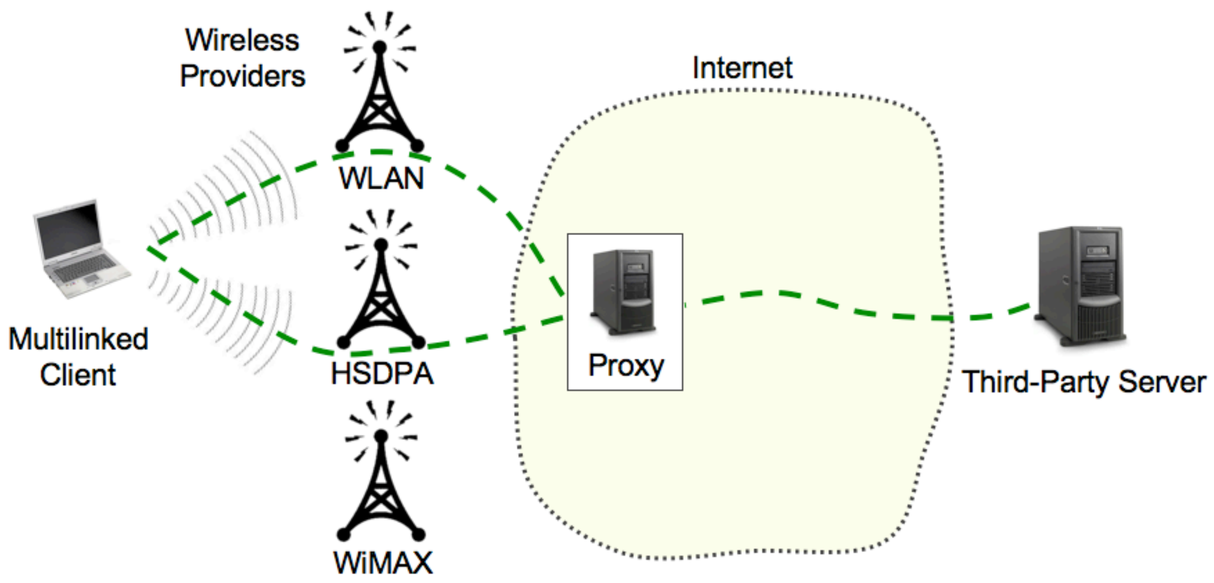
Bandwidth Aggregation over Heterogeneous Wireless Links

Kristian Evensen and Dominik Kaspar
Simula Research Laboratory, Norway

General Scenario

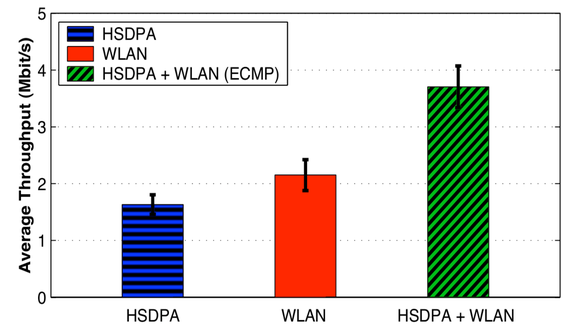


Motivation

Optimization idea:
- Utilize all links simultaneously

Benefits:
- Increased data throughput
- Better connectivity (reliability)
- Smooth handover across networks

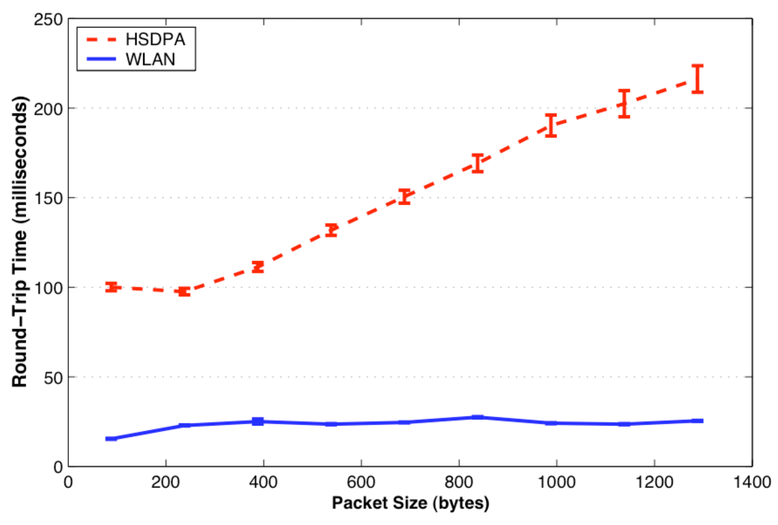
Challenges:
- Implementation (clients, servers, proxies)
- Link heterogeneity (delay, bandwidth, loss)
  - IP packet reordering



The Challenges

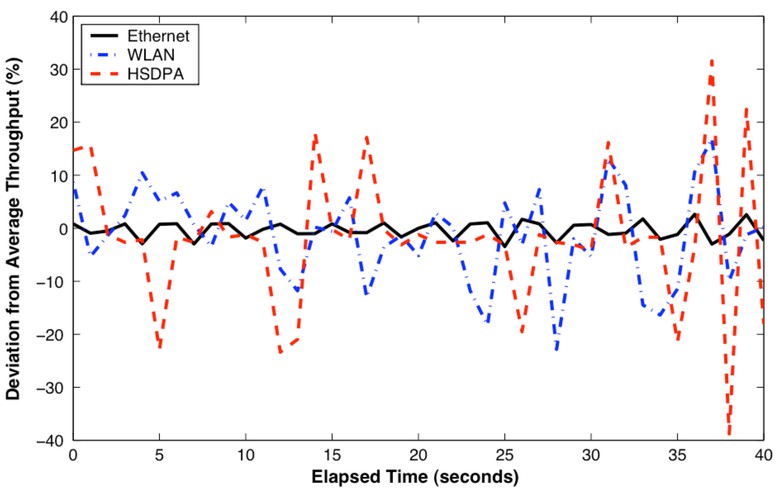
Delay Heterogeneity

Scheduling packets over links with large differences in delay, causes reordering.[1]



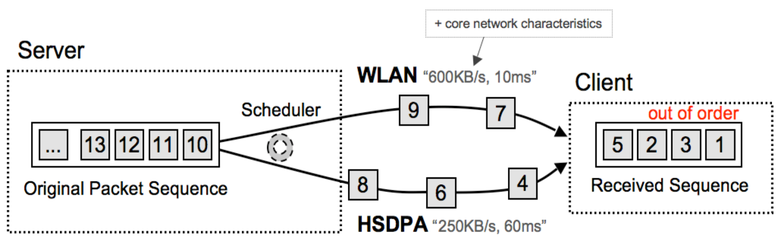
Throughput Dynamics

Assigning traffic to links with high variations is a big challenge for bandwidth aggregation.[4]



Packet Reordering

The IP packet reordering experienced over heterogeneous wireless links is severely higher than the 0 - 2% late packets commonly observed in wired, high-speed networks.[1]

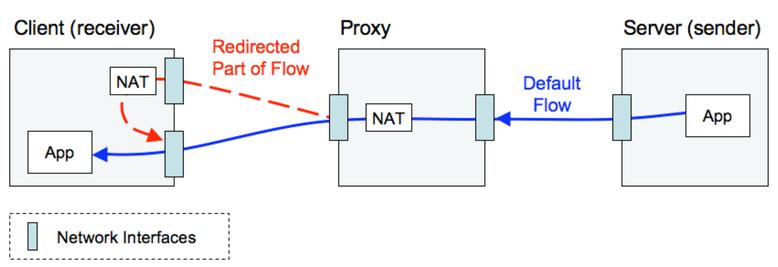


Packet reordering reduces the performance of traditional transport protocols (e.g. TCP).

Our Solutions

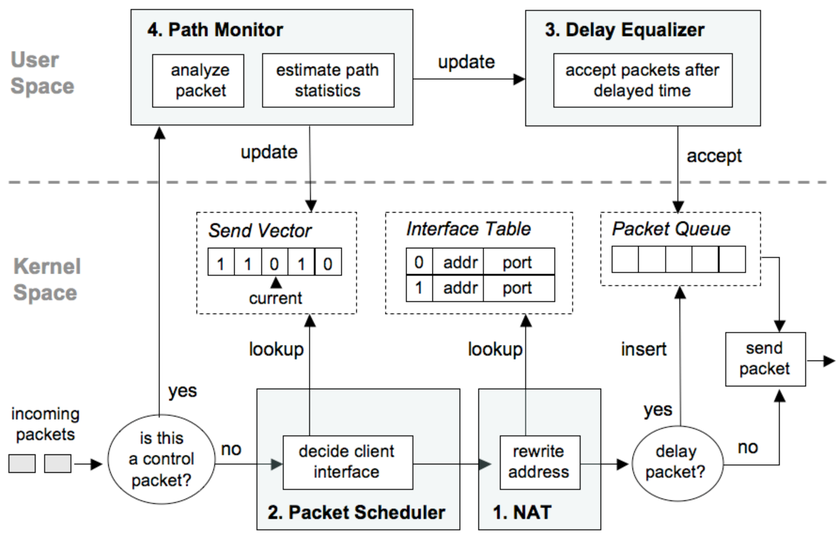
An IP-Layer Proxy

In order to allow servers to remain unchanged, we are working on a proxy solution for redirecting IP packets over independent networks to a client.



The proxy has several functionalities:

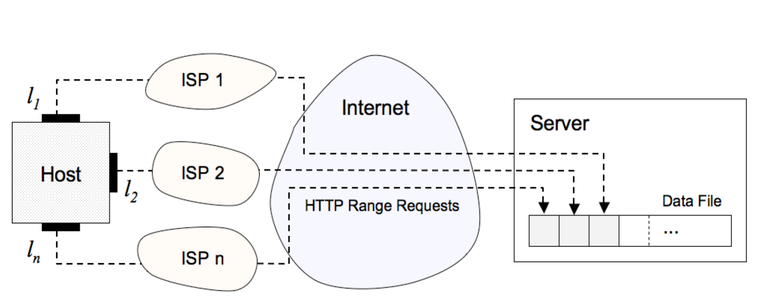
1. Support for network-layer packet striping
2. Bandwidth aggregation of client interfaces
3. Reducing IP packet reordering (delay equalizer)
4. Monitoring of path characteristics



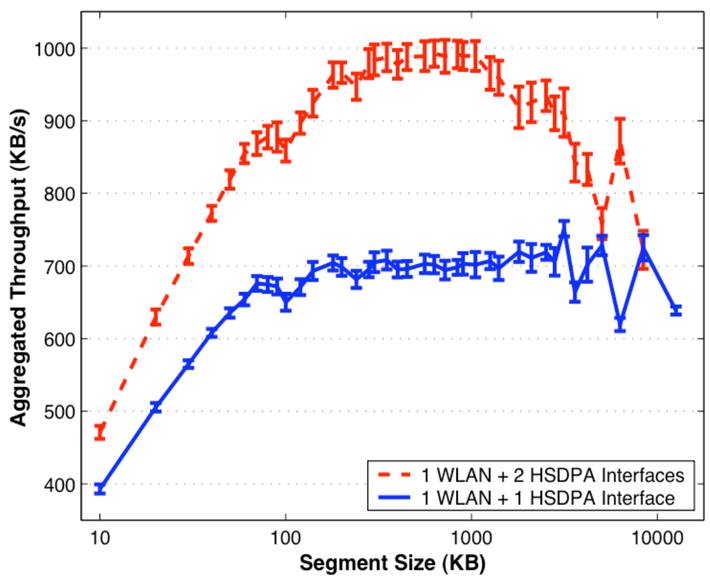
First results from an emulation testbed show close to ideal bandwidth aggregation and a significant reduction in IP packet reordering.[2]

Application-layer Video Playout

We also work on enhancing video-on-demand playout by optimally downloading file segments over multiple heterogeneous access networks.



Using HTTP's ability of handling requests for specific byte ranges, we download a single file over 1 WLAN and 2 HSDPA links concurrently.



We have found many interesting tradeoffs between the chosen segment size, the startup latency, and the buffer requirements.[3]

References

[1] D. Kaspar, K. Evensen, A. F. Hansen, P. E. Engelstad, P. Halvorsen, and C. Griwodz. An Analysis of the Heterogeneity and IP Packet Reordering over Multiple Wireless Networks, International Symposium on Computers and Communication, ISCC 2009.

[2] K. Evensen, D. Kaspar, P. E. Engelstad, A. F. Hansen, C. Griwodz, P. Halvorsen, A Network-Layer Proxy for Bandwidth Aggregation and Reduction of IP Packet Reordering, LCN 2009.

[3] D. Kaspar, K. Evensen, P. Engelstad, A. Hansen, Halvorsen, P., Griwodz, C., Enhancing Video-on-Demand Playout over Multiple Heterogeneous Access Networks, Submitted to Consumer Communications and Networking Conference CCNC 2010.

[4] D. Kaspar, A. F. Hansen, and C. Griwodz. Multilink Transfer over Heterogeneous Networks, In: IEEE International Conference on Network Protocols (ICNP), Poster Session, 2008.