Chapter 7
Sensor Activity Scheduling

Abstract In one random node deployment, the number of scattered sensors is normally higher than that required by the critical sensor density such that this deployment can achieve complete area coverage almost surely. In some cases, the number of deployed sensor nodes may even be much higher than the optimum to provide certain robustness for the deployed network. After nodes have been deployed, there might be some redundant sensors whose covered area can also be covered by other sensors. Sensor activity scheduling is used to schedule nodes to be activated alternatively so that the network operation time may be prolonged and certain area coverage requirement can still be met. Generally speaking, the design of a sensor activity scheduling scheme should answer the following question:

How to determine which sensors to be active at which time and be active for how long?

The first part of the question is the focus of this chapter. The second part of the question can be approached by two ways: One is to let each active sensor operate until it depletes its energy, and after that, reselection for active sensors is performed again. The other is to let each active sensor operate for a fixed time interval, and reselection for active sensors is then performed at the beginning of each interval. This chapter first summarizes the assumptions and objectives when designing an activity scheduling scheme and then introduces some representative schemes to illustrate how to select active sensors.

7.1 Assumptions and Objectives

Many activity scheduling schemes proposed in the literature have different assumptions and objectives. The basic assumption is that the coverage model of individual sensors or the covered area of individual sensors is known a priori. Another assumption is on the availability of the nodes’ location or distance information: whether each node knows its own Cartesian coordinates, or two neighboring nodes know the Euclidean distance between them. Knowing the nodes locations can be used to derive distances between any pair of nodes, but knowing the distance information
may not be enough to derive nodes’ locations. If the covered area of individual sensor is not a regular shape (e.g., not a disk), a sensor normally needs its own and its neighbors’ locations to decide whether its covered area can also be covered by its neighbors. On the other hand, if the covered area of a sensor is modeled as a disk, a sensor may check its redundancy based only on the distance information. Sometimes, all sensors are assumed to have the same coverage model, and the design of a sensor activity scheduling scheme can be based on the absence of both the nodes’ location and distance information.

The basic objective of sensor activity scheduling is to guarantee the area coverage ratio, which is defined as the fraction between covered area and uncovered area of a sensor field. We use $\mathcal{A}$ to denote a sensor field and $A(\mathcal{A})$ to denote its area. Let $\mathcal{S} = \{s_1, s_2, \ldots \}$ and $\mathcal{S}_a \subseteq \mathcal{S}$ denote the set of all the deployed sensors and the set of selected active sensors, respectively. Sometimes, $\mathcal{S}_a$ is called a cover. Let $A(s)$ denote the area covered by a sensor $s$. We use $A(\mathcal{S}) = A(\mathcal{A}) \cap (\bigcup_{s \in \mathcal{S}} A(s))$ to denote the area of the sensor field covered by all the deployed sensors. Similarly, we use $A(\mathcal{S}_a) = A(\mathcal{A}) \cap (\bigcup_{s \in \mathcal{S}_a} A(s))$ to denote the area of the sensor field covered by the selected active sensors. A sensor field is completely covered if $A(\mathcal{S}_a) = A(\mathcal{A})$ and is partially covered if $A(\mathcal{S}_a) < A(\mathcal{A})$. The area coverage ratio that is achieved by the selected active sensors is defined as $\frac{A(\mathcal{S}_a)}{A(\mathcal{A})}$.

Generally, we can specify two basic coverage requirements, namely, complete coverage and partial coverage, for the sensor activity scheduling schemes. Complete coverage requires that the coverage ratio equals one. That is, $A(\mathcal{S}_a) = A(\mathcal{A})$. In most cases, this indicates that a sensor field can also be completely covered by the selected active sensors if all the deployed sensor nodes provide complete area coverage. Partial coverage allows some uncovered area, but it requires that area coverage ratio should be larger than a predefined threshold. That is, $\frac{A(\mathcal{S}_a)}{A(\mathcal{A})} \geq \delta$ where $0 < \delta < 1$.

Another important objective is to select active sensors as least as possible. An active sensor consumes energy to sense physical phenomena and to produce sensing data. Furthermore, its sensing data needs to be sent back to the sink or to be exchanged with other sensor nodes, which increases energy consumption for this active sensor as well as others. Therefore, it is important to reduce the number of active sensors in order to reduce energy consumption and prolong network lifetime. This objective, however, is often in conflict with the coverage ratio objective. In general, the more the active sensors, the higher the coverage ratio. We should make a well balance between coverage ratio and the number of active sensors. This is especially important in the partial coverage requirement.

The network area coverage lifetime is also an important objective. Similar to the definition of target coverage lifetime, the area coverage lifetime is defined as the duration from the time that the network starts operation till the time that the area coverage requirement cannot be satisfied even if all the alive sensor nodes are active. Generally speaking, selecting the least number of active sensors helps to prolong the network lifetime. However, care must be taken, since data processing and dissemination also consume energy and impact on the network lifetime. Sometimes, sensor activity scheduling may not lead to any extension of the network lifetime when preserving complete area coverage is required. For example, consider the case that a