TCP Performance with Vertical Handoffs

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Vertical Handoff (VHO)

Vertical handoff is the switching between access routers which use a different link level technology

Vertical handoff is likely to result in changes in access link (first-hop/last-hop) characteristics. A significant change in the access link characteristics is likely to change the end-to-end path properties

TCP behaviour depends on the end-to-end path properties and is affected by a vertical handoff

Cross-layer notifications

TCP sender gets a cross-layer notification regarding the handoff along with the bandwidth and delay of the new and the old access links. The mobile node delivers the above information to the TCP sender at the correspondent node by piggybacking in the mobility signalling messages, for example, incorporated with the binding update message in Mobile IPv6.

Problems of TCP with Vertical handoff

Event	Problem	Enhancements
Handoff from low delay link to high delay link	Spurious Retransmission Timeout (RTO)	Increase RTO value based on the bandwidth and delay of the new access link **†
Handoff from high delay link to low delay link	Packet reordering Slow convergence of RTO	Set the *dupthresh* based on the delay and bandwidth of the old and the new links, use limited transmit. Use DSACK information to determine the *cwnd* and *ssthresh* Initialize RTT Variables and update RTO **
Handoff from high BDP* link to low BDP link	Packet losses	Set the *cwnd* and *ssthresh* to the BDP of the new link **
Handoff from low BDP link to high BDP link	Inability to catch up with high bandwidth	Quick-Start to set the *cwnd* and *ssthresh*
RTOs during disconnection	Unused connection time	Retransmit immediately If TCP is in RTO recovery

* Bandwidth Delay Product (BDP).
** Initialize RTT variables as recommended by RFC 2988 and update RTO when all packets before handoff are acknowledged.

Future work

Experimentation with multiple flows/competing traffic.

Estimation of end-to-end bandwidth and round trip time (RTT).

Evaluation of the algorithm in real network environments.

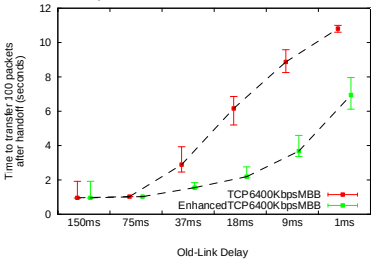
Publications

1. L. Daniel, M. Kojo. Adapting TCP for Vertical Handoff in Wireless Networks, In Proc. Proc. 31st IEEE Conference on Local Computer Networks (LCN'06), 2006
2. P. Sarolahti, J. Korhonen, L. Daniel, M. Kojo. Using Quick-Stat to improve TCP performance with Vertical Handoffs, In Proc. 31st IEEE Conference on Local Computer Networks (LCN'06), 2006
3. L. Daniel, M. Kojo. TCP Behaviour with Changes in Access Link Bandwidth and Delay During Vertical Handoffs, In Proc. International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST 2007), 2007.
4. L. Daniel, M. Kojo. Using Cross-layer Information to Improve TCP Performance with Vertical Handoffs, In Proc. 2nd International Conference on Access Networks (Accessnets 2007), 2007.
5. L. Daniel, M. Kojo. Employing Cross-layer Assisted TCP Algorithms to Improve TCP Performance with Vertical Handoffs, International Journal of Communication Networks and Distributed Systems (IJCNDS), 2008.
6. L. Daniel, I. Järvinen, M. Kojo Combating packet reordering in vertical handoff using cross-layer notifications to TCP, Wimob 2008

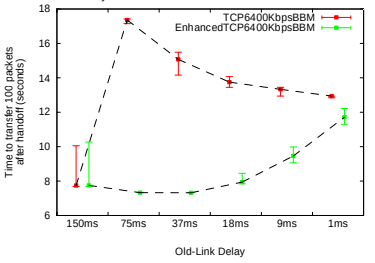
Performance evaluation of the VHO algorithms

The performance comparison of TCP enhanced by VHO algorithms and regular TCP (TCP SACK) for a wide range of access link bandwidths and delays have been carried out using ns-2 simulations. The results obtained show that the VHO algorithms are effective in different vertical handoff scenarios and improve TCP performance up to 40 %

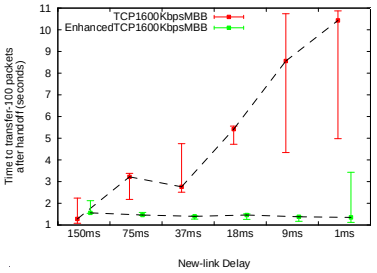
Make-before-break handoff from a low-delay link to a high-delay link with bandwidth of the links fixed at 6400 Kbps. The delay of the new link is fixed at 300 ms.



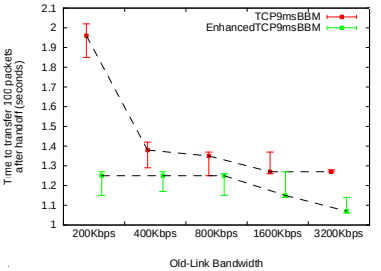
Break-before-make handoff from a low-delay link to a high-delay link with bandwidth of the links fixed at 6400 Kbps. The delay of the new link is fixed at 300 ms.



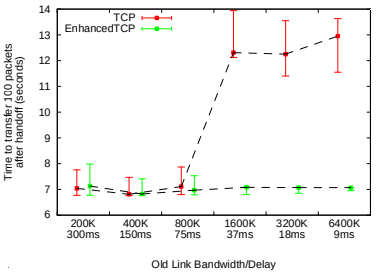
Make-before-break handoff from a high-delay link to a low-delay link with bandwidth of the links fixed at 6400 Kbps. The delay of the old link is fixed at 300 ms.



Break-before-make handoff from a low-bandwidth link to a high-bandwidth link with delay of the links fixed at 9 ms. The bandwidth of the new link is fixed at 6400 Kbps.



Make-before-break handoff from a low-delay/high-bandwidth link to a high-delay/low-bandwidth link with BDP of the links fixed at 10 packets. The new link has 200 Kbps/300 ms.



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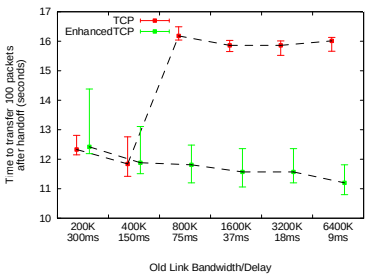
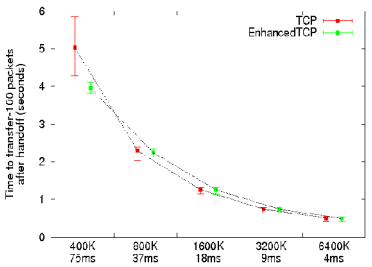
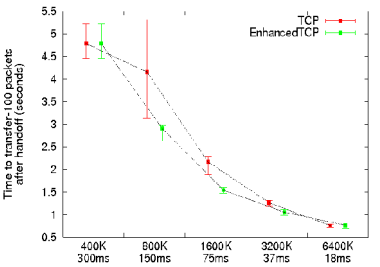


Make-before-break handoff from a high-delay/low-bandwidth link to a low-delay/high-bandwidth link. The BDP of the new link is smaller than the BDP of the old link. The old link has 200 Kbps/300 ms.



Make-before-break handoff from a high-delay/low-bandwidth link to a low-delay/high-bandwidth link. The BDP of the new link is higher than the BDP of the old link. The old link has 200 Kbps/300 ms.



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