Effective Data Transport for Reliable End-to-End Communication in Multihop Wireless Networks

Abstract

Sherif M. ElRakabawy

This thesis addresses the problem of effective reliable data transport in multihop wireless networks. Multihop wireless networks are mostly autonomous, decentralized networks, in which a wireless node acts both as a host and a router for data packets. As reliable data transport makes up over 90% out of all traffic in the Internet, its effective operation is of significant importance. Unfortunately, TCP, the de facto standard reliable data transport protocol, suffers from severe performance deficiencies in multihop wireless networks. The standard congestion control algorithm of TCP is tailored for the Internet, and does not consider the special characteristics of such unique networks.

First, the thesis introduces a novel transport protocol for multihop wireless networks, denoted as TCP with Adaptive Pacing (TCP-AP). TCP-AP implements rate-based scheduling of transmissions within the TCP congestion window. The TCP sender adaptively sets its transmission rate using an estimate of the current 4-hop propagation delay and the coefficient of variation of recently measured round trip times. A comprehensive simulation study using the network simulator ns-2 shows that TCP-AP significantly improves goodput and fairness compared to the widely deployed TCP NewReno.

Second, an effective congestion control scheme for TCP over hybrid wireless/wired networks comprising a multihop wireless network and the wired Internet is introduced. The novel congestion control scheme, which is denoted as TCP with Gateway Adaptive Pacing (TCP-GAP), builds on the previous contribution and is also implemented in the network simulator ns-2. For the effective operation of TCP over hybrid networks, we propose to distinguish the direction of the TCP flows: For wired-to-wireless TCP flows, we introduce an adaptive pacing scheme at the Internet gateway. For wireless-to-wired flows, we propose an adaptive pacing scheme at the TCP sender.

The third contribution of this thesis is the construction and evaluation of ScaleMesh, a novel 20-node scalable dual-radio mesh testbed based on IEEE 802.11b/g technology. Using ScaleMesh, large-scale mesh networks can be emulated within a miniaturized experimentation area by adaptively shrinking the transmission range of mesh nodes. Different network topologies can then be emulated by adjusting the positions of the testbed antenna-stations. Furthermore, we derive the correlation between fundamental measures, which are crucial for downscaling large-scale networks using ScaleMesh.

Within the fourth contribution, this thesis introduces and evaluates a feasible, and TCP-compatible, end-to-end approach for improving TCP goodput and fairness in a real wireless mesh testbed rather than in simulators. Building on the first two contributions, a Linux-based prototype of the adaptive pacing approach with an extended end-to-end algorithm is implemented and evaluated in ScaleMesh. The vast majority of previous approaches for improving TCP performance in mulihop wireless networks have been only designed and evaluated in network simulators. This thesis goes beyond simulation-only implementations and validates the adaptive pacing scheme in reality. Thereby, the main challenge that has been addressed constitutes the fact that physical measures in reality, such as the distance between nodes in a network, can be simply inquired in simulations, but are not available at nodes in reality due to the absence of global knowledge.