Smartphone-Based IoT Healthcare Monitoring System for Vital Signal Analysis and Remote Patient Care

Dr. R. Sofia,
Assistant Professor
Department of Electronics and Communication Engineering
Manakula Vinayagar Institute of Technology

Mr. R. Sambathkumar
Assistant Professor,
Department of Electronics and Communication Engineering
Manakula Vinayagar Institute of Technology

Abstract

Advancements in information and communication technologies have brought about a profound transformation in the realm of healthcare. The downsizing of signal acquisition devices has facilitated greater portability, yet this development has also presented challenges in terms of power consumption. To surmount this, a solution that is lightweight and power-efficient becomes imperative. One such solution involves harnessing the capabilities of smartphones to collect and analyze vital signals. Leveraging Internet of Things (IoT) technology enables the remote monitoring of diverse patient parameters, accessible through a range of devices such as computers and smartphones, facilitated by cloud services like ThingSpeak. Diverging from conventional tests, modern sensors, encompassing metrics like heart rate, temperature, and SPO2, provide daily readings that empower doctors to remotely prescribe treatments and exercises, thereby elevating the quality of life for patients. This innovative system offers instantaneous sensing, precise prognostications, and swift responses, culminating in streamlined healthcare practices that alleviate the burden on medical practitioners. Instances of anomalies prompt alerts to caregivers. The trajectory of this approach portends further enhancements, encompassing additional modules such as blood pressure monitoring and dental screening, to engender a comprehensive, real-time patient care continuum. This paradigm represents a notable stride towards the augmentation of patient care systems.

Introduction:

Contemporary healthcare monitoring systems demand rapid sensing, meticulous prognostications, and immediate intervention via medicative measures. This entails the utilization of sensing modules that gauge critical parameters—such as body temperature, heart rate, and SPO2—and subsequently transmit this data to a central computing system, thereby facilitating the remote analysis of a patient's health condition. This pivotal development not only lightens the load borne by medical practitioners but also furnishes highly accurate results. The data inputs are meticulously scrutinized through an IoT framework, and any deviations from the norm that a patient may experience prompt the monitoring system to dispatch an IoT alert to the designated caregiver.

Research Methodology:

Within the confines of the existing system, manual adjustments to parameter values are the norm. However, when these values approach their upper thresholds, the system promptly notifies stakeholders either through alarm signals or messages. This proactive approach serves to optimize the efficacy of medical personnel within the hospital, ensuring timely interventions that could potentially save lives. Wireless telemedicine, also colloquially referred to as mobile health, harnesses the advancements in wireless technologies to establish a seamless conduit for healthcare delivery and the exchange of medical data, transcending geographical, temporal, and logistical constraints. This innovation facilitates remote diagnosis, continuous monitoring, and seamless transmission of medical data and records.

The incumbent system features a PIC microcontroller-based wireless technology, depicted in Figure 1, and employs GSM technology and sensor arrays to facilitate real-time monitoring of a patient's physiological parameters. Furthermore, it facilitates the transmission of medical data and promptly notifies caregivers. Of paramount significance is the incorporation of a recording system that comprehensively documents the patient's health history, culminating in a comprehensive repository of health records.

The human body offers two primary locations for measuring heart rate: the right side wrist and the neck. This method involves placing the index and middle fingers on either the wrist or the neck, beneath the windpipe, and counting the pulses for 30 seconds. By multiplying the pulse count by two, the heart rate can be determined. For accurate results, it's essential to apply minimal pressure during measurement. Gentle movement of the fingers can help locate the pulse rhythm. Alternatively, sensor technology capitalizes on the disturbance of light as it traverses the blood's path. This disturbance causes fluctuations in heart rate, which can be measured.

Heart rate, denoted in beats per minute (bpm), represents the pace of heart contractions. The normal rhythm, known as sinus rhythm, typically ranges from 50 bpm to 90 bpm based on the body's physical demands and activities. The regulation of heart rhythm involves the exchange of sodium and potassium ions. Various factors such as hyponatremia (low sodium ion concentration), hypokalemia (low potassium ion concentration), hypothermia (low body temperature), hypoxia (low oxygen supply to the body), and acidosis (low pH value with elevated hydrogen ion concentration) can impact this rhythm. Monitoring heart rhythm is essential to safeguard individuals against these factors. Heart rate measurement is facilitated through wrist heart rate monitors and heart rate sensors. These sensors detect and measure the heart rhythm within the body. While heart rate can be assessed in different body regions, this research focuses on utilizing the apex of the forefinger.

The heart rate detector operates by synchronizing the flashing of a LED with each heartbeat. The digital output generated can be directly connected to a microcontroller for determining the beats per minute. The device operates on the principle of light modulation by blood flow within the finger during each pulse. The sensor incorporates a high-intensity light source to maximize light transmission through the finger, which is then detected by a light sensor. As the heart pumps blood, the finger becomes slightly less transparent, leading to reduced light reaching the sensor. This modulation results in electrical pulses, which are amplified and processed by an amplifier to yield a +5V logic level signal. A LED indicator also flashes with each heartbeat, utilizing a technique termed "Photo Plethysmography." This technique capitalizes on the light's interaction with bodily organs, where intensity variations convey organ conditions. Blood volume changes according to light intensity, correlating with heart pulse rhythms.

The heartbeat sensor employs Phlethysmography, based on the alteration in blood volume within a bodily organ causing corresponding changes in light intensity. In heart rate monitoring applications, the timing of pulses is crucial. Blood volume flow corresponds to the rate of heart pulses, and since blood absorbs light, the signal pulses align with heartbeat pulses. A light-dependent resistor (LDR) serves as the light detector, with its resistance altering based on light intensity. A comparator, specifically an LM358, compares the LDR's output voltage to a threshold voltage. When human tissue is illuminated, the decreased light intensity prompts increased resistance and voltage drop across the LDR. This comparison generates a series of logic high and low signals, representing pulse intervals. These pulses are fed to a microcontroller, which processes the data to calculate heart rate, subsequently displayed on a connected interface.

The work proposed by Purnima Puneet Singh et al., [1] healthcare monitoring system that uses GSM technology to gather vital health parameters like body temperature, heart rate, and sweat rate. The system analyzes the inputs through a microcontroller platform and sends messages to caretakers in case of abnormalities. The focus of Melanie Swan et al., [2] on IoT-based health monitoring systems collecting data such as temperature and pressure. This technology has reduced routine care needs, making remote monitoring of non-severe COVID-19 patients possible, even in quarantine settings.

The Matina Kiourexidou et al., [3] highlights the need for a portable healthcare system to provide basic health parameter readings in remote areas. This system transmits data to doctors, allowing treatment without travel and assisting in emergencies. The study presented by Poltak Sihombing et al., [4] method to measure heart rate using a pulse sensor, Arduino, and an Android smartphone. The tool detects heart rate by monitoring blood volume variations, displaying the results on an Android screen. The paper proposed by Sushma Pawar, P. Kulkarni et al.,[5] describes a wireless system using Android smartphones to collect vital signs like body temperature and ECG. The data is processed using an ARM processor and displayed on doctors' or relatives' smartphones and personal computers.

Praveen Halapeti et al., [6] focused on pregnant women's health, this research emphasizes wireless sensors to monitor blood pressure, heart rate, and fetal movement. The wireless body sensor network transmits signals to a base station for analysis. Benhauddu et al., [7] introduces MACH, a scheme for healthcare sensor networks that ensures quality of service, particularly for emergency traffic. The system extends medical applications to underserved areas through sensor networks. The Vikramsingh R Parihar et al [8] study presents a computer-based heart rate monitor using Arduino and a pulse sensor. The Arduino board transfers pulse signal data to a computer application, displaying the heart pulse rate using photo-plethysography (PPG).

IoT-based smart health monitoring system proposed by Vaneeta Bhardwaj et al [9] measures blood pressure, heart rate, oxygen level, and temperature. High-speed internet and cloud storage allow real-time data collection, aiding doctors in diagnosis and treatment. The research focused by Mohammad Monirujjaman Khan et al., [10] on a healthcare monitoring system for various patients, including those with COVID-19, high blood pressure, and diabetes. It measures body temperature, heart rate, and blood oxygen levels, transmitting data to a mobile app via Bluetooth.

Proposed Work

The IoT patient monitoring has 3 sensors. The first one is a Heartbeat rate monitoring, the second is the SPO2, and the third is Temperature Sensor. It is very useful since the doctor can monitor patient health parameters just by visiting a website or URL. And nowadays many IOT apps also being developed. So now the doctor or family members can monitor or track patients health through the apps.

To operate an IOT based health care monitoring system so you need a Wi-Fi connection. The arduino boards connect to the Wi-Fi network using a Wi-Fi module. This project will not work without Wi-Fi network. You can create a Wi-Fi zone using a Wi-Fi module or you can even create a Wi-Fi zone using hotspot on your smartphone .Arduino UNO board continuously reads input from these 3 senses. Then its sends this data to the cloud by sending this data to a particular URL/IP address. Then this action of this sending data to IP is repeated after a particular interval of time. For example. In this project, we have sent data after every 30 seconds.

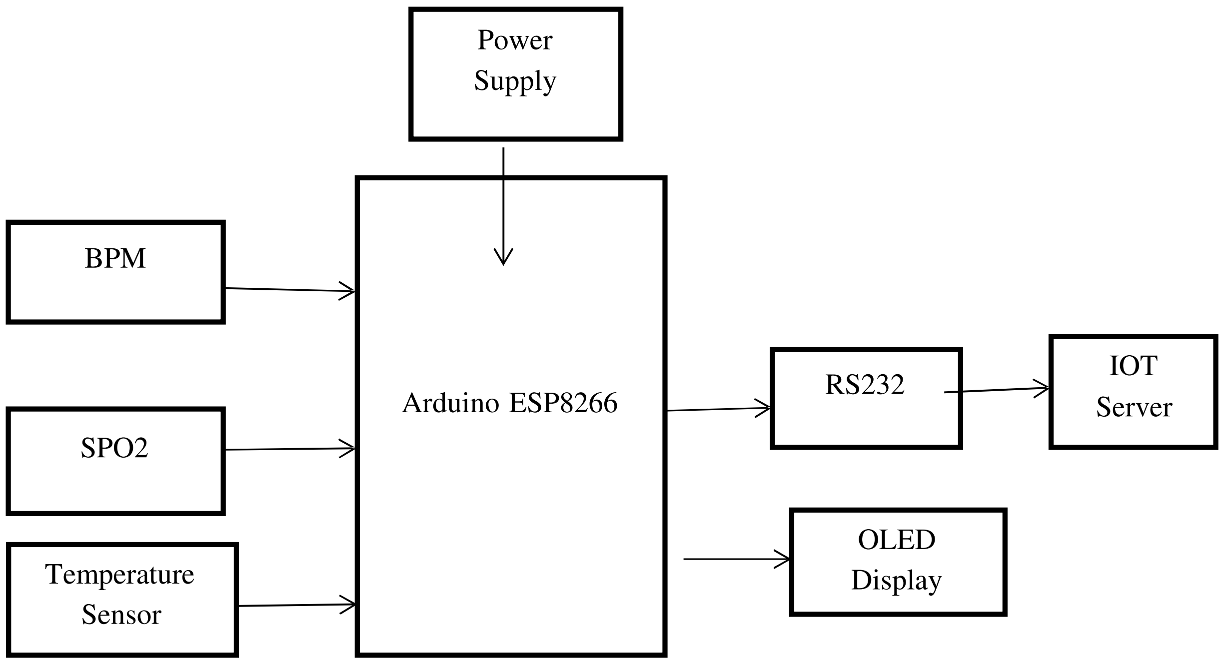

Figure 1 Block Diagram of Proposed System

Arduino collects real-time health data from a pulse sensor that measures heart rate in minutes or BPM (beats per minute). An Arduino digital temperature sensor measures the patient's body temperature. The standard ESP8266 IoT module connects to Arduino via UART, is responsible for connecting the machine to the internet and sending health data to the IoT (Thingspeak) server for storage and monitoring. This region can not only send patient health data to the server but can also display real-time data on an OLED display. This is helpful for health care professionals who actively monitor the patient on site is shown in figure 1.

HARDWARE DESCRIPTION

The hardware required for this project are

- Arduino
- Pulse sensor/ Heartbeat sensor
- MAX30102
- ESP8266
- OLED display

PROPOSED WORK

Initially the three different sensors includes temperature, heartbeat sensor, SPO2 the body condition of the humans and sends message to the doctors or caretakers to monitor the patient's health. We can monitor them by analysing the parameters received from the sensor through computer and do the necessary immediate action to the patients which reduces the workload of doctors. It consist of transmitting unit and receiving unit. The transmitting unit is placed near the patient and receiving unit is placed near the doctors.

The arduino gains the parameter values from sensor in form of voltage and it compares with predefined value. If it not matches, the receiver unit will receives the signal and it intimates through alarm .Then the patient could be easily treat according to his body condition. In the system, various call forward options, barring options of incoming calls or going out calls.

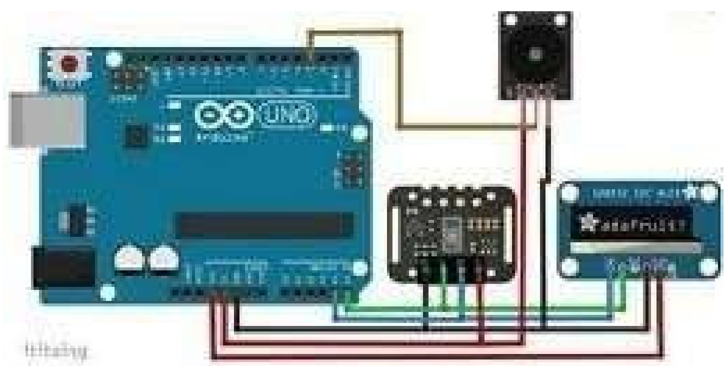

Figure 2 Experimental setup

This is also done when travelling in another country. Several add ones can be added as multiple channels, identification of a call, conference proceedings through phone etc. The conversations can be made to record for flexible recalling the data for the requirements and analysis purpose is shown in figure 2.

SOFTWARE DESCRIPTION

Thinkspeak

It is an open source software written in Ruby which allows user to communicate with internet enabled device. It facilities data access, retrieval and logging of data by providing an API to both the device and social network websites. Thinkspeak was originally launched by IoBridge in 2010 as a service in support of IoT applications. There are sensors all around—in our homes, smart phones, automobiles, city infrastructure, and industrial equipment. Sensors detect and measure information on all sorts of things like temperature, humidity, and pressure. And they communicate that data in some form, such as a numerical value or electrical signal. In this project, we are going to send the MAX30102 temperature sensor data to ThingSpeak using the ESP8266. ThingSpeak is basically an IOT platform that lets us store the data in the cloud and develop internet of things (IOT) applications. We will create a channel on ThingSpeak, and after connecting the ESP8266 to our Wi-Fi network, we will send the data to the ThingSpeak IP address and API key. For connecting the ESP8266 with Arduino, we have used the ESP-01 adapter, which makes connecting much easier. Using this adapter, we don't require the voltage divider circuit or any external power, because this adapter has a built-in voltage regulator. Connect the VCC of the ESP-01 adapter to the 5V of Arduino and GND of adapter to the GND of Arduino. Then connect the TX of the adapter to pin 2 of Arduino, and the RX of the adapter to pin 3 of Arduino. Sensors, or things, sense data and typically act locally. ThingSpeak enables sensors, instruments, and websites to send data to the cloud where it is stored in either a private or a public channel. ThingSpeak stores data in private channels by default, but public channels can be used to share data with others. Once data is in a ThingSpeak channel, you can analyze and visualize it, calculate new data, or interactwith social media, web services, and other devices.

- Storing data in the cloud provides easy access to your data. Using online analytical tools, you can explore and visualize data. You can discover relationships, patterns, and trends in data. You can calculate new data. And you can visualize it in plots, charts, and gauges.
- Creating a Channel on ThingSpeak First, go to ThingSpeak.com and click on "Get Started for Free".
- The sign-up form will come up. Enter the information required and sign up for ThingSpeak is shown in figure 3.

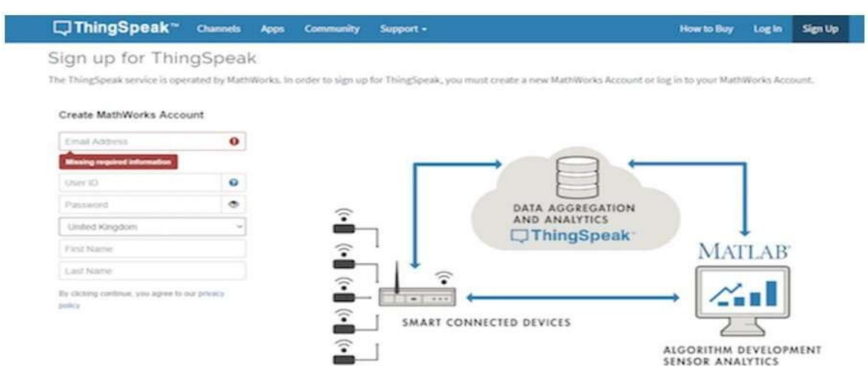

Figure 3 Thinkspeak

- After that, click on "New Channel" to create a channel to store the information..

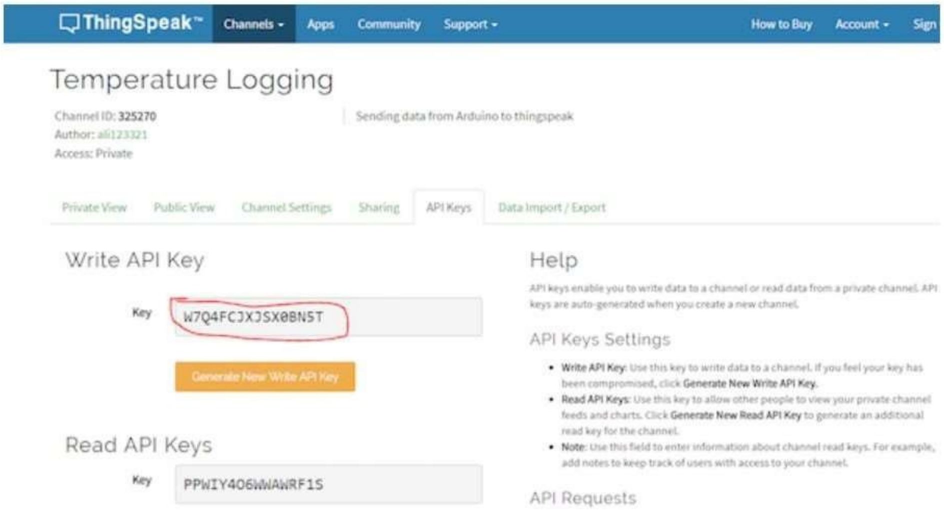

Figure 4 Thinkspeak Channel creation

- Then enter the information about the new channel as I have done below, and leave the other information as it is. After that, go to the API keys section and copy your write API key is shown in figure 4.
- You will need to enter this in the below code

ThingSpeak provides access to MATLAB to help you make sense of data. You can:

- Convert, combine, and calculate new data
- Schedule calculations to run at certain times
- Visually understand relationships in data using built-in plotting functions
- Combine data from multiple channels to build a more sophisticated analysis

The measuring parameters like temperature of body, beat rate of heart, SPO2 and transfer it to the computer so that health condition of a patient can be analysed remotely. Thus, it reduces the doctor's workload and also gives accurate results. Further this system uses IOT technology which enables the monitoring of all parameters on the mobile phone. The inputs are analysed through IOT platform from the patient and any abnormality felt by the patient causes the monitoring system to send an IOT to the respected caretaker. These are the essential data for the future analysis and review of patient's health condition. This may be added with additional features like monitoring pressure of blood modules, dental screening modules etc. so as to make this a very real time application oriented device. This will enhance the another stepping stone towards patient care systems. It has integrated support from the numerical computing software MATLAB from Mathworks, allowing thinkspeak users to analyse and visualize upload data using MATLAB without requiring purchase of a MATLAB license from mathworks.

EXPERIMENTAL RESULTS AND CALCULUS

Internet of Things (IoT) is a concept that aims to expand the benefits of connected internet connectivity continuously the ability to share data, remote control, and etc, as well as an objects in the real world. For example, food, electronics, collectibles, any equipment, including living things that are all connected to local and global networks the through embedded and active sensors patient health parameter data is stored over the cloud. So, it is more beneficial then maintaining the records on printed paper kept in the file. Or even the digital records which are kept in a particular computer or laptop or memory device like a pen drive. Because there are chances that these device can get corrupt and data might lost.

Heart Rate Monitoring with ThingSpeak

In the IoT Heart Rate Monitoring with ThingSpeak Platform tutorial, we set up the heart rate sensor or pulse sensor using a Wi-Fi board that uses the ESP8266 chip. We then transfer the information received from the sensor to the IoT platform. Of course, you have often seen connecting this sensor with different boards, including Arduino. But this project is different from other examples. In this project, using the ESP8266 board and the Wi-Fi capability of this chip, we will display all the output values in the IoT platform called ThingSpeak.

This platform allows us to build a dashboard with the ability to monitor the values coming from different IoT hardware. And in this project, using this feature, we will measure the heart rate of a person using a relevant sensor and display it as a graph on this dashboard. In this project we have used a pulse sensor. Just place the sensor on the surface of the skin or you can also place a finger on top of this sensor to get the values.

Figure 5 BPM

We have connected the sensor with ESP8266 board as per the connection diagram. Once we power up the hardware and keep the finger on top of the sensor, it starts capturing and sending the data to IoT platform is shown in figure 5.

It shows the heart rate pulse data in a chart and also in a Gauge. After you upload it, make sure that the Wi-Fi used connected with internet connection. Then, open serial monitoring to see at command data. Data which sent is a random data. You can change it with data of sensor or etc. Here is the value of monitoring result after many data processing.

SPO2 monitoring with thinkspeak

The ESP8266 modules reads raw sensor data from a MAX30102 sensor at 25 samples/second. The sample are inserted into a circular buffer containing the last 125 samples. SPO2 are computer 30 times per seconds using Robert Fraczkiwicz procedure is shown in figure 6.

Figure 6 SPO2

Filtered readings are published to your personal channel on the IoT website thinkspeak, with a configurable update interval. We can view a 'Real-time' chart of the data on our Thinkspeak channel page. It shows the SPO2 data in a chart and also in a Gauge. After you upload it, make sure that the Wi-Fi used connected with internet connection. Then, open serial monitoring to see at command data. Data which sent is a random data. You can change it with data of sensor or etc. Here is the value of monitoring result after many data processing.

Body Temperature monitoring with Thinkspeak

The MAX30102 has an on-chip temperature sensor that can be used to compensate for the changes in the environment and to calibrate the measurements. This is reasonably precise temperature sensor that measure the die temperature in the range of -40 degree Celsius to +85 degree Celsius with an accuracy of ±1 degree Celsius.

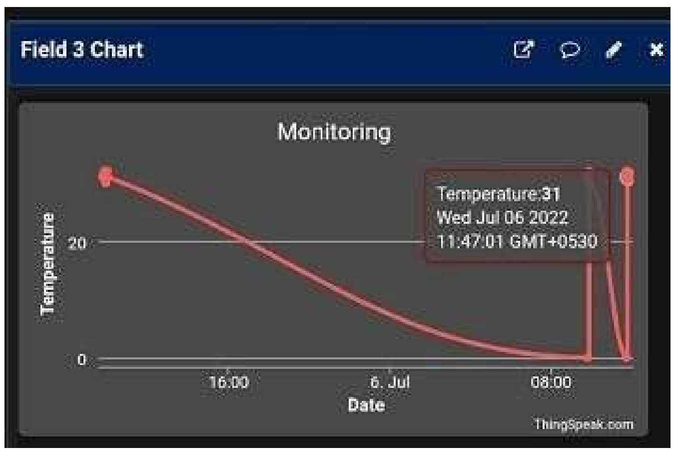

Figure 7 Body Temperature

It shows the Body temperature data in a chart and also in a Gauge. After you upload it, make sure that the Wi-Fi used connected with internet connection. Then, open serial monitoring to see at command data. Data which sent is a random data is shown in figure 7. You can change it with data of sensor or etc. Here is the value of monitoring result after many data processing.

Open the private view tab on the thinkspeak channel to see your temperature graph plotted with the data sent from thermometer. You can cross-check the graph readings with the temperature values being printed on your terminal.

CONCLUSION

The proposed system enables to evaluate the performance of the doctors in the hospital and also the patient can be treated truly and save their life. From this proposed system, the love fit of making the patient towards the awareness of healthy life style is also initiated. By incorporating the blood pressure sensor and dental care monitoring systems the progression of the system is upgraded in the future for the health monitoring system. By proper precise experiments, they system may be incorporated into real time environment in the hospital which may save lives for several patients. The quick, accuracy and real time methodologies can be imposed to the proposed system to make this system into more efficient. The cost reduction also one of the main key factor focus to adopt this system to all levels of patients irrespective of their level of diseases.

IoT was defined as main distributor of health care systems as one of IoT most important uses. Helps to better to provide people with healthcare at any time in any region by eliminating geography, time and other barriers while increasing their coverage and efficiency at the same time. Cloud computing, through its Base, is a promising approach for efficient knowledge processing in the health sector. The framework provided is special and can be used to handle cloud device and network data specific to a patient. Built on IoT and its design principles, the cloud app allows for direct communication of sensor devices while at the same time making it versatile and effective to serve stored data, users and sensors.

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