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Implementation of Remote Patient ECG Monitoring System Using IoT Platform

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Abstract—*Internet of things(IoT) is the new technology in which diverse range of devices share data and communicate with each other over the internet. The IoT is the new revolution which has recorded its presence in almost every domain of our lives since its inception. According to one estimation, more than 50 billion objects would be communicating with each other over the internet by 2030[7].IoT has got numerous applications in various domains viz. Health care, Industrial IoT(IIoT), automobile industry, climatic conditions monitoring and so on. As the basic infrastructure of IoT involves the internet based cloud so this facility can be used to monitor the health of the remotely located patient. This application is very helpful in poor countries where quality health facilities are not available owing to the physical distance between doctor and patient. Moreover, the cardiovascular abnormality is one of the biggest causes of deaths. So, The focus of this research paper is to design low cost, cloud based system by using Arduino UNO development board and Ethernet shield to monitor real-time ECG of the remotely located patient using the internet of things (IoT) based platform. The IBM Watson Bluemix[11] cloud is used in this designed system which uses MQTT protocol [13] to dispatch the messages between publisher and subscriber. The collected bio medical data from the patient in the form of ECG signals may be saved in the database available on the cloud for later analysis.*

Keywords*: Healthcare System,ECG,Internet of Things, Arduino UNO, Ethernet shield, IBM Bluemix,MQTT.*

1. "INTRODUCTION"

Internet of Things (IoT) is defined as the interconnection of various hardware devices, sensors, actuators and other computing devices via the internet and enabling them to send the data to each other without the human interference. IoT has got its applications in almost every aspect of our lives and it has been termed as the new revolution in the industry. This new technology has potential to address almost every challenge which exists in our society. The most remarkable application of IoT is in the field of health care. In this sector, IoT has emerged as the panacea to address the problem which is associated with monitoring of the health of the remotely located patient. The cardiovascular diseases (CVD)[2] are one of the prominent causes of deaths in both genders. The timely detection and action may help the people to save their precious lives. ECG (Electrocardiogram) is the representation of cardiac rhythms of heart and one ECG cycle is divided into sub-parts viz. ST, PQR interval. Any cardiovascular anomaly may get reflected in the ECG waveform in the form of increased or decreased PQR or ST interval. So in this paper, an IoT-based system is designed by using Arduino development board, Ethernet shield, AD 8232 ECG sensor module and IBM Watson Bluemix cloud to measure the ECG of people remotely so that cardiologist can analyze this to detect any anomaly. People may utilize this technology in order to get them diagnosed remotely from their homes without traveling to health centers. This will save their time which they spend while traveling to health clinics and waiting in queues.

II. "Motivation"

Cardiovascular Diseases (CVD) are one of the leading causes of deaths among people across the globe especially in the case of people belonging to old age group [2]. The timely detection of cardiac abnormalities can prompt the patients to take preventive action which may save their precious lives. ECG (Electrocardiogram) is the process of recording the electrical activity are produced by the heart. By visualizing the ECG waveform, cardiologists diagnose any abnormality or deviation in the normal functioning of the heart. So in this paper, a system has been designed to monitor the real-time ECG of the patient remotely which will eliminate the physical barrier between patient and health-clinic and may prove a boon for people, especially for old age people and athletes.

III. "Literature survey"

Dogru Bolat et al [1] designed the web-based system to record the ECG of the patient using ECG sensor and Raspberry Pi development board. The main attributes of this system are its portability and low cost. In this system, the bio-signals were acquired from patient's body and stored in SQL database by designing the software in c++ language.

Bor-Shyh Lin et al [2] implemented the community-based low power features proved decisive factors in its acceptability.

Hristijan Gjoreski et al [8] proposed the system to monitor the ECG and another physical parameter of user's body. The

acquired data was then analyzed to extract the relevant information: respiration rate and heart rate. The acquired data from the ECG signal and accelerometer may be combined together to detect any anomaly in the patient's health.

Colin Jones et al [4] designed the system which was implemented by IOIO microcontroller and the ECG data from patient's body was stored in SD card, installed in Android based mobile phone. Moreover, file compression algorithms were also used to compress the large data.

IV. "System Design"

The design of proposed system can be divided into 2 parts

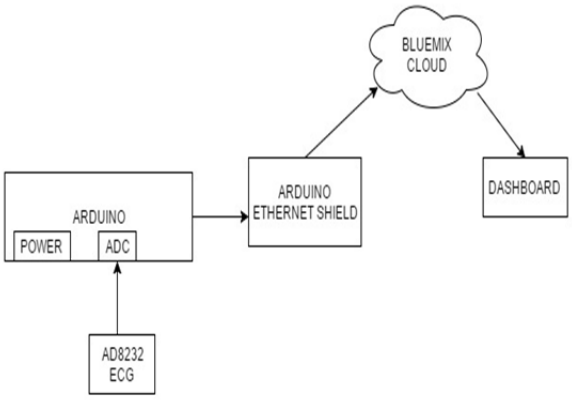

Figure 1 System Design

A. "Hardware part"

The hardware part of the system composes following parts.

1. Arduino

Arduino board[10] is an open source, ready to use, the cheap platform which is designed to build various applications. This platform today consist of around 20 different boards which are programmable in various languages viz. java, C, C++.Moreover, there are the plethora of IDEs(Integrated development environment) available to be used with different operating system viz. Windows, Mac, and variety of other Linux based platforms. The most attractive feature of Arduino platform is its open source nature means both software and hardware are free to use, it one of the most popular system to wirelessly monitored the heart rate and ECG of the remote patients and electronically managed the collected data. Its low cost coupled with easy to use and development boards. In the designed system, we have used Arduino Uno which is an ATmega328P based development boards with 14 input-output pins and on board oscillator to produce the required clock signal for its operation.

2. Arduino Ethernet shield

The Arduino Ethernet shield allows the Arduino board to connect to the internet using CAT 5 or CAT 6 cables by utilizing the pre-defined Ethernet library. Sometimes cross over cables are required to connect to computers.

3. AD 8232 ECG sensor

AD 8232 ECG sensor[12] is designed to measure electrical signals which are produced due to the cardiac rhythms of the heart. Owing to its low cost coupled with its ability to detect the clear signals in presence of noise, has made this device as the very popular ECG measuring sensor for research purpose. In this sensor AD8232 board is use to amplify the weak biomedical signal which gets mixed with noise. The noise which, may get produced by muscles activities and the motion artifacts those are produced by patient's physical movements. The pin architecture of ECG sensor contains 6 pins viz. SDN, GND, LO+, LO-, OUTPUT, 3.3V. Moreover, one LED is also installed on the board which will change the intensity of light according to the rhythm of the heart .Bio medical sensor cable and sensor pads are required to attach the sensor to the body of the patient.

The features of the above sensor can be summarized into following points.

1. Operating voltage (3.3 V)
2. Analog output
3. A LED indicator
4. Shutdown pin

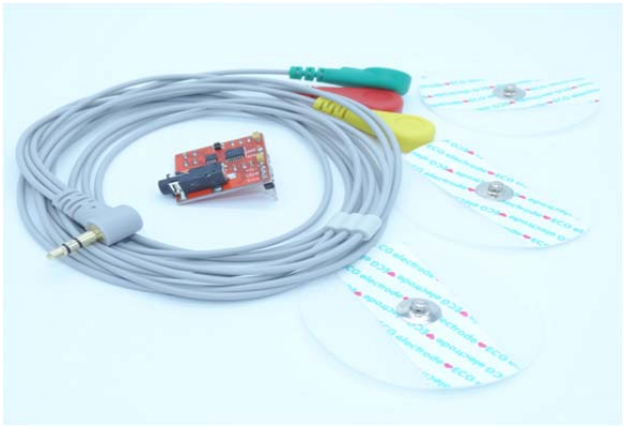

Figure 2 AD 8232 ECG sensor

B. "Software used in the design"

The software and protocols used in the design of system are explained in this section.

1. "IDE"

Arduino provides the open source, programming tool, known as IDE(Integrated Development Environment), which is used to upload the codes written in Arduino programming language to Arduino board.

1. "MQTT protocol"

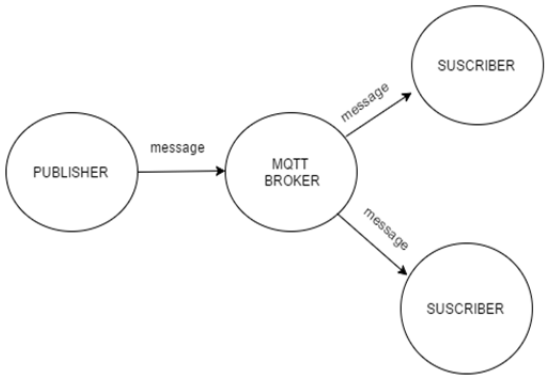

Figure 3 MQTT Protocol

MQTT (Message Queuing Telemetry Transport)[13] is a publish/subscribe paradigm based protocol which was developed to connect various devices together and for the machine to machine (M2M) communication. It is a lightweight low bandwidth based protocol which finds its application in publishing message from one publisher to many subscribers. In MQTT Broker and Client are used which are explained in following module.

The client in MQTT may be any microcontroller or any Hardware device or development board which is running with preinstalled MQTT library and which is connected to the MQTT broker over the network.

The broker is the heart of the MQTT protocol. The broker is responsible for the receiving all the incoming messages, filtering them and sending them to subscribed clients. The other important functionality of the broker is the authorization and authentication of the clients.

The modus operandi of the MQTT is that it pushes the messages to the clients whenever some new event occurs, while in the case of HTTP, messages are requested by the clients.

V. "Experimental setup"

The arrangement of different hardware components is shown in the figure. The working of the system can be explained by dividing the system into sub-parts which contain sensor module, signal processing module and IBM Watson cloud. The working of the sub-modules of the system is explained in this section.

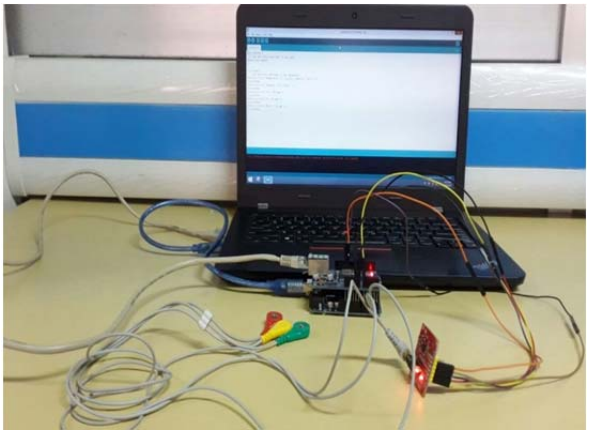

Figure 4 Experimental Setup

A. Sensor module

This module is the front-end of the system which acquires the bio-signals from the subject's body by using the electrodes, fixed on subject's body. The AD8232 ECG sensor is used for the signals acquisition purpose, which is a low cost, low power, 3 electrodes board designed for bio medical applications.

B. Signal processing module

The signal processing unit is the second stage in the designed system which receives signals from the AD8232 ECG sensor. Arduino Uno is used in this stage, in which 6 pins are available for connecting analog values to the board. In the designed system, the output of the sensor is given at analog input pin (A0). The Arduino contains 10-bit ADC which receives analog values in the range of 0-5V and maps the input analog values in the range of 0-1023. Moreover, Arduino - Ethernet shield is attached to this development board which makes it the internet enable device and connects it to the internet via Ethernet cable (Cat 5 cable) by utilizing the pre-installed Ethernet libraries in Arduino library. The Ethernet shield requires 5 V supply, which is provided by Arduino board and the data can be sent at the rate of 10-100 Mb/s by using SPI (serial peripheral interface) protocol.

C. IBM Bluemix cloud

The IBM Watson Bluemix [11] is a platform offered by IBM incorporation which can be used for creating the IoT-based application and this is available for private use as well as for commercial use. In order to use this platform user has to register himself. The Arduino board sends the data to the cloud by using the Ethernet shield. For receiving the data, Bluemix cloud uses Node-Red, which is a visual programming tool. The data sent over the cloud can be visualized in the form of the graph as well as gauge.

VI. "Results and future work"

After the complete installation of the system the bio-signals were acquired from the patient's body and the real-time graph showing the ECG value was plotted on IBM Watson Bluemix Dashboard. IBM Watson Bluemix platform provides the flexibility to user to select the available options in form of line chart, bar chart or Gauges in order to show the instantaneous value of data obtained on the dashboard. In the designed system, Line chart and Gauge are selected to view the value of obtained data.

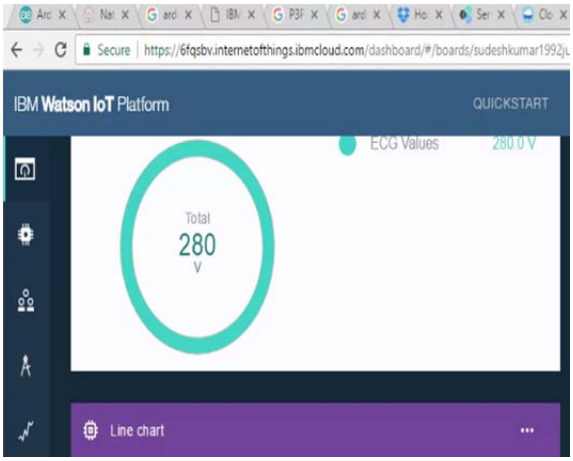

Figure 5 ECG value

Fig. 5 shows the obtained value of ECG signal in(microvolt) in the form of Gauge on dashboard.

Fig. 6 shows the ECG waveform obtained and the time period for which graph is to be plotted, can be adjusted from the drop down box provided in the dashboard. Bluemix also provides the facility to user to trigger some action in the form of email alert if some pre-defined conditions get fulfilled.

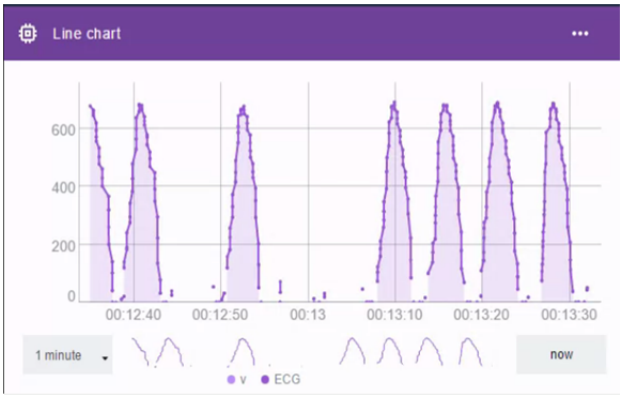

Figure 6 ECG graph

Furthermore, in future, the decision-making mechanism may be introduced which will trigger the alert the caregiver via message or email if any abnormality is detected in the obtained data from the subject's body.

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