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An Enhanced Architecture of Fog Computing for Healthcare Systems based on IoT

Nwachukwu, Chibuike
Research Scholar
Department of Computer Science
Ignatius Ajuru University of Education
Rivers State
Nigeria

&

Onuodu, Friday Eleonu
Visiting Scholar
Department of Computer Science
University of Port-Harcourt
Rivers State
Nigeria

ABSTRACT

Healthcare services are given extraordinary significance these days by every nation with the approach of the novel Covid. So in this perspective, an IoT based wellbeing observing framework is the best answer for such a pestilence. Web of Things (IoT) is the new transformation of the web which is a developing examination zone, particularly in medical services. With the expansion in the utilization of wearable sensors and cell phones, these far off medical services checking has advanced at such a movement. IoT checking of wellbeing helps in forestalling the spread of infection just as to get an appropriate conclusion of the condition of wellbeing, regardless of whether the specialist is at a far distance. Some of them include lack of visualization model for effective patient monitoring, time complexity of monitoring systems, lack of user friendly GUIs for effective communication with monitoring system and so on In this work, we proposed an enhanced architecture of fog computing for healthcare systems based on IoT. The system was implemented using JAVA programming language and iFogsim for fog simulation. The proposed system has a performance score of 86% which is far better than other existing systems. This work could be beneficial to patients in a healthcare system, ministries in charge of healthcare provision and monitoring, healthcare centers such as hospitals, clinics etc. and the research communities.

Keywords: Fog Computing, IoT, Healthcare Monitoring Systems.

Introduction

Health is consistently a significant worry in each phase of the development of humankind as it is progressing regarding innovation. Like the ongoing Covid assault that has destroyed the economy of China to a degree is a model of how medical services have happened to significant significance. In such zones where the scourge is spread, it is consistently a superior plan to screen these patients utilizing far off wellbeing observing innovation [1]. Medical care is given outrageous significance these days by every nation with the approach of the novel Covid. So in this viewpoint, an IoT-based wellbeing checking framework is the best answer for such a plague. Web of Things (IoT) is the new insurgency of the web which is a developing exploration zone, particularly in medical services. With the expansion in the utilization of wearable sensors and cell phones, these far off medical services observing has advanced at such a movement. IoT observing of well-being helps in forestalling the spread of infection just as to get a legitimate analysis of the condition of wellbeing, regardless of whether the specialist is at a far separation. Distant Patient Monitoring course of action engages the perception of patients outside of standard clinical settings (for example at home), which grows admittance to human administrations workplaces at cutting down costs [2].

Fog Computing offers a versatile and compelling answer to conquer the expanding preparing and organizing requests of the Internet of Things (IoT) gadgets. It is the quickest field in the current world to offer types of assistance at any phase of areas, for example, E-Healthcare and telemedicine framework that is utilized to address the issues which are available everywhere on the world. FC converging with the Wireless Sensor Networks (WSN) gives better outcomes for the clinical gadgets which are identified with the different kinds of patients. This will give a superior clinical sign cycle, energy-proficient figuring, and protection and security [3].

Statement of the Problem

Over the years, researchers have proposed several healthcare monitoring system using various technologies including Fog computing. However, there are serious lapses in these systems implemented by these researchers. Some of them include lack of visualization model for effective patient monitoring, time complexity of monitoring systems, lack of user friendly GUIs for effective communication with monitoring system etc. We hope to solve the problem of lack of visualization by developing a Fog visualization model that can be used for accurate healthcare monitoring

Aim and Objectives

The aim of this work is to develop an enhanced architecture of fog computing for healthcare systems based on IOT. The specific objectives are:

i. Develop a fog visualization system for accurate monitoring of patients in a healthcare system.
ii. Implement with Java Programming Language and Simulate with iFogsim.
iii. Compare our results with other existing system performance.

Significance of the Study

The importance of an effective healthcare monitoring system cannot be overemphasized. This system will above all help in reducing the mortality rates of patients in the healthcare system and also help improve on the quality of healthcare administered to these patients for quicker recovery and discharge. This system will therefore be beneficial to patients in a healthcare system, ministries in charge of healthcare provision and monitoring, healthcare centers such as hospitals, clinics etc and researchers in the field of IoT.

Healthcare Monitoring: A Review

Health is described as a full condition of physical, mental, and social prosperity and not just an absence of ailment. Health is a principal component of individuals' requirements for a superior life. Lamentably, the worldwide medical condition has made a situation in light of specific components, for example, chronic weakness benefits, the presence of huge holes among provincial and metropolitan territories, doctors, and attendants inaccessibility during the hardest time. The ongoing expansion in persistent illnesses and the maturing populace have set off the upset of distant wellbeing checking in created nations. The headway of remote body sensors along with the developing distributed computing applications that offer high handling and capacity abilities for wellbeing information has upheld the improvement of wellbeing observing frameworks that give constant reaction to the patients relating to their ailment. Be that as it may, the transmission of wellbeing related information from an enormous number of patients to the cloud adds to expand the clog in cloud organizing frameworks which prompts high idleness and consequently infringement to Quality-of-Service (QoS) measurements [4].

Ongoing mechanical advances in wireless networking, microelectronics integration and miniaturization, sensors, and the Internet permit us to on a very basic level modernize and change the manner in which medical care administrations are conveyed and conveyed. Zero in on avoidance and early location of sickness or ideal support of persistent conditions guarantee to enlarge existing medical care frameworks that are generally organized and enhanced for responding to emergency and overseeing disease as opposed to health [5]. In the Smart Healthcare monitoring framework, different sensors are utilized for checking the vitals of the human body. Nonetheless, the sensor and savvy gadgets which are utilized for wellbeing checking ordinarily have restricted capacity and low calculation abilities because of which they can't deal with a tremendous measure of created information. Furthermore, there is consistently a tremendous test in IoT with regards to managing information trade, accessibility of assets, security, protection, and interoperability.

Fog Computing

Cloud-based infrastructure has become a significant platform since they give virtual workers all the essential administrations like stockpiling, application, organization, transmission capacity, and other crossbreed offices. As IoT is advancing quickly, the utilization of distributed computing administrations has gotten normal and with the progression of time as gadgets are getting on the web to control and deal with their information with speedy access immediately has become a difficult errand for the current distributed computing stage. To accomplish the previously mentioned prerequisites, the new innovation in particular Fog figuring has been advanced. The term FOG was first presented by Cisco in 2012. Like Cloud structure, a Fog structure is made out of Infrastructure, Platform, and Software-as-a-Service alongside the expansion of Data Service. Mist Computing in IoT gives enormous reciprocal to the past distributed computing administrations [6]. Fog Computing is the disseminated model that grows the good old distributed computing stage to the edge of the organization. Haze Computing offers the calculation, stockpiling, checking, and benefits abilities at the edge of organization [7]. Here we will talk about the current Characteristics and engineering of Fog Computing.

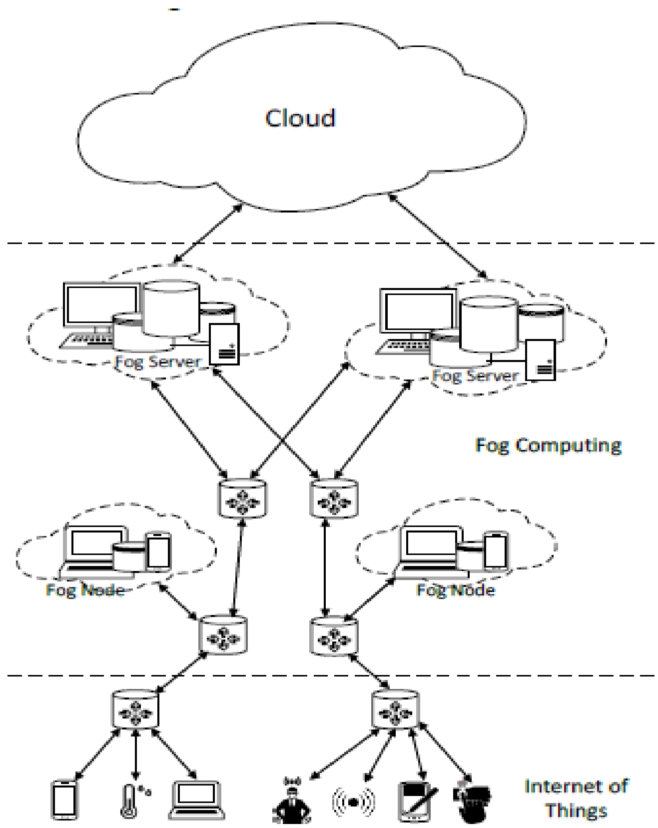

Fig. 1 Architecture of a Typical Fog Computing (Source [2])

Related Work

Some important works have been done in the field of medical science using fog computing to monitor patient's health. The works associated in this field are outlined as follows.

- Tamilselvi et al. [8] proposed a health monitoring framework that can screen essential manifestations of a patient like a pulse, level of oxygen immersion, internal heat level, and eye development in IoT networks. For this reason, the framework utilized Heartbeat, SpO2, Temperature, and Eye squint sensors as catching components and Arduino-UNO as a preparing gadget. The created framework was actualized yet no particular execution measures are depicted for any patient.
- Acharya et al. [9] proposed medical services checking pack in IoT climate. The created framework observed some fundamental boundaries of human wellbeing like Heartbeat, ECG, internal heat level, and Respiration. The significant equipment segments which are utilized here are beat sensor, temperature sensor, BP sensor, ECG sensor, and raspberry pi. The information was gathered from sensors and sent to raspberry pi for preparation and again communicated to the IoT network. The significant disadvantage of the framework is that no interfaces for information the perception was created.
- Banerjee et al. [10] proposed a heartbeat rate recognition framework dependent on a noninvasive procedure. The proposed framework utilized plethysmography measure and correspondingly showed the yield carefully that made it an ongoing checking gadget. The strategy has demonstrated as solid for the patient contrasted with other obtrusive methods.
- Gregoski et al. [11] proposed a cell phone-based pulse checking framework. The framework utilized a versatile light and camera to follow the finger blood stream and determined bloodstream-based heart yield. The created framework portrayed a coordinated gadget that remotely communicated an individual's heartbeat to a PC, engaging individuals to test their pulse by simply taking a gander at their telephones as opposed to utilizing hands each time. This is an amazing plan however it isn't possible if ceaseless heart observing is required.
- Oresko et al. [12] proposed a completely useful cardiovascular sickness detecting framework for cell phones, recognizing a device that is created to be similar given adequate time and financial assets. The created model just followed coronary beat continuously, didn't follow pulse over the long run, and couldn't distinguish any cardiovascular illness.
- Trivedi et al. [13] proposed a cell phone-managed Arduino-based wellbeing boundary reconnaissance system. The gathered sensor information is simple and sent to the leading body of Arduino Uno. By incorporated simple to a computerized converter, the recorded simple qualities are changed over into advanced information. Bluetooth sent the actual characteristics to the created gadget. The Bluetooth gadget utilized a module not covering a wide territory.
- Kumar et al. [14] proposed a versatile IoT health observing gadget. The arrangement of the system is isolated into 3 layers, for example, the control layer, the gadget layer, and the vehicle layer. A DS18B20 sensor was utilized for the estimation of internal heat level in the control fragment and a heartbeat sensor is utilized for the beat estimation. The information was stacked from Arduino into the cloud through the Wi-Fi module and an Ethernet shield on the vehicle layer.

- Desai et al. [15] proposed a remote sensor organization (WSN) to follow shrewd homes and heartbeat. Here, Spartan3 is utilized in equal information handling with FPGA design. The MCU results are appeared by an LCD, and all sensors are associated with a microcontroller. By the by, all machine components are not incorporated into one unit.
- Jiang et al. [16] propose an IoT-based framework for distant outward appearance checking. The framework's sensor hubs secure Electromyography (EMG) and communicate the information to a door through Wi-Fi. The bio-signals are handled and grouped in Cloud with the help of LabVIEW.
- Gomez et al. [17] present a patient checking framework dependent on IoT for observing wellbeing status and prescribing exercises to patients with persistent infections. The framework secures not just bio-signals (for example ECG) yet additionally relevant information (for example time and area). Specialists and patients can get to gathered information through an Android application.
- Nemati et al. [18] propose a remote wearable ECG sensor for long-haul applications. The little size sensor hub can be advantageously sent in a T-shirt or underwear for gathering and communicating ECG information remotely by means of an ANT convention. A patient conveying the sensor can play out their everyday exercises with no aggravation.
- Qi [20] published a review on advanced Internet of things enabled personalized healthcare systems (PHS) considering current works about IoT enabled PHS, and enabling technologies, major IoT enabled applications and successful case studies in healthcare, besides main challenges and future perspectives about IoHT.
- Ara et al., [21], proposed a secure privacy-preserving data aggregation approach based on bilinear ElGamal cryptosystem for RHM systems to improve data aggregation efficiency and data privacy. Security analysis demonstrates that the proposed method preserves data confidentiality, data authenticity, and data privacy and also is resists passive eavesdropping and replay attacks.
- Nkenyereye and Jang [22] evaluated the performance of a server-side JavaScript for healthcare hub server in RHM System being 40 % faster than Apache Sling, presenting high-performance, asynchronous, event-driven healthcare hub server to handle an increasing number of concurrent connections for RHM environment in remote places without local medical aid to local medical care.
- Mamun et al., in [24], developed a cloud system for detecting and monitoring Parkinson patients that will enable healthcare service in low resource setting.
- Ganapathy, Grewal and Castleman, [25], evaluated a remote self-monitoring of blood pressure to detect raised blood pressure in pregnancy (50 women), in which 45 of them agreed that the remote monitoring adopted is easy to use and 39 women prefer the proposed model of testing at home.
- ;Crema et al., in [26], proposed a local biosensor virtualization based on a simplifying the wearable as, for example, relying only on simple analog front ends and communication interfaces, and exploiting the computational capability of the smartphone, not only for implementing gateway features but also for processing raw biosignals as

well, increasing the potentiality of mhealth applications. The virtual sensor was evaluated in electrocardiogram signals analyzing the hearth and respiratory rates.

- Aranki et al., [27], developed a smartphone-based system for real-time tele-monitoring of vital signs and general cardiovascular symptoms thought physical activity in patients with heart disease, being the main challenge to apply in diabetes and hypertension and other chronic disease.
- Barret and Topol, [28], investigated the possibilities in which Smartphone and the Internet of medical things can improve medicine, believing that Smartphone has a direct influence on individual's everyday life, which can bring great contributions to the healthcare field.

Analysis of the Existing System

The existing framework was developed by Kharel et al [19]. They developed a smart health checking framework dependent on haze registering. In the current engineering, the edge clients are furnished with various types of wearable, clinical gadgets, or clinical sensors. Subsequently, these gadgets could perform different clinical estimations. Such estimations could screen the body's imperative signs like pulse, internal heat level, pulse, respiratory rate, rest, feeling of anxiety, and so forth Gadgets had various types of availability like Zigbee, Bluetooth, Wi-Fi, LoRa, 2G/3G, LTE, and so forth These gadgets were associated with the LoRaWAN entryway so the data created by these end gadgets can be sent straightforwardly to the Fog hubs or essential Health Centers for our situation. These essential Health Centers could be more than one that serves individuals dependent on their area.

The utilization of the LoRaWAN entryway makes it conceivable to communicate the information recorded by those gadgets to the Primary Health Centers several kilometers away regardless of whether there is no web office. The information sent through these gadgets were interconnected with the brilliant gadgets, workstations, or PCs of the clinical staff and sponsored up on the Health Center's stockpiling. For the individuals who are now determined to have some clinical issues, their clinical information were put away dependent on their sickness with the goal that it would be simple for the clinical staff to follow their patients.

Disadvantages of the Existing System

The existing system has the following drawbacks:

i. Lack of a visualization model for accurate monitoring of patient health condition.
ii. Lack of a notification system to update patients on health condition progressively.

The existing system could not use ifogsim to simulate the fog computing platform for better monitoring results.

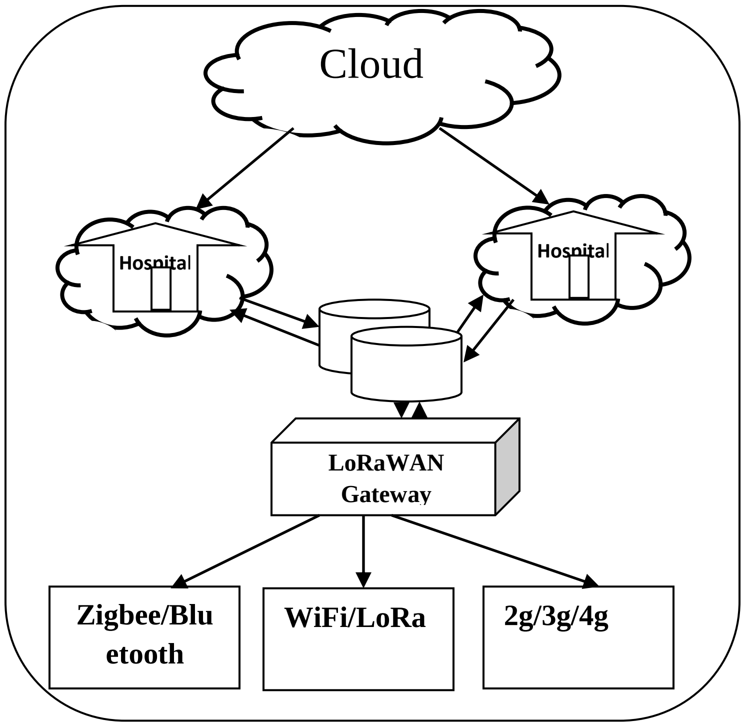

Fig 2: Existing System Architecture [19]

Algorithm of the Existing System

STEP 1: START
STEP 2: Monitor End Users Health Status
STEP 3: IF Health = Normal
THEN
CONTINUE STEP 2
ELSE
STEP 4: Identify Health Service Required
STEP 5: IF Health Center = Available
THEN
STEP 6: Tele-medical Service
STEP 7: Visit Health Care Center
STEP 8: Use Ambulance
ELSE
STEP 9: Recommend Hospital
STEP 10: STOP.

Analysis of the Proposed System

The proposed system is an enhancement of the existing system. It is aimed at solving the challenges encountered in the existing system by developing a better architecture which will accommodate features for better healthcare monitoring. The proposed system architecture employs a visualization model that will enhance health monitoring by displaying results in form of charts and graphs that can be interpreted easily both the patient and the healthcare providers for better quality of service delivery. iFogsim was used to simulate the fog server on Java eclipse IDE. The system monitors patient's conditions such as blood pressure, heart rate, sugar level, cholesterol level and many other vitals that suggest the health of a person. The patient's vitals are monitored using sensors which the patients wear on their wrists like a bracelet. The sensors are connected to the healthcare monitoring system which runs on the iFogsim server. The vitals are stored in the fog servers after they are collected.

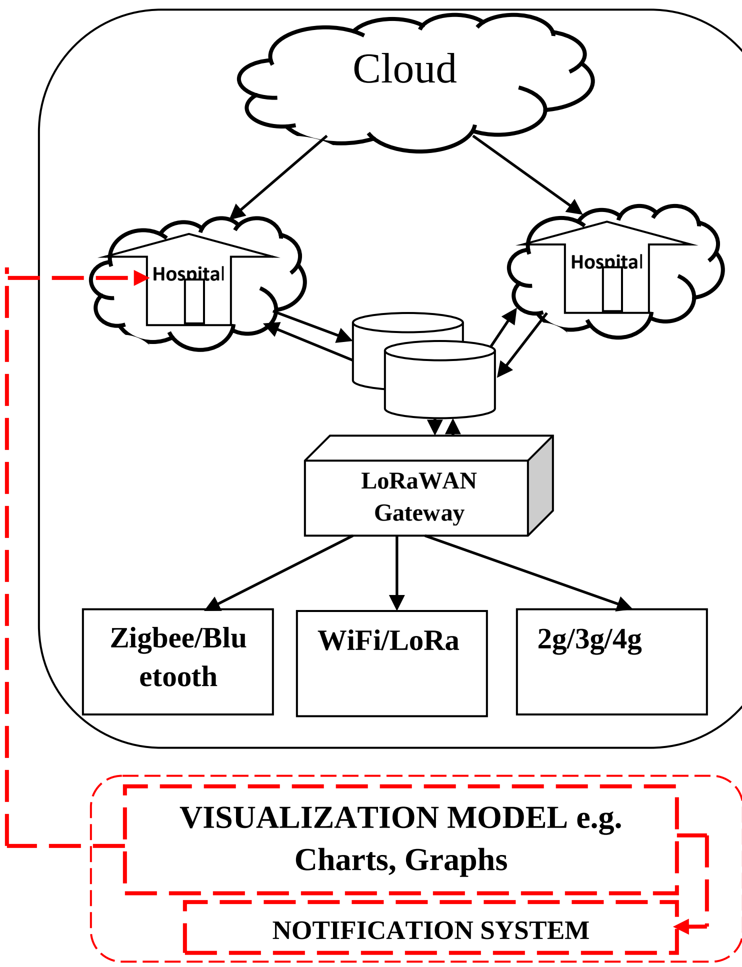

Fig. 3 Architecture of the Proposed System

The monitoring system automatically activates the notification system to send the patient progressive updates of his health status. Also adequate recommendations are made to the patient regarding measures to make for better healthcare

Advantages of the Proposed System

The proposed system has the following advantages:

i. The proposed system has a visualization model for accurate monitoring of patient health condition.
ii. Use of a notification system to update patients on health condition progressively.
iii. The proposed system uses iFogSim to simulate the fog computing platform for better monitoring results.

Algorithm of the Proposed System

STEP 1: START
STEP 2: Launch iFogsim Simulated
STEP 3: Monitor End Users Health Status
STEP 4: IF Health = Normal
THEN
CONTINUE STEP 2
ELSE
STEP 5: Launch Visualization Model
STEP 6: Display Visualized Results
STEP 7: Identify Health Service Required
STEP 8: IF Health Center = Available
THEN
STEP 9: Telemedical Service
STEP 10: Visit Health Care Center
STEP 11: Use Ambulance
ELSE
STEP 12: Recommend Hospital
STEP 13: Send Notification to Patient
STEP 14: STOP.

Methodology

This involves the specification of procedures for collecting and analyzing data necessary to define or solve the problem for which the research is embarked upon. Object Oriented Analysis and Design (OOAD) methodology was used during the software development. Object Oriented Analysis and Design methodology is a software engineering approach that modules a system as a group of interacting object. OOAD models are pictures that illustrate the system's objects from various perspectives such as structures and behaviours. Two stages are involved in the approach; Object Oriented Analysis and Object Oriented Design. Unified Modeling Language (UML) notation is the design tool used for modeling in this research. UML used in the research includes: Use Case diagrams, Sequence diagrams and Class.

Discussion of Results

The proposed system was implemented using JAVA programming language and iFogsim was used to simulate the Fog Cloud system. Eclipse JAVA platform was used to write the program and launch the iFogsim cloud platform. The system included a security platform that allows only authorized users to access the system. The login form is encrypted with a secure MD5 password technique which is not easily cracked by malicious users.

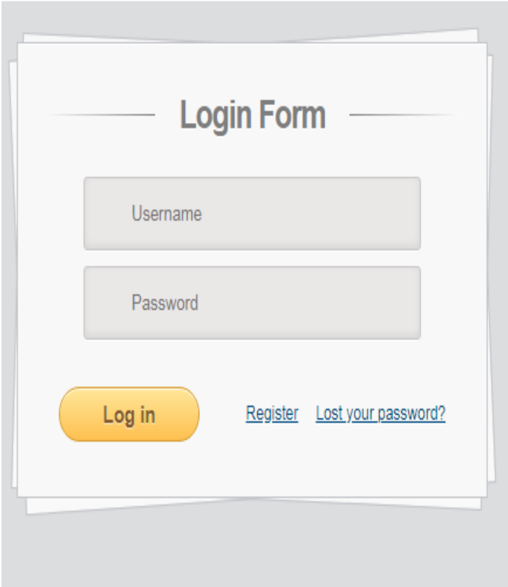

Fig. 4 Login Page for Health Monitoring System

Fig. 5 Homepage for Health Monitoring System

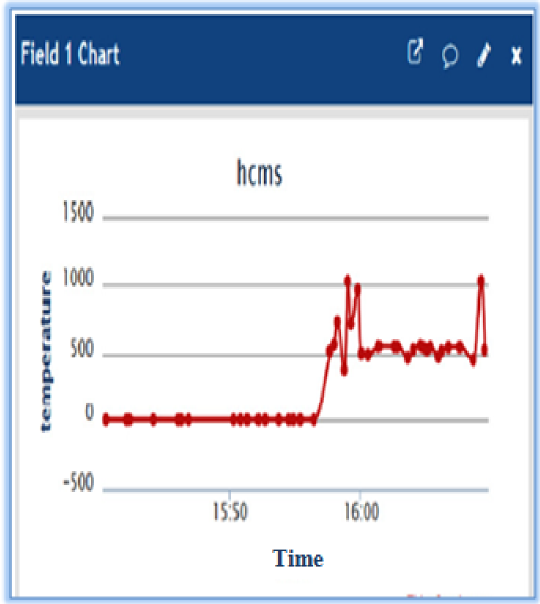

Fig. 6 Patient Temperature Monitoring Chart

The proposed system displays the monitoring results in form of charts which can be easily understood and interpreted by the patient and healthcare provider for adequate and efficient decision making. The output of the system which is represented as a chart displays the temperature readings of a patient which is under monitoring using this system over a time period of 10 minutes interval. The data used for the chart is the vitals collected from the patient during each routine check to monitor the changes in the body temp. From the chart, the patients temp can be interpreted to have risen after being stable for some minutes and continued fluctuating from then.

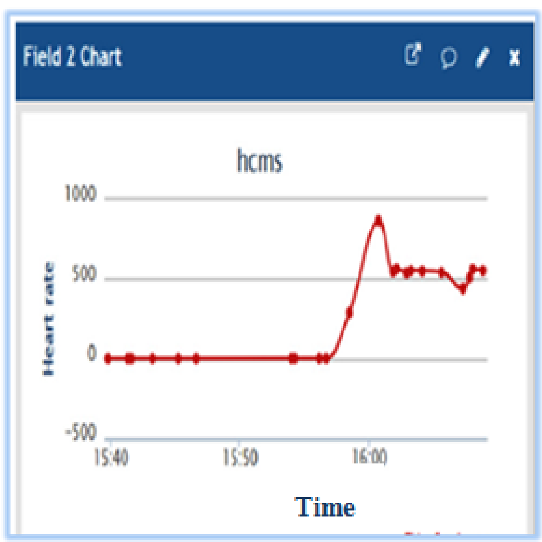

Fig. 7 Patient Heart-Rate Monitoring Chart

The same can be interpreted for the second chart which illustrated the monitoring of the heart rate of the same patient. The iFogSim ensured that all units in the hospital are connected to the same server to facilitate free flow of patient information. Also, if there is need for any medical service after the visualization of the health status, the iFogSim will enable easy transmission of service alert to the required unit for prompt response.

Performance Evaluation

The existing system has a higher performance score than the existing system. It has a performance score of 86% as opposed to the Existing system of 66% when analyzed using certain parameters such as speed of computation etc.

Table 1 Comparative Analysis

SN	EXISTING SYSTEM	Score	Score	PROPOSED SYSTEM
1.	Speed in Processing inputted validation details	20 (seconds)	12 (seconds)	Speed in Processing inputted validation details
2.	Speed in Registration Process	14 (seconds)	8 (seconds)	Speed in Registration Process
3.	Cross Platform Compatibility (CPA)	11	20	Cross Platform Compatibility (CPA)
4	Model Efficiency (ME)	10	23	Model Efficiency (ME)
5	Cost Benefit Analysis (CBA)	11	23	Cost Benefit Analysis (CBA)
Total		66%	86%	Total

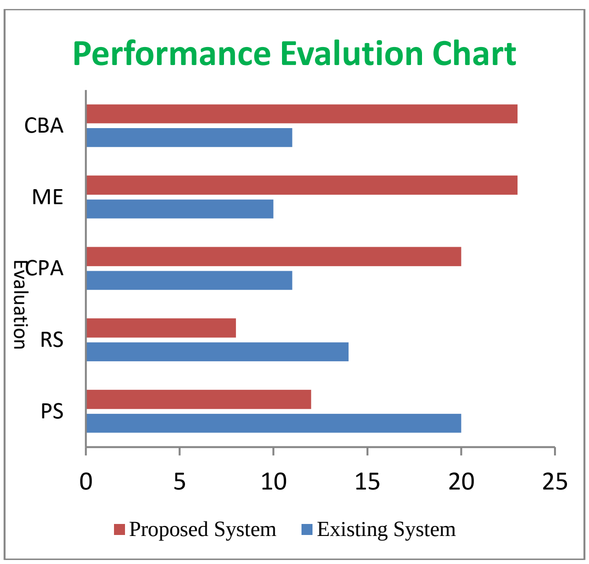

Fig. 8 Performance Evaluation Chart

Conclusion and Future Work

We have proposed an enhanced healthcare monitoring system based on fog computing which can be used to address the current slacks in quality of service delivery in the healthcare sector. The system was implemented using iFog simulator on a JAVA eclipse platform. Evaluation results confirm that this system is efficient for accurate healthcare monitoring. In the future we will like to combine fog computing with other IoT platforms to form a hybrid model for more accurate healthcare monitoring.

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