CHANNEL-AWARE PROTOCOLS FOR WIRELESS NETWORKS

By

Muhammad Naveed Aman

A Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: ELECTRICAL ENGINEERING

Approved by the
Examining Committee:

_____
Biplab Sikdar, Thesis Adviser

_____
Koushik Kar, Member

_____
Gary J. Saulnier, Member

_____
Christopher D. Carothers, Member

Rensselaer Polytechnic Institute
Troy, New York

November 2012
(For Graduation December 2012)

Abstract

The use of wireless technologies for network access has become very popular over the last decade. The use of wireless networks for high speed applications has also increased substantially. Existing networks are based on a layered architecture. However this type of strict layering may lead to sub-optimal overall performance of the network, and particularly so in the case of wireless networks. The characteristics of a wireless channel change both in time and space. Therefore, upper layer protocols that are agnostic of the existing physical layer properties may fail to achieve optimal performance. In this thesis we propose the use of physical layer information by the upper layer protocols to improve the overall network performance.

The first part of the thesis focuses on developing a mechanism for detecting the root cause of a packet loss in wireless networks. There are two major causes of packet losses in IEEE 802.11 based networks: firstly, packets are affected by channel noise, and secondly, interference from other devices. The throughput and spatial reuse of IEEE 802.11 based wireless networks, as well as the effectiveness of the rate adaptation algorithms they use, is adversely affected by their inability to determine the real cause of a packet loss. To address this issue, we propose a mechanism based on Error Vector Magnitude (EVM) to discern random channel errors from collisions in wireless networks. The proposed mechanism is based on first developing an analytic model to characterize the EVM of a packet in the presence and absence of a collision. A threshold based classifier is then proposed that selects the threshold value such that the crossover error rate is achieved. Simulation results are presented to demonstrate the accuracy of the proposed collision detection mechanism.

The second part of the thesis focuses on using our techniques for extracting channel information from the physical layer to develop schemes that improve the performance of the medium access control layer. In particular our interest is in developing transmission strategies for IEEE 802.11 that exploit our techniques for root cause analysis of packet losses. IEEE 802.11 infers a packet loss as an indication of a collision and thus performs an exponential backoff (EB). The EB costs

the transmitting node a significant amount of throughput in terms of waiting and retransmission attempts. We show that by incorporating the information obtained from our proposed classifier, a MAC layer protocol can make more intelligent decisions, resulting in higher throughput and efficiency. To achieve this objective our technique for root cause analysis is applied for partial packet recovery (PPR). We show that once a packet is corrupted by noise or interference, EVM can be used to detect the location of the blocks of a packet that are corrupted. Our results show that PPR can then improve the throughput and utilization of a wireless network, by using a more efficient retransmission mechanism.

The third part of the thesis focuses on maximizing the service capacity of peer-to-peer (P2P) video streaming systems by exploiting the physical layer information and the multicast services provided in wireless networks. Our focus is on using physical layer information at the medium access control and application layers, and in particular, we consider the case of web-based peer-to-peer (P2P) systems for streaming video application with WiMax based wireless access networks. We develop a lightweight mechanism for P2P streaming in WiMAX networks that significantly reduces the load on the network and improves the scalability of the streaming system. The proposed system uses the multicast mechanism provided in the IEEE 802.16 mechanism for providing the scalability, without breaking the P2P semantics. Our proposed mechanism also uses the channel state information (CSI) of the subscriber stations in a WiMax network to improve the scalability of a P2P streaming system. The scalability of the proposed system is analytically evaluated and also quantified using simulations. Our results show that the degree of improvement in the performance of the proposed system is lower bounded by the average number of peers served by an Access Service Network Gateway in the WiMAX networks.