Wireless Sensor Networks for Patient Monitoring

JeongGil Ko, Yin Chen, Jong Hyun Lim
Răzvan Musăloiu-E., Andreas Terzis
Johns Hopkins University

Tia Gao
Walt Destler
AID-Networks

Leo Selavo
University of Latvia

I. Summary of the Patient Monitoring System

The increasing size of the aging population [1], nursing staff shortages [2], and decreasing hospital capacities [3] suggest that the current level of patient care may decrease in the future. Furthermore, lack of resources and communication infrastructure can also prevent care givers from saving lives in disaster response scenarios in which hospitals' emergency departments are overloaded with critical patients.

In response to these challenges, we have assembled an interdisciplinary team of researchers and practitioners to develop a Wireless Sensor Network (WSN) with the goal of automating the patient monitoring process. Figure 1 provides an overview of our system comprising a set of *Patient Monitors* (PMs), *Relay Points* (RPs) and a *Doctor Station*. PMs are motes equipped with medical sensors (e.g., PulseOx, EKG, etc.) which record the patients' vital signs. The PM's processing core is the Sentilla Tmote Mini which combines a Texas Instruments MSP430 microcontroller with a TI/Chipcon CC2420 low-power radio in a mini-SDIO form factor. Unlike previous proposals, our system includes a dedicated wireless mesh infrastructure of relay points (RPs) that relay the PMs' measurements.

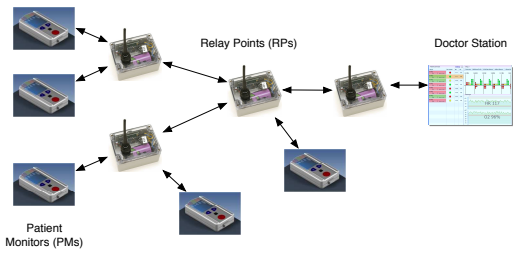

Fig. 1. The patient monitoring wireless sensor network.

Several requirements must be considered when designing a system for use in medical care. First, the privacy of patients' data must be protected. We achieve this by end-to-end encryption and authentication of PM data. Second, due to the large volume of data that medical sensors generate (for example, we sample the EKG sensor at a rate of 250Hz), the measurements must be compressed to conserve bandwidth. We have compared several lossless compression algorithms and found that the delta compression algorithm offers the best combination of high compression ratio and low implementation complexity.

We use the Collection Tree Protocol (CTP) [5] as the routing infrastructure for delivering PM measurements to the Doctor Station. We enhance CTP with a mechanism to deliver commands from the Doctor Station to individual PMs. Data flowing in both directions are protected by hop-by-hop retransmissions. Furthermore, we improve the system's capacity by optimizing the MAC back-off timers that RPs use, considering that they forward large amounts of data. Finally, we have implemented an RP selection mechanism which ensures that PMs stay connected to the wireless backbone even when they are mobile.

II. Preliminary Results

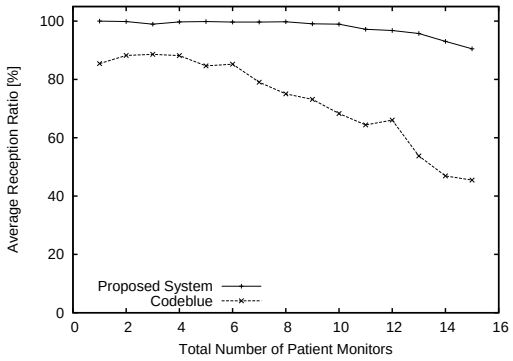

Fig. 2. Performance comparison with CodeBlue.

Figure 2 compares our system with CodeBlue [4] in an indoor environment with variable number of PMs. In this test PMs generate packets at a rate of 3Hz. Additional results from a prototype implementation and simulations indicate that our proposed system can achieve high levels of network utilization and that hop-by-hop retransmissions can effectively mask the effects of collisions and interference. Furthermore, we see that the proposed system can sustain high data delivery ratios even when the PMs are mobile.

References

[1] W. C. Mann, "The Aging Population and Its Needs," *IEEE Pervasive Computing*, 2004

[2] American Association of Colleges of Nursing. Nursing Shortage Fact Sheet. Available at: `http://www.aacn.nche.edu/Media/Backgrounders/shortagefacts.htm`, March 2004.

[3] The Center for Disease Control. Press Release: Visits to U.S. Emergency Departments at All-Time High; Number of Departments Shrinking. Available at: `http://www.cdc.gov/od/oc/media/pressrel/r050526.htm`, May 2005.

[4] D. Malan, T. Fulford-Jones, M. Welsh, S. Moulton, "CodeBlue: An Ad Hoc Sensor Network Infrastructure for Emergency Medical Care," *in proc. International Workshop on Wearable and Implantable Body Sensor Networks*, 2004.

[5] R. Fonseca, O. Gnawali, K. Jamieson, S. Kim, P. Levis, A. Woo, "The Collection Tree Protocol (CTP)," *TEP 123 Draft*, 2006