Abstract

Healthcare in general refers to services provided for preservation or enhancement of health through anticipation, finding, treatment, recovery, or healing of disease, illness, injury, or any physical and mental impairment in humans. Quality of Services in Healthcare Systems may be characterised broadly through parameters such as accuracy of data, speed of decision-making, timely treatment, security of data, real-time monitoring and controlling of the health systems, failure handling and quality of life. In this research work, we have tried to achieve the Quality of Services in Healthcare through IoT and Fog Computing, considering optimization of one or more of these parameters.

The Internet of Things (IoT) describes the network of physical objects —“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. IoT technology facilitates connecting different devices over the internet and providing digital identity to them. When IoT is applied to different fields like healthcare, agriculture, manufacturing, safety and security, supply chain, etc., it adds smartness and hence, has tremendous benefits like real-time monitoring and control. This IoT technology demand has increased in present era, due to its growth supported by growth in various other related technologies like access to low-cost, low-power sensor technology, Connectivity, Cloud Computing platforms, Machine learning and analytics, Conversational Artificial Intelligence (AI).

IoT as an independent element is less efficient due to its low-processing capabilities, its context-sensitivity and incapability of independent decision making. Due to the low-processing power of IoT devices, to make decisions on real-time data generated by IoT devices, the Cloud Computing paradigm is used. The IoT data is huge in volume and when it is sent to the cloud, the network bandwidth required is very high, transmission time to send this data to cloud and receive the results is very high, high delays in acquiring results may be non-negotiable in some applications. In all, decisions made by the cloud are delay-sensitive. Some application domains like Security and Health-care demand real-time decision making. In such sensitive domains, a timely decision made in a fraction of a second can prevent catastrophe. In healthcare, it can save many human lives. In the healthcare domain, if IoT is deployed to monitor ECG signals and if the signal abnormality is detected

as early as possible, then it increases the chance of living. But, when ECG signals are sensed through IoT and sent to the cloud for the analysis purpose, delays are caused by the time results reach the medical staff. This delay in decision making is due to the transmission delay and processing delays. To overcome these issues, Fog Computing can be used.

In this research work, different healthcare applications like monitoring real-time Electro Cardiogram (ECG) signals, recording Electro Myogram (EMG) signals, and finding the real-time GPS location of the patient have been studied and implemented. This is to check the suitability of the IoT devices in healthcare domain. During the study, it has been found that IoT devices need special interfacing, exclusive time-sensitive analog to digital conversions of the signals, and proper placing of sensors on the body. After fulfilling the need, IoT can work well with healthcare applications to get real-time readings in the form of digital signals. For faster processing and to achieve speedy and timely decision-making, Fog Computing has been used. While using the Fog Computing architecture for the healthcare domain, especially with the time-sensitive real-time signal like ECG, it is made sure that no redundant data is sent on the cloud, so as to save the network bandwidth. The suitability of the Fog Node has been projected in this research work.

As part of the research work, Standard Fog Computing architecture for the healthcare domain has been defined and measured with different QoS parameters like Transmission delay, Computational delay, bytes of Data transferred, CO_2 emitted and the total response time. The comparisons of various parameters are done w.r.t Cloud Computing approach. By considering these QoS parameters a new service called “Health-as-a-service” (HaaS) is introduced in the Fog Computing context.

Besides various QoS parameters, security in Fog Computing has also been explored as part of the research study. The lightweight multi-layer security encryption scheme in the Fog-IoT context has been designed to provide different security levels at different layers of architecture based on the capabilities of the device and the sensitivity of the data.

The results obtained from the Fog Node can further be improved in terms of QoS and processing time. QoS considers improving the quality in terms of accuracy, faster decision-making, by changing the processing approach, reducing processing time by considering various Operating Systems process priorities, data security, and pre-processing the training data samples. The processing approach introduces Optimization in the Fog Node to strengthen its computing power. In this, accuracy in type of arrhythmia detection is improved by doing the augmentation for time-series based numerical and graphical ECG signals.

The Genome and skin cancer data has also been considered which has big data processing requirement and generally take more time to produce the results using traditional pattern matching algorithms. Such huge data volume is tested on the Fog Node for processing purpose and better approaches like Run-Length-Encoding and Distributed Computing are applied to get speedier and timely decisions. These healthcare applications have been tested in Fog Computing environment to conclude the suitability of Fog Computing domain in big data. The final improvement in terms of pattern matching time achieved is more than 80% of the traditional computing environment. This shows that the Fog Node is also capable to handle the big data volume and Fog Computing is suitable for handling variety of data types like numeric, text and images from different health care applications. In short we have tried to compare our results with new approach of pattern matching in fog environment and also implemented Distributed Computing approach in fog.

Further, to improve the Fog Computing environment in terms of its computational power, the heterogeneous Distributed Computing approach in Fog Computing has been introduced. In this, the 'dispy' tool has been used to achieve Distributed Computing in the Raspberry Pi clustering environment. After 'dispy' is found suitable for processing ECG signals in distributed environment different processing factors like the number of cores, CPU usage, available memory space, and response time are considered. For every parameter, the ECG processing has been monitored and based on all these parameters the ‘OptiFog’ algorithm has been designed. This algorithm will make sure that the available hardware is used at the optimal level and helps in quicker decision-making w.r.t the 'dispy' Distributed Computing approach. Now, with the ‘OptiFog’ algorithm, the speedup ratio in terms of time achieved here is more than 14 and we can process a larger number of ECG samples with more than 10 number of waves in one go which was not possible in the 'dispy' Distributed Computing approach.

In all, the Fog Computing is made suitable for healthcare applications. To do this, the needed architecture, QoS parameters, fog device standards, fog data security, multi-layer fog model, fog deployment, and different computing approaches have been studied, defined, analyzed and improved. Thus, QoS in Healthcare in terms of parameters such as accuracy of data, speedy and timely decision-making is improved for QoS in results and it is optimized to achieve faster processing.

Here, we have developed the low cost ECG analysis system, low cost IoT based GPS system and ECG sensor based wheel chair controlling system to support the health care domain. For time series ECG signal data classification, accuracy achieved is more than 99% and for graphical ECG signal data classification, accuracy achieved is more than 97%. At the single Fog Node by using different operating system process priorities, improvement of around 500 ms in process computation is acquired. For analysis of Genome pattern matching algorithm, the time improvisation is more than 87%. Using the Fog Computing in Health care system we have achieved reduction in CO_2 emission around 66%, the result is available for decision making is prominently 7s is earlier in Fog Computing as compared to cloud, which is very critical for life expectancy and reducing the damage to the human brain. Moreover, the volume of data transfer to cloud over the internet is reduced by 33% and more when the decision is already taken at the Fog Node. The OptiFog algorithm is able to reduce the processing time around 50% by optimally using the hardware and by dynamically deciding the job size.

The overall research work has been published in form of papers, patents and copyrights as:

1. Kanani P., Padole M. (2018**) Recognizing Real Time ECG Anomalies Using Arduino, AD8232 and Java**. In: Singh M., Gupta P., Tyagi V., Flusser J., Ören T. (eds) Advances in Computing and Data Sciences. ICACDS 2018. Communications in Computer and Information Science, vol 905. Springer, Singapore. ISBN no. 978-981-13-1809-2. **[Scopus indexed]**
https://link.springer.com/chapter/10.1007/978-981-13-1810-8_6
2. Pratik Kanani and Mamta Padole, "**ECG Image Classification using Deep Learning Approach**", Handbook of Research on Disease Prediction Through Data Analytics and Machine Learning, IGI Global, pp.- 343-357. DOI: 10.4018/978-1-7998-2742-9.ch016. ISBN no. 9781799827429. **[NLM indexed]**
https://www.igi-global.com/chapter/ecg-image-classification-using-deep-learning-approach/263326

3. Pratik Kanani and Mamta Padole, "**Deep Learning to Detect Skin Cancer using Google Colab**", International Journal of Engineering and Advanced Technology (IJEAT), Vol. 8, isuue. 6, pp. 2176-2183. ISSN no. 2249-8958. **[Scopus indexed and UGC Care Journal]**
   https://www.ijeat.org/wp-content/uploads/papers/v8i6/F8587088619.pdf
4. Pratik Kanani and Mamta Padole, "**IoT based Eye Movement Guided Wheelchair driving control using AD8232 ECG Sensor**", International Journal of Recent Technology and Engineering, Vol. 8, Issue. 4, pp. 5013-5017. ISSN no. 2277-3878. **[Scopus indexed and UGC Care Journal]**
   https://www.ijrte.org/wp-content/uploads/papers/v8i4/D8182118419.pdf
5. Pratik Kanani and Mamta Padole, "**ECG Heartbeat Arrhythmia Classification Using Time-Series Augmented Signals and Deep Learning Approach**", Third International Conference on Computing and Network Communications (CoCoNet'19). Procedia Computer Science journal, vol. 171(2020), pp. 524-531.ISSN no. 1877-0509. **[Scopus, Web of Science and Ei Compendex indexed]**
   https://www.sciencedirect.com/science/article/pii/S1877050920310231
6. Pratik Kanani and Mamta Padole, "**Exploring and Optimizing the Fog Computing in Different Dimensions**", Third International Conference on Computing and Network Communications (CoCoNet'19). Procedia Computer Science journal, vol. 171(2020), pp. 2694-2703. ISSN no. 1877-0509. **[Scopus, Web of Science and Ei Compendex indexed]**
   https://www.sciencedirect.com/science/article/pii/S1877050920312850
7. Pratik Kanani and Mamta Padole, "**Improving Pattern Matching performance in Genome sequences using Run Length Encoding in Distributed Raspberry Pi Clustering Environment**", Third International Conference on Computing and Network Communications (CoCoNet'19). Procedia Computer Science journal, vol. 171(2020), pp. 1670-1679. ISSN no. 1877-0509. **[Scopus, Web of Science and Ei Compendex indexed]**
   https://www.sciencedirect.com/science/article/pii/S1877050920311601
8. Pratik Kanani and Dr. Mamta Padole, "**Real-time Location Tracker for Critical Health Patient using Arduino, GPS Neo6m and GSM Sim800L in Health Care**", 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2020, pp. 242-249, doi:

10.1109/ICICCS48265.2020.9121128. ISBN no. 978-1-7281-4877-9. **[Scopus indexed]**
https://ieeexplore.ieee.org/abstract/document/9121128

9. P. Kanani and M. Padole, "**Analyzing ECG waves in Fog Computing Environment using Raspberry Pi Cluster**," 2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Palladam, India, 2020, pp. 1165-1172, doi: 10.1109/I-SMAC49090.2020.9243398. ISBN no. 978-1-7281-5465-7. **[Scopus Indexed]**
https://ieeexplore.ieee.org/abstract/document/9243398
10. Pratik Kanani and Mamta Padole, "**Implementing and Evaluating Health as a Service in Fog and Cloud Computing**", The International Journal of Intelligent Engineering and Systems, Vol. 13, No. 6, 2020. DOI: 10.22266/ijies2020.1213.13. ISSN no. 2185-3118. **[Scopus Indexed and UGC Care Journal]**
http://www.inass.org/2020/2020123113.pdf
11. Pratik Kanani and Mamta Padole, "**OptiFog: Optimization of Heterogeneous Fog Computing for QoS in Health Care**", Journal of Theoretical and Applied Information Technology, Vol. 98, No. 22, pp-3625-3642, November 2020. ISSN no. 1992-8645. **[Scopus Indexed and UGC Care Journal]**
http://www.jatit.org/volumes/Vol98No22/4Vol98No22.pdf
12. Pratik Kanani and Dr. Mamta Padole, "**An Effort to reduce the CO2 emission in Computation for Green Computation**", International Conference on Computing Technologies for transforming the Automated World-2020. (In Process of Publication) **(UGC Approved Journal)**
13. International Patent: Mamta Padole and Pratik Kanani, "**A system for Real-Time Heart Health Monitoring**", Patent Number: 2020101730. Australian Government, IP Australia, 02-09-2020. **[Patent Granted]**
14. Indian Copyright: "**Fog Optimization Technique for QoS in Heterogeneous Clustering Environment**". Government of India, 01-01-2021. **[Copyright Granted]**
15. Pratik Kanani and Dr. Mamta Padole, "Light weight Multi-Level authentication scheme for secured Data transmission in Fog-IoT context", **[Copyright filed]**
16. Pratik Kanani and Dr. Mamta Padole, "Light weight Multi-Level authentication scheme for secured Data transmission in Fog-IoT Architecture". **[Paper submitted to the journal]**

Other certifications and STTPs done, to get the more insights of the thesis topic

Course Name	**Accomplishment**	**Source**
Introduction to TensorFlow for Artificial Intelligence, Machine Learning, and Deep Learning (20 Hrs)	99%	Coursera
Introduction to Architecting Smart IoT Devices (09 Hrs)	72.57%	Coursera
Machine Learning (72 Hrs)	94.51%	Coursera
Arduino Step by Step (16 Hrs)	Completed	Udemy
Recent advances in Edge and Fog Computing for Internet of Things (1 week)	Completed	STTP