Chapter 10
QoS Support in Multi-hop Ad-hoc Networks

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ABSTRACT

The chapter contains an overview of existing QoS solutions for multi-hop ad-hoc networks. Firstly, an introduction and short motivation are presented. The authors present an analysis of the QoS aspects of the physical layer because the wireless communication channel is constantly changing and inherently prone to errors. QoS provisioning at the data link layer is studied next. The authors focus on protocols which enable traffic differentiation, solve the hidden node problem and provide fair medium access. The chapter also deals with QoS issues at the network layer, where the authors mostly discuss QoS routing protocols. Additionally, cross-layer solutions for QoS support in multi-hop ad-hoc networks are analyzed. Finally, the expected direction of future work and a brief summary are presented.

INTRODUCTION

Multi-hop ad-hoc networks are distributed, wireless networks without infrastructure in which every node acts as both terminal and router. They are a rapidly evolving telecommunications technology which will assure connectivity for popular mobile devices (laptops, PDAs, cell phones, etc.). Ad-hoc networks can provide spontaneous communications for users which are out of reach of infrastructure networks. They can also be used as extensions to existing networks. For example, community networks can be used to offer Internet access in a neighborhood. Finally, multi-hop ad-hoc networks can provide communications in emergency situations, in which the infrastructure networks have failed or are unavailable. Currently existing wireless networks have demonstrated that it is possible to efficiently deal with data services (e.g., Internet connectivity). Therefore, there is a growing expectation that future wireless networks will efficiently deal with multimedia

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services as well. This is caused by the growing popularity of such applications as VoIP, multimedia streaming, peer-to-peer file sharing, etc. However, the nature of ad-hoc networks makes the task of serving delay sensitive or bandwidth consuming traffic with a proper QoS very complex. In comparison to wired networks, ad-hoc networks offer much smaller bandwidth and, therefore, their design requires much more attention. Additionally, such factors as mobility of devices, unpredictable channel conditions, the hidden and exposed node problems, limited battery power, and heterogeneity of devices make QoS provisioning in ad-hoc networks a very complicated challenge.

We begin with background information regarding the challenges of QoS provisioning in multi-hop ad-hoc networks. Then, we describe QoS solutions proposed for the physical, data link and network layers. Additionally, we discuss cross-layer solutions, which combine features of the previously presented protocols. Finally, we sketch future research directions and present the most important conclusions.

**BACKGROUND**

QoS is a term which has been widely used in modern telecommunications. QoS is the ability to provide different priorities to different applications or flows to guarantee a certain level of performance. QoS guarantees are especially important when the network capacity is insufficient or the network is exposed to congestion. QoS is most commonly measured by the following metrics: bit rate, delay, variation of delay (jitter), packet dropping probability and bit error rate (BER). In multi-hop ad-hoc networks providing QoS is particularly difficult because of the challenges at the following layers:

- **Physical layer.** The use of wireless technologies makes links susceptible to fluctuations in the radio channel. As a result such factors as fading or interferences may lead to low bit rates and high BERs. The physical layer should quickly respond in such situations to prevent high frame error rate (FER) at the data link layer. Furthermore, random movement of mobile nodes introduces unpredictable link failures which lead to network reconfiguration. Additionally, mobile nodes are usually limited by their battery power. Power consumption can be one of the QoS attributes, because it has a strong influence on all QoS metrics.

- **Data link layer.** With the help of adequate MAC protocols, nodes need to support service guarantees for multiple traffic classes and efficiently share a common radio channel with their neighbors. Additionally, traffic scheduling schemes for real-time traffic should be used to avoid starvation of best effort traffic. The protocol should also promptly react to transmission errors and collisions. The automatic repeat request (ARQ) or adaptive error correction methods should also be used when transmission quality degrades on the data link layer.

- **Network layer.** Nodes can move in a random way. Therefore, the network topology changes unpredictably and routing protocols need to quickly adjust. Additionally, there should be a signaling protocol responsible for admission control, resource reservation, reaction to congestion and negotiation of QoS parameters.

All the mentioned features make assuring QoS in multi-hop ad-hoc networks both a challenging task and an interesting research problem. Providing a complete QoS solution for the ad-hoc networking environment requires the interaction and cooperation between three OSI/ISO layers, i.e., the physical, data link and network layers. The first two layers allow for QoS support in a single-hop connection, the third layer is responsible for end-to-end QoS. Therefore, in a multi-hop
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