IJCSE International Journal of Computer Sciences and Engineering Open Access

Review Paper Vol.-7, Special Issue-18, May 2019 E-ISSN: 2347-2693

Internet of Things-Enhanced Healthcare Services

Bidisha Das Adhikary

Master of Computer Application, Pailan College of Management & Technology, Kolkata, India

Corresponding Author: imbidisha@outlook.com

Available online at: www.ijcseonline.org

Abstract— Internet of Things (IoT) technology has attracted much attention in recent years for its potential to alleviate the strain on healthcare systems caused by an aging population and a rise in chronic illness. In IoT based healthcare, various distributed devices aggregate, analyze and communicate real time medical information to the cloud, thus making it possible to collect, store and analyze the large amount of data in several new forms and activate context based warnings. IoT has helped both practitioners and researchers to design innovative solutions in healthcare. The IoT-enabled healthcare research is significant due to its valuable inference, including higher quality and lower cost of services and reliable preventive care.[1]

***Keywords*—**IoT services, CGM, Pulse Sensor, Arduino

I. INTRODUCTION

Healthcare is an essential part of life. Unfortunately, the steadily growing population and the related rise in chronic and rare diseases is placing significant pressure on modern health-care systems, and the demand for resources from hospital beds to doctors and nurses is extremely high. Evidently, a solution is required to reduce the pressure on healthcare systems while continuing to provide high-quality care to at-risk patients.

The Internet of Things is a concept reflecting a connected set of anyone, anything, anytime, anyplace, and any network. The IoT is a huge trend in next-generation technologies that can impact the whole business spectrum and can be thought of as the interconnection of smart objects and devices within today's internet infrastructure with extended benefits.

Medical care and health care represent one of the most attractive application areas for the IoT. The IoT has the potential to give rise to many medical applications such as remote health monitoring, fitness programs, chronic diseases, and elderly care. Various medical devices, sensors, and diagnostic and imaging devices can be viewed as smart devices or objects constituting a core part of the IoT.

Depending on an individual's unique biological, behavioural and cultural characteristics, the combined practice of well-being, healthcare and patient support is defined as personalized healthcare. IoT ensures the personalization of healthcare services by maintaining digital identity for each patient. Due to non-availability of ready to access healthcare systems, many health problems have been getting undetected in conventional health-care systems. In IoT based healthcare, various distributed devices gather, analyze and pass real time medical information to the cloud, thus making it possible to collect, store and analyses the big data streams in several new forms and activate context dependent alarms. . IoT-based healthcare services are expected to reduce costs, increase the quality of life, and enrich the user's experience.
This paper discusses about one of the most important applications of IoT in healthcare sector- Pulse Sensors. It also discusses about the benefits and challenges of Iot applications in the matter of healthcare.

II. EXAMPLES OF IOT SERVICES IN HEALTHCARE

1.Smart continuous glucose monitoring (CGM) and insulin pens:

Diabetes has proven to be a fertile ground for the development of smart devices, as a condition that affects roughly one in ten adults, and one that requires continual monitoring and administration of treatment.

A Continuous Glucose Monitor (CGM) is a device that helps diabetics to continuously monitor their blood glucose levels for several days at a time, by taking readings at regular intervals.

Smart CGMs like Eversense and Freestyle Libre send data on blood glucose levels to an app on iPhone, Android or Apple Watch, allowing the wearer to easily check their information and detect trends. The FreeStyle LibreLink app also allows for remote monitoring by caregivers, which could include the parents of diabetic children or the relatives of elderly patients.

Another smart device currently improving the lives of diabetes patients is the smart insulin pen. Smart insulin pens – or pen caps – like Gocap, InPen and Esysta have the ability to automatically record the time, amount and type of insulin injected in a dose, and recommend the correct type of insulin injection at the right time.

The devices interact with a Smartphone app that can store long-term data, help diabetes patients calculate their insulin dose, and even (in the case of the Gocap) allow patients to record their meals and blood sugar levels, to see how their food and insulin intake are affecting their blood sugar.

2.Closed-loop (automated) insulin delivery:
One of the most fascinating areas in IoT medicine is the open-source initiative OpenAPS, which stands for Open Artificial Pancreas System. OpenAPS is a type of closed-loop insulin delivery system, which differs from a CGM in that as well as gauging the amount of glucose in a patient's bloodstream; it also delivers insulin – thus "closing the loop".

Automating insulin delivery offers a number of benefits that can change the lives of diabetics.By monitoring an individual's blood glucose levels and automatically adjusting the amount of insulin delivered into their system, the APS helps to keep blood glucose within a safe range, preventing extreme highs and lows.

The automatic delivery of insulin also allows diabetics to sleep through the night without the danger of their blood sugar dropping.

3.Blood Pressure Monitoring:
A patient's Blood pressure (BP) can continuously be monitored by using a wearable sensor device. The machine consists of a BP apparatus with network-based communication abilities. Blipcare is such a device that uses a home Wi-Fi network to record BP and upload the recorded data. The device also has an LCD display to show the BP.[2]

4.Body Temperature Monitoring:
The change in body temperature is used to identify homeostasis, which forms an essential part of healthcare services. A TelosB mote, used in a medical IoT, has an embedded sensor to record body temperature.

5.Coagulation testing:
In 2016, Roche launched a Bluetooth-enabled coagulation system that allows patients to check how quickly their blood clots. This is the first device of its kind for anti-coagulated patients, with self-testing shown to help patients stay within their therapeutic range and lower the risk of stroke or bleeding.

Being able to transmit results to healthcare providers means fewer visits to the clinic. The device also allows patients to add comments to their results, reminds them to test, and flags the results in relation to the target range.

6.The Apple Watch app that monitors depression:
Wearable technology doesn't always have to be designed with a medical use in mind to have healthcare benefits. Takeda Pharmaceuticals U.S.A. and Cognition Kit Limited, a platform for measuring cognitive health, collaborated in 2017 to explore the use of an Apple Watch app for monitoring and assessing patients with Major Depressive Disorder (MDD).

The study found a very high level of compliance with the app, which participants used daily to monitor their mood and cognition. The app's daily assessments were also found to correspond with more in-depth and objective cognition tests and patient-reported outcomes, showing that cognitive tests delivered via an app can still be robust and reliable.
Like other smart medical devices that gather data, the Apple Watch app could also give patients and healthcare professionals more insight into their condition, and enable more informed conversations about care.

III. BENEFITS

1. END-TO-END CONNECTIVITY AND AFFORDABILITY:

IoT can automate patient care workflow with the help healthcare mobility solution and other new technologies, and next-gen healthcare facilities. IoT enables machine-to-machine communication, information exchange, and data movement that make healthcare service delivery effective.

Connectivity protocols: Bluetooth LE, Wi-Fi, ZigBee, and other modern protocols, healthcare personnel can change the way they spot illness in patients and can also innovate revolutionary ways of treatment.

Consequently, technology-driven setup brings down the cost, by cutting down unnecessary visits, utilizing better quality resources, and improving the planning.

2. DATA SELECTION AND ANALYSIS:

Large amount of data that a healthcare device sends in a very short time to their real-time application is hard to store and manage if the access to cloud is unavailable. Even for healthcare providers to acquire data originating from multiple devices and sources and analyze it manually is a tough work.

IoT devices can collect report and analyses the data in real-time and cut the need to store the raw data. This all can happen over cloud with the providers only getting access to final reports with graphs. Moreover, healthcare operations allow organizations to get vital healthcare analytics and insights which speed up decision-making and are less prone to errors.

3. TRACKING AND ALERTS:

On-time alert is critical in event of life-threatening circumstances. IoT allows devices to gather vital data and transfer that data to doctors for real-time tracking, while dropping notifications to people about critical parts via mobile apps and other linked devices. Reports and alerts give a firm opinion about a patient's condition, irrespective of place and time. It also helps make well-versed decision and provide on-time treatment.

Thus, IoT enables real-time alerting, tracking, and monitoring, which permits hands-on treatments, better accuracy, and appropriate involvement by doctors and improve complete patient care delivery results.

4. REMOTE MEDICAL ASSISTANCE:

In event of an emergency, patients can contact a doctor who is many kilometres away with smart mobile apps. With mobility solutions in healthcare, the doctor can instantly check the patients and identify the ailments on-the-go.
Also, numerous healthcare delivery chains that are forecasting to build machines that can distribute drugs on the basis of patient's prescription and ailment-related data available via linked devices.[3]

IV. CHALLENGES

1. DATA SECURITY AND PRIVACY:

One of the most significant threats that IoT poses is of data security & privacy. IoT devices capture and transmit data in real-time. However, most of the IoT devices lack data protocols and standards. In addition to that, there is significant ambiguity regarding data ownership regulation. All these factors make the data highly susceptible to cybercriminal who can hack into the system and compromise Personal Health Information (PHI) of both patients as well as doctors.

Cybercriminals can misuse patient's data to create fake IDs to buy drugs and medical equipment which they can sell later. Hackers can also file a fraudulent Insurance claim in patient's name.

2. DATA OVERLOAD & ACCURACY:

Data aggregation is difficult due to the use of different communication protocols & standards. However, IoT devices still record a ton of data. The data collected by IoT devices are utilized to gain vital insights.
However, the amount of data is so tremendous that deriving insights from it are becoming extremely difficult for doctors which, ultimately affects the quality of decision-making. Moreover, this concern is rising as more devices are connected which record more and more data.[4]

V. IOT APPLICATION IN HEALTHCARE- PULSE SENSORS

Perhaps the most commonly read important sign; pulse can be used to detect a wide range of emergency conditions, such as cardiac arrest, pulmonary embolisms, and vasovagal syncope. Pulse sensors have been widely researched, both for medical purposes and for fitness tracking. Pulse can be read from the chest, wrist, earlobe, finger-tip, and more. Earlobe and finger tip readings provide high accuracy, but are not highly wearable. A chest-worn system is wearable, but wrist sensors are generally considered most comfortable for a long-term wearable system.

Commercially, several fitness tracking chest straps and wristwatches are available with pulse measurement functionality. These include HRM-Tri by Garmin, H7 by Polar, FitBit PurePulse, and TomTom Spark Cardio. However, these companies all disclose that their devices are not for medical use and should not be relied upon for detecting health conditions. As such, the sensing systems employed by these devices cannot be directly implemented into a critical health monitoring system. Much research has been conducted into suitable methods for sensing pulse. Sensor types developed, used, and analyzed in recent works include pressure, photoplethysmographic (PPG), ultrasonic, and radio frequency (RF) sensors.

PPG sensors operate by an LED transmitting light into the artery, with a photodiode receiving the amount not absorbed by the blood. Changes in the amount of light can be recorded and a pulse rate can thus be determined.

PPG sensors are used to measure pulse, pulse rate variability, and blood oxygen in one small wrist-wearable sensor. As motion affects the accuracy of pulse readings from PPG sensors, an accelerometer is used to check for movement. When motion is high, the device goes into a low power state and does not record pulse. This is not entirely suitable as pulse may be relevant when motion is high, such as when a person is seizing or suffering cardiac issues during exercise. Improving the accuracy of pulse sensors during motion would-be preferred to disregarding readings when movement levels are high.

The effects of motion on PPG sensors are reduced by using two different LED light intensities and comparing the amount of light received at the photodiode. Significant improvement in signal quality is seen as motion artefacts are greatly reduced through this technique.

Pressure sensors aim to mimic a healthcare professional manually reading the radial pulse by pressing down with their fingers. The sensor is placed firmly against the wrist, and pressure is continuously measured to acquire a pulse waveform.

A flexible and highly-sensitive pressure sensor for pulse detection is developed and tested, showing promising results. However, increasing the sensitivity to better detect pulse also increases the amount of noise that is detected due to movement of the wearer. This sensor was tested in at rest conditions, and further research would be required to determine that it performed well during motion.

Pressure sensors and PPG sensors are combined where pulse sensor modules are developed with arrays of nine PPG sensors and one pressure sensor. Pulse is taken from multiple points on the wrist, providing clear pulse readings and the potential to use these readings for diagnostics of certain diseases such as diabetes.

Diagnostics through pulse sensing is also investigated where pressure, PPG, and ultrasonic sensors are compared. Reasonable accuracy was achieved with all three, but the authors concluded that specific diseases required diagnos is using different sensor types; pressure was found to be best for arteriosclerosis, while ultrasonic was superior for diabetes.

Based on these works, it is strongly recommended that PPG sensors are used for pulse sensing. These have repeatedly been proven to be effective for measuring pulse rate, and techniques have already been developed to algorithmically reduce the impacts of noise on the signal quality.

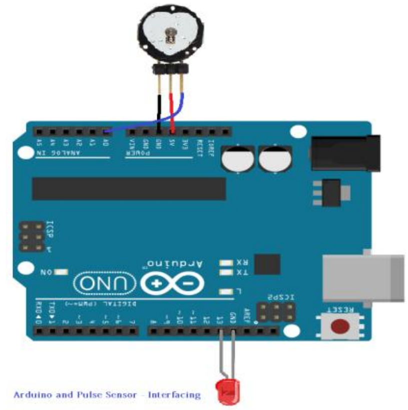
<u>Implementation</u>*:*

Here we are going to discuss about the basic implementation of pulse sensor using Arduino.

Arduino is an open hardware development board that can be used to design and build devices that interact with the real world. Most Arduino enthusiasts, especially when they are starting out, will choose to use the official integrated development environment (IDE) for the Arduino[5]. The Arduino IDE is open source software which is written in Java and will work on a variety of platforms: Windows, Mac, and Linux. The IDE enables us to write code in a special environment with syntax highlighting and other features which will make coding easier, and then easily load our code onto the device with a simple click of a button. The code for Arduino is generally written in Wiring, which is based on the Processing programming language.

The pulse sensor used here is a plug and play heart rate sensor. This sensor is quite easy to use and operate. We have to place our finger on top of the sensor and it will sense the heartbeat by measuring the change in light from the expansion of capillary blood vessels.[6]

1. *Circuit diagram –Pulse Sensor*



2.Working of the Pulse Sensor:

When a heartbeat occurs blood is pumped through the human body and gets squeezed into the capillary tissues. The volume of these capillary tissues increases as a result of the heartbeat. But in between the heartbeats (the time between two consecutive heartbeats,) this volume inside capillary tissues decreases. This change in volume between the heartbeats affects the amount of light that will transmit through these tissues. This change is very small but we can measure it with the help of Arduino.[6]

The pulse sensor module has a light which helps in measuring the pulse rate. When we place the finger on the pulse sensor, the light reflected will change based on the volume of blood inside the capillary blood vessels. During a heartbeat, the volume inside the capillary blood vessels will be high. This affects the reflection of light and the light reflected at the time of a heartbeat will be less compared to that of the time during which there is no heartbeat (during the period of time when there is no heartbeat or the time period in between heartbeats, the volume inside the capillary vessels will be lesser. This will lead higher reflection of light). This variation in light transmission and reflection can be obtained as a pulse from the output of pulse sensor. This pulse can be then conditioned to measure heartbeat and then programmed accordingly to read as heartbeat count.

3.Pseudocode:

```
int sensor_pin = 0;
int led_pin = 13;
volatile int heart_rate;
```

```
volatile int analog_data;
volatile int time_between_beats = 600;
volatile boolean pulse_signal = false;
volatile int beat[10];
  //heartbeat values will be sotred in this array
volatile int peak_value = 512;
volatile int trough_value = 512;
volatile int thresh = 525;
volatile int amplitude = 100;
volatile boolean first_heartpulse = true;
volatile boolean second_heartpulse = false;
volatile unsigned long samplecounter = 0;
 //This counter will tell us the pulse timing
volatile unsigned long lastBeatTime = 0;
void setup()
{
pinMode(led_pin,OUTPUT);
Serial.begin(115200);
  interruptSetup();
}
void loop( )
{
Serial.print("BPM: ");
Serial.println(heart_rate);
delay(200); //  take a break
}
void interruptSetup()
{
 TCCR2A = 0x02;
 // This will disable the PWM on pin 3 and 11
  OCR2A = 0X7C;
 // This will set the top of count to 124 for the 500Hz sample rate
  TCCR2B = 0x06;
// DON'T FORCE COMPARE, 256 PRESCALER
TIMSK2 = 0x02;
 // This will enable interrupt on match between
  OCR2A and Timer
  sei();
  // This will make sure that the global interrupts are enable
}
ISR(TIMER2_COMPA_vect)
{
  cli();
  analog_data = analogRead(sensor_pin);
  samplecounter += 2;
  int N = samplecounter - lastBeatTime;
  if(analog_data < thresh && N > (time_between_beats/5)*3)
    {
  if (analog_data < trough_value)
  {
int sensor_pin = 0;
int led_pin = 13;
volatile int heart_rate;
volatile int analog_data;
volatile int time_between_beats = 600;
volatile boolean pulse_signal = false;
volatile int beat[10];
//heartbeat values will be sotred in this array
volatile int peak_value = 512;
volatile int trough_value = 512;
volatile int thresh = 525;
volatile int amplitude = 100;
volatile boolean first_heartpulse = true;
volatile boolean second_heartpulse = false;
volatile unsigned long samplecounter = 0;
//This counter will tell us the pulse timing
volatile unsigned long lastBeatTime = 0;
void setup()
{
   pinMode(led_pin,OUTPUT);
   Serial.begin(115200);
   interruptSetup();
}
void loop()
{
void interruptSetup()
{
  TCCR2A = 0x02;  // This will disable the PWM on pin 3 and 11
  OCR2A = 0X7C;
 // This will set the top of count to 124 for the 500Hz sample rate
  TCCR2B = 0x06;
 // DON'T FORCE COMPARE, 256 PRESCALER
  TIMSK2 = 0x02;
 // This will enable interrupt on match between OCR2A and Timer
  sei();
// This will make sure that the global interrupts are enable
}
ISR(TIMER2_COMPA_vect)
```



```
{
 cli();
 analog_data = analogRead(sensor_pin);
 samplecounter += 2;
 int N = samplecounter - lastBeatTime;
 if(analog_data < thresh && N > (time_between_beats/5)*3)
 {
      if (analog_data < trough_value)
      {
           trough_value = analog_data;
       }
   }
 if(analog_data > thresh && analog_data > peak_value)
 {
     peak_value = analog_data;
  }
  if (N > 250)
 {
         if ( (analog_data > thresh) && (pulse_signal == false)
         && (N > (time_between_beats/5)*3) )
     {
      pulse_signal = true;
      digitalWrite(led_pin,HIGH);
      time_between_beats = samplecounter - lastBeatTime;
      lastBeatTime = samplecounter;
     if(second_heartpulse)
      {
        second_heartpulse = false;
        for(int i=0; i<=9; i++)
        {
          beat[i] = time_between_beats;
//Filling the array with the heart beat values
        }
      }
      if(first_heartpulse)
      {
        first_heartpulse = false;
        second_heartpulse = true;
        sei();
        return;
      }
        word runningTotal = 0;
        for(int i=0; i<=8; i++)
          {
beat[i] = beat[i+1];
          runningTotal += beat[i];
}
beat[9] = time_between_beats;
      runningTotal += beat[9];
      runningTotal /= 10;
      heart_rate = 60000/runningTotal;
    }
  }
if (analog_data < thresh && pulse_signal == true)
    {
      digitalWrite(led_pin,LOW);
      pulse_signal = false;
      amplitude = peak_value - trough_value;
      thresh = amplitude/2 + trough_value;
peak_value = thresh;
      trough_value = thresh;
    }
  if (N > 2500)
    {
      thresh = 512;
      peak_value = 512;
      trough_value = 512;
      lastBeatTime = samplecounter;
      first_heartpulse = true;
      second_heartpulse = false;
    }
  sei();
}[7]
```

VI. CONCLUSION

The rapid advancement of cloud computing, mobile applications and wearable devices facilitates the IoT's role in transforming the traditional approach to healthcare into smart and personalized healthcare. Despite the value of implementing IoT solutions in healthcare, it might encounter some challenges, including security, scalability and mobility, but security and privacy remain the most critical issues. The security of IoT-healthcare building blocks should be prioritized, including medical sensors, the network of IoT nodes and cloud services. Furthermore, proper policies and technical security measures are essential to enable data sharing among authorized devices, users and organizations. Due to the potential risk of storing sensitive health data in IoT cloud services, further research should consider designing data-transparent cloud services.

ACKNOWLEDGMENT

I greatly acknowledge the support of the teachers
Of Pailan College Of Management And Technology.

REFERENCES

[1] "Internet of Things for Smart Healthcare:Technologies, Challenges, and Opportunities", Stephanie Baker, Wei Xiang, Senior Member, IEEE, and Ian Atkinson .
[2] "The Application of the Internet of Things in Healthcare", Fayez Hussain Alqahtani King Saud University P. O. BOX 2454, Riyadh 11451 Kingdom of Saudi Arabia.
[2]"Internet of things in healthcare: applications, benefits, and challenges", Peerbits.
[3]"Internet of things in healthcare: applications, benefits, and challenges", Peerbits.
[4]Red Hat Opensource
[5]Github
[6] Heartbeats in Your Project, Lickety-Split.
[7] PreciousFeedz.

Authors Profile

Ms. Bidisha Das Adhkary has completed secondary education from Amtala Nivedita Balika Vidyalaya under West Bengal Board of Secondary Education in 2012. She has completed her higher secondary education from Fatepur Sreenath Instituition under West Bengal Council of Higher Secondary Education in 2014. Bidisha pursued Bachelor of Science from University of Calcutta, Kolkata in 2017. She is currently pursuing Master of Computer Application from Pailan College of Management and Technology under Maulana Abul Kalam Azad University of Technology.