Chapter XLII
Techniques for Exploiting Mobility in Wireless Sensor Networks

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ABSTRACT

A sensor network consists of tiny, low-powered and multifunctional sensor devices and is able to perform complex tasks through the collaborative efforts of a large number of sensor nodes that are densely deployed within the sensing field. Maintaining connectivity and maximizing the network lifetime are among the critical considerations in designing sensor networks and its protocols. Conservation of limited energy reserves at each sensor node is one of the greatest challenges in a sensor network. It has been suggested that mobility of some nodes/entities in a sensor network can be exploited to improve network performance in a number of areas, including coverage, lifetime, connectivityy, and fault-tolerance. In this context, techniques for effectively utilizing the unique capabilities of mobile nodes have been attracting increasing research attention in the past few years. In this chapter, the authors focus on some of the new and innovative techniques that have been recently proposed to handle a number of important problems in this field. It also presents a number of open problems and some developing trends and directions for future work in this emerging research area.

INTRODUCTION

A *sensor network* is an interconnection of tiny, lightweight, energy-constrained devices, known as *sensor nodes*, and is usually deployed to monitor some kind of physical phenomena from the territory of its deployment. For example, a sensor network may be deployed to monitor the humidity or the temperature of a certain region, or it may be deployed to detect the presence or absence of some objects, as well as the movement of objects within the area being monitored. Recent technological advances in the field of micro-electro-mechanical systems (MEMS) have made the development of such tiny, low-cost, low-powered and multi-functional sensor devices technically and economically feasible (Akyildiz, 2002; Chong, 2003). These nodes are usually equipped with a sensing unit, a processing unit, a memory unit and a RF unit that is used for wireless data communication.

The data generated by each sensor is required to be sent to a central point, known as *Base Station (BS)* (also referred to as *sink* or *access point*). The base station is not power constrained and its location may or may not be fixed. A general layout of a sensor network, including the sensor nodes and a base station, is shown in Figure 1. Some researchers have also proposed the deployment of multiple sinks within a sensor network.

The nodes in a sensor network are deployed inside or very close to the phenomenon being monitored, in order to carry out the sensing task effectively. The placement of sensor nodes in a network can be predetermined (e.g. the deployment of a sensor network in a factory or in the body of a human, an animal or a robot) or random (e.g. the deployment of nodes by dropping them from a helicopter/airplane or delivering them in an artillery shell or in a missile) (Akyildiz, 2002; Chong, 2003). All data from the sensor nodes must eventually be collected at the base station(s) or sink(s). The collected data may be aggregated and forwarded to the user, possibly using the Internet, where it can be further analyzed to extract useful information.

Although the capability of an individual sensor node is limited, a sensor network is able to perform bigger tasks through the collaborative efforts of a large number of sensor nodes (hundreds or even thousands) that are densely deployed within the sensing field (Akkaya, 2005; Akyildiz, 2002; Chong, 2003). There is a wide range of applications, for both military and civil purposes, where the use of sensor networks can be very useful that include medical, industrial, military, and environmental fields. For example, sensor networks can be used for target and/or movement detection, which is extremely important for military/battlefield applications as well as habitat monitoring and health monitoring.

In sensor networks, all data flow from the sensor nodes towards the base station(s). The transmission power dissipated by a source node to transmit each bit of data to a destination node increases significantly with the distance between the source and the destination (Akyildiz, 2002; Chong, 2003; Duarte-Melo, 2002; Gupta, 2003, Heinzelman, 2000). As a result, the use of multi-hop paths has been proposed for conserving energy, in both *flat architectures* (where all sensor nodes are treated equally and each are responsible to send/route data towards the sink) and *hierarchical architectures* (where sensor nodes are partitioned into clusters and one node takes responsibility of being the cluster head of a cluster (Bari, 2006). Each sensor sends data to the respective cluster head, which sends/routes data towards the sink). In the multi-hop routing scheme, nodes located further away from the base station use some intermediate nodes to forward the data to the base station. In such a data-gathering model, it is possible that some nodes (close to the base station) are required to relay more data, which they have received from the neighboring nodes, compared to other nodes. Therefore, these nodes may dissipate energy at higher rates than the nodes which are not relaying (or relaying very little) data from other nodes. This uneven energy dissipation among the nodes may lead to the faster *death* of some nodes in the network due to the complete depletion of the batteries of these nodes, assuming that initial energy provisioning for all nodes are equal. Such unbalanced energy dissipation has an undesirable effect on the functionality of the sensor networks, as the inoperative node(s) will not be able to perform either sensing or routing. This can cause the entire network to prematurely lose its usefulness, even though many other nodes in the networks still retain power. Therefore, a careful load distribution scheme can be effective to prolong the useful lifetime of the network (Bari, 2007).

Role of Mobility in Addressing Sensor Network Design Challenges

Sensor networks pose many challenges in design, operation and maintenance in each layer of the networking protocol stack. Some important issues in the design of sensor networks include:

- *Network deployment in ad hoc manner:* The nodes in sensor networks, which are deployed in remote areas, need to self-configure and self-organize themselves so that they can form the networks.
- *Unattended operation with limited battery power:* Replacing or recharging batteries in sensor networks is usually not feasible, either physically or economically, so that, in many cases, the lifetime of a sensor network expires as soon as *critical* node(s) run out of battery power (Heinzelman, 2000).

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