Chapter 8
Lifetime Maximization in Wireless Sensor Networks

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ABSTRACT

One of the fundamental requirements in wireless sensor networks (WSNs) is to prolong the lifetime of sensor nodes by minimizing the energy consumption. The information about the energy status of sensor nodes can be used to notify the base station about energy depletion in any part of the network. An energy map of WSN can be constructed with available remaining energy at sensor nodes. The energy map can increase the lifetime of sensor networks by adaptive clustering, energy centric routing, data aggregation, and so forth. In this paper, the authors describe use of energy map techniques for WSNs and summarize the applications in routing, aggregation, clustering, data dissemination, and so forth. The authors also present an energy map construction algorithm that is based on prediction.

1. INTRODUCTION

A lot of applications require acquisition of data from physical environment. This leads to development of a new kind of network of tiny sensor nodes. These sensor nodes have ability of sensing, transmitting and forwarding data wirelessly to another node of same or different type. These types of networks are known as wireless sensor networks (WSN). A lot of research can be seen in WSNs like development of energy efficient routing protocol, clustering, data aggregation, etc. Battle field surveillance (Bokareva et al., 2006) habitat monitoring (Hart & Martinez, 2006) medical (Yan, Xu, & Gidlund, 2009) smart home (Hussain, Schaffner, & Moseychuck, 2009) and sports (Espina, Falck, Muehlsteff, Yilin, Adan, & Aubert, 2008) are some of the major application areas of sensor networks.

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In WSNs, the sensor nodes are very constrained in terms of battery power. Sensor nodes in WSNs have non-rechargeable batteries. At the same time, it is not easy to replace batteries because WSNs are deployed generally in inhospitable environments like forests, sea and battlefields. The only way to make a WSN alive for longer time is to make the efficient use of available battery power of sensor nodes. Power optimization must be taken into account at each layer of network model including physical and application layer. Since a large fraction of the energy of a sensor node is consumed in data transmission, so most of the energy efficient protocols are designed at network layer. A large number of protocols for energy efficient clustering (Heinzelman, Chandrakasan, & Balakrishnan, 2002; Liu & Lin, 2005), routing (Al-Karaki & Kamal, 2004; Shah & Rabaey, 2002; Al-Karaki, Ul-Mustafa, & Kamal, 2004), and data aggregation (Rajagopalan & Varshney, 2006; Kalpakis, Dasgupta, & Namjoshi, 2003) exist in the literature. Heinzelman et al. (2002) proposed an energy efficient clustering protocol that selects clusterheads based on probability. In Liu and Lin (2005) authors introduced a re-clustering strategy and a redirection scheme for cluster-based WSNs in order to address the power-conserving issues in such networks, while maintaining the merits of a clustering approach. A good survey on the routing algorithms for WSNs has been presented in Al-Karaki and Kamal (2004). Some examples of the energy efficient routing algorithms are Energy Aware Routing (EAR) (Shah & Rabaey, 2002) and Virtual Grid Architecture routing (VGA) (Al-Karaki, Ul-Mustafa, & Kamal, 2004). Rajagopalan et al. (2006) presented data aggregation techniques for WSNs. Kalpakis et al. (2003) have proposed maximum lifetime data gathering with aggregation (MLDA) algorithm to obtain data gathering schedule with maximum lifetime where sensors aggregate incoming data packets.

To optimize the energy consumption in sensor nodes, Zhao et al. (2002) have designed a residual energy scan for whole sensor network to monitor the energy consumption in every part of the sensor network. Mini et al. (2004, 2005) extended their work of energy scan construction and named it as Energy map. An energy map is a scan of available remaining energy at sensor nodes in WSNs. Energy maps can also be useful in increasing lifetime of sensor network by adaptive clustering, energy centric routings, data aggregation, etc. With the help of energy map we can determine if any part of the sensor network is about to fail in near future due to depleted energy.

In Zhao, Govindan, and Estrin (2002) authors described the aggregation based approach for energy map construction. In this approach, a composite scan is created by combining all local scans by sensor nodes. Another approach for energy map construction used in Mini et al. (2004, 2005) is based on prediction. In prediction based approach, a sensor node can predict its energy consumption based on its past history. Based on that prediction, energy map can be constructed. In the mechanism proposed by Mini et al. (2004, 2005) every sensor node need not to send energy information to the monitoring node, it can just send its available energy and parameters of energy consumption model. In this way authors minimized the cost of energy map construction. Song et al. (2006) proposed an energy map construction approach based on non-linear manifold learning algorithm. In general, we should devise some efficient methods for energy map construction so that utility of the energy information compensate the amount of energy spent in this process.

Energy map is a very important phenomenon in the context of WSN because the energy information is usually very crucial to develop a good sensor network protocol stack such as clustering algorithms and routing protocols. In Song,
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