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Research Article

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Remote Health Monitoring using Embedded Systems

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Abstract—

The increase in the population of aged people is now the leading healthcare concern of many countries in the world. Aged patients need more healthcare efforts as they present more cases of chronic illnesses involving higher healthcare costs. e-Health systems based on modern information technology are expected to play a role in solving this problem. India, with its huge population, is an ideal setting for telemedicine. Here, the design of an embedded telemedicine system and web server for remote health monitoring of patients is proposed. It enlightens the technique to remotely monitor patients' data. This real time telemedicine system which utilizes GSM/GPRS protocol is proposed for the third world countries with the help of which, the patients can be monitored from any part of the world by the doctors through the internet. This system uses a set of software simulators and a DAC as a solution to low cost testing. Here, LabView software is used as the software simulator for generating the ECG signal and NI equipment to get a real time analog output. That signal is fed into a GSM modem to transmit data over the internet.

Keywords— Electrocardiogram (ECG), Telemedicine, Low power devices, Electrodes, Heart rate, Patient

I. INTRODUCTION

Health telematics plays a major role in improving the health of patients, particularly in the weaker sections of the society including disabled, aged and chronically ill patients. Mobile health-monitoring devices offer great help to both patient and doctors; doctors can focus more on tasks with high priority by saving time normally spent with treating chronically ill patients [1]. In modern medicine, there are many methods to diagnose heart disease, such as electrocardiogram (ECG), MRI, CT, ultrasound and so on. Among these methods, ECG diagnosis is a low cost and convenient method of diagnosis. Telemedicine systems can be used for monitoring of vital clinical parameters such as ECG from patients at home, and can be utilized to treat the patients in emergency condition not only in remote rural areas, but also in urban areas. This Wireless Telemedicine System, can make continuous and real-time remote monitoring possible. To transmit the vital clinical parameters, an embedded system based approach can be used. In which, the ECG signals are recorded and transmitted to the doctor wirelessly using internet. Using this system, a cost effective appropriate health care and reliable diagnosis by competent doctors can be made available to all.

II. LITERATURE SURVEY

In India as per the survey conducted by Indian Medical Society (IMS) in the year 2009, it has been revealed that 75% of qualified consulting doctors practice in urban areas, 23% in semi urban areas and only 2% at rural areas [2]. The non-availability of appropriate medical facilities at right time is a huge problem for people at rural places. Providing a cost effective solution for this problem by utilizing the available resources to give good medical facilities not only to urban but also to rural areas definitely reduces the gap present. The method that can be applied successfully to overcome all these problems is Telemedicine. Many studies have demonstrated the applications and advantages of such systems [3]. The advantages of telemedicine are in the areas like:

- Ambulances
- Rural areas
- Transmitting vital signals from one place to another

Heart disease is the main cause of early disability and premature death in most countries. In modern medical science, there are many methods to diagnose heart disease, such as electrocardiogram (ECG), ultrasound, MRI, CT and so on. Among these methods, ECG is a widely used method. Most of the deaths due to cardiac diseases occur outside the hospital and majority of the times due to lack of facilities.

However, the main challenge being faced is that, the ECG signal of the patient is only available to doctors present close to the patient. Since there is no electronic storage of this data, patients need to travel large distances to consult the specialist doctors. Some of the devices used to capture ECG signals are mentioned below.

Devices like the Actiwave are used to capture EEG, ECG and EMG signal in daily livings. A recorder is taped (sticked) to the skin near the position of electrodes. The signal is recorded in it and then downloaded in the PC and analysed [6].

A software named AliveECG transmits ECG signal through the Bluetooth connection over Alive Heart and Activity Monitor [7].

Another type of ECG tracing device called a Holter monitor is used to capture any abnormal heartbeats. Here, the patient wears ECG electrode patches on his/her chest, and the electrodes are connected to a recording device. The recent improvements in Holter monitor include store medium, playback methods, algorithm analyser and transmission approach. But the major problems of these devices are:

- High cost.
- Not able to transmit the ECG information to the doctors anywhere at any time.
- High power consumption [4].

In order to solve the problems presented above, a novel telemedicine system consisting of an embedded device that transmits ECG signals of a patient wirelessly to a web server is developed. This system ensures reliable and safe transfer of ECG signal over the internet. The system presents a low cost solution and it will be affordable to everyone. This data will be accessible to the doctor anywhere in the world as long as he has an internet connection and the patient is connected to a cellular network.

Goals of the proposed system are:

- Availability of best medical services to all regardless of their trusted physician's location.
- To develop an interactive website hosted on a web server equipped with a secure database that can be accessed by authorized personnel only.
- To provide a low power, cost effective service with wide area coverage.

To maintain the integrity and confidentiality of this sensitive data.

III. SYSTEM OVERVIEW

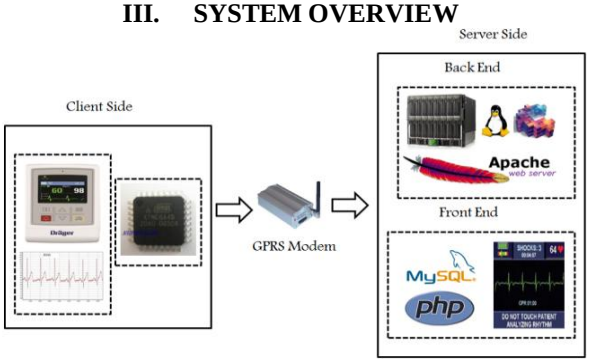

Figure 1. Client-Server Approach to the System

A client end can be interpreted as the combination of the ECG collection equipment, user interface and the microcontroller.

The server is composed of two parts: a back end and front end.

The back end is responsible for capturing data packets sent by the GPRS modem.

IV. BLOCK DIAGRAM

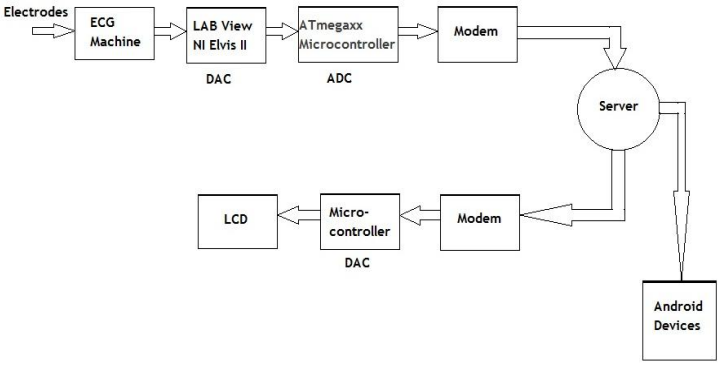

FIGURE 2. BLOCK DIAGRAM

V. ARCHITECTURE

A. HARDWARE ARCHITECTURE

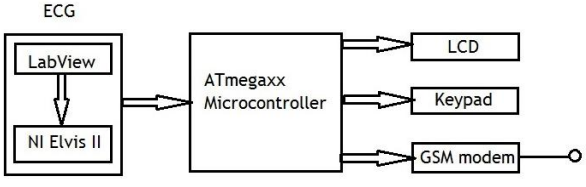

Figure 3. Architecture

- **ECG Generation Unit:**

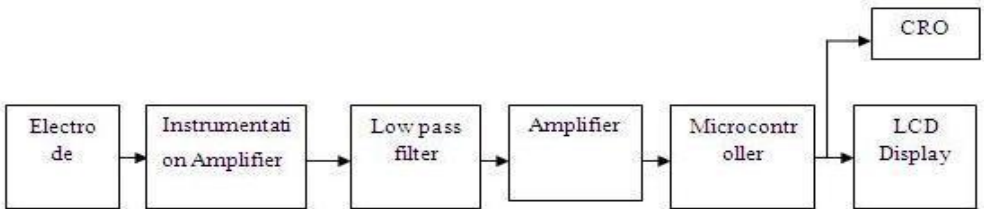

Figure 4. ECG generation unit

One of the methods to generate human ECG signals is to get actual electrodes, connect them to the human body and measure the ECG. But this type of signal is very weak and contains lot of noise. The only way to make use of this type of ECG is to filter out the signal and then amplify it. The only way to make use of this type of ECG is to filter out the signal and then amplify it. This requires an additional circuitry and exceeds the scope of our experiment. The most feasible option is to simulate the ECG signal using some specialized software programs. Eg: LabView
This method presents a cheaper alternative. This software allows us to generate ECG signal with the known strength and frequency on a PC. NI ELVIS II (a digital to analog converter created by NI) equipment is used to generate ECG signal in real form.

- **Control System:**

Here, a RISC based microcontroller called ATmegaxx, manufactured by Atmel is used. It is an 8bit microcontroller with 16bits of in system, self-programmable flash memory and also, it consumes low power. It makes the hardware design process easy, stable and low cost. The clinical bandwidth used for recording the standard ECG is 0.05 to 100 Hz and the standard bandwidth for GSM/GPRS is 900/1800 MHz. This high speed allows to capture maximum of ECG samples for further processing.

- **GSM/GPRS Modem:**

GSM/GPRS provides the widest mobility range (covering the largest geographical range). Here, SimCom's GSM modem (Sim300Z) is used which can be used as a GPRS modem. It has built-in TCP/IP protocol stack to be the transmitter/receiver so that the user could send his/her ECG signals at any time wherever GSM network coverage is available. It supports theoretical speeds of up to 170 to180kbps.

- **Server Implementation:**

As described earlier, server consists of two ends:

Back End

Back end of the server is designed to receive the data from the GPRS. The system is designed to receive C-sockets that extract data (ECG Signal) and store it in a secure database.

Front End

Front end of the server is used to display the ECG signal on the internet to the doctors through a screen. PHP and MySQL are used to develop the front end. The digital data received from the GPRS on the server is reconstructed at the server side and displayed. Doctors and Patients can register themselves and then login at the website given to view the ECG record.

B. SOFTWARE ARCHITECTURE

The software design is implemented using a layered approach. It is divided into three major layers as shown in Fig. 5:

- Application layer interface
- Software layer
- Hardware layer

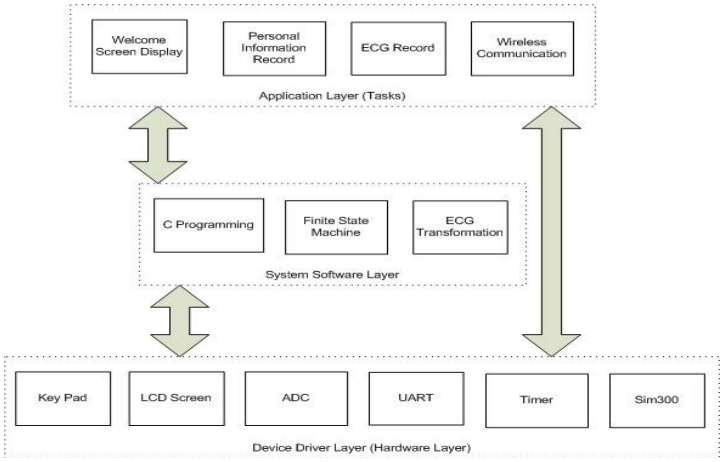

Figure 5. Software Architecture

VI. FUNCTIONALITY

- **Signal Generation:**

LabView simulates the required electrocardiogram which is received as real time output from ELVIS. This analog output is fed into the ATmegaxx microcontroller for analog to digital conversion.

- **Transmission:**

The digital ECG signal from the microcontroller is fed into the modem that triggers GPRS connectivity as soon as it starts receiving the data. The microcontroller is programmed to check for connection establishment and when GPRS connection is lost. It attempts to re-establish the connection automatically. After successful connection establishment, the data is fed to the GSM module that converts it into appropriate data packets by attaching the necessary header fields. Once this is done, the modem is ready for data transmission to the web server.

- **Reception at Server**

MySQL database is used to keep record of the patients and the doctors affiliated with the health monitoring program. The database is designed keeping in focus the following major entities in the system like:

- Patient__Name
- Doctor__Name
- ECG Data
- Doctor__ID

Description of the above mentioned entities

Patient: This entity class handles all clients using the system for their ECG monitoring. The members of this class have the embedded hardware and are present at the client side of the system architecture. The main attributes of this class are: First__Name, Last__Name, City, Country, Contact__Num, User__Name, Password, Serial__Num, Doctor__ID etc.

Doctor: This entity class belongs to the clients using the system to monitor the ECG. These members log in to the website with their set accounts and view the ECG signal of their individual patients. They are present at the server end of the system architecture. Main attributes of this class are: First__Name, Last__Name, City, Country, Contact__Num, User__Name, Password, and Designation etc.

ECG Data: This class contains the ECG record of patients. Its main attributes are: Serial__Num, Data__Value, Time__Reception etc.

Doctor_ID: This entity class contains the list of patients assigned to one signal doctor. It is generated at run time and it is named according to a specific doctor's ID.

For example, for a doctor who has been assigned the ID 134255, this table would be created as Doctor_134255. Main attributes of this class are: Serial__Number__Patient, Disease__Name, Disease__Diagnosis, Check__Up__Date, Next__Appointment etc.

VII. THE USER INTERFACE

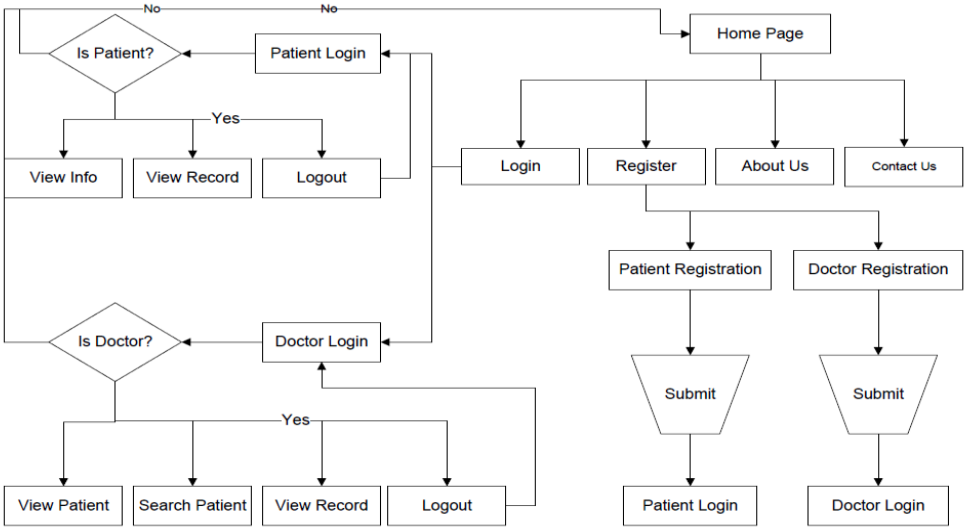

Figure 6. The User Interface - Flow of Website

VIII. DISCUSSIONS

The mobile communication system for telecommunication based home healthcare presented here, provided high reliability and user compliance. Mobile communication system has been used in telemedicine for remote monitoring of patient for a long time [15]. The results regarding the usability of the system in clinical practice from patients and

healthcare personals' point of view showed that the system is easy to use, and there was no significant problem faced. The patients expressed their satisfaction and confidence in using the real-time wireless remote monitoring system. In the same way, the in-charge healthcare personals also expressed reasonably high confidence regarding the application of the real-time wireless remote monitoring system in clinical practice.
The information on current telemedicine programs across the country, upcoming national initiatives, policy, and so on are grouped into following categories [11]:

Pilot projects supported by central ministries of Government of India (GOI)
The major initiative in establishing several telemedicine nodes all over the country is carried out by the Department of Information Technology (DIT), Indian Space Research Organization (ISRO), and the Ministry of Communications and Information Technology in collaboration with the state governments, various premier technical, and medical institutions of India.

Ministry of Communication and IT (MOC)
Some of the successful telemedicine projects implemented by MOC in various states are the telemedicine network in West Bengal for diagnosis and monitoring of tropical diseases, the Oncology Network in Kerala and Tamil Nadu, the network for specialty healthcare access in rural areas in Punjab, Maharashtra, Himachal Pradesh, and the North-Eastern region of India. MOC also established links among the three premier institutions, namely, The Sanjay Gandhi Postgraduate Institute of Medical Sciences (SGPGIMS), All India Institute of Medical Sciences (AIIMS), and Post Graduate Institute of Medical Sciences (PGIMER), which in turn connected to the state level hospitals.

Indian Space Research Organization (ISRO)
ISRO's satellite-based Telemedicine network through Indian Satellite System (INSAT), which started in 2001 under the GRAMSAT (rural satellite) program now includes 315 hospitals: 271 remote/rural district hospitals/health centres connected to 44 superspecialty hospitals located in major cities. 10 mobile tele-ophthalmology units are also part of this network. This has been implemented in the remote areas of north-eastern states of Tripura, Nagaland and in some regions of Karnataka in its tribal belt. District hospitals of Andaman and Nicobar Islands are linked to specialty hospitals in mainland India.

IX. CONCLUSION

In modern day healthcare services, where the health authorities tend to optimize the resources most effectively, it is in many cases an advantage to treat/monitor as many patients as possible at their home. Telemedicine technology can bring revolution to the field of medicine. By using a number of high-speed satellite and terrestrial telecommunication links, centralization and coordination of resources, it has been possible to reach and access more patients (especially in remote areas) and thus achieve the goal of health for all. India has taken a lead in this field among the developing countries. With this project, we can ensure cost effective appropriate health care and reliable diagnosis by competent doctors available to all. In other words, it can be concluded that the designed and implemented real-time wireless monitoring system is generally applicable in clinical practice.

X. FUTURE SCOPE

This system could be made HL7 compliant. Health Level 7 (HL 7) is a global standard for communication of patient data between health institutions. The system can be further developed by adding expert system features like speed variations with moving screen, exact heart rate with analysis, displaying 12 lead graphs, and monitoring ECG wave form on PC monitor. We can enhance the feature of the project by enabling the reception of ECG signals on android devices. It can be accomplished by installing JDBC driver. The system can be made generic (access to all doctors).

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