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DESIGN AND DEVELOPMENT OF INTERNET ENABLED HEART RATE MONITORING SYSTEM

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ABSTRACT
Over the last several years, there are a number of convincing development steps in the area of Internet-of-Things (IoT) which enables a way for the development of many novel and fascinating applications. Today, real time monitoring of patient's health is very difficult. So to bring the concept of real time monitoring of patient's health, this project proposes a ideal IoT enabled architecture for heart rate monitoring system. Staying ideally to the IoT vision, it relies on different, yet smart, technologies, specifically WSN (Wireless Sensor Networks), smart mobile, which are interoperating with each other through a wide variety of IoT protocols. The designed system will be collecting the patient heart rate in real time and monitoring any drastic change in the reading. The system also monitors the surrounding environment conditions of the patient too. The parameters obtained are then published to the internet. Later a mobile based application (android) will be developed so that these sensory data's can be accessed from anywhere using this app. For supporting the IoT functionalities an internet enabled board called Raspberry Pi is used.

INDEX TERMS: Pulse Measurement, MQTT, Internet of Things, Photoplethysmography.

I. INTRODUCTION

The Internet of Things has changed the world a lot. It influences both our life style and working environment. Today, Broadband Internet is available to all the users at affordable cost. Hence by coupling the Wi-Fi capabilities and sensors into a wide range of devices and gadgets, we could attain much useful information. All these aspects have brought a path for the IoT in the everyday lives of people and in various sections of the economy, including healthcare. This technology will transform the healthcare systems within the next decade, because it is having a great potential for remote monitoring and for the medical device integration. With the introduction of IoT technology into the present health care domain, the real time monitoring of the patients becomes possible. It also helps in easy dealing of the emergencies of patients. This is all made possible with the help of internet.

Technology plays its major role in healthcare not only for sensing devices but also for the communication, recording and display of the parameters of the patients being obtained with the help of sensors. It is very important to monitor various health parameters and post operational days of the patients inside a hospital. Hence the emerging trend in Healthcare communication method called the IoT is incorporated into the present healthcare. The implemented design is meant for monitoring the heart rate of the patient inside the ICU's. Along with that it also monitors the environmental conditions near the patients in ICUs so as to provide a sustainable condition for the patients inside the ICU's. The system is designed in such a manner that it will submit the data collected to the internet where the health parameters obtained can be monitored even remotely. This is all made possible with the idea of Internet of Things (IoT).

The main idea of the proposed system is that it will continuously monitor the patients via internet. The proposed system will monitor the heart rate and the surrounding atmospheric conditions of the patients inside the ICU's with the help of various sensors.

Among adults the normal range of a patient's heart rate is 60-100 Beats Per Minute (BPM). Heart rate varies from one to another with body fitness. If a person is fitter, his/her heart rate will be lower. If heart rate is

higher than its normal value, the condition is known as tachycardia, in the opposite case it is called as bradycardia.

Different sensors are available in the market that can be used to measure the patient's heart rate and the surrounding conditions inside the ICU's. The heart rate sensor and various other sensor used here for measuring the environmental conditions, brings about some major changes compared to the ones available in the market now. Firstly, these are the cost effective options. Secondly, these devices can be interfaced with computers and mobile phones. This can open up many other opportunities to perform further analysis on the recorded data. Thirdly, there are only a few analog devices to measure heart rate and apart from that all these devices needs help from another person to do so. This device will solve that problem as they can be used without any need for a help from others. Finally, the device is also very easy to use.

The major component that is used to measure the heart rate in this project is an optical reflective sensor that works on the principle of Photoplethysmography. A controller board named ATMega16 microcontroller is used to count heart beats and monitor the environmental conditions. Optionally an Arduino board can also be used to interface these devices to personal computer for data analysis.

The data processed by the controller board is then passed to the pi board for the further processing. It is the one which is responsible for publishing these collected sensory data's into any publishing sites. Later a mobile based application (android) developed is used to retrieve this data's remotely from anywhere.

II. BACKGROUND

The heart rate sensor used here is the Pulse Sensor (shown in Fig 1). The word Plethysmograph had got its origin from two Greek words 'plethysmos', meaning increase and 'graph' meaning write. It is a device used to measure the variations in blood volume or blood flow in the body which varies with every beat of the patient's heart. Plethysmography is the volumetric measurement of an organ. It is resulting from the fluctuations in the amount of blood or air that the organ contains. This change in blood volume is similar to the heart beat, so it can be used to detect heart rate. Photoplethysmography uses optical techniques to measure the heart rate of a patient. There are basically two types of photoplethysmography, Transmittance and Reflectance photoplethysmography. In this designed system reflectance photoplethysmography has been used. In reflectance photoplethysmography, a light source and a light detector are placed on the same side of a patient's body part. The light source used is an infrared Light Emitting Diode (LED), and the detector generally used is a phototransistor. The sensor can be placed on the fingertip/ear lobe of a patient. It is then illuminated by the light source. Three things will happen depending on the volume of blood present in the finger tip/ear lobe ie, certain amount of the light will be absorbed, certain amount of the light will be transmitted, and certain amount of light will be reflected.

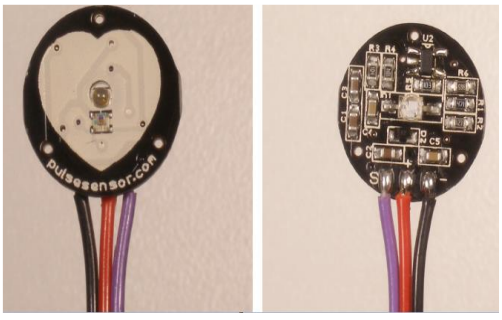

Fig 1. PULSE SENSOR

Patient's surrounding environment conditions like temperature and humidity is monitored by a Humidity and Temperature Sensor. DHT11 Humidity and Temperature Sensor is used in this work (shown in Fig 2). Features like small size, low power and signal transmission distance up to 20 meters are making it popular to be used in wide variety of applications in health care domain. The product is a 4-pin single row pin package. Communication is through three stages of connection. By Request, to make the DHT-11 sensor to send us the sensor readings, a request is sent from the microcontroller.

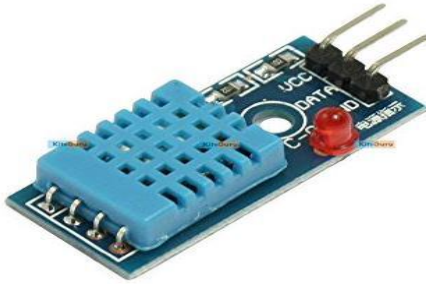

Fig 2. DHT11 TEPERATURE & HUMIDITY SENSOR

Hydrogen gas (H2), at room temperature and under standard pressure conditions, is tasteless, odourless, and colourless. Its presence is very much dangerous to human beings. Hydrogen can produce a spark when it gets mixed up with the air. So its presence must be detected. So to detect its presence in the patient's room, MQ-8 gas sensor is used (shown in Fig 3). The sensor is made up of a gas sensitive material called tin dioxide (SnO2). It has a lower electrical conductivity in clean air. When there is a presence of hydrogen in the environment increases beyond a certain value, the electrical conductivity of the sensor increases with the increase in that hydrogen concentration in the air.

Fig 3. MQ-8 HYDROGEN GAS SENSOR

There are several protocols that can be adopted for IoT communications depending on the constrained environments. Most frequently adopted protocols are MQTT (Message Queue Telemetry Transport), CoAP (Constrained Application Protocol), XMPP (Extensible Messaging and Presence Protocol), RESTFUL Services (Representational State Transfer) and AMQP (Advanced Message Queuing Protocol). Our main task is to test the performance these data protocols and compare them based on the different scenarios. Results are then used for determining which protocol should be used.

III. INTERNET OF THINGS(IOT)

Today Internet has become an important part of our daily life. It has changed the way the people live, play, work, and learn.. The products developed based on IoT include embedded technology which allows them to exchange information with each other via Internet.

Determining the appropriate IoT protocol for the application is a major concern. There are many IoT protocols available. This application need a protocol that is capable of publishing the sensory data's into any data collecting websites, so that the doctors and nursing staffs can acquire it by using the mobile apps developed. All these criterions can be accomplished by the MQTT Protocol. So the proposed system is working based on that protocol.

A. MQTT PROTOCOL

It is a publish-subscribe-based messaging protocol. It works on the top layer of the TCP/IP protocol. It has three basic things, a Broker that manages a topic and relay a message between publisher and subscriber, a Publisher that publishes the messages to specific topic and a Subscriber that subscribes a message to specific topic. MQTT is designed for a lightweight M2M communications. It was originally developed by IBM and is now it became an open standard.

In this architecture, a publisher will continuously produce and send data to the server. The Central server that is, the MQTT broker will collect the messages from publishers and examines to whom the message

needs to be sent. On the other hand, every device who had previously registered with a server will keep on receiving messages until the subscription is canceled. In this architecture, it is not necessary that the publishers and subscribers do not need to know for each other which is one among the major advantages of this protocol. Devices that send data need not to know who are the clients that are subscribed for receiving data and conversely. Also it is not necessary that the publishers and subscribers do not need to participate in the communication at the same time and do not need to be familiar with each other. It is intended for devices with limited power and memory capabilities, where the network is expensive, has low bandwidth or is unreliable. One of the key requirements of an Internet of Things concept is low network bandwidth used to send data and minimal device resource requirements.

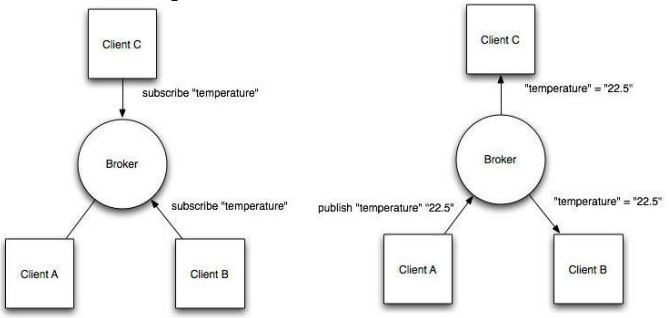

Fig 4. PUBLISH AND SUBSCRIBE MECHANISMS IN MQTT PROTOCOL

IV. EXISTING SYSTEM

Most of the present healthcares monitoring systems available now are standalone systems, without any warning mechanisms. Patient and their surrounding environment monitoring are considered as an individual application system in healthcare automation environment. Integration of environment and patient monitoring does not exist in the present systems. Doctor has to generate the patient report in a hospital. In case of any emergency the doctor must be in hospital to generate a prescription. If a doctor is in some other location apart from hospital, doctor may send report via messages or by call may lead to conflicts. So a mobile based application of a patient is mandatory for the doctor, so that a doctor can provide prescription from any location. Some of the disadvantages of the existing system include redundancy of data in sensor network, communication and data management issues in sensor network, increase in the data overhead and bandwidth requirements of the sensor networks. Also in case of any emergency for the patient, doctor must be available in the hospital to generate prescription.

V. PROPOSED IoT BASED HEALTH CARE SYSTEM ARCHITECTURE

The following Fig 5 shows the block diagram representation of the work. The main components of the block diagram are ATMega16 microcontroller, DHT 11, MQ-8, heart beat sensor, switch and buzzer.ATMega16 forms the heart of the system where it reads all data fed into it and thus it can take necessary action based on the information obtained. DHT 11 is the temperature and humidity sensor which measures temperature and humidity in the atmosphere around the patient. Similarly, MQ 8 is the gas sensor which measures the ratio of gases that is present in the atmosphere and continuously monitors whether it has exceeded certain limit or not. If the gas ratio has violated the default then the required actions will be taken by the microcontroller. Heart beat sensor named Pulse sensor is used to measure the heart beat of the patient. This sensor is placed on the finger tip/ear lobe of patient. A switch is used to start the counting of heart beat sensor. Rate is given in beats per minute. All these information from all the sensors are fed as inputs to the ATMega16 micro-controller. The microcontroller will process all these data's and takes necessary action if required. If there is a drastic change in the readings of the person's heart rate or the surrounding environment conditions, it will be made known to others with the help of a buzzer sound. These data will be provided as input to the Raspberry Pi processor via USB to UART converter. All these information's from the micro-controller are made available to the Pi. This is then uploaded to the cloud storage using MQTT protocol with the aid of an internet connection from the Pi board. These parameters obtained are then published to any of the MQTT enabled data collecting websites using an internet enabled board called the raspberry pi. An android

application will also be developed which will helps in accessing these published data's and helps in the continuous monitoring of the patients via internet.

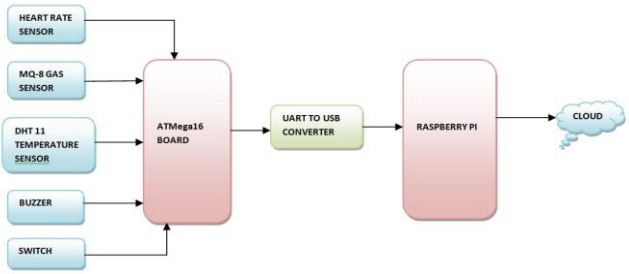

Fig 5. BLOCK DIAGRAM REPRESENTATION

VI. CIRCUIT CONSTRUCTION

The full circuit has been constructed in two steps:

A. PROCESSING SECTION

This board will process all these sensor values and will give the results. While measuring heart rate it is important that the person movements are minimized as much as possible because movements might cause extra changes in volume of blood, which can cause variation in the heart rate measured. So the sensors are susceptible to movement.

Initially all these sensors are connected to the ATMega16 board. This board will process the sensors as a whole. The various sensor values will be read to the ATMega16 board using the program developed in AVR Studio. After successful compilation of the programs corresponding hex file will be generated. This is then burned into the memory of the ATMega16 controller using ISP (In System Programming) pins. The hex file is of Intel Hex Format (shown in Fig 6).

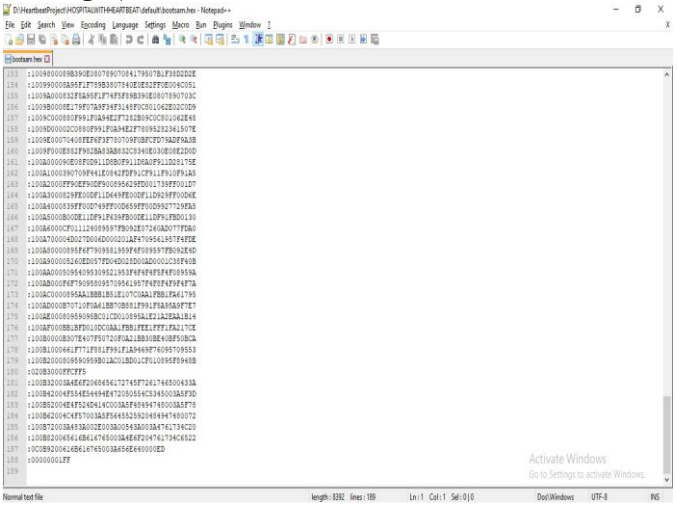

Fig 6. INTEL HEX FORMAT

Before connecting the ATMega16 board and the Pi board together the UART output from the microcontroller can be viewed using the putty software. The screenshot of the putty software is shown in Fig 7.

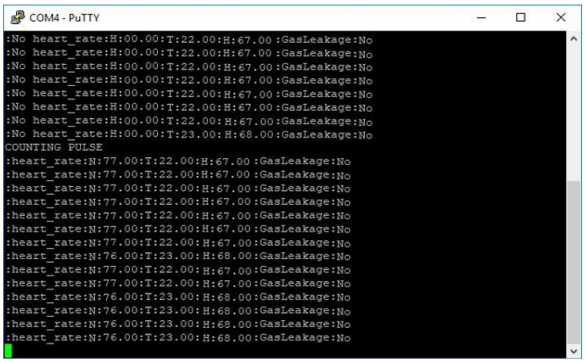

Fig 7. UART OUTPUT FROM MICROCONTROLLER

B.PUBLISHING SECTION

Now the task is to publish this collected information to MQTT enabled data collecting websites so that we can subscribe the information with a help of an android application developed. For that the information processed by the controller board is transferred to the internet enabled board using an UART to USB converter. Raspberry pi is used to publish the information to the site. The Raspberry Pi is ideal for IoT applications that are server based. This is because it has high storage space and RAM and a powerful processor. Also, it supports many programming languages that can create server-side apps. It can also be used in situations where we want to access web pages and also view the data posted on online servers. The Raspberry Pi can be connected to both LAN and Wi-Fi networks. However, it is not advisable to use the Raspberry Pi for projects where we want to integrate it into a finished product or to create a custom made PCB.

The Raspberry pi board will publish these data's into the MQTT enabled data collecting websites. These data's can then accessed remotely by developing an android application. For that a python code will be running in the Pi board. This program is working on the basis of MQTT protocol. Using this protocol the results will be published to the IoT enabled data collecting websites. An android app developed will be used to subscribe the data published. The android application is developed based on the same protocol that is used for publishing The Fig 8 shows the screenshot of the app developed.

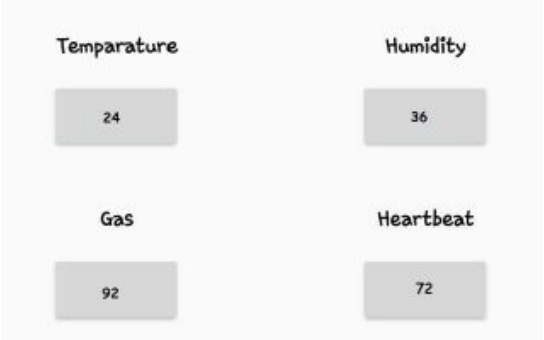

FIG 8. SCREENSHOT OF THE APP

VII. CONCLUSION AND FUTURE SCOPE

In this work, an ideal internet enabled Heart Rate Monitoring System for automatic monitoring of patient within hospitals is implemented. For supporting the IoT application an internet supporting board named Raspberry Pi is used. The sensors will collect all the real-time variation of patient's heart rate as well as the environmental conditions surrounding the patient, which is then processed by the ATMega16 board. The sensed parameters are then collected by the raspberry pi board for further processing. The data's are then delivered to a data collecting website where they can be made easily accessible by the doctor's via internet. Two different use cases have been implemented to validate the proposed system. The former deals with patient's heart rate monitoring, the latter with the management of an emergency situation which are promptly detected and made known by the warning signal produced by the buzzer. The achieved results demonstrate the appropriateness of the proposed system to perform not only the monitoring of patients heart rate and surrounding conditions in real time, but also to provide power effective remote patient monitoring and immediate handling of emergencies.

Further this project can be enhanced by adding several other sensors like the blood pressure sensor, spirometer, glucometer sensor etc... It is possible to add an alert mechanism such as SMS using a GSM. Finally to study about the patient's history a conventional database like MySQL can be created.

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