Remote Vital Signal Monitoring System Based on Wireless Sensor Network Using Ad-Hoc Routing

Gaurav Walia, Young-Dong Lee, and Wan-Young Chung, *Member, KIMICS*

Abstract— A distributed healthcare monitoring system prototype for clinical and trauma patients was developed, using wireless sensor network node. The proposed system aimed to measure various vital physiological health parameters like ECG and body temperature of patients and elderly persons, and transfer his/her health status wirelessly in Ad-hoc network to remote base station which was connected to doctor's PDA/PC or to a hospital's main Server using wireless sensor node. The system also aims to save the cost of healthcare facility for patients and the operating power of the system because sensor network is deployed widely and the distance from sensor to base station was shorter than in general centralized system. The wireless data communication will follow IEEE 802.15.4 frequency communication with ad-hoc routing thus enabling every motes attached to patients, to form a wireless data network to send data to base-station, providing mobility and convenience to the users in home environment.

Index Terms— Ad-hoc Routing, ECG, Monitoring, Vital Sign, and Wireless Sensor Network.

I. INTRODUCTION

With world populations increasing at rapid rate many governments and health-providers are now concerning about the impact of aging population on healthcare management. Therefore there is an urgent need for devising a cheaper and smarter way to provide health care for sufferers of age related disease. Also emphasis has to be paid on providing health monitoring in out-of-hospital conditions for older people and patients who require regular supervision, particularly in remote areas. Various vital health parameters like ECG (Electrocardiogram) signal, body temperature, pulse rate and blood pressure of patients can now be measured by these devices and data can be transferred to a remote doctor or care giver, eliminating the need of their actual presence. However there are some significant disparity between existing sensor network and that required for medical care. Medical sensor network must have support for ad-hoc routing topologies, mobility, wide ranges of data rates and high degree of reliability. Health care market has been one of the fastest growing markets for Wi-Fi and other wireless LAN technologies. The European community's MobiHealth System (2002-2004) demonstrates the Body Area Network (BAN)[1]. Codeblue[2] is a wireless infrastructure for deployment in emergency medical care. Another health monitoring system is Coach's Companion[3], which allows the monitoring of physical activity. CardioNet, employs PDA to collect data from ECG monitor and send it over a cellular network to a service center [4]. Medtronic uses a dedicated monitor connected to the internet to send pacemaker information to a medical professional.

This paper describes our experiences to develop a wireless distributed healthcare monitoring system for clinical and trauma patients, using wireless sensor network nodes Micaz. Vital health parameters like ECG and body temperature of patients will be sensed and the obtained data will be transferred wirelessly to a base-station attached to PC or PDA.

II. SYSTEM DESIGN

A Ubiquitous healthcare system is built around the concept placing unobtrusive sensors on a person's body to form a wireless network. Fig. 1 shows the architecture of our system. In our prototype design we have used a wireless network of motes that provides sensor data from various biomedical sensors attached to a patient's body. The wireless data communication will follow bi-directional radio frequency communication with ad-hoc routing thus enabling every motes attached to patients, to send data to base-station even though they may be not in direct radio range of base-station. The base station comprises MICAz node and RS-232 serial interface (MIB510) circuit for receiving and broadcast packets via node's UART. The UART was set to 57600 bits per second on both MICAz and MIB510.

For making the system power efficient as highly desired, the on-command 'sleep' and 'wake' feature had been incorporated, which enables the motes to transfer data only when desired and sleep for the rest of the time[5].

To ensure that during sleep mode any abnormal change in data is not missed the sensor is kept active. So if any parameter

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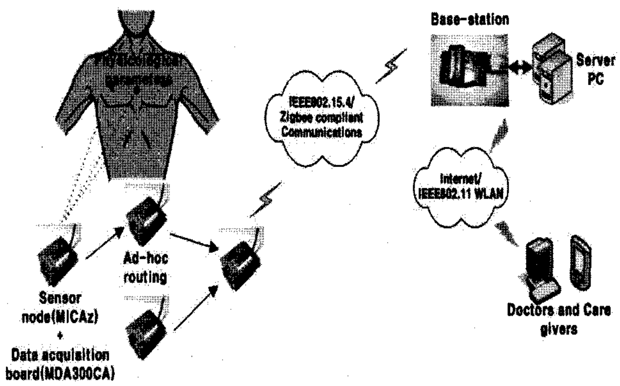

Fig. 1 System Architecture for Ubiquitous Healthcare.

crosses warning threshold the mote is awakened and data transmission is initiated toward the base-station, thus removing the dependency on monitoring system for data acquisition. Also this approach supports immediate sending of essential information with minimum transmission delay. Thus former approach makes the system 'power efficient' and latter makes it 'time efficient'. When any parameter goes beyond warning state the patients and doctors can be notified to take necessary action. The data on base-station will be analyzed by doctors and care providers for effective monitoring of health status of patients. One of most commonly monitored vital sings in clinical and trauma care are ECG signals, two or three electrode ECG is used to evaluate cardiac activity for an extended period. The cardiac response from body is not only weak but also very random and continuously changing, so electrodes and data acquisition board must be sensitive to fluctuation as small as 0.1mV.

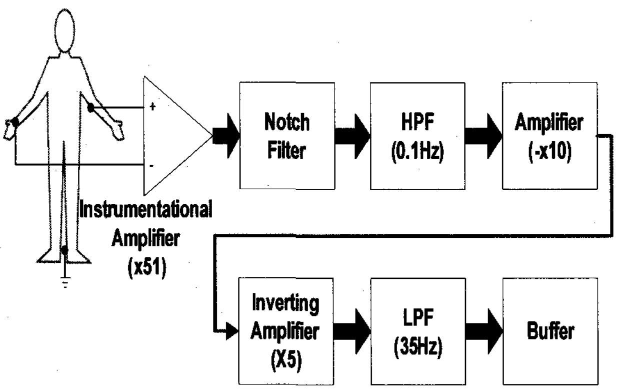

Fig. 2 Block diagram of ECG Amplifier Circuit.

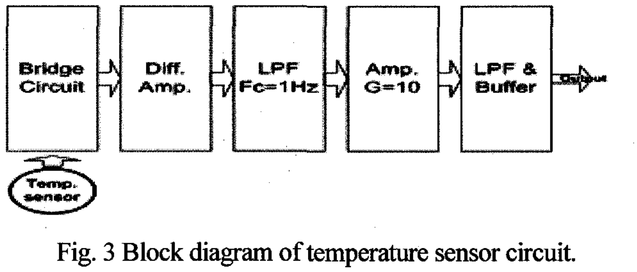

Fig. 3 Block diagram of temperature sensor circuit.

Fig. 2 shows he block diagram of ECG Amplifier. ECG signal can be classified in two modes that are diagnosis mode (0.05-100Hz) and monitoring mode (0.5-40Hz). The system uses monitoring mode. The signal from the electrodes of 3-leads system will first be amplified with low noise instrument amplifier, and then passed through 0.1Hz high pass filter (HPF) and 35 Hz low pass filter (LPF).

Fig. 3 shows block diagram for body temperature sensor. This circuit consists of Wheatstone bridge and differential amplifier which is followed by LPF of cutoff frequency 1Hz and gain 10. These signals are fed to data acquisition board (MDA300CA) for connectivity to Micaz node. Presently we are focusing only for the analog signals so only ADC channels are being used. The signal from the data acquisition board will be sampled and filled in form of packets for transmission. The patient will be identified by the unique id assigned to the each mote. Among various existing routing protocols, presently simple variant of Destination Sequence Distance Vector algorithm [6] with a single destination node (the base-station) and active two-way link estimation has being used for routing and transmission [7]. Each mote in network simultaneously acts as transmitter, receiver and a router.

Wireless sensor nodes run application software for sampling and routing, that was developed using 'nesC language'[8] which runs on TinyOS. The base-station receives data packets from all the motes in the network and directs them to the attached PC or PDA acting as server. At server side user can view a GUI based window showing wave-form for ECG and other parameters. This ability to access the information from the network allows the medical professional to monitor the patient(s) remotely, in a mobile and real-time environment. The health parameters can be stored for future reference, making a health report as desired by doctor. In case of emergency doctors or care givers can provide medical assistance well before time. This provides a better medical environment for near future with least inconvenience to patients.

III. SOFTWARE ARCHITECTURE

Our architecture for software is based on Active Message communication model [9], because it is based on the concepts of combining communication and computation and matching them to the hardware capabilities in concurrent event based operations. Each Active Message holds the name of user-level handler which is to be summoned on target node upon arrival. Event handlers are invoked to deal with hardware events, either directly or indirectly. At lower level components have handlers connected directly to hardware interrupts, which can be external interrupts, timer events, or counter events. Fig.4 shows the application component graph.

A. Packet Format

The overall packet structure for the developed system composed of 36 bytes. Similar to the structure of TOS_MSG the header part of message comprise of destination address, active message handler, group ID and message length. This is followed by data part of 29 bytes which is composed of 7 bytes multi-hop message attributes and data of 22 bytes. We have also included 1 bytes channel for indication of types of sensor. The sensor reading is of 16 bytes and rests are for internal management. The header and data part is followed by 2 byte CRC-CCITT which is used to detect error that may occur in message during reception.

B. Routing Protocol

For constructing our Ad hoc network we have used a variant of Destination-Sequenced Distance Vector algorithm in which final destination of data from all nodes is single base station. Base station periodically broadcast its identity, which is used by receiving nodes for updating its routing information table. They then rebroadcast the new routing update to any nodes in their range. Thus a hierarchy of nodes is formed with base station at top level and all nodes target their data to the nodes which are just above them. Any change in topology is conveyed to the parent nodes, which can update its table.

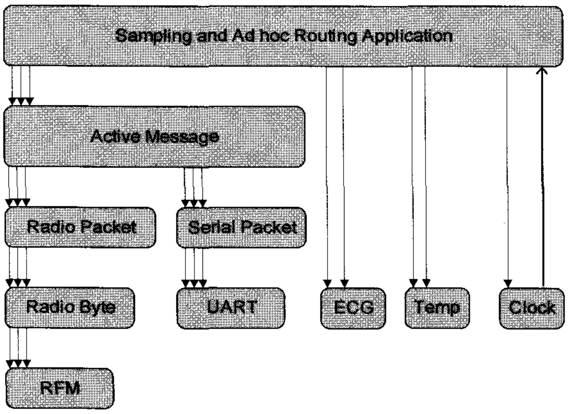

Fig. 4 Application Component Graph.

IV. EXPERIMENTAL RESULTS

In our tests, ECG data was obtained from sensors attached to real human body, via ECG interface circuit. Fig. 5 shows the oscilloscope output of the interface. This analog ECG signal, supplied to wireless sensor node, is nearly identical to a theoretically calculated ECG signal.

There are three peaks in the ECG signal, the R-peak, the Q-peak and S-peak respectively. The interval between two consecutive R-peaks indicates the time between heartbeats. Fig. 6 shows the ad-hoc routing of data through motes. Here it can be seen that data from mote4 is first send to mote5 which then forwards the data to mote1. Finally mote1 send the data to mote0 (base station). Thus data is transferred to base station in four hops.

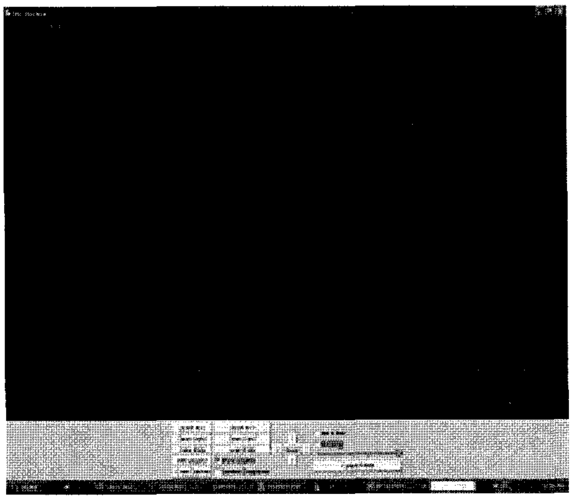

Fig. 5 ECG data in terminal PC's GUI.

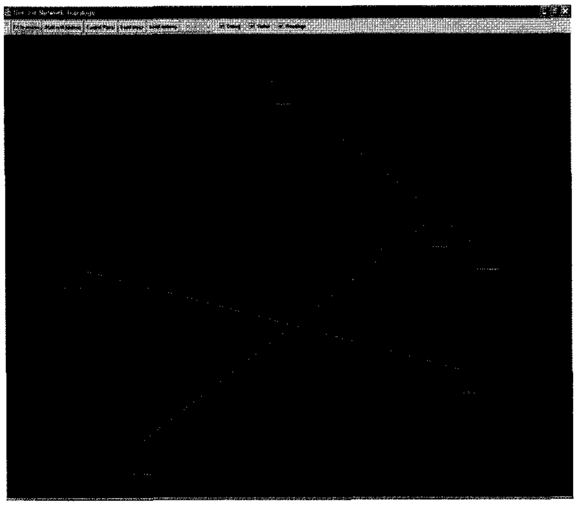

Fig. 6 Ad-hoc routing of data form motes.

V. CONCLUSIONS

A distributed health care system was designed for elderly and trauma patients, which can provided efficient and low cost health care in 'out of hospital' conditions. The system can measure the ECG and temperature of patients and transfer the data wirelessly in Ad hoc network to remote base station connected to doctor's PDA/PC or hospital server, using wireless sensor motes. The data obtained can be analyzed by doctors and care providers to monitor a health status of patient in real time environment.

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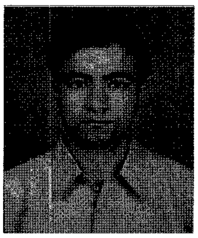

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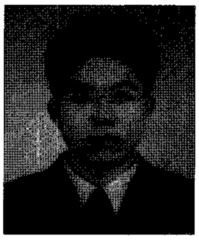

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