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Web Based Remote Patient Monitoring System with Integrated GSM

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Abstract— **Remote Patient Monitoring (RPM) has garnered a lot of interest since the various emerging technologies made it possible to think of; and implement such a concept. Remote monitoring concept raises a lot of interesting possibilities, and helps to address different issues continually faced with effective patient administration. Some notable issues are managing patients in remote areas, monitoring (elderly) patients in their own homes and saving hospital bills. The design presented in this paper is unique in creating portable embedded system based on ARM processor that facilitates RPM using wired, wireless communication and cellular technology. The proposed system implements ZigBee interface for wireless communication and GSM for mobile based remote monitoring along with wired web interface. It is observed that, wired interface provides reliability in communication while wireless interface gives flexibility in patient movement whereas cellular interface provides solution for emergency situations.**

Keywords— **Biomedical- sensors, Electronic- Health- Record, GSM, Remote- Patient- Monitoring, vital-parameters**

[1] INTRODUCTION

There have been huge breakthroughs in the world of medicine in the last century, and efforts are continuing to make waves that try to reach the very pinnacle of medical innovation. Medical care now reaches the far corners of the world – rural areas and strenuous terrains being no exceptions. The cost of hospice for a patient and his preference to stay at home (in case of elderly patients) are concerns that are being addressed on multiple levels. With the global population growing at an alarming rate, hospitals tend to become overcrowded, and the notion of staying at your own home and still being tended to becomes very attractive. With the connected web comes the possibility of remote monitoring of patients and tele-consultation facilities.

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It is possible to record and transmit the vital signs of a patient using wireless and cellular technologies. Also, it is said that, "Growing old in a wireless world will mean not just keeping your body healthy but keeping it online" [1]. This helps to monitor the patient continuously, helping to raise an alarm if any of the vital signs cross the threshold value, indicating that the patient is in mortal danger. Such vital signs may be transmitted live, or kept on the record to be used later which is also known as Electronic Health Record (EHR).

Advances in Internet speed has led to physicians sitting at a remote location and still looking at storage intensive patient data [2] with relative ease, like MRI scans, X- Ray images, etc. Such medical images are transmitted over the Internet to the doctor's machine for his perusal, either in real time or asynchronously.

A portable data acquisition and pre-processing module has been developed in [3] for ECG signal analysis, which is connected to a computer (digital processing unit) at remote site via RS-232 interface. Mobile tele-medicine system in home environment has been developed for patient monitoring, where several parameters from patient monitor are transferred to mobile terminal via RS-232 interface [4].

The concept of connecting wireless sensors to the patients in the general wards of the hospital, there by reducing the need for nurses has been discussed in [5]. The sensors in this system form a wireless ZigBee network which transmits the vital parameters to a central location within the hospital premises that helps in the early detection of the deteriorating condition of a particular patient. ZigBee thus helps in hospital management system.

A typical RPM is a three tier system. Each tier is characterized by its location and functionality. First tier of a RPM system is an embedded system consists of group of sensors that perceive signal of interest from patient and then transfer the information to local machine. Tier two is local machine (computer/mobile phone) which allows data storage or provides further processing before transmitting it to some remote location via GSM, internet or some wireless protocols. And the last tier is remote machine where physiological data is observed and analyzed by medical staff.

First tier, Bio-medical sensors come in all forms, wired or wireless which forms Body Area Network (BAN). 'Heart rate' is the number of heart beats per minute; it helps to understand the overall physical condition of the body. Heart rate variability is one of the most promising quantitative indications of autonomic activity [6]. Number of noninvasive methods exist for sensing the human heartbeat such as acoustic (stethoscope or Doppler), mechanical (sphygmomanometer), electrical (Electrocardiogram), or optical. The electrocardiogram (ECG) is the most common test used to assess the condition of the heart. Using bio-potentials status of the heart can be measured. Bio-potentials are electric voltages produced by individual

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cells and can be measured on the skin surface. The Electrocardiogram method is an accurate method which gives the correct heart rate count, but the setup is sophisticated and may require expert assistance to operate [7]. There is also another handy optical technique for measuring the heart rate, which gets its reading from the tiny subcutaneous blood vessels (capillaries) that expand or contract in time with the heartbeat. Any patch of skin is suitable (fingertip, ear lobe, etc.) for this technique.Doctors measure heartbeats by feeling and counting the pulse of blood flow in body parts, such as a wrist, or a fingertip. The system for counting heart rate which is discussed here is designed by measuring alteration in blood volume with each heartbeat by analyzing change in reflected light after manually projecting infrared light on suitable body parts such as fingertip. Fingertip area provides more reflection and less absorption of light [8], so the heart rate is generally measured at fingertip.

These sensors are further processed using microcontroller unit or directly transferred to next tier. Between First tier and second tier communication happens by either wired or wireless way. Two short range communication technologies, Bluetooth/IEEE 802.15.1 and ZigBee/ IEEE 802.15.4 are considered to network the bio-medical sensors. Serial communication using RS-232 protocol provides wired communication. The data transfer between tier two and three is provided using wireless protocols.

At the remote location, doctors or medical staff can monitor the current status of a patient in real-time. By means of an EHR, doctor or physician can monitor a patient in a better way. EHRs are secure and private lifetime records that helps to maintain person's health history and care. They are formed by collecting information from various sources, including hospitals, clinics, doctors, pharmacies, and laboratories. This information is critical for treatment and is accessible only to health care professionals. It includes patient demographics such as medications, vital signs, clinical history, immunizations, laboratory results, and reports of diagnostic procedures. Now a days EHR system is widely adopted by physicians. Data from the National Ambulatory Medical Care Survey shows that about 57% of office-based physicians used EMR/EHR system [9]. EHR based diabetes clinical decision support significantly improved glucose control and some aspects of blood pressure control in adults with type 2 diabetes [10]. EHR based clinical decision support in RPM can help a physician to improve quality of health care and lower health care costs.

This research work proposes a simple, low cost, reliable efficient RPM system that would allow a doctor/physician to monitor patient physiological parameters (body temperature, heart rate, blood pressure and saline level) over internet with simple graphical user interface. The design considers emergency situations using GSM modem. The system is designed for both the scenarios: if a patient is at home, the embedded system will be connected to a local machine via wired web serial interface, and in case patient is in hospital, the embedded system will be connected via wireless serial interface- ZigBee to monitor many patients at a time. The purpose of this design is to simplify remote monitoring of patients while allowing them some mobility.

The remainder of this paper is organized as follows: Section II overviews the proposed RPM system design. Section III elaborates the first tier of RPM which consists of an embedded system. Section IV covers design of software components in local machine and the structure of front end in remote machine. Next, in Section V, the functionality of developed system is discussed with the aid of some results. Finally, the presented work is concluded in Section VI.

[2] PROPOSED RPM SYSTEM

The architecture setup shown in Fig. 1 is divided into three parts: Tier I forms embedded system for vital parameter measurement, Tier II for storage and Tier III is medical network.

The different components that make up the proposed RPM system are shown in Fig. 1. Tier I of said RPM system is a portable device for the patients to monitor their daily health record. It provides convenient method to examine human health by monitoring parameters such as heart rate, body temperature and saline level. These parameters are then processed and converted into readable (digital) form using microcontroller unit-ARM7. The output of this embedded system is connected to a local machine using wired (RS 232) or wireless (ZigBee) interface for storage and information transfer purpose depending on patient convenience.

First tier consists of bio-medical sensors and microcontroller LPC2148. Second tier compromises of ZigBee unit and a computer with RS-232 interface. The first unit of RPM, bio-medical sensors and ARM7 microcontroller forms BAN which will be with patient and second unit would be at some remote location.

An embedded system sends observed vital parameters of a patient to a local machine of tier II, where PHP based web Graphical User Interface (GUI) for RPM system has been designed. The local machine reads the data every few seconds from tier I and stores it in a MySQL database for real time or later retrieval. This local machine with web GUI is connected to the Internet, such that any individual, doctor, medical staff, family member can view the patient's health on web page in real time. The web page showing patient's health record is accessible from any remote unit that is of tier III connected to the internet for remote monitoring. This remote machine can be a PC, tablet, mobile phone, etc.

The embedded system of tier I checks for threshold values of vital parameters of patient, and send an SMS to pre-designated numbers (close relatives, family) in case of emergency using GSM modem connected to ARM7. This is beneficial, in case someone concerned is not monitoring the patient remotely at the current time.The proposed system is simple, economically affordable and provides many features at a time. User friendly interface based on client server architecture is implemented.

[3] TIER I: EMBEDDED SYSTEM DESIGN

First tier of proposed RPM is an embedded system. Various elements that form an embedded system are sensors, microcontroller and wired/wireless protocol components. Many vital signs of a patient that are monitored remotely are body temperature, heart rate, saline level and blood pressure.

Taking a patient's body temperature is an initial part of a full clinical examination. The reason to measure body

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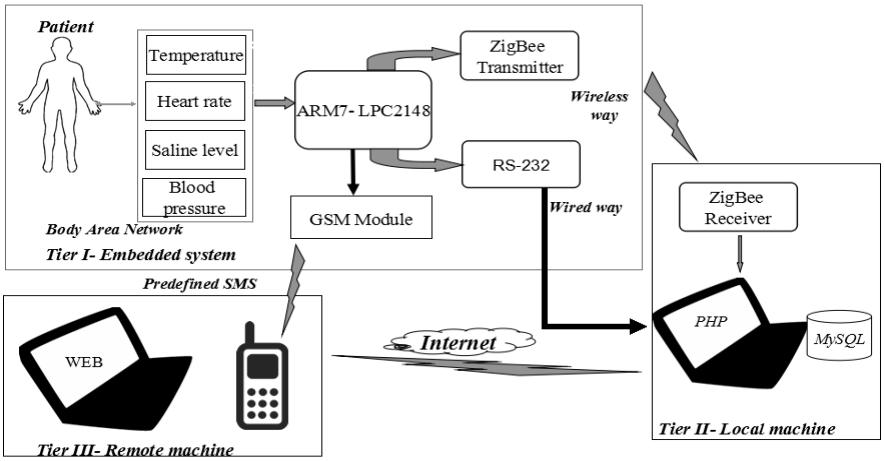

Fig. 1 Proposed RPM system

temperature before starting actual treatment is to observe the changes in body temperature because it is associated with various diseases. And hence it helps doctors to evaluate efficiency of a treatment initiated using body temperature. LM35 temperature sensor is used here to measure body temperature. It is precision IC temperature sensor with its output proportional to temperature in degree Celsius. It provides more accurate reading than a thermistor. The operating temperature range of LM35 is from -55°C to 150°C. The output voltage varies by 10mV in response to every degree celsius rise/fall in ambient temperature; its scale factor is 0.01V/ ^{o} C.

In the proposed work circuit to measure heart rate is implemented and simulated in Orcad Pspice 16.3. Block diagram of heart rate measurement unit is shown in Fig. 2. The designed system has two units: sensing unit and signal conditioning unit.

The sensing unit consists of an Infrared diode and a photo-transistor placed side by side. The infrared diode transmits the light over fingertip which is placed over sensor unit and the photo-transistor receives the part of reflected light. The intensity of reflected light is directly proportional to intensity of pulse.

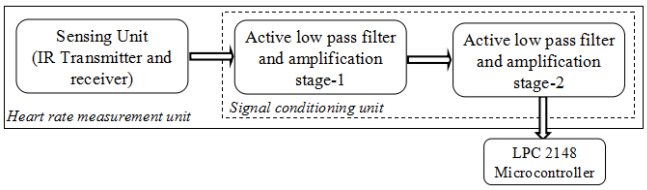

Fig.2 Block diagram of heart rate measurement unit

The signal received is very weak,in the range of 0-10mV and disturbed by higher frequency noise and hence it needs signal conditioning. Undesired noise is removed by means of filters which will block dc components. Class A amplifiers are used to increase the signal components below a definite cut-off frequency. The output after amplification with gain of 100 for each stage-I and stage-II is shown in Fig. 3 and Fig. 4. The comparator stage output in Fig. 5 shows the heart rate signal in digital form.

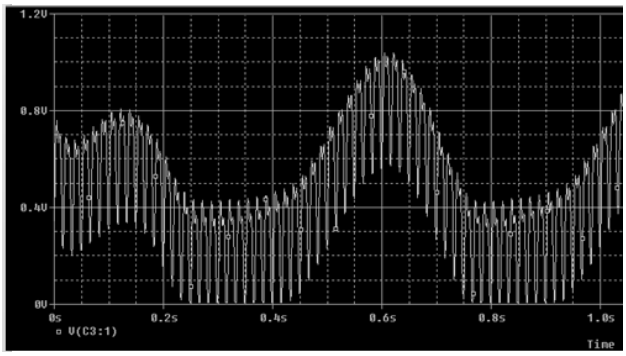

Fig.3 Output after amplification stage-I

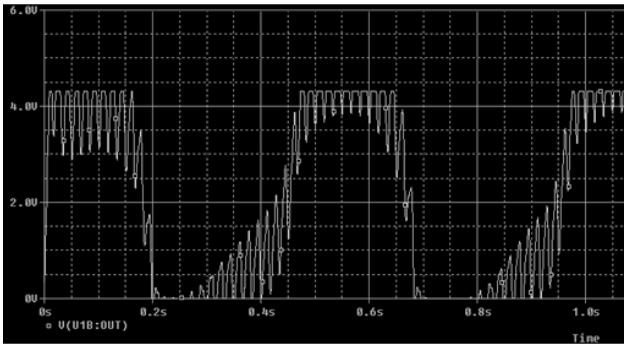

Fig.4 Output after amplification stage 2

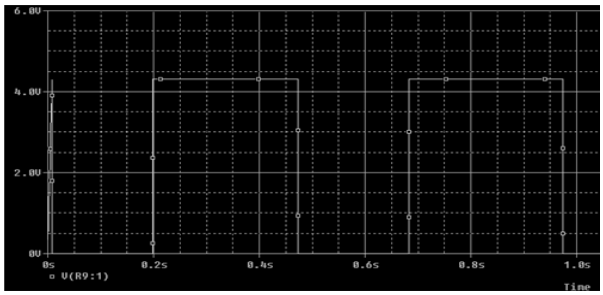

Fig. 5 Digital output using comparator

After noise being properly attenuated, the analog signal from amplification stage-II is fed to microcontroller which converts it into a digital form for counting number of heart beats. An algorithm to count heart rate has been implemented. The Analog to digital converter in microcontroller will first convert the signal in digital form. After converting a signal in digital form it is compared with predefined value, if the measured value is greater than the predefined value, the heart rate count will be incremented.

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This process will last for a minute; in a minute implemented algorithm will count heart rate.

For saline level monitoring two wires are connected from saline level bottle. One wire is grounded and other one is connected to microcontroller unit which will check the status of saline level.

The designed RPM system uses different biological sensors and both wired and wireless technology to monitor vital parameters providing real time health status of a patient. The RPM system is also providing alerts to patients or his relatives via SMS. The data rate of each sensor represents a hard real-time time threshold. If an RPM system can not process incoming data as quickly as it arrives, the interpretation of patient health will gradually lag behind than actual status [11]. One solution to address this issue is to select real-time operating system (RTOS) for a given application. RTOS uses preemptive scheduling based algorithm.RTX RTOS is used with LPC 2148 microcontroller.Tasks are allocated for the user interface (serial port) and the sensor in order for them to work in the background.

The next part discusses the structure of second entity of the system, a Local machine and last entity, a Remote machine.

[4] TIER II: LOCAL MACHINE

In remote monitoring of a patient the general assumption is that a patient is located at home and hence remote monitoring is required. Irrespective of the location of the patient, the hardware used for monitoring the health of the patient is attached to his/her body. A personal computer is placed at his bedside which functions as a local machine, that will capture vital parameters received from the embedded system via wired or wireless serial interface. This information is stored in a database. It is after this step that the remote monitoring of the patient is possible. Once the data is stored in a database, it is made accessible over the Internet. Now a doctor at some remote location can view this data on his/her computer. A local machine provides WWW service to the client machines (doctor's machine at the remote location).

The local machine runs a service, also known as data monitoring service which monitors the port - where an embedded system is attached to which the patient is connected. This service collects the vital parameters via the port, and stores it into the database. Another service, also called as data provider service will serve this data from the database to the clients requesting the data. This data is provided by rendering the values into dynamic web pages, and serving those pages to the requesting clients. However, authentication of clients is a mandatory pre-requisite before the web server handles the requests from the clients. Therefore, the doctor at the remote location will have to access the web server by providing his credentials. Upon authentication, the web server will start serving the dynamic web pages with the relevant data and send it to the client machine. Clearly, the data from the database varies at different times, and consequently the pages serving this data have to be dynamic in nature. PHP is used to create such dynamic pages. PHP is free, open source and a server-side scripting language. Data monitoring service will store the vital parameters in MySQL database.

The database tables have to be created before any data storage is done. Also, the patient profile has to be created and stored into the database before any values are captured from an embedded system attached to the patient's body. Once the patient's profile and the doctor's credentials are created, the system is ready to accept the patient's vital signs and store them into the database.

[5] TIER III: REMOTE MACHINE

The last entity of the proposed system is the remote machine which provides access to a patient's EHR using the Internet. The person sitting on the remote location is a doctor or a health professional who will log in to system using the credentials already given to him. An administrator can log in to the system either from the local machine itself (tier II) or from a remote location.After the administrator logs in a dashboard is shown containing options on the top and left navigation menus as shown in Fig. 6. The top navigation menu consists of options to add a new doctor, add a new patient, view the administrator profile, change the administrator password and log out. The left navigation window consists of links for doctor's page, patient's page and back to the dashboard. The administrator can add, update and delete new patients and doctors as required. He can also view the records of all doctors and patients in the system as shown in Fig. 7. The actions of viewing, updating the details, changing the password and deletion are available to the administrator for each doctor record.

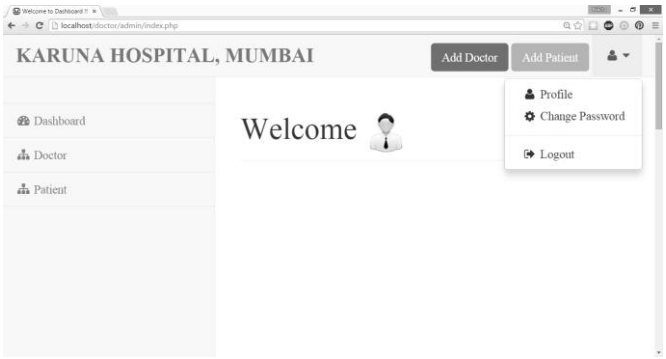

Fig.6 Administrator Panel

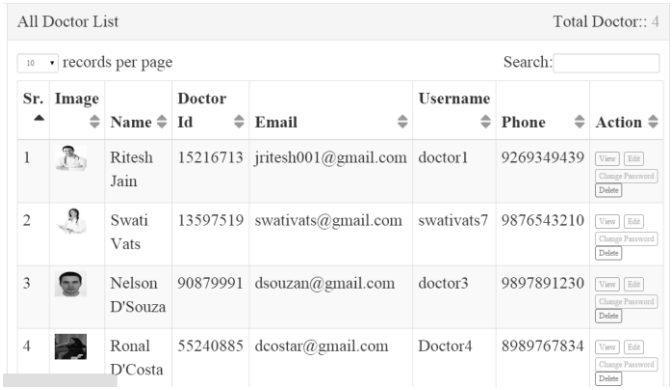

Fig. 7 Doctor list window

After click on 'Edit' option, an administrator can edit doctor's profile as shown in Fig. 8. Likewise an

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administrator can update patient's profile.

Fig. 8 Update doctor's profile window

Fig. 9 Patient list window

Doctor can see a list of their assigned patients' records in their page as shown in Fig. 9. With the list of patients, for every patient there is a separate option provided to a doctor, such as to view all the details of a patient, emergency numbers and health records attached.

Fig. 10 Electronic health record of a patient

After selecting a 'view' option, the doctor can view the profile that is an EHR of a corresponding patient. EHR provides patient demographics details as shown in Fig. 10, with name of a patient as 'Ankit Jain'. A separate column in the right side of the page shows the readings of the vital parameters in real time. This patient page will automatically refresh the content of vital parameters with every minute, so that doctor can view very recent data. On the left side of a patient EHR, there is box provided which will indicate current health condition. The page in Fig. 10 is showing the health status of a patient as 'stable'. This health status is updated if any vital parameter exceeds the normal range.

One more important feature is added in the system which shows medical records of a patient. On click of 'Medical Records' option it shows all the medical reports such as X-ray reports, MRI scans, blood reports and prescriptions as shown in Fig. 11. This helps the doctor to look at storage intensive data with relative ease. Also the graph in Fig. 12 on the patient page shows reading for heart rate and temperature.

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Fig. 11 Medical records of a patient

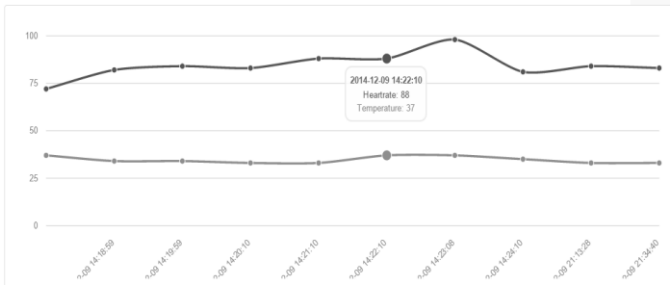

Fig. 12 Vital parameters in graphical form

[6] CONCLUSION

The proposed RPM system with integration of GSM together with the web, provides a low cost technical solution for connecting an expert physician at a remote location with a possibly elderly patient bedridden at his home. A system at the bedside of the patient is the gateway between the hardware connected to the patient's body and the Internet. Data is processed and stored locally, which is made accessible to the physician through an installed web server. In case the doctor is offline, an emergency system is in place, which will send an SMS to all pre-stored numbers; family members and the doctor. Most of processes in the system provide automatism that is with minimal patient interference. Reliability is always a concern in remote monitoring system, it is provided by means of two different way communications with medical staff. An EHR provides real-time reading of vital parameters along with patient demographics, which will help in patient health diagnosis and in critical health conditions. Future scope of the paper should consider wireless body sensor network to transmit data, so as it will provide patient movement.

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