Wireless Sensor Networks for Remote Health Monitoring

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The embedded and adaptive computing group (EACG) at UTD is involved towards designing wireless sensor systems that monitor patient vital sign information in real-time. These systems are targeted for applications in both hospital and household environments. Patient monitoring within hospitals requires the use of non-invasive sensors that are hard wired to bedside monitors. This set-up is cumbersome, forcing the patient to be confined to his hospital bed thereby not allowing him to move around freely within the hospital premises. Similarly, in the case of household monitoring, physicians hand over specialized devices to patients for continuously recording data over a period of time. These devices store data locally and the patient takes it back to his physician who downloads the data to his PC for analysis. Such systems obviously suffer from a lack of real-time monitoring. The EACG system on the other hand uses Crossbow MICAz motes in a mesh network to routes patient data to a base station. A care giver can have access to this data at any point in time and doesn't have to be physically present with the patient to record the readings. The network router nodes are self-powered and draw energy from overhead 34W fluorescent lights via solar panels. The sensor nodes have been interfaced to a variety of vital sign sensors such as electrocardiograms (ECGs), pulse-oximeters and blood pressure (BP) sensors. Also, a graphical user interface has been designed for the physician to monitor patient data on the base station PC. The set-up was found to be extremely robust with no packet loss and low power consumption.

Research Motivation

- To develop new and novel applications that use wireless sensor networks (WSNs) in healthcare
- To create new technologies that expand the capabilities and usage of telemedicine

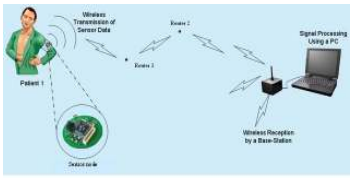
Why telemedicine?
- This is a rapidly expanding field
- Current applications are limited
- WSNs possess an enormous potential to simplify and improve healthcare
- Allow healthcare practitioners to "do more with less"

WSN advantages
- Low cost, low power nodes
- Can easily be used in multi-hop, high redundancy mesh networks
- Ideal for short packet, short distance communication applications

Issues with WSNs
- Difficult to create true low power hardware
- Long term viability in question
- Lack of network protocol standards
- Hardware available from several vendors who use proprietary protocols resulting in interoperability issues

Research Challenges

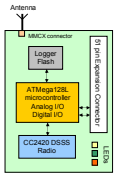
- Develop unique energy scavenging techniques to self-powered WSN nodes
- Identify appropriate biomedical sensors for possible interface with WSN nodes
- Develop energy efficient network protocol with low packet loss for router nodes and sensor nodes
- Identify feasible applications in the biomedical arena
- Present focus on using WSNs for monitoring patient vital sign data from a remote location



Remote vital sign monitoring system using WSNs

WSN Hardware

Crossbow MICAz and MICA2 motes



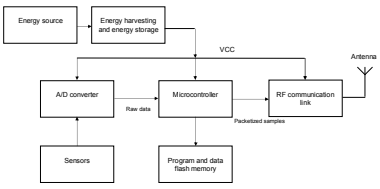
	Operating current (mA)
ATMega128L, full operation	15.0
ATMega128L, sleep mode	0.010
Radio, receive mode	19.7
Radio, transmit mode (1 mW power)	17.0
Radio, sleep mode	0.001
Serial flash memory, write	15.0
Serial flash memory, read	4.0
Serial flash memory, sleep	0.002

Mote block diagram and current consumption details

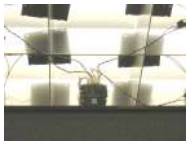
Energy Scavenging Methodology

- Present technique uses monocrystalline solar panels for indoor router nodes
- Future designs will use piezoelectric vibration generators for indoor sensor nodes
- Ultracapacitors for energy storage
- Each design uses sophisticated power management circuits and algorithms

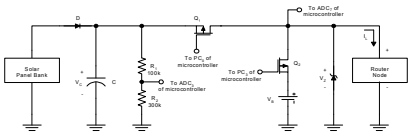
Solar energy harvesting experimental set-up



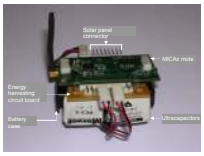
Block diagram of an energy harvesting WSN



Self-powered router node located close to overhead 34W fluorescent lights



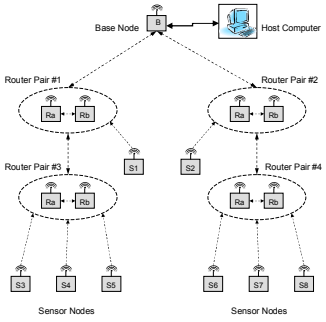
Indoor solar energy scavenging power management circuit with back-up battery power



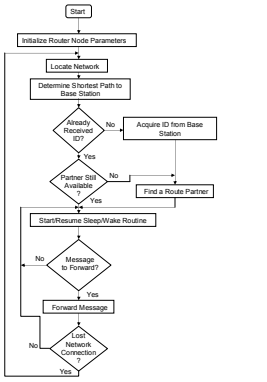
Router node with energy harvesting circuit

Network Structure

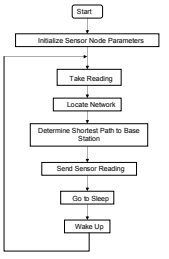
- Ad-hoc network where nodes are self-aware and self-configure
- Multi-hop mesh network
- Router nodes are the key to the network and operate in pairs and use a special dual router (DR) algorithm
- Router nodes are self-powered and draw energy from overhead 34W fluorescent lights
- Sensor nodes could be mobile or fixed and control operation of the biomedical instrument



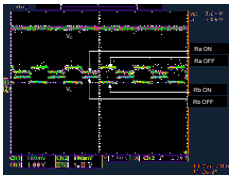
Network protocol with DR algorithm



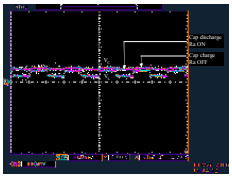
Router node flowchart



Sensor node flowchart



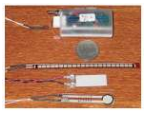
Router pair V_L and V_C waveforms



Router node V_L and V_C waveforms indicating ultracapacitor charge and discharge.

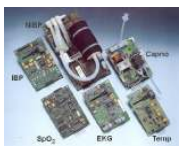
Biomedical sensor boards for WSN interface

UA 767-PC blood pressure sensor



Crossbow mote with medical sensors

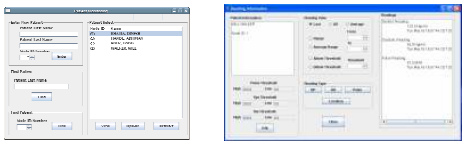
Smiths Medical micro pulse oximeter board



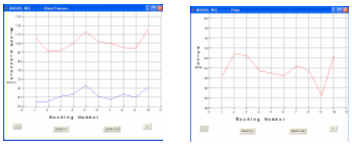
Medlab Gmbh medical OEM boards

EACG systems

- Remote blood pressure (BP) and heart-rate monitoring system using BP sensors
- Remote cardiac monitoring system using ECG sensors
- Pulse oximeter sensors for monitoring heart-rate and BP
- WSN sensor nodes interfaced to a variety of biomedical sensors
- Systems for both in-hospital vital sign monitoring and at-home remote monitoring
- Network router nodes are self-powered and draw energy from overhead 34W fluorescent lights
- Sensor nodes could be mobile or fixed and control operation of the biomedical instrument



Patient monitoring graphical user interface



Real-time patient BP and heart-rate data display at base-station

Publications

[1] A. Hande, T. Polk, W. Walker, and D. Bhatia, "Indoor Solar Energy Harvesting for Sensor Network Router Nodes", under review, Journal of Microprocessors and Microsystems – Special Issue on Sensor Systems, December 2006.

[2] T. Polk, A. Hande, W. Walker, and D. Bhatia, "A Wireless Sensor Network Protocol for Self-Powered Nodes", under review, Fourteenth IEEE International Conference on Network Protocols, Santa Barbara, CA, November 2006.

[3] T. Polk, A. Hande, W. Walker, and D. Bhatia, "Wireless Telemetry for Oxygen Saturation Measurements", under preparation, IEEE Biomedical Circuits and Systems Conference, London, U.K, November 2006.

[4] W. Walker, T. Polk, A. Hande, and D. Bhatia, "Remote Blood Pressure Monitoring using a Wireless Sensor Network", under review, Sixth IEEE Annual Emerging Information Technology Conference, Dallas, TX, August 2006.

[5] A. Hande, T. Polk, W. Walker, and D. Bhatia, "Self-Powered Wireless Sensor Networks for Remote Patient Monitoring in Hospitals", under review, Sensors, 2006.

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