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Research paper

IOT based real-time ECG monitoring of rural cardiac patients

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Abstract

According to the census in India, about 83 crores people live in rural area out of 121 crores total population. Patients living in these rural area mainly depends on Primary Health Centre (PHC). Due to insufficient and low facility health care center in rural area in India, patients have to depend on nearby cities to get proper treatment. With the help of new technologies such as wireless communication and Internet of Things (IoT) we can improve the health care requirements of rural cardiac patients. In this work, a telemedicine application for online moni-toring and analysis of cardiac patient is implemented. A low cost high quality wireless ECG monitoring system based on IoT is implement-ed in this work. With the help of this system, doctors in a specialty hospital can monitor the distant patient in a rural area through PHC. In this manner, symptoms can be early detected and this helps the doctors to give proper advice to physicians in PHC. The Electrocardiogram (ECG) is wirelessly transmitted from patient side to a laptop in PHC which is configured as local server. The serial ECG data are then transmitted to the web server. Website www.ecgtrack.in is created and hosted with server so that doctors can view patient's ECG after log-ging on to the web site. Doctor can view the ECG of patients with three previous recordings. Multiple patient ECG from rural areas can be viewed by the doctor in the specialty hospital in real time and can make effective diagnose. This is a reporting of an emerging research work in this area.

Keywords: *Diagnose; ECG; IOT; PHC; Telemedicine; Website.*

1. Introduction

Telemedicine in India will allow patients in rural areas to have access to specialist doctors in urban hospitals. Leading cause of death in rural areas is due to cardiac diseases. Telemedicine have many applications in cardiovascular disease continuum and have an important role for the delivery of health care for cardiac patients [1].Early detection of heart disease has important significance for heart disease prevention and timely treatment. Developments in telemedicine due to the new technologies in electronics and communication engineering helps to monitor rural patients in primary health centre from a specialty hospital in urban area. Internet of things (IoT) allows objects to be controlled or sensed from a remote location and to transfer data to the internet.IoT include sensors, wearables and actuators at one end which are connected to the internet through uniquely identifiable IP addresses [2]. This latest technology is used for telemedicine application to monitor the ECG of rural cardiac patients in real time. Change in the rate of heart rhythm is called arrhythmia and are difficult to obtain on an ECG tracing which are captured within few seconds. Some of the arrhythmia are dangerous like ventricular fibrillation which is the main cause of cardiac arrest or stroke. So early detection of these arrhythmias for people living in rural areas can be made possible by Telemedicine.

Telemedicine uses electronic communications to exchange medical information for improving the patient's health. There are three main categories of Telemedicine namely remote monitoring, store and forward and interactive telemedicine. In this work remote monitoring category using IoT is used for diagnosis of cardiac patients. Developments in wireless technologies leads to wireless telemedicine in which doctors can view physiological data of patients from anywhere at any time. Different wireless technologies are used in telemedicine to transmit different physiological parameters. This includes wireless technologies like Bluetooth, Zigbee,Wi-Fi and GSM [3]. ECG monitoring using Bluetooth wireless technology will transmit the ECG data via the Bluetooth wireless link and display it in a laptop [4]. Parameters like temperature, heartbeat and blood pressure are transmitted and displayed with the help of Wi-Fi module[5]. Monitoring of ECG in real time using Zigbee wireless technology has been implemented [6]. ECG is monitored in a laptop from a remote location using Zigbee transmitter and receiver.ECG signal are stored in the database of Wamp server and then plotted in real time in the browser. Zigbee technology is used to transmit the ECG signals in real time. Zigbee transmitter and receiver are used for transmission and Lab VIEW is used to plot the signal in the laptop. The ECG signals transmitted to a remote laptop using zigbee are stored in the same lap top configured as server and are finally plotted in another laptop using internet [7]. In this work ECG recording system will capture the ECG from the patient and zigbee transmitter interfaced with this system will transmit the data to the laptop connected to zigbee receiver. ECG signal from the laptop is transmitted to the web server from the local server. The ECG signals are stored in the database of server and plotted in the browser of any laptop using internet.

2. IOT system description

The work mainly aims to design highly accurate, durable and inexpensive ECG recording and wireless transmission system based on IoT. Block diagram of IoT based ECG monitoring system is shown in Fig.1.The ECG recording system consists of surface electrodes, instrumentation amplifier using op-amps, low pass filters, band reject filters and microcontroller. It captures the ECG signal from the surface of the body, amplifies the signal, filters will remove undesired signal and pass only the ECG signal.

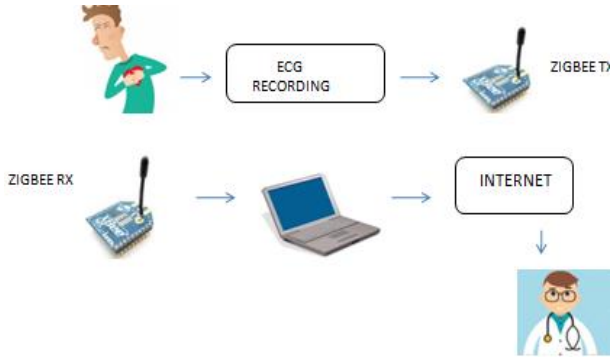


Fig.1: Block Diagram of IOT Based ECG Monitoring.

The filtered analog ECG output is then converted to digital data which contain the time and voltage information in a specific format. The serial data from the output of microcontroller is converted to USB standard and wirelessly transmitted to a remote laptop using Zigbee module. Wamp server is used as local server and it takes the incoming serial data and transmit it to the web server. The transmitted ECG signals are stored in the data base of the server. From the server it is retrieved and then plotted in the website www.ecgtrack.in. Doctor in the specialty hospital can view the ECG signal of patient from rural area in real time and can diagnose the patient.

3. ECG Recording

The ECG signals from the patient's body are sensed with the help of disposable surface electrodes attached to the body and are amplified using instrumentation amplifier. The amplified signal is then filtered, digitized, and transmitted to the laptop. Three lead ECG recording block diagram is shown in Fig. 2. For this system, three electrodes in which two of the electrodes among Right arm - RA, Left arm -LA or Left leg –LL are used to form lead according to Einthoven triangle and the third is used as the ground.

Lead I configuration is used, it is the voltage between Left arm electrode and Right arm electrode (I= LA - RA). ECG signals are low voltage signals varying from microvolt to the mill volt range so these signals need to be amplified in order to be better interpreted [8]. Instrumentation amplifier used for amplification of ECG signal in this work is Texas Instrument's INA321 EA. It provide low cost, low noise ,micro power consumption with minimum gain of 5 and maximum gain up to 1000 [9]. Driven Right leg drive or DRL is used to eliminate 50 Hz interference noise by canceling the interference. Filters using op-amps are used to remove the unwanted signals and line frequency noise. The last stage of the acquisition system is an 8 bit microcontroller by Atmel. It is a low power microcontroller based on AVR enhanced RISC architecture with 32K bytes of FLASH 1 Kbytes of EEPROM and 2Kbytes of SRAM. Real time analog ECG signals are captured and converted to digital serial data using microcontroller which have an in built 10 bit Analog to Digital Converter. Using FT232RL USB to Serial UART adapter the serial data is then converted to USB standard in order to transfer the data to laptop.

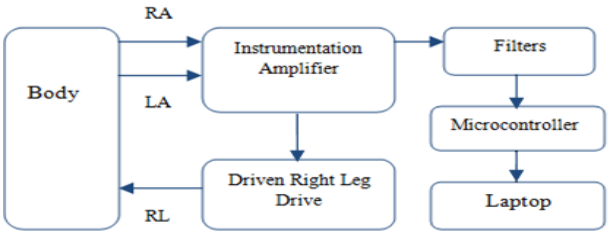


Fig. 2: Three Lead ECG Recording System.

The ECG recording system used in this work is light weight and easily portable device. This device can be placed at the patient side for capturing the real time ECG signals .For transmitting the signals to nearby PHC this recording system can be interfaced with wireless module. Among the different wireless technologies available Zigbee technology is used here to transmit ECG signals to PHC.

4. Wireless transmission

Wireless transmission used here is Zigbee technology to transmit ECG signal from acquisition system to a laptop in PHC. Zigbee is less expensive when compared to other wireless technologies like Wi-Fi and Bluetooth [10]. It operates in the industrial, scientific and medical (ISM) radio bands with low power consumption, data rates up to 250 kbps and support for low latency devices [11]. It can transmit signals up to 100 meters and supports star, cluster and mesh networks. Zigbee series 2 module is used as transmitter and receiver. This module allows very reliable and simple communication between microcontrollers and systems. Analog ECG signals are first digitized and then converted to time voltage serial data by ECG recording system which is interfaced with Zigbee transmitter. This serial digital data are then transmitted wirelessly using zigbee technology to the nearby PHC.

5. Reception and display of ECG signal

ECG signals transmitted from the Zigbee transmitter are received from a nearby PHC, which consist of Zigbee module, MAX232 IC and laptop .The received signal remain between the limits of 0 and Vcc and is referred to as TTL serial. Serial port of laptop supports RS232 standard so it should be converted into RS232 level. MAX232 IC is used for this level conversion. The TTL serial data from Zigbee module is fed to MAX232 IC where this TTL signals are converted to RS232 standard .The data output from MAX232 are fed to PC using serial connector DB9 and FT232 convertor is used for serial to USB conversion.

6. ECG display on local server

Before loading ECG signals in the database of server and plotting in web page, these signals are plotted in local server for testing.ECG signals are wirelessly transmitted using Zigbee technology to a remote laptop. The Serial ECG data received by the laptop are stored in the data base of the server configured as local server. These Signals are then retrieved and plotted in the browser of the system configured as server. Web servers are computers that deliver web pages and any computer can be turned into a Web server by installing server software. In this work WAMP Server is used to make the laptop as local server. It is a Windows OS based program that installs and configures Apache web server, MySQL database and PHP scripting language [12].

7. ECG display on internet

ECG signals stored in the database of local server are send to the data base of web server and stored there. It is retrieved and plotted in the web browser. Domain name www.ecgtrack.in is taken and

hosted on a web server. For viewing patients ECG in real time doctor can log on to the web site www.ecgtrack.in .First page is the login page for the doctor for authentication.Fig.3 shows the login page for doctor. After entering the required username and password it direct to display page for ECG.When the leads are properly placed and transmitting and receiving sections are ON the ECG signals will be first stored in the local server database and finally in database of web server. From there it is finally plotted in this display page. JQuery is a fast JavaScript Library and Flot is a pure JavaScript plotting library for JQuery are used in this work to plot the ECG signal. It is simple to use, have attractive looks and also have interactive features [13]. ECG signal of remote cardiac patient is transmitted from patient side to nearby PHC by Zigbee wireless technology. Signals are received with the help of zigbee receiver and are stored in the data base of laptop configured as local sever in the PHC. On logging on to the website doctor in the specialty hospital can see the ECG of the remote cardiac patient and diagnose him.

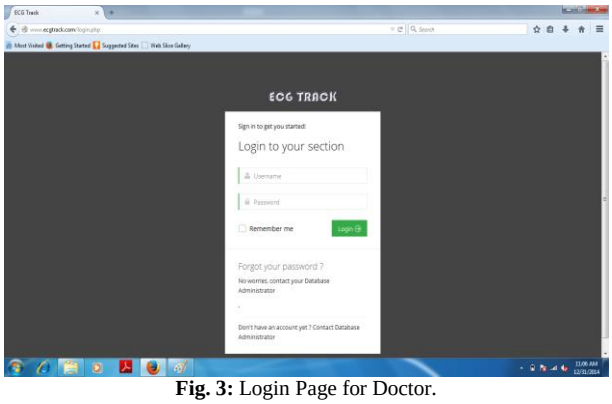
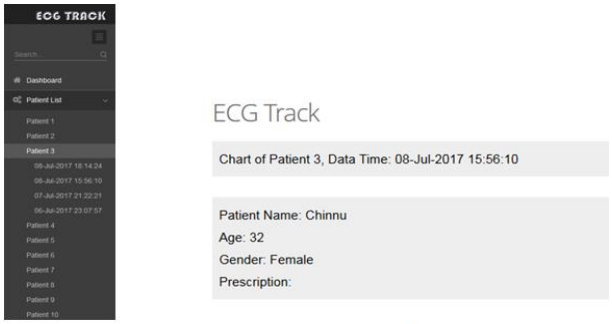


Fig. 3: Login Page for Doctor.



a b

Fig. 4: Display Page Showing A) Patient List on Left Side. B) Details of Individual Patients Showing above the ECG Waveform.

Three patients ECG has been transmitted in real time and diagnosed by the doctor.Three previous recordings along with prescription is made available in the web page. For each waveform patient details like name,age,date of birth,gender are also displayed as shown in Fig. 4. In this way the doctor can easily identify the patient and his records and can give early medical instructions.

8. Results

ECG signals wirelessly transmitted from patient side using Zigbee technology is plotted and displayed in the laptop using LabVIEW software. Fig.5 shows transmitted ECG signal received and plotted in PC using LabVIEW. Fig.6 shows the ECG signal plotted in the browser of the laptop configured as server. ECG signals from the data base of the local server are send to the web server and are stored in the database of web server.It is plotted in the web browser of any other laptop and can be viewed by logging on to the web site www.ecgtrack.in. Fig.7 shows the ECG signal plotted in the web browser. Ten patients ECG was taken and wirelessly transmitted and displayed in the web page. It was successfully diagnosed by the doctor.Bradycardia means heart rate less than 60 beats per minute.It has regular rhythm,normal QRS duration and P wave – Visible before each QRS Complex. If heart rate computed is less than 60 beats per minute, then it is detected as bradycardia. Trachycardia is for heart beat greater than 60 beats per minute. It also has regular rhythm,normal QRS duration and P wave – Visible before each QRS Complex.Ten patients ECG has been transmitted and diagnosed by this method.

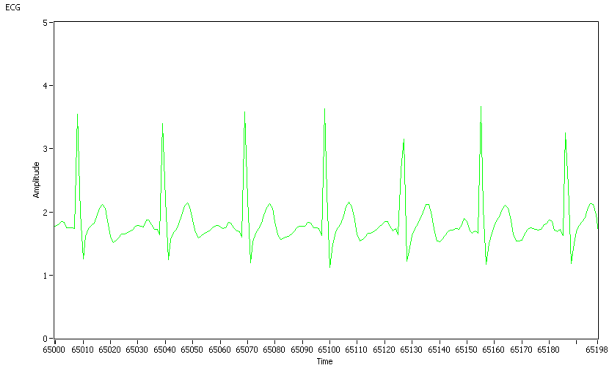


Fig. 5: Transmitted ECG Signal Received And Plotted in PC Using Lab VIEW.

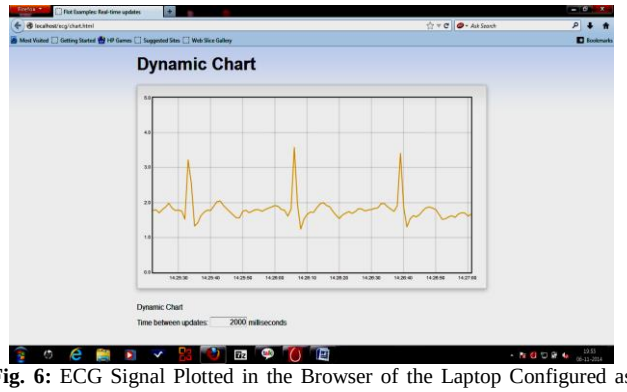


Fig. 6: ECG Signal Plotted in the Browser of the Laptop Configured as Server.

Fig. 7: Screen Shot of the Plotted ECG Waveform in the Web Browser.

9. Conclusion

IoT has a large number of applications in various fields and the major contribution of IoT in the future will be in the health care.IoT based ECG monitoring system is implemented in this work where the ECG signals of rural cardiac patients in a rural area can be transmitted to a laptop in the nearby PHC by using Zigbee technology. Laptop in the PHC can be configured as local server and the ECG data are stored in the database of the local server.Website www.ecgtrack.in is created and hosted in a server with MySQL database. From the local server data are send to the data base of web server.Stored signals in the MySQL data base of web server are retrieved and plotted in the web browser. So that doctor in a specialist hospital can view the ECG signal by logging

on to the web site and can give medical instructions to the doctors in the PHC.Ten people who attended PHC,seven of them were normal and three had heart ailments.Doctor could identify seven as normal and three with problems.Three previous recordings along with prescription is made available in the web page. For each waveform patient details like name,age,date of birth,gender are also displayed. The doctor can easily identify the patient in the rural area and view his ECG in real time and analyze by comparing the previous records thereby he can give early medical instructions to them. Work is going on and it will be continuous for about 200 patients with different heart problems.

10. Future scope

A real time arrhythmia detection algorithm along with ECG database can be added to this work. Using this detection algorithm doctor in the PHC can easily detect and analyze the arrhythmia.

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