Performance Evaluation of Multipath TCP Linux Implementations

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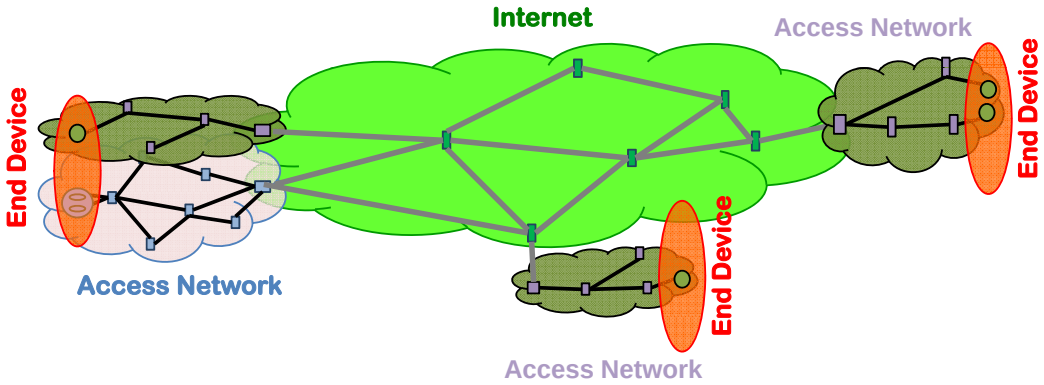
Outline

- Motivation
- TCP-based Multipath Protocol Implementations
  - MPTCP
  - MCTCP
- Experimental Setup
  - G-Lab Experimental Facitility - TOMATO
- Performance Evaluation
- Conclusion & Outlook

Motivation

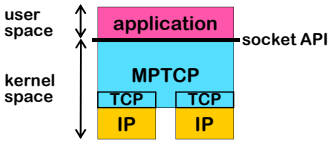
- End-hosts are often equipped with multiple interfaces
  - allows for deploying multipath transport to *increase throughput, improve resilience and balance congestion* in the network [RFC 6182]



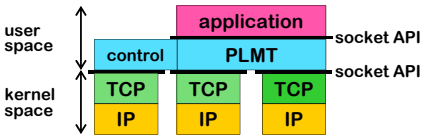
- This has led to the design and development of Multipath TCP solutions
  - a set of extensions for TCP that allows spreading of a single TCP flow across multiple subflows

Multipath TCP Variants

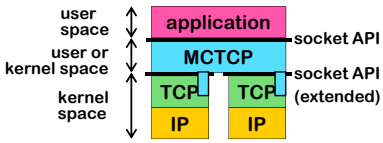
- Different solutions were published in the Multipath TCP working group in IETF as drafts
- MultiPath TCP (MPTCP) [draft-ietf-mptcp-multiaddressed-03]
  - MPTCP's Linux kernel implementation is open source [https://scm.info.ucl.ac.be/trac/mptcp/downloads]
  - each multipath TCP subflow looks to the network as a normal TCP flow
  - TCP option field is used for signalling information exchange



- PayLoad Multi-connection Transport (PLMT) [draft-singh-mptcp-plmt-00]
  - user space solution, avoids TCP stack modification
  - encodes signalling information in the payload



- Multiple Connection TCP (MCTCP) [draft-scharf-mptcp-mctcp-01]
  - A hybrid variant transparent in the single-path case
  - TCP option field is used only for connection setup



Performance Evaluation Setup

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- Use Topology Management Tool (ToMaTo) - a virtual networking testbed to design and use virtual networking topologies (consisting of devices and connectors)
  - End-hosts (KVM Devices) - KVM virtualization technology with hardware emulated by qemu
  - Network connectivity is through Tinc VPN - Configurable link delay and bandwidth
- Linux Vanilla Kernel 2.6.32 patched with MCTCP and 2.6.35 patched with MPTCP are used to boot KVM devices
- Test Strategy
  - Client and Server programs in C are used to shape application traffic (10Mbps, 20Mbps or higher)
  - Socket buffer size is set to 262,144B to avoid TCP flow control
  - Link bandwidth is set to 10Mbps and delay is varied between 1ms to 100ms
  - Numerical results are averaged over 5 runs

G-Lab Experimental Facility

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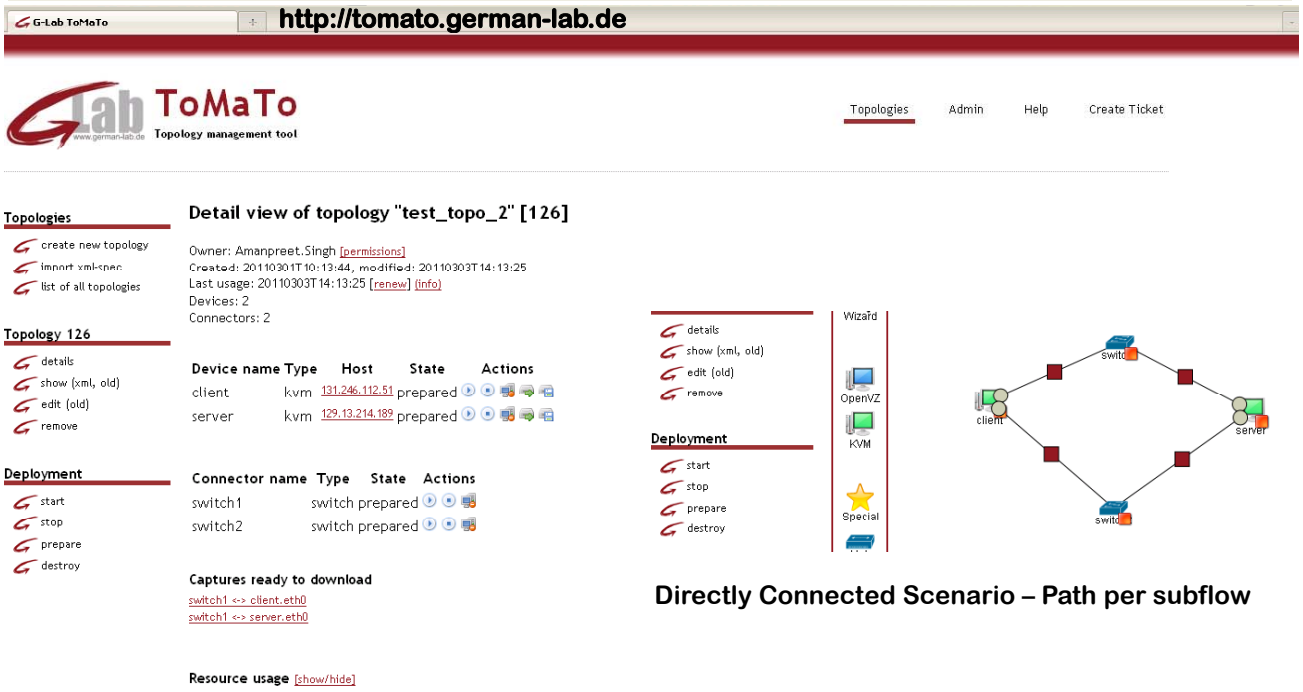

Directly Connected Scenario – Path per subflow

Path per Subflow – Load Distribution

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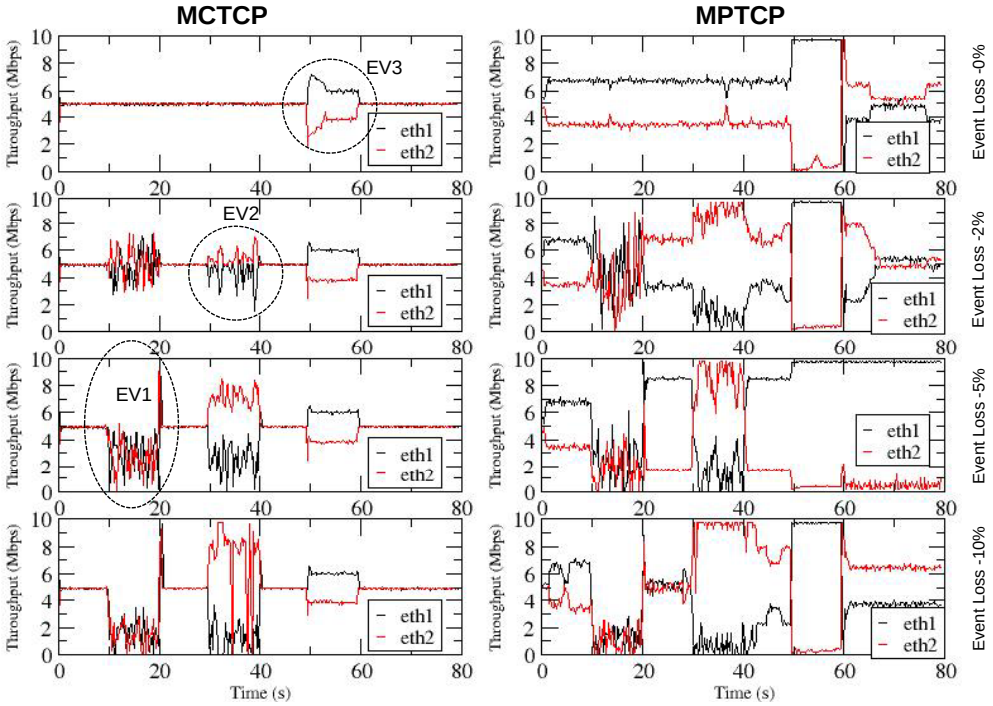
Server Rate 10Mbps, Link delay 10ms, Cubic Congestion Control

Event 3 (EV3): 50-60s
Higher delay of 100ms on one (red) link

Event 2 (EV2): 30-40s
Packet loss only on one (black) links

Event 1 (EV1): 10-20s
Packet loss on both links



MCTCP is robust to link dynamics (packet loss/e2e Delay) and performs fair scheduling over its subflows

Path per Subflow - Background Traffic - 2Mbps

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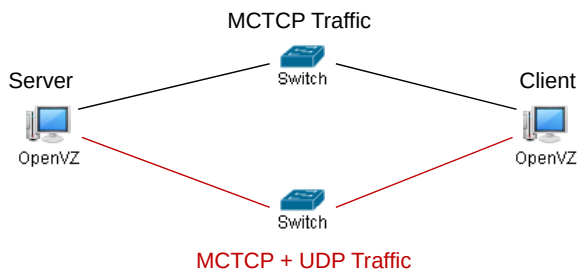
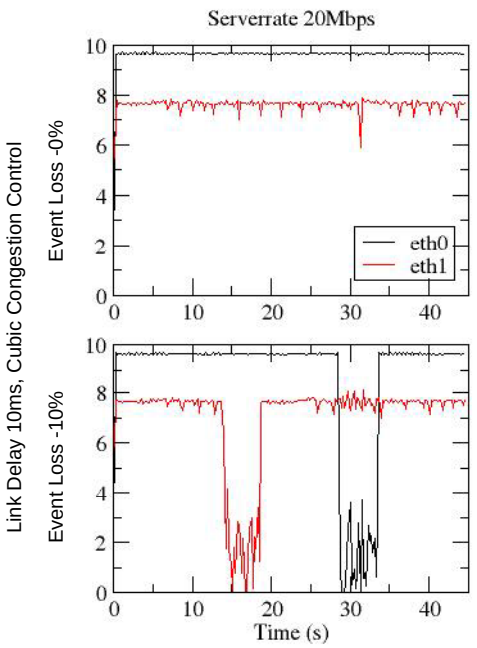
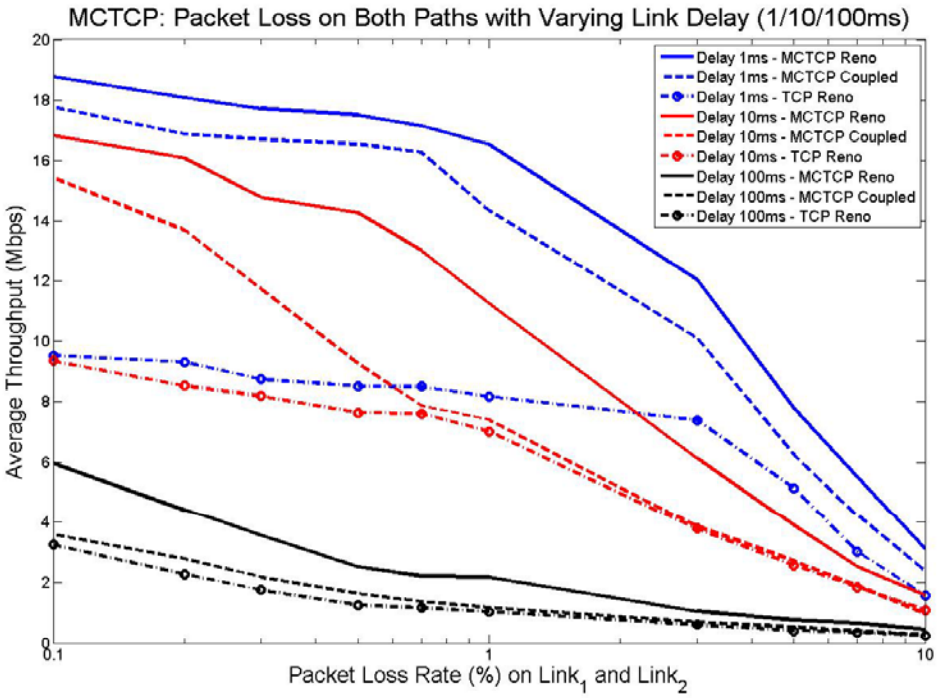




MCTCP can adapt to asymmetric path quality of its subflows and can aggregate the available bandwidth

Path per Subflow – Packet Loss on both Links



MCTCP may use coupled*# congestion control optionally

* draft-ietf-mptcp-congestion-03

see also MCTCP: A Multipath Transport Shim Layer

Conclusion

- Multipath TCP solutions adhere to the requirement goals of the multipath TCP architecture
  - increase throughput, more resilient
  - offer reliable, in-order transport being transparent to applications
- MCTCP
  - is optimized for bulk data transfer (multipath operation is initiated after a short delay – can introduce overhead)
  - is robust to dynamic changes in the network such as variations in the packet loss rate, end-to-end delay and available bandwidth
  - more MCTCP performance results and implementation details are published in "MCTCP: A Multipath Transport Shim Layer," M. Scharf and T.-R. Banniza, Globecom 2011
- MPTCP
  - is a kernel-based solution that uses TCP options field for signalling
  - the current scheduling strategy doesn't seem to work well in all cases
  - more elaborate results are presented in „*MultiPath TCP: From Theory to Practice,*" S. Barre´, C. Paasch, and O. Bonaventure, IFIP Networking, 2011

Outlook

- Multipath TCP tests
  - with larger network topologies
  - in heterogeneous environment
  - for different application types
- Design Issues
  - How many MxTCP subflows?
  - Criteria to close an underperforming subflow
  - Scheduler to minimize reordering between subflows and resulting jitter
- Implementation Issues
  - APIs for multipath-aware applications

- Both MPTCP and MCTCP implementation work is in progress and hence evolving to provide a better solution for Future Internet demands