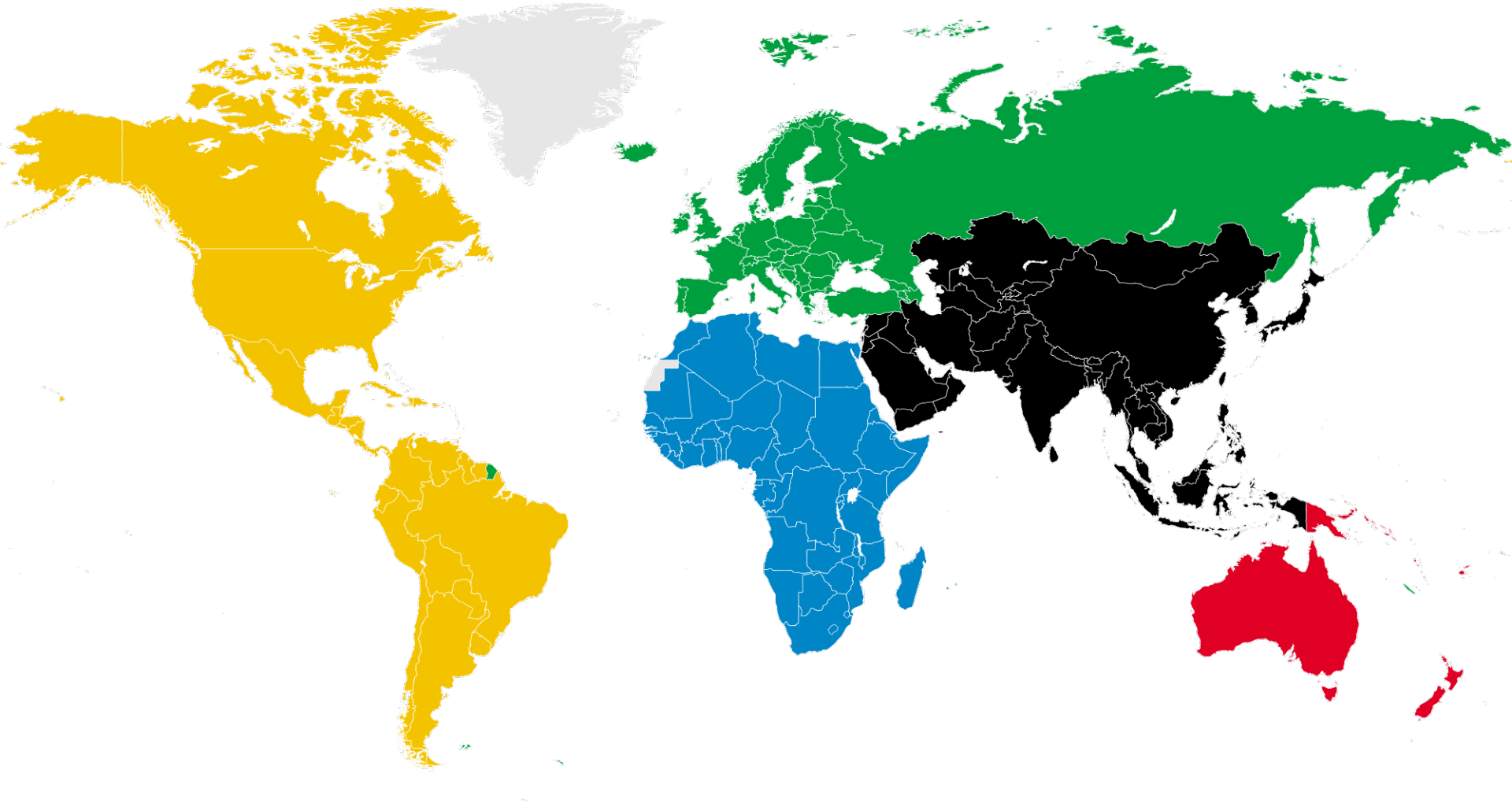
Improving Multipath TCP

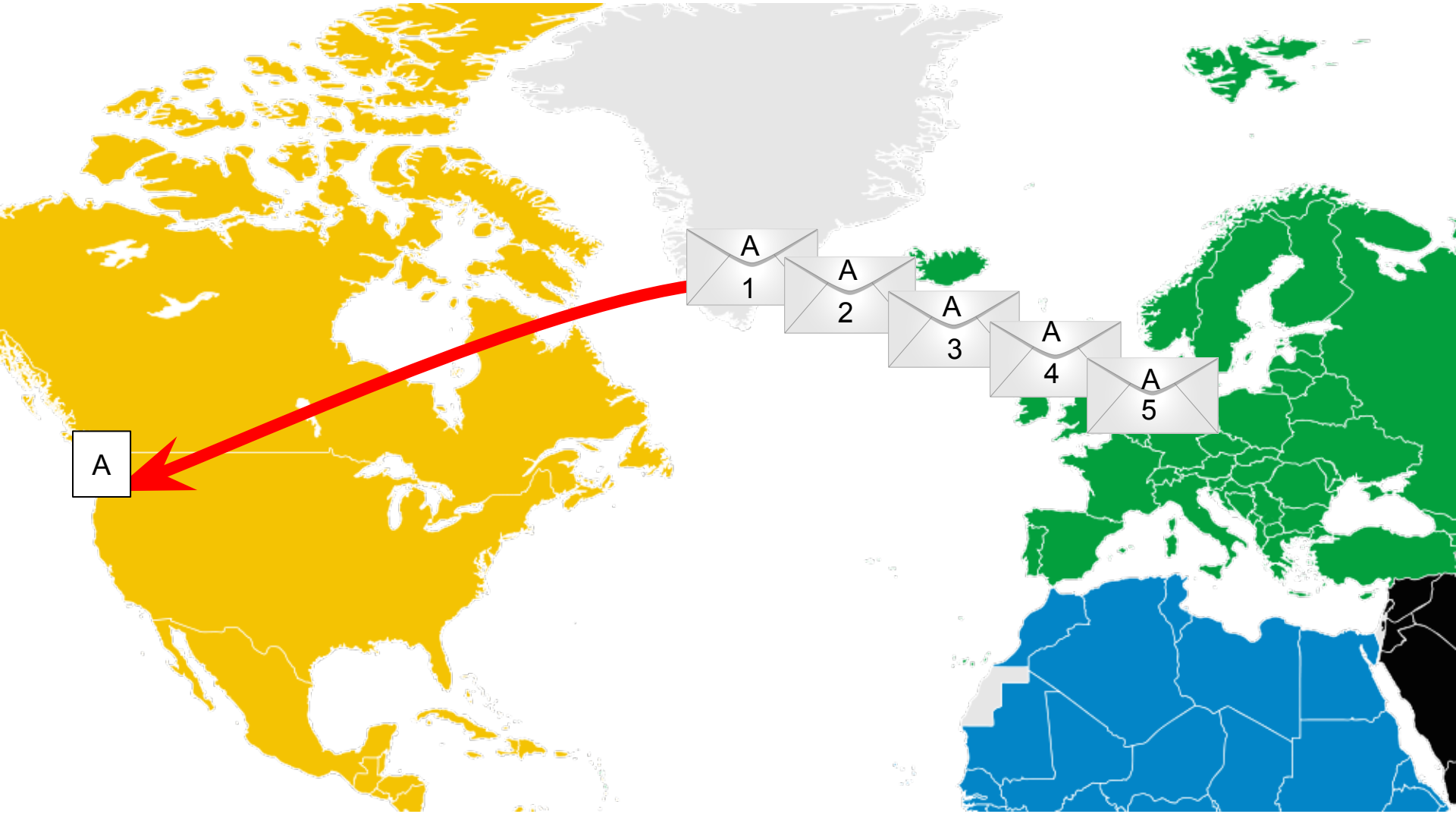
PhD Thesis - Christoph Paasch

The Internet is like a map ...

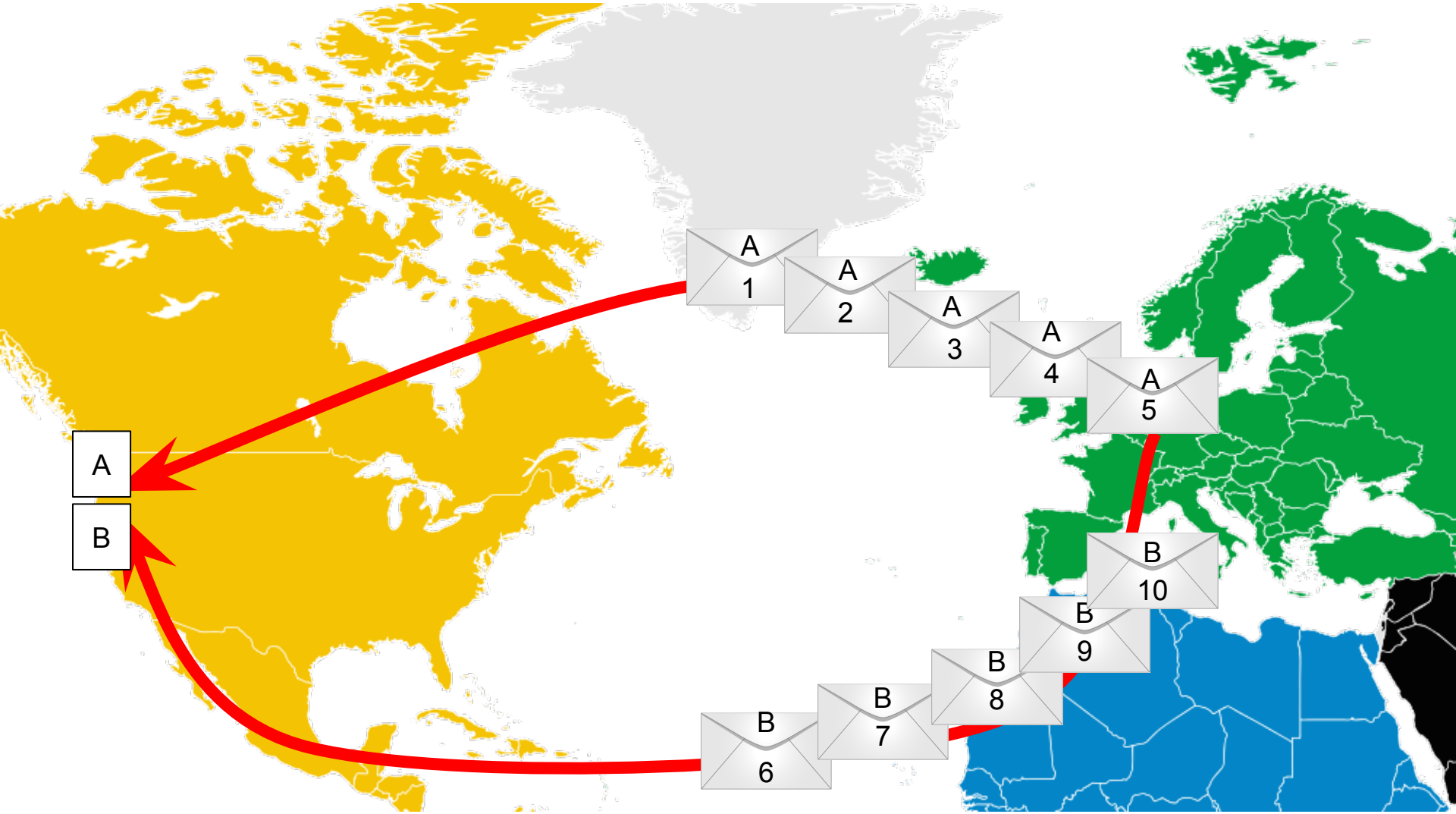


… highly connected

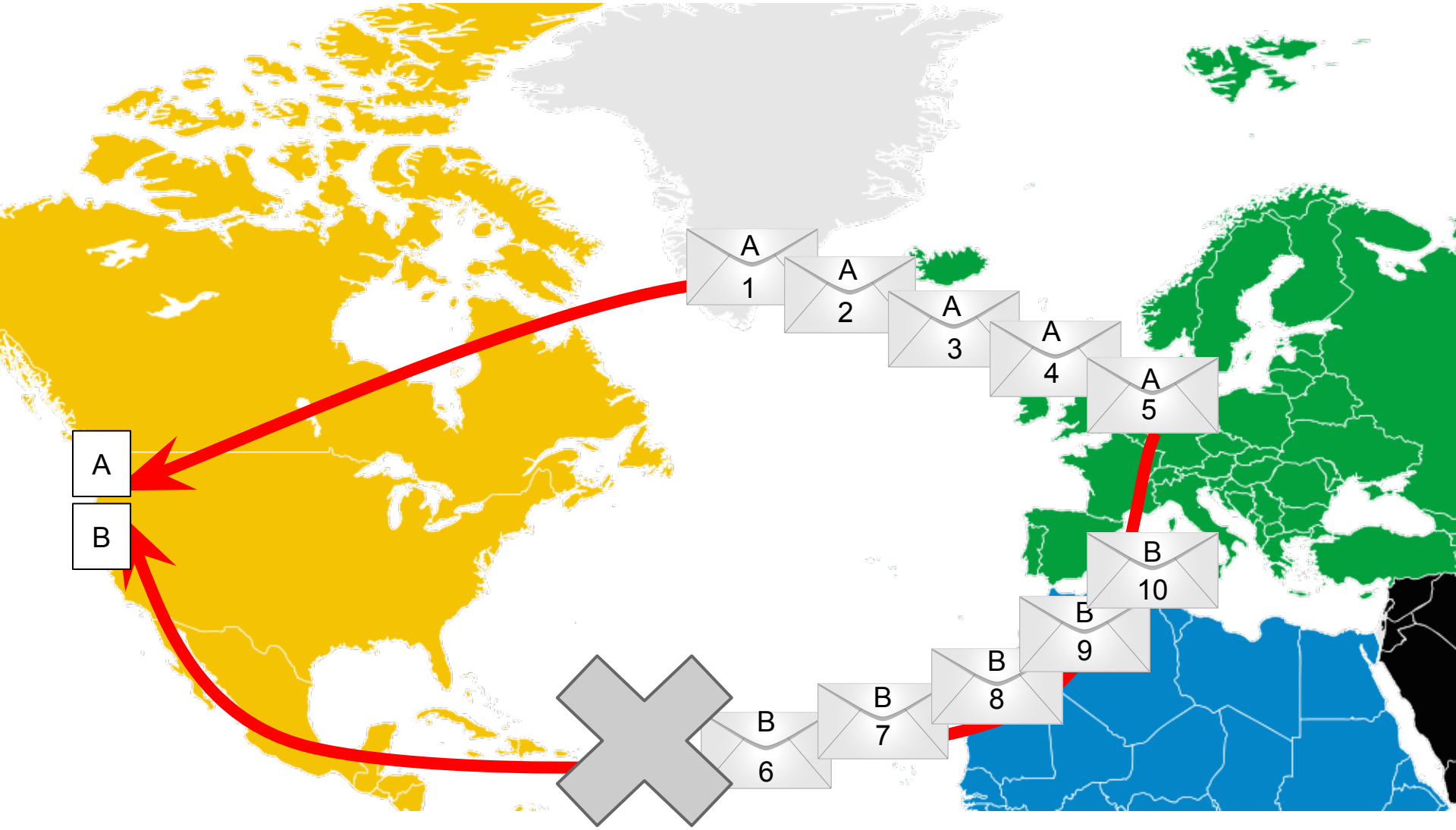
Communicating over the Internet



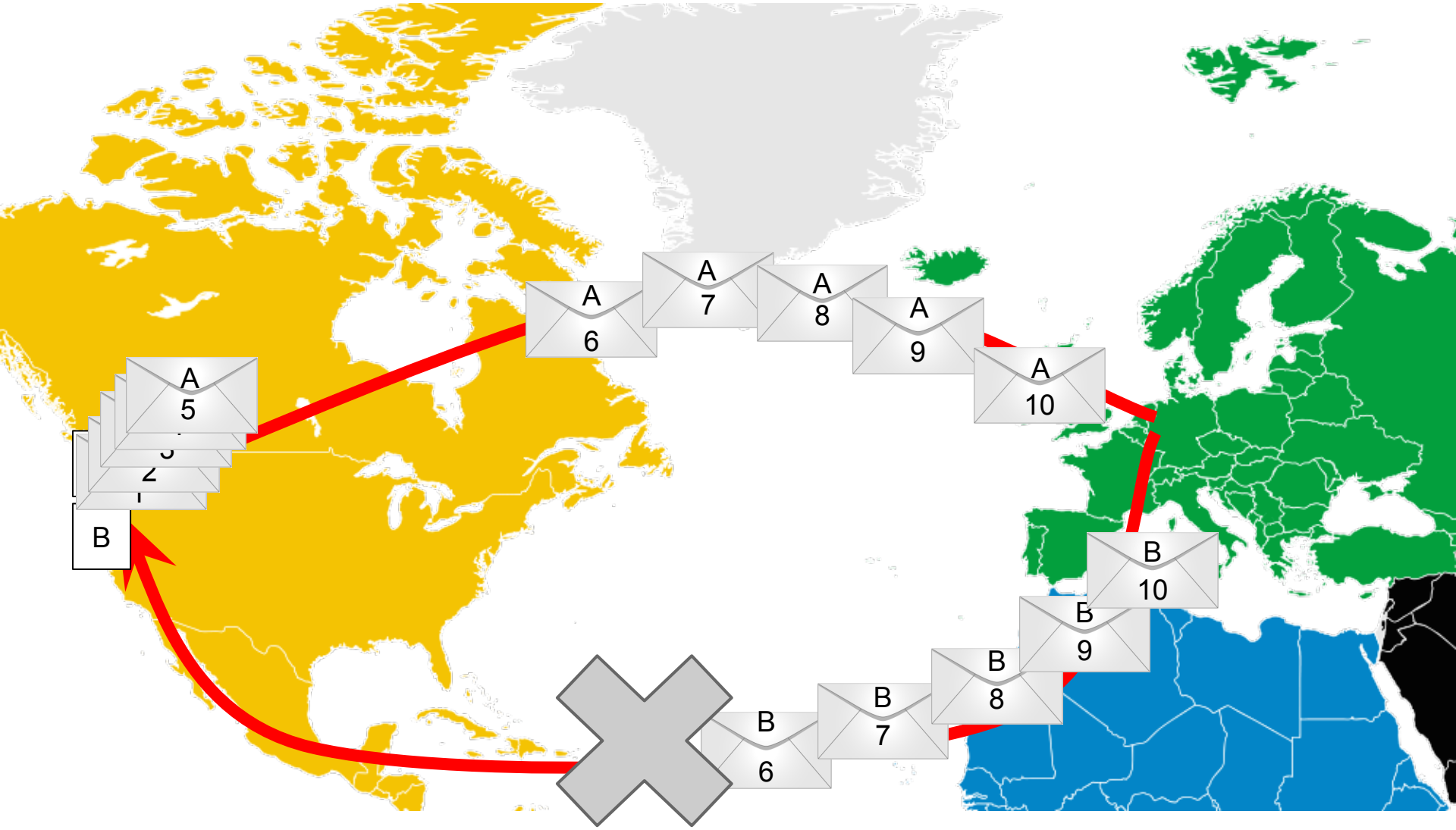
Multipath communication



Multipath communication



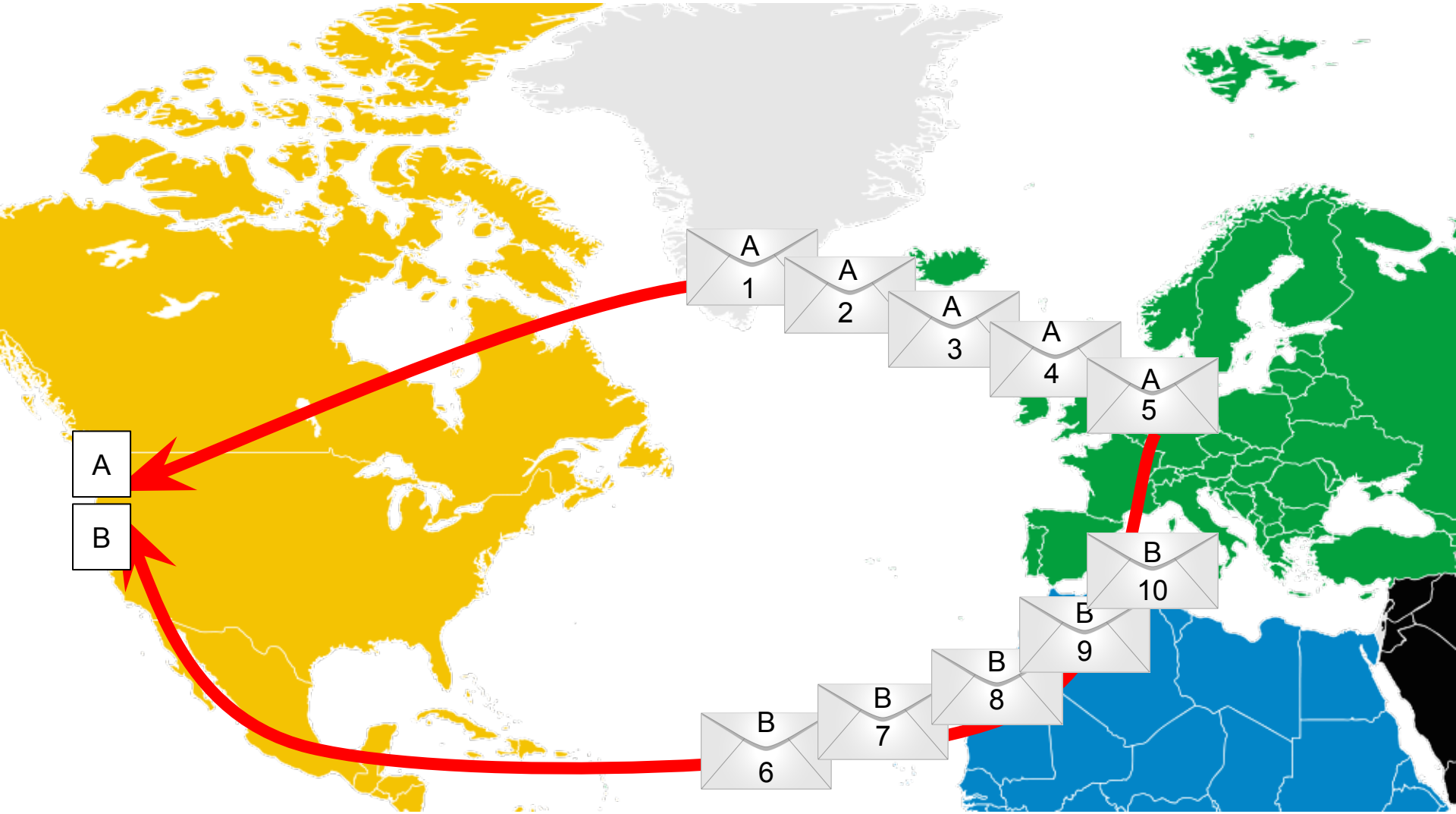
Multipath communication



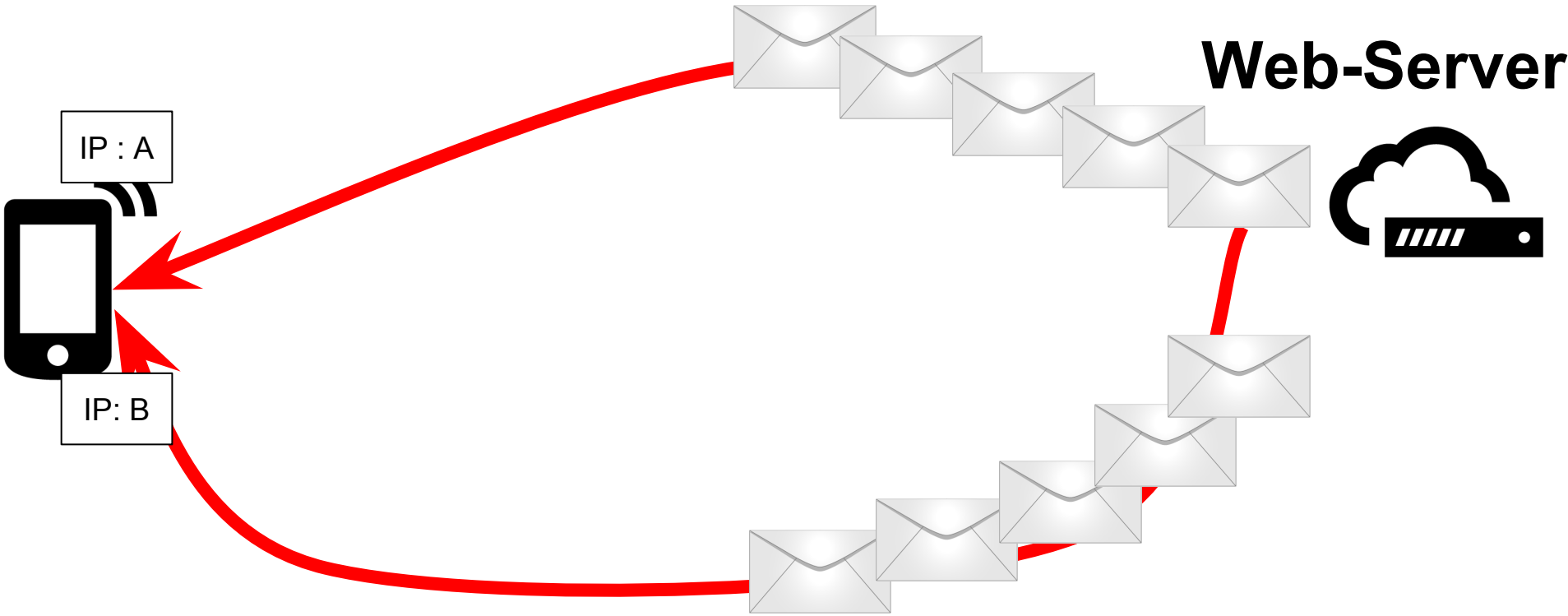
Multipath communication

- Faster communication (resource pooling)
- Seamless handover (resilience to failures)

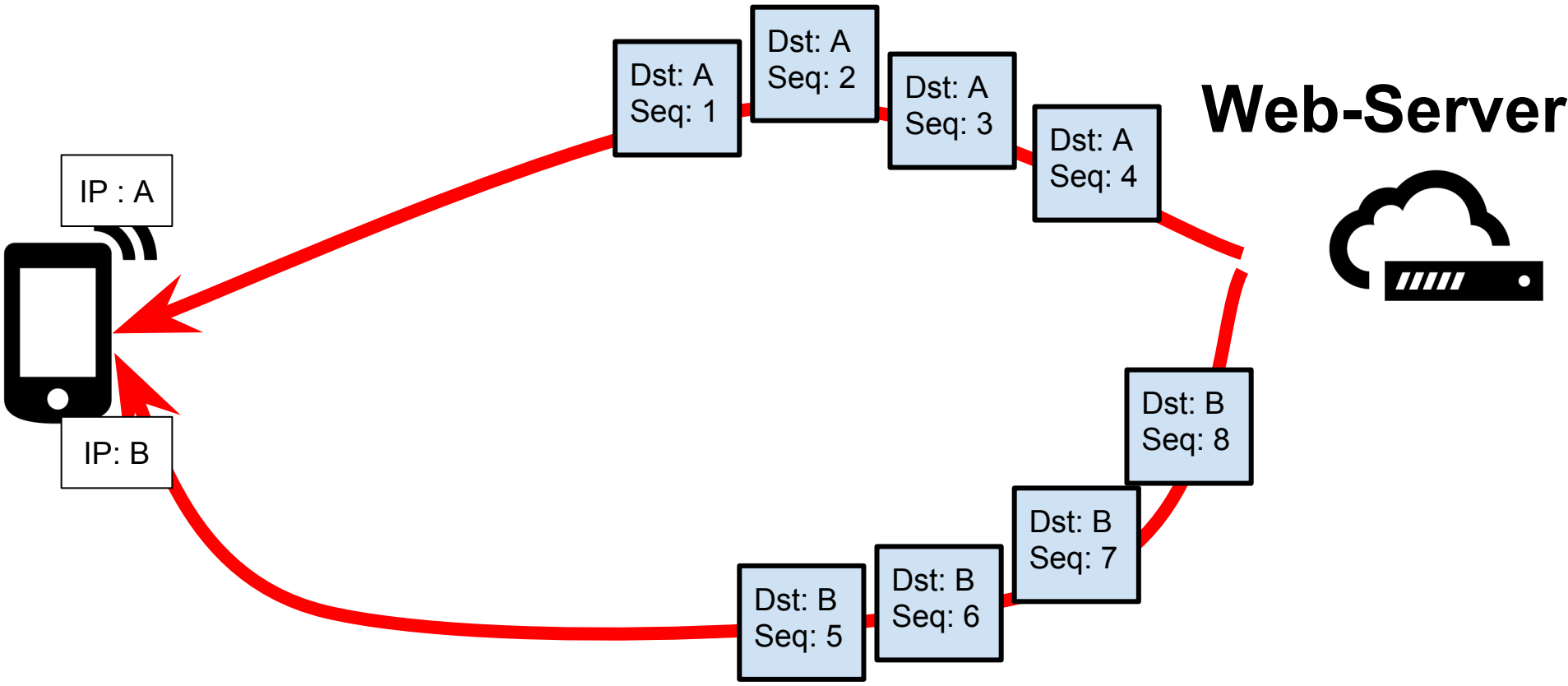
Multipath TCP



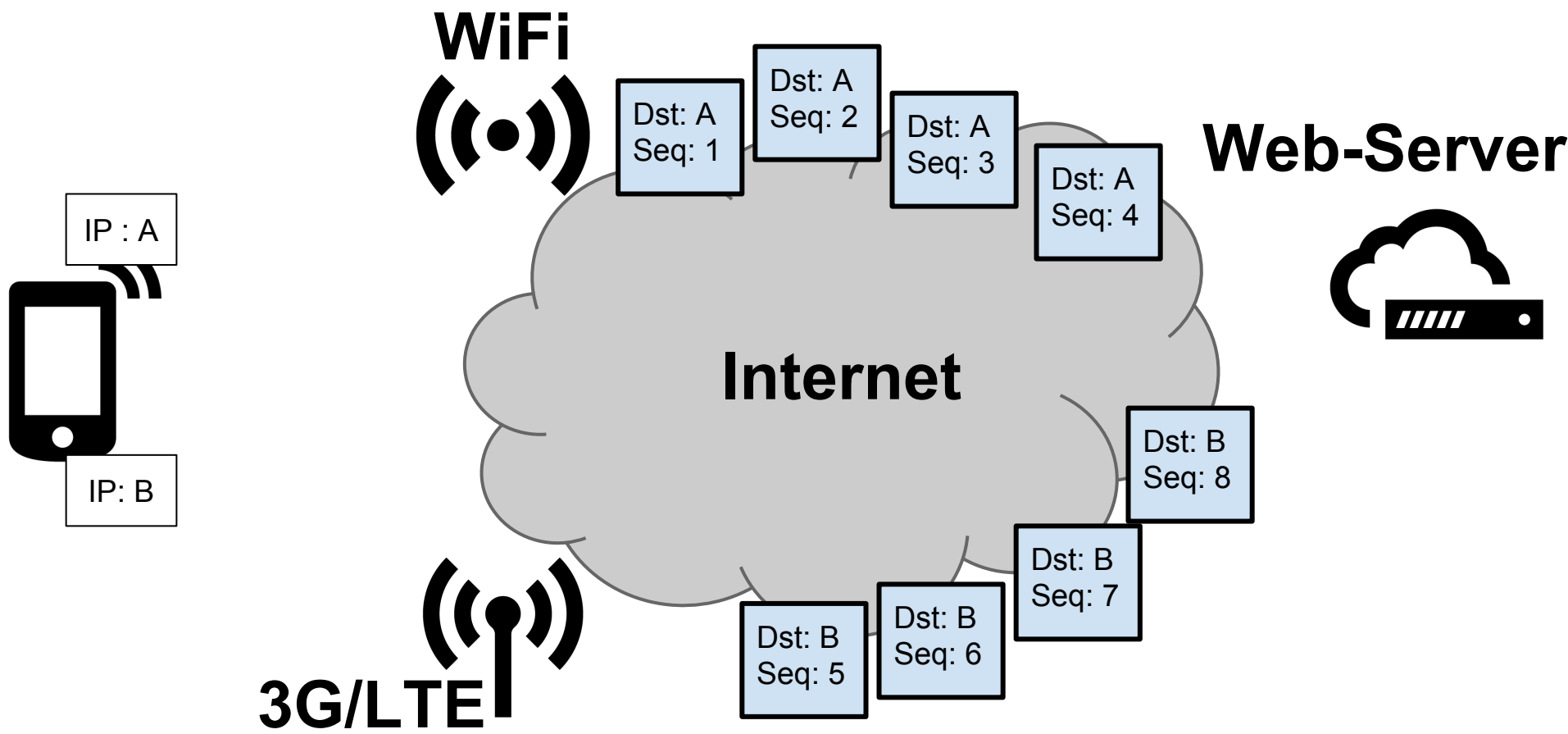
Multipath TCP



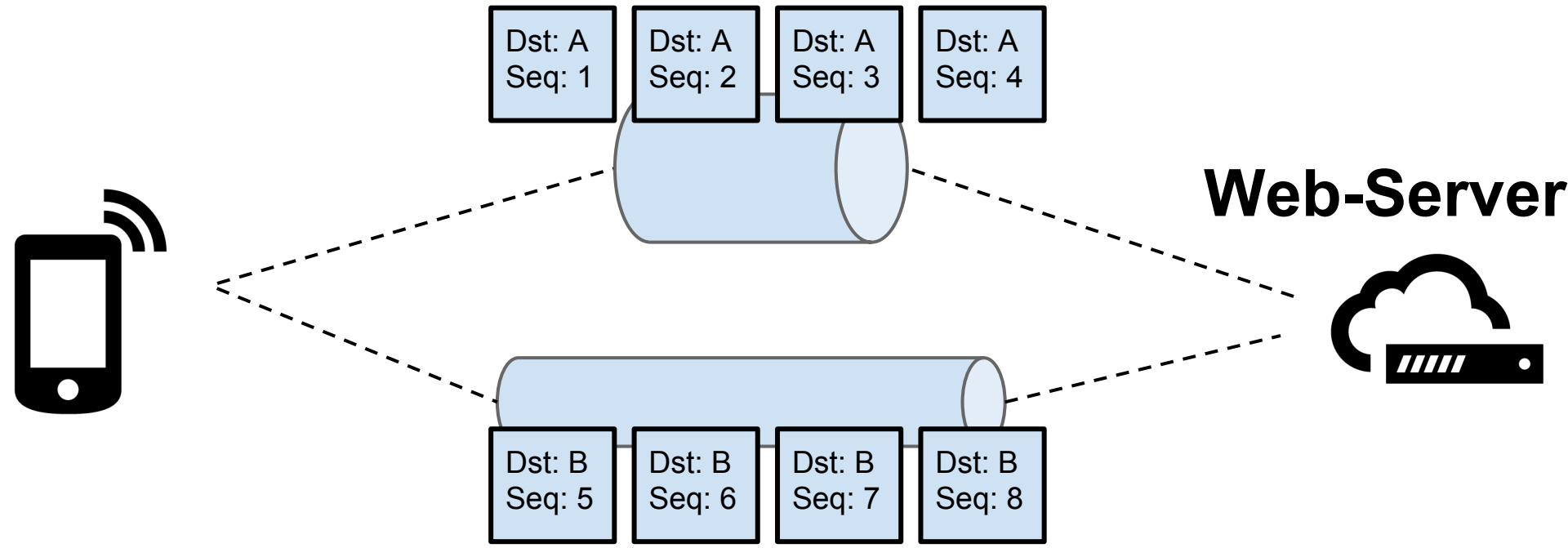
Multipath TCP



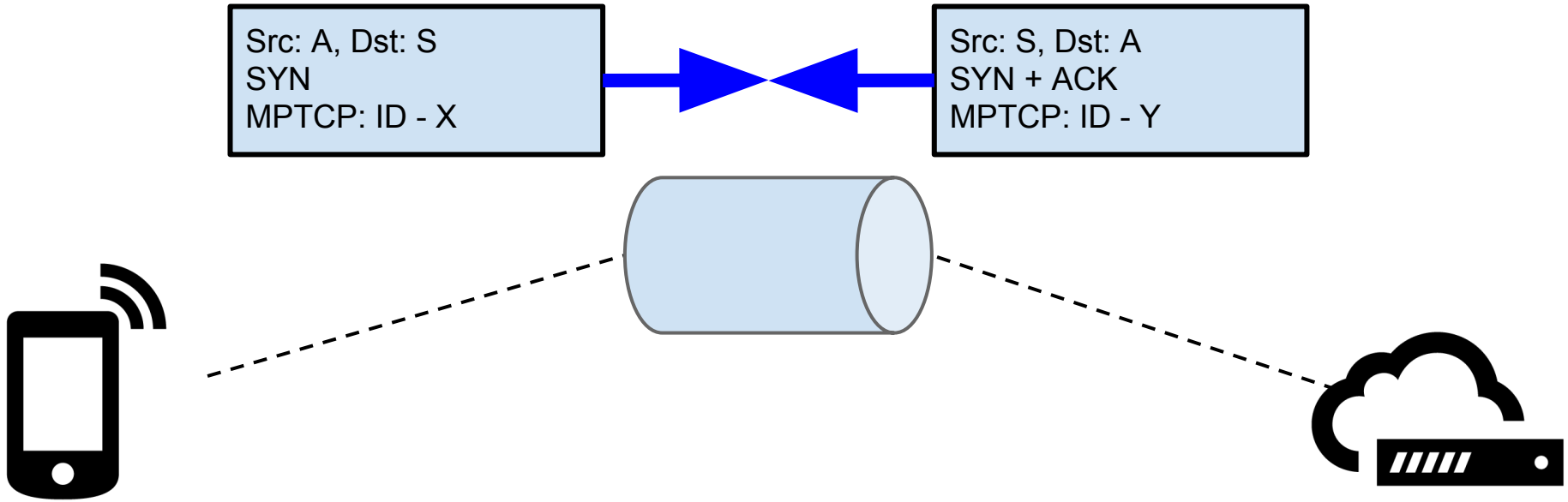
Multipath TCP



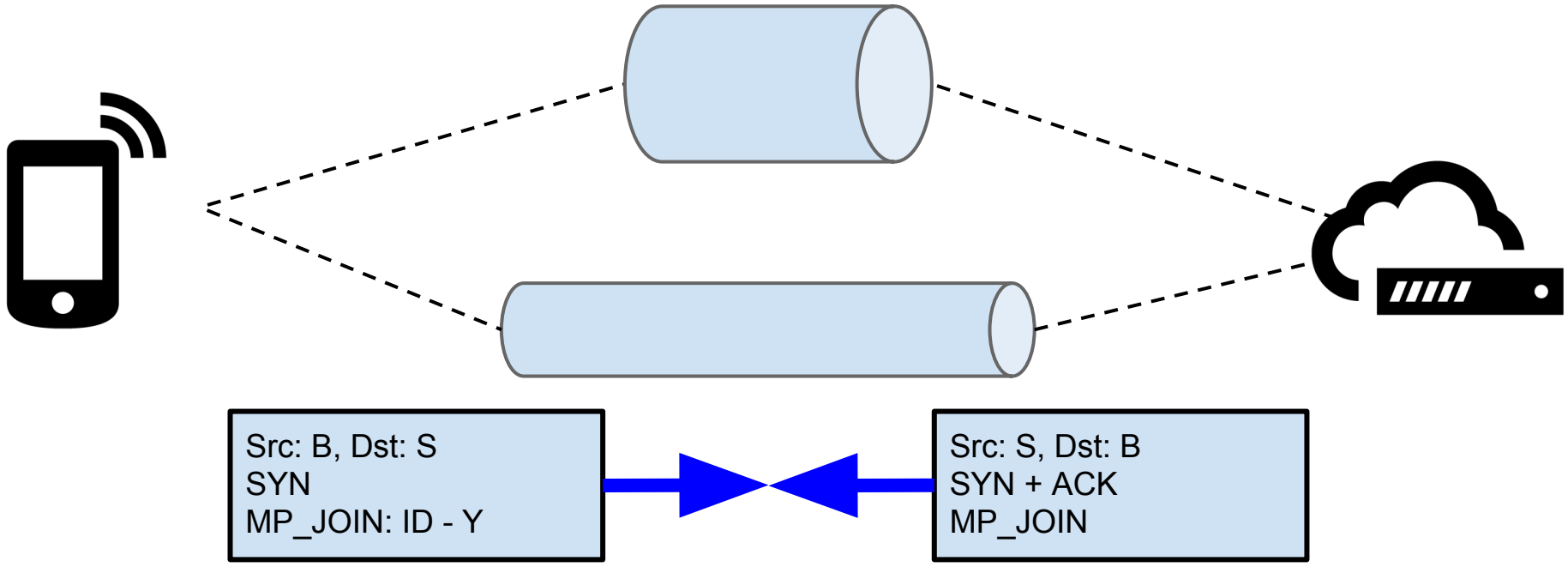
Multipath TCP



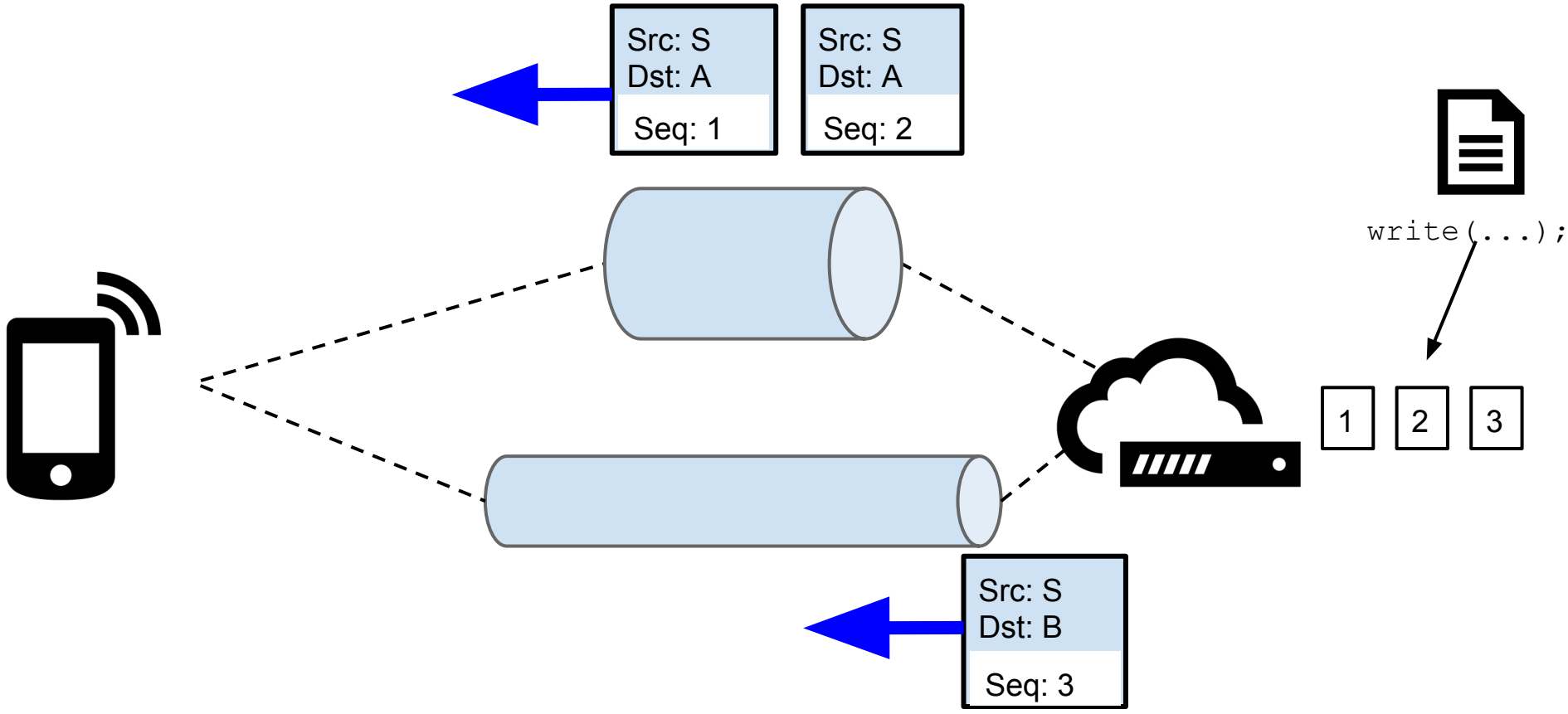
Multipath TCP handshake



Multipath TCP handshake



Transmit data with Multipath TCP



Multipath TCP

Can Multipath TCP be used on the Internet?

- Performance ?
- Can it be implemented ?
- Could it be designed differently ?

Improving Multipath TCP

Improving Multipath TCP

- Implementing Multipath TCP
- Evaluating Transport Protocols
- Multipath TCP *“in action"*

Improving Multipath TCP

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Implementing Multipath TCP

Goals of the implementation

1. Minimize performance impact on regular TCP
2. Reduce complexity within regular TCP
3. Achieve high performance for Multipath TCP

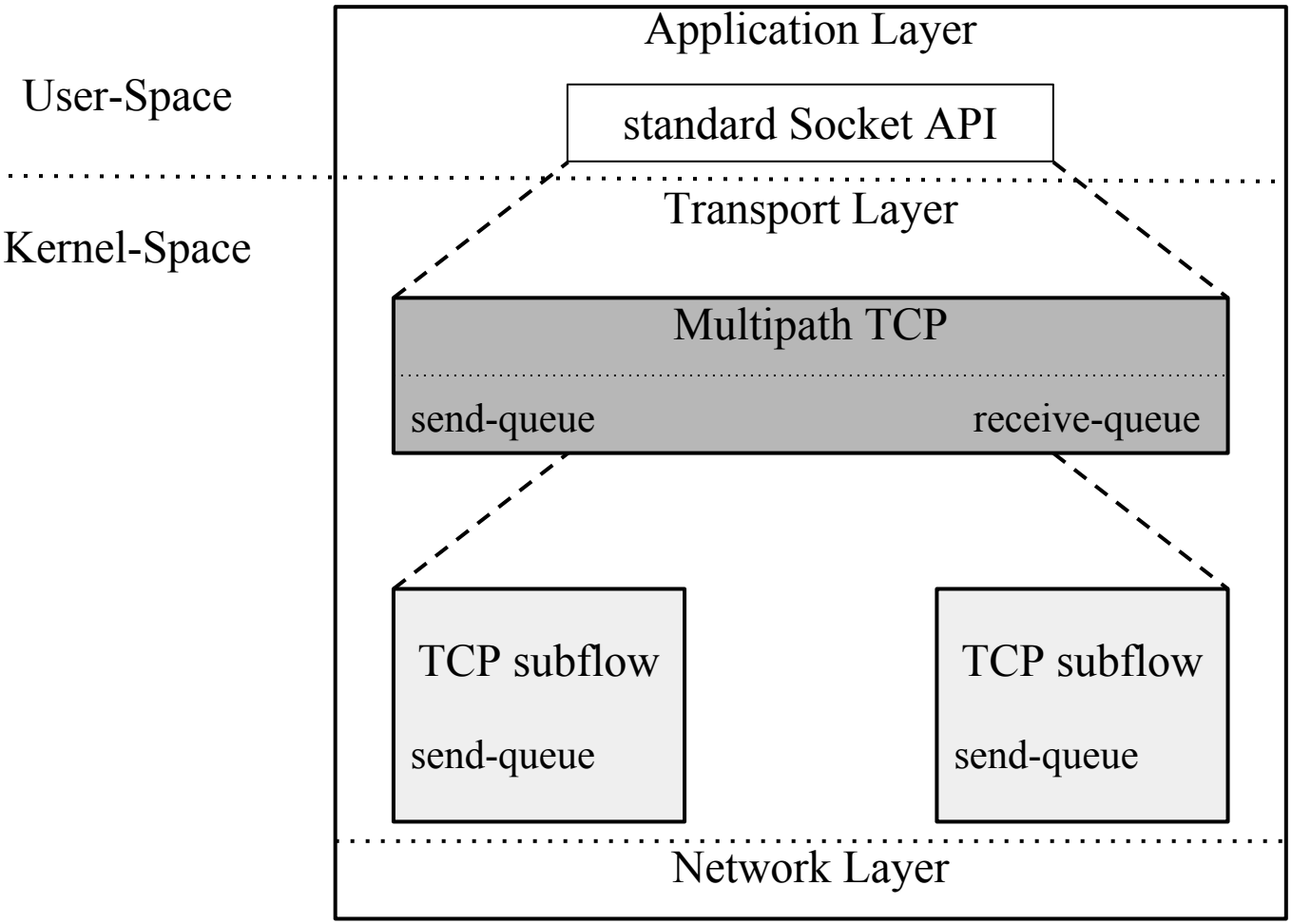
Why a Linux Kernel implementation?

- Tightly integrated into the TCP-stack
- Best performance
- Reactive to changes in path characteristics

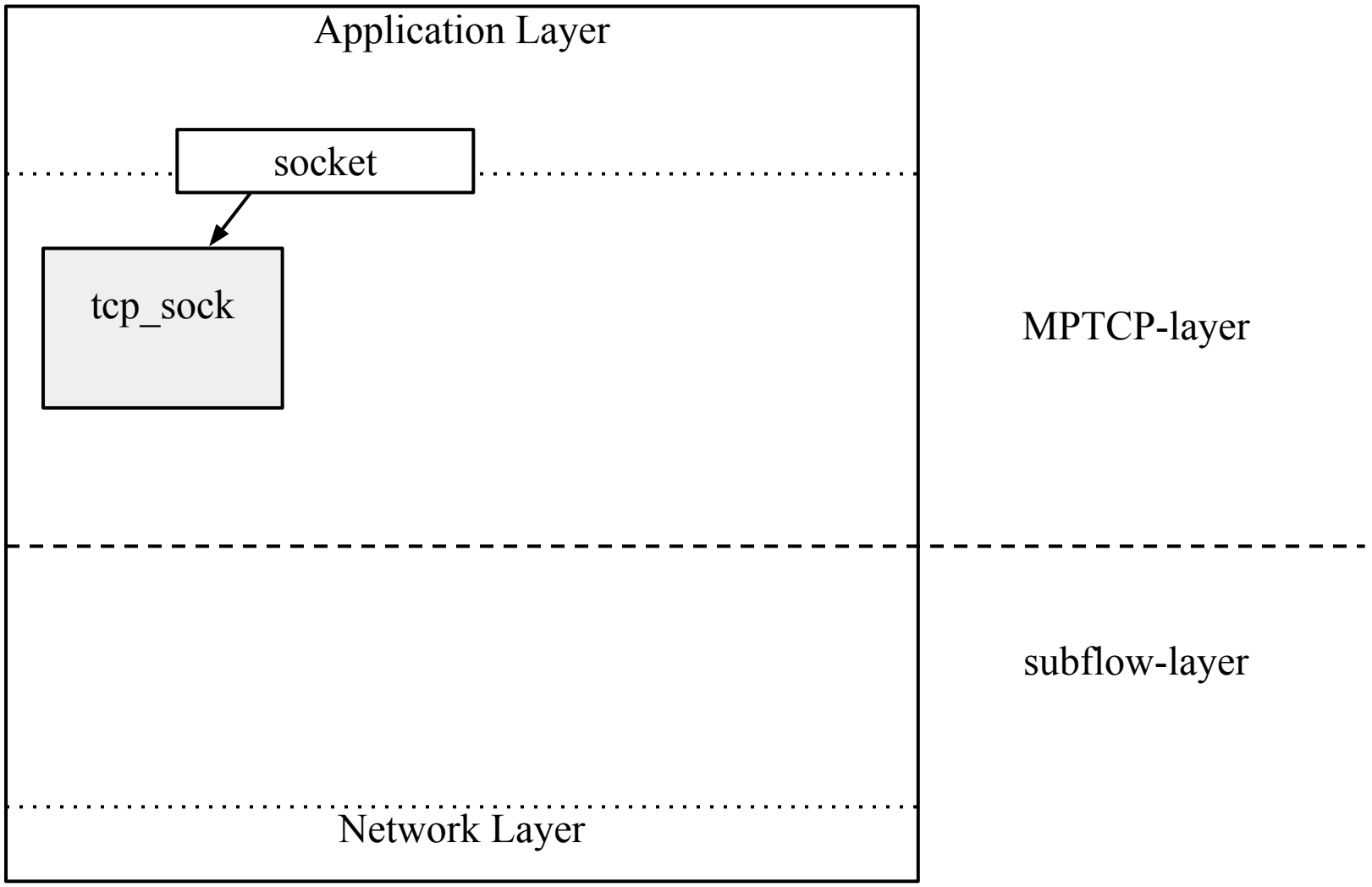
Implementing Multipath TCP

… and how it fits inside the Linux Kernel
(based on a prototype from Sébastien Barré)

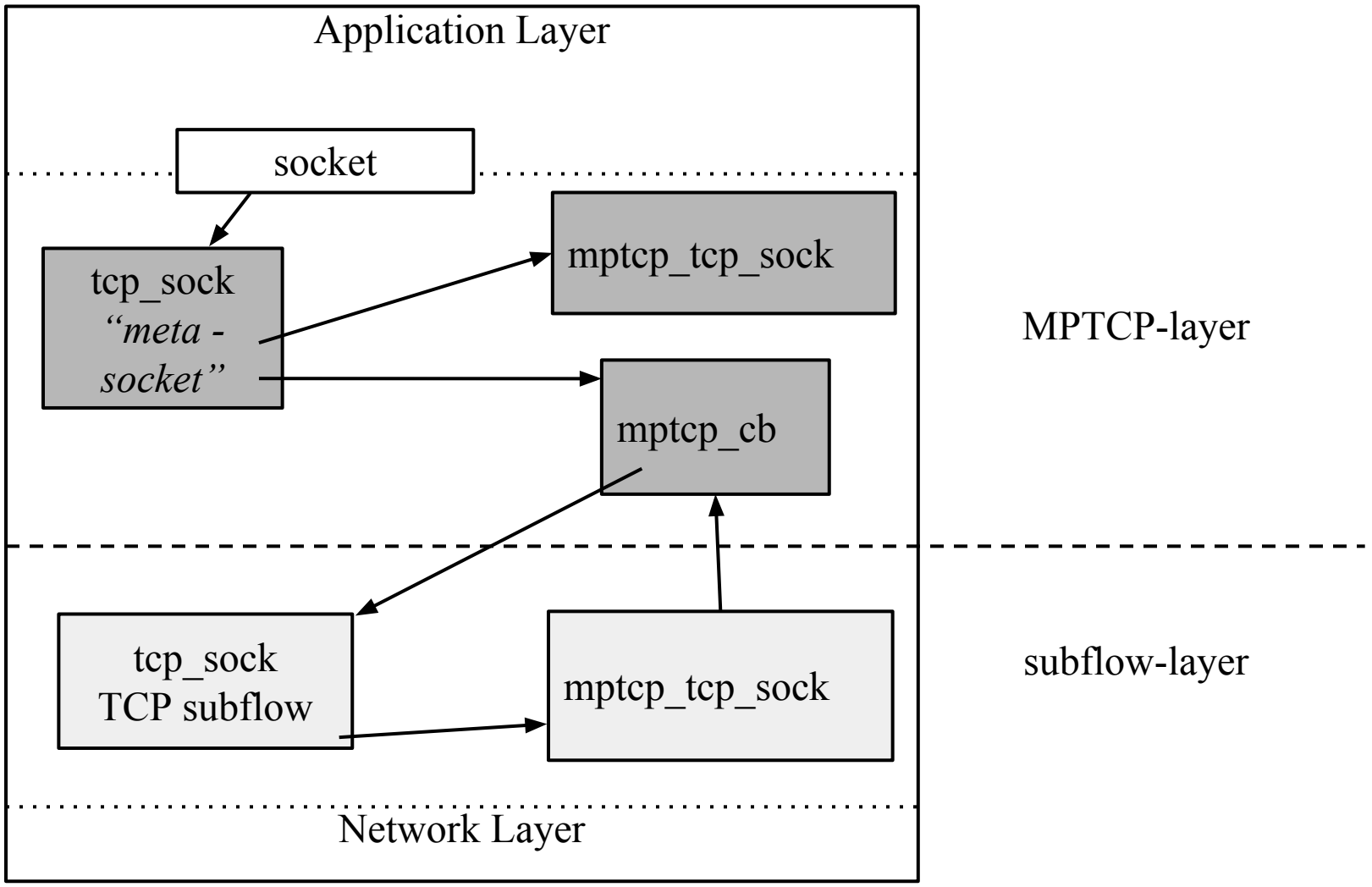
Architecture of Multipath TCP



Data structures of regular TCP



Data structures of Multipath TCP

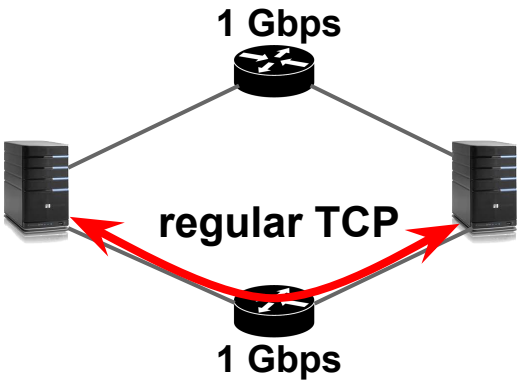


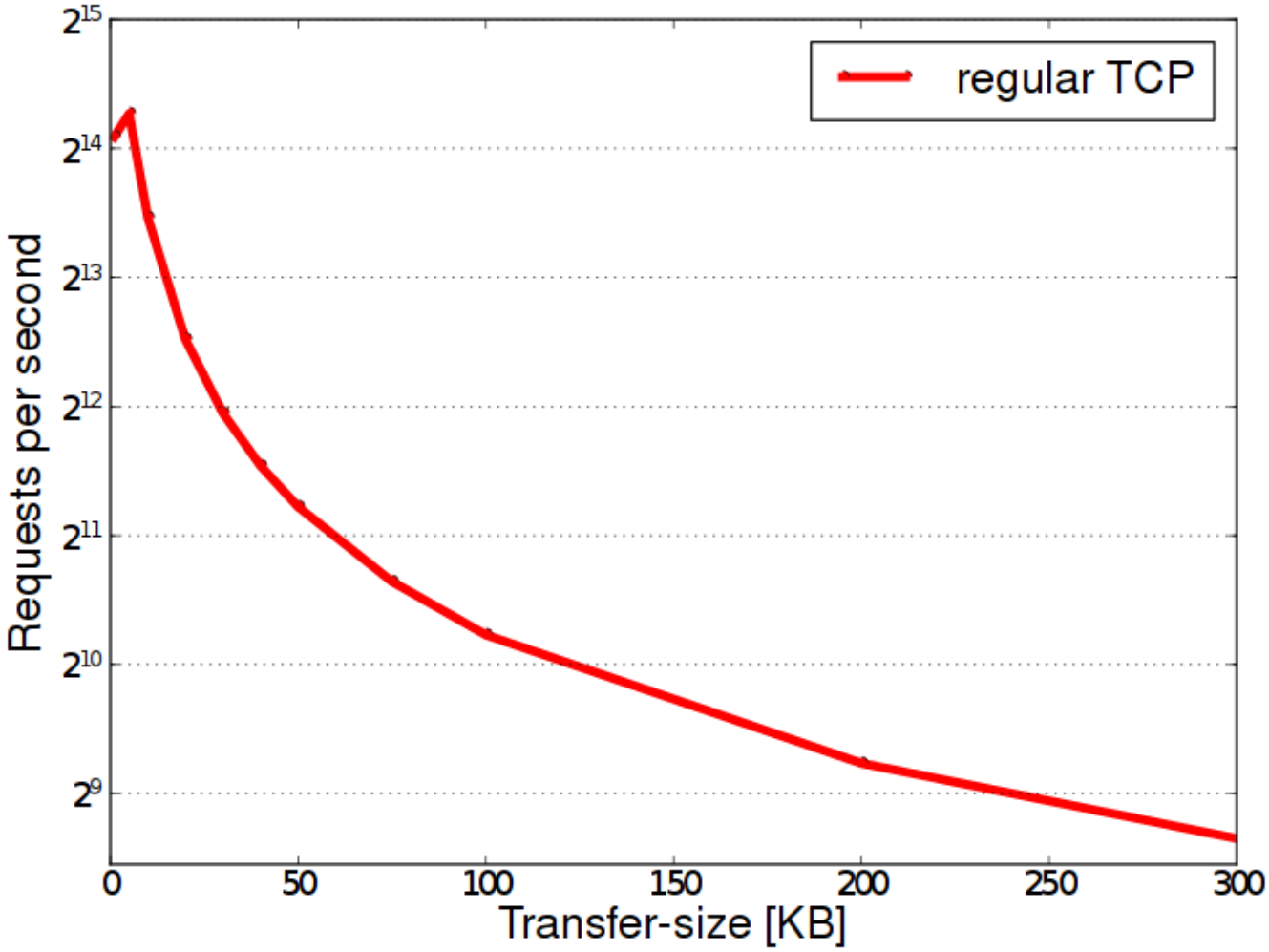
Linux Kernel Multipath TCP

… and its performance compared to regular TCP

MPTCP performance with Apache

100 simultaneous HTTP-Requests, total of 100000





MPTCP performance with Apache

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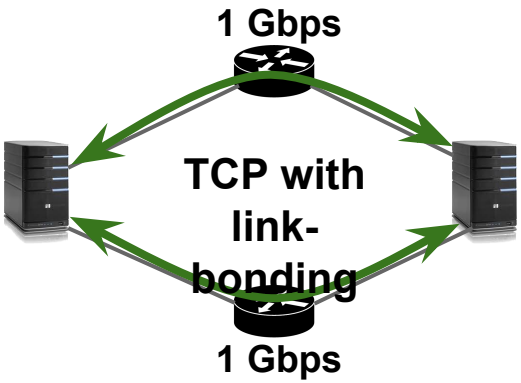

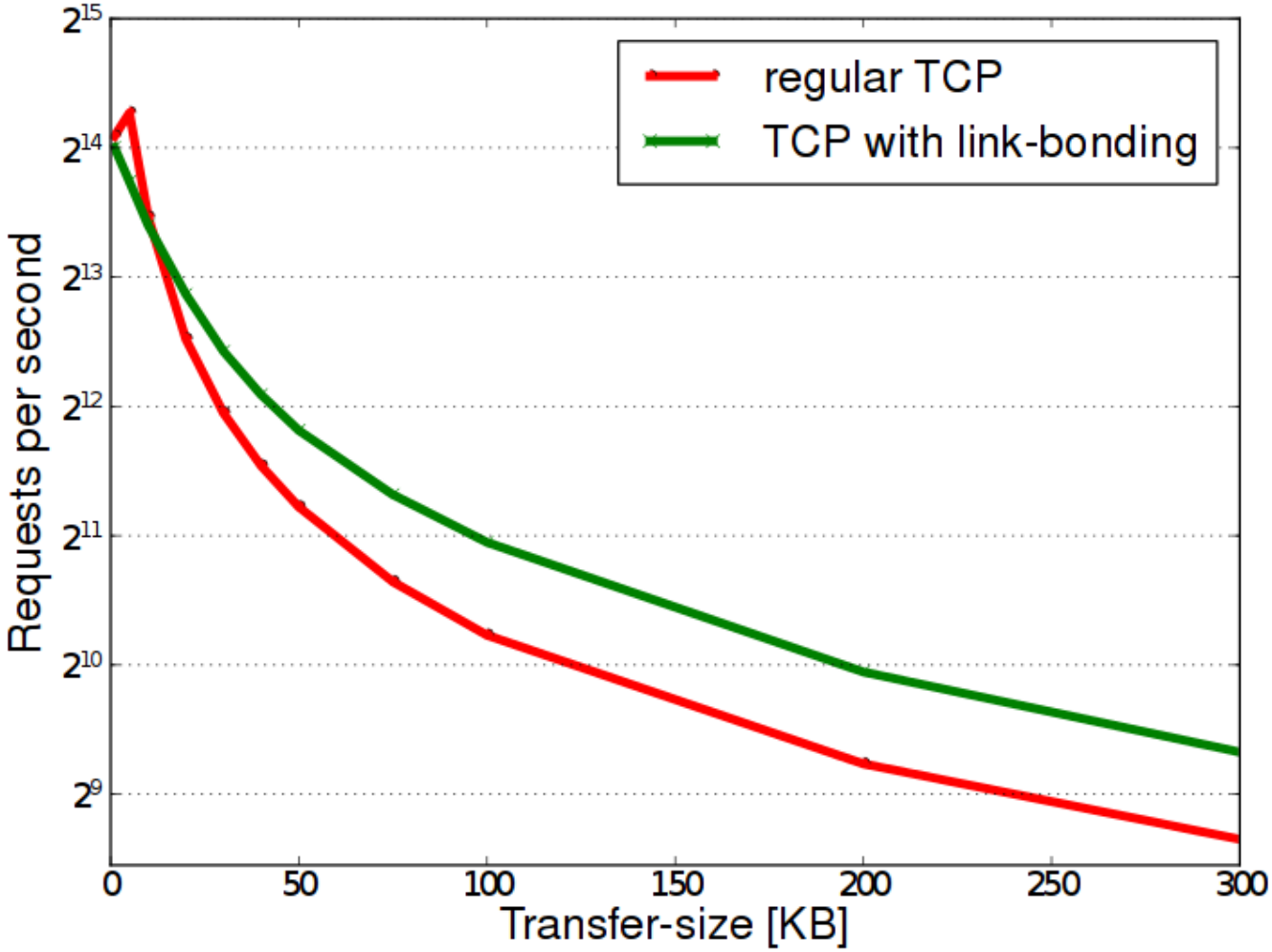

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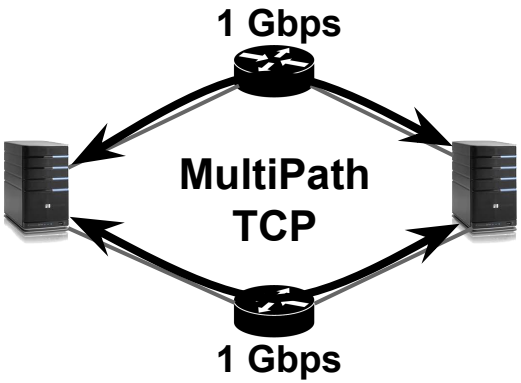
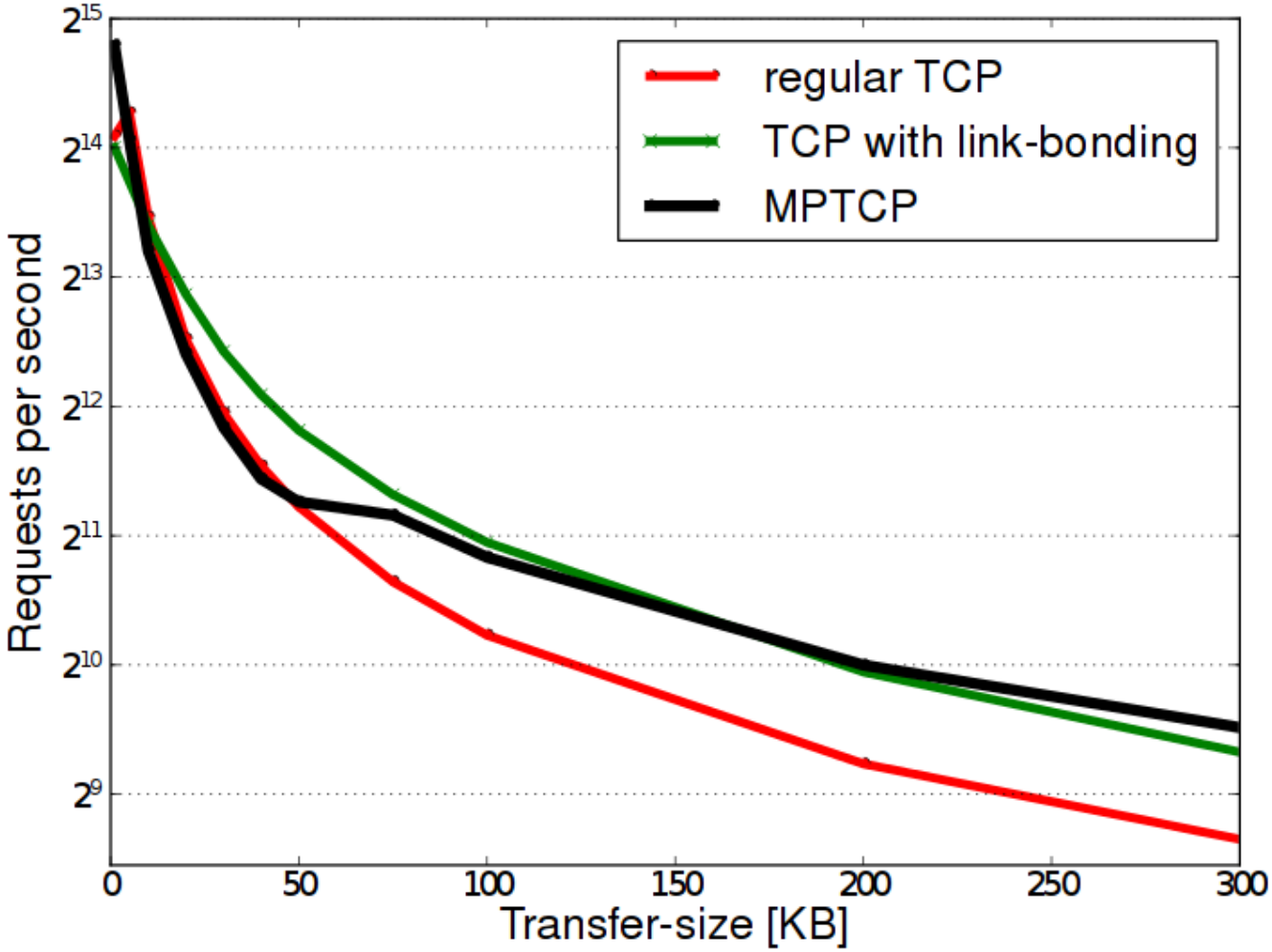


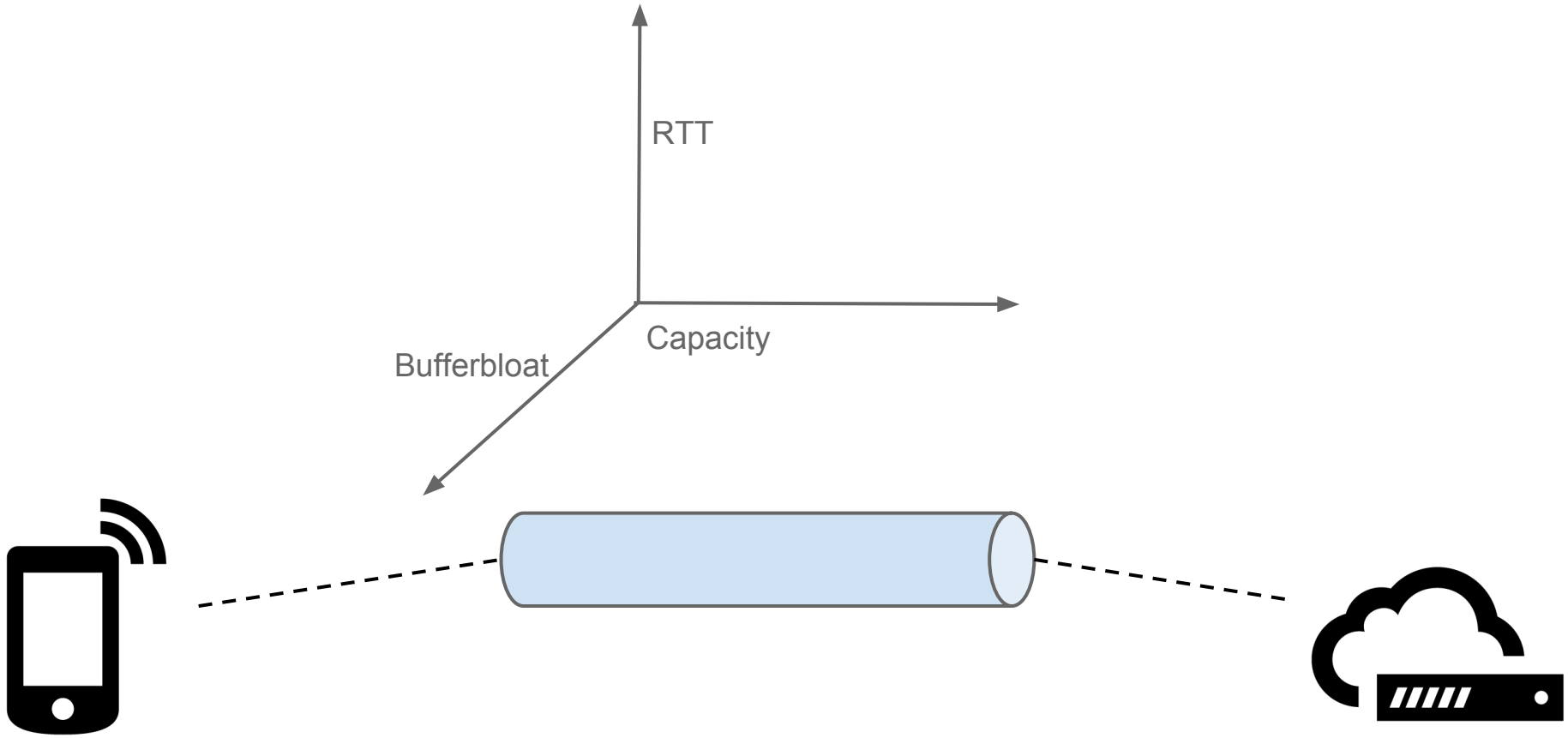


Improving Multipath TCP

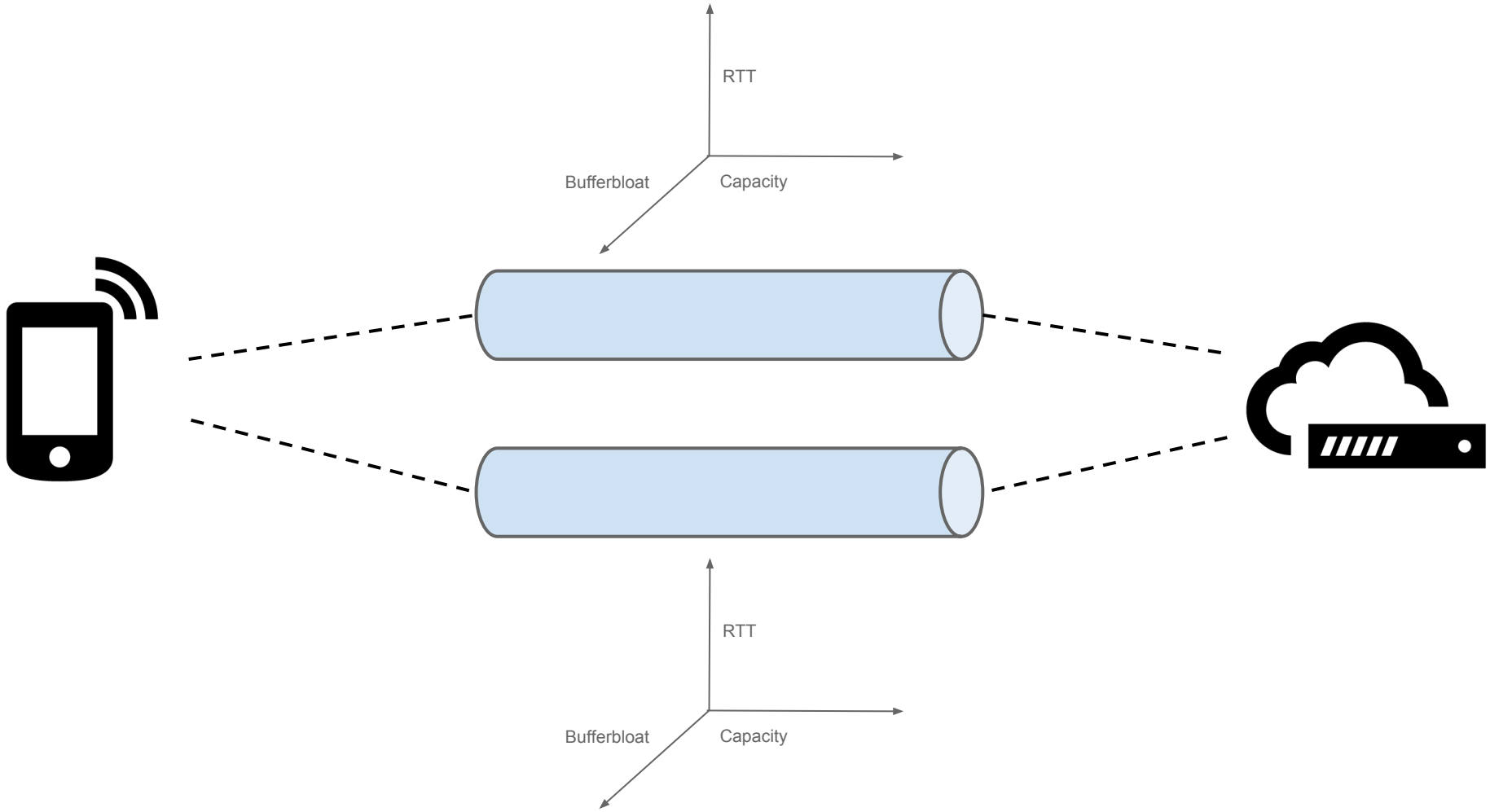
- Implementing Multipath TCP
- Evaluating Transport Protocols
- Multipath TCP *“in action”*

Evaluating Transport Protocols

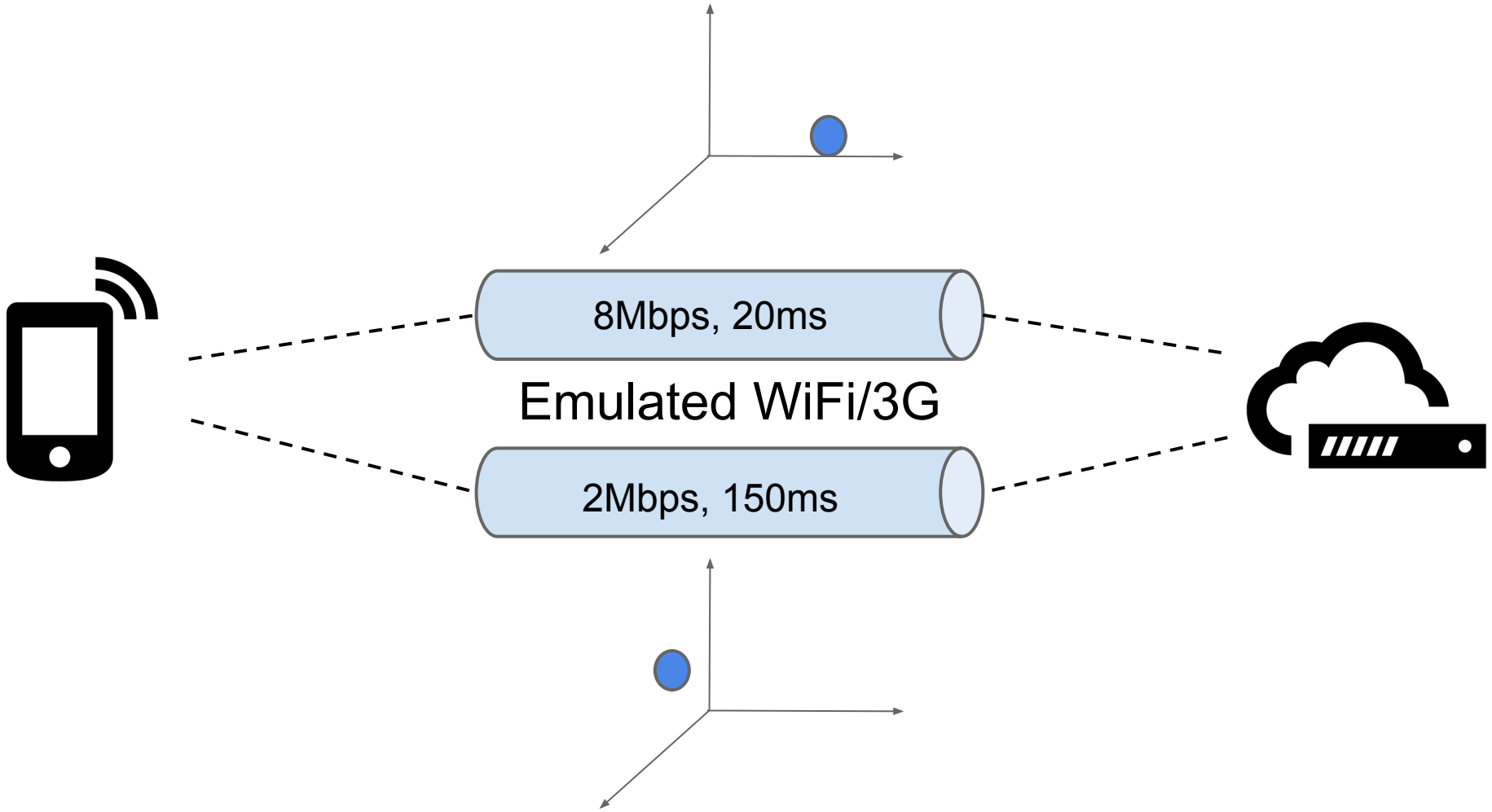
Evaluating Multipath TCP



Evaluating Multipath TCP

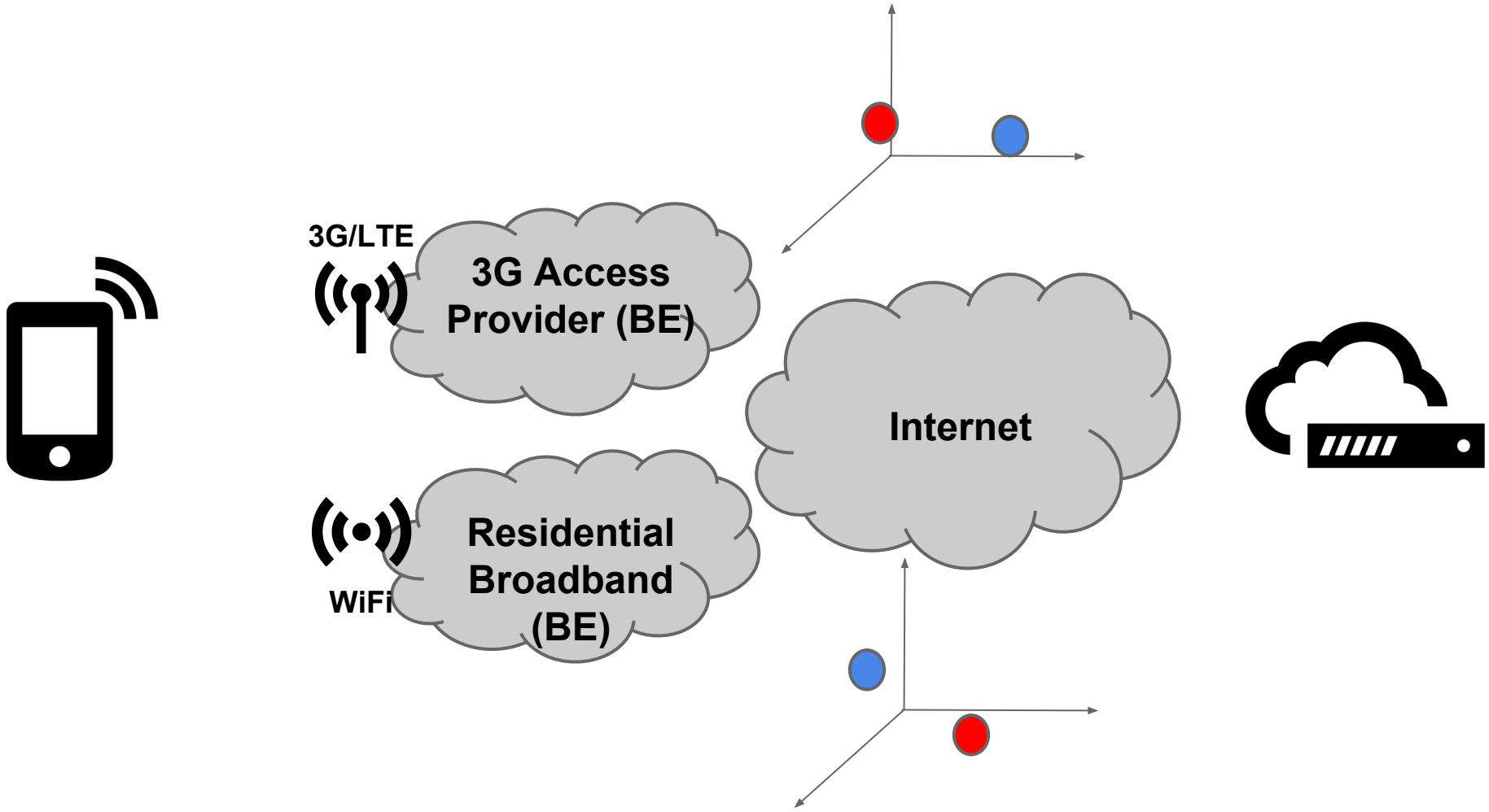


Evaluating Multipath TCP



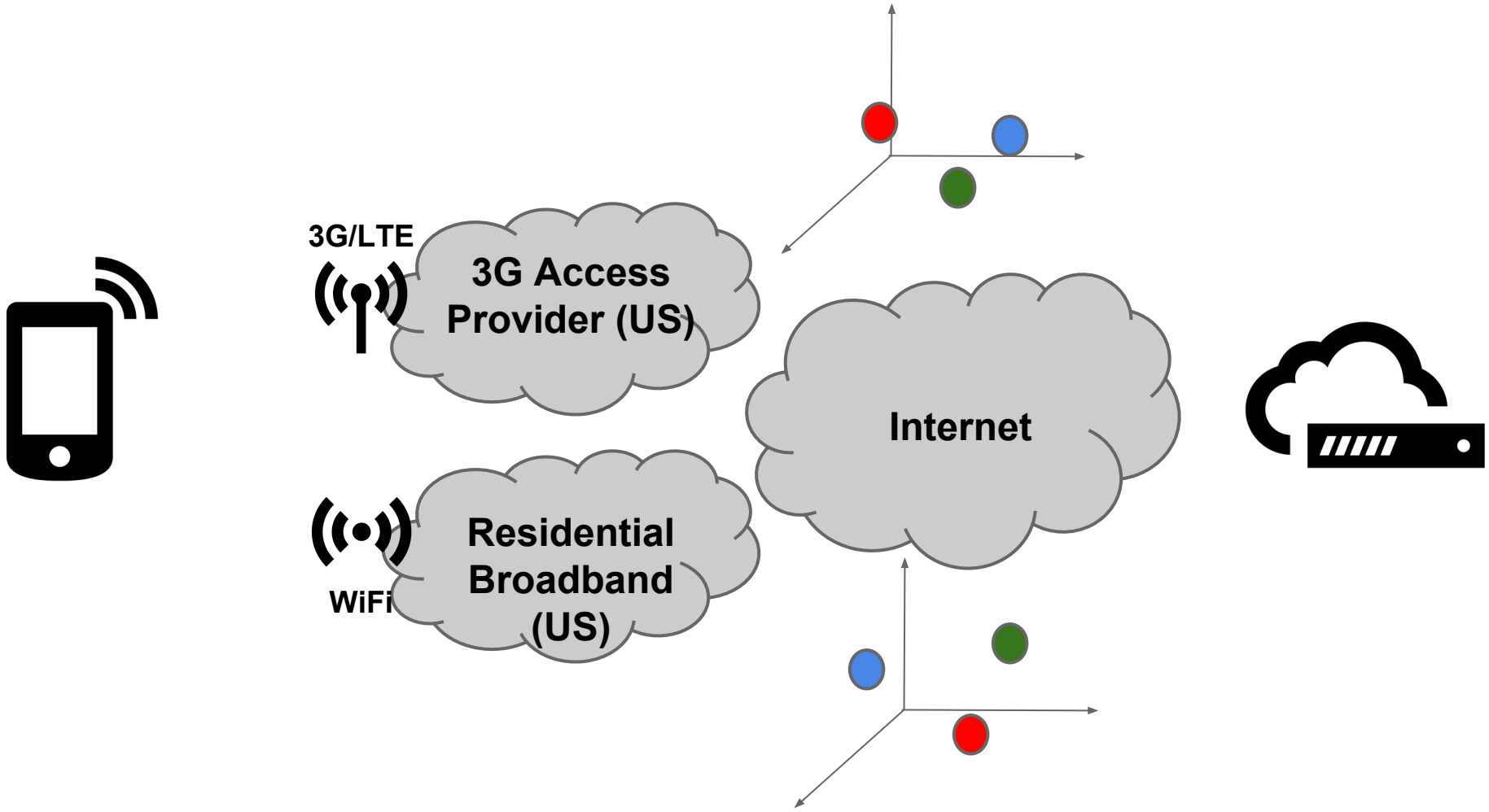
"How Hard Can It Be? Designing and Implementing a Deployable Multipath TCP". C. Raiciu, et al. NSDI'12

Evaluating Multipath TCP



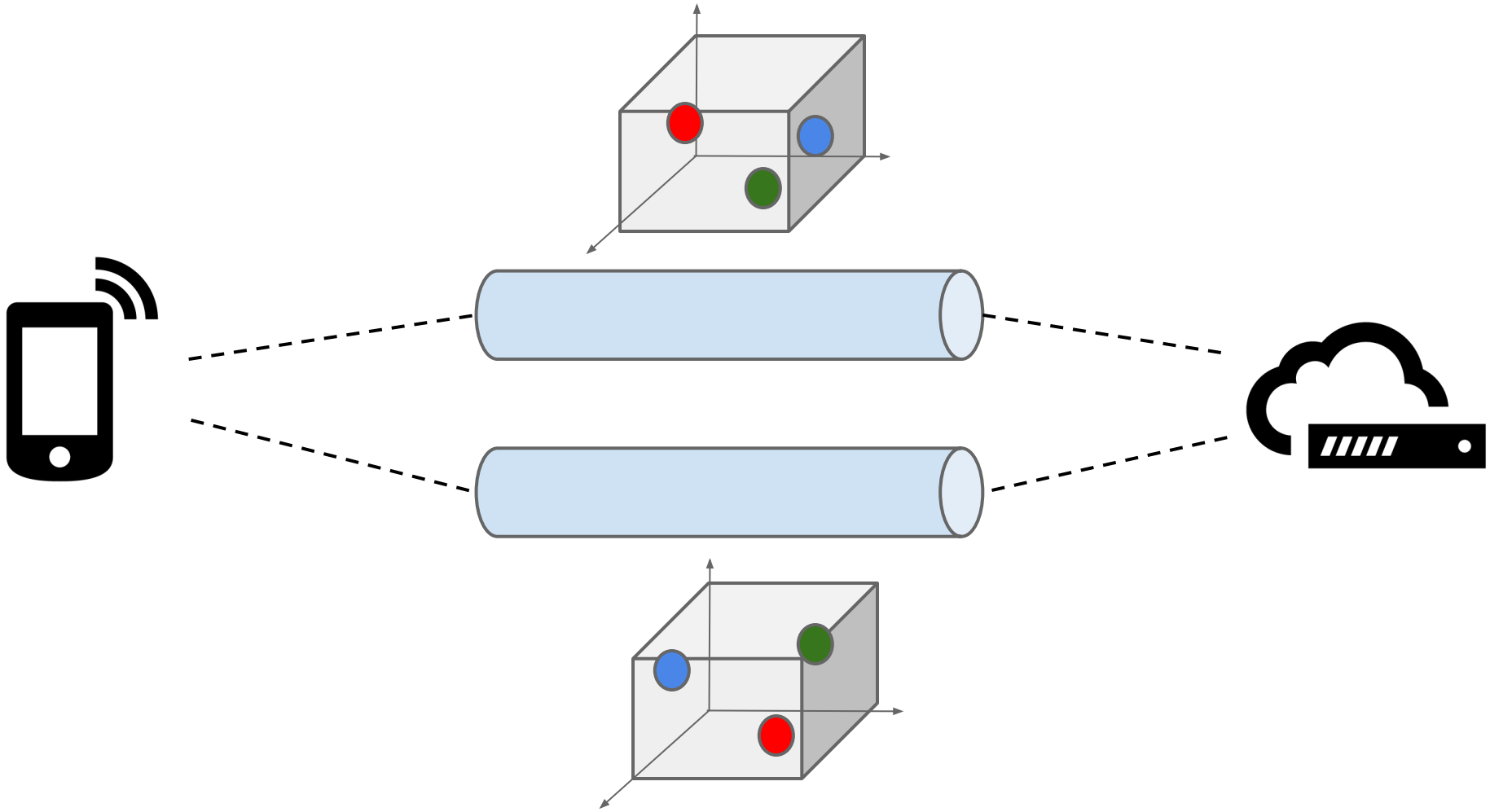
"Exploring Mobile/WiFi Handover with Multipath TCP". C. Paasch, et al. CellNet'12

Evaluating Multipath TCP

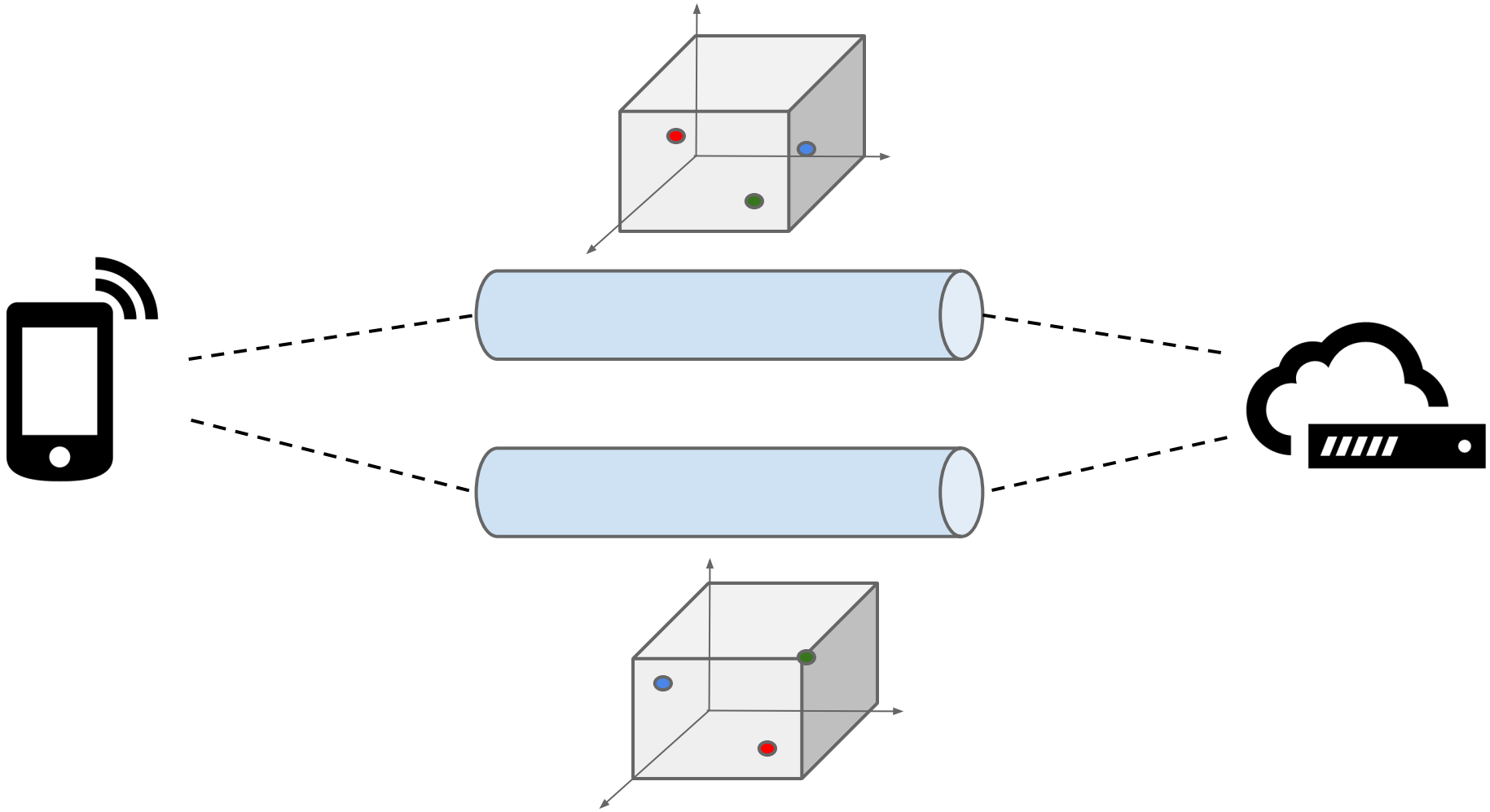


"A Measurement-based Study of Multipath TCP Performance over Wireless Networks". Y.-C. Chen, et al. IMC'13

Evaluating Multipath TCP



Evaluating Multipath TCP



Experimental Design

… a scientific approach to evaluation

The planned approach to evaluation

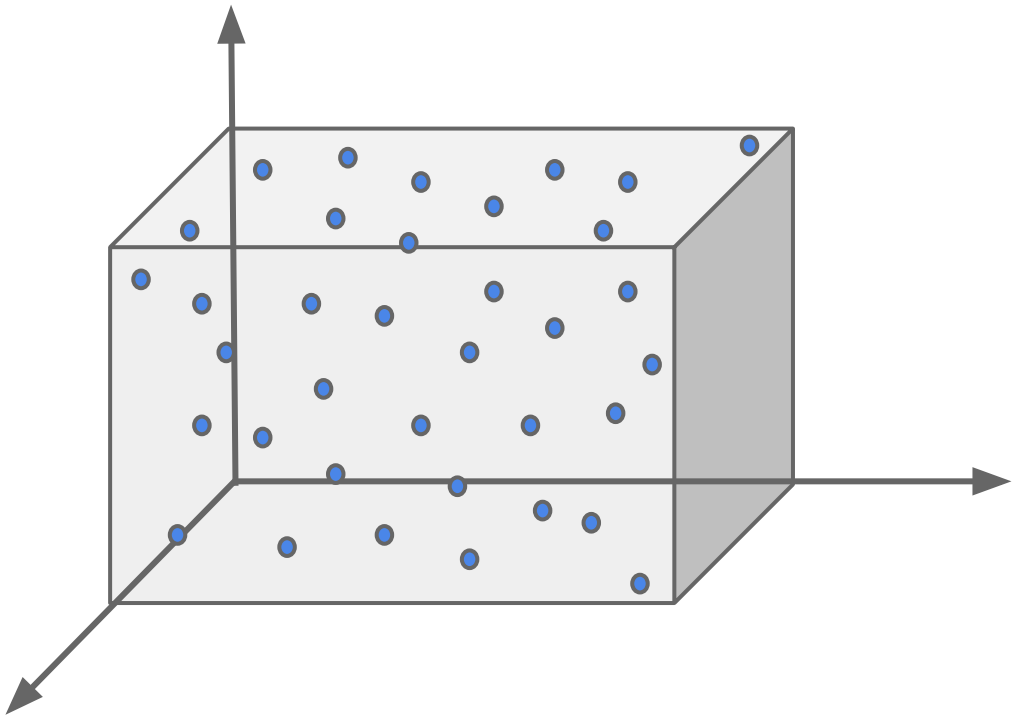
1. Define the objective

2. Decide the factors

3. Design the experiment

Design the experiment

Space-Filling Designs

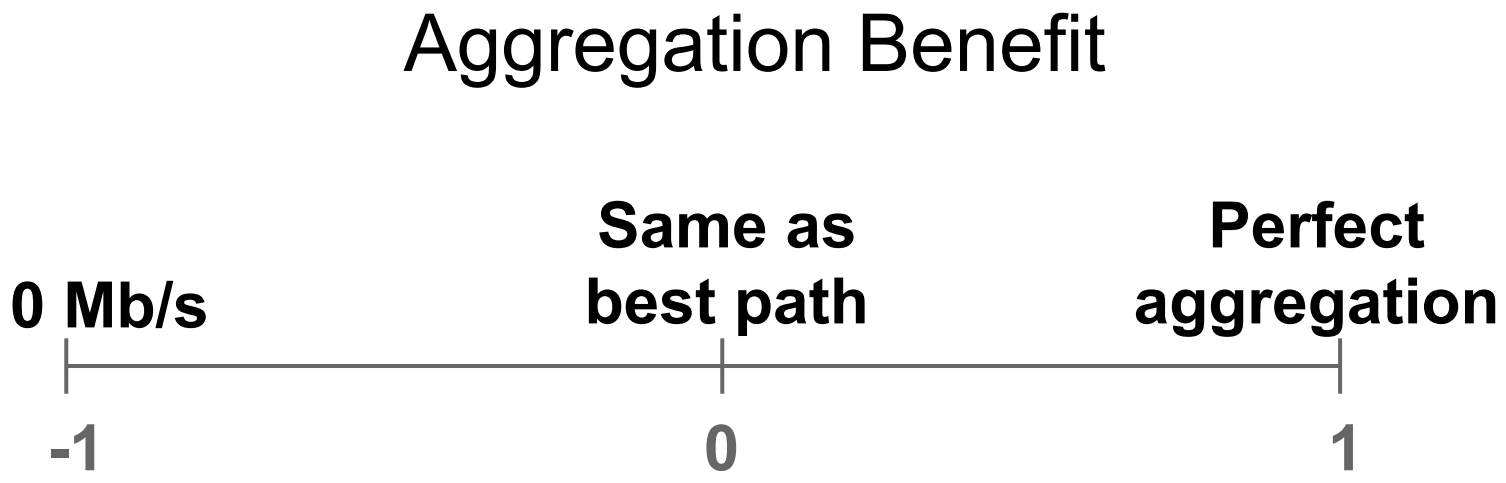


Evaluating Multipath TCP's resource pooling

… using the Experimental Design approach

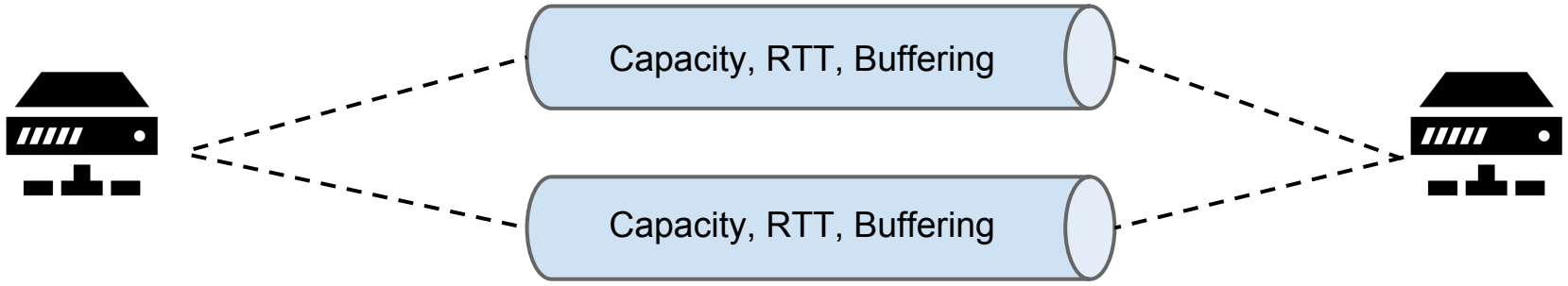
1. Objective

Quantify Multipath TCP's resource pooling capabilities



"Multipath Aggregation of Heterogeneous Access Networks". D. Kaspar. Phd Thesis. University of Oslo. 2011.

2. Domains of the factors



Capacity
RTT
Buffering

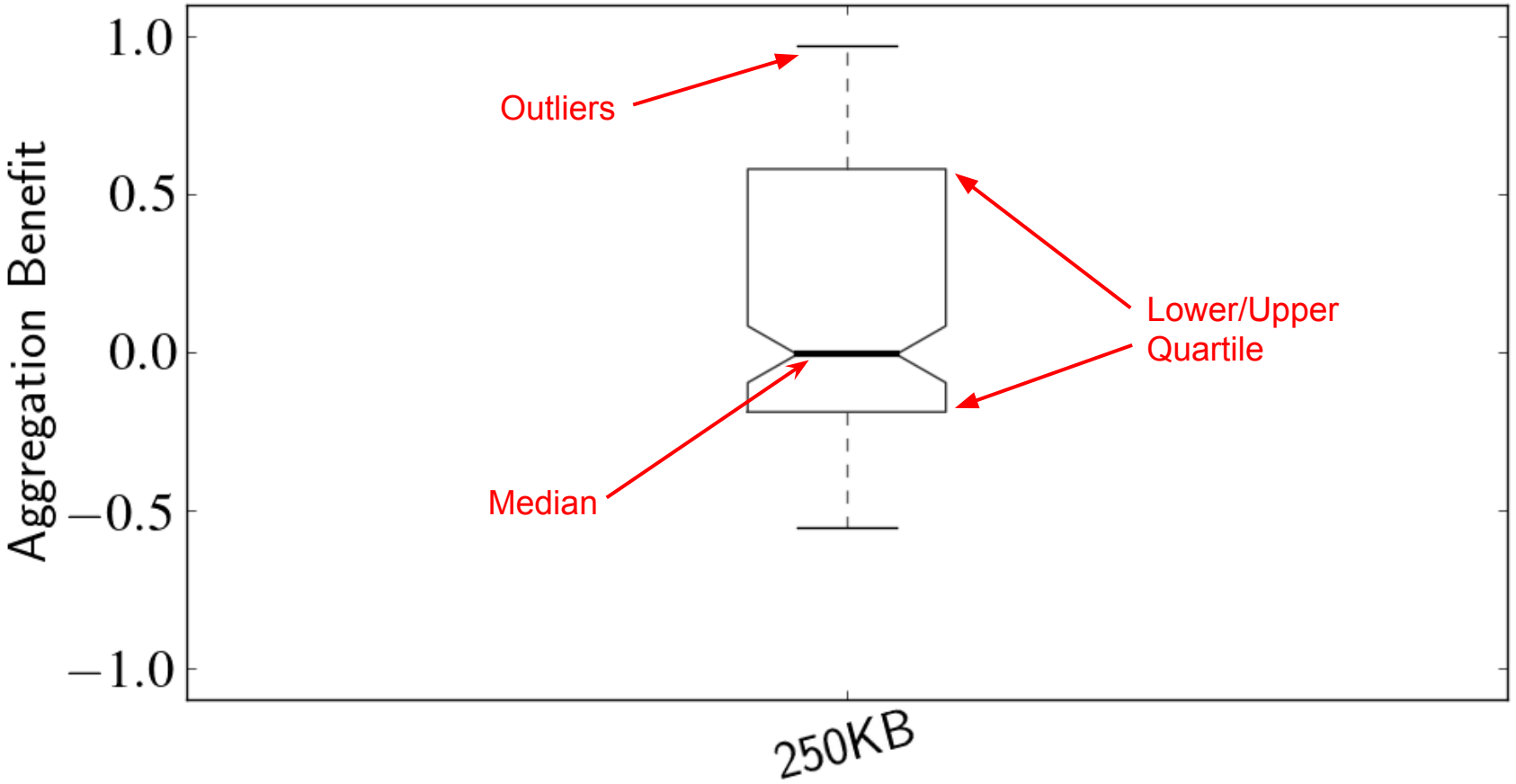
3. Experiment design

6-Dimensional Space

~200 parameter-sets in a space-filling design

~4 hours of experiments

Visualizing the output

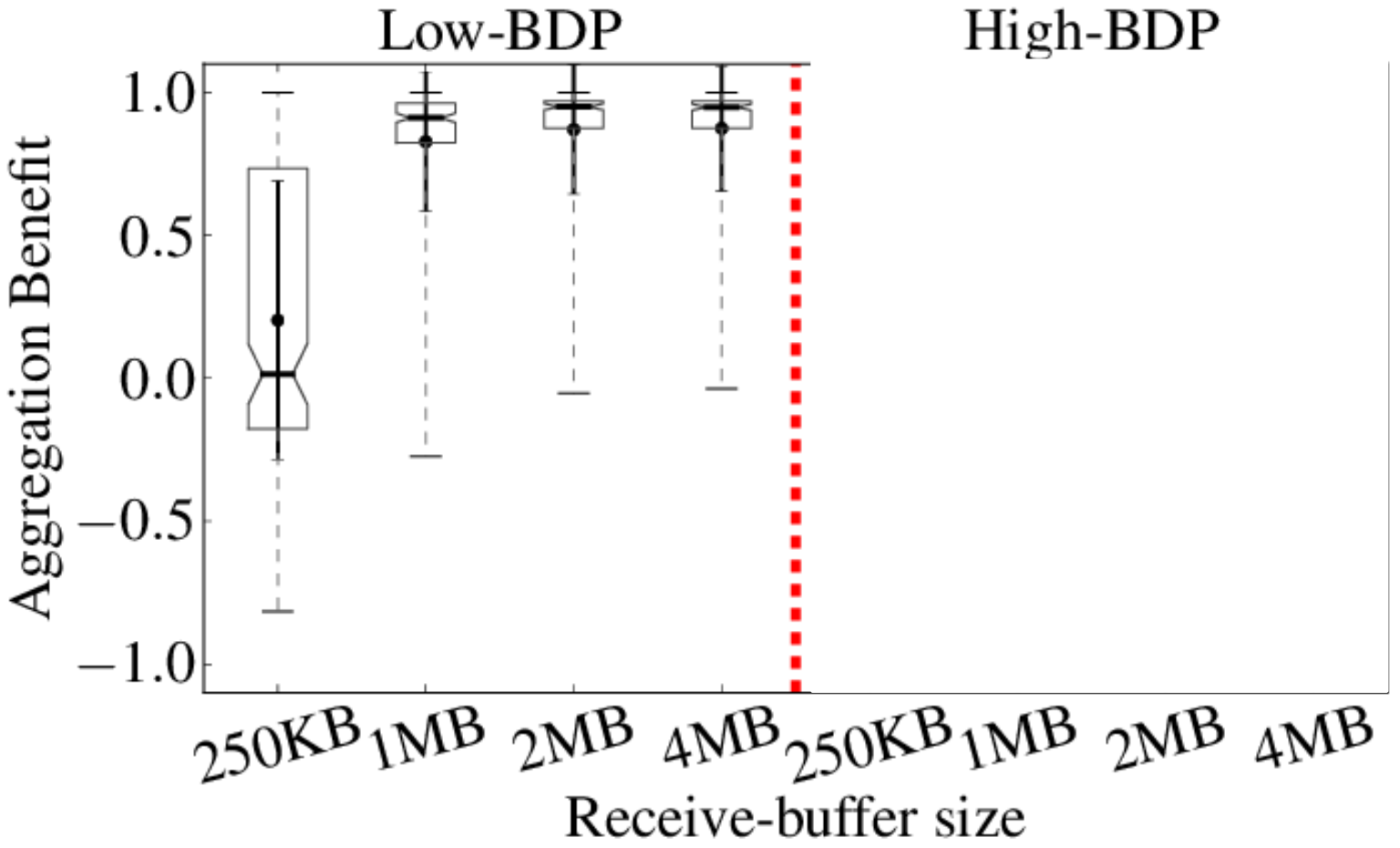


Congestion Control

Detecting the link’s capacity

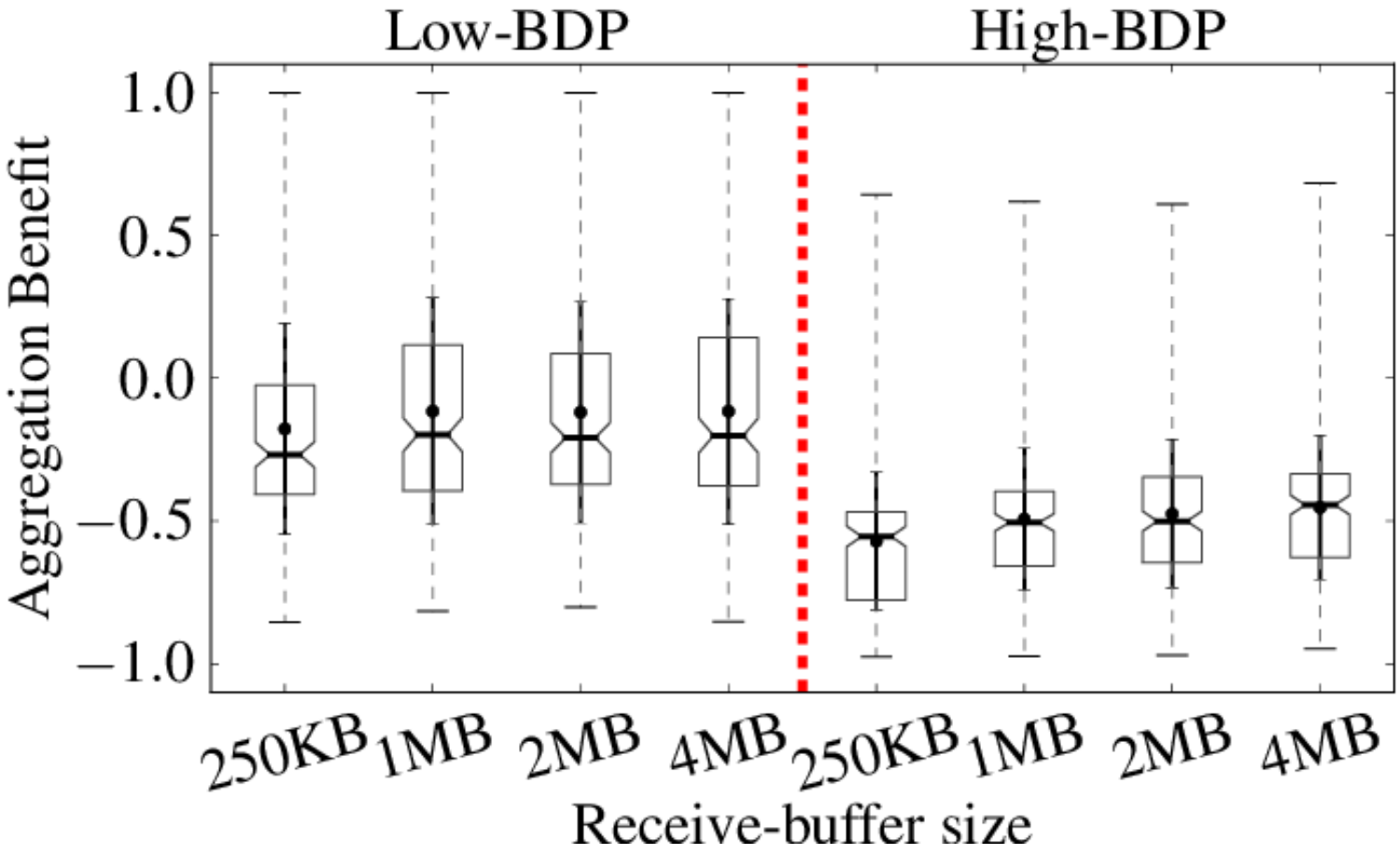
- Loss-based (LIA)
- Delay-based (wVegas)

Resource Pooling (LIA)



"Design, Implementation and Evaluation of Congestion Control for Multipath TCP". D. Wischik, et. al. NSDI 2011

Resource Pooling (wVegas)



"Delay-based congestion control for Multipath TCP". Y. Cao, M. Xu, X. Fu. IEEE ICNP. 2012.

Improving Multipath TCP

- Implementing Multipath TCP
- Evaluating Transport Protocols
- Multipath TCP *“in action”*

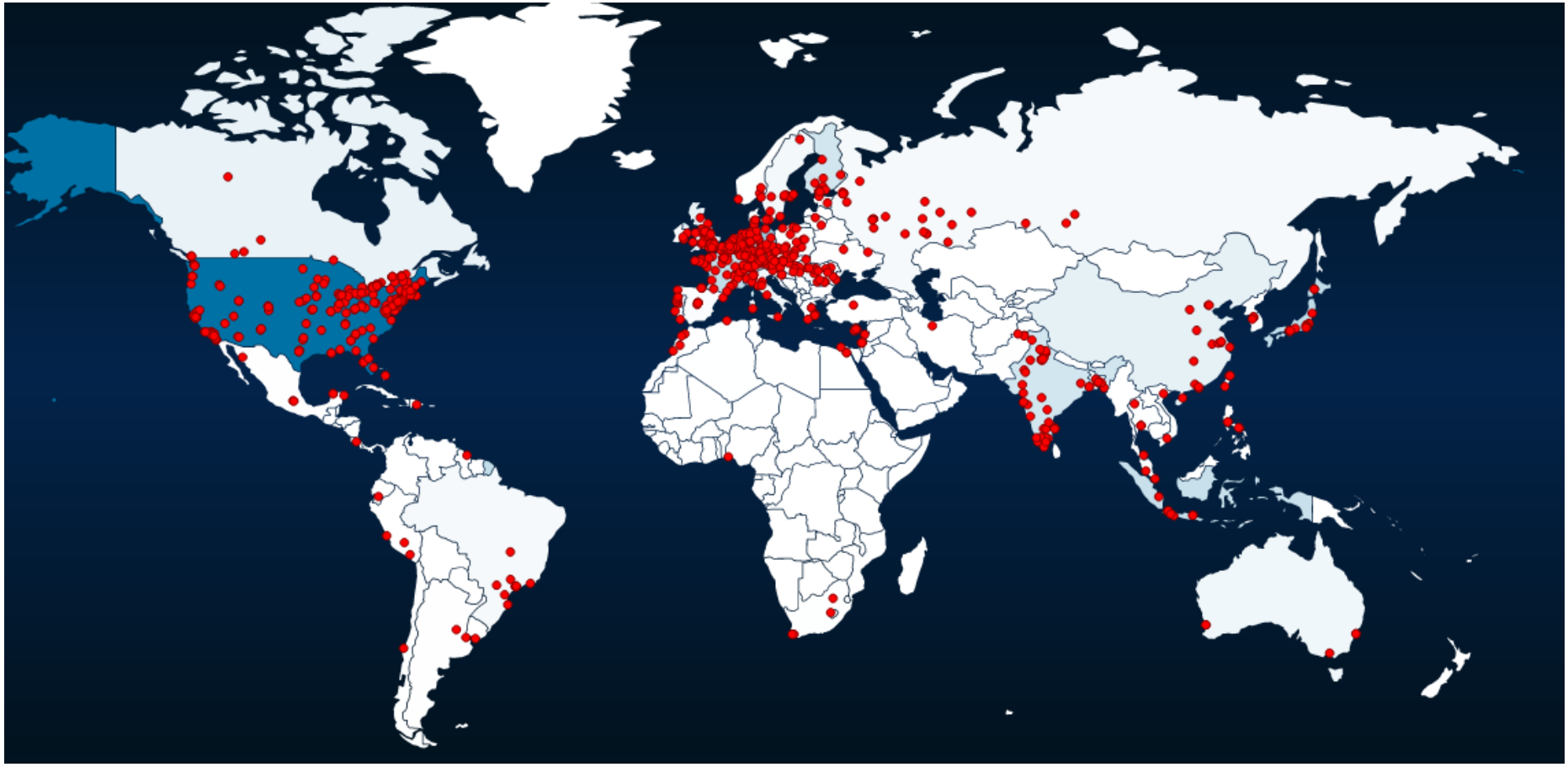
Multipath TCP

- [x] Supported across a middleboxes

Handover traffic from WiFi to 3G

Generic Scheduling Infrastructure

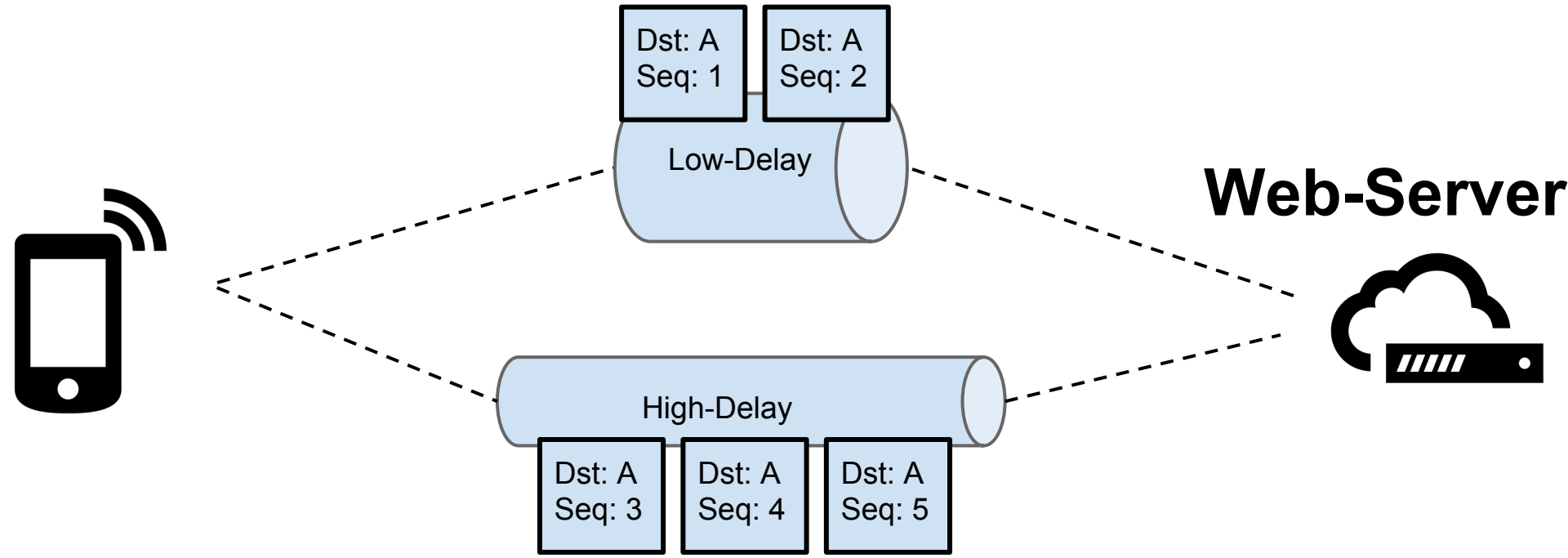
Supported across middleboxes



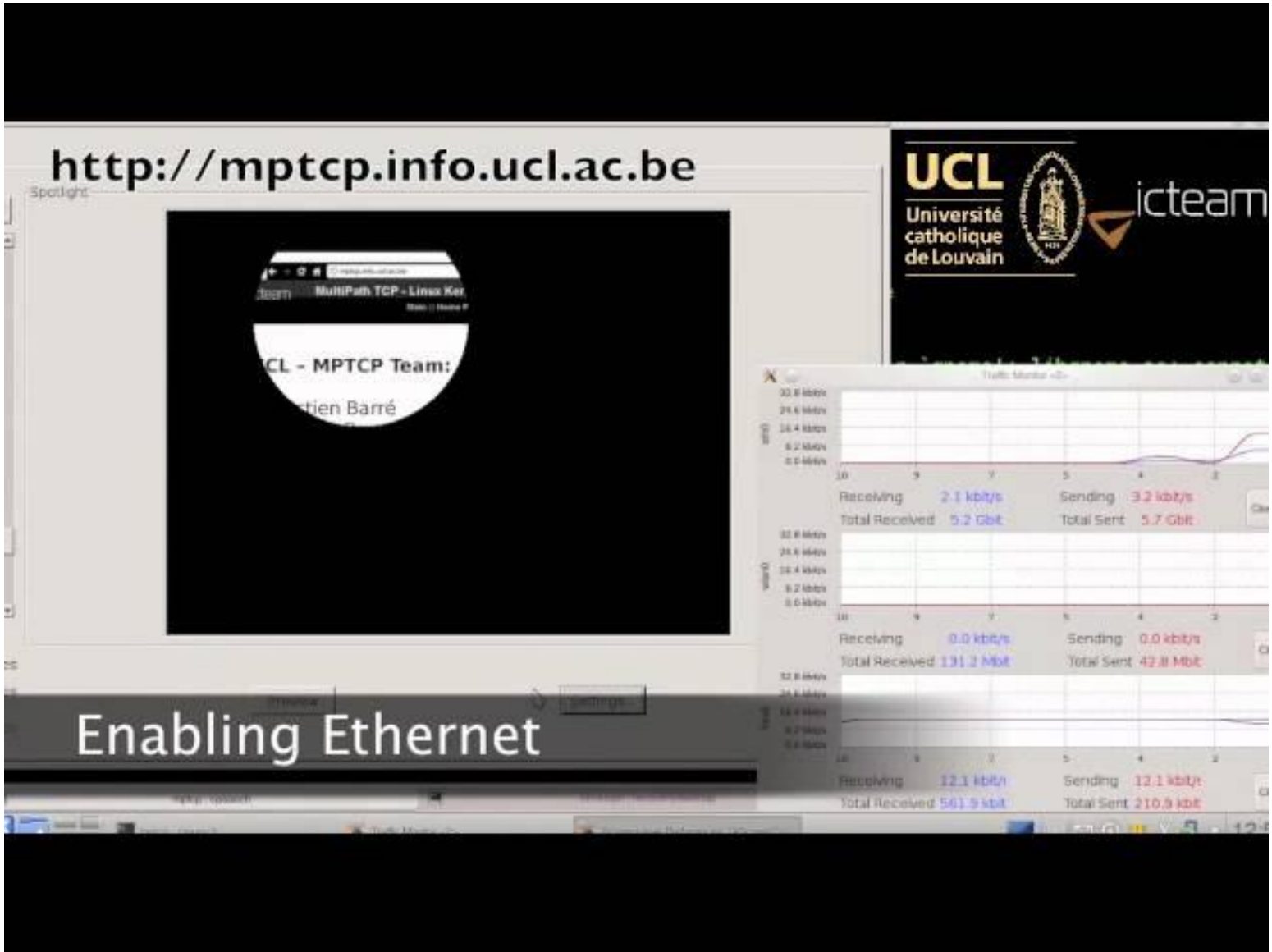
Multipath TCP

- ☑ Supported across a middleboxes
- ☑ Handover traffic from WiFi to 3G
- ☑ Generic Scheduling Infrastructure

Scheduling


Dst: A
Seq: 1
Dst: A
Seq: 2
Low-Delay
Web-Server
High-Delay
Dst: A
Seq: 3
Dst: A
Seq: 4
Dst: A
Seq: 5

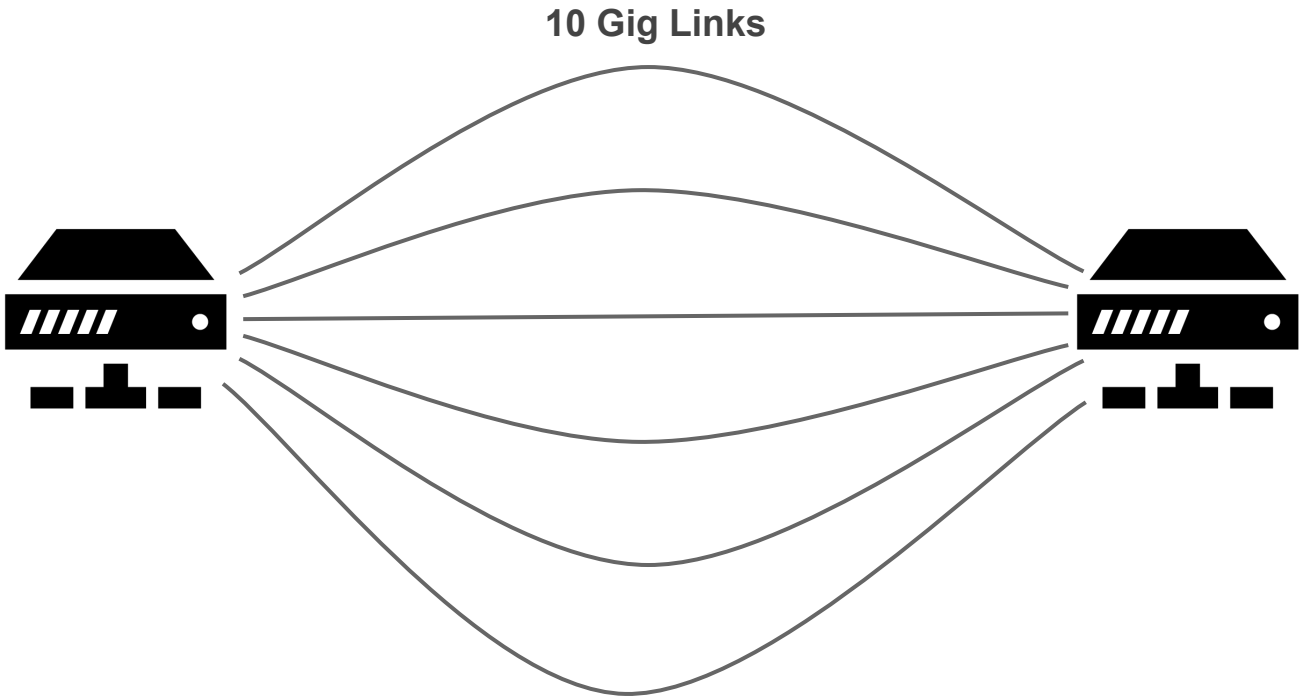
Handover


http://mptcp.info.ucl.ac.be
Spotlight
UCL
Université catholique de Louvain
icteam
MultiPath TCP - Linux Ker
CL - MPTCP Team:
tien Barré
Receiving 2.1 kbit/s
Sending 3.2 kbit/s
Total Received 5.2 Gbit
Total Sent 5.7 Gbit
Receiving 0.0 kbit/s
Sending 0.0 kbit/s
Total Received 131.2 Mbit
Total Sent 42.8 Mbit
Receiving 12.1 kbit/s
Sending 12.1 kbit/s
Total Received 561.9 kbit
Total Sent 210.9 kbit
Enabling Ethernet

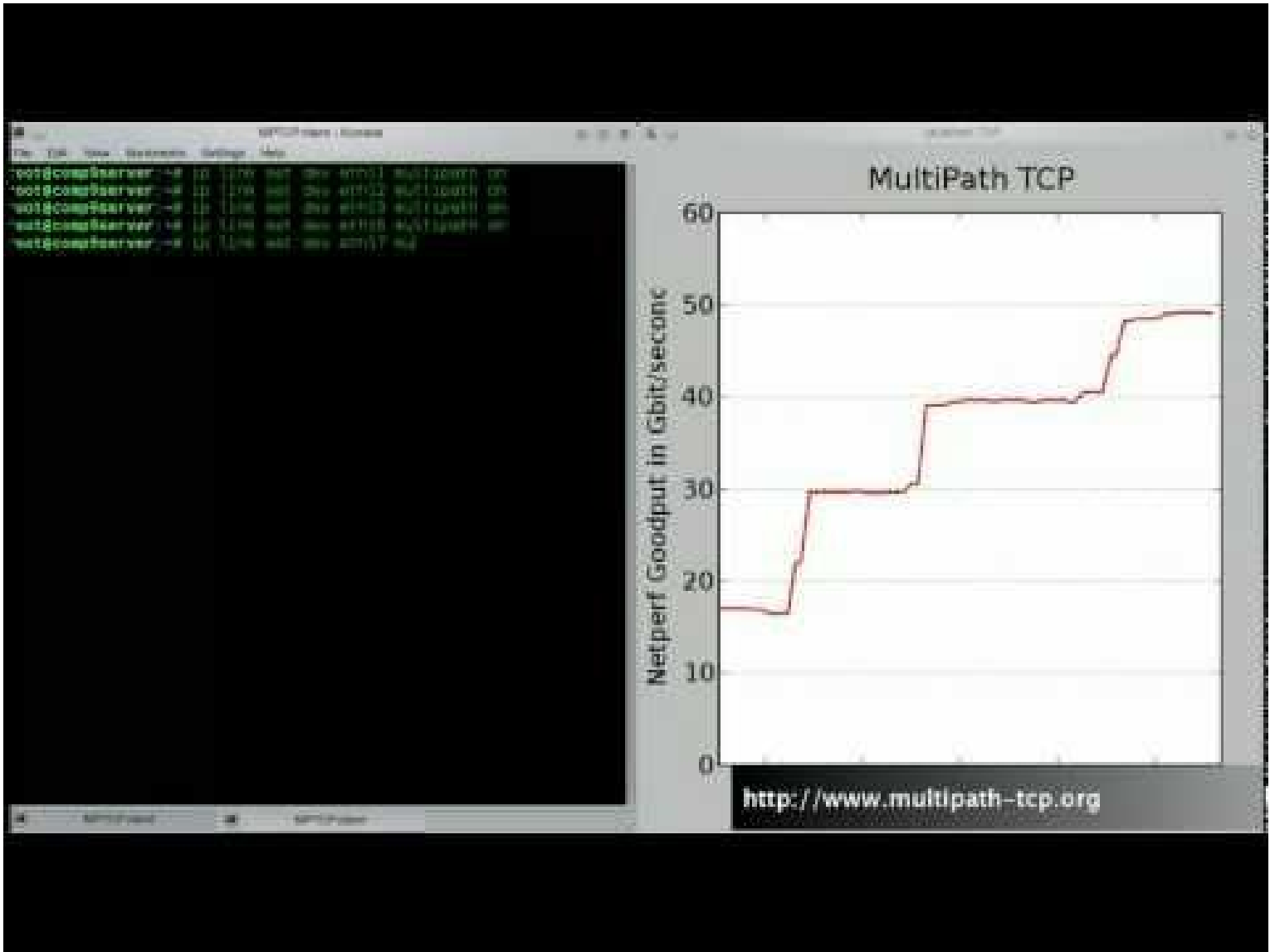
High Performance

- [x] Zero-copy support
- [x] Flow-to-core affinity
- [x] Hardware offloading supported

The fastest TCP connection



The fastest TCP connection



Conclusion

Conclusion

- It is **scalable** in the Linux Kernel
- ***Experimental Design*** allows to better evaluate transport layer protocols
- Works ***"in action"*** across the Internet

Conclusion

- Multipath TCP works mostly well in **heterogeneous environments**
- Possible **design evolution** for more flexibility

Thank you!