Chapter 7.19
Quality of Service in Mobile Ad Hoc Networks

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INTRODUCTION

Mobile ad hoc networks (MANETs) form a class of multi-hop wireless networks that can easily be deployed on-the-fly. These are autonomous systems that do not require existing infrastructure; each participating node in the network acts as a host as well as a packet-forwarding router. In addition to the difficulties experienced by conventional wireless networks, such as wireless interference, noise and obstructions from the environment, hidden/exposed terminal problems, and limited physical security, MANETs are also characterized by dynamically changing network topology and energy constraints.

While MANETs were originally designed for use in disaster emergencies and defense-related applications, there are a number of potential applications of ad hoc networking that are commercially viable. Some of these applications include multimedia teleconferencing, home networking, embedded computing, electronic classrooms, sensor networks, and even underwater surveillance.

The increased interest in MANETs in recent years has led to intensive research efforts which aim to provide quality of service (QoS) support over such infrastructure-less networks with unpredictable behaviour. Generally, the QoS of any particular network can be defined as its ability to deliver a guaranteed level of service to its users and/or applications. These service requirements often include performance metrics such as throughput, delay, jitter (delay variance), bandwidth, reliability, etc., and different applications may have varying service requirements. The performance metrics can be computed in three different ways: (i) concave (e.g., minimum bandwidth along each link); (ii) additive (e.g., total delay along a path); and (iii) multiplicative (e.g., packet delivery ratio along the entire route).

While much effort has been invested in providing QoS in the Internet during the last decade, leading to the development of Internet QoS models such as integrated services (IntServ) (Braden, 1994) and differentiated services (DiffServ) (Blake, 1998), the Internet is currently able to provide only best effort (BE) QoS to its applications. In such networks with predictable resource availability, providing QoS beyond best effort is already a challenge. It is therefore even more difficult to achieve a BE-QoS similar to the Internet in networks like MANETs, which experience a vast spectrum of network dynamics (such as node mobility and link instability). In addition, QoS is only plausible in a MANET if it is combinatorially stable, i.e., topological changes occur slow enough to allow the successful propagation of updates throughout the network. As such, it is often debatable as to whether QoS in MANETs is just a myth or can become a reality.

BACKGROUND

The successful deployment of QoS in MANETs is a challenging task because it depends on the inherent properties of the network: node mobility, variable (and limited) capacity links, as well as rapid deployment and configuration. These factors lead to a network with dynamic topology, complex route maintenance, and unpredictable resource availability. It is difficult to implement existing Internet QoS models on MANETs because these mechanisms cannot be efficiently deployed in a network with unpredictable and varying resource availability.

A very critical assumption is made by most, if not all, MANET protocols, which is the willingness of all nodes to participate in the forwarding of packets for other nodes in the network. QoS provisioning in MANETs is therefore a multi-faceted problem which requires the cooperation and integration of the various network layers, which will be discussed in the following subsections.

1. **Physical layer:** The physical layer of any network is used to provide the means to transmit sequences of bits between any pair of nodes joined by a communication channel. In MANETs, the radio channel is used to provide wireless communication between the nodes in the network. In contrast with wired networks, which offer predictability and stability, radio channels are affected by the effects of reflection, diffraction, and scattering from environmental interferences. As such, the wireless medium is often unreliable and subject to drastic variations in signal strength, leading to higher bit rate errors (BER) at the physical layer. Due to node mobility and the erratic behaviour of the wireless channel, the link characteristics of the network experience rapid changes. The effects of large-scale/small-scale fading, shadowing, and path loss may also cause these communication links to be asymmetric. Hence, the physical mechanisms must be able to adapt to the changes and deterioration in link quality during data transmission and change their modulation scheme accordingly to suit the current channel state.
2. **Medium access control (MAC) layer:** The wireless channel in MANETs is a broadcast and shared medium where nodes are often subject to interference from neighbouring nodes within the transmission and interference ranges, and often suffer from hidden/exposed terminal problems. Although many solutions have been proposed to alleviate the exposed/hidden terminal problems, these problems are more pronounced in autonomous, mobile environments; wireless channels are also subjected to errors which are bursty, location-, and mobility-dependent. The MAC layer for MANETs has to cope with these problems, as well as the challenges of minimizing collisions, allowing fair ac-

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