ABSTRACT

EXPLOITING NODE MOBILITY FOR ENERGY OPTIMIZATION IN WIRELESS SENSOR NETWORKS

By

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Wireless Sensor Networks (WSNs) have become increasingly available for data-intensive applications such as micro-climate monitoring, precision agriculture, and audio/video surveillance. A key challenge faced by data-intensive WSNs is to transmit the sheer amount of data generated within an application’s lifetime to the base station despite the fact that sensor nodes have limited power supplies such as batteries or small solar panels. The availability of numerous low-cost robotic units (e.g. Robomote, and Khepera) has made it possible to construct sensor networks consisting of mobile sensor nodes. It has been shown that the controlled mobility offered by mobile sensors can be exploited to improve the energy efficiency of a network. In this thesis, we propose schemes that use mobile sensor nodes to reduce the energy consumption of data-intensive WSNs. Our approaches differ from previous work in two main aspects. First, our approaches do not require complex motion planning of mobile nodes, and hence can be implemented on a number of low-cost mobile sensor platforms. Second, we integrate the energy consumption due to both mobility and wireless communications into a holistic optimization framework.

We consider three problems arising from the limited energy in the sensor nodes. In the first problem, the network consists of mostly static nodes and contains only a few mobile nodes. In the second and third problems, we assume essentially that all nodes in the WSN are mobile. We first study a new problem called max-data mobile relay configuration (MMRC) that finds the positions of a set of mobile sensors, referred to as relays, that maximize the total amount of data gathered by the network during its lifetime. We show that the MMRC problem is surprisingly complex even for a trivial network topology due to the joint consideration of the energy consumption of both wireless communication and mechanical locomotion. We present optimal MMRC algorithms and practical distributed implementations for several important network topologies and applications. Second, we consider the problem of minimizing the total energy consumption of a network. We design an iterative algorithm that improves a given configuration by relocating nodes to new positions. We show that this algorithm converges to the optimal configuration for the given transmission routes. Moreover, we propose an efficient distributed implementation that does not require explicit synchronization. Finally, we consider the problem of maximizing the lifetime of the network. We propose an approach that exploits the mobility of the nodes to balance the energy consumption throughout the network. We develop efficient algorithms for single and multiple round approaches. For all three problems, we evaluate the efficiency of our algorithms through simulations. Our simulation results based on realistic energy models obtained from existing mobile and static sensor platforms show that our approaches significantly improve the network’s performance and outperform existing approaches.