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Analysis of energy-tax for multipath routing in wireless sensor networks

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Abstract Recently, multipath routing in wireless sensor networks (WSN) has got immense research interest due to its capability of providing increased robustness, reliability, throughput, and security. However, a theoretical analysis on the energy consumption behavior of multipath routing has not yet been studied. In this paper, we present a general framework for analyzing the energy consumption overhead (i.e., energy tax) resulting from multipath routing protocol in WSN. The framework includes a baseline routing model, a network model, and two energy consumption schemes for sensor nodes, namely, periodic listening and selective wake-up schemes. It exploits the influence of node density, link failure rates, number of multiple paths, and transmission environment on the energy consumption. Scaling laws of energy-tax due to routing and data traffic are derived through analysis, which provide energy profiles of single-path and multipath routing and serve as a guideline for designing energy-efficient protocols for WSN. The crossover points of relative energy taxes, paid by single-path and multipath routing, reception, and transmission, are obtained. Finally, the scaling laws are validated and performance comparisons are depicted for a reference network via numerical results.

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1 Introduction

While energy minimization is the primary design driver of communication protocols for Wireless Sensor Networks (WSN), secondary metrics, such as reliability, throughput, security, and adaptivity to dynamic topology, are also very important in meeting certain application requirements. There has been a recent emergence of using multipath routing (MPR) in many applications of WSN; it provides increased reliability [1–3], end-to-end throughput [4], security [5], robustness [6, 7], etc. Even though the strategies of using multiple paths in them are different, it is intuitive that creation of multiple paths from each source node to the sink and their maintenance in MPR would drain more energy than for that in single-path routing (SPR). In this paper, our key objective is neither proposing new energy-aware heuristics nor new protocols aimed at increasing network lifetime or application reliability. Instead, it is to analyze and compare MPR and SPR routing mechanisms in WSN, where links are subject to failure, in terms of energy consumption overhead, namely, energy tax. More specifically, our goal is to investigate the interdependencies among network parameters and specify operation regions where MPR is more energy-efficient than SPR or vice versa.

There exist a number of research works that analyze the energy consumption, network lifetime, and tradeoff between energy and quality of service (QoS) in WSNs [8–12]. In [8], using Erlang distribution theory, a quantitative analysis on the tradeoffs between energy