Health Monitoring and Logging System for Patients using Wireless Standalone Network

Pramod Kumar S, Narendra T.V, Vinay N.A
Kalpataru Institute of Technology, Tiptur,
Karnataka, India

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Abstract— Telemedicine (health-care delivery where physicians examine distant patients using mobile communications technologies) has been heralded as one of several possible solutions to some of the medical dilemmas that face many developing countries. In this paper, we propose a wireless stand-alone novel approach to patient health monitoring. The embedded system design integrates the monitoring of three biomedical parameters into a single personal medical device. The three parameters are: body temperature, blood pressure and heart rate. The goal of this work is to build a compact and cost-effective monitoring system. The device is developed and implemented based on the existing industry standard communication network and patient monitoring software, application are developed to store data that can be used for real time monitoring and later downloaded to a physician’s workstation for analysis and diagnosis. It specifically targets assisted-living residents and others who may be benefited from continuous remote health monitoring and decision support system.

Keywords—Telemedicine, Global System for Mobile communication (GSM), Short Message Service(SMS), Wireless technologies, Patient Monitoring Systems, Intelligent Decision Support System (DSS), Central monitoring

I. INTRODUCTION

In healthcare practice, physicians have to monitor more than one medical parameter for patients that are either hospitalized or leading their normal daily activities at home or at work but in need of constant medical care.

The traditional way of providing telemedicine services is to transmit biomedical signals from a patient to a hospital using “landlines”, such as the PSTN and integrated services digital network [1]. While examine the current state of telemedicine in developing country, India. Telemedicine has brought a plethora of benefits to the populace of India, especially those living in rural and remote areas (constituting about 70% of India’s population)[2]. Telemedicine diffusion makes patient’s in remote areas are diagnosed and treated for numerous medical conditions proves to be more economical, beneficial and effective. It will helps country like India, with an exponentially high population growth rate and a historically poor health-care delivery system.

A. Need of Telemedicine

Very few medical facilities exist to serve the large population that resides in the villages. India has 80% of its main health-care centers located in cities that host only 30% of the population, these percentages reveal a dismal health-care scenario where only 20% of India’s quality health-care facilities center to 70% of Indians confined to rural communities.

According to survey [2], India’s rural population is more vulnerable than its urban counterpart based on three particular reasons: late discovery of ailment, transport time to urban health care facilities, and inexperienced primary health-care providers in rural areas. The rapid growth of mobile communications technologies in India offers the potential to address these concerns and to save the patient extra cost associated with treatment, such as travel and other living expenses.

B. Wireless Telemedicine

The adoption of mobile technology has led to new m-Health applications in health-care provision [3], as shown in fig.1. Although face-to-face consultations between a clinician and a patient will never be replaced, there are medical cases that can be managed more efficiently by adopting wireless Telemedicine, such as emergency and rescue situations, and sport science physiological measurements etc.

Thus medical services can now be delivered to any location within the coverage of cellular networks. Wireless Telemedicine can be categorized in terms of the technology usage, namely 1) Satellite link, 2) “Short-range” networks and links, and 3) Mobile cellular networks (e.g., GSM, GPRS, 3G).
Figure 1: Mobile telemedicine system.

The use of satellite communications requires expensive equipment, dedicated links, and skilled operators. Wireless local area networks (LANs) [4], [5] and short-range radio-frequency (RF) Transceivers, as used in hospitals [6], [7], cannot be used for truly mobile applications. Unlike GSM cellular network, which is adopted hear [8]. Before selection of GSM we designed and implemented the system using RF and Bluetooth communication techniques. For RF TLP and RLP series with having 434MHz frequency and ASK modulation. Bluetooth with Gaussian frequency-shift keying, with transmission at a rate 1Msymb/s on one of 79 channels with 2.402-2.480-GHz band. In RF we face noise and in Bluetooth driver as well distance coverage problem. To allow world-wide connection, a mobile cellular net work is also needed; initially this is GSM, while in the future it could be 3G. A comparison of security and encryption for wireless technologies is shown in Table 1 [3] - [16]. The methodology is given in section II, whereas section III shows the system design includes hardware and software design. A prototype for the system was successfully built and tested as explained in section IV.

Table 1: Security and Encryption for Wireless technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Security/Encryption</th>
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<tbody>
<tr>
<td>Bluetooth</td>
<td>128-bit authentication key and 8-128 bit encryption key [1].</td>
</tr>
<tr>
<td>WLAN</td>
<td>Wired equivalent privacy (WEP) protocol with RC4 Encryption algorithm [9], [14].</td>
</tr>
<tr>
<td>GPRS</td>
<td>Three tier security with A3 algorithm for user authentication, A8 Ciphering Key Generating Algorithm and A5 Ciphering Algorithm for Data Encryption [9], [13].</td>
</tr>
<tr>
<td>3G</td>
<td>f8 UMTS Confidentiality Algorithm and f9 UMTS integrity algorithm [1].</td>
</tr>
</tbody>
</table>

II. METHODOLOGY

The methodology includes consideration of a combination of wireless techniques, particularly the exploitation of cellular networks, types of clinical data for transmission and system memory storage.

The architecture of the patient monitoring system is shown in figure 2. The system presented here contains the following links:
1. Monitoring device connected to processing unit (computer) using RS232 serial cable.
2. GPRS to base station and to other mobile telephones.
3. LAN to clinicians.

A. Wireless Technology

The system is designed after a careful consideration. The technical, data security, practical and economical aspects were taken into consideration to achieve a suitable system design and set-up. In order to select the most appropriate technology for the system realization, properties of the existing modern technologies such as Bluetooth, Short-range radio-frequency (RF), GSM and GPRS have been investigated [1], [9]-[11], as shown in Table 2.

In order to reduce the complexity of the mentioned system and to investigate the applicability in the first step a prototype GSM based telemedicine system was designed and implemented, which is presented in this article.

It is essential that patient’s received data is archived and accessible to clinicians when required. The data includes the international Mobile Subscriber Identity number, which is unique to the Subscriber Identity Module card in the telephone. By using a Password, a clinician log on to access that patient’s database.

The GSM/GPRS modem SIMCOM SIM300 module is used here for communication. SIM300 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz. It features GPRS multi-slot class 10/ class 8 (optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4 [12]. The project is mainly focused on the use of GSM, but with the evolution of cellular networks from the second generation such as GSM, to GPRS and enhanced data rate for global evolution (EDGE).
Then to 3G, more services can be designed and modeled for next-generation mobile telemedicine applications. The maximum theoretical data rates of these technologies are presented in Table 3. GPRS represents an enhancement of GSM. Adoption of GPRS is relatively new [1], [13]. Its major advantage is that it enables the transmission of both data and speech.

B. Clinical Data and Sensors

The patient’s health status, the most important parameters that determine the condition of the patient under observation are Body Temperature (BT), Heart Rate (HR) and Blood Pressure (BP). This project makes use of temperature LM35DZ sensor to sense temperature. Blood pressure and Heart beat input to the system is simulated input since actual sensors are costly and the main aim of the project is to bring out the idea that how the control system can be designed to monitor the patient health status using telemedicine technology. BP and HR are simulated by using two square trimming potentiometers.

III. SYSTEM DESIGN

A. Overview of the Implemented System

The principal sketch of telemedicine system is as shown in Fig.3. The project work includes following modules:

1. The hardware design for data accusation.
2. Hardware design for data manipulation and transmission.
3. Hardware design for data reception.
4. Software design for graphical user interface presentation.
5. Software data-base management system with authentication.
6. Reliability enhancement techniques, for enhancing the reliability of the system this include redundancy management techniques, and implementation of the system using different design methodologies.

The implemented system includes features like decision support system (DSS) and central monitoring unit.

An intelligent decision support system based on established clinical guidelines is a key component of the most recent idea of monitoring system. This DSS uses agent technology and provides clinicians as well as patients and there relatives with relevant medical information. Its suggestions are based on medical knowledge embedded into the guidelines, on input from the treating physician, on the patient’s history that is retrieved from the electronic healthcare record. Vital parameters gathered from sensors and transmitted wirelessly, as well as patient feedback are both also used as input for the DSS. If the patient’s state is identified as a potentially critical one, an alert is generated and propagated, triggering local reactions [3]-[5].

Centralized patient monitoring provides the networking of several bedside patient monitors with a central monitoring station.

B. System Architecture

The system is mainly divided in to three units:

1. Acquisition unit.
2. Management unit.
3. Central monitoring unit.
The explanation of the system design is given from input to output of the implemented system. The development of a monitoring system requires an appropriate analogy source. In reality, the vital signals originate from human parts and are measured with electrodes or catheters.

Figure 3: A principal sketch of telemedicine system

The development of a patient monitoring system requires a reproducible and easy-to-control signal source. Therefore, an artificial patient was designed and implemented in order to generate the required vital signal. The sources of biophysical readings are taken from sensors that are interfaced to the embedded system. For body temperature we used LM35DZ that will sense temperature in Celsius. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The features of LM35D is linear + 10.0 mV/°C scale factor (i.e. for every 1°C change it will represents in 10mv variation)[15]. Other two body parameters Blood pressure and Heart beat are simulates by Square Trimming Potentiometer (3296 W - 1 - 10³). It is a variable 10K Ω trimming potentiometer, it require 25 trimming rotations for full-scale reading. If we rotate clock wise, the wiper position will change, this makes linear change in output voltage of pot, and then V_{out} is fed in to the input channel 6 of the ADC0816 for measure Heart beat. Another pot V_{out} is fed in to the input channel 11, for measure Blood pressure.

C. Acquisition unit.

Each of the sensors responsible for measuring these medical parameters must be directly interfaced to the device’s embedded system-based platform. Additional to this, the device must have the ability to store the measured medical parameters for a predefined period of time (called the trial period).

Table 2: Wireless Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Data Rate</th>
<th>Frequency</th>
<th>Max. Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>IrDA (Infrared)</td>
<td>4Mbps</td>
<td>IR Spectrum</td>
<td>2m</td>
</tr>
<tr>
<td>HomeRF (Home Radio Frequency)</td>
<td>1Mbps</td>
<td>2.4GHz</td>
<td>&lt;40m</td>
</tr>
<tr>
<td>Bluetooth IEEE 802.15(Personal Area Network)</td>
<td>723 Kbps</td>
<td>2.4GHz</td>
<td>10-100m</td>
</tr>
<tr>
<td>WLAN (Wireless Local Area Network)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IEEE 802.11a</td>
<td>54Mbps</td>
<td>5GHz</td>
<td>&lt;600m</td>
</tr>
<tr>
<td>IEEE 802.11b</td>
<td>11Mbps</td>
<td>2.4GHz</td>
<td></td>
</tr>
<tr>
<td>IEEE 802.11g</td>
<td>54Mbps</td>
<td>2.4GHz</td>
<td></td>
</tr>
<tr>
<td>MAN(Metropolitan Area Network)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IEEE 802.16(line-of-sight)</td>
<td>&lt;75Mbps</td>
<td>10-66 GHz</td>
<td>5-10km</td>
</tr>
<tr>
<td>IEEE 802.16a(non-line-of-sight)</td>
<td>&lt;75 Mbps</td>
<td>2-11 GHz</td>
<td></td>
</tr>
<tr>
<td>LMDS(Local Multi-point Distribution Service)</td>
<td>34-38Mbps</td>
<td>26 GHz</td>
<td>3-5 km</td>
</tr>
<tr>
<td>DECT(Digital Enhanced Cordless Telecommunication)</td>
<td>736 Kbps</td>
<td>1.88 GHz</td>
<td>300-2500m</td>
</tr>
</tbody>
</table>

Table 3: Mobile Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Maximum Theoretical Data Rates</th>
<th>Frequency Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM</td>
<td>9.6Kbps</td>
<td>900/1800/1900MHz</td>
</tr>
<tr>
<td>GPRS</td>
<td>141.2Kbps</td>
<td>900/1800/1900 MHz</td>
</tr>
<tr>
<td>EDGE</td>
<td>384Kbps</td>
<td>900/1800/1900 MHz</td>
</tr>
<tr>
<td>3G/UMTS</td>
<td>2Mbps</td>
<td>1885 MHz – 2200 MHz</td>
</tr>
</tbody>
</table>
These values must be transferable through a standard networking interface from the device to a computing device (PC). For this a small embedded device is designed with several considerations are taken into account. First, an embedded system-based platform was needed with enough memory to hold the medical parameter readings over an extended period of time. Second, the device must be accurate to make precise conversions from the voltage readings to meaningful biophysical values. Third, the device must have the networking options needed to transfer data into a computing device. The core area of the board does not exceed 14*8 cm in size. The board contain system, Atmel™ AT89S8252 microcontroller unit (MCU), it’s an 8-bit microcontroller with several on-chip peripherals and modules [14]. Our system main required features are, MCU has 8K Bytes of In-System Reprogrammable Downloadable Flash Memory, 2K Bytes EEPROM, 256 x 8-bit Internal RAM Low-power Idle, Power-down Modes and it supports programmable clock out and serial communication [15].

The sensor output voltage which is linearly changes with time, is given to the Analog-to-Digital (A/D) conversion model. Here ADC0816 8-Bit μP Compatible A/D Converters with 16-Channel Multiplexer is used. This ADC having 8bit resolution with Conversion Time is 100 μs [15]. Using Keil software (IDE for microcontroller) program the MCU [16]. The device was programmed such that it converts samples of analog signal data from the sensor voltage terminal into a series of hex values.

D. Management unit.

In order for these values to be displayed to physicians for patient diagnosis purposes and also for communication, software application that is compatible with the device must be developed. Developers and system engineers must have the ability to upgrade the device’s firmware as needed or upon request of application that is compatible with the device must be developed. The performance of the device is also of major importance for its users. It should have the ability to render a Body temperature level reading in a period that does not exceed 30 seconds from the time a patient switches sensor. Another set of functional requirements like GUI for monitoring display and GSM communication has been specified in the customized E-Med software application.

The management unit consists mainly of a fixed personal computer, and the management program i.e. customized E-med software application. The management unit normally located nearby patient and provides a user-friendly interface for telemonitoring a patient’s vital-sign signals. The management terminal can receive patient’s physiological data from the acquisition unit via the serial communication with having 9600 Baud rate. For management unit E-med software is implemented on a Windows XP platform and developed by the Microsoft Visual Studio 2005 windows application builder using C# language . The application software receives the data from the acquisition unit, displays BT, HR and BP waveforms on the screen, check for parameters criticality and stores the data in the local database. In this work, a MS-SQL database system is set up to manage the raw data of BT, HR and BP, patients’ information for doctors’ diagnosis in a real-time. The database can also be accessed from authorized terminals through GSM network. Moreover the vital-sign signal can be delivered in real-time to a mobile platform for sharing data. The waveforms are plotted in a 723 X 373 pixels window, which plots three parameters in a same window with different color-code. The plot is done by amplitude on Y-axis and time on X-axis. Graph is refreshing for every 6 point values of each sensor parameters. The program also supports the selection of leads, the replay of waveforms, analysis of raw data and the scaling of amplitude and time.

Management unit have an alarm setting window which enables the medical staff to set up the alarm threshold of BT, HR and BP individually according to the physiological status of the patient this is taken care by DSS functionality of the E-med software. When the recorded vital signs are beyond the present limits, the mobile unit would trigger an alarm automatically by sending warning SMS’s to the monitoring station and a warning window will pop-up the screen.

E. Software design

The software program is developed by using Microsoft visual C#, and was installed in PC to monitor the signals. This software design includes communication between patient and physician using GSM/GPRS modem. GUI design is as shown in Fig.5. The application must have the ability to poll the stored medical parameters by establishing a communication link with the monitoring device. It should also have the ability to read an identification code unique to each Patient. This ID is used to differentiate between the different patients devices when several patients are monitored during the same period of time. After reading this information, the application must have the ability to store the medical parameter readings into a patient-information database. In this work, Microsoft SQL server database system is setup to manage the raw data of patient’s information. The attributes for each patient record are the patient’s name, age, symptoms and diseases, and a unique ID that serves as the public key.

IV. SYSTEM TESTING

The patient monitoring system has been tested at two levels before a final system test was made, in order to make sure that the unwanted serial data was dropped and meaningful values for Body temperature, heart rate and blood pressure levels were displayed. This test includes displaying medical parameter values to make sure they were realistic. Figure 4 and 5 illustrates how the three parameters measurement function was tested by comparing values generated from the monitoring device with the values produced by sensors. Integrity tests includes E-med software application test. The GSM communication protocol was tested later and verified with the device connected to the serial port of a PC.

The current design relies on the RS-232 serial wire line connection to upload data from the monitor device to the nearby PC. In computer process the received data and maintain parameter database. If sensor value is above or below the threshold value, then E-med software itself trigger the alarm by sending via short messaging system (SMS) message using GSM modem to the Hospital network, physician and also to well-wisher.
Figure 4: Layout of the acquisition unit with instant results.

The end-to-end monitoring system architecture is shown in Fig 1. A communication protocol is devised for this purpose, as shown in figure 7; the monitoring device takes patient readings and stores them to the computer. Normal readings are periodically reported to physician’s monitoring system in the form of an SMS via the general packet radio service (GPRS) modem. The GPRS modem is interfaced with the computer via the standard RS-232 serial port. GSM technology uses Time Division Multiple Access (TDMA) with 8 time slots per frame hence supporting 8 simultaneous users at any given time [8], [17].

A persistence time is allotted before reporting an alert SMS message to the physician’s monitoring system. This persistence time is necessary to avoid any unnecessary reaction to a sporadic reading that is not representative of the actual patient health condition. The E-Med software analyzes the reported data and correlates it to the patient’s known illness, the previously reported data, and the time of the day the abnormal readings were reported, and may choose to instruct the patient, or alternatively the care-giver, again through an SMS message to take the necessary actions that can be lifesaving before healthcare professionals intervene. This novel design allows monitoring several patients at the same time.

Figure 5: communicate and case analysis form with plotting all 3 parameters.
The complete system is tested in a room. In the test scenario patient unit contain acquisition as well as management unit. In patient unit (acquisition and management unit) one computer, GSM modem and vital-sign signal generate board. In other end (central monitoring unit) two computers with LAN, in that one computer is connected to another GSM modem. Three Cell phones for care-giver scenario (for mobile computing).

The monitoring and data reporting take place nearly real-time. This relieves incapable patients from needing to go in-person to the physician’s office. It also gives the healthcare professionals the ability to react promptly to life-threatening situations, in a proactive way that involves the patients themselves.

**V. CONCLUSION**

Telemedicine can open a world of health-care delivery by building clinical bridges between patient and available health care. The main contribution of the work described above is to demonstrate the present scope and future potential of mobile communications in telemedicine. A modular structured GSM based mobile system is presented to illustrate the concept. The unit carried in patient scenario is acquisition and management unit with a GSM modem. The prototype version is designed to transmit digitalized signals to a hospital scenario (central monitor) unit via the GSM communication network. This allows the transmission of medical data in a real-time. As evidenced by the literature outlined in chapter 2, the system is expected to become a novel approach aid to monitoring and diagnosis as well as a convenient means of communication. The main benefit of the system from the signal interpretation point of view is in the design of the central monitor. The central monitoring allows the real-time access of bedside data via standard hardware and software interface. We believe this system design will greatly enhance quality of life, health, and security for those in assisted-living communities.
A feature telemedicine provides to adopt mobile GPRS, 3G standards, which allow much more data to be transmitted, like audio and video signals.

REFERENCES


