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Machine Learning and Blockchain based Frontend and Backend Framework for Healthcare Internet of Things (HIoT) Smart System

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Abstract

In the medical field, conventional sensor-based diagnosis requires more sensors and human effort if it is processed on a large scale. It is a challenging task due to lack of medical practitioners and system setup. In this paper, an automated e-health patient monitoring framework based on Healthy Pi is developed. We designed and implemented an e-health system based on a new prediction model, Efficient Deep Convolution Neural Network (EDCNN) to provide real-time 24/7 health monitoring facilities, which can be convenient to both doctors and patients while preserving access control mechanism and securing patients sensitive data coming through the machine learning model by applying blockchain technology to secure the vital patients data. The objective is to incorporate a low-cost system using machine learning and blockchain and transmit the patient vital signs in emergency situations using wireless Healthy Pi kit sensor network to collect the patient's data and transmitted to a cloud. Moreover, we implement the frontend including the website and backend including database as well the mobile apps for easy access of healthcare Internet of Things (HIoT) for patients, doctors, and admins. The object is to have a complete and secure smart HIoT.

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Inroduction

One of the world's fastest growing industries is healthcare. For many countries and districts, it is also one of the most significant markets. This is a large service industry that serves the entire world and employs millions of people. According to the World Health Organization (WHO), millions of people die as a result of high cholesterol, obesity, and other factors [1]. The person affected by chronic illness must manage his or her life properly with the utmost care and should be handled and supervised by a physician most of the time. The heart rate, temperature, SPO2, blood pressure, respiration, glucose level, etc. are the significant parameters for chronic diseases. The patient management system allows multiple patients to be monitored by physicians at a time. Internet of Things (IoT) is intended for networked devices that have integrated intelligence to collaborate. Resent development of IoT integrated many technologies including machine-to-machine communication, Supervisory Control and Data Acquisition (SCADA), and machine learning to provide real time monitoring 24/7 patients data and intelligent results of patient's data to help doctors with smart analytics. The IoT offers a way to access and connect devices with unique identification [1]. This device is capable of measuring and tracking basic physiological parameters like pulse rate, body temperature, blood pressure (BP), electrocardiography (ECG), etc., and efficiently obtaining results through the Healthy Pi sensor kit on the front-end application. The Healthy Pi kit enables the cloud to exchange medical information and readings and conducts real-time data diagnosis. The Healthy Pi kit is multiplexed and covert the analog signal into digital and then process the data and conduct medical and biometric health applications after digitization and signal processing, including filtration and acquisition process. The information is used to monitor the condition of the patient in real time in order to provide better diagnosis. The biometric details of patients stored in the database can be sent to the web server using Application programmable interface (API) and can be accessed on the desktop frontend application and mobile application. Since the sharing of information is being done through the cloud, the flow of the data is not secure. It is susceptible to attacks like man in the middle or DDoS [1]. This non-security of the data violates the Health Insurance Portability and Accountability Act (HIPAA) of 1996 regulation [2]. To counter this problem our paper proposes a framework with two storage locations, the main database and an off-chain database to avoid single point of failure. Our Framework uses IoT sensors already available in the market but integrate them with the blockchain technology so that patients can securely send data to the relevant parties. Since blockchain technology is immutable that means any tampering in the data is detected as soon as it is done. Typically, blockchain managed by a peer-to-peer network collectively validating new blocks to be added the chain. This is because blockchain creates transactional hashes when blockchain is applied to the data.

The general IoT-structure is illustrated in Figure 1. The architecture is characterized by several devices and gateway to create a connection between devices provide services across divergent applications across different networks. Information can be stored on the backend server/cloud and accessed via the web client and mobile phone application. The market is evolving and instrumental in developing technologies such as smart cities, smart homes, smart farming, smart transportation, and advanced health and medical applications with the broad range of IoT applications [3-9].

However, it is difficult for healthcare providers to maintain multiple data sets over a large amount of patient's data. Healthcare machine learning apps provide real-time identification of behavior across healthcare networks to address this, and further aid with enhanced diagnosis and treatment. To help people accomplish the task and overcome these obstacles, human intelligence is incorporated into machines and computers to create the notion of artificial intelligence (AI).

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Machine learning (ML) is an AI branch that allows computers to learn and perform the function of experts without being specifically programmed [10]. Another example of ML, with an interconnection of nodes called neurons with three major layers, input, hidden, and output layers, is the artificial neural network or neural network (NN) [same], where the hidden layer is a single layer linking the input layer to the output layer. Deep learning (DL) is the recurrent phase of learning carried out in DNN that helps it to find an optimal data representation function. DL's creativity is a growing trend in data analysis and is rated as one of the best technical innovations [10]. DNN is an active ML branch and its objective is to make machines think and understand as human beings by mimicking the human brain connection grid, concentrating on learning data representation (DR) rather than task-specific algorithms [11]. Figure 2 shows the relationship between DL, ML, and AI. At present, because of its growing attention and efficiency, DL is set to take over the ML space.

Recently, Artificial Neural Networks (ANNs) have been widely used to model the extremely fluctuating patient data. ANNs combined with optimization techniques show a reasonable patient's data prediction accuracy. The ANNs however, have a few drawbacks such as over-training, initial set parameter sensitivity and instability. Because the algorithms outlined above are shallow learners, they are unable to understand the deep underlying structures buried in patient data. The

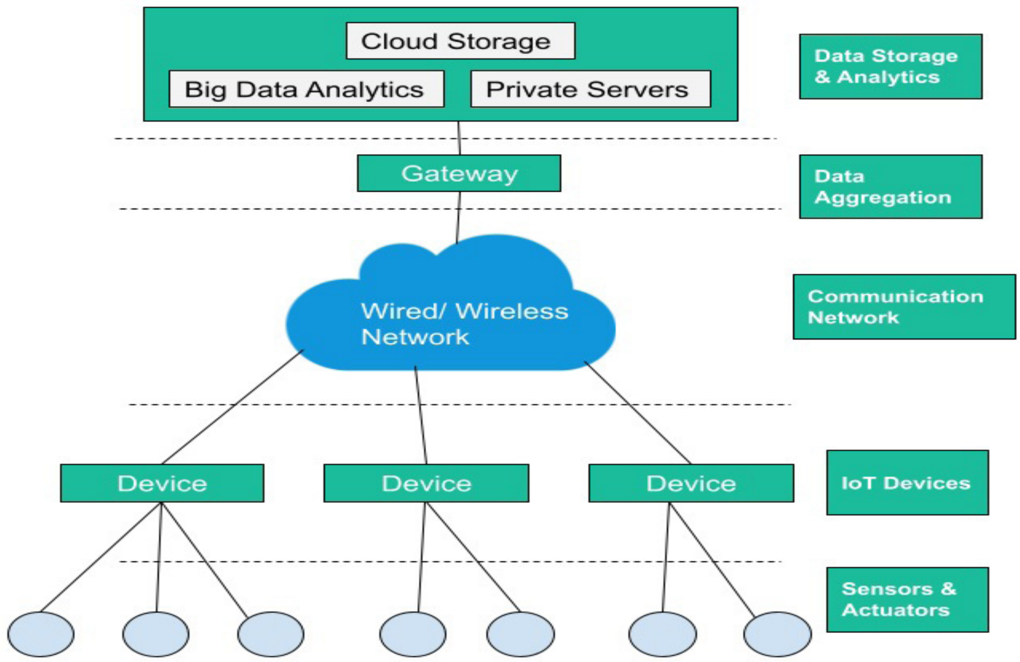

Figure 1: Generalized IoT Structure.

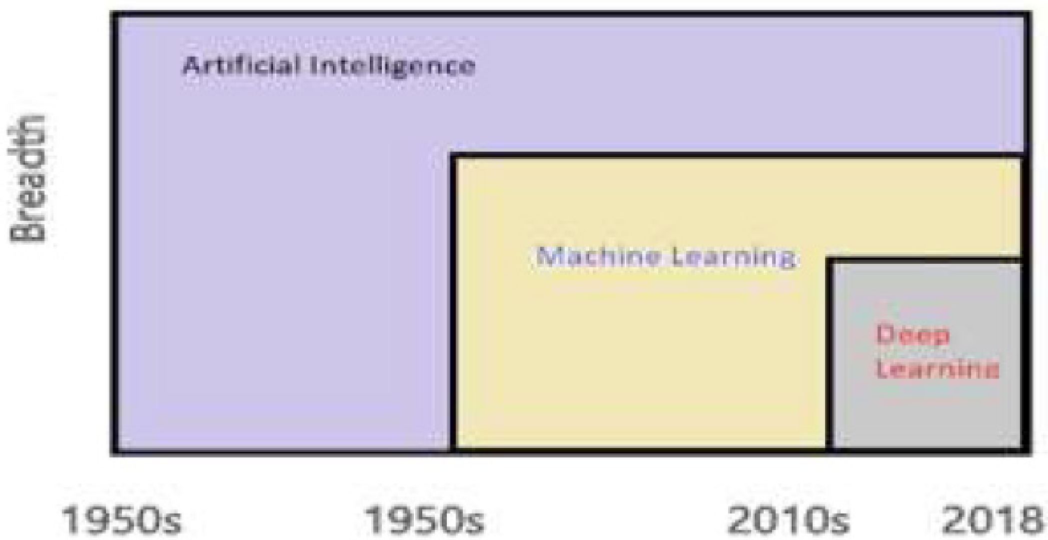

Figure 2: Relation between AI, ML and DL with emerging time.

methods of deep learning are introduced to solve the issue of shallow learning. Deep Neural Networks (DNNs) are a type of neural network that can model abstract properties in data. The popular DNN methods used for healthcare are Deep Belief Networks (DBNs), Recurrent Neural Networks (RNNs), Long Short-term Memory (LSTM) and Convolution Neural Networks (CNNs) [12]. Within the health informatics sector, coevolutionary neural networks (CNNs) have had the greatest impact. Its structure can be described as an interleaved set of feed forward layers that integrate coevolutionary filters followed by layers of reduction, rectification, or pooling. CNN produces high-level abstract features for each layer [13]. Our contribution: In this paper we have implemented an automated device to provide 24/7 real-time health monitoring facilities, which supports the coordination and quality of healthcare for the rural and remote communities and convenient to both doctors and patients. The objective is to incorporate a low-cost system and transmit the patient vital signs in emergency situations using wireless Healthy Pi kit sensor network to collect the patient's data and transmitted to a cloud. Moreover, we implement the frontend including the website and backend including database as well the mobile apps for easy access of HIoT for patients, doctors, and admins. The object is to have a complete and secure smart HIoT. The remainder of the paper is organized as follow: Section II present literature review. In section III, we provide the proposed methodology and an implementation design. In section IV, we present the result and analysis of the methodology. In section V, we conclude the paper. Finally, in section VI we present the future scope of this work.

Literature Review

Internet of things (IoT)

There are several methods for estimating the necessary criteria for health monitoring. The prototype for a wireless patient monitoring system has been developed by Alexsis Bell et al. [6].The system was used to determine the concentration of oxygen in the blood, pulse and temperature by communicating with sensors. Thermistor positioning was the downside of the design, the blood oxygen concentration was not calibrated; the need for hardware was greater and contributed to the prototype's high cost. Sagar R Patil et al. [7] used wireless technology to design patient monitoring systems. It uses electrodes to assess patients' vital signs. The downside was that the readings were not right and displayed glitches when the production was shown. The system for tracking patients using IoT was developed by Sohail Shaikh et al. [8]. Only the transmission of data from patients to doctors was the key goal. The downside was the inability to include MAC protocols for data transmission that were still efficient. A wireless network protocol for patient monitoring has been developed by T K Ramesh et al. [9]. It is done to compare wireless network protocols. The downside was that contact was not successful in rural areas. A design was proposed by Dr. Bharath Kumar GJ [14] to track the vegetative state of the patient using cloud computing and IoT. It shows the patient's condition remotely to family members. The primary downside is that it is only available to patients in a vegetative condition. Jha et al. [15] surveyed all acute care hospitals of American Hospital Association. They determined the presence of specific electronic record functionalities and the proportion of hospitals that had such systems in their clinical areas. They also examined the relationship of adoption of electronic health records to specific hospital characteristics and factors that were reported to be barriers to or facilitators of adoption. Thermolia et al. [16] present the semantic model to extract health knowledge to be used for analyzing the patient records and recommending personalized diagnosis and treatment approaches.

Network layer discovers connects and translates devices over a network and in coordination with the application layer. Finally, the application layer data process and storage the date with specialized services and functionality for users as shown in Figure 3.

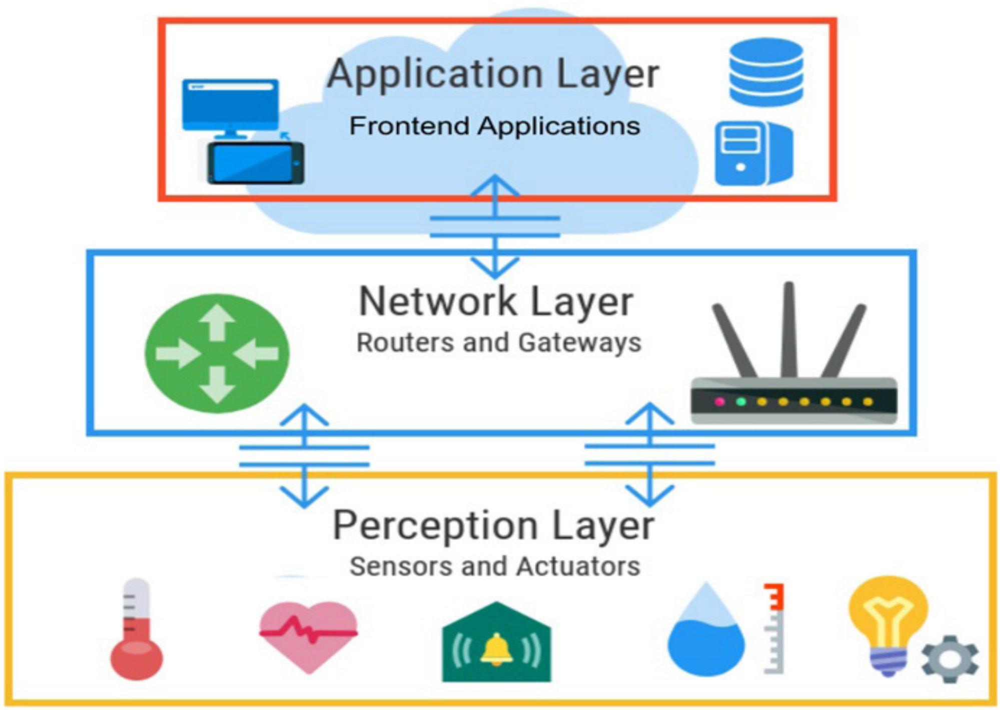

Figure 3: Fundamental IoT Three-Layer Architecture.

The following Table 1 shows the pros and cons of different systems that we discussed earlier.

Portability, the essential bit of leeway of versatile applications, coordinated into associations' activity can possibly make data stream all the more productively and to all the more likely arrange activities inside the medical services gracefully chain per Siau [17], subsequently making numerous new open doors for the medical care world to grasp.

Various advances for deciding areas of cell phones being used are accessible. Worldwide Positioning Systems (GPS) is one of the most broadly utilized area distinguishing proof advances. The situating innovations can be applied to pinpoint the area of individuals or on the other hand resources for following purposes and crisis administrations, and for area significant applications for example, driving course and traffic reports as per Evans [18].

In every exchange, each gathering included should have the option to validate its partners, to ensure that got messages are not altered, to keep the correspondence content secret, and to accept that they got messages come from the right senders. Owing to the inalienable weakness of the portable climate, clients in versatile applications are more worried about security issues including portable exchanges. As per Marcus [19], US shoppers are not prepared to purchase portable administrations. Additionally, medical care customers should be guaranteed that their clinical and monetary data are secure, and that remote exchanges are protected. The mass reception of portable applications and the boundless utilization of versatile medical services won't be acknowledged until clients start to confide in portable applications as per Shen et al. [20].

Machine learning

Quan Zou et al. [21] Identified fast improvements in machine learning techniques related to the study of medical health implemented by neural, decision tree, and random forest Techniques. The 2 main components are considered in experimentation with the dataset mainly Principal Component Analysis (PCA) and Minimum Redundancy Maximum Relevance (mRMR) for prediction of type1 and type2 diabetes. ML is used for dataset evaluation, variation, and cross-validations. Neural networks, identification of patterns and MAT laboratories used forward and feedback networks. Recent advances are being made in Artificial Intelligence and Neural Networks. Many applications come into the picture with such developments, in which one of the growing interests in developing Artificial Intelligence systems related to health. To code the medical record using local mining and global approaches, a scheme was proposed [22]. An Intelligent System was proposed that uses natural language processing, fuzzy logic, deep learning and a continuously expanding knowledge base to correctly diagnose diseases [23]. An artificial intelligence system has been proposed that can predict diseases based on symptoms and include a list of treatments available [24]. With various artificial intelligence mechanisms, an intelligent health and decision support agent was constructed. Using the patient's Electronic Health Records (EHR) to direct the search process when the system receives user symptom descriptions, it performs both web search and local medical knowledge database search [25]. For conversational modeling, another approach was proposed that uses the sequence-to-sequence system proposed by Google. It needs less hand-crafted rules and can be trained from end-to-end that is the main advantage of using this technique of modeling [26]. If compare the methods of DNN, due to its reduced training time and effective feature mining, CNN is superior to DBN and RNN. A state-of-the-art form of deep learning is CNN. It is the attribute of CNN that it can automatically extract the spatial characteristics [27], and [28].

Blockchain use cases in healthcare

In this section, we center around the main examinations grouped by a few use cases, for example, electronic clinical records, pharmaceutical supply chain and medical coverage claims.

Electronic healthcare records (EHR)

Electronic Healthcare Records (EHR) can benefit a lot from the blockchain infrastructure [29], and [30]. These HER records contain patient information as well as their medical history, projects about their health, if any progress they have made during the treatment. Having the EHR on blockchain makes them public which removes the obstacles of having a centralized source controlling the data and makes the information easily verifiable. The patient will be more at ease and share his records with any 3rd party affiliates like doctors, pharmacists, insurance companies giving them security and privacy [31], and [32].

Pharmaceutical supply chain

Pharmaceutical industry is another use case in healthcare where blockchain can be efficiently put into good use. Blockchain address can address a lot of issues pharmaceutical supply chain some of those implementations are mentioned in this paper. The issue of counterfeit drugs have been mentioned in [33], and [34] where the authors have proposed a model system which can trace pharmaceutical supply of drug end to end to end.Modium.io AG [35] is startup which controls the temperature requirements of each individual drug during

Paper	Methods	Pros	Cons
A. Bell et al. [6].	Wireless patient monitoring system	Need for the hardware	Thermistor positioning
Sagar R Patil [7].	Wireless Technology	Electrodes to assess patients' vital signs	Readings were not right and displayed
Sohail Shaikh et al [8].	Tracking patients using IoT	Transmission of data from patients to doctors	The inability to include MAC protocols for data transmission
T K Ramesh et al [9].	Wireless network protocol	Compare wireless network protocols	Contact was not successful in rural areas
Dr. Bharath Kumar G J [14].	To track the vegetative state of the patient using cloud computing and IoT	Patient's condition remotely to family members	Only available to patients in a vegetative condition

Table 1: Comparative tables of e-Health Systems.

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transportation, they do this by creating access to the temperature records to the involved party using blockchain Jamil et al. [36] in his paper has proposed a solution which helps in detecting counterfeit drugs to combat drugs falsification.

Health insurance claims

Another beneficiary of the immutability nature of the blockchain network is the health insurance industry. This is one of those sectors in the healthcare industry which can benefit a lot because health insurance claims need to be validated by the insurance company before granting it to the insurer, however, there have been very limited implementations in this area. MIStore [37] is one of such implementations which provide storage to the medical insurance data through blockchain.

Health internet of things (HIoT)

In Traditional healthcare system patient was only able to communicate with doctor through visits and tele health services. Internet of Things devices made it possible for doctors to monitor patient's health remotely [38]. This increased patient- trust, engagement and also helped the doctors to give patients care even remotely.

IoT for patients

Patients can wear IoT wearable device like the one in our implementation. It can give real time measurements of the patients so immediate care be given to the patients [38].

IoT for physicians

Data from the IoT devices can help physicians track patient's data which can help them in treating the patients in the longer run as it helps them to identify best treatment process for their patients [38].

IoT for hospitals

Hospitals can not only use IoT devices for the patients but can also use them to track their various inventories at various locations. It can also help them in maintain temperature of certain rooms for patient care or to place medicines [38].

Methodology & Implementation

The proposed framework system consists the following modules, sensors data ingestion, machine learning, blockchain, frontend including a website, backend including database storage and mobile app integration. The sensors data ingestion module is encrypted by applying blockchain technology then machine learning module analyzes and process the live data and predict the health status of the patient. Moreover, secured data is store into then database which further can be viewed in the frontend and mobile interface as it shown in Figure 4.

Sensor data perception layer healthy Pi kit

This layer consists of the fundamental essential sensors interfacing with the cloud and frontend application. The healthcare IoT (HIoT) based system is used the healthy PI Kit as it is shown in Figure 4 to collect patient's sensor data using the API integration techniques.

The patient's data that is collected by Healthy Pi Kit sensors are sent wirelessly to cloud through WIFI. Moreover, the patient's collected data is compared to the desired threshold normal healthy medical values to deduct any unhealthy symptoms of the patient. If the sensor values are equal to or above the threshold, then the patient's healthy or not healthy warning is transmitted through a Wi-Fi module with the information of each sensor to the doctors in the desktop frontend application as shown in Figure 3. This information is further moved to the cloud for comprehensive processing and secure storage. On the website, the past few hours can be viewed, and the data is saved in the cloud. The suggested method states that the sensor first establishes a connection between the healthy Pi kit and the Wi-Fi network and then reads the sensor data. In real-time, the system measures the parameters and shows them on the web page and in the cloud, which allows patient health monitoring while the doctor is with the patient or wireless monitoring anywhere. Figure 5 displays the flow chart of the proposed method of continuous patient monitoring. Sensor data is sent to the cloud via the Wi-Fi, and a warning message is sent to the mobile application if the sensor data is not within an appropriate range. The doctor will take steps very quickly to assist the patient.

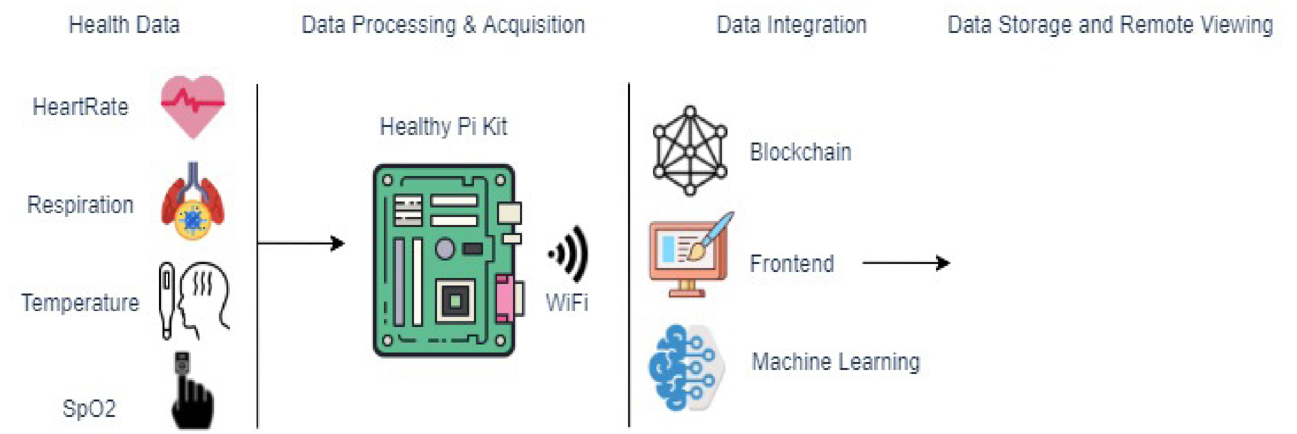

Figure 4: Overall System Architecture.

The hardware implementation of the proposed system is shown in Figure 6. Healthy Pi Kit transmits the health info to constantly perform medical and biometric applications. But In in this paper, we are using only 4 sensors including the Heart rate, Temperature and SPO2 and Respiration.

Healthcare IoT website

In this paper, a healthcare IoT website using frontend, backend and data transformation is designed. It shows the designing and architecture of our website, functionality, and communication.

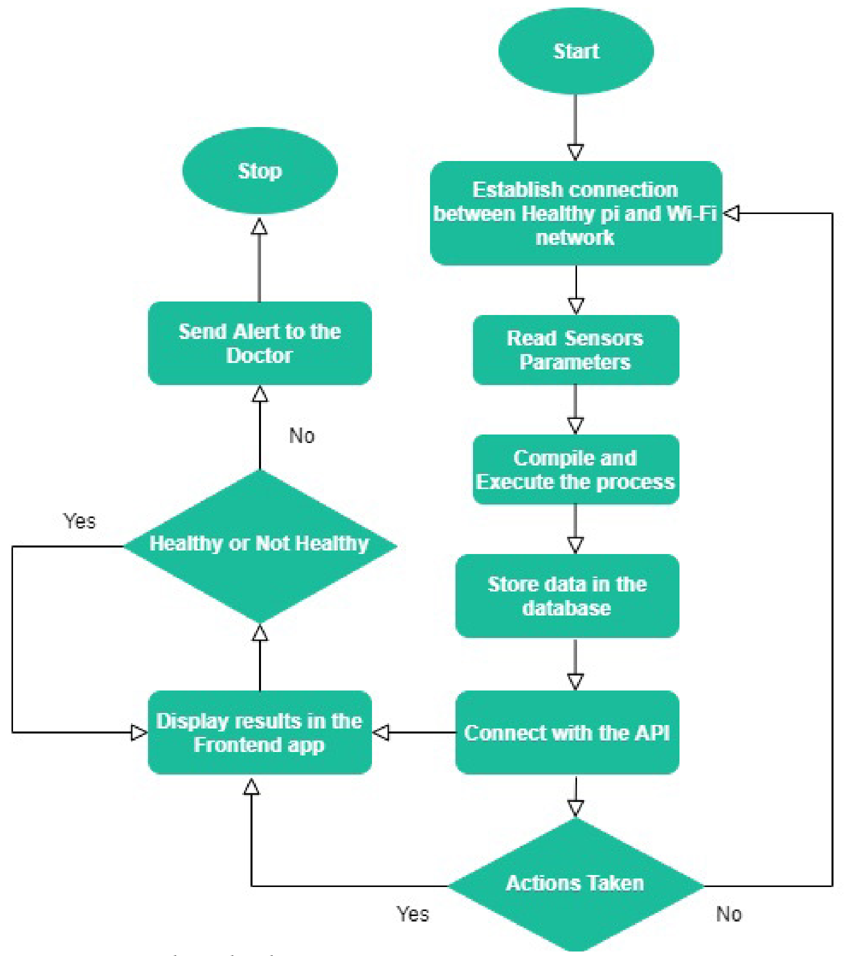

Figure 5: Sensors and IoT Flowchart.

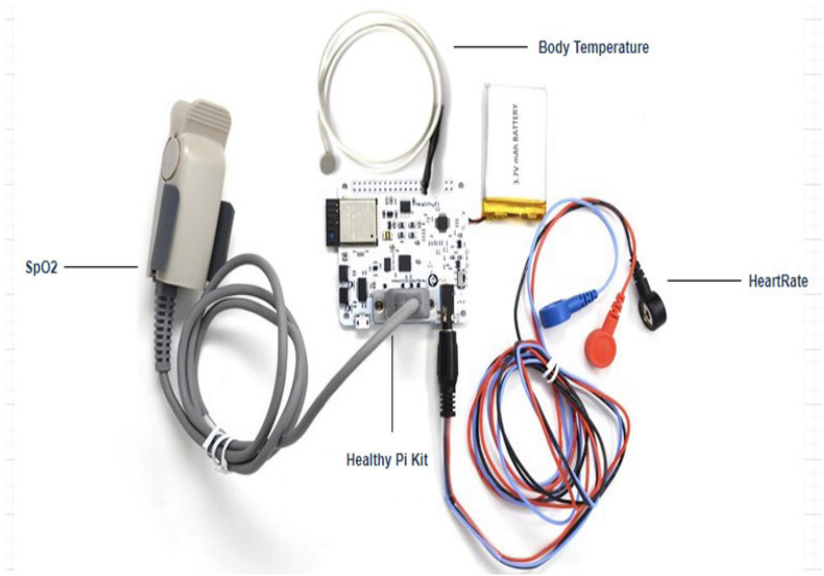

Figure 6: Hardware Setup with Healthy Pi 4 including ECG, Temperature and SPO2 sensor.

Website architecture

The aim of this system was to design and build a smart healthcare monitoring system with a user-friendly, responsive web application. It can be clearly seen in Figure 7 that a working web application prototype was built with an admin to easily maintain the web application. An established working model of a doctor and a patient. This paper is made up of numerous pieces. The initial section explains the web technology used and another part with practical experience offers descriptions of the web development implementation process. Web development tools have been selected, such as HTML, CSS, JavaScript, PHP and Bootstrap. For the development of this project, XAMPP local host was used as a local server. User interfaces have been modified according to user specifications. The architecture design of the database and tables helps build a healthcare system that socializes between doctors, patients and admin.

Website functionality

This paper explores the use of the MySQL database language for PHP scripting. Any website can require a variety of information or data to be displayed and retrieved from the database. This could involve the showing of a basic list based on the data contained in the database for running the website. The MySQL database configuration process varies depending on the host. In order to access the database, every database needs a user name and password. This refers to the three distinct styles of web development strategies that we use with your website, including HTML that constructs the page layout, CSS enables our website to alter colors, positioning, stunning looks, and themes. The dynamic and interactive elements on the page are defined by JavaScript.

Website communication

As the Figure 8 depicts that the complete kit which consist of Arduino software where we can compile the code and execute the process for data acquisition, audio processing, and processing control flow.

The paper depicts that CURL, AJAX and JS between server and client-side implementation are various forms of communication for accessing the Web API service. From the local server, we load jQuery and use the ajax () function. CURL is mainly used to send

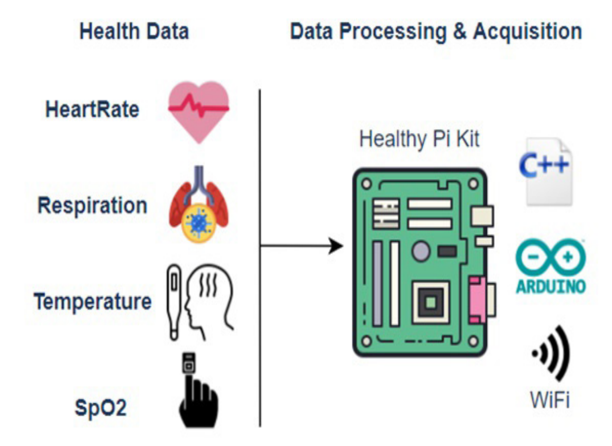

Figure 8: Heath data processing and acquisition.

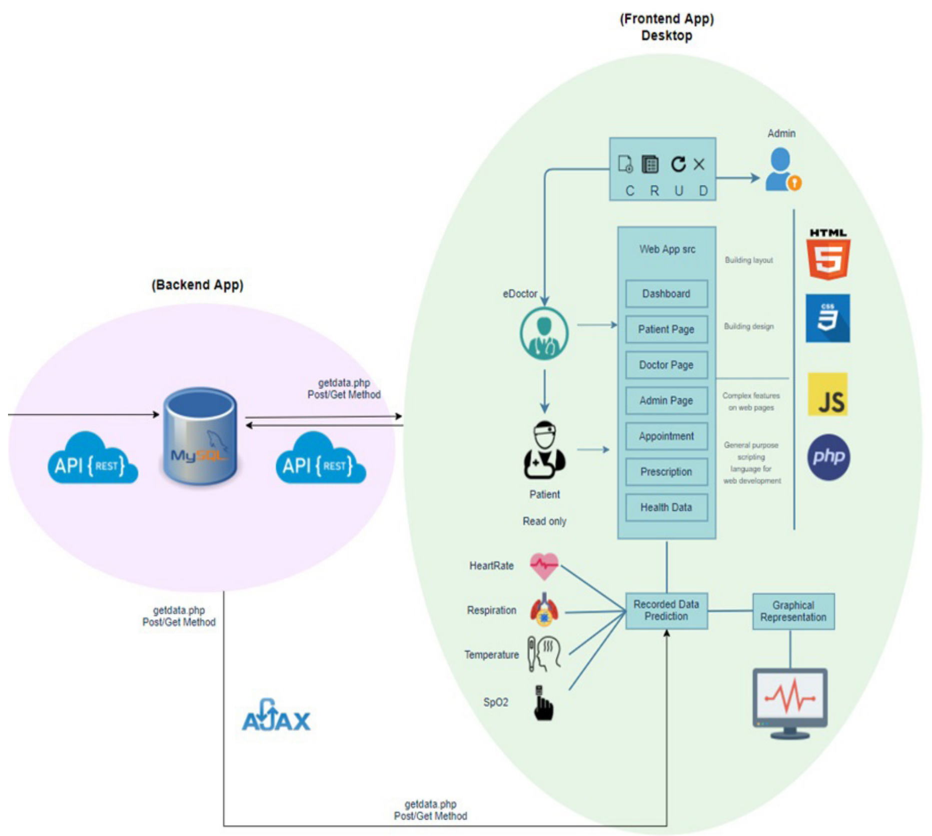

Figure 7: Website Architecture of the system.

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data via http using the POST and GET methods for the client URL. A REST (Representational State Transfer) style-based API will return different data based on the requested HTTP verb and resource. The asynchronous sending of arbitrary data is commonly called AJAX, which stands for "Asynchronous JavaScript and XML. A POST request could post a request that the operation was successful, while a GET request could "get from the server the data it requested. The $.get () and $.post() methods of AJAX jQuery include basic resources for sending and retrieving data asynchronously from a web server. You can submit JSON/XML and process it as you wish if you monitor the front-end (the code that is executed in the browser) and the back-end (the code that is executed on the server.

This is used for continuous monitoring of patient data for medical diagnosis. The gathered information can be sent using Wi-Fi depending on the application we are making. Using curl scripts to transfer data in the database with the help of URL. MySQL databases are relational and stores data in separate tables rather than putting all the data in one big storeroom. AJAX is an asynchronous java scripting used to update a web page with send and receive data to the server as shown in the Figure 6. After the data is successfully stored and integrated it will display the data to the front end application with the help of web designing tools demonstrated in Figure 4.

Machine learning

The proposed framework system consists four components, live data transfer from sensors to database, applying machine learning algorithm on input data, prediction of the health status, send the results to the frontend as it shown in Figure 9. The proposed model for the E-health Monitoring System (EHMS) is trained by supervised learning which is discussed in this section.

Data preprocess

The model is provided with six kinds of inputs:

Age, Gender, Temperature in Celsius, SPO2, Heart rate and Respiration. All inputs have some conditions mentioned as below:

1. Age is in between 20 to 35.
2. gender is either male or female.
3. If the temperature is in between 32-38 then the person is healthy, otherwise the person is not healthy.
4. If the SPO2 is in between 95 to 100, then the person is healthy, otherwise the person is not healthy.
5. If the heart rate is between 60 to 100 then the person is healthy, if it is >100 then the person is not healthy.
6. If the respiration rate is in between 11-29 then the person is healthy, otherwise the person is not healthy.

This is used to track patient data continuously for medical diagnosis. MySQL databases are relational and store information in separate tables instead of storing all the information in one huge storeroom. The Figure 4 depicts that the machine learning model fetch the data from database.

Efficient deep convolution neural network

Convolution Neural Network has an exceptional ability to derive deep underlying data features. By convolution operation, the CNN effectively identifies the spatially local correlations in data. A filter is added to a block of spatially adjacent neurons in the convolution operation and the result is passed through an activation function. This output of the convolution layer is an input to the neurons of the next layer. The input to each neuron of a layer is therefore the output of a convolved block of the previous layer.

Unlike ANN, due to the weight sharing scheme, CNN training is successful. Due to the sharing of weight, the effectiveness of learning increases. Three altering layers are composed of CNN: (i) convolution layer; (ii) sampling layer; and (iii) entirely connected layer. Equation (a) will clarify the convolution process. Assume $X = [x_1, x_2, x_3,\dots, x_n]$ is the training sample vector and $C = [c_1, c_2, c_3,\dots,c_n]$ is vector of the corresponding targets. n is the number of training samples. CNN seeks to explain the optimal filter weights and biases that decrease the error of predicting. It is possible to describe CNN as: $Yim= f (wm \otimes Xim+ bm)$ (a) Where, $i = [1, 2,\dots, n]$, $m = [1, 2,\dots, M]$.

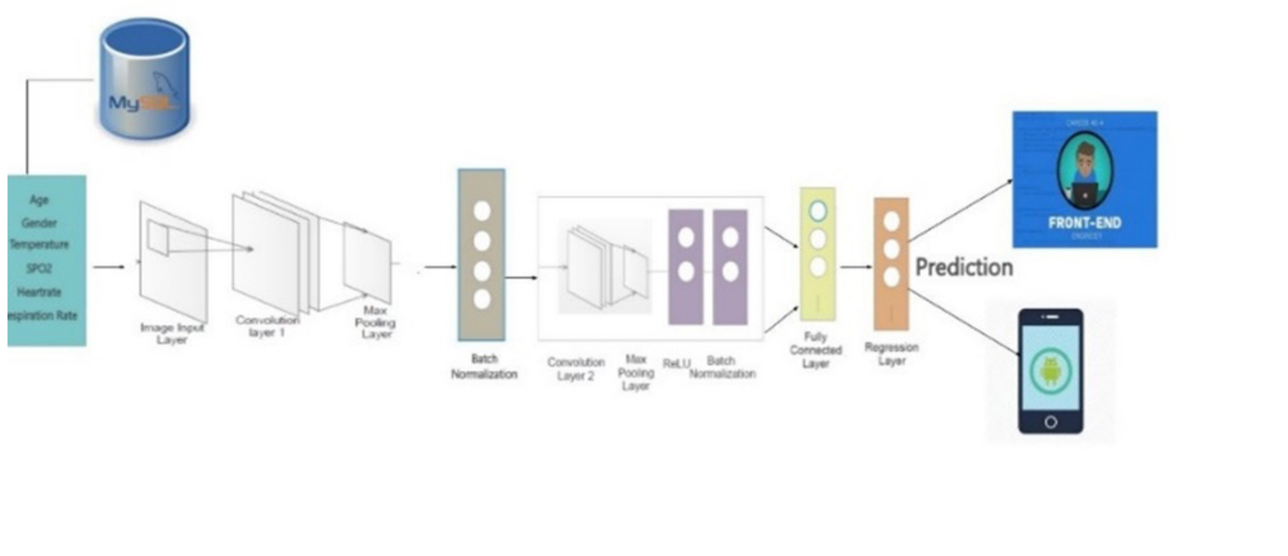

Figure 9: Proposed system for health data Prediction.

m is the number of layers that should be examined. Wm denotes the filter weights of the layer of mth. The biases are represented by bm, and the convolution operator is f (.) is the nonlinear activation function. Yimis the feature map generated by sample Xi at layer m. In the proposed prediction method for health data, there are total eleven layers: three convolution layers, three max pooling layers, two batch normalization layers, three Rectified Linear Unit (ReLU) layers, one modified fully connected layer and one modified output layer (Enhanced Regression Output Layer (EROL)). In all convolution layers, the number of filters is 9. In all the hidden layers, the number of neurons is 200. To boost the prediction efficiency of EDCNN, the functionality of two layers is modified. There is no standard way to select an optimal activation function, according to the ANN literature. In a hidden layer, a modified activation mechanism is employed. The proposed activation function is the set of results of three activation functions (Equations 2-4, respectively): hyperbolic tangent, sigmoid, and radial base function. Equation (5), the activation function proposed, takes the average of the results of the three activation functions used.

$$z = \sum_{i=0}^{n} w_i x_i + b \qquad (1)$$

$$\mathrm{TH} = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}} \qquad (2)$$

$$\sigma = \frac{1}{1 + e^{-z}} \qquad (3)$$

$$\phi = \phi \left\| xw - c \right\| \qquad (4)$$

$$\mathrm{F(x,\,w)} = \frac{(TH + \sigma + \phi)}{3} \qquad (5)$$

Where xw is the network layer intermediate output (weighted input sum) to which activation is to be applied to achieve the final output. The radial base function is f. To measure the effects of the corresponding hidden layer, the proposed activation function uses an average of the three functions mentioned above.

A modified objective function is embedded in the proposed output layer EROL. The goal is to minimize the absolute percentage error between the values of the forecast and the actual targets. The objective can be represented as an equation. min Loss

$$(\mathrm{w},\, \mathrm{X}_i,\, \mathrm{c}_i) = \mathrm{L}(\mathrm{w},\, \mathrm{X}_i,\, \mathrm{c}_i) \qquad (6)$$

where $\mathrm{L}(\mathrm{w}, \mathrm{X}_i, \mathrm{C}_i)$ is the prediction error or loss from sample Xi. The function of loss is expressed as Equation

$$\mathrm{L}(\mathrm{w},\, \mathrm{X}_i,\, \mathrm{c}_i) = \frac{1}{n} \sum\nolimits_{i=1}^{n} \left| \frac{y_i - c_i}{y_i} \right| \qquad (7)$$

Where c_i is the desired or desired target. Y_i is the output of EDCNN's output layer, and its value is measured as:

$$\mathrm{Y}_i = \mathrm{F}\left(\sum\nolimits_{i=1}^{n} X_i w_i + b \right) \qquad (8)$$

Step by step procedure of proposed methodology

Convolution operation

The first building block used in convolution neural network. The simple application of a filter to an input that results in an activation is a convolution. When repeatedly applying the same filter to an input, an activation map called a feature map shows the position and intensity of the detected feature in an input, such as an image.

Rectified linear unit (ReLU) layer

As data travels through each layer of the network, the ReLU layer functions as an activation function, ensuring non-linearity. Without it, the data sent into each layer would lose its dimensionality, which is something that users want to keep.

Pooling layer

This decreases the sample size of a feature map by down sampling it. This also speeds up processing by reducing the amount of parameters that the network must process. A pooled feature map is the result of this. The average presence of a feature and the highest activated presence of a feature are summarized using two prominent pooling methods: average pooling and max pooling.

Fully connected layer

The Fully Connected Layer simply feeds neural networks forward. Last few layers in the network are formed by fully connected layer. The input to the fully connected layer is the output, which is flattened and then fed into the fully connected layer, from the final Pooling or Convolutional Layer.

Blockchain

Figure 10 shows the system architecture of our proposed model where Blockchain Hyperledger Fabric, detail is in subsection A, is applied directly at the IoT sensors and the data flows. Then one secure copy will be send to the cloud's storage and redundant copy of the same patient's date will be send to the doctor through frontend applications.

Inter planetary file system (IPFS), which is a protocol designed to store decentralized and shared files to make the web safer, faster and have second copy of the patient's data.

The processes involved in the process are below.

1. Blockchain hyperledger fabric

Hyperledger Fabric (HF) is a product of the Linux Foundation's Hyperledger Project. HF was developed in March 2016 from a combination of several existing initiatives, including IBM's Open Blockchain, Digital Asset's Hyperledger, and Block stream's libconsensus. Of the various products available from the Hyperledger Project, Hyperledger Fabric has become the most successful to date. It is being utilized in production environments in more than twenty companies around the world, including IBM and Oracle.

Hyperledger Fabric is a permissioned-only, or private-only, distributed ledger. All nodes participating in its network require permission from the hosting organization. Permission is granted via a public key infrastructure (PKI) using either a Hyperledger Fabric certificate authority (CA) or a public CA. This permission usually takes the form of an X.509 digital certificate, but other forms of verification can be used, although, HF does not support RSA keys [9]. One feature of HF is the use of communication channels. Channels provide separation of transactions within the network, granting privacy based on who is allowed on that transaction's channel. They function like virtual local area networks (VLANs). Communication only occurs between nodes which are part of the channel, and membership to a channel must be granted by that channel's controlling organization [9].

2. IoT device

For our project's Implementation we have used Healthy pi kit [2]. This kit comes embedded with four sensors and measure these parameters in real time with high accuracy. Electrocardiogram (ECG) data, heart rate, and heart-rate variability, impedance pneumography-based respiration, pulse oximetry (SPO2), and body temperature are among the sensors. This real time data passes through our blockchain network and creates transactions which creates secure immutable records. These sensitive records are then saved into an off-chain database.

3. Off-Chain database

It is the information base where the basic boundaries of the body and different records of patients are put away. The shrewd agreement controls admittance to this information base. Perusing or composing procedure on this information base depend on the rights the situation director awards to the clients. Information base level assurance measures are utilized to guarantee protection and uprightness of information. Alternatively, information can be hashed to the information base prior to being put away.

4. Inter planetary file system (IPFS)

IPFS is a technology that enables a P2P distributed file system to make the web safer, quicker, and more open by storing decentralized and shared data. IPFS is intended to increase the efficiency of the web at the same time as it removes duplication and tracks version history for each file [18], Hence in order keep a redundant storage option. The patient vital information is also stored by a peer in IPFS. That storing results in the IPFS creating a content-based hash which can be decrypted to view the patients vital.

5. Doctor

A Doctor can verily access the application and get access to patients' vital information. The blockchain is designed in such a way that only authorized doctors can see patient's vital data through the frontend applications.

Database integration

Database used in this project is MySQL, it stores all the necessary and sensitive data. The Figure 11 shows various tables in the project like patients table which stores the patient data like name, address, age and id, doctors table consists of doctor's personal details and their specialization, appointment table which consists of patients upcoming and history of appointment dates and times, table for sensors secured data and Prescription table which is about patients' medication and patients Id. It also shows the relationship between the two tables. Various statements like INSERT and ALTER are used to insert and update the data. The SELECT statement is used to display the data to the user using appropriate APIs written in PHP. The Admin table is associated with Contact table, patient table, doctor table, and prescription table. The Admin has maximum rights in the database, the admin can see patient details and doctor details, and can also modify or add or delete the user. The admin can also view the appointments made by the patient and prescriptions that is prescribed by the doctor. The doctor table is associated with the appointment table and prescription table. The patient table is associated with prescription table and appointment table. The tables have association among each other. The prescription table has optional one to many relationships that means the doctor can write zero to many prescriptions to a patient and similarly the patient's prescription given by a particular doctor.

The Figure 12 displays the entire architecture of the backend framework where various modules like web application, artificial Intelligence, and blockchain are interacting with the database and Figure 13 shows the sequence diagram of the backend framework of the healthcare IoT. Sensors capture the vital signs of the patients which are connected to the raspberry Pi. The data which is in transit is secured by applying the Blockchain technology and converts the data

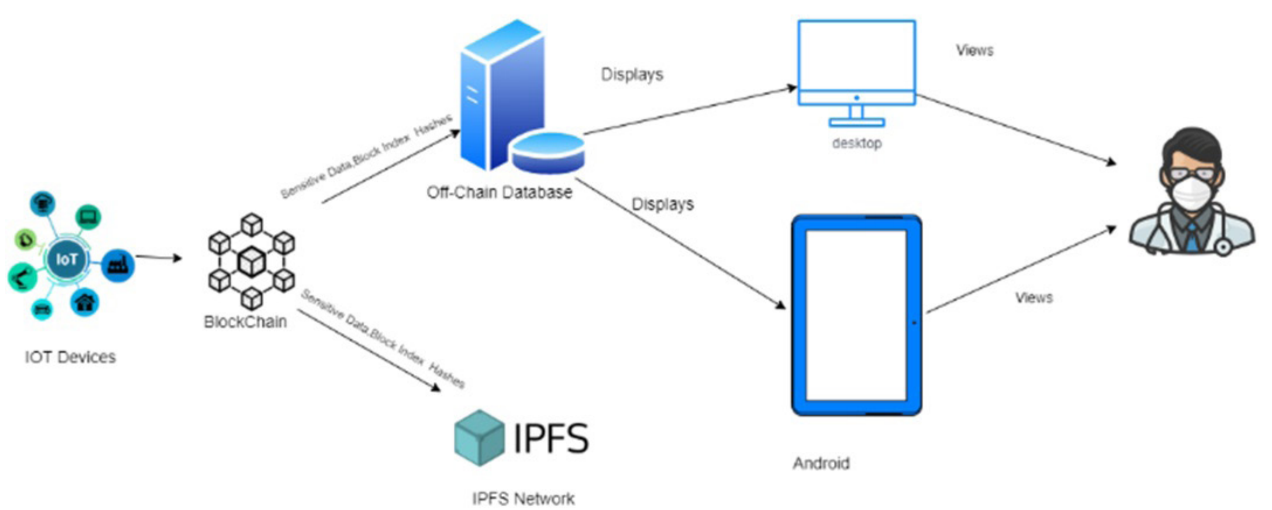

Figure 10: IoT devices and Blockchain storage.

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into one-way hash which is then stored in MYSQL database where it is fetched and get by the PHP using INSERT, SELECT, DELETE, UPDATE, queries depending on the HTTP GET and POST methods. This transfer of hashed data to off-chain database is done by applying REST APIs. These APIs allow to expose the connected device to users in a secure manner. RESTful APIs are widely being used in the modern web and are easy to use and provide more security to the flow of data from the various modules. Data transfer is usually done using JSON or XML over HTTP. Now that the data is stored in the database. The AI takes the data from the database using cURL. cURL is a command line language for getting or sending data including files using URL syntax. It uses URL syntax to transfer data to and from server, process and analyze the data and apply the Machine Learning algorithms which is integrated with Flask Framework.

The Flask framework makes an AJAX call with the help of jQuery and predicts the health status of the patient and displays the alert message to the health care provider based on which the healthcare provider provides the prescription to the patient. Web interfaces that allow monitoring and administrating, and processing, End uses can interact with the data storage and processing engine through the web applications with a set of security and access permissions.

The proposed work is a mobile application interface to the healthcare IoT system between the users and cloud. The target users will be in three main and important categories. These users are patients, doctors and administrators. The patients are provided with the ability to register, login, book appointments, cancel appointments, view prescriptions, ask queries.

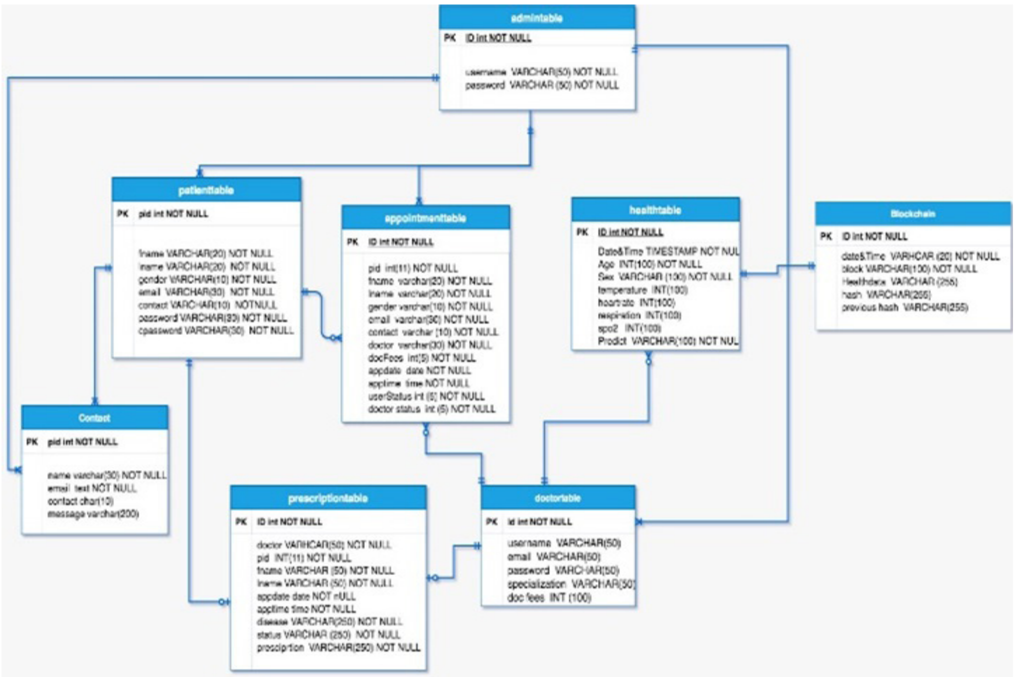

Figure 11: ERD Diagram of database Architecture.

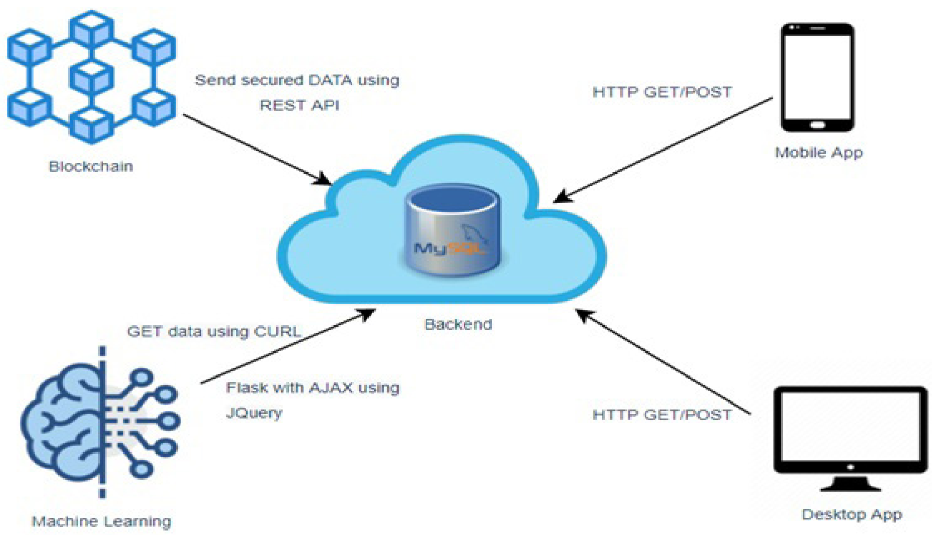

Figure 12: Application programmable integration and database.

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As shown in Figure 14, the users of the mobile application are: patients, doctors and administrators. These three users interact with the mobile application and subsequently interact with the data that is stored on the database. The database being used is a MySQL database. The data is retrieved using API calls. These API calls are unique for each object and referenced within the mobile application. Each API call is tailored to each user category. This means that doctors, patients and administrators all have access to the data as per their level of access. Additionally, the doctor will be able to view patient appointments, cancel patient appointments, prescribe and diagnose patients after their appointments and view patient health data. The mobile application presents the user with an interface to update the doctor directly on their respective health data. These data include temperature, oxygen levels, blood pressure and heartrate. These data

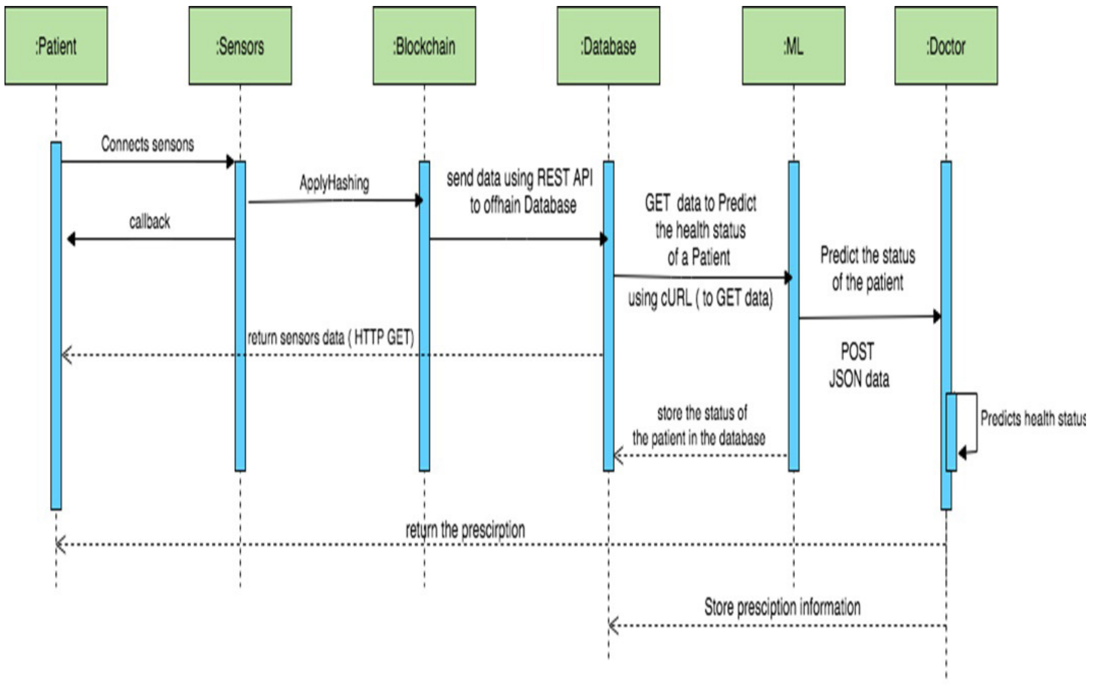

Figure 13: Sequence diagram of Back-End.

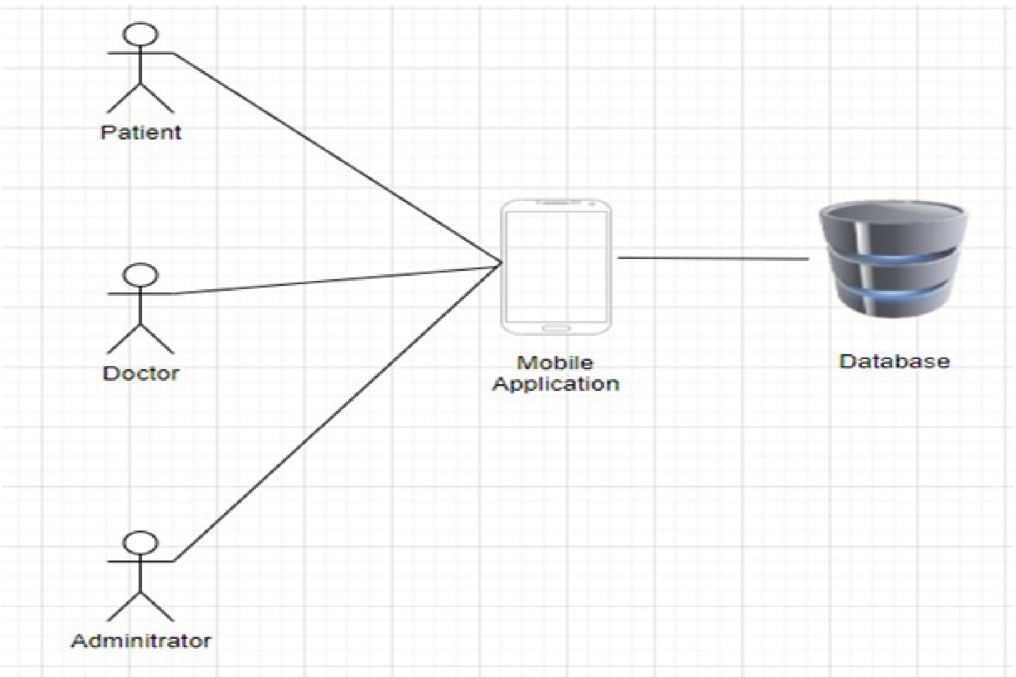

Figure 14: Overall system architecture.

were selected because of their high level of importance for users in order to track their health and ensure any issues are handled early on. Using this health data as well identifying patient information, the doctor will be then presented with the feature of predicting the patient's health status. An added feature is that the patient can update their respective health data on the mobile application and therefore, update the doctor of any changes that they may have.

Mobile application design

While looking for assistance, a patient will need to create an account. After signing up the patient will then be able to create an appointment with a doctor, view the appointment, get a prescription and ask questions to the doctor.

In the use case diagram in Figure 15, the main users are the administrator, the patient, and the doctor. They are all able to achieve specific tasks depending on their roles. The patient is able to register, login, create an appointment, view appointments, view prescriptions and post health data and post queries that they may have. The doctor is able to view appointments, assign prescriptions, view patient queries and view patient health data details. The administrator is able to view appointments, view prescriptions, view queries and view health data details.

In the entity relationship diagram in Fig. 16, the main entities are: the patient, health data, doctor, prescriptions and appointments.

Result and Analysis

In the proposed model, the vital parameters for the patient are acquired by attaching on the patient's body. The Wi-Fi module sends the data to the cloud. The sensors are interfaced with the Healthy Pi kit that use Arduino firmware with ESP32 module. The patient can move freely if the patient wants. A fingerprint sensor is used so that an authorized person can only access the data. The basic hardware connections of the system are shown in Figure 6. The Healthy Pi Kit processes the data acquired by sensors and transferred to the cloud through a Wi-Fi module. The processed data can be seen on the webpage using the computer or the mobile. The real-time vital parameters are measured every 30 seconds. The readings of the sensors are displayed on the webpage. If there is an increase in the threshold values, then the doctor will receive an alert message that states, patient is healthy or not. Figure 17 and 18 shows the sensors data to the client and waveform of the health sensor values.

This Figure 19 depicts that after the web server application is created, we need the web service as to communicate the health data with the frontend application. The web service is created on API JSON (Application Programmable Interface) JavaScript Object Notation using PHP coding to connect with the database. The web service system produces status code response in JSON format. To interact with MySQL database, we need to build an Application Programmable Interface first. The API's duty is to take the client's request, interact with the database, and then return the response to the client. Therefore, we have created a simple PHP, MySQL API on JSON format. API can do following jobs includes accepts requests in GET/POST methods. It interacts with database by inserting / fetching data. Finally, the response will be in JSON format. The REST API works using four of the most common HTTP methods including GET, PUT, POST, and DELETE. We will be using GET and POST in our project only. Using GET to obtain health data and record via the API and display it and have used POST method for Sign up and login pages. A right URL is assigned in the Java scripting file using AJAX and jQuery libraries.

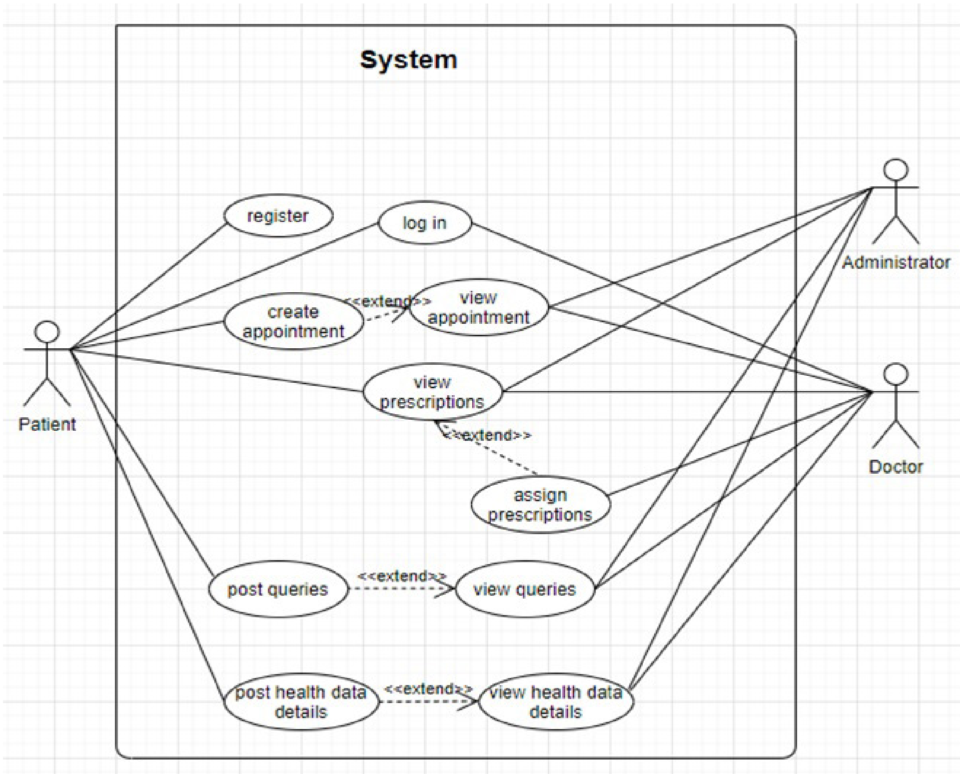

Figure 15: Use Case Diagram.

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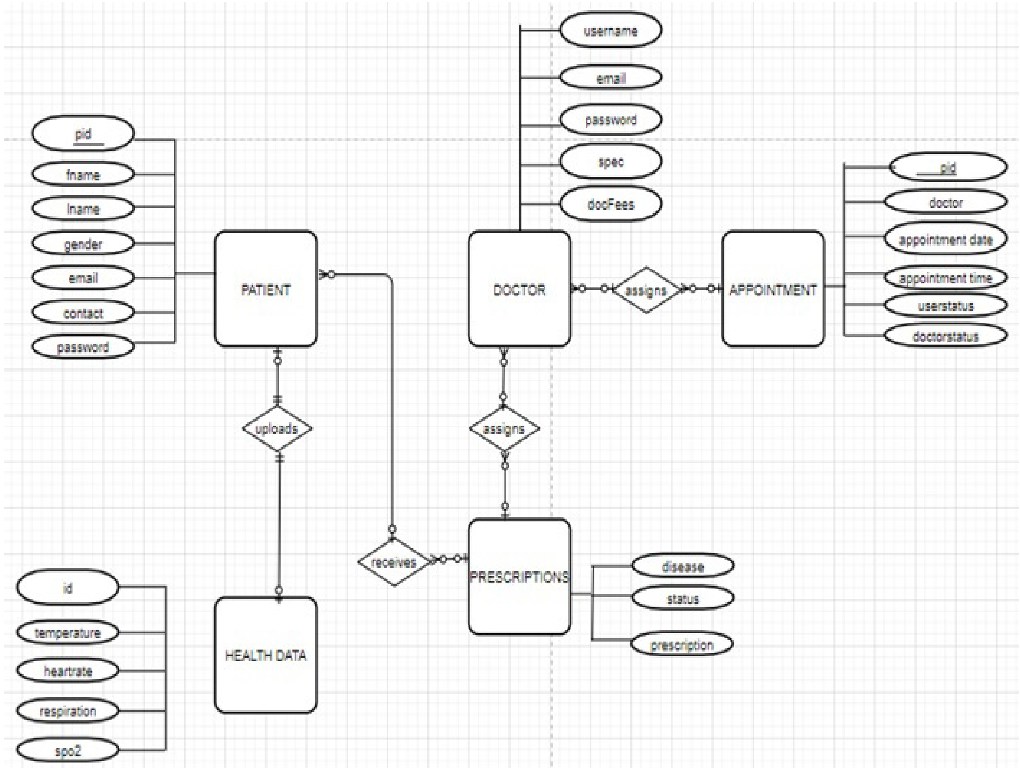

Figure 16: Entity Relationship Diagram.

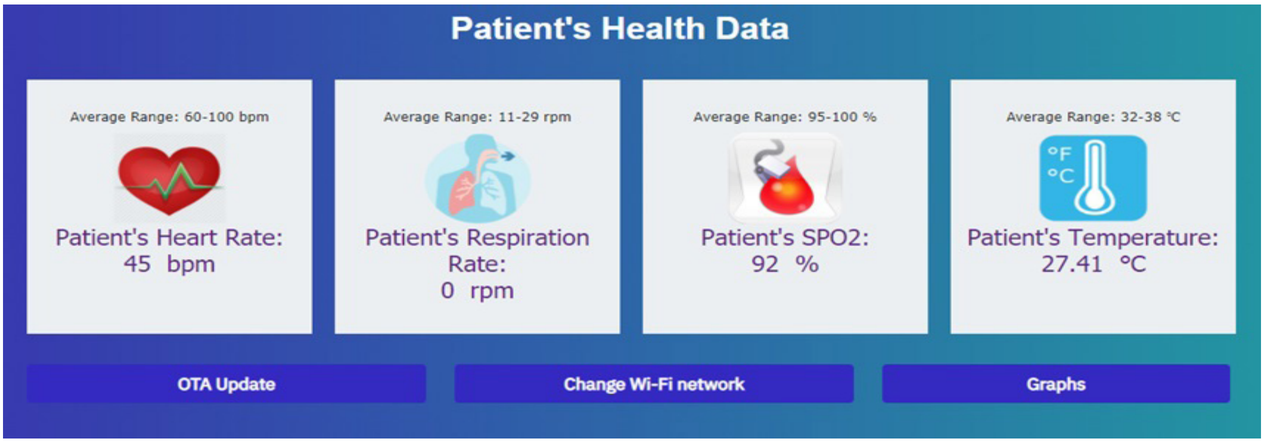

Figure 17: Sensors data display on client side

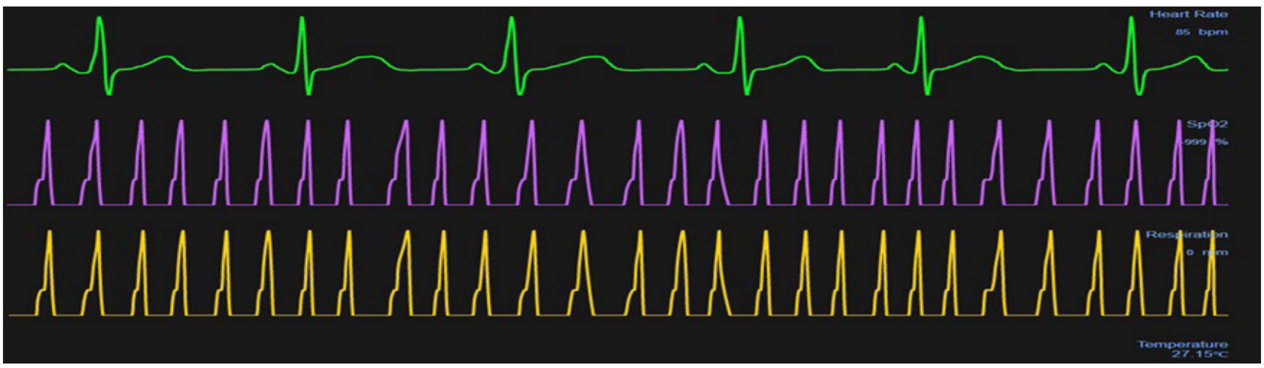

Figure 18: Waveform of the health sensor.

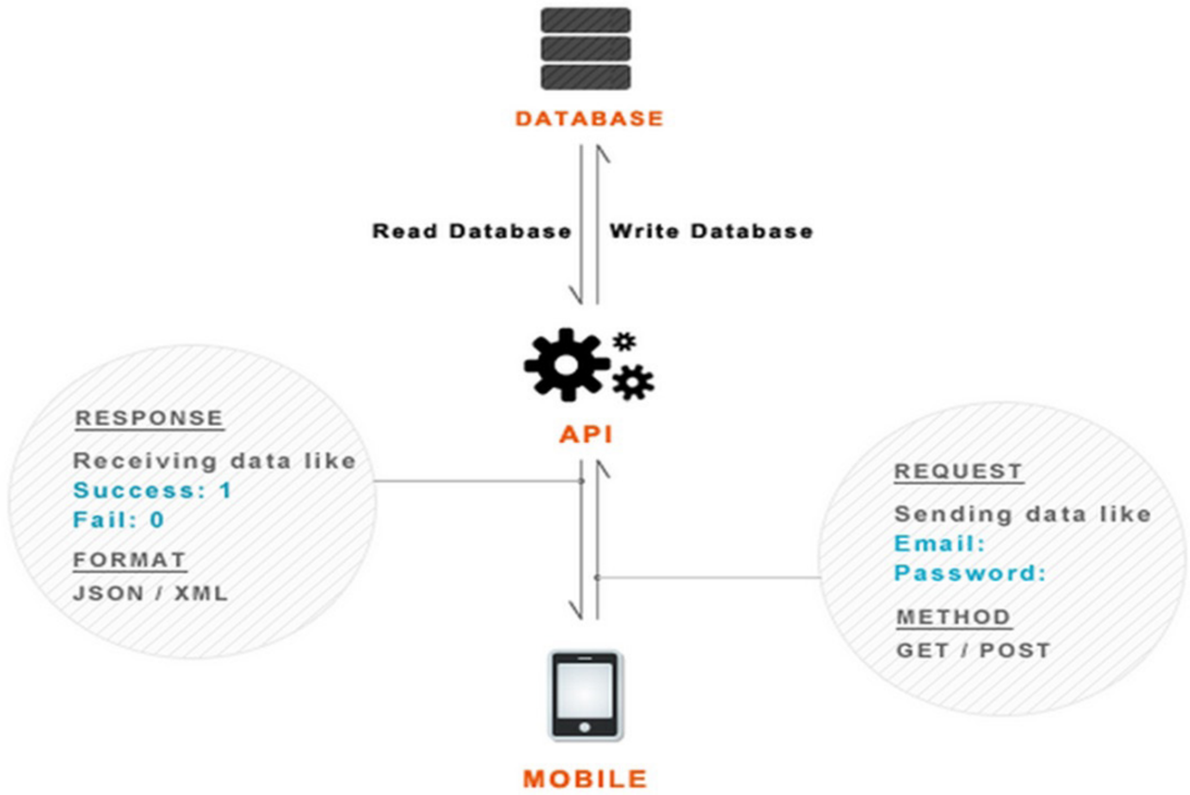

Figure 19: Rest API Integration with the sensors and MySQL.

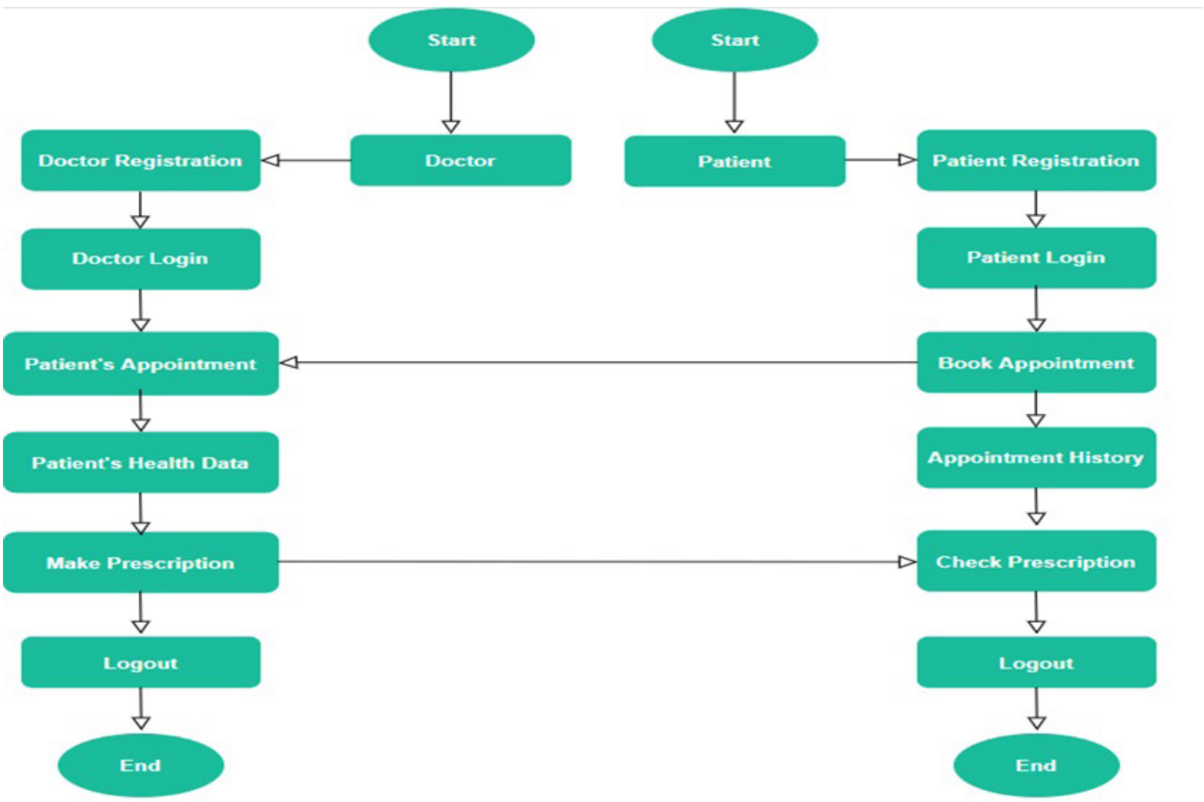

Figure 20: State diagram between patient and doctor.

Our project model also states about the scenario of our frontend application where we discuss about the relationship between doctor admin and patient. As discussed in Figure 20 and Figure 21. Both doctors, patients and admin have the access to sign up and sign in. Patient will book appointment. Admin will register the patient with patient and doctor ID. Patient then can wait for the results of his status. Doctor will diagnose by his health status. Prescribe the patient. A new window will be opened, which will show the vital parameters when the patient will wear the sensor. Then API is called from the jQuery Ajax for accessing the data through Wi-Fi and plotting the Temperature, Heart rate, Respiration and SPO2 graph.

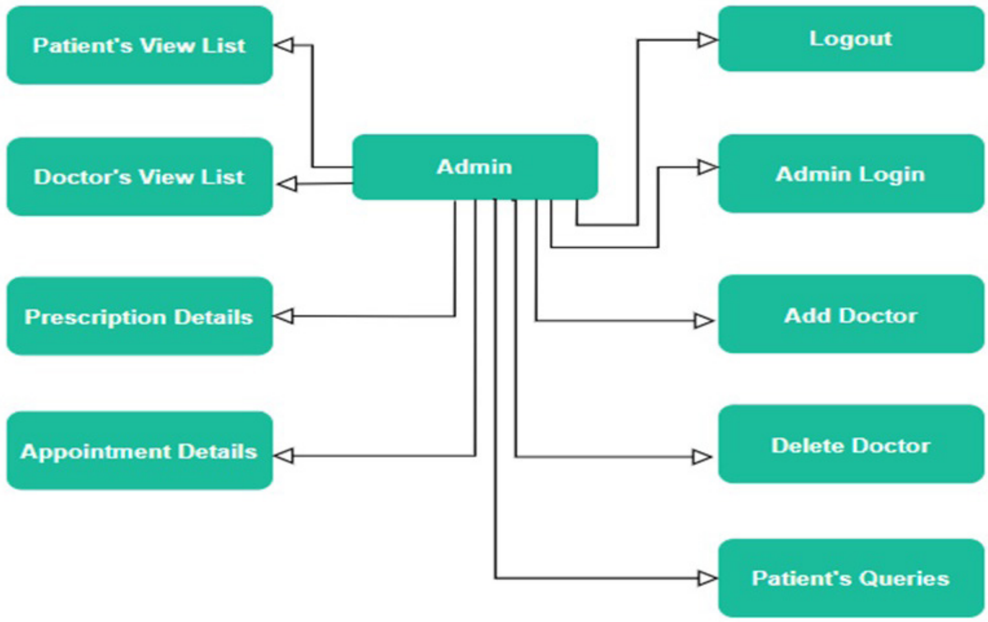

Figure 21: State diagram of admin panel.

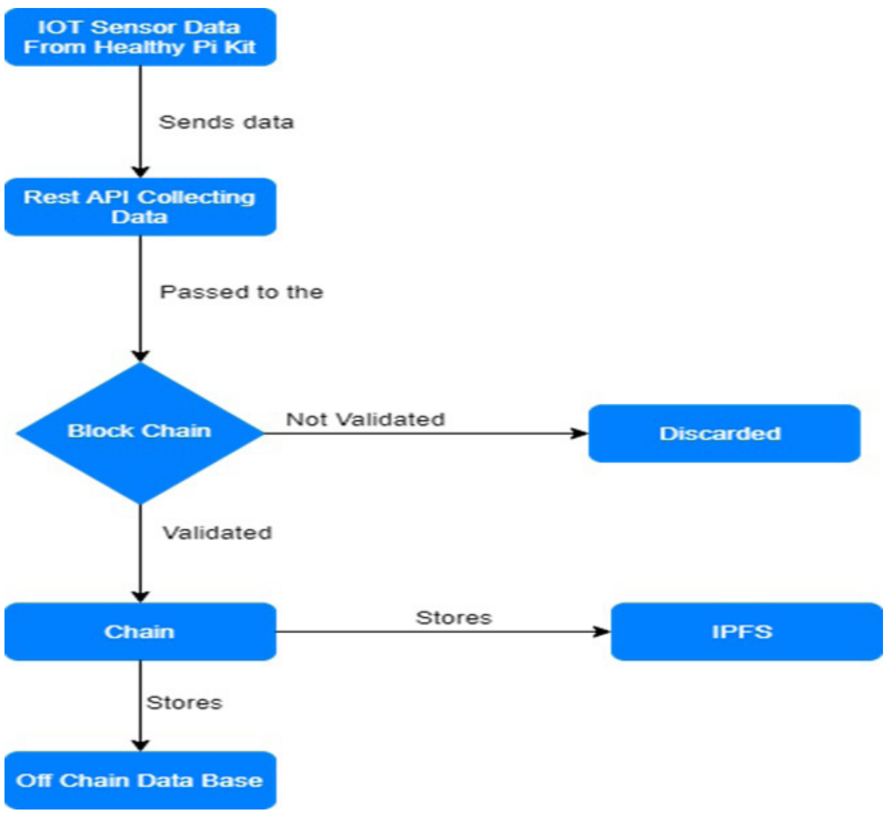

Figure 22: Flow of data.

Figure 22 shows a flowchart which explains the flow of data flow from the sensors to the storage. Figure 10(b) shows the Json format for the blockchain which contains all the blocks that have been mined. That json load is displayed into the URL using flask application and all those blocks are real time measurements of the wearer of the healthy pi kit. That json load then with help of an API gets stored in the Off-chain database from where it is then displayed into the frontend.

Figure 23 and 24 shows the blockchain in json format and displayed in the frontend with each blocked mine separately but forming a chain. The values shown there are just for demonstration purposes final version will not have the sensor measurements there. Another copy of the blockchain gets uploaded into the IPFS networks where individual nodes in that network store the sensitive patient information.

If the doctor wants to see the sensor values, the doctor needs to login the health care web app as shown in Figure 25 the values of all the sensors are displayed in the frontend application. The doctor has four basic principle contents namely patient's appointment, create prescription, predict patient's health and patient's health data. As discussed in Figure 26, Figure 27 and Figure 28. Doctor can check appointment and prescribe the patient according to the health data. If health values increased or extend the threshold value than a patient has to come in the emergency situation.

Figure 11(c) shows the front end integrated with the model and giving the healthy input, so the result is healthy.

Further, Figure 11(d) shows the overall output of our framework and technologies integrated with each other. The data first goes through the blockchain and produces a hash result. The readings are then passed into the Machine learning model which predicts the diagnosis of the patient. We found the accuracy of our machine learning model to be 93%.


```
{
  - chain: [
    - {
          index: 1,
          previous_hash: "0",
          proof: 1,
          timestamp: "2020-12-09 03:39:29.175088"
      },
    - {
          index: 2,
          previous_hash: "458f96710709aaa68389e1590c5bdbbd304d538edcd667da4f8ccfa4a4655028",
          proof: 533,
          timestamp: "2020-12-09 03:39:34.099642"
      },
    - {
          index: 3,
          previous_hash: "ca6cd9f6ecc1ba359a805e2dd0d6183b204ece3dc9432faedbed7d5461c151c9",
          proof: 45293,
          timestamp: "2020-12-09 03:41:49.280037"
      }
    ],
    length: 3
}
```


Figure 23: Blocks in json format.

ID	Temperature	Heartrate	Respiration	Spo2	Timestamp	Block	Proof	PreviousHash
1	85	0	-999	29.96	2020-12-09 03:39:35	2	533	458f96710709aaa68389e1590c5bdbbd304d538edcd667da4f8ccfa4a4655028
2	119	0	-999	29.82	2020-12-09 03:41:50	3	45293	ca6cd9f6ecc1ba359a805e2dd0d6183b204ece3dc9432faedbed7d5461c151c9

Figure 24: Blocks in frontend application.

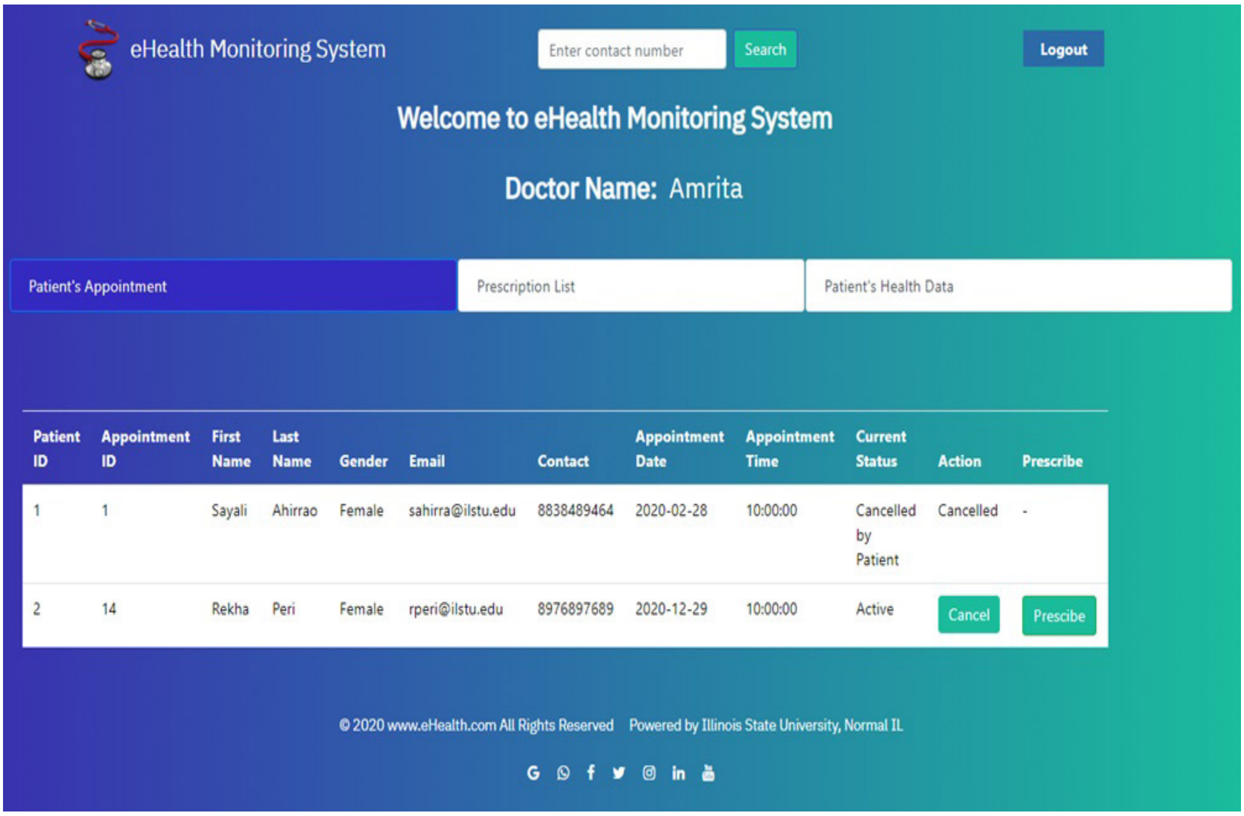

Figure 25: Doctor's panel with patient appointment.

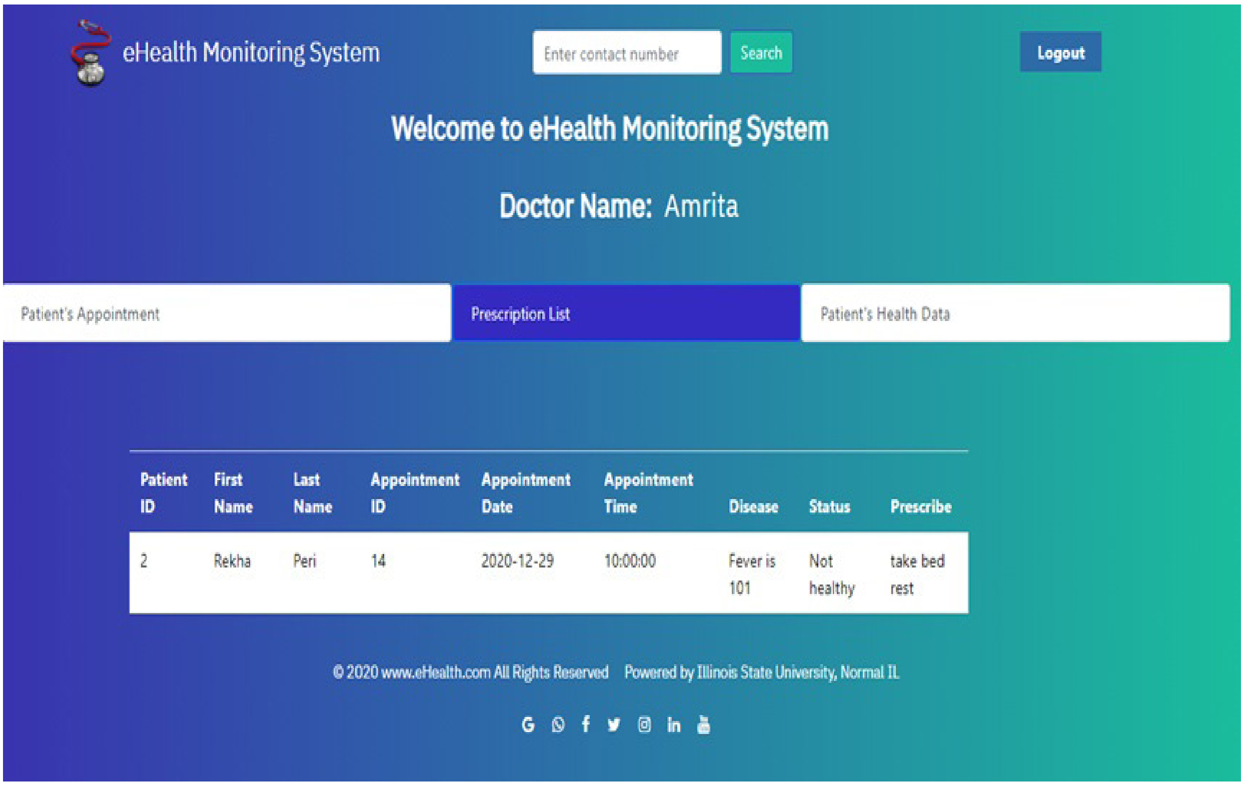

Figure 26: Doctor's panel with prescription list.

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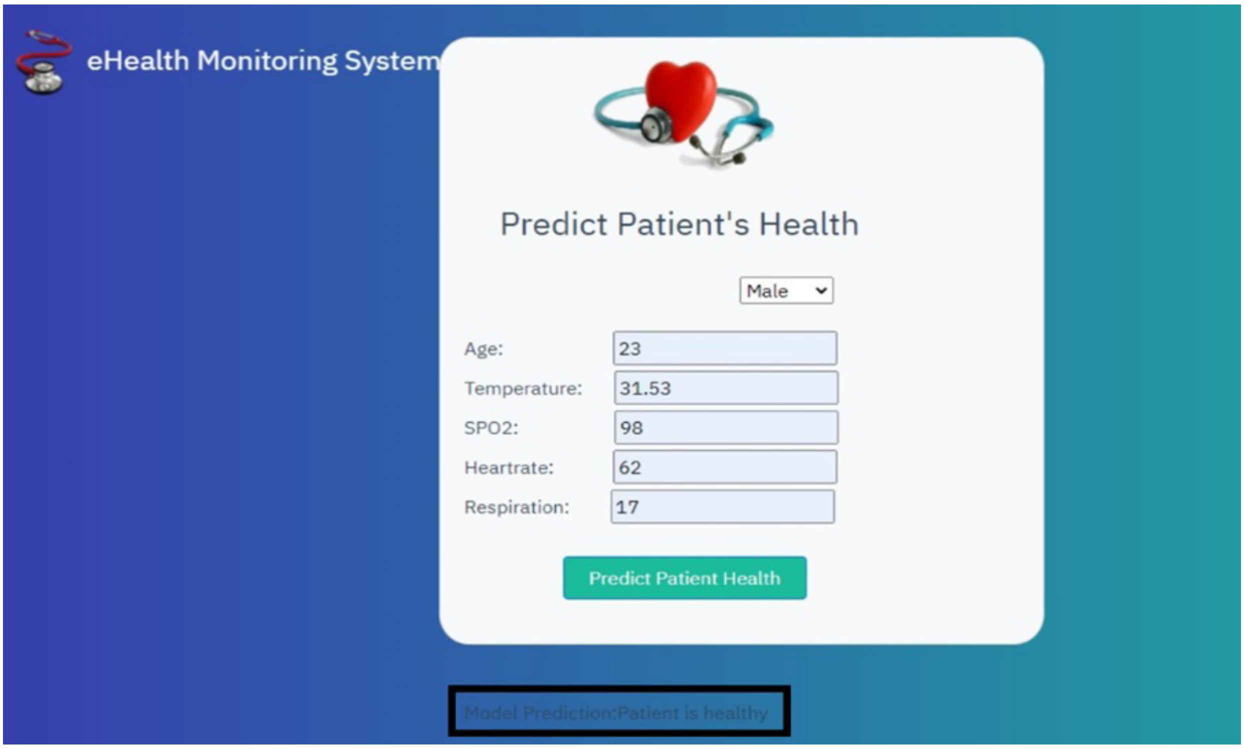

Figure 27: Health Status Prediction using Machine Learning.

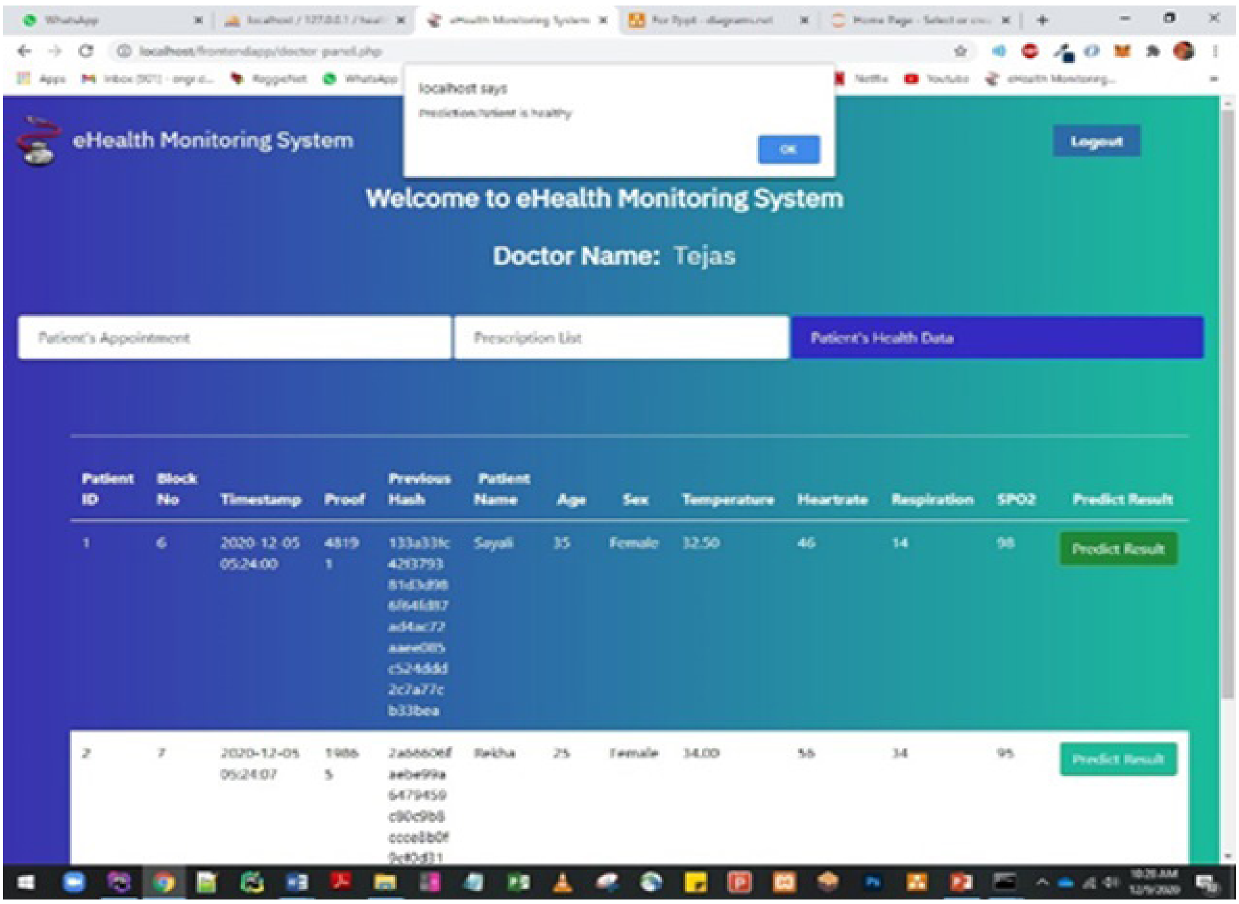

Figure 28: Doctor's panel with patient's health data prediction.

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Similarly, if the patient wants to see the prescriptions, the patient needs to login the health care web app as shown in Figure 29 the prescription and history are displayed in the frontend application. The patient has 3 basis principle contents namely create appointment, get prescription and patient's appointment history. As discussed in Figure 30 and 31. It is clear that patient has to create appointment and wait for his health status and prescription. Patient has also the access to cancel his appointment and get invoice from the admin.

Likewise, the admin has also the access rights to manage data including add or delete doctor and patient. Admin is also responsible to see the registered patients and doctors as well. Moreover, admin is playing a vital role to check the cancellation of the appointment and patient's queries as mentioned in Figure 32.

In Figure 33 we discuss about all the flow of the data ingestion and frontend application. From the sensors side, data will be processed

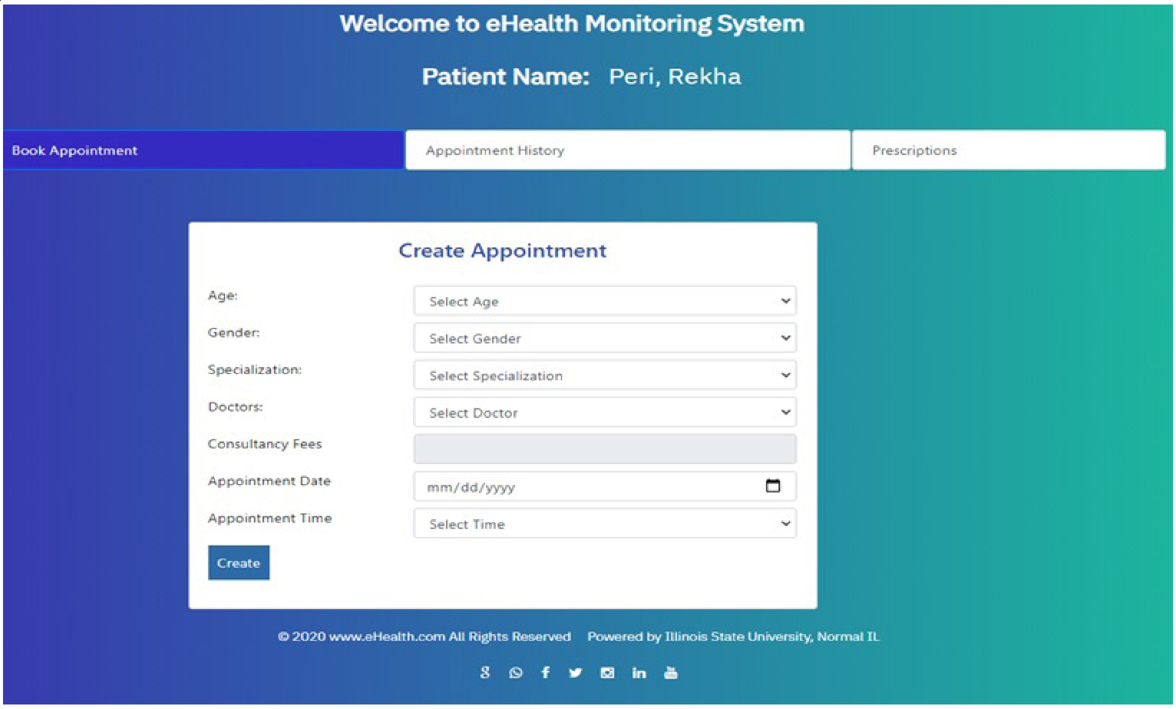

Figure 29: Patient's panel with book appointment.

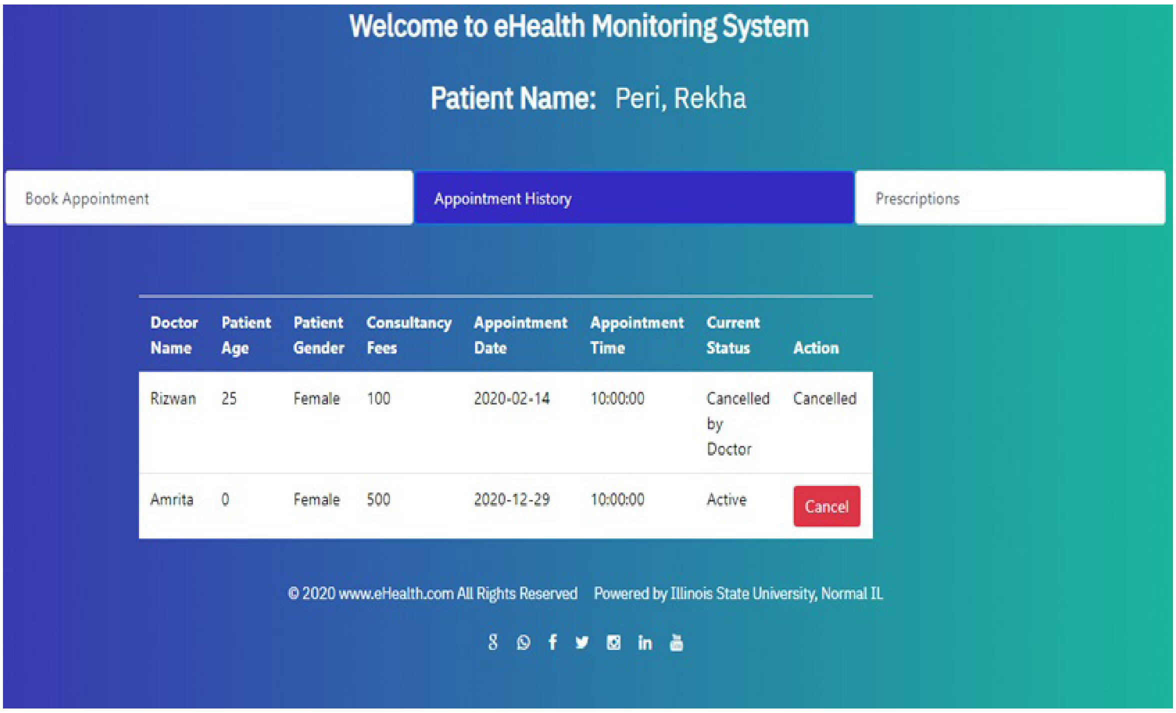

Figure 30: Patient's panel with appointment history.

Citation: Qaddour J, Ullah S, Siddqui A, Baig MD, Agallo M, et al. (2021) Machine Learning and Blockchain based Frontend and Backend Framework for Healthcare Internet of Things (HIoT) Smart System. Int J Comput Softw Eng 6: 172. doi: https://doi.org/10.15344/2456-4451/2021/172

and transmitted to the database and after storage it will post to the doctors panel. Database is playing an essential role to connect the sensors and frontend with the API as discussed above. Patient will make the appointment and appointment will receive to the doctor then doctor will check the health status according to the sensors reading and prescribe the patient.

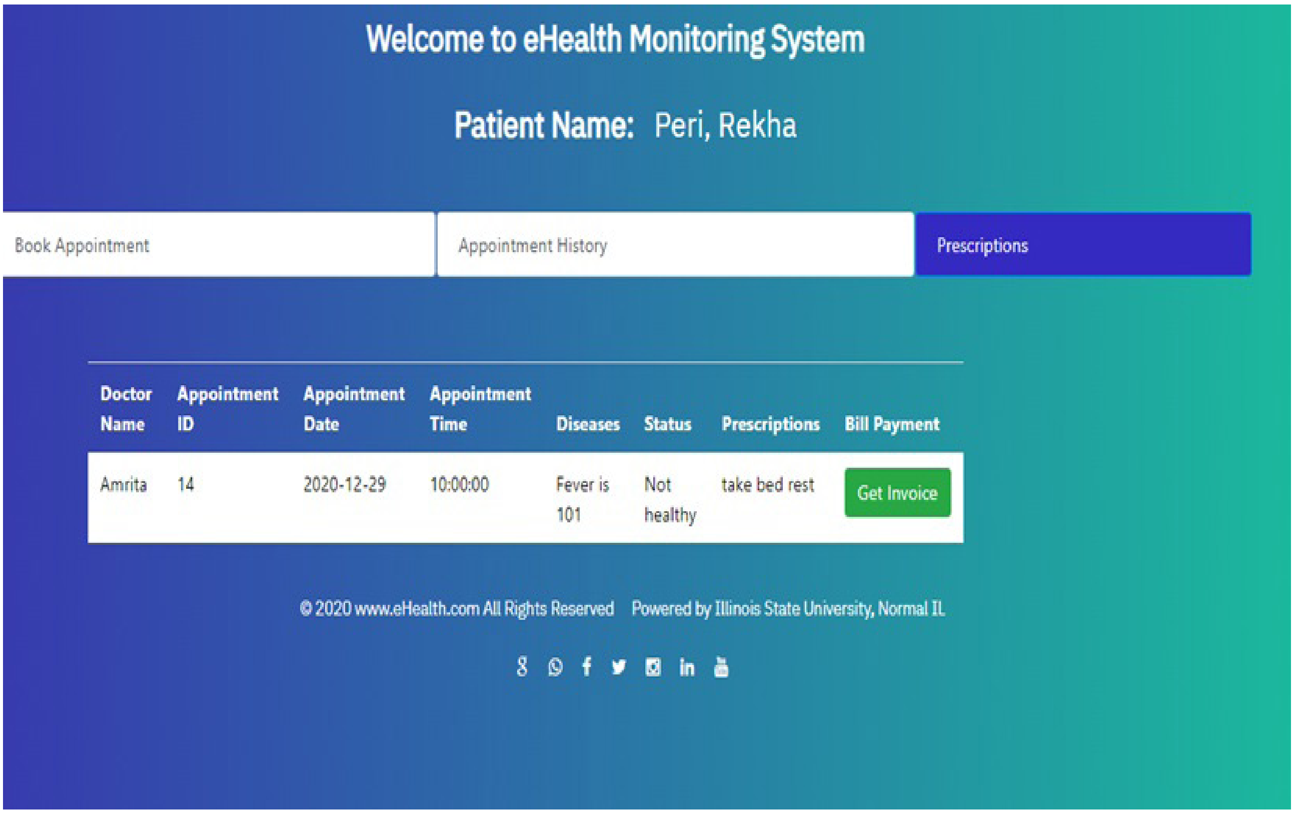

Figure 31: Patient's panel with patient's prescription.

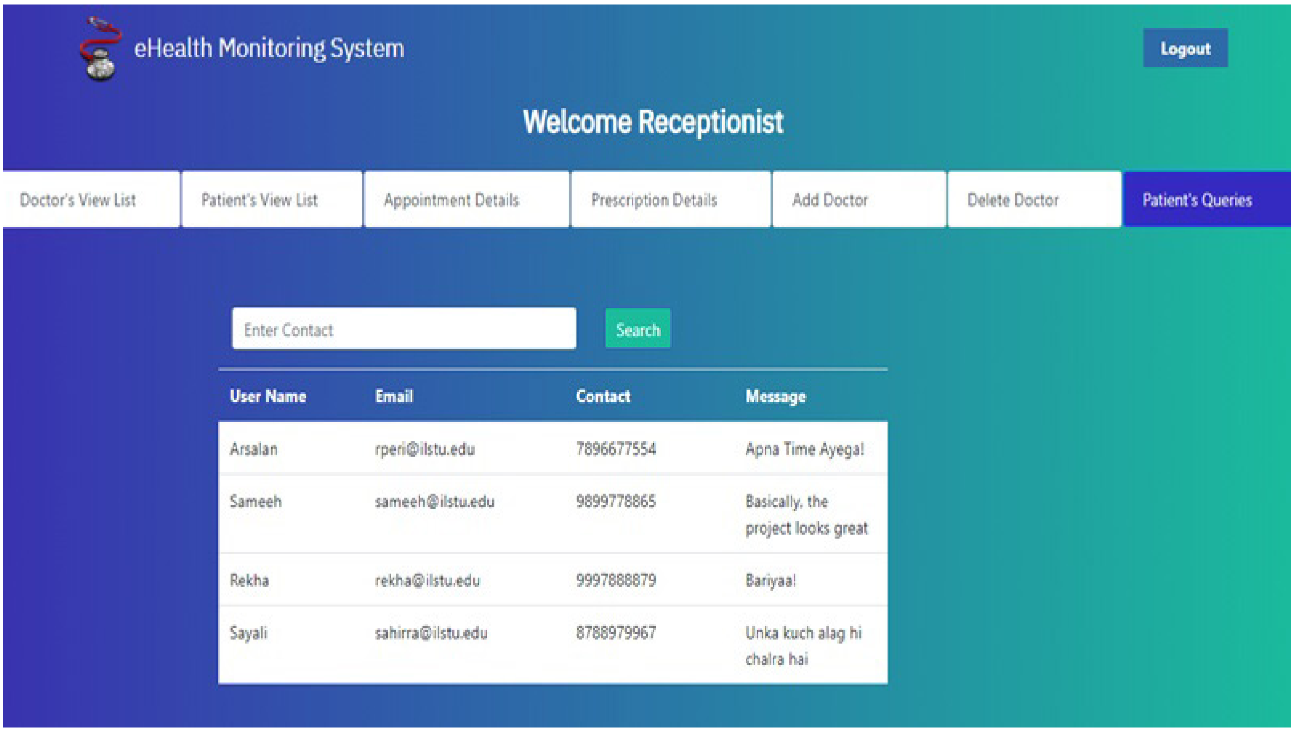

Figure 32: Admin's panel with all administration access.

Citation: Qaddour J, Ullah S, Siddqui A, Baig MD, Agallo M, et al. (2021) Machine Learning and Blockchain based Frontend and Backend Framework for Healthcare Internet of Things (HIoT) Smart System. Int J Comput Softw Eng 6: 172. doi: https://doi.org/10.15344/2456-4451/2021/172

Figure 34 displays the main features that each patient views once they log onto the application. The options are identified in Figure 35. These features are: viewing their own personally created profiles after registration onto the mobile application, accessing appointments, sending a message to the administrator, posting their health data to the application, and viewing all prescriptions that have been assigned to them by the doctor after each appointment.

When a patient needs to book an appointment, the select the appointment page in the home page and are presented with two options. The first is to create an appointment with the doctor and secondly, they can select to view existing appointment on the mobile application. These details are displayed in Figure 16. Above, we display the specific details that are needed from the patient in order to create an appointment. These include the: specialization of the doctor the patient needs to see, the doctors who are registered onto the mobile application database. Next, the fees charged for consultation are auto filled as shown. Finally, the patient selects the time and date of the appointment the want to have with the doctor.

Once appointments are booked, they are displayed as above in Figure 36. For each appointment, the patient is shown a date, time doctor with whom the appointment is booked and the cost of the consultation. Additionally, a cancel button is attached to each appointment in case the patient decides not to go for their appointment.

However, before the patient cancels the appointment, the are required to confirm the cancelation first before the request is initiated to the database and subsequent tables. This is shown in Figure 37.

Next the patient is able to view the prescriptions that are assigned to them after each appointment. The view is displayed as shown in Figure 38.

Above, the Figure 39 displays the doctor's homepage. The doctor's module has slightly more features over the patient module. For one, the doctor is able to view patients who have booked appointments with them specifically as shown in Figure 40.

Then, the doctor is able to prescribe prescriptions to the patients after the appointment is complete. The data collected at the prescription page is the disease, status of the patient and prescription for that patient specifically. The fields on this page are designed to auto update such that no text is cut off. This is depicted in Figure 41.

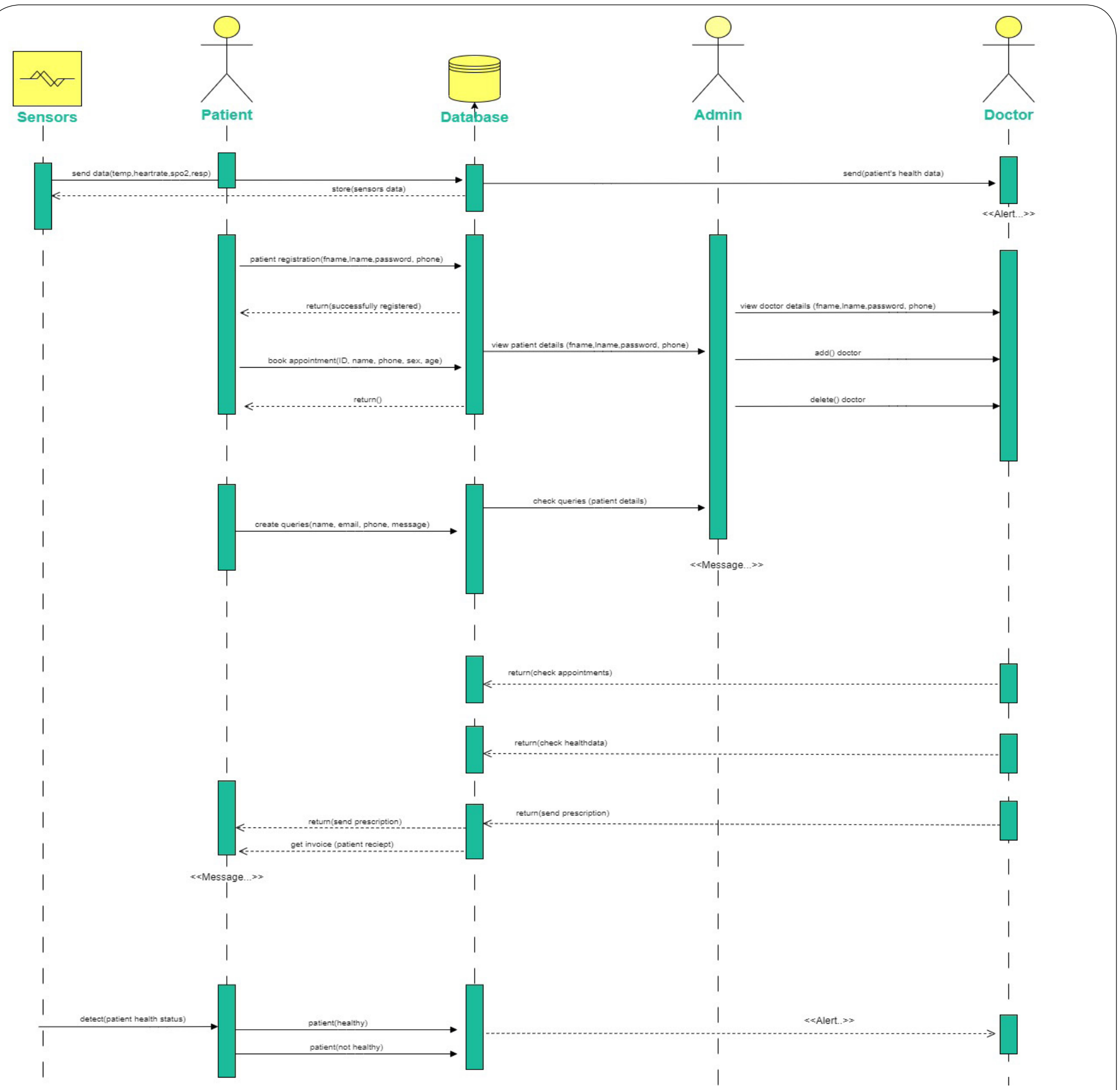

Figure 33: Sequence Diagram showing the relationship between sensors, database, patient, doctor and admin.

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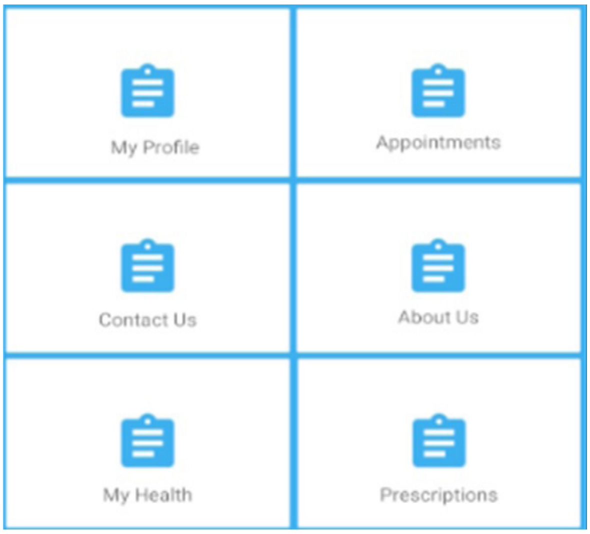

Figure 34: Patient Homepage.

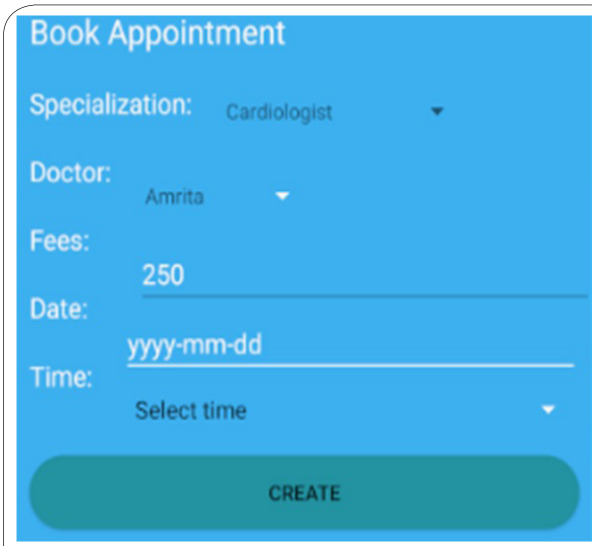

Figure 35: Patient Book Appointment.

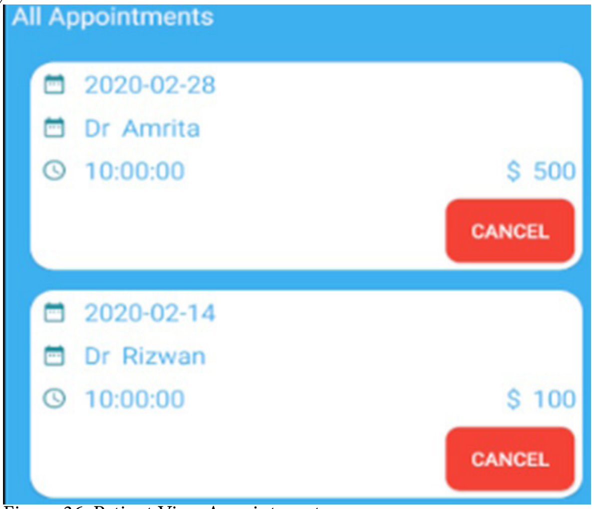

Figure 36: Patient View Appointment.

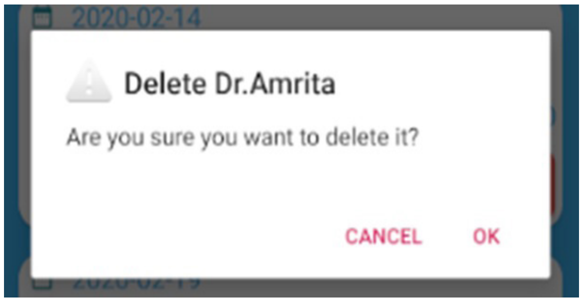

Figure 37: Patient Cancel Appointment.

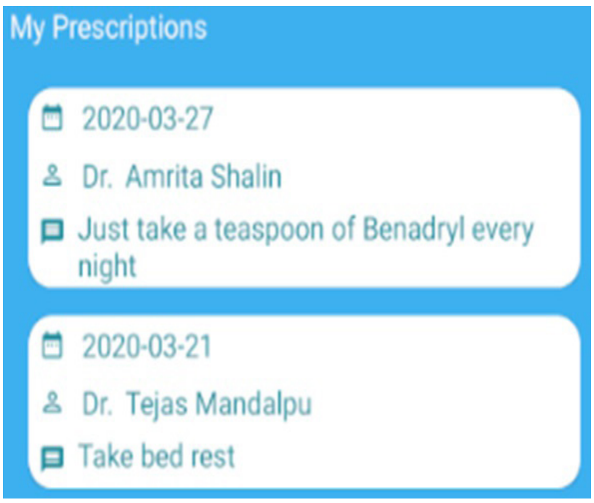

Figure 38: Patient Prescriptions.

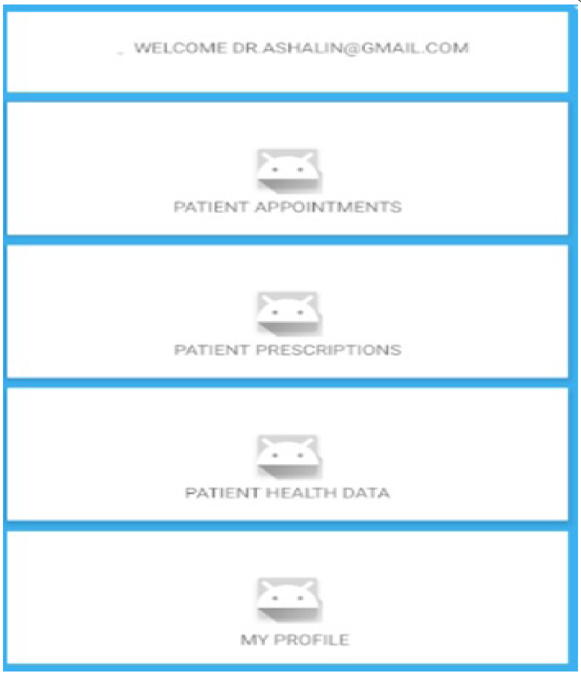

Figure 39: Doctor Homepage.

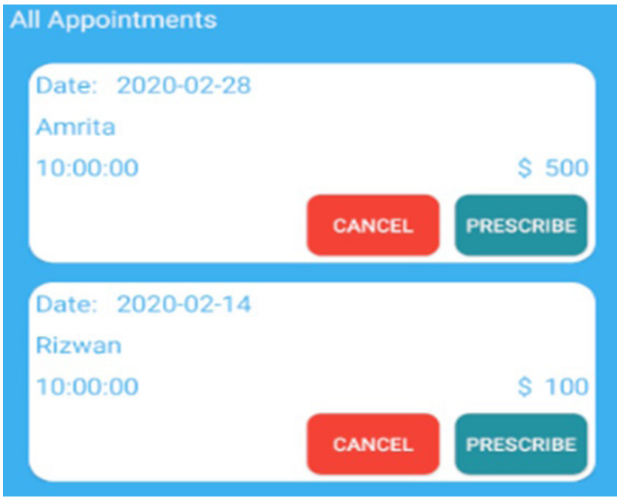

Figure 40: Doctor View Appointments.

Figure 41: Doctor Assign Prescription.

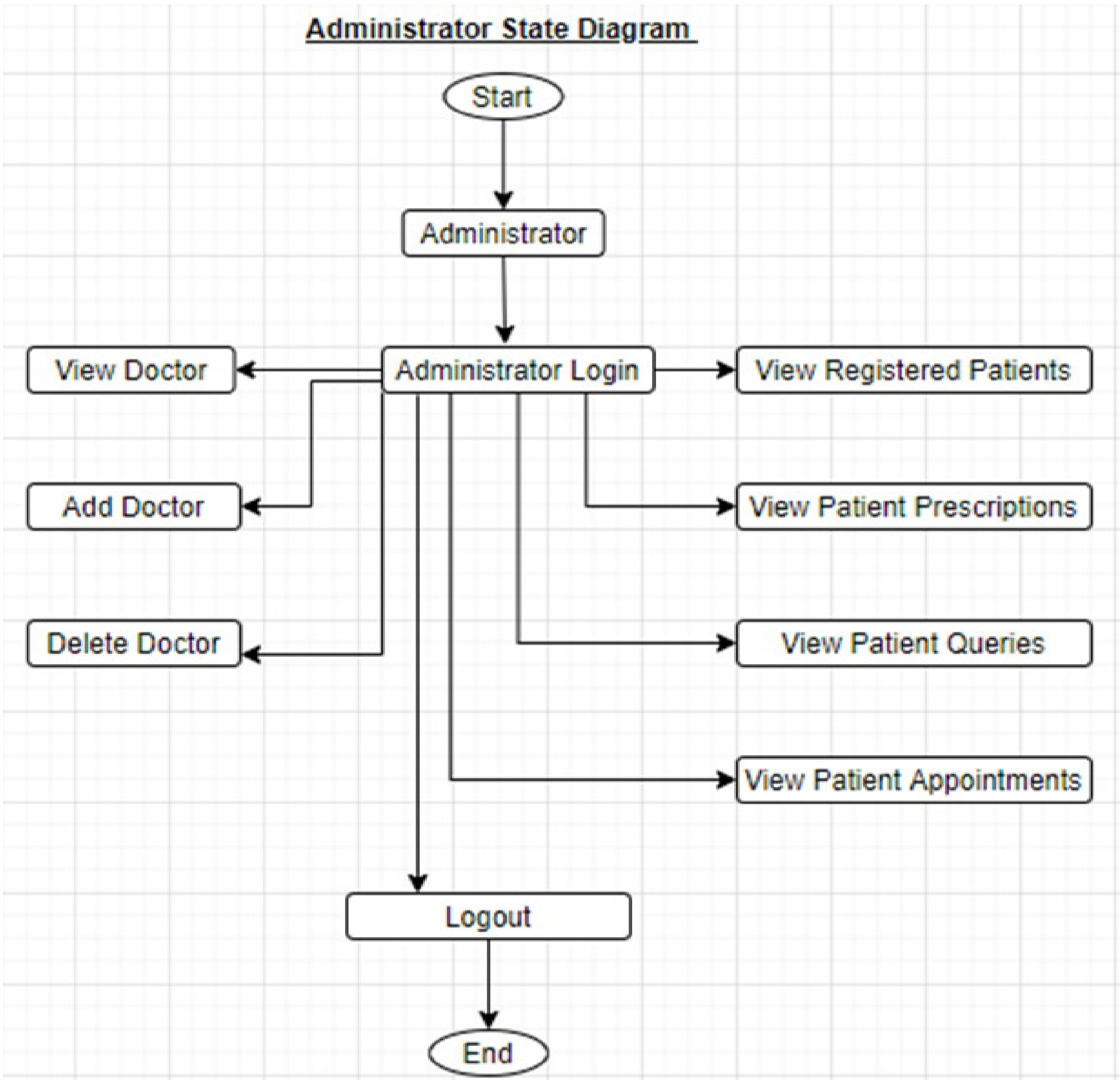

Figure 42: Administrator State Diagram.

Additionally, within this category, the doctor is able to cancel the appointment easily. Once either the patient or doctor cancel the appointment, the list of appointments is updated to only show those that are still active.

Finally, the super user of the application is the administrator. They have the privileges to add new doctors onto the mobile application. Additionally, the administrator has access to view all registered doctors as well as users on the application. Moreover, the administrator is able to view appointments made by patients, and even the prescriptions made to the patient after their designated appointments. The administrator state diagram displays all these features in Figure 43.

Using this health data as well identifying patient information, the doctor will be then presented with the feature of predicting the patient's health status.

Conclusion

In several different fields, such as traffic monitoring, health and insurance, the advent of IoT in the healthcare system has exposed possibilities for the use of technology that were previously not feasible. The vital signs that are sensed and registered are transmitted through wireless networks to a phone or a table. With GUIs optimized for the end-user, physiological parameters can be processed, analyzed and visualized. Here talk briefly about the contribution designs what did we do then talk about the benefits This prototype offers continuous physiological data monitoring capabilities with minimal medical staff involvement and ubiquitous accessibility to a variety of facilities that make it possible to massively reuse distributed healthcare resources to provide cost-effective services, as well as to ensure links between health sensors and front application.The suggested model enables doctors to monitor the health of patients from anywhere. The suggested method allows individuals all over the world to consult the specialist. For accurate health tracking, the device uses IoT and wireless sensor technology. The sensor data is taken every 10 seconds. The data is stored on the webserver and can be visualized. The system is configured in such a way that a 'patient is not healthy' alarm is issued to the doctor's panel if the sensor data exceeds the threshold values. The primary benefit is that the intervention period between doctor and patient is minimized in the event of an emergency. The goal is accomplished by proposing a low-cost system to save human lives so that human lives are comfortable.

In this paper we have applied blockchain to the patient's data that is coming from the HIoT device. The hashed data is then passed through the machine learning model which picks up the reading and applied deep convolution neural network with logistic regression to predict the patient's health condition. The patient's data and the diagnosis is then stored into two storage locations, IPFS P2P network and off-chain database (MySQL) using REST API's for communication and data exchange and successfully assists all modules integration by exposing REST API and providing an interface to the user and then securely accessing data collected by the sensors.

Future Scope

Doctors will track the patient's condition without any trouble during the lockdown. It is also possible to extend this system to patients with COVID-19. The system may be updated to support daily long-distance check-ups of patients as it decreases travel time [39] The State ID or License ID for monitoring the health of the nation can be connected to all people's records. In case the patient misses out in the hospital, the patient can be monitored with the place. It is possible to send the data collected by the sensors to family members. To warn the physicians, each patient must be mapped to the doctors' care region. The proposed system can be installed as a kit and can be supplied for substantial parameter monitoring at low cost to all individuals. Results should be checked for several patients as part of the potential scope, and accuracy needs to be measured. When high-end sensors are used the waiting time and disappointment can be minimized for patients. If the number of patients increases, the processing of data increases [39]. Big data with cloud computing techniques can be used to handle this. Our future proposal is to implement the backend on cloud services like AWS or Azure for high availability and easily manageable API calls and for more secure environment with IAM roles for accessing the database. Also, implementing much powerful and secured NOSQL databases which can handle the large amount of data easily.

The Use Cases discussed in section II C can work well if integrated with our model. All those use cases are relevant and the integration of those uses case with our model can create a one window experience for the patient. He will no longer have to coordinate with 3rd parties as the patient can share real time records with pharmacists, insurance and any doctor as long as they agree to the smart contract. Since other parties will join the model smart contract would be generated which should be agreeable by all the parties. Integration of our model with the health insurance claim also makes it easy for them to track and verify patient's data, since our measurements are real time, they don't have to worry about outdated data being presented to them. Our future scope will really revolutionize the medical industry as blockchain solves all their problems regarding security, trust, privacy ease of access to data and no centralize authority controlling everything. Using more sensors to capture various medical parameters to predict the abnormalities and improve the accuracy of the model will be considered and for example, diabetes, cancer etc. Furthermore, to develop the application for various mobile and handheld devices can be consider.

Competing Interests

The authors declare that they have no competing interests.

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