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Maximum-Lifetime Routing Algorithms for Wireless Networks

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Abstract

A major problem in wireless networks is how to route either broadcast, unicast or multicast traffic so as to maximize the *lifetime*, i.e., the time until the battery of a transmitting node drains out. Taking an algorithmic approach, we aim at finding solutions with provable performance bounds.

Focusing on the fundamental single-session problem, our solution approach is based on the employment of multi-topology routing schemes. Such a scheme consists of a *sequence of routing topologies*, which are employed sequentially, for some prescribed duration times.

First, we establish *optimal solutions* of polynomial complexity for the restricted cases of either single-topology schemes or unicast sessions. We then show that the general (multi-topology) cases of broadcast and multicast are NP-hard. Accordingly, we establish polynomial approximation schemes with *proven performance bounds*. We also derive a *novel heuristic scheme*, and demonstrate its efficiency by way of simulations.

We then consider an alternative, *single receiver* wireless environment. This change in the environment is shown to have major impacts on the complexity of the various problems, in both directions. Finally, we discuss the extension of our results to the case of multiple sessions.

1 Introduction

In recent years, stationary wireless networks were extensively studied due to their potential applications in the civil and military domains, in particular for the implementation of sensor networks. A sensor network is composed of numerous power constrained nodes, each equipped with processing, memory, short-range radio transmission and sensing capabilities. Scattered over a target environment, the nodes can monitor and collect useful information that is carried to some base-station by using the sensor nodes as relays [1], [2].

Since the amount of energy that can be stored on such nodes is limited, energy efficiency is a crucial aspect in the establishment of such networks. Thus, it is essential to develop protocols that optimize the overall energy utilization of the network, in order to maximize its capability to function for the longest possible time.

Accordingly, a wide variety of energy-efficiency problems have been addressed. One problem that received considerable attention was that of *minimum-energy broadcast*, i.e., finding a broadcast routing that minimizes the total energy consumed by all the nodes. In a wireless network, each node can adjust its transmission power. Transmitting at higher power levels enables more distant nodes to receive the transmission. Furthermore, broadcast transmissions can be received by all nodes within transmission radius. Hence, there is a trade-off between using higher power levels versus reaching more nodes. Two different variations of the energy-efficient broadcast problem have been studied. The first, termed as the *topology control problem*, is to assign each node a transmission power, such that each node in the network can reach any other node, i.e., any node can be a source of a broadcast tree. An optimal topology is then one that minimizes the total transmission power. This problem was shown to be NP-hard [3],[4], and approximate solutions were established [5],[6]. Another studied broadcast problem was the special case where only a single source is considered. This problem was also shown to be NP-hard [7],[8], and a greedy heuristic was proposed in [9]. That