Real-time ECG monitoring system for the assessment of rural cardiac patients

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ABSTRACT

Patients living in rural areas in India mainly depend 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 and telemedicine we can improve the health care requirements of rural cardiac patients. In this work a telemedicine application for online monitoring and diagnosis of cardiac patient is implemented. A low cost wireless ECG monitoring system called REMS Real –Time ECG Monitoring System is implemented in this work. With the help of this system doctors in a specialty hospital can monitor the patient in a rural Primary Health Centre so that symptoms can be early detected. 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 logging on to the web site. Doctor can see the ECG of patients with three previous recordings. Multiple patients ECG from rural areas can be viewed by the doctor in the specialty hospital in real time along with previous three recordings and prescription for analysis.

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. Prevalence of cardiovascular diseases in India is higher than other countries of the same region [1]. Early detection of heart disease has important significance for heart disease prevention and timely treatment. A development in telemedicine due to the new technologies in electronics industry helps in the monitoring of patients with cardiac disorders within the home or rural hospitals. 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 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. There are different wireless technologies that are used to transmit ECG signals such as Bluetooth, Zigbee Wi-Fi and GSM. This work is an extension of the earlier works of the authors [2-3]. Wireless ECG monitoring using Bluetooth low

energy (BLE) technology consist of acquisition module Bluetooth module and smart phone. It capture ECG signal and transmit the ECG data via the Bluetooth wireless link and display it in a smart phone [4]. ECG transmission using Wi-Fi technology is developed which consist of a single chip ECG signal acquisition module, Wi-Fi module and a smart phone [5]. Patient's heart beat, temperature and pressure are transmitted using Zigbee wireless technology [6]. Zigbee technology is used in this work to transmit the ECG signals in real time. 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. In this work ECG signal from the acquisition module is transmitted to the laptop using Zigbee module. 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. SYSTEM DESCRIPTION

The aim of the work is to design an inexpensive highly accurate ECG acquisition and wireless transmission system called REMS Real –Time ECG Monitoring System. The Fig.1 shows the main block diagram of REMS. The ECG acquisition system consists of electrodes, instrumentation amplifier, 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.

The analog output from the filter is given to

microcontroller for analog to digital conversion (ADC) and the serial data from the output of microcontroller is converted to USB standard and fed to laptop using USB cable. Wamp server is used as local server and it takes the incoming serial data and transmits it to the web server. The transmitted ECG signals are stored in the data base of the server. Virtual private server is used as server and finally, the ECG signals are 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.
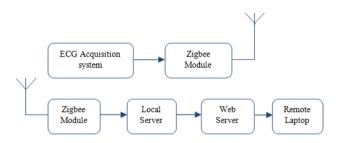

Figure 1. Block diagram of REMS

3. ECG ACQUISITION SYSTEM

The signals acquired from the electrodes are amplified, filtered, digitized, and transmitted. Block diagram of ECG acquisition system is shown in Fig. 2. For three lead systems, electrodes Right arm (RA), Left arm (LA) and Left leg (LL) are used, two of the electrodes are used to form lead and the third is used as the ground.
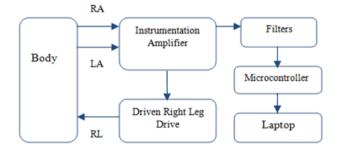

Figure 2. Block diagram of ECG acquisition system

Lead I configuration is used, it is the voltage between Left arm electrode and Right arm electrode (I= LA - RA). ECG signals vary from microvolt to the mill volt range due to this small range, the signals measured need to be amplified in order to be better interpreted [7]. Texas Instrument's instrumentation amplifier INA321 EA is used here. With an internally set gain of 5, the INA321 can be programmed for gains greater than 5 [8].

Instrumentation amplifier is a differential amplifier with additional input buffer stages. It has low offset voltage, high Common mode rejection ratio (CMRR), high input impedance and high gain. Driven Right leg drive is used to reduce the common mode interference. Filters using op-amps

are used to remove the unwanted signals and line frequency noise. The last stage of the acquisition system is ATmega 328 microcontroller which is a low power CMOS 8 bit microcontroller based on AVR enhanced RISC architecture with 32K bytes of FLASH 1 Kbytes of EEPROM and 2Kbytes of SRAM. Real time ECG signals are first digitized and converted to serial data using ATmega 328 which have an in built 10 bit ADC. The output serial data from the microcontroller is then converted to USB standard using FT232RL USB to Serial UART adapter.

The ECG acquisition 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 acquisition system can be interfaced with wireless modules. Among the different wireless technologies available Zigbee technology is used here to transmit ECG signals to PHC.

4. WIRELESS TRANSMISSION

Zigbee technology is used in this work to transmit ECG signal from acquisition system to a laptop in PHC. It is a low-cost, low power, wireless mesh network standard which operates in the industrial, scientific and medical (ISM) radio bands [9]. It is less expensive and can transmit signals up to 100 meters. Zigbee technology has low power consumption, very robust and supports low to medium data rates. The Zigbee network layer natively supports star, tree and mesh networks. It can accommodate up to 64654 nodes and very easy to add or remove nodes from network. 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 digitized and converted to serial data by ATmega microcontroller. This serial data is fed to Zigbee module and are then transmitted wirelessly using Zigbee technology.

5. RECEPTION AND DISPLAY OF THE ECG SIGNAL

Zigbee module and MAX232 IC are used in the receiver side. The received signal from the Zigbee module is TTL level, so it should be converted into RS232 level. For this level conversion MAX232 IC is used. The Signals from Zigbee module is connected to MAX232 IC where this TTL signals are converted to RS232. The output serial data from MAX232 are fed to PC using serial connector DB9.For connecting to laptop FT232 can be used for serial to USB conversion.

6. ECG DISPLAY ON LAPTOP USING LABVIEW

Before plotting the ECG in the browser the signals are viewed in the laptop using Lab VIEW. Lab VIEW programs consist of two windows a front panel and block diagram. XY graph is used in this work to display the ECG in real time. The back panel, which is a block diagram, contains the graphical source code. Figure 3 shows the block diagram for receiving the serial ECG data and plotting it in real time.
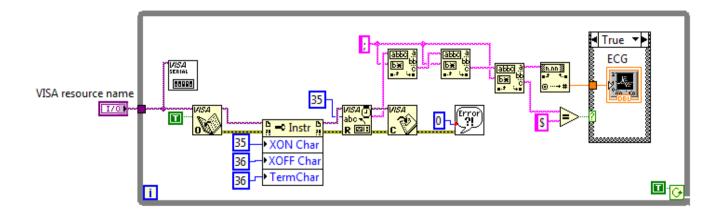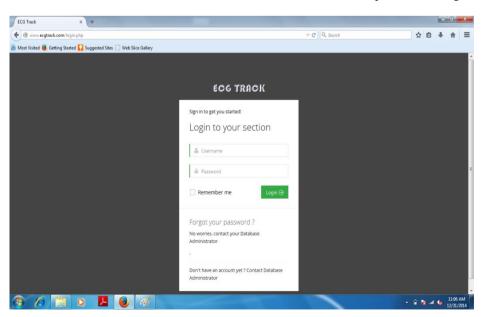
Figure 3. Block diagram for ECG display in Lab VIEW

7. ECG DISPLAY ON LOCAL SERVER

Before loading ECG signals in the database of server and ploting 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 [10].

8. 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.4 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 virtual private 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 is used in this work to plot the ECG signal. It is simple to use, have attractive looks and also have interactive features [11]. 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.

Figure 4. Login page for doctor

Ten patients ECG has been transmitted in real time and diagnosed by the doctor. Two previous recordings along with prescription is made available in the web page. For each waveform patient details like name, age, date of birth, gender is also displayed as shown in Fig. 5. In this way the doctor can easily identify the patient and his records and can give early medical instructions.
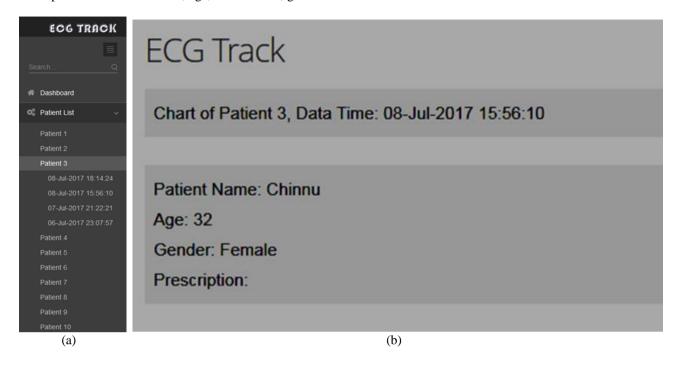

(a)   (b)

Figure 5. Display page showing a) Patient list on left side. b) Details of individual patients showing above the ECG waveform

9. RESULTS

ECG signals wirelessly transmitted from patient side using Zigbee technology is plotted and displayed in the laptop using Lab VIEW software. Fig.6 shows transmitted ECG signal received and plotted in PC using Lab VIEW. Fig.7 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.8 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. Fifty patients ECG has been transmitted and diagnosed by this method.
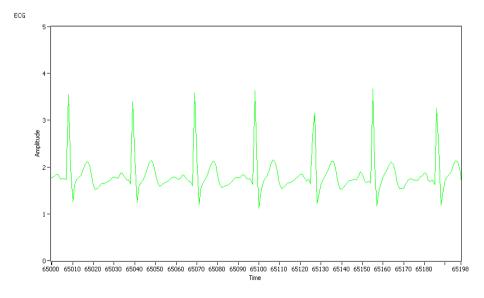

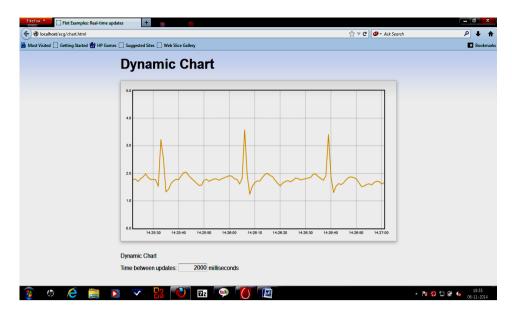**Figure 6.** Transmitted ECG signal received and plotted in PC using Lab VIEW

Figure 7. ECG signal plotted in the browser of the laptop configured as server
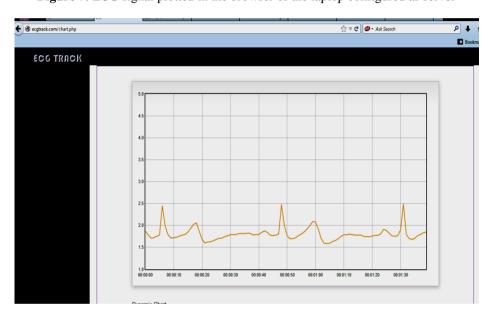

Figure 8. Screen shot of the potted ECG waveform in the web browser

10. CONCLUSION

ECG signals of 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 from rural area who attended the nearby PHC, six of them have normal heart rate and four with arrhythmia. Three previous recordings along with prescription are made available in the web page. For each waveform patient details like name, age, date of birth, gender is also displayed. The doctor in the specialty hospital could easily identify the patient in the rural area and can view his ECG in real time.

He can also analyze by comparing the previous records and can give early medical instructions to them. Work is going on and arrhythmia detection algorithm will also be included in for analysis.

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