Amalgamation of Fog Computing and Software Defined Networking in Healthcare 4.0: The Challenges, and a Way Forward

Khushi Shah[1][a], Mohammad S. Obaidat[2,3,4,*], Preet Modi[1][b], Jitendra Bhatia[1][c], Sudeep Tanwar[5,**] and Balqies Sadoun[6]

[1] *Vishwakarma Government Engineering College, Gujarat Technological University, Ahmedabad, Gujarat, India*
[2] *College of Computing and Informatics, University of Sharjah, U.A.E.*
[3] *KAIST, University of Jordan, Jordan*
[4] *University of Science and Technology Beijing, China*
[5] *Department of CSE, Institute of Technology, Nirma University, Ahmedabad, Gujarat, India*
[6] *College of Engineering, Al-Balqa' Applied University, Al-Salt, Jordan*

Keywords: Healthcare, Cloud Computing, Fog Computing, Software Defined Networking.

Abstract: Rapid recent advances in automated data collection routines have led to a tsunami of health care oriented data stored in the distributed, heterogeneous, and a large databases. Healthcare is one of the pioneering fields that has started using Machine Learning (ML) and IoT (Internet of Things) for increasing life expectancies and decreasing death risks. Since then, major improvements are being witnessed for achieving real-time results and decreasing latency. This work attempts to provide an extensive and objective walkthrough in the direction of adoption of fog computing and software defined networking (SDN) framework for a huge data processing in healthcare domain. Both of these technologies, holds a great promise for the healthcare industry. In this paper, first of all, we survey various communication technologies involved in heathcare and also discuss the need of data processing and its security. Finally, we conclude with future research issues and challenges in this domain.

SCIENCE AND TECHNOLOGY PUBLICATIONS

1 INTRODUCTION

Health is a prominent aspect for concern to human. Healthcare sector is growing on an expeditious scale. With the increase in living expectancy of people, the aging population is increasing by the day which is the major reason to bring in advancements in healthcare that are effective, essential and most importantly-quick (Vora et al., 2017). The main purpose of including IoT in healthcare is to provide real-time results for patients in critical conditions. The Summary of various notations used in the paper is given in Table 1.

Table 1: Summary of Notations.

Abbreviation	Description
IoT	Internet of Things
CC	Cloud computing
FC	Fog computing
SDN	Software defined network
RFID	Radio-Frequency identification
DL	Deep Learning
DN	Deep Network
ML	Machine Learning
DT	Decision Trees
NB	Naive Bayes
KNN	K-Nearest Neighbours
SVM	Support Vector Machine
RF	Random Forests
ANN	Artificial Neural Network
BBN	Bayesian Belief Network

1.1 IoT in Healthcare

IoT provides an end-to-end communication and processing. This archetype is an ecosystem of connected

[a] https://orcid.org/0000-0001-9157-5245
[b] https://orcid.org/0000-0001-7172-125X
[c] https://orcid.org/0000-0002-2375-5057
[*] Fellow of IEEE and Fellow of SCS
[**] Member, IEEE

Shah, K., Obaidat, M., Modi, P., Bhatia, J., Tanwar, S. and Sadoun, B.
Amalgamation of Fog Computing and Software Defined Networking in Healthcare 4.0: The Challenges, and a Way Forward.
DOI: 10.5220/0009911300250032
In *Proceedings of the 17th International Joint Conference on e-Business and Telecommunications (ICETE 2020) - Volume 3: ICE-B*, pages 25-32
ISBN: 978-989-758-447-3
Copyright © 2020 by SCITEPRESS – Science and Technology Publications, Lda. All rights reserved

Introduction	Related Work	Case Study	Conclusion
• Iot for Healthcare • Data Processing and Analysis for healthcare • Cloud Computing for Healthcare • Fog Computing for Healthcare • Software Defined Networking for Healthcare • Contribution	• Communication channel • Compute Engine • Emerging Technologies	• Fog Assisted-IoT Enabled Patient Health Monitoring in Smart Homes	• Conclusion

Figure 1: Organization of Paper.

devices that are accessible through the Internet. Internet of Things (IoT)-enabled devices have made remote monitoring in the healthcare sector possible and results into superlative care by physicians. Besides, remote checking of patient's wellbeing helps in decreasing the length of hospital stay and preventing readmission. IoT also has a major impact on treatment outcome and significant reduction in healthcare costs. However, monitoring all these objects in real time is really difficult. These devices inter-communicate and generate an enormous amount of data. The management of this massive amount of data generated is a hassle. Smart and efficient utilization of this data could proves to be beneficial. We need to process and analyze these data for various applications.

1.2 Data Processing and Analysis in Healthcare

The data generated due to millions of interactions between these objects is usually unstructured and not effectively employed. The expansion of healthcare-specific IoT devices opens up large number opportunities and the huge amount of data generated hold the potential to transform the healthcare. Data Processing helps in structuring of this raw data, whereas data analysis plays a crucial role in handling this mismanaged data. By performing proper segregation of data, profitable data sets can be obtained. The analysis of these data sets can generate trends to track and monitor the human health anatomy. These processes can be performed on a high performance compute engine like cloud.

1.3 Cloud Computing in Healthcare

Buying and maintaining expensive hardware devices for computations can be quite expensive; computer resources can be made available whenever and wherever needed with the help of cloud computing. In simple words, cloud computing(CC) is *pay for what you use*. This term refers to allocation of computer resources as per demands or requirements of the user and charging for the same(Shah et al., 2019). The data obtained from the IoT devices is sent to the cloud for data processing and analysis to generate trends and perform calculations (Lakshmanachari et al., 2017)(Bhatia et al., 2012). The vital information of the patients can be sent to cloud compute engine for data processing and trends are accordingly generated and obtained as reports. The only drawbacks with cloud computing are heavy load or traffic and delay in response time. The patient oriented IoT is delay sensitive, so there is a need of a paradigm which does the nearest computing or server offloading(Jaykrushna et al.,).

1.4 Fog Computing in Healthcare

Fog computing works as an intermediate layer between the cloud and the IoT devices. The data obtained from the source, is first sent to the fog devices to perform critical computations that require immediate processing. It increases the efficiency of the network by providing real time results to the devices nearer to the network (Verma and Sood, 2018) (Kumari et al., 2019) (Guelzim et al., 2016) (Tanwar et al., 2017). Fog computing or edge computing overcomes the latency issues. This approach usually involves a three layered architecture. The layers can be classified as:
1. Data Source Layer
2. Fog Layer
3. Cloud Layer.
Fog Layer is also beneficial with regard to security aspects (Hathaliya and Tanwar, 2020).

1.5 Software Defined Networking in Healthcare

Healthcare organizations are under pressure to scale and upgrade their network infrastructure to cope up

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

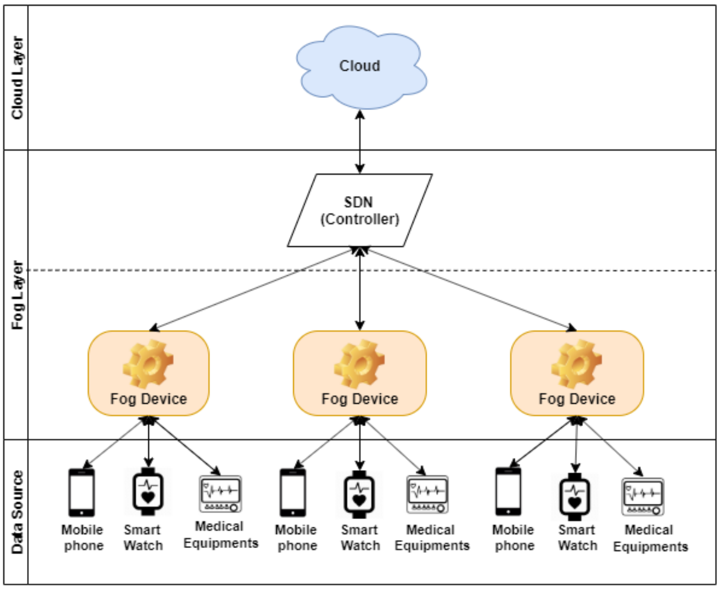

Figure 2: Three Layered Architecture(Wadhwa and Aron, 2018) (Tanwar et al., 2020).

with latest medical technologies for patient care (Vora et al., 2018) (Tanwar et al., 2018a) (Tanwar et al., 2020a). While addressing these needs, upgraded networks can avail the advantage of SDN's programmability, speed, flexibility and agility. SDN is a rising paradigm that aims at providing the facility to program the network. With SDN, creating new notions in networking is possible (Bhatia et al., 2017)(Bhatia et al., 2018).

SDN helps in innovation and evolution of the networks along with drastically simplifying the network management. It does so, by decoupling the software logic from the hardware to apply new protocols with ease. An adoption of the SDN in the three layered architecture improves the efficiency of the system by selecting the appropriate node of the fog layer and provides real-time results with the minimum delay(Bhatia et al., 2020).

1.6 Contributions

The primary objective of this paper is to give an insight of the current ongoing technologies used and the future directions and scopes in the area of healthcare and smart health homes(Azibek et al., 2020). We have also provided key apprehension of the ML algorithms used in the past.

- We reviewed the existing survey of the past few years by comparing and briefing the various technologies used in the field of healthcare.
- We categorised the review, on the basis of different approaches used.
- We also projected the future scopes in the field of healthcare.

The organization of the paper is shown in the Fig. 1.

2 RELATED WORK

A lots of work has been done in healthcare using IoT, fog computing and cloud computing(Bhatia and Kumhar, 2015)(Obaidat and Nicopolitidis, 2016). Some of the relevant works have been included in this survey. The review is done based on the communication and compute engine technologies. We also provide coverage of various emerging trendy technologies used in healthcare domain. The taxonomy of the review work is shown in the Fig. 3.

2.1 Communication Technologies

RFID communicates via radio waves which can be used in healthcare to keep a track of patients, staff and equipments and hence, facilitating the monitoring of *in* and *out* of the hospital. In 2017, Lakshmanachari *et al.*(Lakshmanachari et al., 2017) used RFID, which works on a frequency of 125 kHz. This was beneficial in terms of low power consumption, low complexity and high portability, which are some of the important aspects in area of healthcare. In 2018, Kumari *et al.*(Kumari et al., 2018) have suggested, the use of RFID, Wi-Fi, 5G and Zigbee in fog computing to decrease the latency and increase in network bandwidth. While in 2019, Rahman *et al.*(Rahman et al., 2019) have stated that, with the use of 5G D2D non-licensed

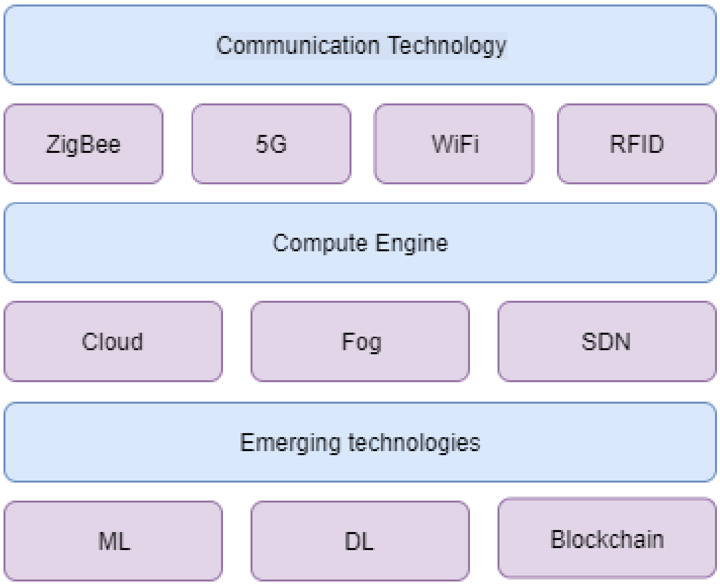

Figure 3: Taxonomy of the related work.

spectrum advancement, different critical IoT data can be configured by keeping in consideration various parameters like latency and jitter. Pasquale *et al.*(Pace et al., 2018) have proposed a system to support mobile healthcare using Zigbee and Wi-Fi in 2018.

2.2 Compute Engine

Authors in (Lakshmanachari et al., 2017) (Singh and Malhotra, 2019) (Maini et al., 2018) (Bhatia, 2015) have used cloud as their compute engine which has proven to be a very convenient option to carry out massive computations in the recent years. One of the biggest reasons behind the success of CC is its cost efficiency. In the field of healthcare, a little delay in results, can put a life in critical situation for the patients. The delay incurred in cloud computing cannot be accepted in healthcare as data is sent to a remote server for data processing and analysis. As these servers are highly employed at all times, heavy traffic is a major concern and the data transmission to these far off servers take a lot of time. These factors cause the users to experience a time delay in the results.

Authors in (Verma and Sood, 2018) (George et al., 2018) (Kumari et al., 2018) (Guibert et al., 2017) used fog computation method, which is more efficient then cloud. In FC, the critical decisions for the computations that are to be made from the data obtained, are processed at the fog node itself. Only the data storage and little bit data analysis is to be made at the cloud. Nevertheless, on the otherside, finding a nearest fog node to the source node is a major challenge. To resolve this, Software Defined Network (SDN) can be used due to its global view of network infrastructure (Tanwar et al., 2018b). SDN controls the data flow and chooses the optimal node from the scattered network of fog nodes to achieve fast results with a minimal latency. The three layered architecture is shown in Fig. 3.

2.3 Emerging Technologies

There is a significant demand of ML and DL in the healthcare sector to train the continuously streaming data using an efficient algorithm. The concept of integrating ML and DL can be of great use to generate accurate trends. The data involved in healthcare is extremely sensitive and it needs to be protected. Blockchain technology can be used for security provisioning to the data flowing in the network(Vora et al., 2018b)(Vora et al., 2018a).

Machine Learning. Data obtained from the hospital can be structured or unstructured. The unstructured data needs to be processed to perform data analytics. ML algorithms have proven to be an optimal choice for performing data analysis on a large data sets. Authors in (Chen et al., 2018) (Singh and Malhotra, 2019)(Maini et al., 2018)(Araújo et al., 2016)(Yahyaoui et al., 2019) have used the state of the art ML algorithms and analysed the medical data to generate trends and results. In 2017, Chen *et al.*(Chen et al., 2018) used CNN algorithm to predict diseases from structured and text data with an accuracy of 0.9420 and recall of 0.9808. Authors in (Chen et al., 2018) used traditional ML algorithms for the structured data with an accuracy roughly around 0.5. Table 3 shows the ML algorithms used and the objectives fulfilled in different articles by researchers.

Deep Learning. An ANN (Artificial Neural Network) with a lot of hidden layers is known as a Deep Network and the method to train this network is known as Deep Learning. This technique involves higher number of parameters which results in obtaining better trends and precise decision boundaries. Authors in (Purushotham et al., 2017) (Rajkomar et al., 2018) have implemented Deep Networks to achieve higher accuracy than traditional ML Algorithms. Pham *et al*. (Pham et al., 2017) used DL algorithm to predict trajectories in Patient Health Records and achieve F-score as high as 80 with the Diabetes data set (Hathaliya et al., 2019).

Blockchain. Security is an important aspect while handling the medical data. Recent advancements in blockchain technology ensures the security of this data. Authors in (Mettler, 2016) (Yue et al., 2016) (Liang et al., 2017) (Hathaliya et al., 2019) have used this technology to ensure security of various Healthcare Systems using blockchain technology for security and interoperablity of Electronic Health Record (EHR) Systems (Tanwar et al., 2020b). Yue *et al.*(Yue et al., 2016) implemented a system where blockchain authorizes the control of medical records of the patients and also proposed Multi-Party Computing monitored by blockchain technology to ensure safety of the healthcare data.

3 CASE STUDY

Prabal *et al.*(Verma and Sood, 2018) has proposed a Fog-assisted IoT enabled health monitoring systems for patients in smart homes where health data of 67 patients was systematically generated for 30 days to check the validity of their model. This model follows the three layered architecture comprising of the following.

1. Data Acquisition Layer: Timely data retrieval from the IoT devices is performed at this layer. The environmental and physiological parameters are obtained from these devices and sent to the fog layer.

2. Fog Layer: The parameters obtained from the IoT devices are converted into adequate format before sending them to the cloud. The event classification also takes place at this layer where the data is

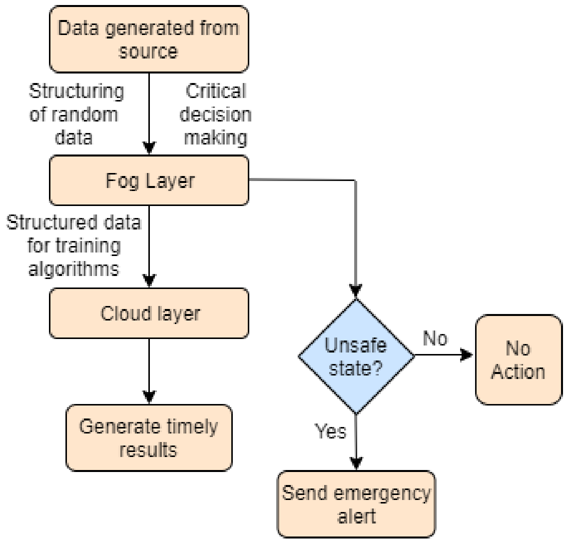

Figure 4: Decision making.

categorised as normal or abnormal. When parameters have higher values than usual, like high blood pressure or high glucose level, they are considered to be abnormal states. The BBN classifier is used to calculate the probability of occurrence of any critical event.

3. Cloud Layer: This layer focuses on extracting or mining useful data from the fog layer in real-time. The training algorithms runs on this layer using the continuous data generated from source.

The parameters of the data can be classified to be in SS (Safe State) or US (Unsafe State) for the patients. If it is an US, emergency alert is sent from the fog layer to the source of data generation, otherwise, the data is sent to cloud and timely results are generated. The decision making of the model is explained in Fig. 4.

4 EXPERIMENTAL RESULTS

We used the Pima Indians diabetes dataset(Pim,) to predict if a person has diabetes or not, which comprises of various attributes such as BMI (Body Mass Index), Age, Blood pressure, Glucose Level, Insulin Level, Skin Thickness, etc., generated from different IoT devices. The first step, that is supposed to be taken in this process is data preprocessing. This data consists of several entries, where some of the attributes were erroneous or outlier. For example, blood pressure of a living person cannot be 0. These entries can mislead our classifier to learn false trends. On performing data preprocessing on our dataset, the number of entries decreased from 768 to 722. For

Table 2: ML Algorithms.

Year	Author	ML Algorithms used	Objectives
2016	Gupta *et al.* (Gupta et al., 2016)	InfoGain, Adaboost	Chronic Disease Prediction
2016	Araújo *et al.* (Araújo et al., 2016)	RF, NB, SVM, KNN	Preauthorization for Healthcare Insurance Providers (HIPs)
2017	Chen *et al.*(Chen et al., 2018)	CNN, NB, KNN, DT	To predict diseases from Structured and text data
2018	Maini *et al.* (Maini et al., 2018)	DT, NB, ANN	Cardiovascular Disease Prediction
2019	Singh *et al.*(Singh and Malhotra, 2019)	RF	To detect epileptic seizure
2019	Yahyaoui *et al.* (Yahyaoui et al., 2019)	SVM, RF, CNN	To predict diabetes
2019	Jadhav *et al.*(Jadhav et al., 2019)	SVM, NB	mHealth disease prediction system

Table 3: ML Algorithms.

ML Algorithms used	Accuracy Obtained
KNN	65%
LR	67%
RF	75%

data analytics, we used the state-of-the-art ML algorithms such as KNN, RF and LR. For the KNN algorithm, we achieved an accuracy of 65% with F1 score as high as 0.72. F1 score is the metric commonly used for evaluation of a model. Only recall or precision is not enough, so F1 score, a combination of recall and precision is used. It is defined as F1 = 2((recall * precision)/(recall + precision)). On using the LR model, we achieved an accuracy of 67% with a learning rate of 0.3 and 800 epochs. On the other hand, with RF algorithm, the accuracy was boosted up to 75.32% when applied with 100 estimators. This data suggests that better results can be obtained from the large unutilized data generated by the current IoT network(s).

5 CONCLUSION

In this paper, we have provided insights about the evolution in the field of healthcare. It can be concluded from the above literature review that CC limits the infrastructure in terms of real-time results for critical data. This issue can be resolved with the help of three layered architecture of FC along with SDN and Cloud. Using ML and DL algorithms in the healthcare infrastructure for data analytics, generation of precise and accurate trends is possible. The amalgamation of various communication technologies and infrastructures will bring in an efficient and effective development in the field of healthcare and smart health homes.

REFERENCES

Pima Indians Diabetes Database predict the onset of diabetes based on diagnostic measures. http://https://www.kaggle.com /uciml/pima-indians-diabetes- database. Accessed: 2019-12-28.

Araújo, F. H., Santana, A. M., and Neto, P. d. A. S. (2016). Using machine learning to support healthcare professionals in making preauthorisation decisions. *International journal of medical informatics*, 94:1–7.

Azibek, B., Zhigerova, S., and Obaidat, M. S. (2020). Smart and efficient health home system. In *Emerging Research in Data Engineering Systems and Computer Communications*, pages 677–691. Springer.

Bhatia, J., Dave, R., Bhayani, H., Tanwar, S., and Nayyar, A. (2020). Sdn-based real-time urban traffic analysis in vanet environment. *Computer Communications*, 149:162–175.

Bhatia, J., Govani, R., and Bhavsar, M. (2018). Software defined networking: From theory to practice. In *2018 Fifth International Conference on Parallel, Distributed and Grid Computing (PDGC)*, pages 789–794.

Bhatia, J. and Kumhar, M. (2015). Perspective study on load balancing paradigms in cloud computing. *IJCSC*, 6(1):112–120.

Bhatia, J., Mehta, R., and Bhavsar, M. (2017). Variants of software defined network (sdn) based load balancing in cloud computing: A quick review. In *International Conference on Future Internet Technologies and Trends*, pages 164–173. Springer.

Bhatia, J., Patel, T., Trivedi, H., and Majmudar, V. (2012). Htv dynamic load balancing algorithm for virtual machine instances in cloud. In *2012 International Symposium on Cloud and Services Computing*, pages 15–20. IEEE.

Bhatia, J. B. (2015). A dynamic model for load balancing in cloud infrastructure. *Nirma University Journal of Engineering and Technology (NUJET)*, 4(1):15.

Chen, M., Li, W., Hao, Y., Qian, Y., and Humar, I. (2018). Edge cognitive computing based smart healthcare system. *Future Generation Computer Systems*, 86:403–411.

George, A., Dhanasekaran, H., Chittiappa, J. P., Challagundla, L. A., Nikkam, S. S., and Abuzaghleh, O. (2018). Internet of things in health care using fog computing. In *2018 IEEE Long Island Systems, Applications and Technology Conference (LISAT)*, pages 1–6. IEEE.

Guelzim, T., Obaidat, M., and Sadoun, B. (2016). Introduction and overview of key enabling technologies for smart cities and homes. In *Smart cities and homes*, pages 1–16. Elsevier.

Guibert, D., Wu, J., He, S., Wang, M., and Li, J. (2017). Cc-fog: Toward content-centric fog networks for e-health. In *2017 IEEE 19th International Conference on e-Health Networking, Applications and Services (Healthcom)*, pages 1–5. IEEE.

Gupta, D., Khare, S., and Aggarwal, A. (2016). A method to predict diagnostic codes for chronic diseases using machine learning techniques. In *2016 International Conference on Computing, Communication and Automation (ICCCA)*, pages 281–287. IEEE.

Hathaliya, J., Sharma, P., Tanwar, S., and Gupta, R. (2019). Blockchain-based remote patient monitoring in healthcare 4.0. In *2019 IEEE 9th International Conference on Advanced Computing (IACC)*, pages 87–91.

Hathaliya, J. J. and Tanwar, S. (2020). An exhaustive survey on security and privacy issues in healthcare 4.0. *Computer Communications*, 153:311 – 335.

Hathaliya, J. J., Tanwar, S., Tyagi, S., and Kumar, N. (2019). Securing electronics healthcare records in healthcare 4.0 : A biometric-based approach. *Computers & Electrical Engineering*, 76:398 – 410.

Jadhav, S., Kasar, R., Lade, N., Patil, M., and Kolte, S. (2019). Disease prediction by machine learning from healthcare communities.

Jaykrushna, A., Patel, P., Trivedi, H., and Bhatia, J. Linear regression assisted prediction based load balancer for cloud computing. In *2018 IEEE Punecon*, pages 1–3. IEEE.

Kumari, A., Tanwar, S., Tyagi, S., and Kumar, N. (2018). Fog computing for healthcare 4.0 environment: Opportunities and challenges. *Computers & Electrical Engineering*, 72:1–13.

Kumari, A., Tanwar, S., Tyagi, S., Kumar, N., Obaidat, M. S., and Rodrigues, J. J. P. C. (2019). Fog computing for smart grid systems in the 5g environment: Challenges and solutions. *IEEE Wireless Communications*, 26(3):47–53.

Lakshmanachari, S., Srihari, C., Sudhakar, A., and Nalajala, P. (2017). Design and implementation of cloud based patient health care monitoring systems using iot. In *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*, pages 3713–3717. IEEE.

Liang, X., Zhao, J., Shetty, S., Liu, J., and Li, D. (2017). Integrating blockchain for data sharing and collaboration in mobile healthcare applications. In *2017 IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, pages 1–5. IEEE.

Maini, E., Venkateswarlu, B., and Gupta, A. (2018). Applying machine learning algorithms to develop a universal cardiovascular disease prediction system. In *International Conference on Intelligent Data Communication Technologies and Internet of Things*, pages 627–632. Springer.

Mettler, M. (2016). Blockchain technology in healthcare: The revolution starts here. In *2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom)*, pages 1–3. IEEE.

Obaidat, M. S. and Nicopolitidis, P. (2016). *Smart cities and homes: Key enabling technologies*. Morgan Kaufmann.

Pace, P., Aloi, G., Gravina, R., Caliciuri, G., Fortino, G., and Liotta, A. (2018). An edge-based architecture to support efficient applications for healthcare industry 4.0. *IEEE Transactions on Industrial Informatics*, 15(1):481–489.

Pham, T., Tran, T., Phung, D., and Venkatesh, S. (2017). Predicting healthcare trajectories from medical records: A deep learning approach. *Journal of biomedical informatics*, 69:218–229.

Purushotham, S., Meng, C., Che, Z., and Liu, Y. (2017). Benchmark of deep learning models on large healthcare mimic datasets. *arXiv preprint arXiv:1710.08531*.

Rahman, M. A., Rashid, M., Barnes, S., Hossain, M. S., Hassanain, E., and Guizani, M. (2019). An iot and blockchain-based multi-sensory in-home quality of life framework for cancer patients. In *2019 15th International Wireless Communications & Mobile Computing Conference (IWCMC)*, pages 2116–2121. IEEE.

Rajkomar, A., Oren, E., Chen, K., Dai, A. M., Hajaj, N., Hardt, M., Liu, P. J., Liu, X., Marcus, J., Sun, M., et al. (2018). Scalable and accurate deep learning with electronic health records. *NPJ Digital Medicine*, 1(1):18.

Shah, N. B., Shah, N. D., Bhatia, J., Trivedi, Harshal", e. S., Akashe, S., and Mahalle, P. N. (2019). Profiling-based effective resource utilization in cloud environment using divide and conquer method. In *Information and Communication Technology for Competitive Strategies*, pages 495–508, Singapore. Springer Singapore.

Singh, K. and Malhotra, J. (2019). Iot and cloud computing based automatic epileptic seizure detection using hos features based random forest classification. *Journal of Ambient Intelligence and Humanized Computing*, pages 1–16.

Tanwar, S., Parekh, K., and Evans, R. (2020a). Blockchain-based electronic healthcare record system for healthcare 4.0 applications. *Journal of Information Security and Applications*, 50:102407.

Tanwar, S., Parekh, K., and Evans, R. (2020b). Blockchain-based electronic healthcare record system for healthcare 4.0 applications. *Journal of Information Security and Applications*, 50:102407.

Tanwar, S., Trivedi, H., and Priyank, T. (2018a). Software defined network-based vehicular adhoc networks for intelligent transportation system: Recent advances and future challenges. *Futuristic Trends in Network and Communication Technologies (FTNCT)*, 858:325–337.

Tanwar, S., Vora, J., Kaneriya, S., and Tyagi, S. (2017). Fog-based enhanced safety management system for miners. In *2017 3rd International Conference on Advances in Computing,Communication Automation (ICACCA) (Fall)*, pages 1–6.

Tanwar, S., Vora, J., Kaneriya, S., Tyagi, S., Kumar, N., Sharma, V., and You, I. (2020). Human arthritis analysis in fog computing environment using bayesian network classifier and thread protocol. *IEEE Consumer Electronics Magazine*, 9(1):88–94.

Tanwar, S., Vora, J., Tyagi, S., Kumar, N., and Obaidat, M. S. (2018b). A systematic review on security issues in vehicular ad hoc network. *Security and Privacy*, 1(5):1–23.

Verma, P. and Sood, S. K. (2018). Fog assisted-iot enabled patient health monitoring in smart homes. *IEEE Internet of Things Journal*, 5(3):1789–1796.

Vora, J., DevMurari, P., Tanwar, S., Tyagi, S., Kumar, N., and Obaidat, M. S. (2018a). Blind signatures based secured e-healthcare system. In *2018 International Conference on Computer, Information and Telecommunication Systems (CITS)*, pages 1–5. IEEE.

Vora, J., Italiya, P., Tanwar, S., Tyagi, S., Kumar, N., Obaidat, M. S., and Hsiao, K.-F. (2018b). Ensuring privacy and security in e-health records. In *2018 International Conference on Computer, Information and Telecommunication Systems (CITS)*, pages 1–5. IEEE.

Vora, J., Kaneriya, S., Tanwar, S., and Tyagi, S. (2018). Performance evaluation of sdn based virtualization for data center networks. In *2018 3rd International Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU)*, pages 1–5.

Vora, J., Tanwar, S., Tyagi, S., Kumar, N., and Rodrigues, J. J. (2017). Faal: Fog computing-based patient monitoring system for ambient assisted living. In *2017 IEEE 19th international conference on e-health networking, applications and services (Healthcom)*, pages 1–6. IEEE.

Wadhwa, H. and Aron, R. (2018). Fog computing with the integration of internet of things: Architecture, applications and future directions. In *International Conference on Parallel and Distributed Processing with Applications, Ubiquitous Computing & Communications, Big Data & Cloud Computing, Social Computing & Networking, Sustainable Computing & Communications*, pages 987–994. IEEE.

Yahyaoui, A., Rasheed, J., Jamil, A., and Yesiltepe, M. (2019). A decision support system for diabetes prediction using machine learning and deep learning techniques.

Yue, X., Wang, H., Jin, D., Li, M., and Jiang, W. (2016). Healthcare data gateways: found healthcare intelligence on blockchain with novel privacy risk control. *Journal of medical systems*, 40(10):218.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS