*Dynamics of Continuous, Discrete and Impulsive Systems*
*Series* **B:** *Applications & Algorithms* **13 (2006)** 77-94


# TCP Performance with Segment-in-Flight Estimation Algorithm over Wireless Links

Jianping Pan, Jon W. Mark, and Xuemin Shen

Department of Electrical and Computer Engineering
University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

**Abstract.** TCP performs reasonably well over the Internet where packet losses are mainly due to network congestion. However, TCP suffers significant throughput degradation over hybrid wireless/IP networks where packet losses are also due to transmission errors in wireless segments and during mobile host handovers. In this paper, the micro-scale behavior and packet-level performance of four popular TCP variants over wireless links are assessed, and a heuristic *Segment-in-Flight Estimation algorithm* for TCP senders is proposed and evaluated. Extensive simulations confirm that the enhanced TCP is more robust against packet losses, can achieve better end-to-end performance, and still keeps the fairness and compatibility with ordinary TCP variants.
**Keywords.** Internet, TCP/IP, Protocol performance, Wireless communications, Network simulation.

## 1 Introduction

The integration of the Internet and wireless networks is expected to offer multimedia services to mobile and fixed users from anywhere at anytime in the near future. There are many different interworking strategies to connect voice-oriented cellular systems and other wireless segments to IP-based data networks [1]. Moreover, the next generation cellular systems are also IP-centric. However, an essential issue here is how to support various existing Internet applications, *e.g.*, web surfing and packetized audio/video, running properly and efficiently over hybrid wireless/wired networks with prescribed end-to-end QoS provisioning.

The performance degradation of TCP over wireless links has received much attention recently. Various approaches in different protocol layers to mitigate this deficiency have been proposed, and they are compared and surveyed in [3, 4]. Data link layer approaches try to transparently enhance the quality of wireless links by Forward Error Correction (FEC), local acknowledgment, and selective retransmissions. However, the end-to-end TCP control logic might be interfered by the complicated lower layer control mechanisms, which may result duplicate retransmissions in multiple layers or rapid changes in packet transit time [6]. Transport layer approaches, which might adopt implicit snooping or explicit notification, or split connection with or without end-to-end semantics, try to help TCP endpoints not to mistakenly react to packet losses due to transmission errors as those due to network congestion. It should be mentioned that the interoperability between these approaches and the original protocols need further investigation.

The strategy adopted in this paper is different from those aforementioned and other approaches discussed in [4] where brand new transport protocols are proposed.