International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2019 IJSRCSEIT | Volume 5 | Issue 2 | ISSN : 2456-3307
DOI : 10.32628/CSEIT1952238

Wearable ECG Monitoring System and Data Analysis

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ABSTRACT

Continuous ECG data monitoring with IoT will be a platform for the healthcare industry, which will enable doctors with quicker, smarter and effective methods of diagnosis. Statistical Analysis of Real time monitoring of patients and feeding the monitored data to the internet is going to be one of the big things in future. IoT Healthcare can be used for critical patients needs to be under continuous observation; especially in the absence or unavailability of medical doctor. Early detection of diseases is possible with IoT Healthcare applications and the doctor can be notified immediately. IoT healthcare has a wide range of applications like Heart-rate monitoring, ECG monitoring, bloodpressure monitoring, etc. ECG monitoring with IoT and the methodology of its implementation. It is proposed and implemented a Smart healthcare application using a IoT system based on AD8232 heart rate sensor interfaced with Arduino UNO and further connected to Cloud using an ESP8266 Wireless LAN Module. The data collected from the sensors are updated in the cloud without identity. The aggregated data can be made available to the doctors for their research and studies. Data analysis tools will be used to interpret and present the data. Since dates are update in the cloud the availability is ensured and by hiding the identity, confidentiality is maintained. Thus continuous monitoring of patients through IoT will help both patients to maintain the health and doctors to diagnose the disease or predict the cause of the disease.

Keywords : AD8232, IoT, ESP8266, Arduino, HTTP, Cloud, Heart Rate Monitoring

I. INTRODUCTION

IoT or Internet of Things refers to the phenomenon of interconnection of people, computers, machines, etc. through the internet for continuous process and exchange of data which can be identified according to a particular trait [1], with the help of sensors for real time monitoring, tracking and management of data.

In many countries, governments are sanctioning good amount of funds to carry out research work to eliminate medical negligence, which is one of the significant loopholes of the healthcare industry. So it is going to be a significant and much needed change in the healthcare industry that the world is looking for. In countries like India, whose population is growing at a steep rate, proper healthcare and monitoring becomes an acute problem since the number of doctors across the length and breadth of the country is limited compared to the population. So, some highly qualified and efficient physicians have to travel throughout the country for checking patients. In this case, acute monitoring of the patients and storing their respective data to cloud becomes very important for the doctor, to know about the present condition of his patients and to take further steps accordingly. For example, in case a doctor operates in

New Delhi and has to leave for Kolkata on that day itself, to make the doctor aware of the details of the patient he had operated in New Delhi, continuous monitoring of the patient and storing the monitored data to cloud finds its importance. The doctor can easily check the monitored data using the internet and give instructions accordingly [2].

For aged people who are suffering from cardiac diseases, this online monitoring of data becomes important to the doctor for proper diagnosis. If the monitored data do not fall below the normal value, then the system may be programmed to alert the doctor.

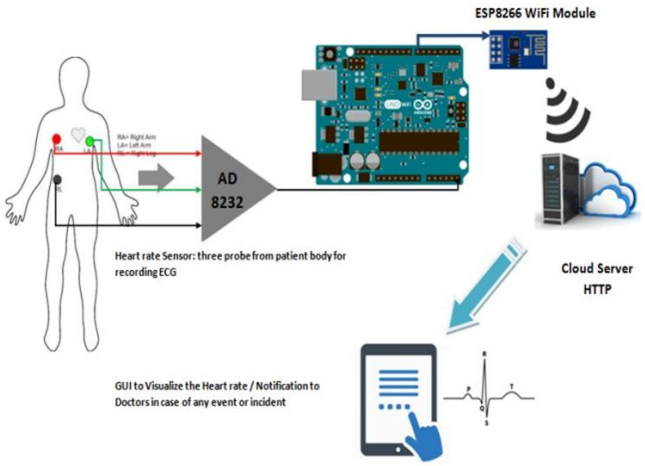

Fig1: Proposed IoT in ECG Healthcare Application

Further IoT will be instrumental in changing the world we live in now and will present us with much simpler ways of living and to deal with things quickly and efficiently. In many countries, there is intense state-funded research work going on in the field of IoT healthcare for smart data monitoring. It can not only help us monitor data, but also provide each patient the attention they deserve to get well.

From the prospective of this paper, as shown in Fig.1 we are going to monitor the data from a AD8232 biometric heart rate sensor and then send the data to the internet for storage and processing. For uploading the data to the internet, there are several techniques. We are using a WiFi module, ESP8266 for sending data to the internet as this process involves simple yet effective architecture along with efficiency and is cost effective. The fact that we are stressing on the cost-effectiveness is because of the fact that it will lead to greater reach for this technology. The ESP8266 is a low cost module, using which we can give a microcontroller access to any WiFi network and further upload data. The ESP8266 is an effective platform for communicating over the internet [3].

II. SYSTEM ARCHITECTURE

Communication is an integral part of the IoT environment since it is related to synchronization between data, processing and the user. Efficient communication is essential for the well-being of the patient and for the effective treatment by the doctor and hence needs to be managed with accuracy and precision. In this paper, apart from the analog data acquisition between our sensor and the Arduino, communication is essentially Wireless by taking patient mobility in to consideration. We tend to use the internet to our advantage in order to notify the doctor about the data collected from the patient and hence communication over the internet is one of the most important parts of this proposed system as shown in Fig.2 .

Fig.2 : Smart Healthcare System a Vision

We will take a bottom to top approach in order to address our communication procedure, starting from

the raw data and ending at our website where the doctor can access processed data. The process starts at the sensors (in our case the ECG sensors), which collect data from the patient and send it via cable to the processor, serially. It is sent as a stream of data which is actually a reading of the voltage and hence is read easily by our microcontroller ATmega328 based Arduino. In the next step our Arduino communicates the data to the ESP8266 WiFi module serially. The ESP8266 acts as an important communication interface in our project as it is the bridge between our raw data in the form of electrical signals, and the data over the internet. Hence after this step, we have successfully sent our data on the internet and have justified our topic of the "Internet Of Things". The following steps are software related and deal with the data which we have sent over the internet. The data is first visualized on the web server to which the ESP8266 has sent and is then stored and Processed and is later presented for the user (in our case, the doctor) to analyze. This sums up our entire process of notifying the doctor, who later with his expertise provides the patient with the best option to getting healthy [4][5].

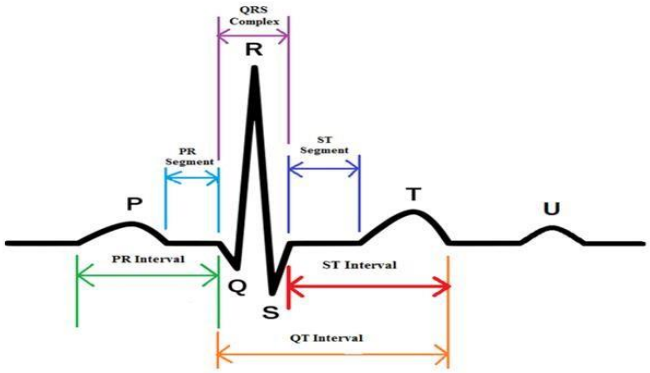

Fig.3 : A Typical ECG Waveform

A. ECG and its Clinical Importance

This is a typical QRS complex which is significant for analyzing the heart rate of a patient. The P-wave represents the activation of the upper chambers of the heart, while the T-wave represents the heart's lower chamber activation along with the QRS complex. Any problem with the functioning of the heart can be determined by analyzing the QRS complex. Any abnormality in the heart rate is indicated by lengthening, widening or shortening of the QRS complex as shown in Fig.3 .

B. Proposed Hardware Model

The proposed hardware model was made by connecting the different modules and sub-modules together and then connecting the circuit to a power supply. The hardware model after complete connection looked like as shown in picture.

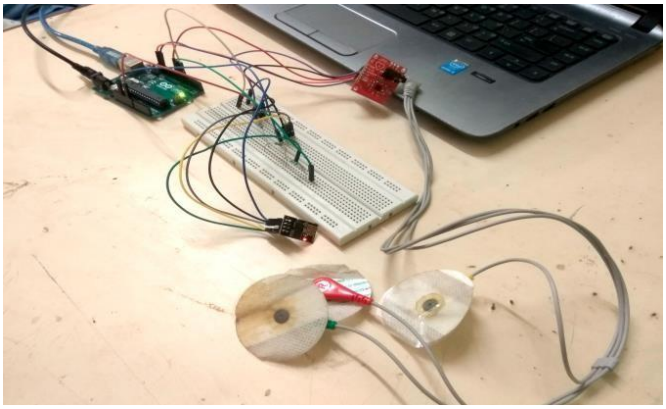

Fig.4 : ECG sensor (AD8232)

Fig.5 shows the schematic diagram for the proposed AD8232 based heart rate monitoring system in the context of smart healthcare & IoT. The ESP8266 is used as the IEEE. 802.11 Network adaptor used to send sensor data to cloud using HTTP POST over AT command over software serial in Arduino. Fig.4 is shows the implementation of proposed design showing the probes to be connected to the patient's RA, LA & RL, who is under real-time heart monitoring. The heart rate sensor data will be sent to cloud server over a TCP connection using HTTP POST command [6][8].

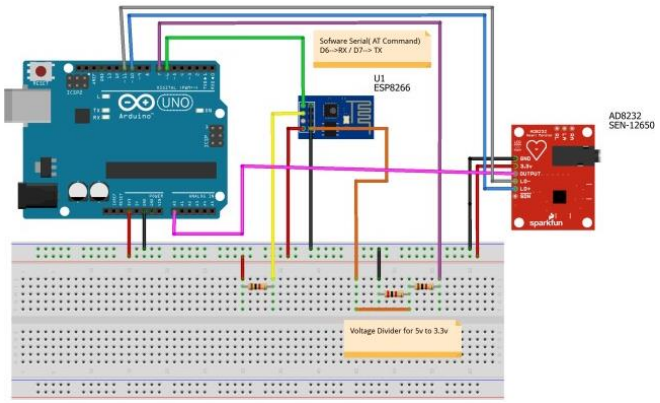

Fig.5 : Schematic diagram of the proposed Smart healthcare system designed in Fritzing

C. Data Handling

Data is handled in basically three stages of our project. We can divide these as the initial data collection stage, the data transmission and interfacing stage and the final data processing stage. In the initial stage as the name suggests, we collect the data using our sensor network from the patient. The handling in this stage is important since the accuracy in data collection will finally determine the outcome and hence requires the highest level of precision. In our second stage, we deal with the transmission of this data from the sensor network to our microcontroller and finally send it via the Wi-Fi module to the internet. This stage can result in some noises introduced in the circuit along with data loss. However, error in this stage has a lower probability and going by the general data trend, can be corrected by proper sampling. Hence the first stage data handing affects the data in this stage to some extent. The final stage basically deals with the processing of data in our server and do not have much chances of error. However, this level determines the efficiency of our final outcome to the largest extent. Data handling in this stage basically deals with algorithms to graph and process our data. Summing up, data handling is probably the most important part of the project and cannot be neglected. We will have a look at the devices that have the biggest role to play in handling of data efficiently:

D. AD8232 Single-Lead, Heart Rate Monitor Sensor

The ECG sensor (AD8232 shown in Fig.6) attached to the patient measures electrical activities of heart over a period of time. The sensor outputs can be monitored using the serial monitor or can be sent directly to the cloud with the help of a microcontroller. It collects the data and sends it serially to the Arduino for further actions. Table.1 shows the pin connection for interfacing of AD8232 with Arduino UNO.

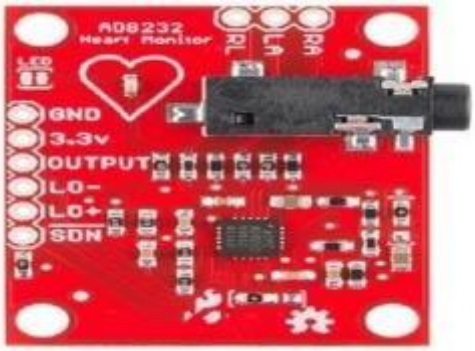

Fig. 6 : AD8232 Heart rate Sensor by ANALOG DEVICE (Courtesy: Sparkfun Electronics)

Table.1 : Pin Level Connection of AD8232 with Arduino

Board Label	Pin Function	Arduino Connection
GND	Ground	GND
3.3v	3.3v Power Supply	3.3v
OUTPUT	Output Signal	A0
LO-	Leads-off Detect -	11
LO+	Leads-off Detect +	10
SDN	Shutdown	Not used

E. Data Processing

Data of the sensor network is processed with the help of the microcontroller Arduino Uno (shown in Fig.7). The sensor network is connected to the Arduino board, which displays the data value or the graphical value on the serial plotter. Arduino has also connections with ESP8266 which through a series of AT commands sends the data to the internet.

Fig.7 : ATmega328 Microcontroller: Arduino Uno (Courtesy: Arduino.cc)

F. ESP8266 WLAN Module

The data acquisition is carried out using Arduino UNO and is transmitted through the ESP 8266 MODULE over to the cloud. The ESP8266 module has been pre-programmed with a set of firmware also knows an AT commands and hence we can connect this to the Arduino directly and then transmit the data. This stage of data handling leads to the insertion of minor errors while transmission from the shield to the internet. However, this does not lead to much damaging impacts on our results and can be adapted to using proper techniques in other stages[6][7][8].

AT Command Set: (HTTP over TCP Connection)
AT+CIPSTART="TCP","internetofthings.pe.hu",80
AT+CIPSEND=170

POST /sensorRead.php HTTP/1.1
Host: internetofthings.pe.hu
Content-type: application/x-www-form-urlencoded
Content-Length: 23

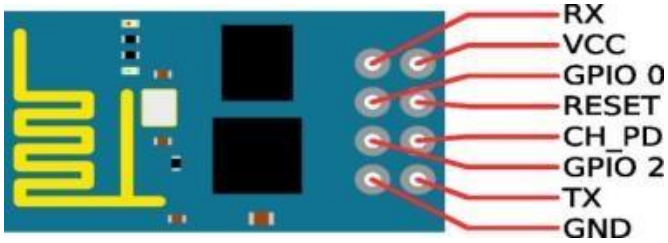

Fig. 8 : WLAN Module ESP8266

Fig.8 shows the pin-out diagram of ESP-01 used to POST HTTP data to Server over a TCP connection.

G. Data Analysis

The data collected from the sensors are updated in the cloud without identity. The aggregated data can be made available to the doctors for their research and studies. Data analysis tools will be used to interpret and present the data. Since dates are update in the cloud the availability is ensured and by hiding the identity, confidentiality is maintained. Thus continuous monitoring of patients through IoT will help both patients to maintain the health and doctors to diagnose the disease or predict the cause of the disease.

III. RESULTS

The circuit, consisting of Arduino Uno, W-LAN module and the ECG sensor was well connected. Then, the ECG leads are placed on the patient's body as per the color coding. Now, with the switching on of the circuit, heart rate gets monitored constantly and the ECG waveform is generated. The voltage values of the ECG are received by the serial monitor at certain intervals of time. The ECG curve is generated in the serial plotter of Arduino Uno and with the help of ESP 8266, the data is sent over the internet to a specific webpage and can be accessed by the respective doctor in any part of the world. If there is some abnormality in the ECG waveform, (i.e. the QRS complex is not well- defined, inversion of T-waves, very low amplitude level, etc.) then the physician is immediately notified using SMTP that there is a problem with this particular patient. Then the physician can log on to the webpage and can see the ECG graph and then can take necessary actions to improve the condition of the patient.

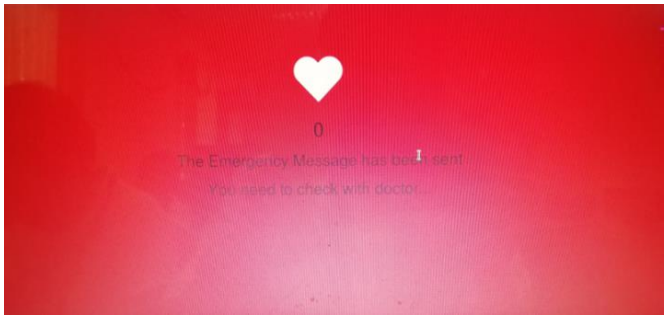

Fig.9 : Screenshot of a typical webpage in the scope of this paper achieved by implementation of proposed system

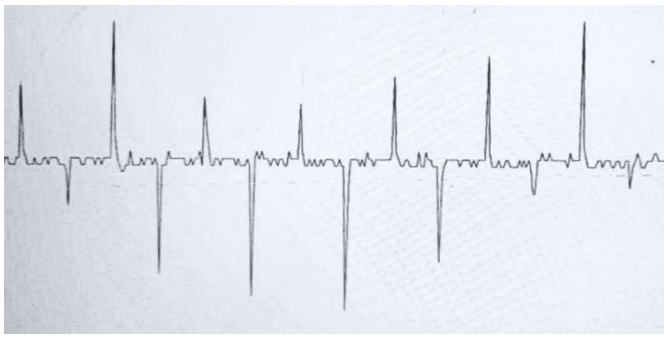

Fig.10 : A typical ECG waveform recorded through proposed hardware model in this paper.

IV. CONCLUSIONS

Integration of healthcare with IoT has opened up a vast arena of development. It will not only facilitate healthcare but will also find out new measures to prevent diseases by processing data and by analyzing global trends. Moreover, a vast future lies entirely on automation of hospitals and treatment mechanisms which can help the doctors understand diseases through artificial intelligence and IoT. However, we should take a step at a time and not rush in into this field, since it deals with human health and safety and security needs to be the top agenda. On a large scale, this can also lead to cheaper treatments and cheaper nursing costs of patients. If technology and health goes hand in hand, we can reach the goal of cheap, safe and efficient disease preventions and treatment. & Networking Lab (WCN LAB), School of Electronics Engineering, KIIT Deemed University. The schematic diagram of Arduino UNO, ESP8266 & AD8232 is designed using Fritzing.

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Cite this article as :

M. Marudhapandi, D. Ramkumar, R. Ramkumar, S. Jeevanandham, Dr. N. Suguna, "Wearable ECG Monitoring System and Data Analysis", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 5 Issue 2, pp. 667-673, March-April 2019.
Journal URL : http://ijsrcseit.com/CSEIT1952238