Chapter 29
QoS and Energy Saving Routing and MAC Mechanisms for Wireless Networks

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ABSTRACT

This chapter describes routing and medium access control (MAC) mechanisms for providing Quality of Service (QoS) together with energy savings in wireless ad hoc networks. The proposed mechanisms operate in a cross-layer optimization logic, in the direction of either minimizing total energy consumption in the network or maximizing network lifetime, while at the same time providing QoS to the end users. The authors present a multi-cost routing approach, where various cost parameters and optimization functions are defined and used for selecting the paths to be followed. Also, routing and MAC protocols are investigated for the case where nodes have variable transmission power capabilities. Finally, the performance of the proposed protocols is evaluated and compared to that of other well-known routing and MAC protocols.

INTRODUCTION

Quality of Service (QoS) mechanisms are important for ad ho c wireless networks, especially since they determine their ability to support delay-sensitive or high-bandwidth applications. Traditional distributed algorithms for QoS routing in wired networks may not work well for wireless ad hoc networks, given that these networks have mobility characteristics, and energy and capacity constraints that are not present in wired networks. Since stations in wireless networks are usually battery-operated and require long operating lifetimes, energy is a crucial resource limiting the

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performance and range of applicability of such networks. However, the advances in battery lifetime during recent years have not kept in pace with the significant decline achieved in computation and communication costs in wireless ad hoc networks. As a result, the design of routing and MAC protocols that make best use of the nodes' energy resources is of outmost importance.

A node in a wireless network consumes energy when transmitting, receiving, or simply listening to the channel. In the transmitting mode, energy is spent in two main ways. The first is in the front-end amplifier that supplies the power for the actual RF transmission (transmission energy), while the second is in the node processor that implements the various signal processing functions (processing energy). In the receiving mode, energy is consumed entirely by the processor. Finally, in the listening mode, the energy consumed is again due to processing operations. However, even in the listening mode, the network protocol may require a device to emit periodic beacon signals. All of the aforementioned modes of operation involve all the components (hardware and software) that constitute a wireless node.

Moreover, energy consumption in a wireless network relates to the higher-level protocols used. At the network layer, extensive collaboration is required among network nodes, in order to establish the routes and to secure the resources that are necessary to provide to the users the required QoS. Most routing protocols proposed to date are based on the single-cost (shortest path) approach, where a single metric is used to represent the cost of using a link. This link metric can be a function of several network parameters, but it is still a scalar. Routing algorithms of this kind calculate the path that has the minimum cost for each source-destination pair, but they cannot optimize the performance with respect to general cost functions, and they do not easily support QoS differentiation. Also, they usually yield only one path per source-destination pair, leading to non-uniform traffic and energy distribution, and to possible instability problems in the network. At the MAC layer, the proposed protocols for ad hoc networks have solved several problems occurring mainly due to the broadcast nature of the wireless medium (for example, the hidden terminal problem). However, many of these MAC protocols do not take into account energy and QoS considerations. At the physical layer, the transmission power used by the nodes obviously affects the energy consumed in the network, since the use of large transmission power results in more energy expenditure. When the wireless nodes have fixed transmission power, independently of the receiving node they are trying to reach, they may expend an unnecessarily large amount of energy and cause unwarranted interference to other nodes (when the desired recipient is at a smaller distance than the static transmission range used), resulting in packet re-transmissions, and consequently more energy expenditure.

At this chapter we describe cross-layer protocols to reduce energy consumption and support QoS differentiation in wireless ad hoc networks. To achieve energy savings in the routing procedure, the multi-cost routing approach is presented where routing decisions are made based on several cost parameters, including information provided by lower levels (e.g., MAC layer). In particular, a cost vector consisting of several cost parameters is assigned to each link. The cost parameters of a link can include many parameters of interest (e.g., the hop count, the energy expended by the transmitting node, its residual energy, etc). These cost parameters are combined in a number of different ways, each corresponding to a different routing algorithm, in order to select the optimal route. Another interesting approach considered is the joint multi-cost routing and power control in wireless networks, where various cost parameters of interest are considered, such as the interference caused, the residual energy and the variable transmission power of the nodes. This joint multi-cost routing and power control approach obtains energy/interference efficient routes and optimizes network performance. Finally, a power control