[128] Gia TN et al. Low-cost fog-assisted health-care IoT system with energy-efficient sensor nodes. In: 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC). Piscataway, New Jersey, US: IEEE; 2017. pp. 1765-1770

[129] Mdhaffar A et al. IoT-based health monitoring via LoRaWAN. In: IEEE EUROCON 2017-17th International Conference on Smart Technologies. Piscataway, New Jersey, US: IEEE; 2017. pp. 519-524

[130] Gupta PK et al. A novel and secure IoT based cloud centric architecture to perform predictive analysis of users activities in sustainable health centres. Multimedia Tools and Applications. 2017;**76**(18):18489-18512

[131] Neyja M et al. An IoT-based e-health monitoring system using ECG signal. In: GLOBECOM 2017–2017 IEEE Global Communications Conference. Piscataway, New Jersey, US: IEEE; 2017. pp. 1-6

[132] Domingues MF et al. Insole optical fiber sensor architecture for remote gait analysis—An e-health solution. IEEE Internet of Things Journal. 2017;**6**(1): 207-214

[133] Rathore MM et al. Hadoop-based intelligent care system (HICS) analytical approach for big data in IoT. ACM Transactions on Internet Technology (TOIT). 2017;**18**(1):1-24

[134] Raj C et al. HEMAN: Health monitoring and nous: An IoT based e-health care system for remote telemedicine. In: 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET). Piscataway, New Jersey, US: IEEE; 2017. pp. 2115-2119

[135] Ali S, Ghazal M. Real-time heart attack mobile detection service (RHAMDS): An IoT use case for software defined networks. In: 2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE). Piscataway, New Jersey, US: IEEE; 2017. pp. 1-6

[136] Buyukakkaslar MT et al. LoRaWAN as an e-health communication technology. In: 2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC). Piscataway, New Jersey, US: IEEE; 2017;**2**:310-313

[137] Chatterjee P et al. IoT-based decision support system for intelligent healthcare—Applied to cardiovascular diseases. In: 2017 7th International Conference on Communication Systems and Network Technologies (CSNT). Piscataway, New Jersey, US: IEEE; 2017. pp. 362-366

[138] Cabra J et al. An IoT approach for wireless sensor networks applied to e-health environmental monitoring. In: 2017 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData). Piscataway, New Jersey, US: IEEE; 2017. pp. 578-583

[139] Budida DAM, Mangrulkar RS. Design and implementation of smart HealthCare system using IoT. In: 2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS). Piscataway, New Jersey, US: IEEE; 2017. pp. 1-7

[140] Rahmani AM et al. Exploiting smart e-health gateways at the edge of healthcare internet-of-things: A fog computing approach. Future Generation Computer Systems. 2018;**78**: 641-658

[141] Farahani B et al. Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare. Future Generation Computer Systems. 2018;**78**:659-676

[142] Kumari A et al. Fog computing for healthcare 4.0 environment: Opportunities and challenges. Computers & Electrical Engineering. 2018;**72**:1-13

[143] Rodrigues JJ, Segundo DBDR, Junqueira HA, Sabino MH, Prince RM, Al-Muhtadi J, et al. Enabling technologies for the internet of health things. IEEE Access. 2018;**6**: 13129-13141

[144] Zhang X, Poslad S. Blockchain support for flexible queries with granular access control to electronic medical records (EMR). In: 2018 IEEE International Conference on Communications (ICC). Piscataway, New Jersey, US: IEEE; 2018. pp. 1-6

[145] Almulhim M, Zaman N. Proposing secure and lightweight authentication scheme for IoT based E-health applications. In: 2018 20th International Conference on Advanced Communication Technology (ICACT). Piscataway, New Jersey, US: IEEE; 2018. pp. 481-487

[146] Bayo-Monton JL et al. Wearable sensors integrated with internet of things for advancing eHealth care. Sensors. 2018;**18**(6):1851

[147] Chen X et al. Dynamic power management and adaptive packet size selection for IoT in e-healthcare. Computers & Electrical Engineering. 2018;**65**:357-375

[148] Santos GL et al. Analyzing the availability and performance of an e-health system integrated with edge, fog and cloud infrastructures. Journal of Cloud Computing. 2018;**7**(1):1-22

[149] Naranjo-Hernández D et al. Smart vest for respiratory rate monitoring of COPD patients based on non-contact capacitive sensing. Sensors. 2018;**18**(7): 2144

[150] Monteiro K et al. Developing an e-health system based on IoT, fog and cloud computing. In: 2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion). Piscataway, New Jersey, US: IEEE; 2018. pp. 17-18

[151] Pasha M, Shah SMW. Framework for E-health systems in IoT-based environments. Wireless Communications and Mobile Computing. 2018;**2018**:11

[152] Santamaria AF et al. A real IoT device deployment for e-health applications under lightweight communication protocols, activity classifier and edge data filtering. Computer Communications. 2018;**128**: 60-73

[153] Abdel-Basset M et al. A novel intelligent medical decision support

model based on soft computing and IoT. IEEE Internet of Things Journal. 2019; **7**(5):4160-4170

[154] Jia X et al. Authenticated key agreement scheme for fog-driven IoT healthcare system. Wireless Networks. 2019;**25**(8):4737-4750

[155] Aghili SF et al. LACO: Lightweight three-factor authentication, access control and ownership transfer scheme for e-health systems in IoT. Future Generation Computer Systems. 2019;**96**: 410-424

[156] Vilela PH et al. Performance evaluation of a fog-assisted IoT solution for e-health applications. Future Generation Computer Systems. 2019;**97**: 379-386

[157] Saha R et al. Privacy ensured e-healthcare for fog-enhanced IoT based applications. IEEE Access. 2019;**7**: 44536-44543

[158] Rath M, Pattanayak B. Technological improvement in modern health care applications using internet of things (IoT) and proposal of novel health care approach. International Journal of Human Rights in Healthcare. 2018;**12**: 148-162

[159] Debauche O et al. Fog IoT for health: A new architecture for patients and elderly monitoring. Procedia Computer Science. 2019;**160**:289-297

[160] Hasan M et al. Real-time healthcare data transmission for remote patient monitoring in patch-based hybrid OCC/BLE networks. Sensors. 2019;**19**(5):1208

[161] Kaw JA et al. A reversible and secure patient information hiding system for IoT driven e-health. International Journal of Information Management. 2019;**45**:262-275

[162] Almulhim M et al. A lightweight and secure authentication scheme for IoT based e-health applications. International Journal of Computer Science and Network Security. 2019; **19**(1):107-120

[163] Hossein KM et al. Blockchain-based privacy-preserving healthcare architecture. In: 2019 IEEE Canadian Conference of Electrical and Computer Engineering (CCECE). Piscataway, New Jersey, US: IEEE; 2019. pp. 1-4

[164] Ben Hassen H et al. An E-health system for monitoring elderly health based on internet of things and fog computing. Health Information Science and Systems. 2019;**7**(1):1-9

[165] Alassaf N, Gutub A. Simulating light-weight-cryptography implementation for IoT healthcare data security applications. International Journal of E-Health and Medical Communications (IJEHMC). 2019; **10**(4):1-15

[166] Celesti A et al. How to develop IoT cloud e-health systems based on FIWARE: A lesson learnt. Journal of Sensor and Actuator Networks. 2019; **8**(1):7

[167] Ali R et al. Q-learning-enabled channel access in next-generation dense wireless networks for IoT-based eHealth systems. EURASIP Journal on Wireless Communications and Networking. 2019; **2019**(1):1-12

[168] Tuli S et al. HealthFog: An ensemble deep learning based smart healthcare system for automatic diagnosis of heart diseases in integrated IoT and fog computing environments. Future Generation Computer Systems. 2020; **104**:187-200

[169] Hamza R et al. A privacy-preserving cryptosystem for IoT E-healthcare. Information Sciences. 2020;**527**:493-510

[170] Jamil F et al. Towards a remote monitoring of patient vital signs based on IoT-based blockchain integrity management platforms in smart hospitals. Sensors. 2020;**20**(8):2195

[171] Ray PP et al. Blockchain for IoT-based healthcare: Background, consensus, platforms, and use cases. IEEE Systems Journal. 2020;**15**(1): 85-94

[172] Vedaei SS et al. COVID-SAFE: An IoT-based system for automated health monitoring and surveillance in post-pandemic life. IEEE Access. 2020;**8**:188538

[173] Khan MA et al. A secure framework for authentication and encryption using improved ECC for IoT-based medical sensor data. IEEE Access. 2020;**8**: 52018-52027

[174] Patan R et al. Smart healthcare and quality of service in IoT using grey filter convolutional based cyber physical system. Sustainable Cities and Society. 2020;**59**:102141

[175] Cai G et al. Design of an MISO-SWIPT-aided code-index modulated multi-carrier M-DCSK system for e-health IoT. IEEE Journal on Selected Areas in Communications. 2020;**39**(2):311-324

[176] Yew HT et al. Iot based real-time remote patient monitoring system. In: 16th IEEE International Colloquium on Signal Processing & its Applications (CSPA). Piscataway, New Jersey, US: IEEE; 2020;**2020**:176-179

[177] Almogren A et al. Ftm-iomt: Fuzzy-based trust management for preventing sybil attacks in internet of medical things. IEEE Internet of Things Journal. 2020;**8**(6):4485-4497

[178] Uddin MA et al. Blockchain leveraged decentralized IoT eHealth framework. Internet of Things. 2020;**9**: 100159

[179] Chowdhury MZ et al. A new 5g ehealth architecture based on optical camera communication: An overview, prospects, and applications. IEEE Consumer Electronics Magazine. 2020; **9**(6):23-33

[180] Rub JNS, Gondim PRL. Interoperable internet of medical things platform for e-health applications. International Journal of Distributed Sensor Networks. 2020;**16**(1): 1550147719889591

[181] Zhang L et al. A multi-stage stochastic programming-based offloading policy for fog enabled IoT-eHealth. IEEE Journal on Selected Areas in Communications. 2020;**39**(2):411-425

[182] Ghosh A et al. Energy-efficient IoT-health monitoring system using approximate computing. Internet of Things. 2020;**9**:100166

[183] Kaur M et al. Secure and energy efficient-based E-health care framework for green internet of things. IEEE Transactions on Green Communications and Networking. 2021;**5**(3):1223-1231

[184] Gadekallu TR et al. Blockchain-based attack detection on machine learning algorithms for IoT-based e-health applications. IEEE Internet of Things Magazine. 2021;**4**(3): 30-33

[185] Ayub MF et al. Lightweight authentication protocol for e-health clouds in IoT-based applications through

5G technology. Digital Communications and Networks. 2021;**7**(2):235-244

[186] Chehri A. Energy-efficient modified DCC-MAC protocol for IoT in e-health applications. Internet of things. 2021;**14**:100119

[187] Deebak B, Al-Turjman F. Secure-user sign-in authentication for IoT-based eHealth systems. Complex & Intelligent Systems. 2021:1-21

[188] Said AM et al. Efficient anomaly detection for smart hospital IoT systems. Sensors. 2021;**21**(4):1026

[189] Frikha T et al. Healthcare and fitness data management using the iot-based blockchain platform. Journal of healthcare. Journal of Healthcare Engineering. 2021;**2021**:12

[190] Huang C et al. A deep segmentation network of stent structs based on IoT for interventional cardiovascular diagnosis. IEEE Wireless Communications. 2021;**28**(3):36-43

[191] Hussain A et al. Security framework for IoT based real-time health applications. Electronics. 2021;**10**(6):719

[192] Alzahrani BA. Secure and efficient cloud-based IoT authenticated key agreement scheme for e-health wireless sensor networks. Arabian Journal for Science and Engineering. 2021;**46**(4):3017-3032

[193] Iqbal N et al. A scheduling mechanism based on optimization using IoT-tasks orchestration for efficient patient health monitoring. Sensors. 2021;**21**(16):5430

[194] Amato F et al. A security and privacy validation methodology for e-health systems. ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM). 2021;**17**(2s):1-22

[195] Luna-Perejón F, Domínguez-Morales M, Gutiérrez-Galán D, Civit-Balcells A. Low-power embedded system for gait classification using neural networks. Journal of Low Power Electronics and Applications. 2020;**10**(2):14

[196] Escobar-Linero E, Domnguez-Morales M, Sevillano JL. Worker's physical fatigue classification using neural networks. Expert Systems with Applications. 2022;**198**:116784

[197] Civit-Masot J, Luna-Perejón F, Corral JMR, Domínguez-Morales M, Morgado-Estévez A, Civit A. A study on the use of edge TPUs for eye fundus image segmentation. Engineering Applications of Artificial Intelligence. 2021;**104**:104384