Chapter 8

Network Energy Driven Wireless Sensor Networks

Swades De
Indian Institute of Technology Delhi, India

Shouri Chatterjee
Indian Institute of Technology Delhi, India

ABSTRACT

Scarcity of energy in tiny battery-powered wireless sensor nodes have led to a tremendous amount of research thrust at all protocol levels in wireless networks. Despite efficient design of the underlying communication protocols, limited battery energy primarily restricts the usage of nodes and hence the lifetime of the network. As a result, although there has been a lot of promise of pervasive networking via sensors, limited energy of the nodes has been a major bottleneck to deployment feasibility and cost of such a network. With this view, alongside many innovative network communication protocol research to increase nodal as well as network lifetime, there have been significant ongoing efforts on how to impart energy to the depleted batteries on-line. In this chapter, we propose to apply the lessons learnt from our surrounding nature and practices of the living world to realize network energy operated field sensors. We show that, although the regular communicating nodes may not benefit from network energy harvesting, by modifying the carrier sensing principle in a hierarchical network setting, the low power consuming field nodes can extend their lifetimes, or even the scavenged RF energy can be sufficient for the uninterrupted processing and transmission activities of the field nodes.

INTRODUCTION

A common challenge in wireless sensor networks is the limited energy resource of field nodes. Existing techniques on increasing network lifetime aim at efficient processor design and network protocol level solutions, none of which can help replenish the drained battery of a field sensor node. Many deployment scenarios in hazardous and inaccessible terrains demand that once the sensor nodes are deployed they cannot be physically accessed for replacing the drained batteries. Also, since the field nodes could be hundreds of thousands in number in many cases, once deployed, it is not feasible to physically access all of them for recharging. This restriction puts a huge cost
of network operation and waste of technology resources, as new nodes need to be redeployed to replace the existing nodes that have drained batteries but are otherwise functionally capable. Even if the energy drained nodes can be collected and recharged, off-line recharging solution adds disruption to the network operation. Certainly, a disruption-free network operation, which requires online recharging of the sensor nodes, would add a significant value to the physical world networking via field sensors.

One technology that serves the purpose of disruption-free operation is energy harvesting -- a process by which energy is derived from an external ambient source. The available online recharging solutions in the research literature propose to use natural energy resources, such as solar (Raghunathan, et al., 2005), vibration (Meninger, et al., 2001; Roundy, et al., 2004), wind (Weimer, et al., 2006), thermal gradient and strain (Starner, 1996; Shenck and Paradiso, 2001; Gonzalez, et al., 2002), etc., as well as a combination of them (Kansal, et al., 2007), (Paradiso and Starner, 2005; the references therein), which are available subject to the specific deployment scenarios. The possibility of charging wireless node batteries from ambient (other than in-network) radio frequency (RF) energy sources is also being investigated via suitable broadband rectenna designs, e.g., (Hagerty, et al., 2004). Since the non-network ambient RF signal can be of any polarization and frequency, the rectenna design has to be adaptive and uniquely designed for wireless recharging only.

Wireless energy transfer from dedicated RF sources is being studied (Paing, et al., 2007) and commercialized (Powercast Corp., 2010; Wild-Charge Technology, 2010; E-coupled technology, 2010). Wild charge technology is based on MIT’s wireless electricity technology. E-coupled technology provides wireless energy transfer using electromagnetic induction. The RF technique is also being investigated for solar energy transfer from space to the earth at a mega scale (MIT Space Solar Power Workshop, 2007). While RF energy transfer technique at a low power domain has been demonstrated to be feasible, in general energy transfer by RF waves involves significant waste of energy due to power law decay of RF signal power with distance. Also, in a remote area deployment setting such an approach to power a large number of spatially dispersed nodes may prove inefficient.

As an alternative and possibly a more generic and cost-effective solution, we propose to harvest the available network RF energy in a field deployment scenario for powering the field sensors. This approach does not require any special antenna design, as the RF energy is available in the same frequency band and with same polarization as the desired information signal. To this end, we use our observations from the surrounding nature and propose to put in effect the learning from practices of the living world.

**Motivation: Learning from Nature**

The network RF energy harvesting concept is an attempt to build a communication system that mimics thermo-regulation in animals and plants. Animals other than humans regulate and maintain their own body temperature with certain behavioral traits and physiological adjustments. Below, through examples from the living world, the different concepts in a network energy driven sensor network are presented.

- Desert lizards bask in the sun and absorb solar heat. They may also absorb heat by conduction from heated rocks that have stored radiant solar energy. An energy scavenging communication network absorbs ambient RF (or solar, or any other form of ambient energy). This RF energy absorbed could have been transmitted from a super node (analogous to the sun), or from any other node (analogous to reflected heat from rocks.)