Abstract

A wireless sensor network (WSN) consists of a number of tiny battery-powered devices with the capability to sense some parameters. Each sensor node also has limited computation and communication capability. One important problem in many wireless sensor network applications involving surveillance or monitoring is that of *coverage*. This thesis addresses two broad problems in the area of coverage, namely, covering a set of line segments in a region by a set of sensors, and maintaining the quality of coverage in the presence of sensor failures.

We first address the problem of measuring the overall quality of line coverage achieved by a given sensor deployment in a region. A line segment is said to be *k-covered* (resp. *k-uncovered*) if it intersects the sensing regions of at least k (resp. at most $k-1$) sensors. We propose two new metrics, *smallest k-covered line segment* and *longest k-uncovered line segment*, that attempt to characterize the quality of line coverage. Given any arbitrary sensor deployment, we present polynomial time algorithms for computing the two measures for three different cases: when the line segments to be covered are restricted to be axis-parallel, when the line segments can have arbitrary orientations but are restricted to have one endpoint fixed, and when the line segments can have arbitrary orientations and arbitrary endpoints within the region.

In the second work, we address the complementary problem of finding a sensor deployment to achieve some desired degree of line coverage. We show that the problem of finding the minimum number of sensors needed for k-covering a given set of line segments is NP-complete even for $k = 1$. Hence, we investigate the design of approximation algorithms for the problem. We first present a 12-factor and an 8-factor approximation algorithm for finding the minimum number of sensors and their positions for 1-covering a given set of axis-parallel line segments. It is also shown that the problem for axis-parallel line segments admits a PTAS (Polynomial Time Approximation Scheme). We next present another PTAS for 1-covering arbitrarily oriented line segments for the case where the length of the segments are bounded by some constant factor of the sensing range. The above algorithms do not put any restriction on the position of the sensors. However, in practice, a minimum

separation may be needed between any two sensors. We next address this problem and present an approximation algorithm to deploy minimum number of sensors to 1-cover a set of axis-parallel line segments while maintaining a minimum separation between two sensors. Finally, we extend this algorithm to k-cover the set of axis-parallel line segments for arbitrary k.

The third work addresses the problem of maintaining *support coverage*. Given any area A and a placement of n sensors in A, the support value of any path between two given points i and f is the maximum distance of any point on the path from its closest sensor. The *maximal support path* is the path between i and f with the minimum support value. Note that the support value of such a path may increase if one or more sensors fail. In this work, we present algorithms for maintaining the support value of a path after the failure of a sensor for two cases, (i) when the sensors are allowed to move in any direction, and (ii) when they are constrained to move only in one of the four directions, *east*, *west*, *north*, and *south*. Both algorithms achieve a support value that is within a low constant factor of the maximal support value before the failure, moving exactly one sensor by a bounded amount. It is also shown that the constant-factor guarantee on the support value is maintained even for a constant number of failures while moving only one sensor for each failure. Detailed simulation results are given to evaluate the schemes. We also present distributed implementations of the algorithms.

The final work addresses the problem of maintaining *barrier coverage* in a sensor network deployment. A *barrier* is an annular belt-like region surrounding an area. The barrier is said to be *k-barrier covered* if every path that crosses the barrier cuts the sensing range of at least k sensors. In this work, we present an algorithm for maintaining 1-barrier coverage of a rectangular region in the presence of sensor failures. The algorithm reconstructs the barrier after a failure locally using communication between sensors close to the failed sensor, without involving all sensors in the barrier. Detailed simulation results are presented to show that the scheme can repair the barrier even in the presence of a significant number of sensor failures. Distributed implementation of the algorithm is also discussed.