Design of a Wireless Cost Effective Patient Monitoring System using IoT

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Abstract: The IOT is a network of intelligently connected devices and systems comprising of smart machines that interact and communicate with other machines, environments, objects. We have developed a multiprotocol system for monitoring health parameters of patient over the internet. Few sensor nodes are designed that can sense information such as body temperature, beats per minute and motion and transfer this data to the base station. A gateway prior to the base station is designed that will receive all the sensor data through different wireless protocols such as bluetooth, zigbee and send it to the base station for global sharing. The designed system can be integrated to a patient monitoring system and is able to continuously process data at a small amount of time. An alert system is also incorporated into system to make the system more convenient to use.

Key–Words: IoT, Sensor, Gateway

1 INTRODUCTION

The Internet of Things (IoT) is seen as another information and industrial wave after the invent of personal computers, the Internet, and mobile communication networks [1]. It will become the main driving force of the future global economic development.It is a system that consist of interrelated computing devices, digital machines, objects. Each object is provided with unique identifier and has the ability to transfer data over the network without any human interaction.From [5] we can observe that all IoT based platform consist of sensors, devices, gateways, integrated middleware and application. The sensors collects the information and sends it to the gateways which then transfer it to the cloud. The gateway acts as a connection between the sensor and internet.It must be considered while designing the sensors and gateways that minimize power consumption, reliable and robust network connections and wireless connectivity range to a large extent.The heart of IoT systems is a processor unit or micro controller (MCU) that controls the system. It processes the data and runs software stacks interfaced to a wireless device for connectivity. Thus IoT is the concept of connecting anything to the internet.

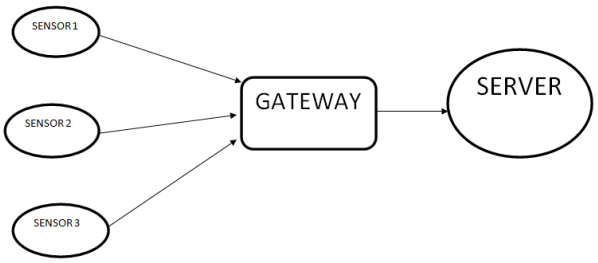


Figure 1: IoT system

In this paper a system is designed with the concept of IoT technology to monitor certain health parameters of a patient. The system will allow the doctors to access the current state of the patient without physically visiting the patient. This may save patient from the future health problems and help doctors to take certain measures at the right time.

The system designed is used to measure body temperature, beat per minute and detect motion of the patient continuously through some wireless sensors. These data will be later transferred to the IoT platform

which will be accessibly by the clients via internet.

The system is designed in such a way that it can support various communication protocols. The sensors can transmit their data through various communication protocols according to their range.This data are then received by the gateway which acts as the summing point of all the sensor data received. The gateway connects the sensor nodes to the internet. Here the gateway receives data through bluetooth and zigbee and send the data through esp8266.

The data sent to the server are stored in a database that is created using MySQL. These data are stored permanently which helps the doctor to study the history of the patient health. Also the doctor can take measures before the patient health gets deteriorated.

An alert system is created so that when the patient needs medical help doctor or the client can get alert. The alert system is a device that is controlled by the server. It can be carried by the doctor or the client and whenever the patient needs help it will automatically ring.

The remaining part of the paper is systematized in the following ways:Section II contains the theoritical background. In section III the various parts of the systems are discussed. In section IV,the results obtained are tabulated and discussed. Finally, section V concludes the paper.

2 THEORITICAL BACKGROUND

The Internet of Things refers to the network of physical objects that is ever growing and each object has an IP address for internet connectivity, and the communication that occurs between the objects and other devices connected to the internet.It is a system that consist of interrelated computing devices, digital machines, objects. Each object is provided with unique identifier and has the ability to transfer data over the network without any human interaction.

2.1 LITERATURE SURVEY

The literature survey has been carried out thoroughly to make an in depth analysis of the project related work done previously. These works are discussed below:

Ganchev et al. [1] represents the design and realization of a small, robust, low-cost and easily accessible data transfer unit which acts as the gateway between the wireless sensor network (WSN) and a corresponding information center (server) that is operating on the Internet. The unit consists of an Advanced RISC Machine (ARM) microcontroller unit (MCU) having 32bit with speed 72 MHZ, a SIMCOM quad-band GSM/GPRS SIM800C module, and a power supply. A uC/OS-III based embedded software and a corresponding device for use in data centers will be developed as part of future research.

Pardeshi et. al. [7] a health monitoring system is proposed that can monitor patient health wirelessly. The propose system establish a connection between the doctor and the patient without actually visiting the patient.Here Rapberry pi is not only used as a sensor node but also as a controller.The system is designed to measure health parameters like body temperature, blood pressure, heartbeat and ecg. It provide the concept of wireless monitoring of the patients. The propose system is simple, power efficient and user friendly.

Jadhav et. al. [8] proposes a system that will be an important part in development in agricultural field. The propose system can be used on universally at any scale to monitor the parameters in a given environment. In this system Raspberry Pi is used as the main board and sensors will collect all the real time data from environment and this real time data will be fetched by the web server and display it. User can access this data from anywhere through Internet.

Brattstrom et. al. [9] The current network monitoring system specially those are agent based are costly and are not scalable.Thus a lightweight, scalable agentless system which can be con figured, setup, and begin monitoring network health within minutes is introduced. The architecture utilizes a polling script to query Simple Network Monitoring Protocol (SNMP) demon for metrics, Prometheus Time Series Database instances for storage, and a Grafana Dashboard for metric presentation and alerting. The system is design in such a way that it does not require advanced computing skills. The approach demonstrated here shows the ease and security with which specific site network monitoring can be deployed in a cloud configuration.This provides secure network monitoring, in isolation without disrupting network traffic.

Guth et. al. [5]introduces an IOT reference architecture based on several state-of-the-art IOT platforms. The reference architecture is compared to three open-sources and one proprietary IOT platform. The considered state-of-the-art IOT platforms are Open MTC, FIWARE, Site-Where and Amazon Web Services IOT.By comparing it was observed that each component of the reference architecture was present in each platform thus providing an uniform basis for understanding, comparing different IoT solutions. The reference architecture consist of sensors, actuators, device, gateway, IOT Integration Middleware,application. The IOT reference architecture can be mapped onto each of the considered platform. Con-

sequently, each component of the IOT reference architecture is represented in each investigated platform. The consideration of multiple platforms showed that the defination of the components of the architectures contains synonyms, homonyms, and that they differ strongly within the granularity of their components.

2.2 COMMUNICATION PROTOCOLS

The following are some of the wireless communication protocols used in IOT:

- **Bluetooth**:Bluetooth communication is a wireless technology which is based on IEEE 802.15.1 standard for data exchanging. It has a frequency of 2.4 Ghz and has a range upto 10 meters. Its data rates is 723 kbps.

- **Zigbee**:ZigBee is an IEEE 802.15.4 standard-based protocol for personal area network with short range, low power, and low data rate wireless data transfer. It has frequency of 2.4 Ghz and a range of 100 meters. It has a data rates upto 250 kbps.

- **WiFi**: Wi-Fi is a technology developed for electronic devices to connect to a wireless Local Area Network (WLAN).It is based on the IEEE 802.11 standards. It has a frequency of 2.4 to 5.8 Ghz. It has a data rate of 11 to 105 Mbps.

2.3 COMMUNICATION PROTOCOLS

The IOT has four common communication models: Device-to-Device, Device-to-Cloud,Device to-Gateway, and Back-End Data-Sharing.

2.3.1 DEVICE TO DEVICE MODEL

In this type of communication the devices are connected directly to one another. These connected devices can communicate with one another through various networks such as internet or IP network but the most often protocols used are Bluetooth, Zigbee and Z-wave.

2.3.2 DEVICE TO CLOUD MODEL

In Device to Cloud communication technique an IoT device is directly connected to the internet cloud service so that it can exchange data and message traffic can be controlled. Here often traditional wired ethernet or WiFi connections are used but also sometimes cellular technology are used.

2.3.3 DEVICE TO GATEWAY MODEL

In the Device-to-Gateway communication model, IoT devices are basically connect to an intermediary device or the gateway to access a cloud service. This model often involves application software that operates on a local gateway device such as smart phones or hub that will act as an intermediary device between an IoT device and a cloud service.

2.3.4 BACK END SHARING MODEL

Back-End Data-Sharing communication essentially extends the single device-to-cloud communication model so that IoT devices and sensor data can be accessed by authorized third parties. Under this model,user can receive data not only from the IoT enabled devices from the cloud service but also the data from other resources can be achieved.These data can also be send to other services for analysis and aggregation.

For the design of the systems certain sensors are used to measure the health parameters. The sensors used are LM35, Pulse sensor, PIR motion detectors. The hardware platform used are Arduino, WeMos D1 and Raspberry Pi and software platforms used are Arduino IDE, MySQL and PHP.

2.4 SENSORS

- **LM35** LM35 is a precision IC temperature sensor with an output voltage linearly proportional to the centrigate temperature. The measurement of temperature with LM35 is more accurate than the thermistor. Due to its low self heating property it does not cause more than 0.1 oC rise in temperature in still air.Its operating temperature has a range from -55 oC to 150 oC.In this project it is used to measure body temperature.

- **Pulse sensor** Pulse Sensor is a sensor that is basically used to measure the heart rate of the patient.The sensor can be clip onto a fingertip or earlobe and connect to the arduino using some jumper cable.

- **PIR sensor** HC-SR501 PIR sensor is the type of sensor that can detect movement of any object by means of detecting infrared (IR) light radiated from the object.

- **Piezoelectric Buzzer** A buzzer is a audio signaling device that can be electrical, mechanical or piezo.

2.5 TRANSCEIVER MODULES

- **HC-05 Bluetooth Module** The HC-05 is a bluetooth module which can add two-way (full-duplex) wireless functionality to our projects.This module can be used to communicate between two microcontrollers like Arduino or communicate with any device with Bluetooth functionality like a Phone or Laptop. The module communicates with the help of USART at 9600 baud rate hence it is easy to interface with any microcontroller that supports USART.

2.5.1 ESTABLISHING CONNECTION BETWEEN TWO HC-05 MODULE

For pairing of two Bluetooth modules, one of them needs to be configured to Master role and other needs to be configured to Slave role. The baud rate of both the module must be same.The transmitter module that is used in the sensor node is configured as slave and the receiver module that is connected in ground is configured as master.

- **ESP8266 WiFi Module** The ESP8266 is a really useful, cheap WiFi system on chip (SoC) module for controlling devices over the Internet. It can work with a micro-controller like the Arduino or it can be programmed to work on its own.It employs a 32-bit RISC CPU based on the Tensilica Xtensa L106 running at 80 MHz (or overclocked to 160 MHz). It has a 64 KB boot ROM, 64 KB instruction RAM and 96 KB data RAM.

- **XBee Module** XBee transceivers module is a RF module for Zigbee wireless communication. XBee series are available in two dierent types of Zigbee modules. XBee series 1 and XBee series 2. Both of these two cannot work together. The XBees can operate either in a transparent data mode or in a packet based application programming interface (API) mode.

2.5.2 establishing connection between two zigbee

For Zigbee communication two Xbee module is required. One of the Xbee module is configured as the Coordinator and another as the router.

2.6 HARDWARE PLATFORM

- **Arduino Boards** Arduino is an open-source hardware platform. Arduino consists of both a physical programmable circuit board referred as a micro controller and a software called IDE (Integrated Development Environment) that runs on computer and is used to write and upload code to the physical board.The Arduino board consist of analog input pins and digital I/O pins.The board feature serial communication interfaces including USB.

- **WeMos D1** The WeMos D1 is a ESP8266 WiFi based board that looks similar to the arduino uno. The microcontroller is mainly the ESP8266-12 chip thus the board is controlled by the ESP8266.

- **Raspberry Pi** It is a powerful, low cost, and a small card sized device which is a perfect platform for interfacing with many devices. The board contains a processor, graphics chip, RAM memory, interfaces to other devices and connectors for external devices, of which some are necessary and some are optional. The CPU is somewhat cheap, powerful and efficient and it does not consume a lot of power. It works in the same way as a standard PC requiring a keyboard for giving commands, a display unit and power supply.The Raspberry-Pi runs on Linux based OS, an open source operating system.

2.7 SOFTWARE PLATFORM

- **Arduino IDE** Arduino IDE (Integrated Development Environment) software is used to write and upload code to the physical board.The Arduino IDE software supports C and C++, making it easier to learn for the programmer.It runs on windows, Mac OS X and Linux.

- **MySQL** MySQl is a structural database management system that is based on Structural Query Language(SQL).It is an open source platform.A datatable is created in MySQL database that stores the data that are sent by the gateway.

- **PHP** Hypertext Preprocessor is a server-side scripting language designed for Web development, but also used as a general-purpose programming language.

3 SYSTEM DESIGN

The system consist of two sensor nodes, a gateway, an alert system and a basestation.

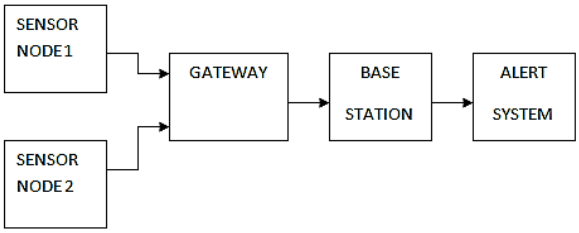


Figure 2: Block Diagram of the system

3.1 SENSOR NODE 1

The sensor node consist of sensors, microcontroller and a transmitter. The sensor collect data and the microcontroller send this data to the transmitter for sending the data to the required destination. The sensor node of the system consist of LM35 and pulse sensor. LM35 is used to measure the body temperature of the patient and pulse sensor is used to measure the bpm.Bluetoth HC-05 module is used to transfer the data from the sensor node to the gateway.The sensors are connected to an Arduino uno board which collects the data from the sensor and send it to the gateway through bluetooth.

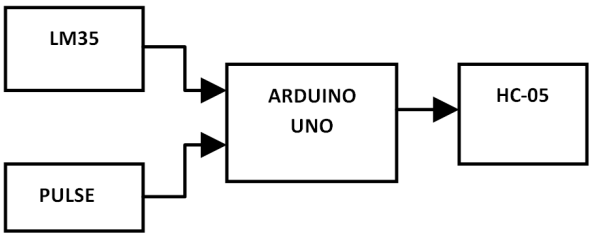


Figure 3: Block Diagram of Sensor Node 1

3.2 SENSOR NODE 2

The second sensor node is used to detect movements.It is used to detect movements in patient. If the patient becomes unconscious or falls from bed the PIR sensor can detect the movement. It consist of a PIR motion detector sensor which will send data through zigbee to the gateway. Here PIR motion detector sensor is used to detect the movement. They typically has a range of 5m to 12m.It simply detects the Infrared Radiation(IR) that comes from human being. It consist of a Pyro electric sensor that converts change in temperature to electric signals. It consist of three pins: Vcc,Gnd and Output.It works in 5V power supply and gives digital output.

3.3 MULTIPROTOCOL GATEWAY

The gateway of the system is the most important part. It connects the sensor nodes to the server. It collects the data from the sensors and send them to the server.It acts as the summing point. The gateway is connected wirelessly to the server.

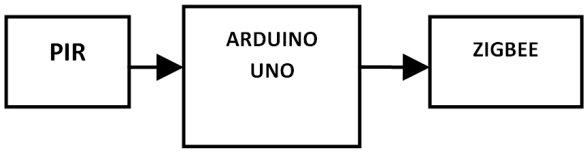


Figure 4: Block Diagram of Sensor Node 2

The gateway is designed as a multiprotocol system. It receives the temperature and bpm data from sensor node 1 through bluetooth. The bluetooth HC-05 module receives the data send from sensor node 1.It receives the data from PIR sensor connected from sensor node 2 through Zigbee. The Xbee module receives data from sensor node 2. The gateway receives data from one port at a time. It checks the port one by one if data are available. After checking both the port it analysis the data and convert the data into string.After converting the data into string it sends the data to the raspberry pi through wifi. The esp8266 acts as the transmitter that transfers the data from the gateway to the server.

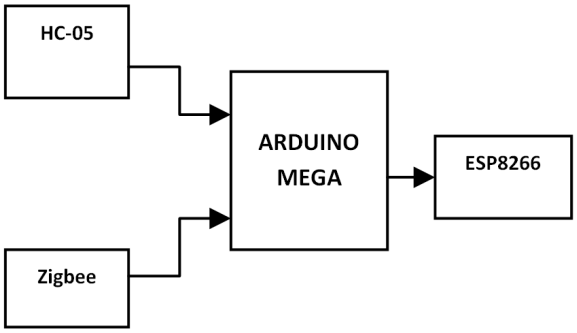


Figure 5: Block Diagram of the Gateway

3.4 ALERT SYSTEM

Monitoring of a patient health is very important task. The IoT based system that is designed till now can give user details of the patient health whenever they want to access. But in case of emergency of the patient how will the client or the doctor know. For such emergency situation an alert system is design which will ring whenever there is an emergency case to let the doctor or aware the client. The receiver is connected to server wirelessly and so even if the doctor is very far from the the patient he will immediately get notified about it and so that required steps can be taken. The alert system is designed using a WeMos board and a piezoelectric buzzer.

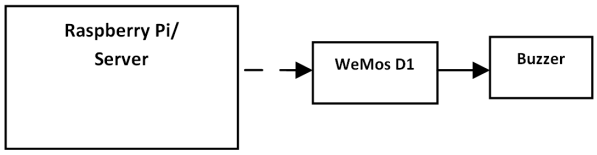


Figure 6: Block Diagram of Alert System1

3.5 BASESTATION

Here Raspberry Pi 3 model B is used as the base station. Raspberry Pi is a low cost single board computer with inbuilt bluetooth and Wi-Fi. The base station is used to host the web server. It helps to remotely access the sensor network and collect data. To make the web server work certain software such as Apache, MySQL and PHP are installed. The gateway connects to the server network and post send data to the server. MySQL is used to store the received data so that it can be accessed later. PHP scripting is done to store the received data in MySQL database. Also in order to display the sensor data for the client certain web pages are designed using PHP scripting.

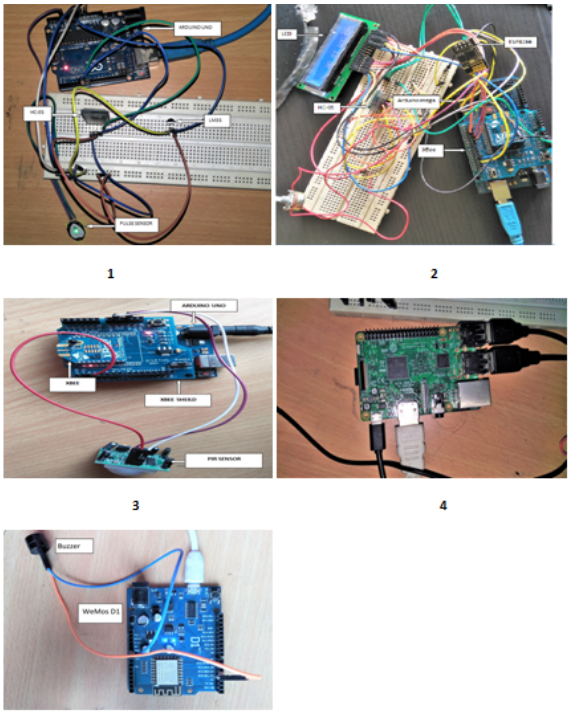
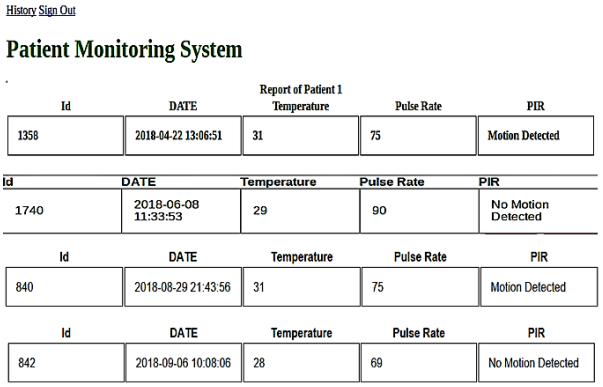


Figure 7: 1(Sensor node 1) 2 (Gateway)3(Sensor node 2)4(Basestation)5(Alert System)

4 RESULTS

HTML web interface is developed for the actual interaction between the client and the server.Client can access the data through the HTML web interface that is created using PHP scripting. The interface is authorized with username and password so only those users who have created an account can only login and can access the data. This page can be accessed by the clients by using the IP address of the server. The first page is the login page that consist of two fields: username and password. The client has to enter his/her user name and password then the page will go to the second page. The second page consist of a table that shows the current data of the patient. It also includes a history and sign out button.


History Sign Out

Patient Monitoring System

Report of Patient 1

Id	DATE	Temperature	Pulse Rate	PIR
1358	2018-04-22 13:06:51	31	75	Motion Detected

Id	DATE	Temperature	Pulse Rate	PIR
1740	2018-06-08 11:33:53	29	90	No Motion Detected

Id	DATE	Temperature	Pulse Rate	PIR
840	2018-08-29 21:43:56	31	75	Motion Detected

Id	DATE	Temperature	Pulse Rate	PIR
842	2018-09-06 10:08:06	28	69	No Motion Detected

Figure 8: Webpage that shows current status of the patient

5 CONCLUSION

In this paper, we have designed a IoT based system that can be used to monitor the patient from anywhere. The design of the system consist of using various communication protocol such as bluetooth, zigbee and WiFi.The two sensor nodes wirelessly transferred data to the gateway through different communication protocols using the transceiver modules. The gateway receives the sensor data through the transceiver module and transfer it to the server. As the gateway is connected wirelessly to the server hence it can be placed anywhere thus making the system more flexible.The server which is the Raspberry Pi stores the received data in database and display them in the webpages so that they can be accessed by the clients. Also a alert system is connected to the server through which the client or the doctor can be alerted in emergency cases.

The system is designed for monitoring a single patient. But it can be made multiple patient monitoring system by connecting more gateways to the servers. The system can measure only body temperature, bpm and detect motion. But in real scenario this factors are not enough. Hence more no of sensor such as glucometer,blood pressure etc should be added to the sensor.

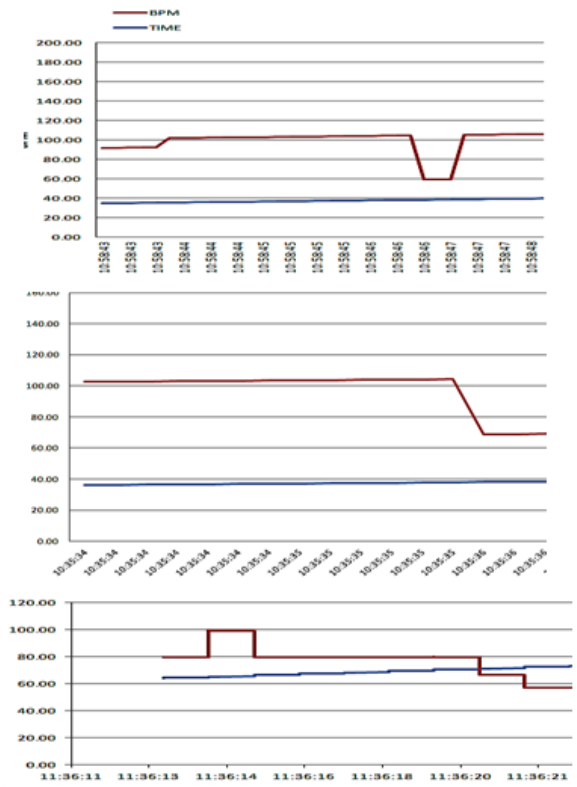


Figure 9: The graph of pule sensor data at given time interval. One of the output is the increasing time and another is the data shown by the sensor during the time.

Figure 10: The graph of lm35 data at given time interval. One of the output is the increasing time and another is the data shown by the sensor during the time.

In case of patient that are monitored from home a GPS system can be added to the system in order to show the location of the patient. The receiver that is designed for alert system can be further modified in case of monitoring multiple patients by adding an lcd that will display which patient needs help.

Acknowledgment

I would like to thank the Department of Electronics and Communication Engineering, Gauhati University, Assam for their guidance and support throughout the project.

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