Chapter XIII

Distributed Scheduling Protocols for Energy Efficient Large-Scale Wireless Sensor Networks

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ABSTRACT

A major design challenge in wireless sensor network application development is to provide appropriate middleware service protocols to control the energy consumption according to specific application scenarios. In common application scenarios such as in monitoring or surveillance systems, it is usually necessary to extend the system monitoring area as large as possible to cover the maximal area. The two issues of power conservation and maximizing the coverage area have to be considered together with both the sensors’ communication connectivity and their power management strategy. In this chapter, the authors proposed novel enhanced sensor scheduling protocols to address the application scenario of typical surveillance systems. Their protocols take into consideration of both power conservation and coverage ratio to search for the balance between the different requirements. They proposed both centralized and de-centralized sensor scheduling versions, and compared the performance of different algorithms using several metrics. The results provide evidence of the advantages of our proposed protocols comparing with existing sensor scheduling protocols.
INTRODUCTION

The rapid advancements in wireless sensor networks (WSNs) have been made possible by recent developments in wireless communication technologies, embedded systems, and sensor devices. Nowadays, commercial WSN platforms are widely available, and the sensor nodes are tiny in size, low cost, and power efficient. These small sensor nodes are capable of sensing the environment, storing and processing the collected sensor data, and interacting and collaborating with each other within the network. WSNs have very important applications where the continuous data collection and information processing are required. Some typical applications include surveillance systems, environment monitoring and healthcare monitoring as in (Akyildiz, 2002; Huang, H., 2005).

In many application scenarios, the deployment environment of a wireless sensor network may be hazardous or difficult to access. For example, a seismic monitoring system may be deployed on a volcano. The growing size of the sensor network also makes it costly and impractical to manually replace or recharge the battery of each sensor nodes. The sensor network deployments in some applications may contain hundreds of sensor nodes. In these cases, the power supply for the sensor nodes becomes a serious problem that needs to be addressed during the system design. How to prolong the life time of the WSN system? A straightforward solution is to limit the number of sensor nodes which are assigned duties and thus consume their battery power, while keeping the rest of the nodes inactive. By intelligently distributing the power consumption among all of the deployed sensor nodes, the system can significantly extend its lifetime and be robust to unexpected sensor node failures.

However, a major design challenge for energy-efficient surveillance sensor network is to provide the optimal coverage for the monitoring area meanwhile considering the energy conservation issue. This coverage ratio is one of the main performance metrics to evaluate the quality of service for the system. The coverage problem cannot be solved alone without the consideration of sensor scheduling strategy. It is heavily dependent on the coverage model and locations of the deployed sensor nodes. Sensor coverage model can be considered as a metric for the quality of service of each sensor’s sensing function, and it is subject to a wide range of interpretations due to a large variety of sensors and applications. On the other hand, network coverage can be considered as a collective measure of the quality of service provided by sensor nodes at different geographical locations.

In the literature, the coverage problem in WSNs has been formulated in various ways with different assumptions and objectives (Cardei, 2004; Cardei, 2006; Huang, C.F., 2005a; Huang, C.F., 2005b). The sensor coverage model may need to take into consideration of specific signal processing techniques for individual sensor node as well as cooperative signal processing techniques for multiple sensor nodes. In the design stage, one may want to know at least how many sensor nodes are needed such that the entire sensor field is covered. During the deployment stage, sensor nodes may be deterministically placed into the sensor field or simply randomly scattered. Also mobile sensor nodes may move to more preferable locations after the initial deployment. During the operation stage, one may want to schedule different sensor nodes to work collaboratively in order to prolong the network life time while still preserving network coverage. Other network performance metrics such as energy consumption and network connectivity may need to be integrated with the coverage problem in the context of WSNs.

In this chapter, we propose novel enhanced sensor scheduling protocols designed for the implementation of large-scale sensor networks for surveillance applications. The paper is organized as follows. In Section 2, we briefly review the related work in sensor scheduling and coverage control. Section 3 presents the system model, assumptions and some definitions. The centralized and de-centralized