Demo Abstract: RFID Sensor Networks with the Intel WISP

Michael Buettner*, Richa Prasad*,
Alanson Sample*†, Daniel Yeager*
*University of Washington
Seattle, USA
{buettner, richa}@cs.washington.edu
alanson@u.washington.edu
yeagerd@ee.washington.edu

Ben Greenstein†, Joshua R. Smith†,
David Wetherall†*
†Intel Research Seattle
Seattle, USA
{benjamin.m.greenstein, joshua.r.smith,
david.wetherall}@intel.com

ABSTRACT

We demonstrate a simple *RFID sensor network* comprised of an Intel WISP and a commodity UHF RFID reader. WISPs are devices that gather their operating energy from RFID reader transmissions, in the manner of passive RFID tags, and further include sensors, e.g., accelerometers, and provide a very small-scale computing platform. We believe that the small form factor and lack of battery makes the WISP an attractive alternative to motes for many of the original smart dust applications that require very small or long-lived sensors. The Intel WISP that we demonstrate has an ultra-low-power microcontroller, 32K of program space, 8K of flash, and accelerometer and temperature sensors. It harvests power from and communicates sensor data to standard (EPC Class 1 Gen 2) UHF RFID readers with a range of roughly 10 feet. This combination of RFID technology and sensor networks raises many research challenges, such as how to function with intermittent power and how to modify RFID protocols to support sensor queries.

Categories and Subject Descriptors: C.2.1 Network Architecture and Design: Wireless Communication

General Terms: Design, Experimentation

1. INTRODUCTION

Wireless sensor networks (WSNs) based on "mote" sensing platforms have been applied to many practical sensing problems ranging from animal behavior[3] to structural integrity. However, they have not led to an approximation of sensing embedded in the fabric of everyday life, where walls, clothes, products, and personal items are all equipped with networked sensors. For this manner of deployment, truly unobtrusive sensing devices are necessary. The size and finite lifetime of motes make them unsuitable for many such applications.

Radio Frequency Identification (RFID) technology has a number of key attributes that make it attractive for sensing applications where form-factor and lifetime are paramount. Passive UHF RFID already allows inexpensive tags to be remotely powered and interrogated for identifiers and other information at a range of more than 30 feet. The tags can be small as they are powered by the RF signal transmitted from a reader rather than an onboard battery. Moreover, their lifetime can be measured in decades as they are reliable and have no power source which can be exhausted. These advantages have resulted in the widespread deployment of RFID for industrial supply-chain applications such as tracking pallets and items. However, RFID technology is limited to only identifying and inventorying items in a given space.

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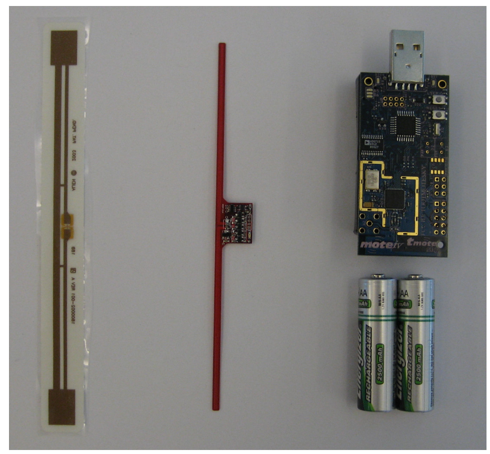

Figure 1—A standard UHF Class 1 Gen 2 RFID tag, Intel WISP, and Telos Mote (left to right)

We are exploring the use of Wireles Identification and Sensing Platform (WISP)[4] devices in an RFID sensor network to combine the advantages of RFID technology with those of existing sensor networks. WISPs are small, battery-free devices that use the RFID PHY and MAC layer to power themselves, sense, compute, and communicate. Due to their small size and lack of battery, WISPs are an attractive alternative to motes for sensing applications that require very small or long-lived sensors. An RFID sensor network (RSN) consists of multiple WISPs and one or more readers. While the feasibility of WISPs has been established, how to operate a system of such devices is an open question. Realizing full-scale RSNs will require development at both the WISP and the reader, as new protocols and techniques must be developed unlike those of either RFID or WSNs. The rest of this abstract gives an overview of the Intel WISP, a sample application using it, and the ongoing research challenges that we face. Our demonstration will show a WISP gathering and reporting sensor data via a commodity UHF RFID reader.

2. THE INTEL WISP

The Intel WISP, shown in Figure 1, features a wireless power supply, bidirectional UHF communication, and a fully programmable ultra-low-power 16-bit flash microcontroller with analog to digital converter. The most recent WISP includes 32K of flash program space, an accelerometer, temperature sensor, and 8K serial

Figure 2—Picture of WISP and fill sensor on milk carton

flash. Small header pins expose microcontroller ports for expansion daughter boards, external sensors and peripherals. In addition to the standard WISP, we have developed a version that uses a storage capacitor to store RF energy when in range of a reader. This enables unpowered functionality for up to 24 hours. Such a WISP can sustain operation across occasional reader contacts despite the lack of an internal, long-lived power source.

The WISP communicates using the EPCglobal Class-1 Generation-2 (C1G2) protocol [2]. Consequently, WISPs can be used with commercial RFID readers at a range of 10 feet. This allows the WISP to leverage existing infrastructure and to inter-operate with standard tags. The WISP writes sensor data to flash memory, and the data is collected using the C1G2 *READ* command which allows the reading of arbitrary tag memory locations.

3. SENSING APPLICATIONS

The Intel WISP has been used to implement a variety of demonstration applications that read data from a single sensor unit. These include the first accelerometer to be powered and read wirelessly in the UHF band, and also the first UHF powered-and-read strain gage [6]. Even without its sensing capabilities, the Intel WISP can be used as an open and programmable RFID tag: the RC5 encryption algorithm was implemented on the Intel WISP [1].

As a sample RFID sensing application, we instrumented a milk carton used by various people in an office environment for tea and coffee drinks. We placed a WISP on the carton and an RFID reader outside the refrigerator in which it was kept. The goal was to track the state of the carton as a small-scale example of a scenario where perishable goods are monitored for spoilage.

The WISP included temperature and fullness sensors, and the milk carton and WISP are shown in Figure 2. We measured fill percent by affixing two wires along the edge of the milk carton to act as capacitive sensing plates. In our experiment, the WISP was only in view of the reader when it was out of the refrigerator. Thus, we used a WISP equipped with a storage capacitor so that it could continue to sense for a limited time while in the refrigerator. When out of the refrigerator and in view of the reader, the WISP was able to accumulate charge and relay sensor data to the application program driving the reader. With this setup we were able to log temperature and fill percent readings over the course of a day [5].

4. TOWARDS RFID SENSOR NETWORKS

We believe that RSNs can bring the advantages of RFID technology to wireless sensor networks. While we do not expect them to replace WSNs for all applications, they do open up new application spaces where small form-factor, long-lived, or inaccessible devices are paramount. However, as the traditional RFID usage model is very different from that of WSNs, RSNs face at least two substantial research challenges to integrate the two technologies.

WISPs are powered only when they are in range of an RFID reader. This can result in the WISP losing power in the middle of a task. Additionally, when tags are powered the cost of transmission is essentially zero, which allows them to be re-tasked. Thus, techniques must be developed that enable task completion in the face of intermittent power.

A second challenge arises since RSNs will be highly asymmetric in terms of their communication abilities because they build on RFID. This complicates protocols designed to gather and process sensor data. The standard RFID strategy of identifying and then communicating with each device is wasteful as most devices may not have relevant data. Instead, query languages and protocols need to be developed, ideally in a manner that is compatible with the C1G2 standard.

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