Abstract

Due to the recent advances in digital technology, developments of low-cost and multi-functional sensors become possible. When a large number of sensors collaborate using wireless communication, they constitute wireless sensor network. Although wireless sensor network has many applications, it has limited lifetime due to the limited amount of power equipped in each sensor, and replacing the battery is impractical in many applications.. Therefore, one of the important design issues in the network is how to use the energy efficiently to extend the network lifetime for performing the sensing and communication tasks. To monitor a set of targets with known hostile locations, we can spread a large population of sensors in the proximity of the targets instead of positioning them in precise locations. This increases the network density, thus the sensing area of some sensors may overlap. Now we can schedule the sensors` activities such as to allow the redundant sensors to enter the sleep state and save energy for future use. Let the set of sensors which can perform the monitoring task independently as an active set. To maximize the network lifetime, it is critical to rotate the roles of the active set among the sensors in the network. Thus, at any time, only one set of sensors belong to one active set are asked to be active, instead of all the network sensors. Generally, we use a graph to represent the network. Each sensor of the network is represented as a vertex and there exists an edge between two vertices if and only if two vertices are located within a communication range. A dominating set is a subset of vertices such that each vertex of the graph is either in the dominating set or has a neighbor in the dominating set. Now an active set in the network equivalent to the dominating set in a graph. In this thesis, we consider several optimization problems to extend the network lifetime in wireless sensor network . First, we consider the maximum disjoint set covers problem. In maximum disjoint set covers problem, we assume that, targets are stationary, all sensors in network are homogeneous and each sensor can participate in at most one dominating set. Under this assumption, the larger the number of disjoint sets, the longer the network lifetime. To obtain a maximum number of disjoint sets, we propose a mathematical formulation, and computational experiments show that our formulation outperforms the previous mathematical formulation in terms of the run times to obtain an exact solution. Also, we propose a heuristic and this algorithm can be used when the expected run time to obtain an exact solution is probably too long. For a given graph with the different amount of resources in each vertex, obtaining a maximum network lifetime is referred to as a maximum lifetime coverage problem. One of the main difficulties to obtain an exact solution is, if we use a linear programming to formulate the problem, exponential number of variables is required to represent the problem. To overcome this difficulty, we applied a column generation procedure to handle the variables implicitly rather than explicitly. We also suggest using two techniques to accelerate the convergence to an optimal solution during the column generation procedure. We performed extensive computational experiments on randomly generated graphs, and we obtained exact solutions in all cases within a reasonable amount of time. Next we consider the case when the sensors in a dominating set need to be connected. This requirement happens for proper routing protocol functioning and asks to obtain a minimum connected dominating set for a given graph. In this thesis, we first propose an improved algorithm for the minimum connected dominating set problem. Generally, representing the connectivity requires an exponential number of constraints, thus we first solve the mathematical formulation without the connectivity constraints. If the constructed subgraph using the selected vertices forms a connected dominating set, we obtained a minimum connected dominating set, thus stop the algorithm. Otherwise, since the solution from the formulation is disconnected, we have several components. Now, for each component, we identify the minimum sized vertex cut which separates the current component and the other components, and we only add the corresponding violated constraint to the formulation. Then we solve the enlarged formulation again. This process is continued until we obtain a connected dominating set. We performed extensive computational experiments and the results show that our algorithm can obtain an exact solution in a reasonable amount of time. Also, our exact algorithm is applied to the maximum lifetime coverage problem to obtain a maximum network lifetime, and computational results are included. Lastly, we consider how the robustness can be achieved in a dominating set. Since sensors in wireless sensor network are prone to failure, it is also important to maintain a certain degree of redundancy in the dominating set. This requirement asks to solve the minimum k-connected m-dominating set problem exactly. In k-connected m-dominating set, there exist at least k vertex disjoint paths between any pair of sensors in the dominating set, and each sensor not included the dominating set has at least m adjacent sensors in the dominating set. Therefore, this type of the dominating set can enhance the routing flexibility and the fault tolerance of the network. In this thesis, we propose an exact algorithm for the minimum k-connected m-dominating set problem and the scheme is almost similar to the algorithm used for the minimum connected dominating set. Also, we suggest a heuristic algorithm which can be used to construct the k-connected m-dominating set efficiently, and we discuss about the existence of the k-connected m-dominating set when a graph is given with two natural numbers k and m. We executed performance tests for the algorithms, and our algorithms are also extended to obtain a maximum network lifetime.