Demo Abstract: Heliomote: Enabling Long-Lived Sensor Networks Through Solar Energy Harvesting

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1. INTRODUCTION

The crucial need for long-lived and autonomous operation has elevated power and energy consumption to primary optimization metrics during wireless sensor network design. While most work in the field of power management and low-power design has focused on optimizing the energy consumer (*i.e.,* the sensor node, including its hardware, software, applications, and network protocols), very little work has targeted the energy supply system itself. A practical approach to alleviating the problem of limited battery resources in sensor nodes is the use of environmental energy harvesting. Solar energy harvesting, in particular, holds significant promise since photovoltaic conversion techniques are now mature enough to permit the development of cheap and small, yet reasonably efficient, solar panels. Our demonstration showcases our recent research in designing solar energy harvesting systems, as well as harvesting aware performance scaling algorithms and network protocols [1].

2. HARVESTING SYSTEM DESIGN

We present Heliomote3 (shown in Figure 1), the latest of our solar harvesting modules for sensor nodes. Heliomote3 is capable of powering most commonly used sensor nodes, including Crossbow's Mica2 and MicaZ, Moteiv's Telos, Yale's XYZ, Intel's Stargate, and ISI's PASTA. It is capable of fully autonomous operation and manages all decisions related to energy harvesting, energy storage, and energy supply without any intervention from the sensor node. Heliomote3 features several design optimizations that enable it to achieve unprecedented levels of energy efficiency, including: (i) multi-modal energy storage combining batteries and an ultra-capacitor to guarantee high round trip efficiency, (ii) analog voltage elevator circuit and processing elements to learn any solar panel's V-I characteristics and reconfigure the Heliomote to ensure operation at the solar panel's maximal power point, (iii) overcharge protection for the battery pack and ultra-capacitor and undercharge protection for the battery pack, (iv) adjustable output voltage to power a variety of sensor nodes, (v) switch network to completely bypass the output DC-DC converters when the battery voltage is high, avoiding unnecessary power loss, (vi) boot-strapping circuit to ensure safe and reliable system boot up from either solar power or the battery, and (vii) digital interface (I^2C) for the sensor node to obtain information regarding battery, ultra-capacitor, and solar-panel status, as well as the power consumed by the sensor node itself.

Figure 1: The Heliomote solar harvesting sensor node in a weather proof case.

3. HARVESTING AWARE PROTOCOLS

To realize the full benefit of energy harvesting, it is crucial to make the applications and network protocols running on the sensor node "harvesting aware", thereby adapting themselves to the spatio-temporal variations in solar energy availability. For example, the routing protocol should select routes through nodes that are in sunlight longer/more often and hence, receive more solar energy. Similarly, the performance level at each sensor node can be varied in accordance with energy availability. Nodes that receive more solar energy can operate at a higher duty cycle than nodes that are in the shade for most of the time, leading to improved sensing and communication performance. We will demonstrate our harvesting aware performance scaling algorithms and network protocols on a miniature, tabletop sensor network with emulated insolation patterns using a set of lamps. A graphical user interface running on a computer attached to one of the sensor nodes will provide a visual display of the adaptations taking place in the network in real-time.

4. REFERENCES

[1] V. Raghunathan, A. Kansal, J. Hsu, J. Friedman, and M. B. Srivastava. Design considerations for solar energy harvesting wireless embedded systems. In *IEEE IPSN*, pages 457–462, 2005.

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