Chapter 1
Introduction

The act of taking necessary medical procedure to improve a person's well-being is a Health Care. Traditional IT healthcare systems have tribulations like cost, location, continuous monitoring, applications, administrative burdens, processing delays and accuracies. Many healthcare applications have been implemented by using different IT infrastructures. Available IT, healthcare solution works very well for non-invasive healthcare. In non-invasive application, the medical devices are mounted on the body and they keep on generating organ health related data. This data is captured and interpreted by the devices using various processing and methods and accordingly the actions are taken to maintain the patient's health. But there are some critical health care applications which needs parametric information like Electrocardiography (ECG), Electromyography (EMG), blood pressure, glucose level sensing, Blood Pressure monitoring, Oxygen sensing, rehabilitation, medication and blood temperature. Based on the data recorded IT support systems will aid in taking decisions about health. But in any case if decision for such critical healthcare are delayed by one or the other means, then it results in catastrophic situations. If deployed health care systems are not giving responses on time sensitive basis, then QoS is compromised. In proposed work we intend to improvise the existing IT based health care application in QoS approach.

1.1 Internet of Things (IoT) in Health Care

When the word "Internet" and "Things" put together has introduced an immense innovation in the world of ICT. It is a paradigm where each device has a unique identification/addresses and are connected to the internet [1]. It is a worldwide network of objects which are connected together and can be referred, process, store and transfer the environmental data. It seems as a convergence of different visions as IoT has found its applications in major domains with application scenarios like [1]

- Transportation and logistics domain (Logistics, Assisted Driving, Mobile Ticketing)
- Healthcare domain (Tracking, Data Collection, Sensing)
- Smart environment domain (Smart city, Smart Museum and gym, Comfortable homes)
- Personal and social domain (Losses, Thefts, Social Networking)
- Futuristic (Robot Taxi,)

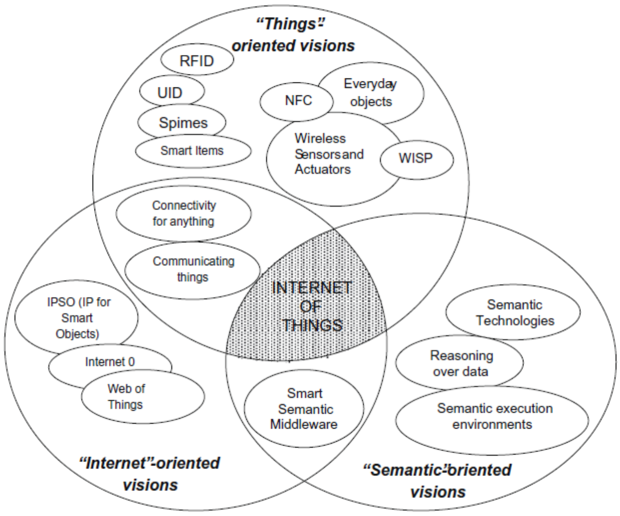

Figure 1.1 "Internet of Things" paradigms as a result of the convergence of different visions [1].

In Healthcare domain IoT can track objects and people, identify and authenticate people and automatically collect the data by sensing environments. Also, IoT is able to communicate in heterogeneous environment using different protocols and wired and wireless media. In the given figure 1.2, the patient is mounted with devices which generates sensing data, and this data is given to local data centre for further access and actions.

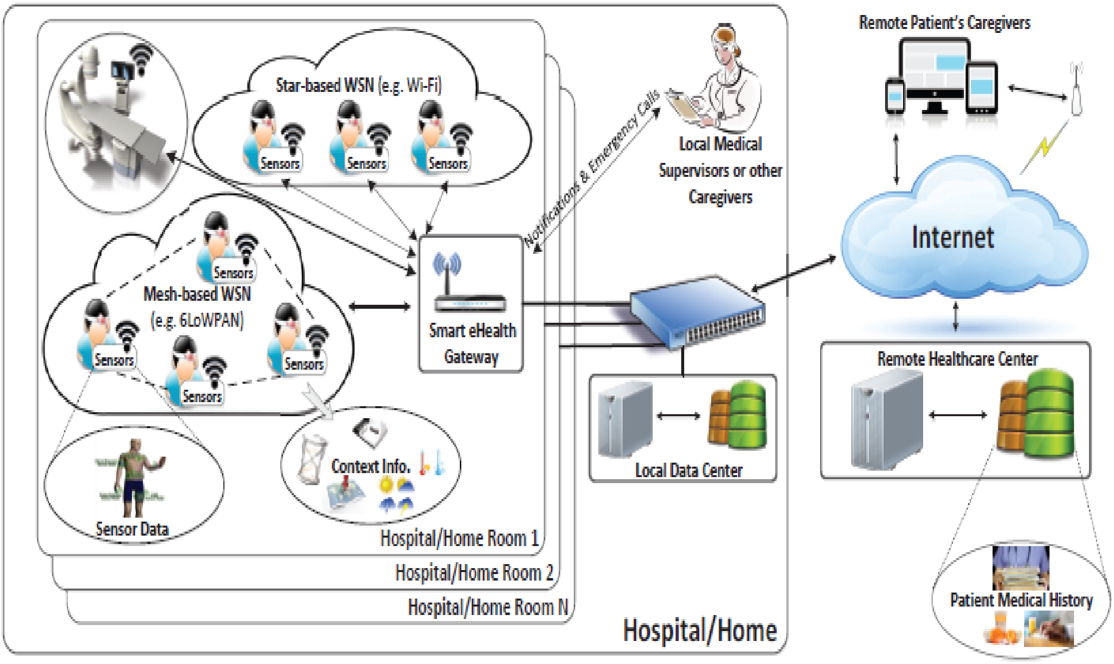

Figure 1.2 IoT based Health monitoring Architecture [2]

1.2 Cloud Computing in Healthcare

Cloud Computing is the internet based computing, meant to provide any sort of computing on demand. The two models which make cloud accessible and feasible to end users are service model and deployment models. Cloud can be deployed as a private, public, hybrid and a community cloud where "as" service models refers to

1. **Infrastructure as a Service (IaaS):** It provides access to resources like virtual storage, virtual machine and physical machine etc.
2. **Platform as a Service (PaaS):** It provides runtime environment for application, development and deployment tools.
3. **Software as a Service (SaaS):** It provides use of different software as a service.

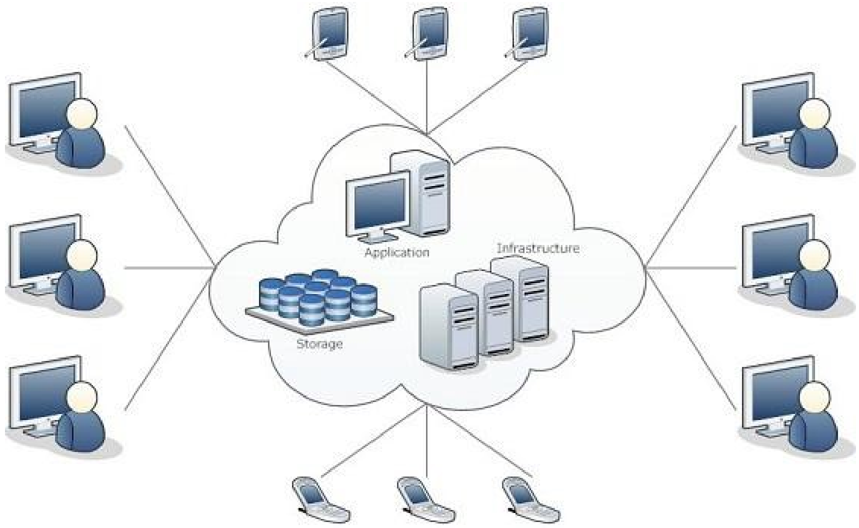

Figure 1.3 Cloud Computing as on demand service

The Cloud Computing is the internet delivery of anything, anytime, anywhere. The charging methods of the cloud are pay as you use. When Health care systems are realized using Cloud Computing, it can have the benefits as

- On demand self service
- Security and privacy
- Resource pooling
- Real-time actions
- Accessibility
- Reliability
- Scalability
- Measured services

To explore the knowledge from the data, cloud does mining, storage, processing and analytics on data. But on Cloud Computing, devices access the user environment through network communication. If number of devices increases, the data coming to and fro cloud also increases, this results in

- Larger storage space
- High processing power
- Greater bandwidth
- More delays

Alternatively high cost as cloud follows pay-as-you go model [3]. And it increases the financial implications in health care scenario to patient. If load on cloud increases then consequences are delayed treatment time, resulting in reduced quality of life.

1.3 Integration of IoT and Cloud Computing

When IoT and cloud viewed as a paradigm, it's called as CloudIoT paradigm. It is pervasive and hence now your cloud architecture can sense the real time data in client environments. In this approach the IoT devices continuously senses the data and sends it to the cloud server and cloud server stores data, where it can be analyzed for decision making or can be accessed to other users [4]. Moreover it provides new set of services, different from the cloud and they are shown in Table 1 [4].

Table 1: New Paradigm enabled by CloudIoT: everything as a service

Xaas (Acronym)	**X(Expansion)**	**Description**
S^2 aaS	Sensing as a Service	Providing ubiquitous access to sensor data
SAaaS	Sensing and Actuation as a Service	Enabling automatic control logics implemented in the cloud
SEaaS	Sensor Event as a Service	Dispatching messaging services triggered by sensor events
SenaaS	Sensor as a Service	Enabling ubiquitous management of remote sensors
DBaaS	DataBase as a Service	Enabling ubiquitous database management
DaaS	Data as a Service	Providing ubiquitous access to any kind of data
EaaS	Ethernet as a Service	Providing ubiquitous layer-2 connectivity to remote devices
IPMaaS	Identity and Policy Management as a Service	Enabling ubiquitous access to policy and identity management functionalities
VSaaS	Video surveillance as a Service	Providing ubiquitous access to recorded video and implementing complex analyses in the cloud.

IoT and Cloud is advantageous, but some of the pitfalls are

- Pervasive Architecture generates a vast amount of data if they are used in healthcare applications where continuous monitoring is needed.
- IoT devices are bounded in context aware Intelligence

1.4 Fog Computing in Health care

1.4.1 Overview of Fog Computing

Fog Computing, popularly known as Edge computing is the novel paradigm/architecture that provides limited computing, storing and network services at the end user devices at user's edge. Simple Fog Computing architecture is shown in figure. 1.4 [1].

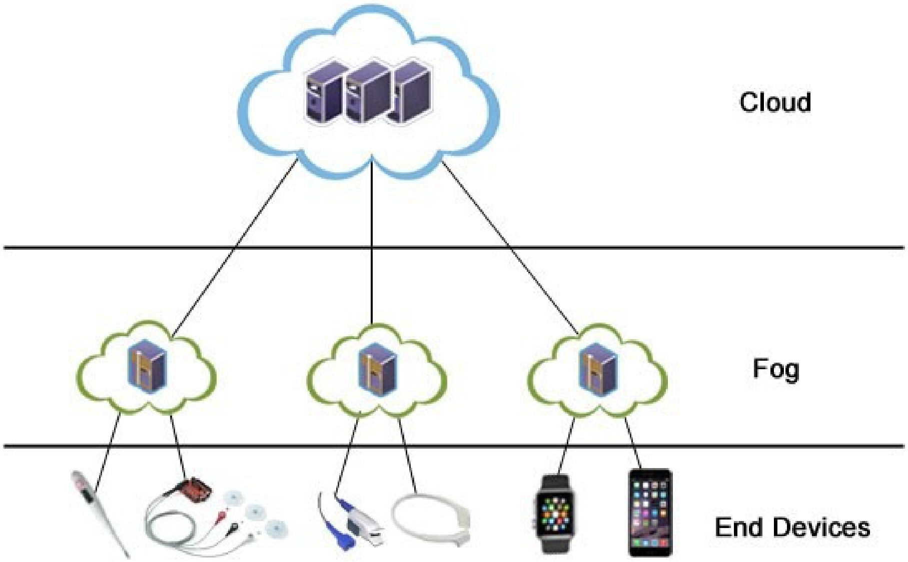

Figure 1.4 Fog Computing Architecture

The implanted Fog Computing extends the Cloud Computing paradigm to the edge of end users and it is able to perform storage, processing and data forwarding. In the given figure 1.4 the Fog Node/server is at layer-2. Whatever data gets forwarded by end devices will be first received by Fog Node. This node keeps on processing the data and is able to take actions and also it forwards the filtrated data to the cloud for future use and analysis. It has characteristics [1] like

1. **Adjacent Physical Location:** Fog devices are near the user end, and hence they can process the user data with less delay and can be made custom in user's need context. They can use protocols of WLAN too.
2. **Support for on-line analytics:** Due to limited capability of processing and storing, Fog devices are connected to cloud servers where they can have on demand real time analytics of live data streams.

3. **Service is provided by smart but not powerful devices:** As the Fog Node has limited storing and processing power, it cannot do big data analytics because of its limited processing power and storage, but it can have real time decision making on certain conditions, when it occurs.
4. **Supports for various communication networks:** when different sensors connect to internet different protocols are involved. Some of the supported protocols are Bluetooth, Zigbee, WLAN, WiFi, 2g/3G/4G, WiMax and so on.
5. **Distributed Computing:** Fog Nodes can communicate to other fogs. And cloud sees the environment as a collection of different fogs, i.e., the whole computation needed by user is available via distributed Fogs.

Fog Computing does not eliminate the Cloud Computing but of course it will reduce the Cloud traffic at a greater extent and also to access and store historical data, the Cloud Computing is only the option for any applications.

1.4.2 Fog Computing in Healthcare domain

In recent years, the dramatic growth of Internet of Things (IoT) linearly increases the unprecedented volume and variety of stream data. IoT [2] is a dynamic and global network infrastructure interconnecting objects with unique identities for diverse advanced application services. Despite offering the advanced services, IoT is incapable in processing and storing the massive amount of data due to its limited storage and processing capacity. Cloud Computing technology has unlimited capabilities regarding processing and storage resources, resolving the inconvenience of IoT by providing the virtual resources in pay-as-you-go manner [4]. Although the vast availability of Cloud Computing resources, services and applications, but several kinds of such resources are not completely attained due to the latency concerns. Owing to the rapid increase in internet-connected smart devices and several service requests, a heavy burden comes to the network bandwidth and degrades the Quality of Service (QoS). Also, the high network latency between the smart devices and the cloud is infeasible for delay-sensitive applications [5].

Fog Computing [6] is the most promising paradigm that significantly reduces the latency and provides the advantages of Cloud Computing by extending the cloud resources to the network edge [7]. It offers distributed services and allows the knowledge generation and data analytics of the streams generated by the smart IoT devices. The benefits of Fog Computing are especially useful for pervasive healthcare monitoring applications [1]. The IoT plays a crucial role in constantly monitoring the physiological status of the hospitalized patients without the need of actively engaging the caretaker [8]. Healthcare monitoring applications [9] widely rely on the Wireless Body Area Networks (WBAN) which is the most underlying technology in healthcare IoT. WBAN assists in ubiquitously acquiring the physiological information involving Electrocardiography (ECG), Electromyography (EMG), blood pressure, glucose level sensing, Blood Pressure monitoring, Oxygen sensing, rehabilitation, medication and blood temperature in the efficient and unobtrusive way. To effectively support the pervasive healthcare applications, the prior research work utilizes the Cloud Computing technology for IoT devices [10]. Fog Computing Architecture [11] in health care domain is as follows:

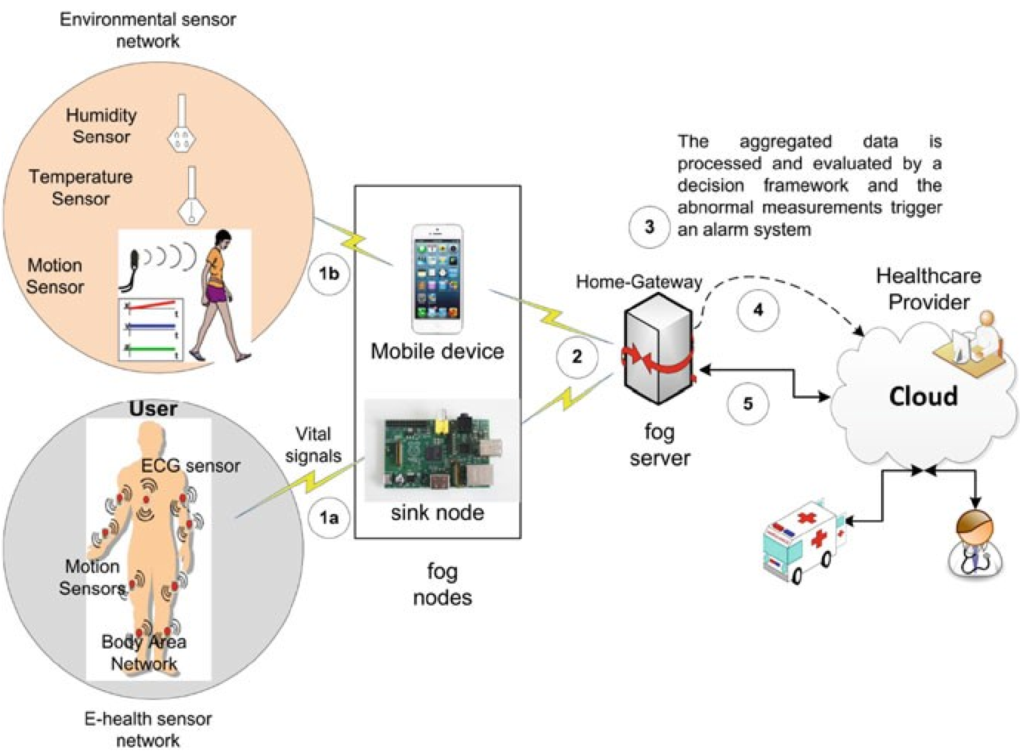

Figure 1.5 The use case of daily monitoring for provisioning timely healthcare services with low latency

The conventional Fog Computing methods [12] present variety of solutions by focusing on the different application scenarios in mitigating the service latency. However, these techniques are still in its infancy stage in attempting to provide the services to pervasive healthcare computing in real-world. Thus, the proposed approach focuses on introducing a smart fog gateway by applying the smart partitioning and decision-making using the linear decision tree in fog environment and optimally utilizing the cloud resources for the healthcare IoT requests. It intends to reduce the response latency and increase the resource utilization, which is defined in SLAs while providing the service to healthcare applications.

1.5 Motivation

Most of the formerly presented Fog Computing research work presents the different architecture and framework for latency reduction in healthcare IoT systems. However, these methods are not able to effectively utilize the fog as well as cloud environments with the knowledge of application context and the resource availability. The resource management in the distributed fog environment is the challenging task. Nonetheless, the prior fog gateway architectures fail in manipulating the task orchestration and partitioning the IoT data streams from the massive amount of stream data. Moreover, it lacks in optimally allocating the application of the edge devices and storing the context-defined Fog Computing data in the transient fog storage.

1.6 Aims and Objectives

- To extend the Cloud Computing to the Fog Computing to support latency-sensitive healthcare IoT applications like ECG signal Analysis
- To design the smart fog gateway with smart allocation to satisfy the QoS in terms of ensuring the optimal response time and resource utilization
- To develop an algorithm to dynamically take a decision regarding stream and process execution of IoT applications in fog.
- Developing needed IoT systems to improve QoS in Healthcare
- Improving QoS in terms of accuracy for different Healthcare applications

- Introducing Distributed Computing on Fog Node to analyze its effect in Fog Computing domain to process faster results
- Developing an algorithm to provide dynamic Optimizations in terms of computational power
- Securing Healthcare data transmission by light weight cryptography to maintain the QoS in Healthcare

1.7 Proposed methodology

With the rapid pace of application developments in pervasive and context-aware computing, Internet of Things (IoT) has become an integral part of day-to-day human's life. It is the web working on smart devices embedded with software, electronics, sensors, and network connectivity, ubiquitously providing the diverse and advanced services. Accordingly, service discovery, resource management, and energy management require more desirable infrastructure and sophisticated mechanism. Moreover, standalone energy-constrained IoTs deal with several bottlenecks while continuous generating the stream data. Cloud Computing plays a crucial role in resolving the bottleneck of IoTs by integrating the Cloud Computing with the IoTs. However, the IoT-Cloud integration involves many challenges for delay-sensitive applications due to the high network latency of the centralized cloud server.

Hence, the delay-sensitive applications, especially healthcare applications demand smart gateway such as Fog Computing to extend the cloud services to the edge of the network. In essence, the proposed approach targets to develop the smart fog gateway involving smart partitioning and allocation by exploiting the decision tree and the dynamic allocation method. It utilizes the knowledge of both the application context and the SLAs to attain the QoS. Figure 1.6 shows the overall process of the proposed methodology.

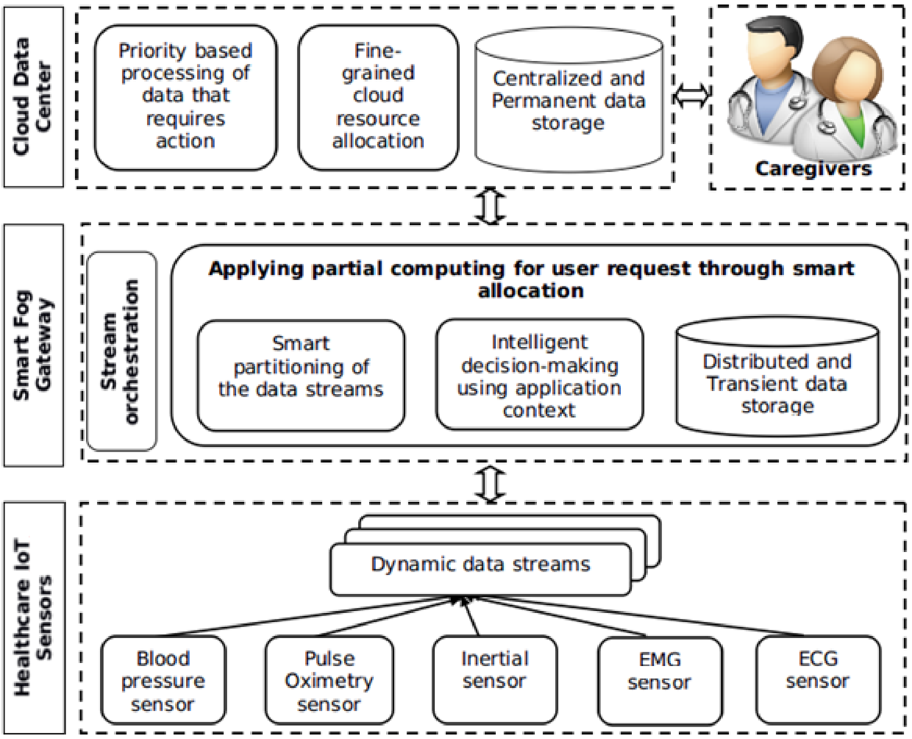

Figure 1.6 The process of Smart allocation from fog to cloud environment

The proposed approach presents a smart Fog gateway with the assistance of the Cloud Computing environment for healthcare IoT applications. In smart fog gateway, the proposed approach applies only partial computing of user request by smart allocation. The smart allocation involves smart partitioning and decision-making based on the application context and the resource availability on the Fog Node. Smart partitioning divides the continuously arriving data streams into a set of chunks, which decides a set of data streams which are to be processed in the Fog Node based on the application. By utilizing the application context, the proposed approach explores the data streams to determine a set of actions to execute the application by a linear decision tree in which action refers the analysis such as any healthcare parameter analysis above or below a specific threshold. Finally, the proposed approach analyzes the de-centralized Fog Computing execution results and provides the desired service to the end users. For the proposed work, we are considering real-time ECG monitoring. ECG monitoring helps in diagnosis of chest pain, adverse drug effects, structural changes of the heart and many [13].

1.8 Overview of Research

Fog Computing helps to reduce the data load of the cloud by sending only the needed data. Fog Computing node must have computation power, memory and communication capability. These functionalities of Fog Node helps to process the data and then filtered data is sent on the cloud, but how a Fog Node will behave when processing the real-time sensitive health care data? To find that the real-time ECG analysis is chosen, to get tested on the Fog Node. The first task was to understand the ECG signal, its reference points PQRSTU, their associated intervals and different types of Arrhythmias. After understanding the insights of the ECG signal, the real-time ECG sensor is needed. The AD8232 ECG sensor is chosen to record the real-time ECG signal because, it is handy, uses 3-lead approach which generates the data which is more suitable in IoT architecture and it is cost effective. The AD8232 sensor generates the analog signal as output which cannot be processed on the digital devices. So to convert this analog signal to digital signal the Arduino Nano is used. The sampling rate is kept as 500 Hz, so that none of the natural characteristic of the ECG signal is loss. This accurate sampling is achieved by using the counters logic in the Arduino. Once the perfect digital signal with 2 ms time interval between two points is achieved then the windowing algorithm is used to get different ECG intervals like RR, PR, QR and QT. basis on this interval values whether the given ECG signal is normal or abnormal is decided.
In detailed work about getting the ECG signal, using its sensor, sensor specifications, Arduino coding for Analog to Digital (ADC) converter, windowing algorithms and its decision making based on the ECG intervals is published in the following paper.

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.

After ECG signals are classified as normal and abnormal, there is the scope of finding the arrhythmia if the ECG signal is abnormal. There are different methods and algorithms existing to find the ECG arrhythmia, but the best suitable approach is the Machine Learning and Deep Learning Techniques. A total of 1,09,446 samples of ECG signals are taken comprising of five major Arrhythmia categories like Normal, Atrial Premature, Premature Ventricular Contraction, Fusion of Ventricular and Fusion of Paced. These signals from the data set are taken and they are pre-processed by considering possible augmentations techniques and Deep Learning model is applied on it. The ranking based average precision and f1 score achieved are 0.9912 and 0.98 respectively. In detailed work, ECG dataset description, augmentation techniques used and the Deep Learning model description is published in the paper, given as below.

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.

The techniques mentioned above works well if and only if the sampling rate is as per the designed system. If the sampling rate of the sampling device differs then the designed system becomes inaccurate. So, to make the system independent of sampling rate, the image based ECG signal classification is also done. Whenever the ECG signals are recorded, some noise gets induced in the ECG signal due to different environmental factors. To remove this noise different hardware based high frequency and low frequency filters are used. But in our work, we have shown the use of software based Savitzky-Golay filter to de-noise the given ECG signal. Different required polynomial function degree and the windowing size is also mentioned. The available dataset of 1,09,446 samples are first plotted in the image form. Then each image is cropped to get only the required signal portion. After that each image is augmented and Deep Learning model is applied. The accuracy of 97.78% is achieved in this case. The detailed work describing Golay filter de-noising, ECG dataset, ECG image dimension, cropping algorithm, augmentation techniques, Optimizers and Deep Learning model is well written in the paper as given.

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.

Also, to make the Health Care domain more efficient in terms of computation based decisions and to understand and use the different available platforms the Skin Cancer data is taken. These data is processed using Deep Learning approach on Google Colab framework. The accuracy is improved to 82%. The detailed work is presented in the paper below.

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.

IoT can send real-time data to the processing devices over the internet. In Health care domain the real-time location of the patient is very important to track the patient. This device giving the real-time GPS co-ordinates of the patient’s data, should be handy and affordable. The available sensors like GPS Neo 6m, GSM Sim 800L are used along with Arduino Uno and real time GPS tracking system is made. This device will keep on sending the GPS co-ordinates after a particular time threshold. This data is received by ThingSpeak cloud. The given web interface will fetch the data from this ThingSpeak cloud and it will show the real-time location using Google Map using the Google Map API. In detailed components description, its specifications and its interfacing is explained in the paper mentioned below.

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.

The AD8232 sensor is generally used to get the Heart rate in BPM and the ECG signal of the user, But when this sensor was kept on different body parts, it was generating different output waves. While doing such experiments and AD8232 sensor is kept on the fore-head, it is observed that the sensor is able to recognize the Eye gazing movement towards left-straight-middle. For every eye movement the graphs obtained were unique and differing from each other in a particular way. These data when taken and processed, we were able to detect eye movement successfully without using any retina or cameras to detect the eye motion. Based on this the eye movement based applications like wheel chair movement can be developed, where the handicapped person sitting on the wheel chair, mounted with AD8232 sensor on forehead will use the eye movements to control the direction of moving wheel chair. The thorough work is presented in the paper said below.

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.

After getting good experience of IoT sensors, it's interfacing, coding, its deployments and its working environment with insight of ECG signal. The Fog Computing is used to do the real-time analysis of ECG signal. This system development is based on the idea of Fog Computing where it will do all the processing on-the-go manner and only the needed crucial data is send over the cloud for future and remote use purpose. Here, a new term is coined as "Health-as-a-Service (HaaS)". Basically this term is to implement the health care related services on the cloud and on the fog, where delay in the decision making is as early as possible. This to get early detection of abnormalities to get the quicker treatments. Based on the requirement analysis done over the Fog Node configuration and its characteristics, the Raspberry-Pi is chosen is as a Fog Computing node. In this system the same ECG signal is sent over the cloud and over the Fog and different measuring QoS parameters are measured. All QoS parameters in HaaS are first defined w.r.t to cloud and Fog Computing and then measured. The obtained results show that the Fog Computing outperforms the Cloud Computing in terms of real-time decision making for less number of patients. But, when more number of patients are subjected over the same Fog Node then it is observed that it lags in terms of computation power. Which opens the research door called as "Optimization" of the Fog Node in terms of faster decision-making. The comprehensive work with its deployment steps are presented in the paper stated below.

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.

Optimizing existing Fog Nodes can be in two ways. The first way is to make the algorithm doing the processing is made efficient and the second way is to increase the overall computation capabilities of the Fog Node. The algorithm used to process the ECG signal is based on the concept of moving window and uses array based approach. It is computationally less intensive. Here the Optimization in the Fog Node is achieved by using different user and process priority aspects of the Operating system. It introduces fast computation in operating system for a particular task. The paper given below is describing the work and its details. Also, the insights of Fog Computing, need of Fog Computing, working of Fog Computing, its applications, security need with pros and cons of the Fog Computing is talked in the paper. Paper also covers different analysis of available hardware, which can be used as a Fog Node for computation.

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.

Distributed Computing is used to achieve faster results by making multiple nodes to work on the same task. This Distributed Computing can improve the computation in Fog. The Distributed Computing is introduced first time in the Fog Computing to get faster computations. Most often scalability and deployment are the challenges in the Distributed Computing. Deployment of the application is difficult on all slave nodes for different context based applications. To simplify it, we have used “dispy”. The dispy is a tool which makes scalability and deployments of any task very easy and automated in Distributed Computing environment. The Raspberry Pi cluster is used as a Fog Node where each Raspberry Pi will act as slave nodes except one Master node. When such set-up is made and used to process the ECG signal, the results found shows a significant improvement in resulting time. This proves that the Distributed Computing in a Fog Computing is a good choice. The overall set-up description and final results are shown in the paper mentioned.

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.

Health care is the field where we get variety of data, for example: ECG data, Skin cancer data, cancer data, DNA data etc. The Genome data in health care is very huge where long protein sequences are present and searching for a particular patterns in these longer texts are very time consuming and more memory intensive as loading very large strings in the memory consumes a lot of memory spaces. We have done Genome processing using Fog Computing approach. Where the Genome data is stored and run on the single Raspberry Pi node. After that to improve it further the Distributed Computing is applied with run-length encoding technique. The results obtained shows the improvement of 87% w.r.t the single Fog Node implementation. This proves that the Distributed Computing in Fog Computing is also able to handle the larger data and more processing if used with proper techniques and algorithms. The entire Genome processing work is published and as shown in the paper mentioned below.

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.

Computation is based on different parameters like response time, memory, CPU usage and number of cores etc. each and every parameter has their own impact on the computation of the task. Here, ECG signals with higher number of waves are taken and computation is done on the dispy manner where each slave gets two waves in one go in Round-Robin manner. But when number of waves in one job for one go is altered the resulting time was improved. This becomes one of the optimizing parameter and is "number of waves in one job". In other aspects each and every of above mentioned parameter is taken and the ECG signal processing task is computed for different number of waves and for different number of nodes in the Raspberry Pi cluster. The obtained results are observed and based on the impact of the parameter the "OptiFog" algorithm is designed. This algorithm works best in the heterogeneous distributed environment. The OptiFog is a dynamic algorithm and at run time only it decides the node processing capability and as per the capability value it assigns the job to the node with optimal job size. The algorithm is designed by considering the worst case scenario in the mind. This to make sure that the algorithm gives the shown improvement everywhere and in every case. The detailed step by step designing and development of this OptiFog algorithm is given in the published paper given below.

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.

The Health care data is sensitive data and if it becomes vulnerable in transit then the health care system losses its trust value and users would not prefer its use. Now a days, different Health care data is sensed by IoT devices and sent to Fog Nodes and the Cloud servers. The IoT device remain unsupervised for most of the time which makes it more vulnerable for data leakage or data modification. IoT devices have less computational power and if we want to make its data secured then we need some lightweight security standard which makes this data secured and will not cause any extra burden on the computational task of IoT device. These data will transmit further from IoT to Fog Node and from Fog to the server. The extensive literature review done shows that if multi-level Fog architecture is used then it is able to reduce the data load on the network and huge network bandwidth can be saved. By keeping the computation power of IoT devices and different Fog Node characteristics in mind, the security algorithm is developed. This algorithm uses all logical functions like OR, AND, EXOR and so on, to facilitate the lightweight encryption and decryption mechanism. Further different chaining and non-repudiation functions are used in this designing process to make it more secured from different security attacks. Its time and space complexity shows that the designed algorithm is suitable for IoT and Fog architecture and is able to provide the higher level of security for higher data levels as it adapts the dynamic key length based on the security need. The experimented and tested work is written in the paper called as “Light weight Multi-Level authentication scheme for secured Data transmission in IoT-Fog Architecture” and is in the process of publication.

As a concluding remark the overall research work is concerned with the suitability of Fog Node in the health care domain for real-time decision making for time-sensitive applications, Improvements in the existing systems by improving the quality of results, developing new and handy IoT based systems, defining Health as a Service in Fog Computing, optimization in Fog Computing and its security aspect.

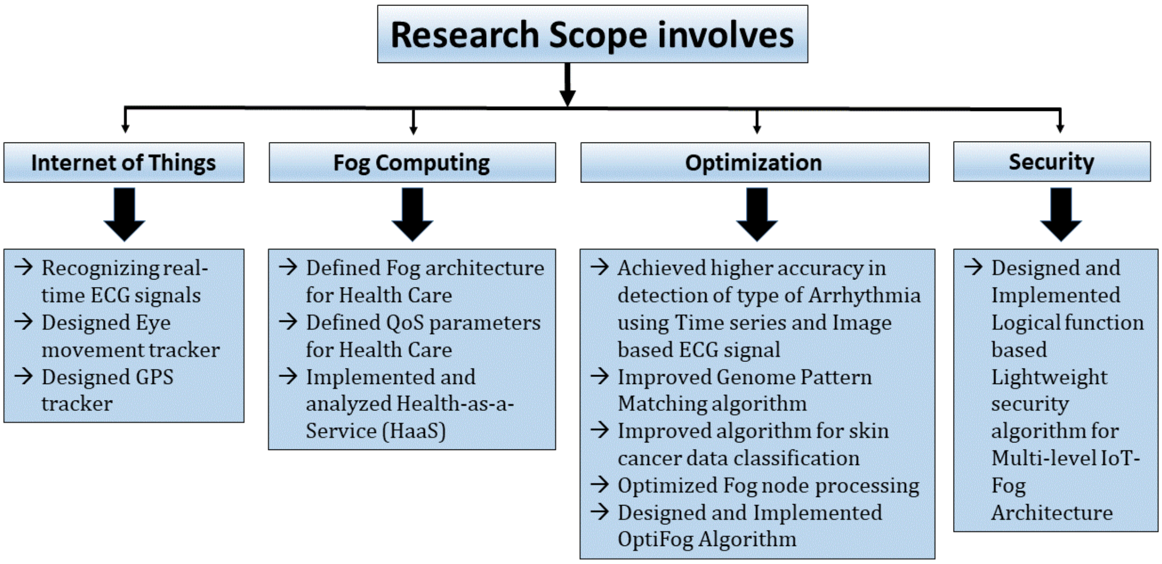

Figure 1.7 Scope of the Research work

1.9 Thesis Organization

The rest of the thesis is organized as follows.

Chapter-2 presents literature review. This section presents different approaches in healthcare domain w.r.t IoT, Cloud and Fog Computing. Also, in this section different papers are referred and summarized showing different computing parameters and their role in the computation. Further, different lightweight encryption techniques, a need of IoT and Fog Computing is studied and analyzed in this chapter.

Chapter-3 presents the work done to implement “Health-as-a-Service (HaaS)” utility in Fog Computing domain. The HaaS utility is implemented and fully discussed in detail in [14]. This chapter shows the final result in terms of decision making for different parameters in contrast to Cloud Computing and Fog Computing.

Chapter-4 and chapter-5 are describing the work to achieve Computation Optimization on the Fog Node. The Optimization includes the study of different computing parameters, introduces Distributed Computing in the Fog Computing, deciding optimal job size and the best combination of all these parameters to get best possible computation power. The entire work is discussed and published in detail in [15] paper.

Chapter-6 summarizes different existing lightweight encryption algorithms to support healthcare application in Fog Computing domain. The need for new multi-level security algorithm is identified here. And the experimental results are shown to fill up the existing research gaps.

Chapter-7 concludes the research carried out and discusses the future work.