A MULTIPATH TRANSPORT PROTOCOL FOR LOSSY AND DISRUPTION PRONE NETWORKS

By

Vicky Sharma

An Abstract of 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 COMPUTER AND SYSTEMS ENGINEERING

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Prof. Koushik Kar, Thesis Adviser
Dr. S. Kalyanaraman, Member
Prof. A. Abouzeid, Member
Prof. A. Gupta, Member
Dr. K. K. Ramakrishnan, Member

Rensselaer Polytechnic Institute
Troy, New York

June 2010
(For Graduation August 2010)

ABSTRACT

The past decade has witnessed an exponential growth in wireless mesh network deployment. Wireless networks are increasingly replacing the traditional wired networks as well as nding new areas of application. This growth coupled with unique properties of wireless channels has prompted a reconsideration of several layer-2 and 3 protocols (e.g. Routing, Transport etc.) as they have been shown to be in-optimal when operating over a wireless network.

Towards this end, we propose MPLOT (Multi-Path LOss Tolerant) transport protocol that can tolerate the volatile nature of a wireless link while providing a high,stable goodput(data-rate) and stable latency. MPLOT is able to able to tolerate extremely high packet loss-rates (up to 50%) and differences in path delays and bandwidths by leveraging an important feature of wireless networks - diversity. We show that MPLOT intelligently uses multiplicity of paths and the differences in their parameters (delay, bandwidth etc.) to (i) aggregate bandwidths of different paths, (ii) provide a stable, high goodput in presence of high packet losses, (iii) control packet latency and (iv) use diversity across paths to gain goodput relative to the case of single-path transmission with the same aggregated bandwidth. MPLOT is able to fulll the above mentioned goals by (a) intelligently using erasure-coding with a Hybrid-ARQ/FEC scheme to reduce packet latency, (b) provision- ing for packet redundancy proactively and reactively and (c) transmitting/mapping packets on the available paths based on the current path conditions. A consequence of FEC block coding is that it allows MPLOT to get rid of the need for in-order transmission of packets. As result, MPLOT uses the difference in path delays to transmit packets out-of-order such that the packets are received at the destination when required.

We show analytically that the various design choices made for MPLOT allows for an optimal trade-off between goodput and delay-constraints. We also derive the expressions for the diversity gain that can be leveraged as a function of number of paths. We study the fairness of MPLOT with traditional single-path transport protocols (e.g. TCP-SACK) and compare its performance with previously proposed

multi-path protocols (e.g. PTCP). Additionally, we also investigate MPLOTs ability to deliver small-sized ($\leq$ 10Kb) les quickly.

We then proceed to investigate the statistical characteristics of airborne links using data gathered from actual experiments and develop mathematical models for such links. We then use these models to show that MPLOT delivers higher goodput and lower latency than conventional multipath transport protocols.

We also show that FEC encoding by MPLOT, acting complimentarily to TCP congestion control, enables it to recover from short term congestion losses quicker than the conventional TCP method of reducing window size and re-transmitting the lost data. This allows MPLOT to deliver higher goodput with lower latency, especially in high speed networks with small queue sizes at routers.

Finally, we investigate the performance of MPLOT under disruptive conditions. Link disruptions lead to complete loss of packets in transit on the link.This results in frequent timeouts, high retransmissions, low goodput and high latency. We show that MPLOT with a holistic combination of timeout mitigation, backpressure and local rerouting is able to counter link disruptions that may last a fraction of the path RTT to a duration of multiple RTTs. We show through simulations, analysis and a trace-driven evaluation with real-world data collected from an airborne wireless environment, that our solution is extremely effective in overcoming the penalties of disruptions in multi-hop, multipath wireless environments.