Modeling of Energy Consumption for Mobile Wireless Ad Hoc and Sensor Networks

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Abstract. In this paper, we study energy consumption of mobile two-tier wireless ad hoc and sensor networks in comparison with flat mobile wireless ad hoc and sensor networks. Based on idealized wireless network model, we study the total energy expenditure of both these architectures. We provide general formulas for the trajectory of the movement of the mobile nodes in two-tier mobile wireless ad hoc and sensor networks. Finally, we investigate the case with multiple mobile nodes both with their cooperation and without. Simulation results are presented for commonly used network architectures.

Keywords: ad hoc networks, wireless sensor networks, energy consumption.

1 Introduction

Wireless ad hoc networks [1,2] are decentralized, self-organized networks capable of forming a communication network without any fixed infrastructure. In these networks all nodes are equipped with a radio transmitter and receiver which allow it to communicate with other nodes over wireless channels. Ad hoc networks allow for a multi-hop transmission of data between nodes outside the direct radio links.

Wireless sensor networks [3] are a particular type of ad hoc networks [4], in which the nodes are equipped with advanced sensing functionalities (acoustic, pressure, thermal, etc.), a small processor, and a short-range wireless transceiver. Wireless sensor networks are used for building a global view of the monitored region, which is accessible to the external user(s) from outside through one or more gateway nodes.

Node mobility is a prominent feature of ad hoc and sensor networks. Mobile ad hoc networks (MANETs) [5] are driven mainly by their ability to provide instant wireless networking solutions in situations where infrastructures do not exist. It is obvious that that these networks are more robust than their wired or cellular infrastructures. While the deployment of MANETs is yet to come, extensive research efforts are being currently undertaken to provide a high throughput and low-energy wireless access to resources of such networks.

The sensor network with mobile agents was at first proposed by Tong et al. [6]. In the paper by W. Zhao and M.Ammar [7], the concept of using mobile
nodes for message ferrying is considered, where the objective is to use mobiles to provide nonrandom proactive routers. Many different approaches and protocols have been presented by Basagni et al. [5], the authors of a valuable textbook. An analysis of energy consumption for ad hoc wireless networks using a bit-meter-per-oule metric was suggested by Gao [8]. Currently, an analytical result on the average number of hops between any two nodes if the transmission is successful and the average number of hops traversed by packets before being dropped if the transmission is unsuccessful was presented by Z. Zhang et al. [9]. The energy correlations between node core components, including processors, RF modules and sensors was given by Hai-Ying Zhou et al. [10].

Two layer networks, often called two-tier networks, belong to a typical form of wireless ad hoc and sensor networks. The first layer is formed by ordinary network nodes which are responsible for gathering the information from the monitored region. Some network nodes as belonging to a backbone network form a dominant set. To these nodes belong all clusterhead nodes which are treated as the second layer. They are natural places for an aggregated and compressed traffic converging from many ordinary nodes (sensors).

The main goal of this paper is to analyse energy of flat ad hoc and sensor networks in comparison with the two-tier ad hoc and sensor networks. On the other hand, we examine the dependencies between the total energy expenditure of these two architectures as well. Furthermore, we study the effect of the node density and mobility on energy consumption. It allows us to design the network parameters, such as the mobile nodes trajectory or radio coverage area.

The rest of the paper is organized as follows. Section 2 presents the background and the related work. Section 3 details the energy consumption analysis over flat mobile wireless ad hoc and sensor networks. In Section 4, we provide an analysis of energy consumption over two-tier mobile ad hoc and sensor networks. Section 5 presents some numerical results of energy consumption in mobile wireless ad hoc and sensor networks. In Section 6, we summarize the findings of this paper and present conclusions.

2 Background and Related Work

In our model, we assume that a certain non-zero minimum level of power will be radiated regardless of how short a radio link is. The total power required for communicating over distance $r$ is given by [11], namely

$$p(r) = \max\{p_{\text{min}}, \beta r^\alpha\} + p_{\text{rx}}$$

(1)

where $\alpha$ is the power index for the channel path loss in the field of the antenna, $p_{\text{min}}$ is the minimum transmitter power, $\beta$ represents the minimum transmission power required to communicate at a reference near-field distance of 1 meter, $p_{\text{rx}}$ is the fixed overhead for receiving data. We can follow the remark of Equation (1) as all the nodes are closer than $r_{\text{min}} = (p_{\text{min}}/\beta)^{1/\alpha}$. Then, we obtain the power requirement as a constant at $p_{\text{min}}$ watts.