# Query Based Duplex Vital Signal Monitoring System using Wireless Sensor Network for Ubiquitous Healthcare

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*Abstract*— **Query based duplex vital signal monitoring system using wireless sensor network for Ubiquitous Healthcare was designed and tested. In this system, a wireless sensor network node attached on the human body provides sensor signal of an ECG (Electrocardiogram) and body temperature from multiple patients using wireless sensor network technology. A mote-based 3-lead ECG and body temperature monitoring system operating in wireless sensor network nodes was developed. The signal from sensors first is amplified with low noise instrument amplifier, and output of which is then fed to data acquisition board for connectivity to the sensor node. Vital signal from multiple patients can be relayed using an adaptive, multi-hop routing scheme to a wired base-station. The sampled signal will be filled in the form of packets for transmission using Zigbee compatible IEEE 802.15.4 standard wireless communication. The patients will be identified by the unique id assigned to the each mote. Among various existing routing protocols, presently simple variant of DSDV algorithm with a single destination node (the base-station) has being used for routing and transmission. Each mote in network simultaneously acts as transmitter, receiver and a router.**

*Keywords*— **Wireless Sensor Network, ECG, Query, Vital Signal, Ubiquitous Healthcare**

## I. Introduction

Many governments and health-providers are now concerning about the impact of aging population on healthcare management, as the world population increases at rapid rate. This is provoked 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 requires 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]. Code blue [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.

In this paper, query based duplex vital signal monitoring system using wireless sensor network for Ubiquitous Healthcare was designed and tested. 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

The concept of Ubiquitous healthcare system is to place unobtrusive sensors on a person's body to form a wireless network.

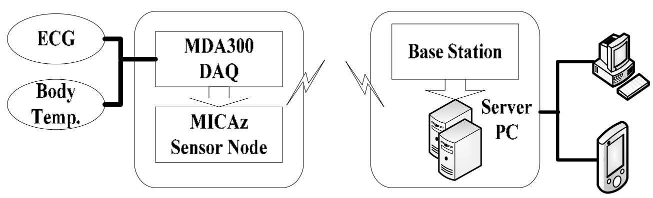


Fig. 1. System architecture for Ubiquitous Healthcare.

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 placed on a patient's body. The wireless data communication will follow bidirectional radio frequency communication with ad-hoc routing thus enabling every motes attached to patients, to send data to base-station even if they are 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 for long-life of such systems, 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 sensors are kept active. So if any parameter 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. Health providers also have the option of accessing specific health parameter of any patient through a simple query feature. As ECG signal still remains one of most commonly monitored vital sings in clinical and trauma care, 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 shows the 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.

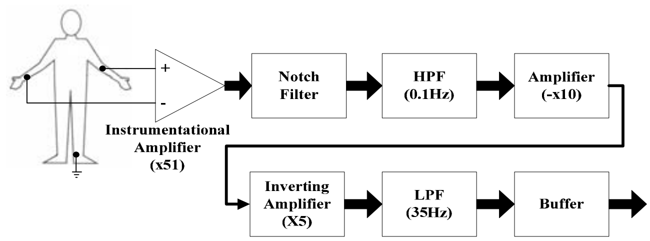


Fig. 2. ECG Amplifier Circuit Block diagram.

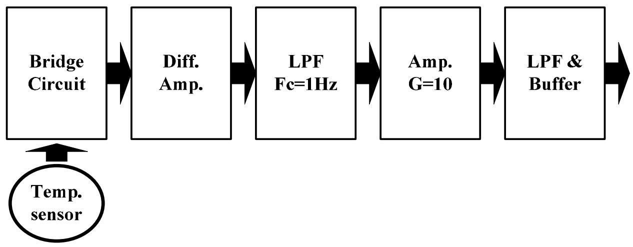


Fig. 3. Temperature sensor circuit's block diagram.

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 patients 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

Wireless sensor nodes run application software for sampling and routing, that was developed using 'nesC language' [8] which runs on TinyOS. 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.

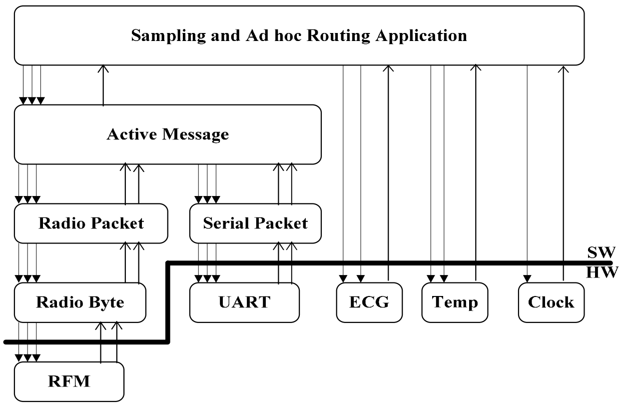


Fig. 4. Application component graph.

### 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 multihop 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 their table.

### C. Query System

The system is designed to have a query processing system for deriving information from the network. This is done using a declarative query interface that is similar to the SQL interface of a relational database system [10]. The data of interest specified in query are collected from the nodes, filtered and after assembling send to the PC. Along with polling based data acquisition there is support for event as a mechanism for initiating data collection. This can be highly effective when the mote is sleeping and doctor wants to access health parameters.

## IV. EXPERIMENTAL RESULTS

In our tests, ECG data was obtained from sensors attached to real human body, via ECG interface circuit. Fig.5 shows a real time human body ECG and body temperature graphic on terminal PC screen. The heart rate is 75 which indicate the normal condition of patient.


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

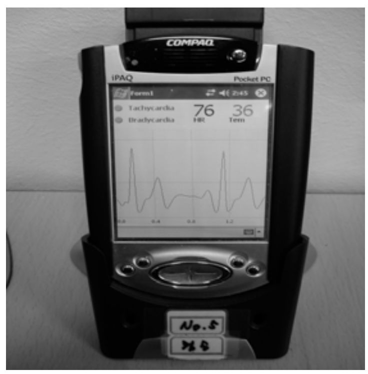


Fig. 6. A real time ECG monitoring at PDA.

Fig. 6 shows the ECG on PDA. The red colored number expresses the body temperature of the patient. This analog ECG and body temperature signal, supplied to wireless sensor node, is nearly identical to a theoretically calculated ECG and body temperature signal.

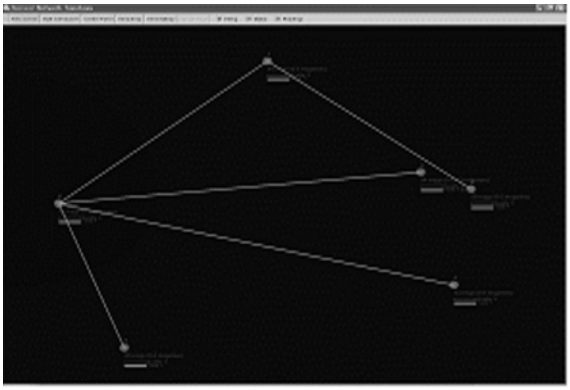

Fig. 7. The typical Ad-hoc routing of data from motes.

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 modes. 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.

## V. CONCLUSIONS

The query based duplex vital signal monitoring system using wireless sensor network for Ubiquitous Healthcare was designed. 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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