Notice of Violation of IEEE Publication Principles

"Patient Data Management Systems—Periodic Model using GSM"
by Anup B. Goutham, Manjunath Iyer, and Rajiv R.
in the Proceedings of the Fifth International Conference on Digital Information Management (ICDIM), July 2010, pp. 519-524

After careful and considered review of the content and authorship of this paper by a duly constituted expert committee, this paper has been found to be in violation of IEEE's Publication Principles.

This paper contains portions of text from the paper(s) cited below. A credit notice is used, but due to the absence of quotation marks or offset text, copied material is not clearly referenced or specifically identified.

"Mobile Messaging Services-based Personal Electrocardiogram Monitoring System"
by Ashraf A. Tahat
in the International Journal of Telemedicine and Applications, Vol 2009, Hindawi
2009

Patient Data Management System – Periodic Model using GSM

Anup.B.Goutham
Department of Electronics and Communication
RNS Institute of Technology
Bangalore, India

Manjunath Iyer B.S , Rajiv R
Department of Electronics and Communication
Yellamma Dasappa Institute of Technology
Bangalore, India

Abstract— **In monitoring a patient's real-time vital signs through Body Area Networks (BAN), rich data sources are communicated to medical practitioners. It is essential that data is delivered in timely-context aware manner. In this paper a system is designed for patients with cardiac disorders, with an emphasis on the design of the sensing device and communication scheme chosen. Several existing wearable physiological devices (Patient Sensing Device - PSD) used in the Healthcare systems are bulky in design and are not flexible and comfortable for the elderly patients. Presented is a unique flexible, as well as detachable PSD for the comfort of patients. Also discussed is a model for transmission, storage and processing of patient related data, which ensures periodic logging of patient data without saturating communication networks. A proof of concept prototype has been developed and implemented to enable transmission of Electrocardiogram (ECG) signal and body temperature of a patient, which can be expanded to include other vital signs. Communication between a mobile smart-phone and the ECG and temperature acquisition apparatus is implemented Bluetooth. The presented Data Management System – Periodic Model (DMS - PM) is designed to manage wireless interface of sensor units with the patient database at a Medical Service Provider (MSP) through a Personal Digital Assistant (PDA) or a Smart phone making use of the existing GSM network.**

I. INTRODUCTION

The number of elderly people is rapidly increasing around the world. The worldwide population of people over 65 years old will reach 761 million by 2025[1]. Healthcare costs can be reduced by providing for more efficient utilization of physicians, shortened stays, reducing the skill level and frequency of visits of home-care professional, promoting health education to all and reducing hospital readmission rates. Providing acute care and cardiac surgery in the so called golden hour can save lives. Therefore, patients who are at risk require that their cardiac health to be monitored periodically whether they are indoors or outdoors so that emergency treatment can be given if problems arise. Elderly people admitted to hospitals for cardiac disorders is the highest number is comparison with any other disorder and it is the problems related to heart which are highly critical and needs an immediate attention. The Healthcare system presented here enables medical professionals to remotely perform real-time monitoring, early diagnosis, and treatment for potential risky disease. Furthermore, the medical diagnosis and patient consultations can be delivered via wireless channels. Thus, the healthcare system presented can provide a cheaper and smarter way to manage and care for patients suffering from cardiac diseases.

Conventional telemedicine systems using Public Switched Telephone Network (PSTN) land lines are already available to enable a doctor to monitor a patient remotely for home care or emergency applications. Many concepts using the internet have been proposed with continuous data logging from the patient site to the hospital site through internet. The mobile phone has been recognized as a possible tool for such systems since it became commercially available, and in the past few years, some parties have shown that with a bio-signal acquisition unit connected to a notebook computer, which interfaces to a cellular phone equipped with a built-in wireless modem, vital signs can be transmitted from an ambulance to a hospital in a store-and-forward mode [7, 8] or in real-time mode [9].

In this paper, we describe a system based on mobile messaging services, namely, Short Messaging Service (SMS), which is an integral part of the original 2G GSM cellular system and subsequent generations, and Multimedia Messaging Service (MMS), which became available as part of the 2.5G cellular technologies and onward. This system transfers a patient's Electrocardiogram (ECG) signal and body temperature and can also be expanded to include other vital signs. The motivation to use mobile messaging services is that not only does it provide an alternative means of transmission in a cellular communication system but it is a more versatile and convenient option since all new phones are SMS and MMS capable. We use the patient site PDA for a continuous monitoring and send a report of this to the data base at the hospital or medical service provider (MSP) site at regular intervals. In case of emergency, the concerned doctors, as well the MSP are alerted through SMS and the patient data

978-1-4244-7571-1/10/$26.00 ©2010 IEEE

is logged into the data base at very short intervals for a continuous monitoring.

II. SYSTEM CONCEPT

The proposed Data Management System – Periodic Model (DMS–PM) architecture is shown in Fig.1. A creative visualization can be seen in Fig.2. The patient (client) and the health-care professional can be located anywhere in the globe where there is 2G cellular network coverage. The patient's ECG, body temperature, and other vital-signs are acquired by the system on the patient himself which and is forwarded to a health-care professional in a periodic manner and in case of any anomaly; depending on particular patient's case.

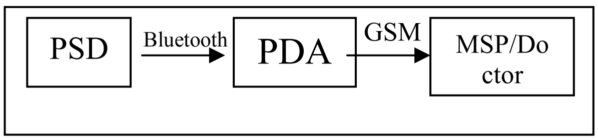

Figure.1 Basic architecture of DMS-PM

The primary purpose is to monitor patient's cardiac activity for problems such as an irregular heartbeat or arrhythmia that require close monitoring or that occur intermittently. The signal acquisition process is performed by attaching the ECG electrodes (three in the present setup) to the patient's body at designated places as is normally done in a typical single-lead ECG setup, with an Infrared temperature sensor with any of the ECG electrodes. The ECG signal and temperature acquisition unit acts as a temporary storage for the acquired ECG signal and temperature readings; then it processes the patient data and communicates with the smart mobile phone via a Bluetooth transceiver. The mobile phone in-turn is tasked with displaying relevant simplified data related to ECG signal before it is sent to the health care professional. This could be done by sending SMSs that contains the ECG samples and a temperature reading if only 2G cellular network coverage is available. Additionally, the received data on the smart-phone is written continuously to the secure digital (SD) memory of the smart-phone for future retrieval and analysis.

Fig.3 gives a structured or layered description of the DMS-PM architecture. When the MMS or SMS message reaches their destination mobile phone (or PDA), it is displayed directly on the screen of the medical professional. These signals or data is periodically logged into the Medical Service Provider database in the form of images of the ECG or discrete values of the ECG plot, which is again plotted in

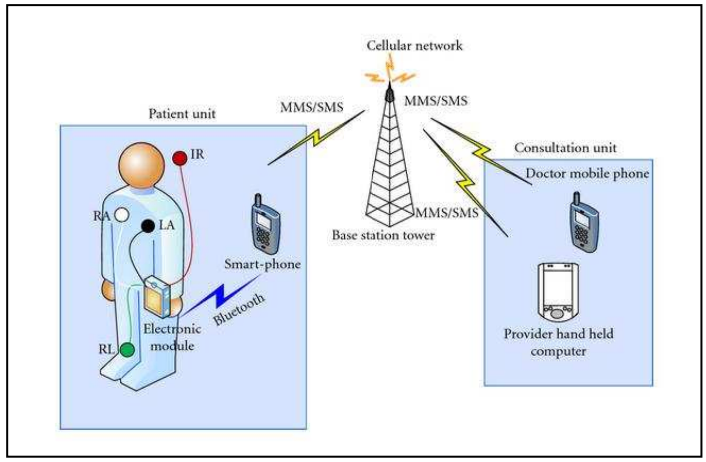

Figure.2 Visualization of DMS-PM

the MSP site server which is equipped with GSM modems for data reception and appropriate software to maintain the patient database.

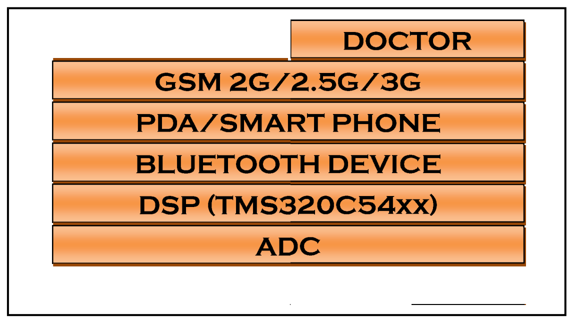

Figure.3 Structure of DMS-PM

III. PATIENT SENSING DEVICE (PSD) UNIT

The patient unit is comprised of the ECG signal and temperature (vital-signs) acquisition module and a smart mobile phone. The architecture of the signal acquisition, conditioning and transmission circuitry is shown in Fig.4 and the flow of operations in Fig.5. The DSP acquires the amplified and conditioned signals and then performs the necessary processing and interface with the Bluetooth transceiver.

A. Ecg Leads

The ECG is a graphical representation of electrical activities of the heart. The resulting heart dipole vector is used as a source for the ECG signal, which is the spatial sum in space of all distributed dipoles in cardiac tissue. A normal electrocardiogram with its characteristic patterns and significant points and intervals is shown in fig (4).We feed the signals from the three ECG electrodes, Left Arm (LA), Right Arm (RA), and Right Leg (RL), into the inputs of the designed instrumentation amplifier conditioning circuit of an overall gain of 800. The single-channel ECG signal that is fed into the microcontroller is composed of Lead-I (i.e., LA, RA), which is the lead most often chosen for cardiac monitoring.

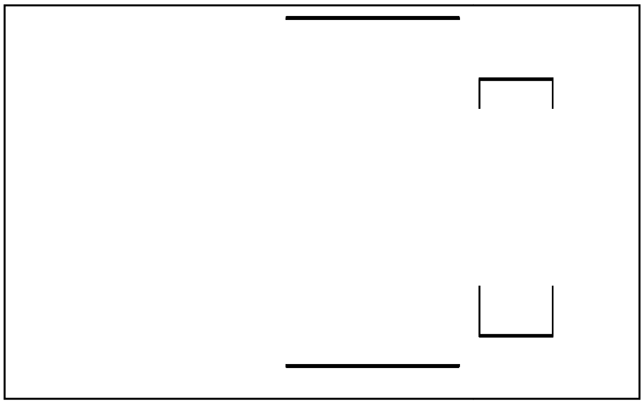

Fig.4 Signal Acquisition Module Architecture

The signal is band pass-filtered with a frequency range from 0.15 to 75 Hz. The ECG derived from the surface bears frequency components up to a maximum frequency of 100 Hz, but most of the spectrum is concentrated below 75 Hz.

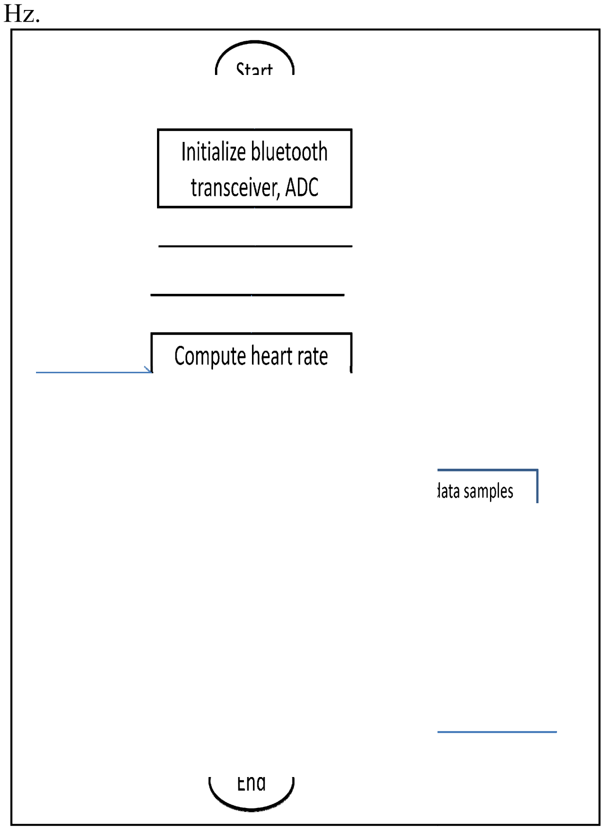

Fig.5 Flow chart representing program in the DSP

B. *Body Temperature Sensor*

A special rapid response, low-cost, integrated, noncontact, Infrared (IR) temperature sensor IC, the MLX90614, that delivers medical accuracy over a wide operating range was used. This particular temperature IC delivers measurement accuracy in wide ambient temperature range. It has on-chip amplification, signal processing, and conditioning circuit.

C. *Signal Conditioning*

The front end of an ECG must be able to deal with extremely weak signals ranging from 0.5 mV to 5.0 mV, combined with a dc component of up to ±300 mV—resulting from the electrode-skin contact—plus a common-mode component of up to 1.5 V, resulting from the potential between the electrodes and ground. A sensitive Instrumentation amplifier with a high CMRR and care is also taken to minimize effects of electro-magnetic waves due to the Bluetooth transceiver.

D. *The DSP*

TMS 320C54xx is a DSP from the Texas Instruments having a 40-bit ALU, two 40-bit accumulators, a barrel shifter, a 17x17 multiplier, a 40-bit adder. It has two analog channels for analog input and internal analog-to-digital converters.

The most important information contained in an ECG signal is the associated heart rate. Determining the heart rate involves determining the time interval between the Q-R-S complexes. Therefore, a reliable algorithm is used to compute the heart rate.

A non-linear transformation is used to enhance the QRS complex so that it can be detected reliably with a threshold detector. The transformation in our implementation uses absolute values of the first and second order derivatives of the signal as follows:

$$y1(n) = |x(n) - x(n-1)|$$
$$y2(n) = |x(n-2) - 2x(n-1) + x(n)|$$
$$y3(n) = y1(n) + y2(n)$$

Where, x represents data from ECG leads, y the transforms. The time interval between two complexes is the QRS interval. Finally, the heart rate (HR) in beats per minute (BPM) is computed using the formula

HR = (Sampling rate X 60)/QRS Interval

As shown in the flow, the DSP looks for any anomaly in the data read from the patient and if it finds any, it immediately sends that data to the medical professional who can take suitable action. In normal circumstances, the patient data is monitored continuously but sent over to the medical professional only periodically. The interval between successive transmitted samples can be defined by taking the patient's health into consideration.

E. The Bluetooth Transceiver

Bluetooth (IEEE 802.15) is an industrial specification for wireless Personal Area Networks (PANs). It provides a means to connect various deices over a secure, globally unlicensed short-range radio frequency. It is a standard communications protocol primarily designed for low power consumption, with a short range.

The Bluetooth 2.0 transceiver module is a class-1 model that has an approximate range of 100 meters, is most suitable. The data from the DSP is delivered to the Bluetooth module on the serial port at a speed of 9600 bps. The Bluetooth module is configured as a *Master*, and the mobile phone is considered to be functioning as a *Slave.* The signal acquisition unit sends data to the Bluetooth module, which transmits data continuously, in blocks of 500 ECG samples (a duration of 2 seconds long of lead-I)) plus a one temperature reading. The data is sent as raw binary bytes.

F. Patient Sensor Device Design

Presented is a unique flexible, as well as detachable PSD for the comfort of patients. This consists of a fiber base on which the sensors LC – Left Chest sensor, RC – Right Chest sensor, CC – Center Chest sensor with a TS – Temperature sensor and the Transmission unit consisting of the Microcontroller and the Bluetooth transceiver are mounted. This fiber base is flexible in nature and has a unique shape which makes it easy and comfortable for the patients to wear it. It comes with three semi glue strips at the three ends which hold the sensors in contact with the body all the time. The upper portion of the fiber base has a detachable strip which can be used to strap around any chain worn by the patient. The temperature sensor is present with the Centre chest sensor. Fig.6 shows a schematic of the PSD design.

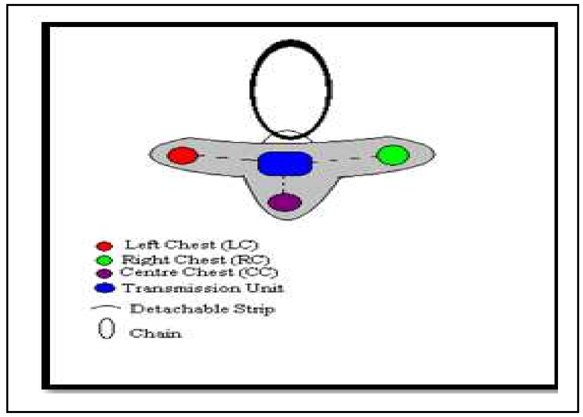

Figure.6 PSD Design Schematic

IV. TRANSMISSION TECHNIQUES

Patient data from the PDA / Smart Phone can be transmitted in two ways; MMS and SMS. The user is provided with the option to select any of these transmission modes as per requirement.

A. Multi-Media Messaging- M.M.S

The setup for the patient (client) unit is composed of mobile application software running on a smart-phone in the MMS-based system that is developed to transfer a patient's ECG signal and body temperature. This mobile application communicates to the PSD through the Bluetooth transceiver. The software application takes the received bytes from the buffer and plots 500 bytes of ECG samples at a time (2 seconds) and displays the temperature in degrees Celsius.

The application software is written under the supervision of an expert cardiologist, such that threshold levels to sense any irregularities in the heartbeat or arrhythmia or myocardial infarction, which need an immediate attention to save the patient from death. Once the measured ECG exceeds the threshold level for any of these cases, an emergency alert is sent to the MSP server as well as the concerned doctor through an SMS and the MMSs are sent to the MSP server at very short intervals of time as prescribed by the cardiologist. These MMSs are also sent to the concerned medical practitioner.

B. Short Messaging Service – S.M.S

Our SMS-based transmission scheme of the ECG signal and body temperature in the proposed DMS-PM system uses the same hardware components and application software on the client smart mobile phone as those of the MMS-based one but requires additional application software to be installed on the consultation (doctor) unit at the receiving device. Here also application takes the received bytes from the buffer and sends 500 bytes of ECG samples at a time and the temperature in degrees Celsius. After completion of signals acquisition, the application software feeds the data bytes of the desired length to the SMS message construction application program interface (API) and sends it to the predefined number of the GSM modem at the destination.

a. The Modes

There are two ways of sending and receiving SMS messages: by Text mode and by Protocol Description Unit (PDU) mode [17]. The text mode is just an encoding of the bit stream represented by the PDU mode. The PDU mode offers to send binary information in 7 bit, 8 bit, and 16 bit format.

PDU mode can be viewed as a management mode of SMS data elements.

At the client unit, the API packs the temperature and ECG samples in a predetermined number of SMS messages that depends on the desired length of duration of the patient's ECG. Since we have originally sampled our ECG signal using the ADC with 8-bit resolution and subsequently stored as 8-bit unsigned integers (bytes) in the API buffer, we use 8-bit data encoding when constructing the SMS messages, this will allow us to load 140 samples (bytes) in each SMS message. And with a sampling frequency of 250 Hz (4 milliseconds intervals), each SMS message is capable of displaying an ECG segment of 2.24 seconds. However, we only transmit 130 samples of ECG signal and one sample (three bytes) of the temperature in each SMS message; this will leave seven unused bytes for other vital signs if desired. Although, in principle, the GSM standard allows for 255 messages to be concatenated and received as one long SMS message, the maximum limit set by most GSM networks allows SMS concatenation up to six messages. In our case, this will allow us to transmit up to 13.44 seconds of ECG at a time.

V. MSP SERVER AND CARDIOLOGIST UNIT

The Medical Service provider is equipped with an exclusive server which maintains the database of the patients. This server is interfaced to a GSM modem, which receives the MMSs/ SMSs from the PDA / Smart phones at the patient site. It also runs the application software which is capable of opening the SMS messages that carry in their payload the temperature and ECG samples, decode the SMS messages, and extract the user data part to display the temperature and plot the ECG of the patient on the screen of the server if required.

The software application running on the server performs the background communications with the modem using AT Commands. The platform used to run the software will influence the choice of the preferred programming language used in implementing the software. The software starts with initializing a registering the desired COM port.

Once the COM port correctly selected and the GSM modem is connected, the software Reads the SMS messages from the GSM modem and decodes their contents. The software decodes each SMS message and extracts the time and date, originating mobile number, the transmitted patient's temperature, and ECG samples in the payload. It will also perform concatenation of received SMS messages when this option is used. The contents of the messages are displayed. When a particular SMS message is selected from the list of received messages, the software converts the ECG data points carried in the message to milli-volts and the temperature value is displayed in degrees Celsius.

VI. ADVANTAGES OF THE PROPOSED MODEL

Various other models have been proposed for collection, storing and transmission of patient data. The advantage with our model is that while patient data gets collected and monitored continuously, the medical professional is only intimated in case of an emergency and also at lapse of a pre-determined interval of time. This prevents clogging of networks and swamping of qualified medical professionals with not-necessarily-useful data. Also, less data transmitted would imply less power and lower air-time costs. This overcomes the problems associated with proposals which transmit data to the MSP continuously. This model also overcomes the drawbacks of the patient or doctor initiated model; the most important one being the automatic reporting of patient data in case of anomalies and the possibility of the patient forgetting to initialize the transmission.

Also, the Patient Sensing Device (PSD) has been designed in a way which would cause little inconvenience to patients, elders specifically.

VII. CONCLUSION AND SCOPE FOR DEVELOPMENT

A low-cost mobile patient monitoring system that utilizes mobile messaging services (MMS/SMSs) is proposed. An Infrared temperature sensor is integrated with a three-electrode ECG signal acquisition circuitry in a new, flexible user friendly design that communicates with a mobile smart-phone via Bluetooth. Also, a scheme for acquisition, processing and transmitting patient data was presented and its advantages were brought out.

The proposed system does not perform any compression of patient data before storage or transmission; a scheme could be evolved to accomplish that. Efficient and powerful processors are needed to achieve this. Similarly, transmitted data could be encrypted to protect the privacy of the patients.

ACKNOWLEDGEMENTS

Manjunath Iyer and Rajiv would like to thank the staff and the management of the Yellamma Dasappa Institute of Technology for the support offered to them.

References

[1] P.E Ross, "Managing Care Through the Air," IEEE Spectrum, December 2004, pp 14-19(2004)

[2] Schepps. J, Rosen A, "Microwave industry outlook – wireless communications in healthcare," Microwave Theory and Techniques vol. 50, issue 3, Mar. 2002, pp 1044-1045(2002)

[3] "Atlas of Heart Disease and Stroke," WHO, September 2004.

[4] Y. B. Choi, J. S. Krause, H. Seo, K. E. Capitan, and K. Chung, "Telemedicine in the USA: standardization through information management and technical applications," *IEEE Communications Magazine*, vol. 44, no. 4, pp. 41–48, 2006.

[5] U. H. Patel and C. F. Babbs, "A computer-based, automated, telephonic system to monitor patient progress in the home setting," *Journal of Medical Systems*, vol. 16, no. 2-3, pp. 101–112, 1992.

[6] G. Coyle, L. Boydell, and L. Brown, "Home telecare for the elderly," *Journal of Telemedicine and Telecare*, vol. 1, no. 3, pp. 183–184, 1995.

[7] P. Giovas, D. Papadoyannis, D. Thomakos, et al., "Transmission of electrocardiograms from a moving ambulance," *Journal of Telemedicine and Telecare*, vol. 4, pp. 5–7, 1998.

[8] T. Samaras, S. Karavasiliadou, E. Kouidi, et al., "Transtelephonic electrocardiographic transmission in the preparticipation screening of athletes," *International Journal of Telemedicine and Applications*, vol. 1, pp. 1–4, 2008.

[9] K. Shimizu, "Telemedicine by mobile communication," *IEEE Engineering in Medicine and Biology Magazine*, vol. 18, no. 4, pp. 32–44, 1999.

[10] http://www.gsmworld.com/, September 2008.

[11] D. Kammer, G. McNutt, and B. Senese, *Bluetooth Application Developer's Guide*, Syngress Publishing, Rockland, Mass, USA, 2002.

[12] R. Bouhenguel, I. Mahgoub, and M. Ilyas, "Bluetooth security in wearable computing applications," in *Proceedings of the International Symposium on High Capacity Optical Networks and Enabling Technologies*, pp. 182–186, November 2008.

[13] D. Ralph and P. Graham, *MMS Technologies, Usage and Business Models*, John Wiley & Sons, West Sussex, UK, 2004.

[14] A. A. Tahat, "Mobile personal electrocardiogram monitoring system and transmission using MMS," in *Proceedings of the 7th International Caribbean Conference on Devices, Circuits and Systems (ICCDCS '08)*, pp. 1–5, Cancun, Mexico, 2008.

[15] G. Bodic, *Mobile Messaging Technologies and Services*, John Wiley & Sons, West Sussex, UK, 2005.

[16] A. A. Tahat, "Implementation of an SMS-based telemedicine system for patient electrocardiogram monitoring," in *Proceedings of the 4th IASTED International Conference on Telehealth and Assistive Technologies (AT '08)*, pp. 223–228, Baltimore, Md, USA, 2008.

[17] S. Guthery and M. Cronin, *Mobile Application Development with SMS and the SIM Toolkit*, McGraw-Hill, New York, NY, USA, 2002.

[18] A. A. Tahat, Mobile Messaging Services-Based Personal Electrocardiogram Monitoring System, International Journal of Telemedicine and Applications Volume 2009 (2009), Article ID 859232, 7 pages doi:10.1155/2009/859232

[19] Joonyoung Jung , Kiryong Ha, Jeonwoo LeeYoungsung Kim and Daeyoung Kim, Wireless Body Area Network in a Ubiquitous Healthcare System for Physiological Signal Monitoring and Health Consulting, *International Journal of Signal Processing, Image Processing and Pattern Recognition*

[20] John O'Donoghue, John Herbert, Rune Fensli, Stephen Dineen, Sensor Validation within a Pervasive Medical Environment, *IEEE Sensors-2006*

About the authors :

Anup B Goutham : Anup is a student, currently in the final year of an Engineering degree in Electronics and Communication. His interests include Communications and VLSI.

Manjunath Iyer : Manjunath is a student, currently in the final year Engineering degree in Electronics and Communication. His interests include Communications, Embedded Systems Design and VLSI.

Rajiv R : Rajiv is a student, currently in the final year Engineering degree in Electronics and Communication. His interests include Embedded Systems Design and VLSI.