

Demo: Prototyping UWB-Enabled EnHANTs

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ABSTRACT

Energy Harvesting Active Networked Tags (EnHANTs) are a new class of devices in the domain between RFIDs and sensor networks. EnHANTs will be small, flexible, and energetically self-reliant. Their development is enabled by advances in ultra-low-power ultra-wideband (UWB) communications and in organic semiconductor-based energy harvesting materials. In this demo, we present UWB-enabled EnHANT prototypes. Each prototype is based on a MICA2 mote integrated with a UWB Transceiver and an energy harvesting module (EHM) that allows demonstrating energy harvesting-adaptive communications. Additional information about EnHANTs is available at [2] and <http://enhants.ee.columbia.edu>.

Categories and Subject Descriptors: C.2.1 [Computer-Communication Networks]: Network Architecture and Design — *Wireless Communication*

General Terms: Design, Experimentation, Performance

Keywords: Energy Harvesting, Energy Adaptive Networking, Ultra Low-Power Communications, Active Tags

1. SYSTEM AND DEMONSTRATION

An EnHANT prototype appears in Figure 1. The prototypes communicate with each other using custom-designed UWB impulse radio (IR) transceivers [1] integrated with MICA2 motes. A custom Fennec Fox platform, running on top of TinyOS, is used to integrate new hardware components.

The prototype uses the UWB transceiver instead of the mote's transceiver. UWB IR technology, which results in significant power savings compared to narrow-band systems, is a compelling technology for short range ultra-low-power wireless communications.

The UWB transceiver Tx frequency can be set from 2.9 to 3.8GHz in 80MHz steps. The nominal measured pulse width is 2ns and the peak PSD is -44.1dBm/MHz. The prototype can achieve 25Kb/s at a distance of 1m with a 0.1% bit error rate. A UWB-specific medium access control (MAC) protocol provides addressing, reliability, and data integrity.

The prototype includes an *Energy Harvesting Module (EHM)* which contains a *thin film* Sanyo AM-5412 (amorphous silicon-based) *solar cell*, an off-the-shelf NiMH battery, and an LED. The battery is charged by the solar cell. When the transceiver transmits a packet, the LED is flashed, thereby discharging the battery and emulating energy consumption by the radio.

Through the logic implemented in the EHM, the prototypes de-

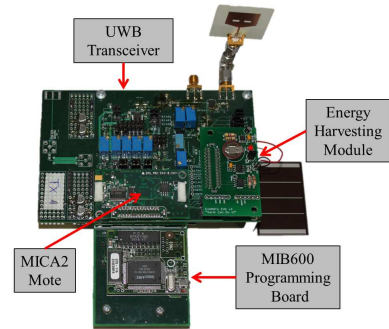


Figure 1: A UWB-enabled EnHANT prototype.

termine the amount of harvested energy and the battery level. When communicating, the prototypes exchange their energy harvesting-related parameters, and determine the communication rates, thereby demonstrating *energy harvesting adaptive communications*.

To easily track the prototypes' behavior, we developed a graphical monitoring system which includes a set of 'live' graphs that demonstrate the changes in nodes' communication parameters and energy states.

In this demo, we show a few prototypes communicating with each other. The prototypes use information about their harvesting and battery levels to determine their communication parameters (data rates and sleep/wake cycles). In order for the demo participants to be able to quickly observe the changes in the communication parameters, the nodes are placed on MIB600 programming boards that are connected via an Ethernet switch to a computer running the monitoring system. When changing the radiant energy levels (by reducing or increasing the amount of light shining on the solar cells), demo participants can observe how the changes in the environmental energy change the power generated by the solar cell, and influence the communication patterns.

2. ACKNOWLEDGEMENTS

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3. REFERENCES

- [1] M. Crepaldi, C. Li, K. Dronson, J. Fernandes, and P. Kinget, "An ultra-low-power interference-robust IR-UWB transceiver chipset using self-synchronizing OOK modulation," in *Proc. IEEE ISSCC'10*, Feb. 2010.
- [2] M. Gorlatova, P. Kinget, I. Kymissis, D. Rubenstein, X. Wang, and G. Zussman, "Challenge: Ultra-Low-Power Energy-Harvesting Active Networked Tags (EnHANTs)," in *Proc. ACM MOBICOM'09*, Sept. 2009.