Demo Abstract: Energy Transference for Sensornets

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1 Introduction

In many cases, sensornets require *continuous* monitoring, 24x7, at remote, inaccessible locations making *energy management* a critical part of most sensornets. The sensornet research community has explored energy conservation and energy harvesting to address this problem of long-lived sensornets. Energy conservation is a primary concern in almost all sensornet work, and techniques from low-power hardware and OSes to coordinated network protocols and applications. Complementing energy conservation, energy harvesting gathers new energy from the environment.

Yet energy conservation and harvesting *cannot* provide a complete solution to long-lived sensornets for three reasons. First, data communication and distributed processing are often uneven, forcing greater energy consumption near aggregation points such as sink nodes. Second, energy harvesting opportunities also often vary across a deployment based on node location and time. For example, with solar-harvesting, nodes may always receive different levels of sunlight (forest canopy vs the understory, e.g. observed at a deployment in Costa Rica [6]), or the sunlight varies significantly with time (nodes on either side of a mountain ridge, e.g. observed in deployments at Matterhorn [2]). These two problems are magnified by the third: in-situ sensing must be done where the application requires it. So attempts to level consumption or place sensors in energy-plentiful regions are impossible if the target is elsewhere. Prior work has focused on extending network lifetime, balancing load, and optimizing use, but these approaches are fundamentally limited—*energy availability must be decoupled from sensornet operation*.

As an example, consider Figure 1 where four solar powered sensor nodes cover four areas. We assume each node consumes x units of energy, and the figure shows solar energy present in each area. Energy generation is reduced in areas with heavy or partial foliage. Under normal circumstances, nodes in the bottom region under the tree will either exhaust their batteries or cut their duty cycle, reducing the fidelity and utility of the sensor network below acceptable levels. Instead, we propose to transfer energy to balance harvesting and demand across the network. Even if transference is inefficient (say, 50% energy loss), the deficit at the shady node of $0.5x$ can be compensated by transferring $0.5x$ of surplus energy from the top areas with excess solar power. An analogous scenario is possible where energy consumption varies (perhaps because all data must be sent to a sink in the top-right area), or if both vary.

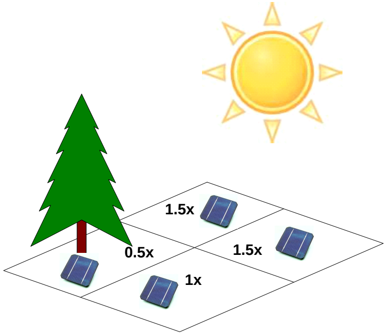

Figure 1. Example scenario showing benefit of Energy Transference. Each area is shown with available ambient-energy as the multiple of required energy x.

This demonstration will show the concept of energy transference, showing that light, as the energy source, can be directed via a computer controlled mirror to provide solar power to multiple shaded sensors.

2 Challenges for An Energy Transference System

We envision that future sensornets will employ energy harvesting, where one or several *energy relays*, possibly with energy harvesting capabilities, distribute available energy to *energy consumers* with limited or no ambient harvesting capability.

Figure 2 shows how we will illustrate these functions in our demonstration. An energy source, here the lamp with wall power on the left, transfers energy through a relay: a computer controlled mirror in the center. The energy consumers are solar powered motes on the right. Although they get minor energy from ambient lighting, an obstruction (center) shades them and they only have enough light when the relay focuses on them.

Efficiency is a large concern for wireless energy transference. Table 1 summarizes categories of currently available mechanisms, and their efficiencies at near their preferred range. As can be seen, the amount of loss is specific to the

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Mechanism	**Efficiency**	**Preferred Range**
Wires	High (90-95%)	Any
Microwave	High (30-80%)	2km or more
Magnetic resonance	High (45-90%)	1–2m
Laser/LED light	Low (10-18%)	1km
Reflected sun light	High (90+%)	1km or more

Table 1. Various Modes of Energy Transference

conversion process, for example conversion from electrical to laser energy is only 10% efficient [3], while converting light to electricity using photo-voltaic technology can theoretically be as high as 31–40 % [1]. Energy lost in the transference channel often dictate the practical range for a particular energy transference mechanism. Accordingly, laser and microwave can be transferred over long range in open space [5], but magnetic resonance can transfer energy over much short, but through obstacles, distance [4]. While the *efficiency* of transference might be low, we argue that here the *energy-sufficiency*, i.e. the ability to provide power at hitherto impossible locations, is of greater importance as it enables energy to be treated as a network wide, exchangeable and route-able commodity.

3 Demonstrating a Prototype Energy Transference System

Our demonstration will show two different algorithms, described below after the setup.

Hardware configuration: In this demo we prototype a light energy transference system using an LED lamp as energy source and a pan-tilt capable mirror to reflect light to appropriate locations (Figure 2). We use COTS based solar-powered batteries that can directly power Telos motes from a USB port. Our solar batteries turn on a green LED when ever light is sufficient to charge them. These LED's provide a good visual indication of energy being transferred.

For our demo application we have two Telos motes that are sensing the ambient temperature periodically. We have an LED lamp to emulate a light-energy source and an opaque wall obstructing its direct path to either motes. A strategically placed mirror, with pan-and-tilt capability, connected to the base station node acts as the energy-relay node. The base-station node can pan-tilt the mirror to reflect the light onto either of the nodes as dictated by the application's energy transference policy.

Demonstrating position configuration:

To reflect light appropriately the relay needs to know the position of each energy consumer nodes. We plan to demonstrate an automated algorithm that learns the correct mirror configuration for each energy consumer interactively.

For this demo, we will walk the relay through all its coordinates, with the motes sending radio feedback when they are illuminated. At the end of the sweep, the base station selects, for each node, the location with the highest intensity as the pan-tilt setting that it will use when it needs to transfer energy to that location. This approach cleanly separates the location of light source or the nodes to achieve good localization.

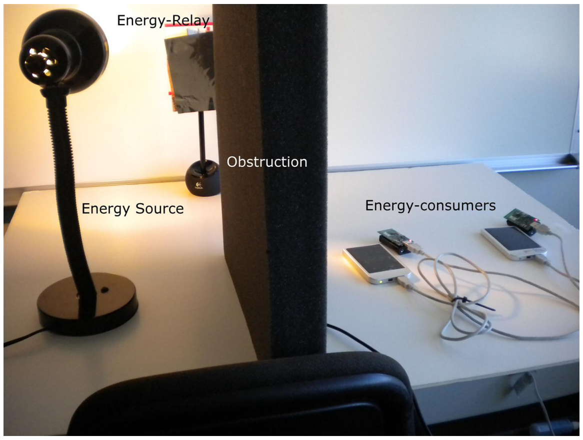

Figure 2. Prototype Energy Transference to two Telos motes. Here the direct transference is obstructed by an artificial wall but is instead achieved by panning and tilting a mirror.

Demonstrating Energy Transference Policies:

A second aspect to our demo is that we must match energy transference to the energy needs of each node. For this demonstration we will show that we can timeshare energy transference between multiple nodes.

In the demo, the relay will divide time into one-minute-long epochs. In each epoch it will rotate through illuminating each of the energy consumers. We will show that non-uniform policies can be provided if nodes have different consumption rates. We therefore, demonstrate an energy transference system that can relay light-energy from nodes with a higher proportion of light to those which have less-than-required available.

4 References

[1] Martin A. Green. Third generation photovoltaics: solar cells for 2020 and beyond. *Physica E: Low-dimensional Systems and Nanostructures*, 14(1-2):65 – 70, 2002.

[2] Andreas Hasler, Igor Talzi, Jan Beutel, Christian Tschudin, and Stephan Gruber. Wireless sensor networks in permafrost research concept, requirements, implementation and challenges. In *Proc. 9th International Conference on Permafrost (NICOP)*, June 2008.

[3] J. Hecht. Ray guns get real. *Spectrum, IEEE*, 46(7):28–33, July 2009.

[4] Andre Kurs, Aristeidis Karalis, Robert Moffatt, J. D. Joannopoulos, Peter Fisher, and Marin Soljacic. Wireless power transfer via strongly coupled magnetic resonances. *Science*, 317(5834):83–86, July 2007.

[5] Daniel Edward Raible. High intensity laser power beaming for wireless power transmission. Master's thesis, Cleveland State University, 2008.

[6] SPAN. Usc/isi span website. web site `http://www.isi.edu/SPAN/` , December 2008.