Improving Datacenter Performance and Robustness with Multipath TCP

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Thanks to:

Presented by Gregory Kesden

Motivation

- Datacenter apps are distributed across thousands of machines
- Want a

This is the wrong place to start

To achiev

- Use dense parallel datacenter topologies
- Map each flow to a path

Problem:

- Naïve random allocation gives poor performance
- Improving performance adds complexity

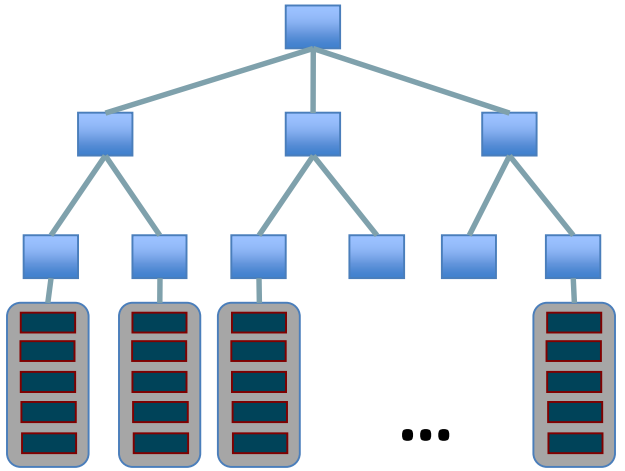
Contributions

Multipath topologies need multipath transport

Multipath transport enables better topologies

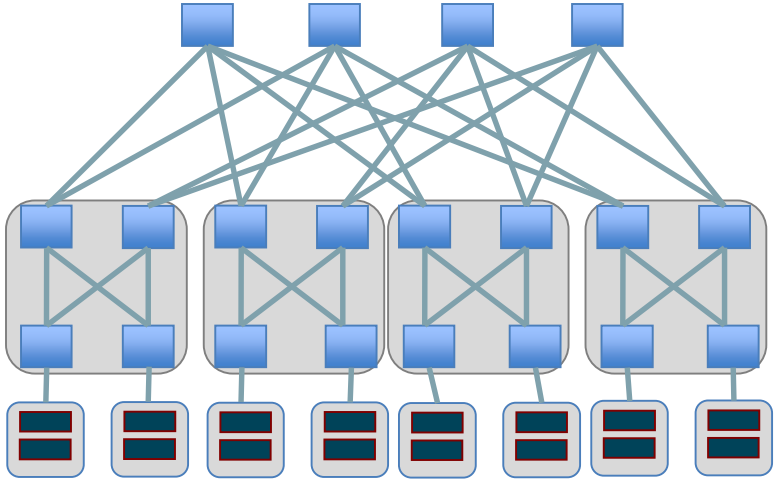
To satisfy demand, modern datacenters provide many parallel paths

- Traditional Topologies are tree-based
  - Poor performance
  - Not fault tolerant

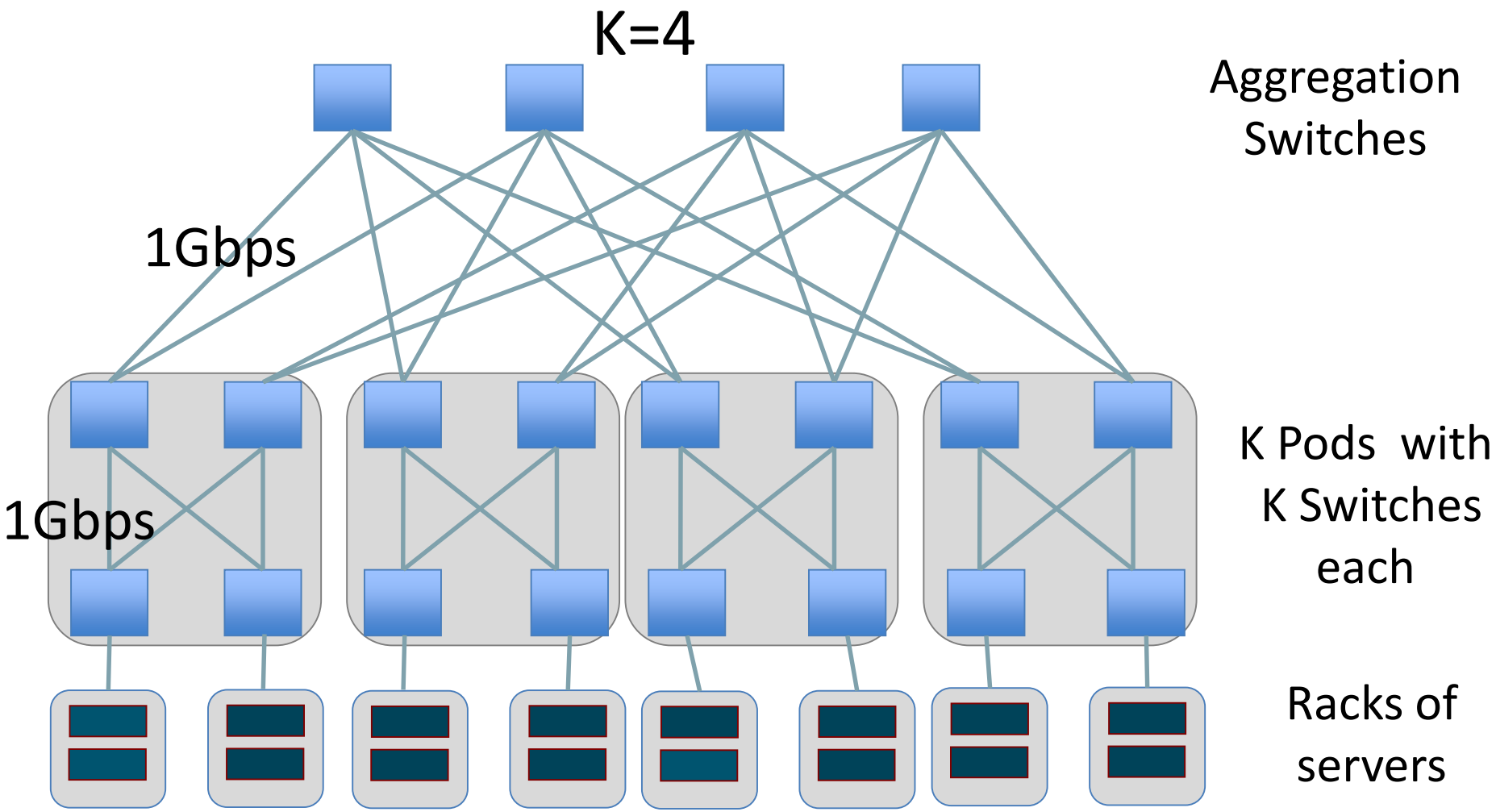


- Shift towards multipath topologies: FatTree, BCube, VL2,

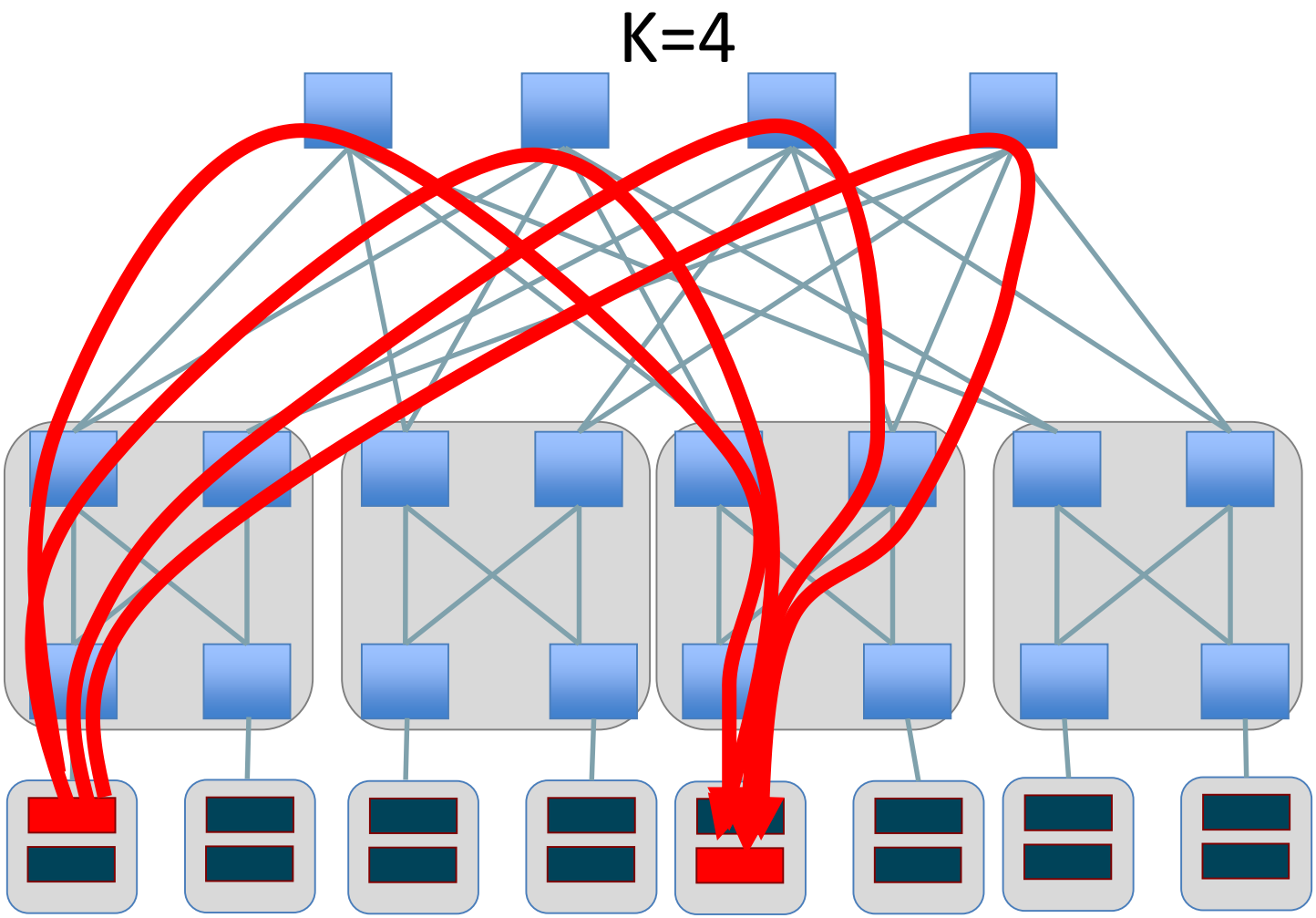
  Cisco, EC2



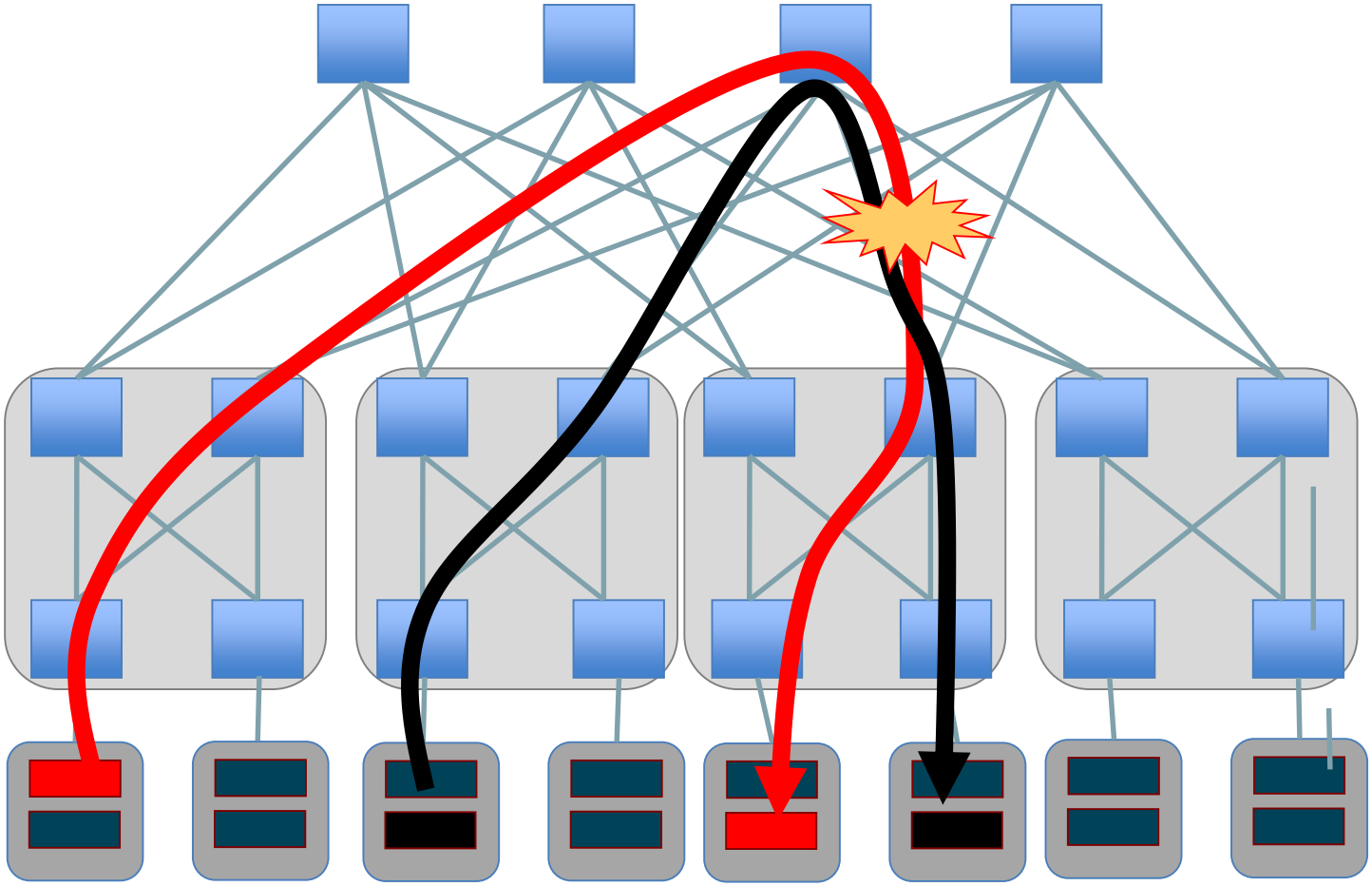
Fat Tree Topology [Fares et al., 2008; Clos, 1953]



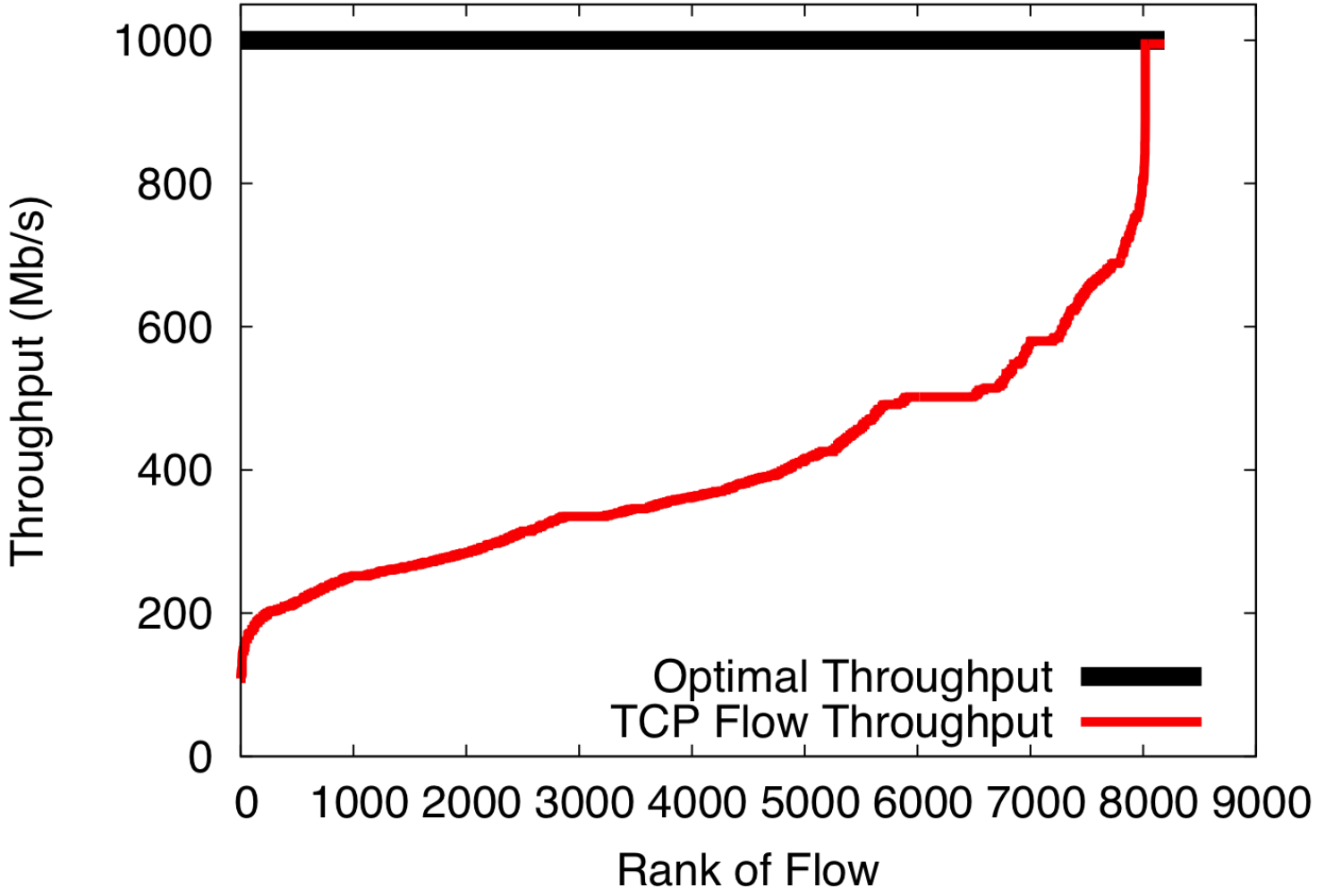
Fat Tree Topology [Fares et al., 2008; Clos, 1953]



Collisions



Single-path TCP collisions reduce throughput



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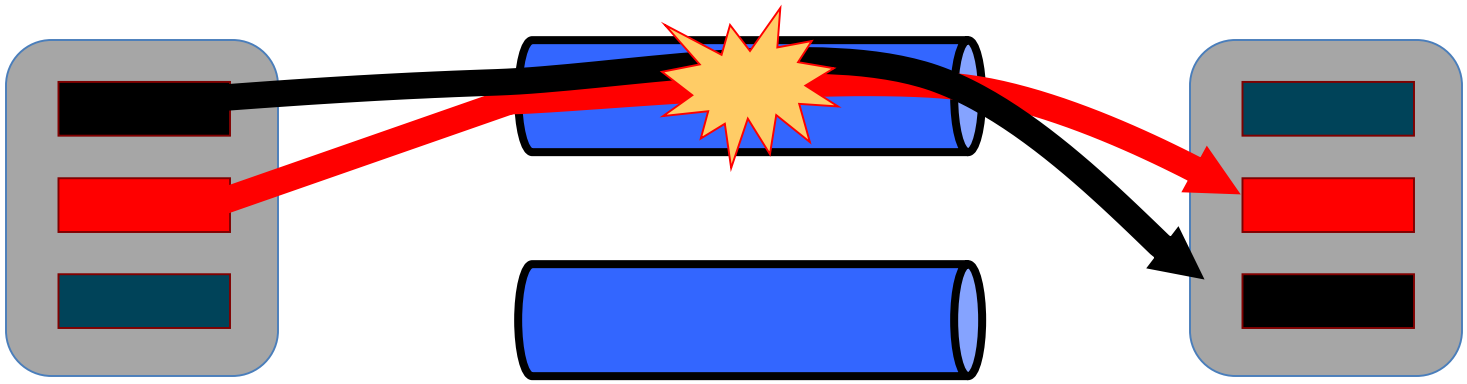
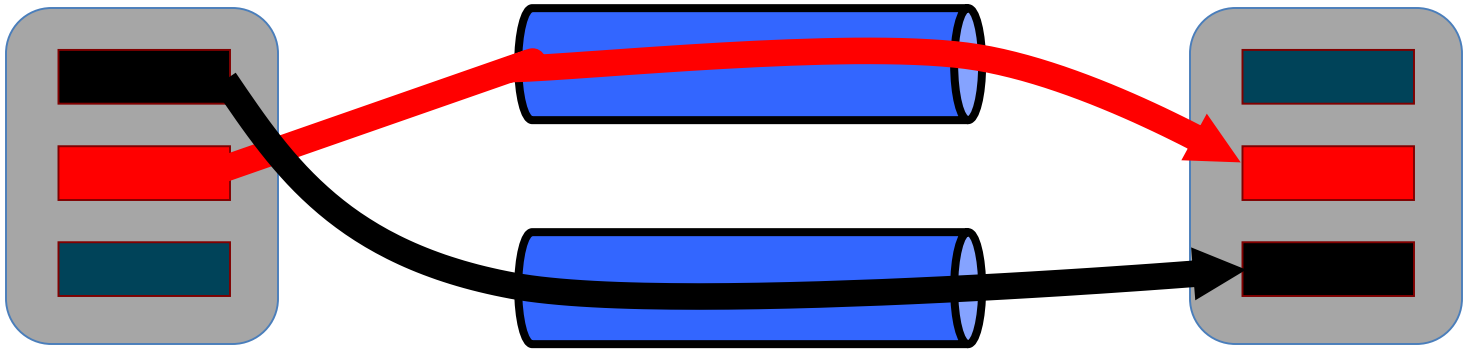
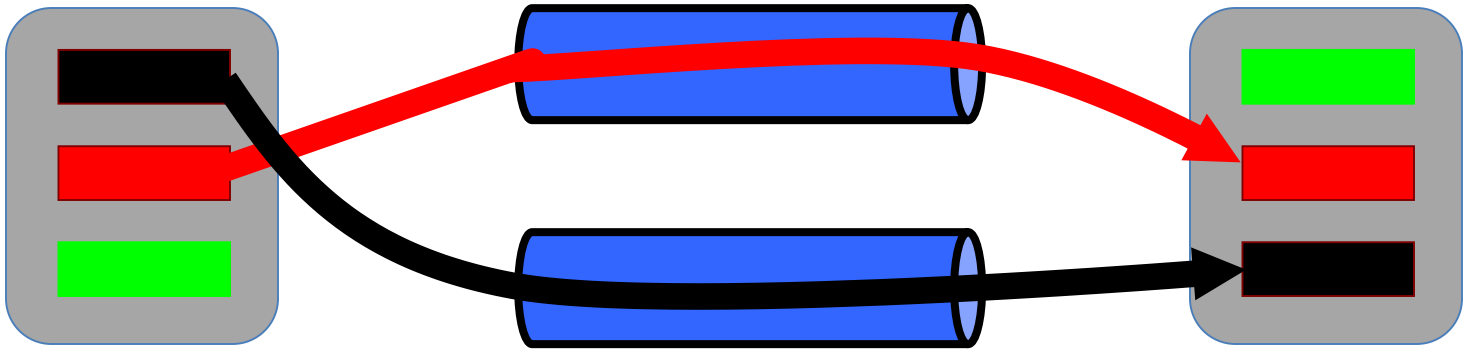
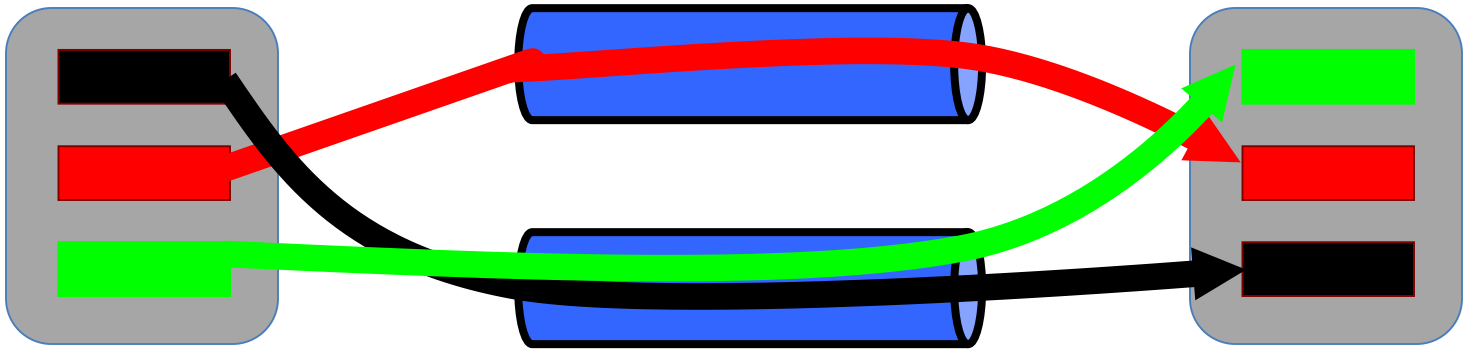






Not fair



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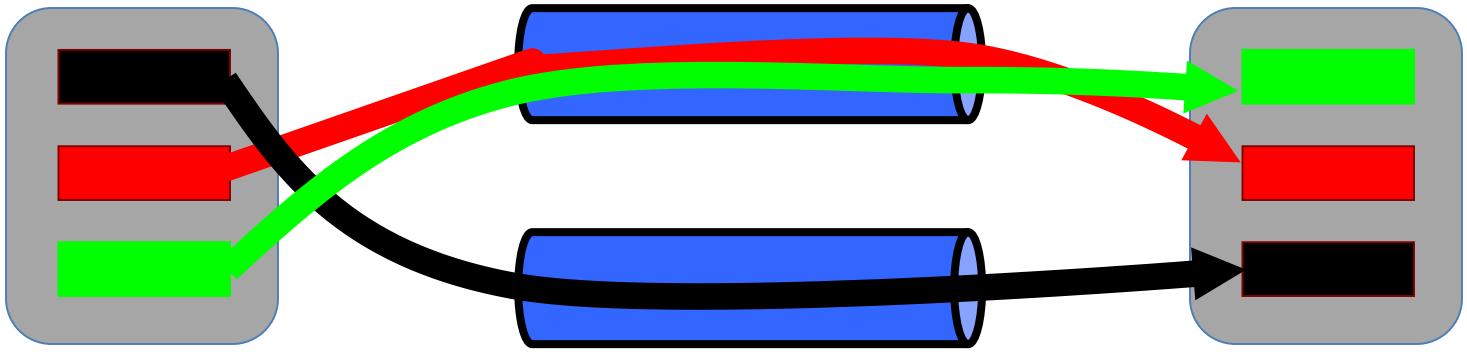
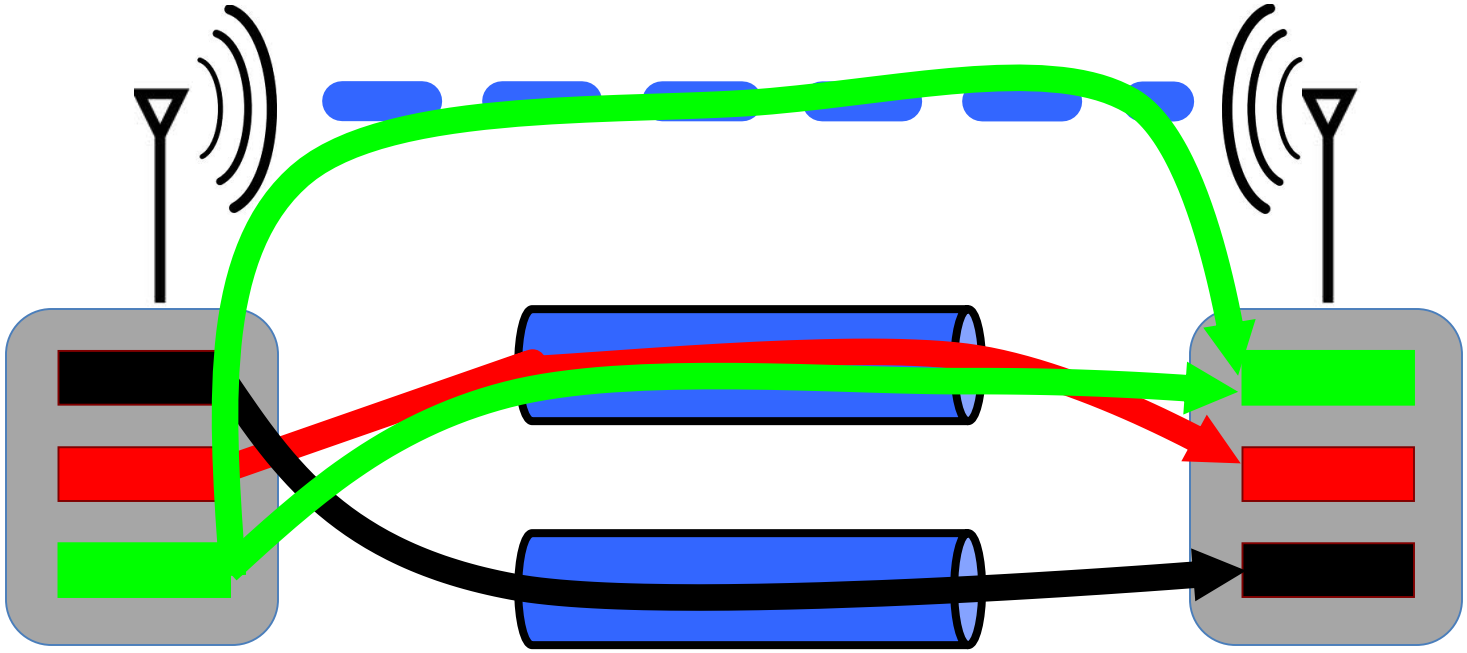
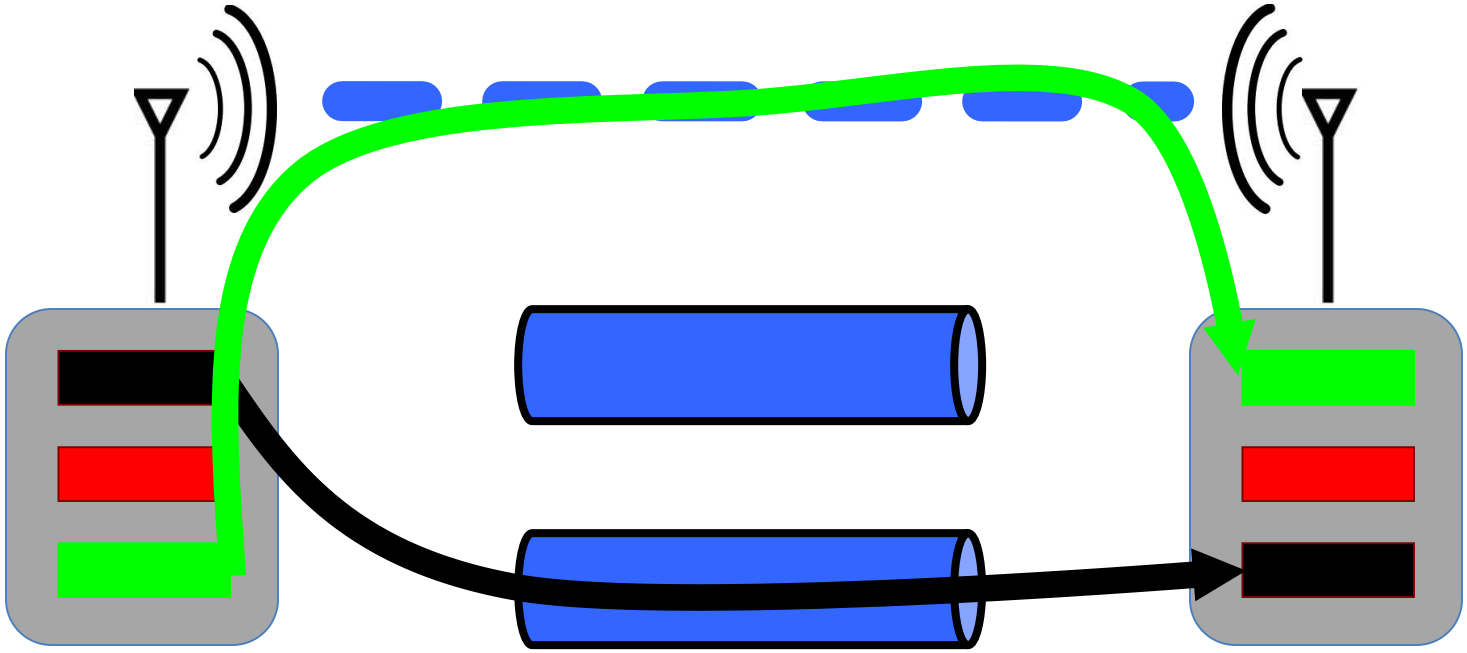
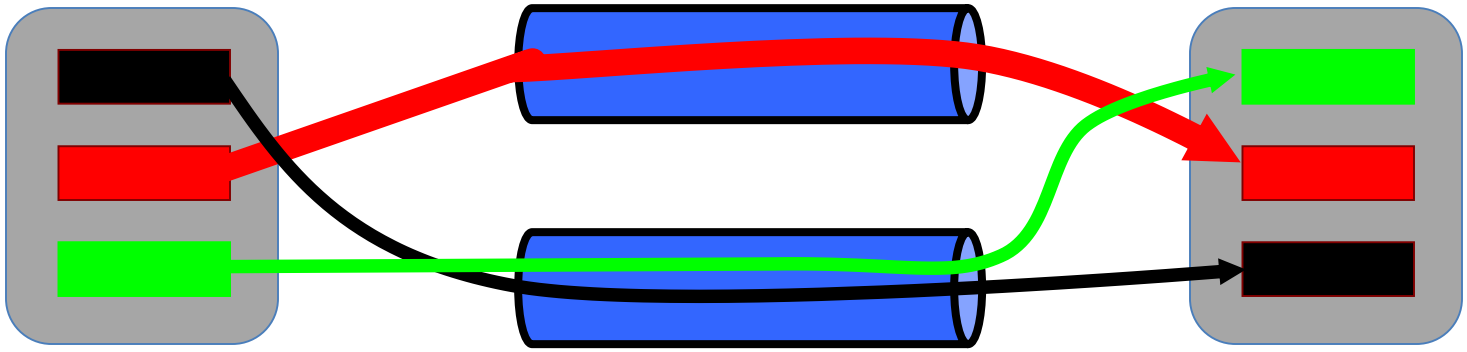


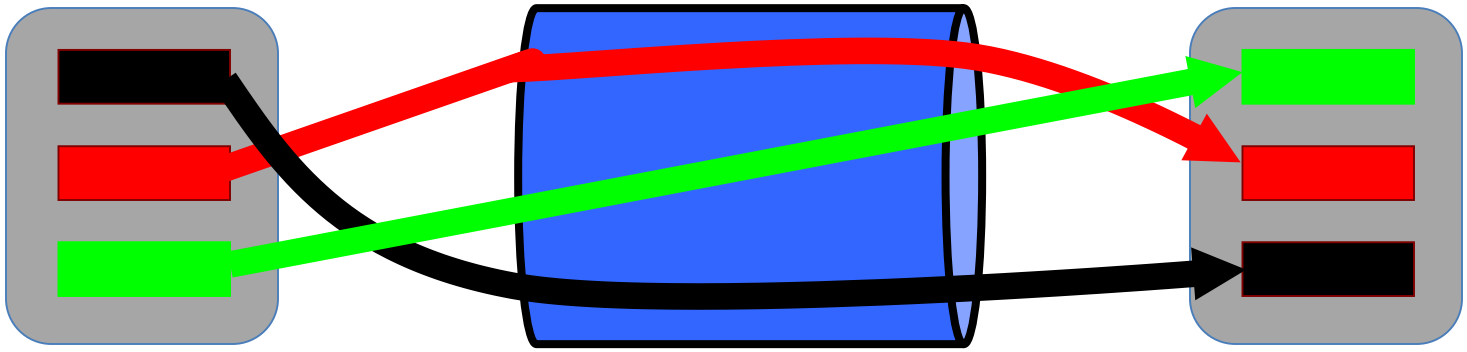




No matter how you do it,
mapping each flow to a path is the wrong goal



Instead, we should **pool** capacity from different



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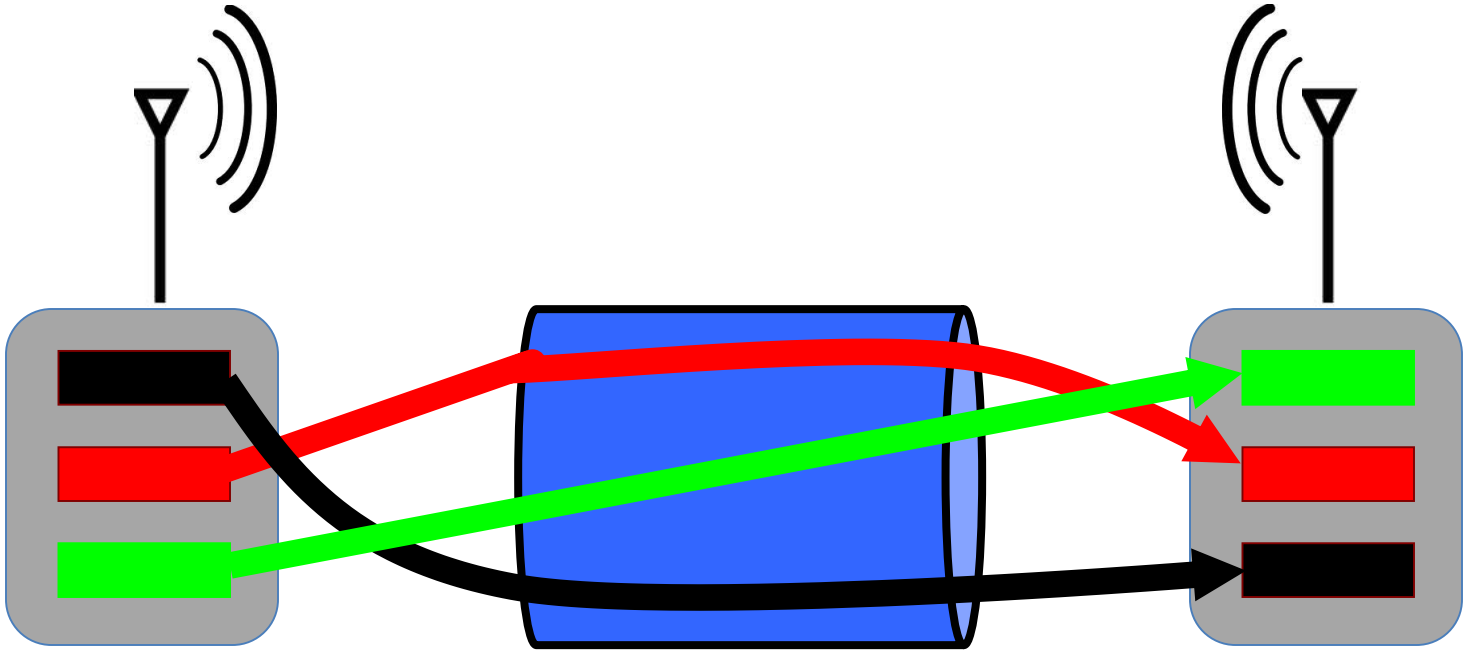

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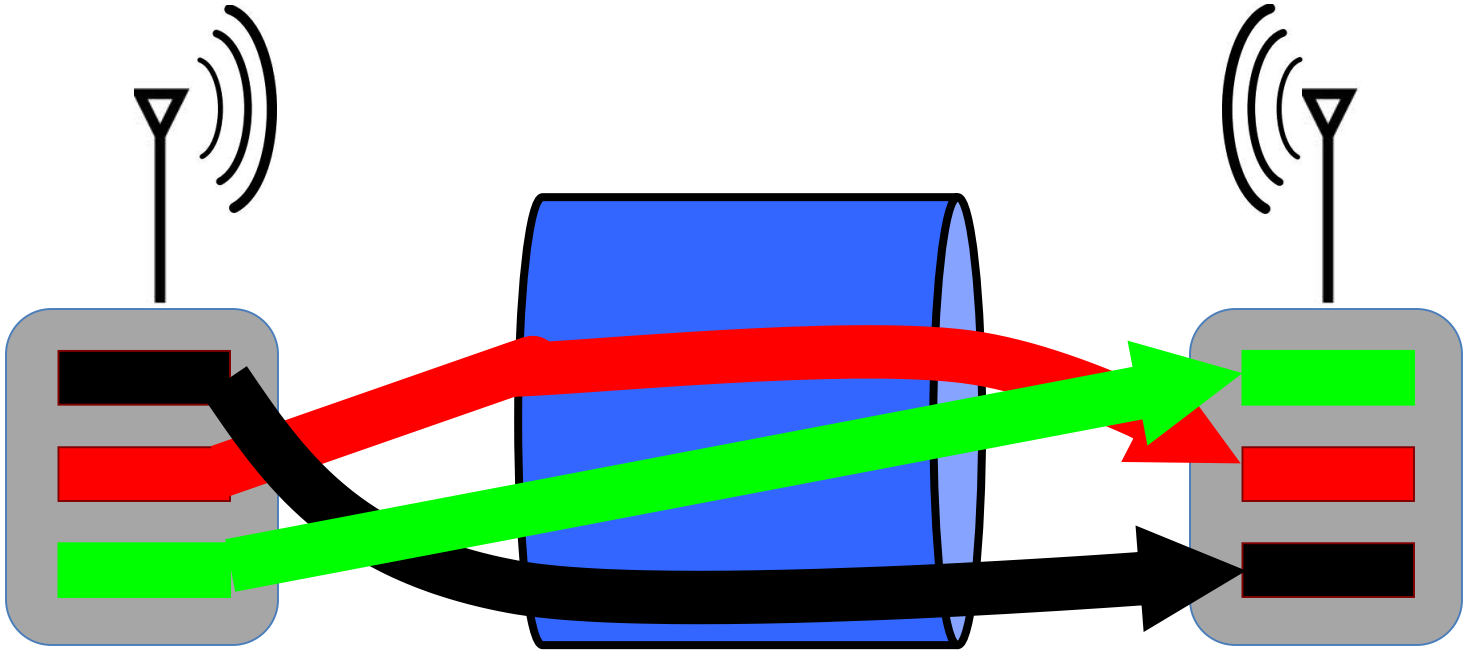

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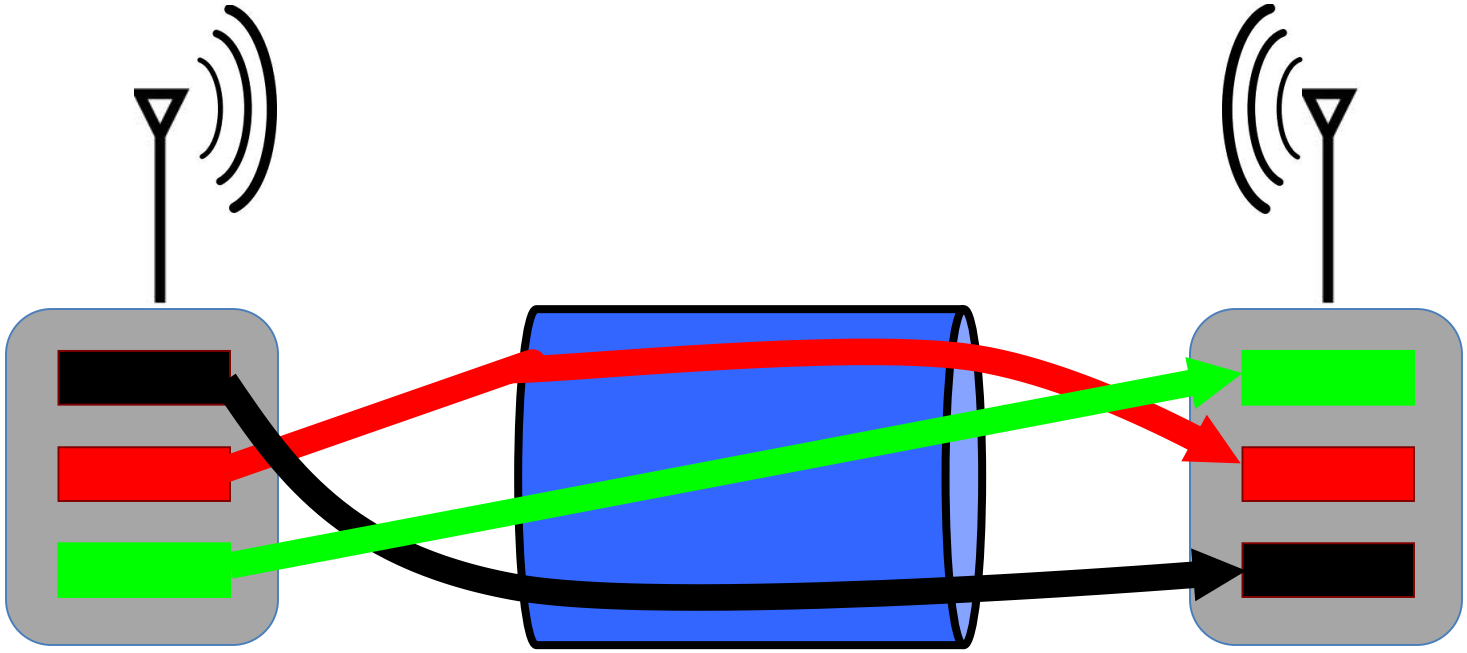


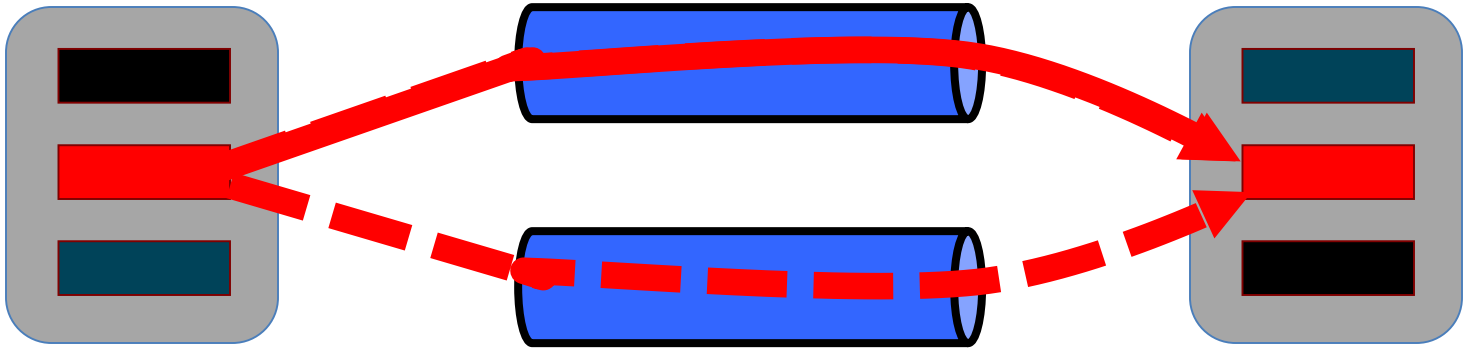
Multipath Transport

Multipath Transport can pool datacenter networks

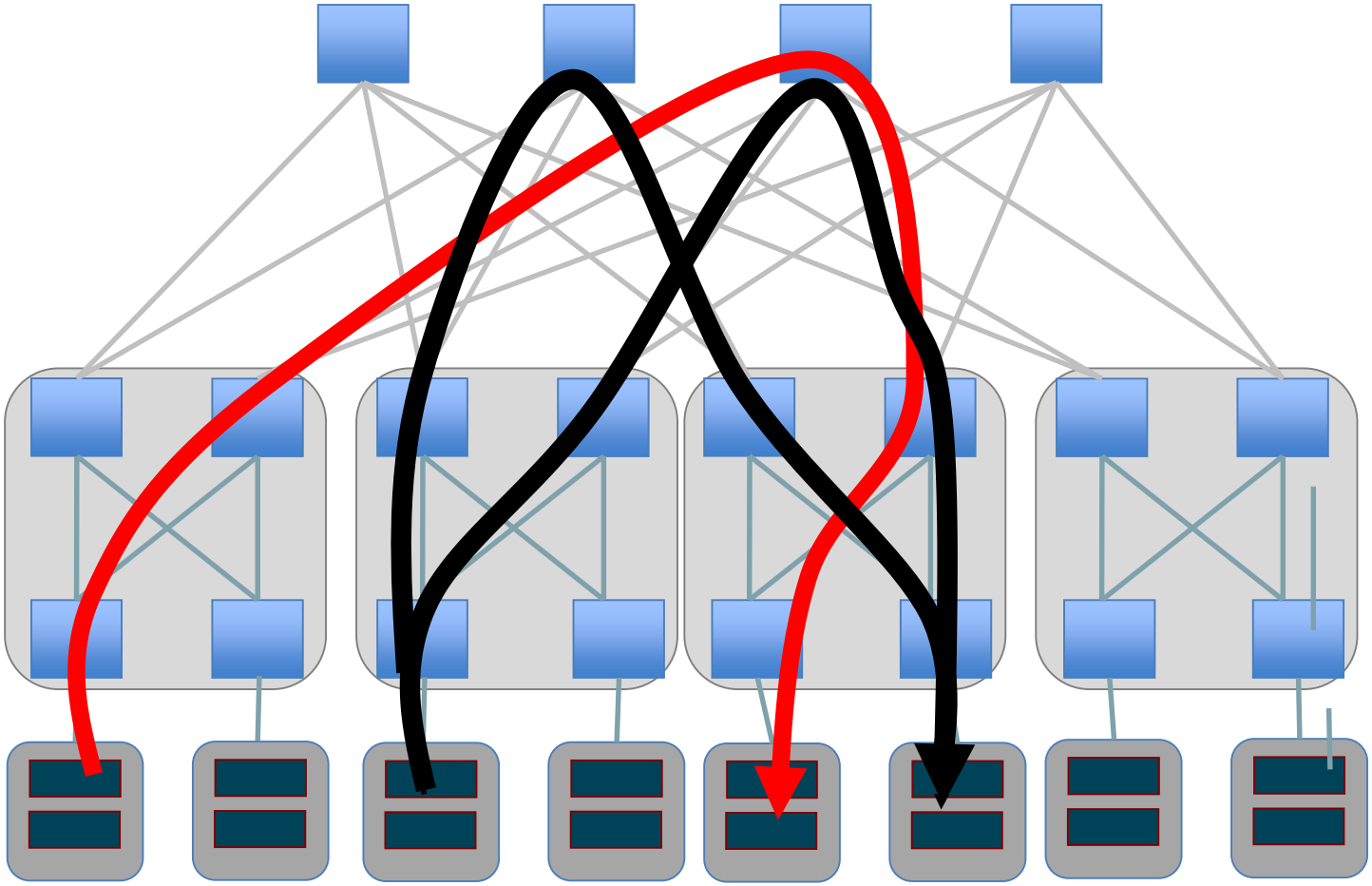
- Instead of using one path for each flow, use many random paths
- Don’t worry about collisions.
- Just don’t send (much) traffic on colliding paths

Multipath TCP Primer [IETF MPTCP WG]

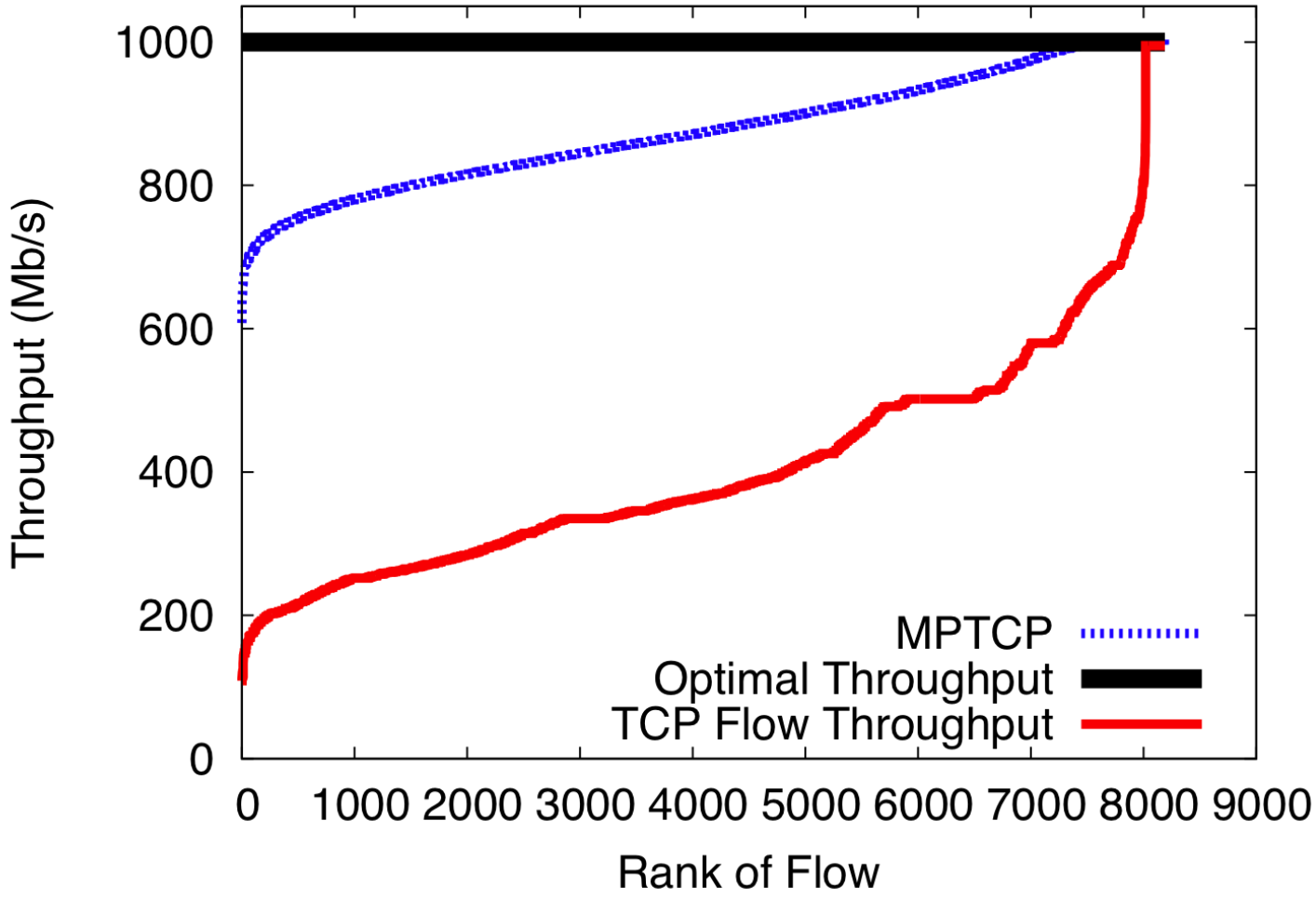
- MPTCP is a drop in replacement for TCP
- MPTCP spreads application data over multiple subflows



Multipath TCP: Congestion Control [NSDI, 2011]



MPTCP better utilizes the FatTree network



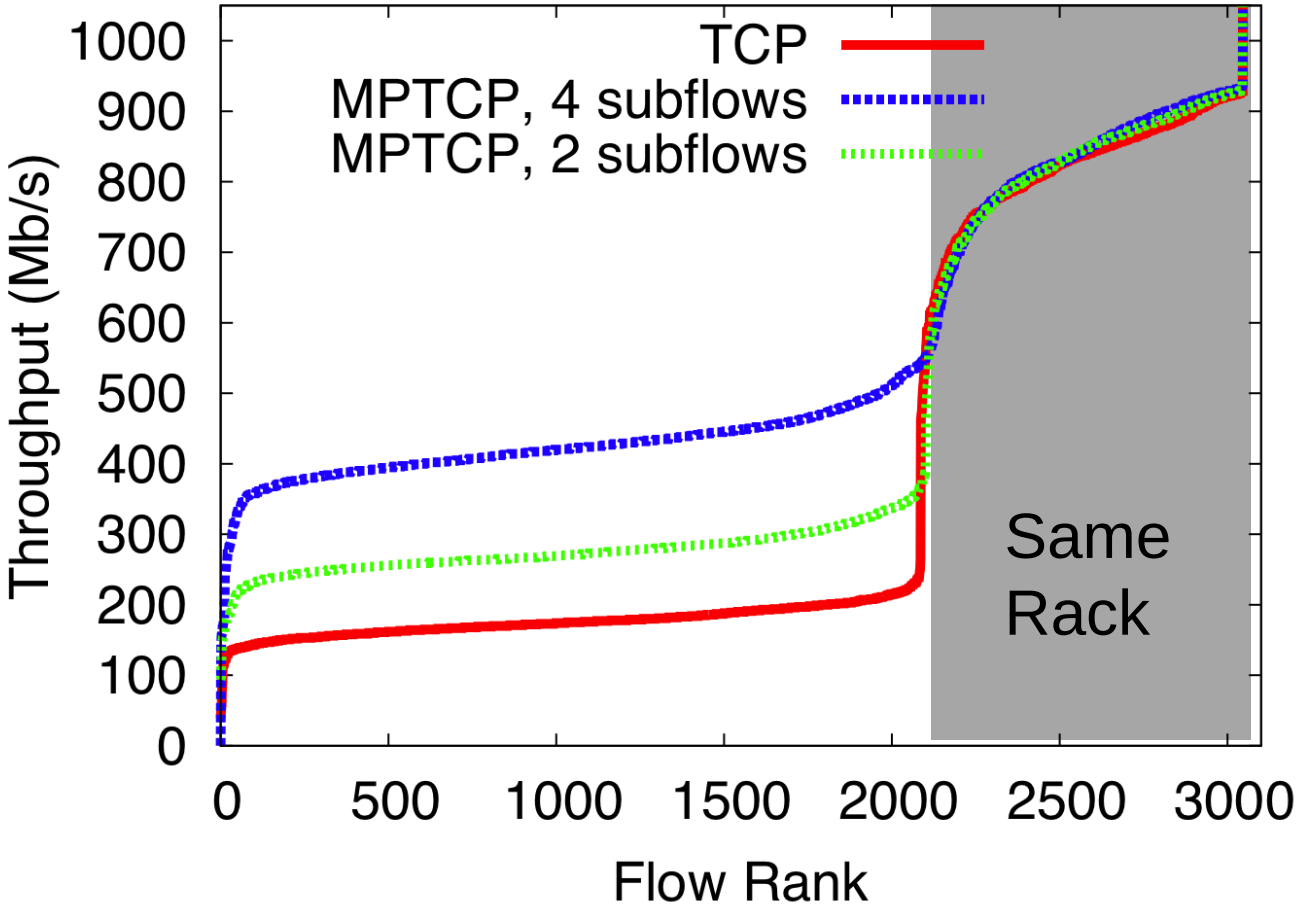
MPTCP on EC2

- Amazon EC2: infrastructure as a service
  - We can borrow virtual machines by the hour
  - These run in Amazon data centers worldwide
  - We can boot our own kernel
- A few availability zones have multipath topologies
  - 2-8 paths available between hosts not on the same machine or in the same rack
  - Available via ECMP

Amazon EC2 Experiment

- 40 medium CPU instances running MPTCP
- For 12 hours, we sequentially ran all-to-all *iperf* cycling through:
  - TCP
  - MPTCP (2 and 4 subflows)

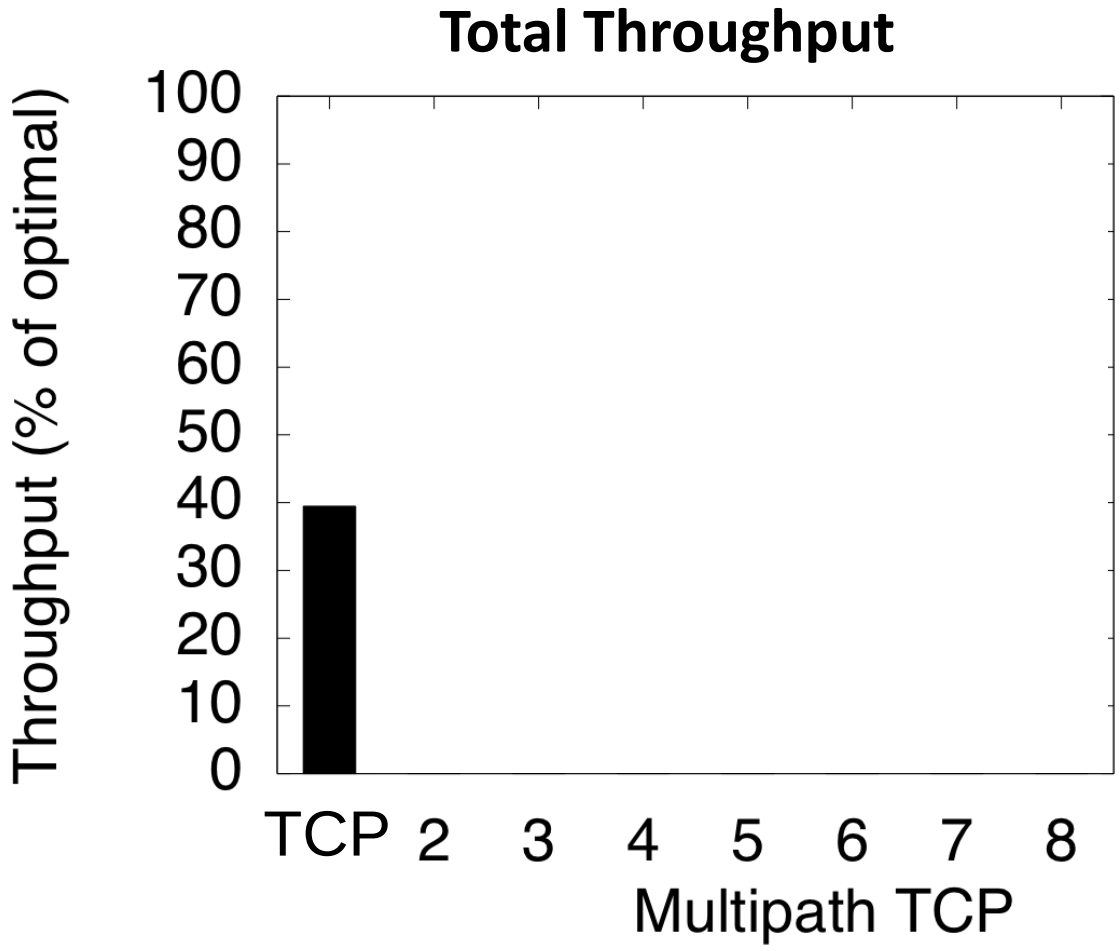
MPTCP improves performance on EC2



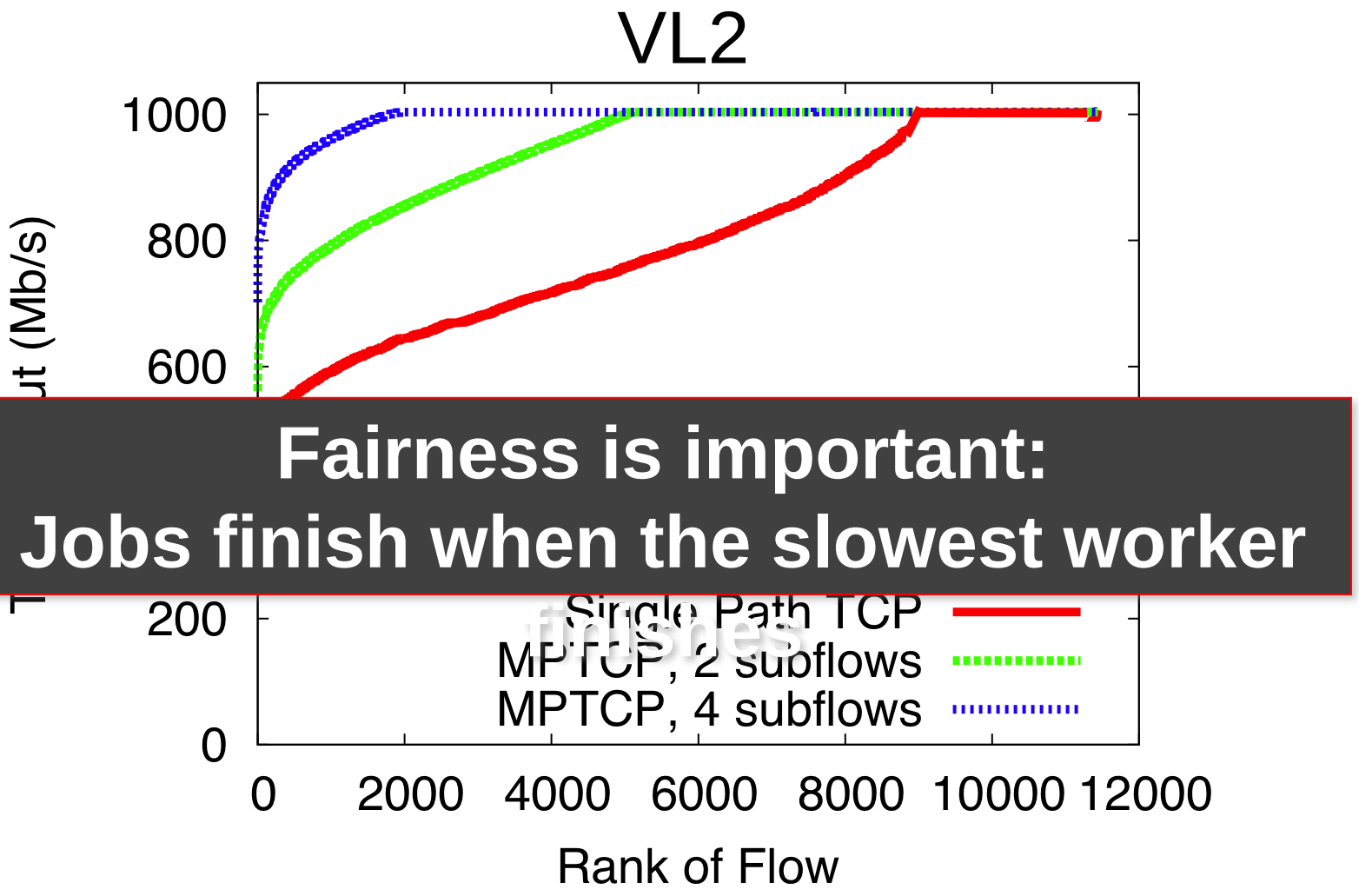
What do the benefits depend on?

- How many subflows are needed?
- How does the topology affect results?
- How does the traffic matrix affect results?

At most 8 subflows are needed

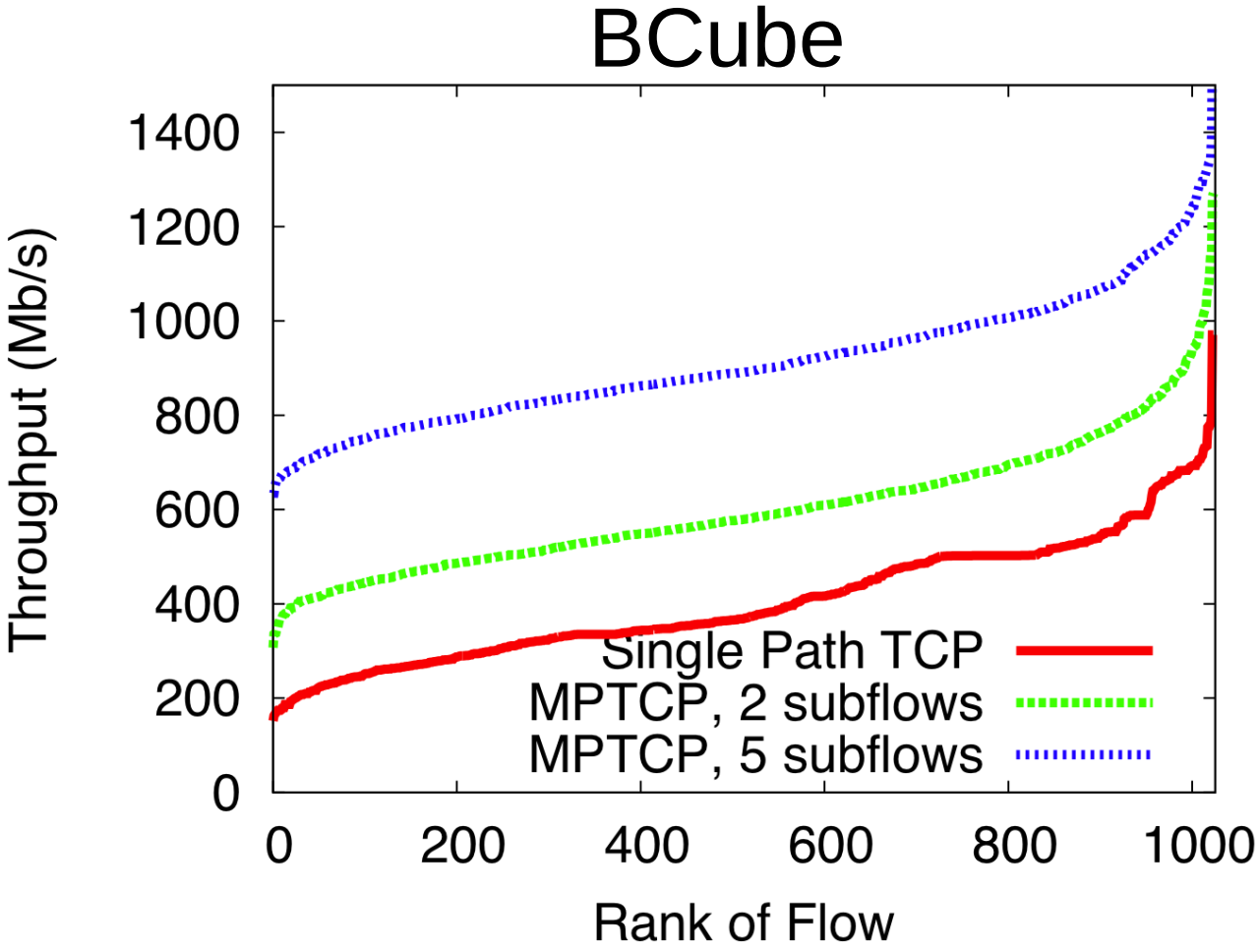


MPTCP improves fairness in VL2 topologies



Fairness is important:
Jobs finish when the slowest worker

MPTCP improves throughput and fairness in BCube

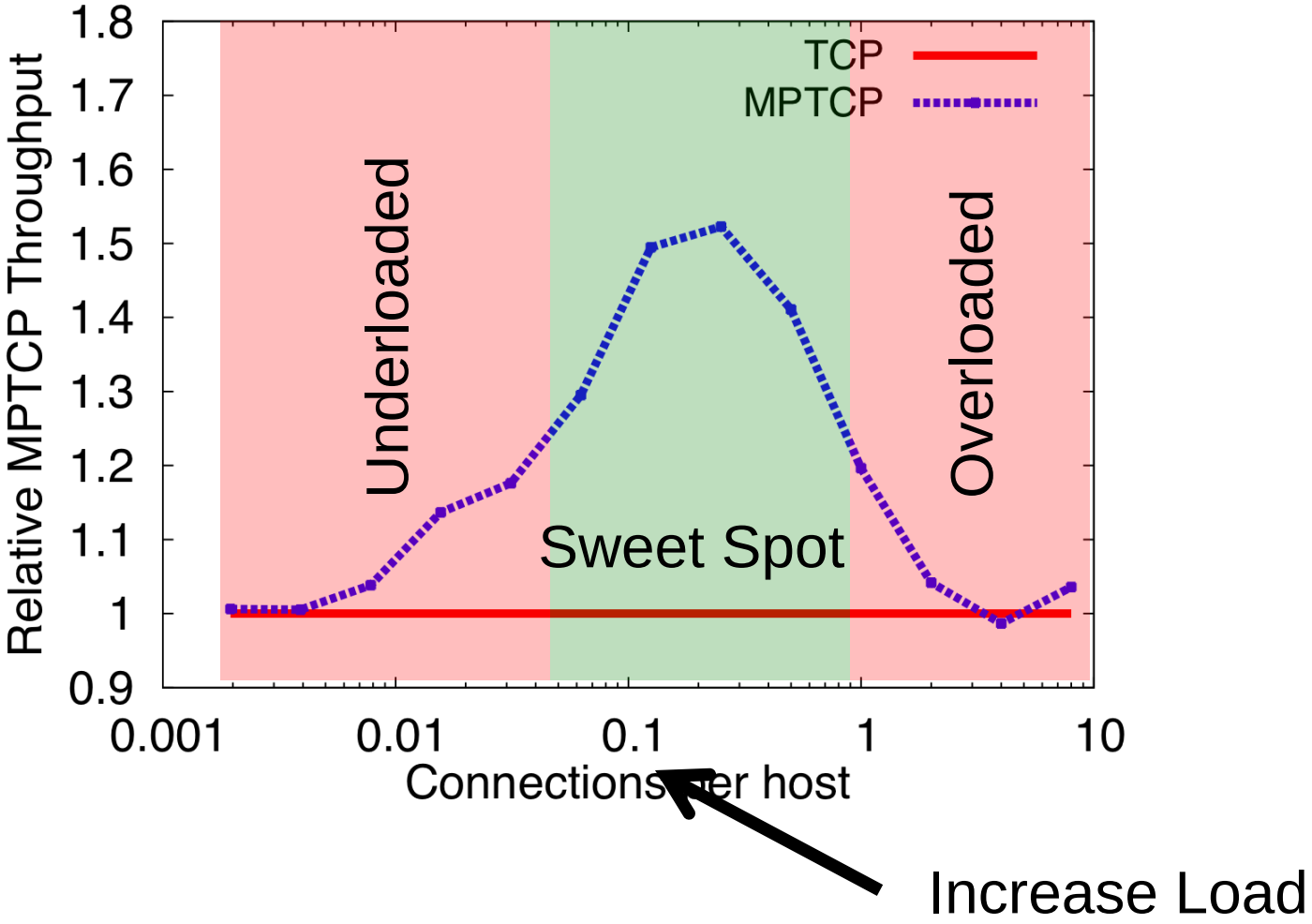


Oversubscribed Topologies

- To saturate full bisectional bandwidth:
  - There must be no traffic locality
  - All hosts must send at the same time
  - Host links must not be bottlenecks

- It makes sense to under-provision the network core
  - This is what happens in practice
  - Does MPTCP still provide benefits?

Performance improvements depend on traffic matrix



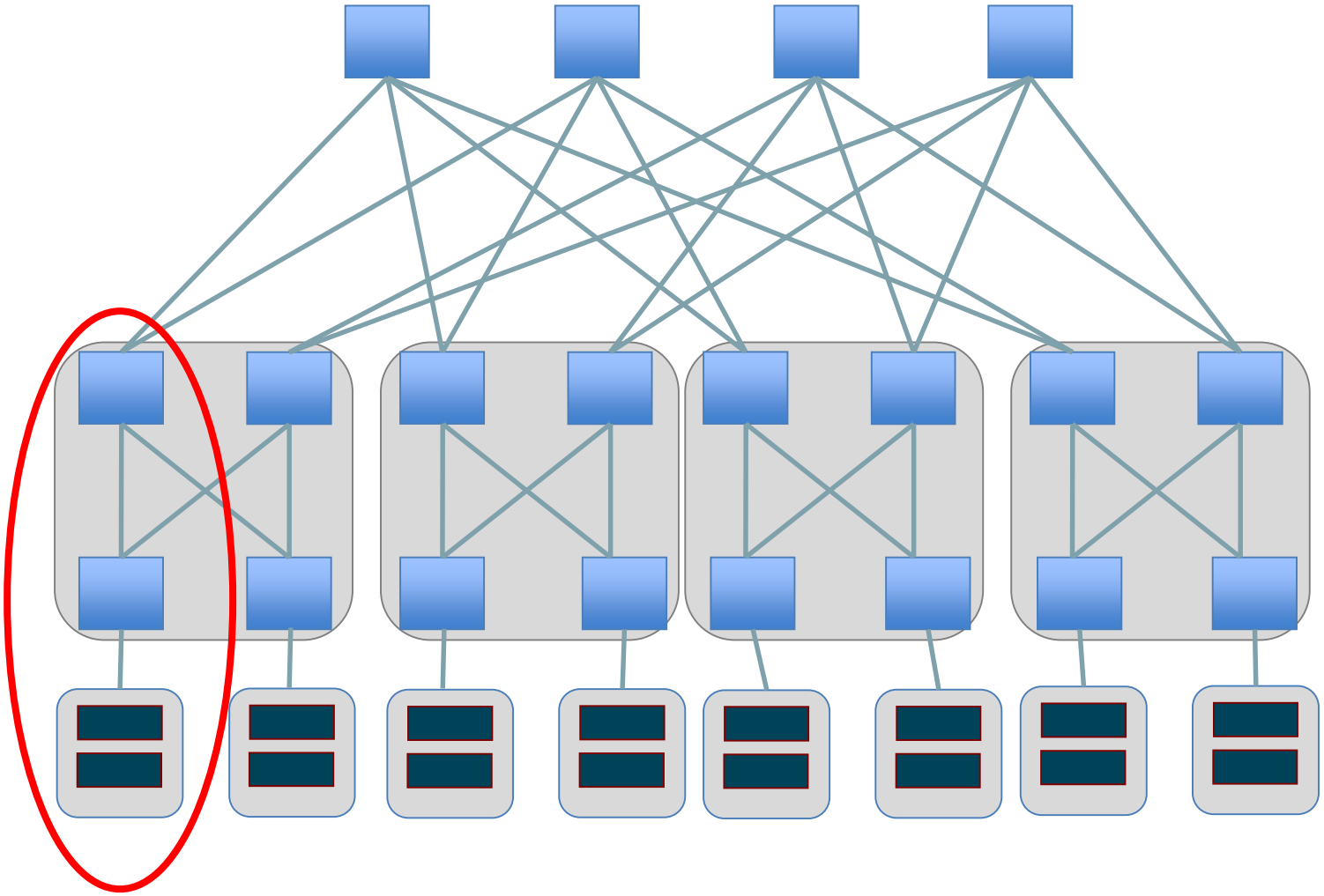
What is an optimal datacenter topology for multipath transport?

In single homed topologies:

- Hosts links are often bottlenecks
- ToR switch failures wipe out tens of hosts for days

Multi-homing servers is the obvious way forward

Fat Tree Topology



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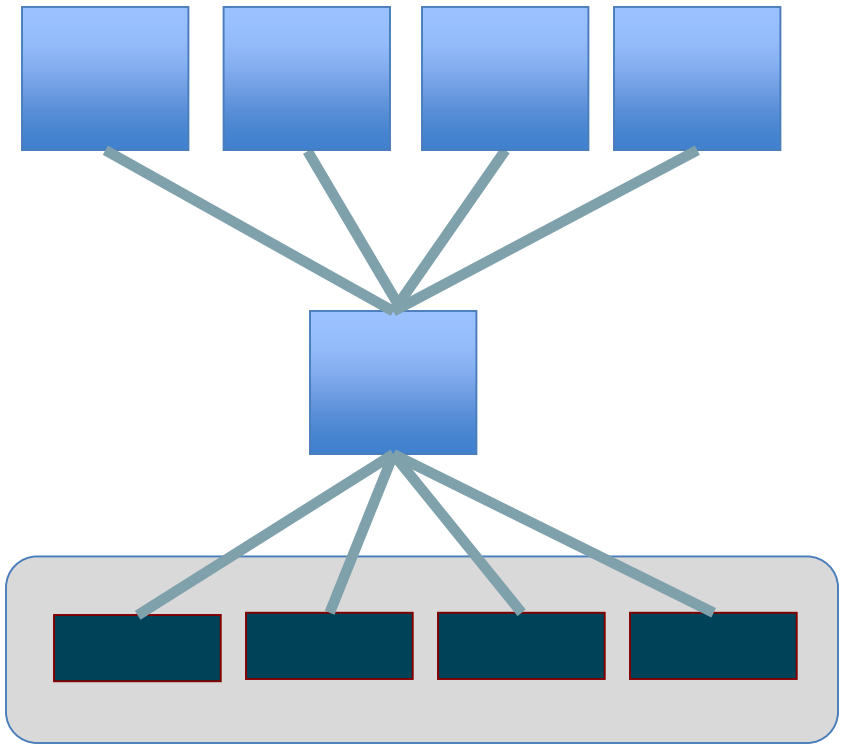
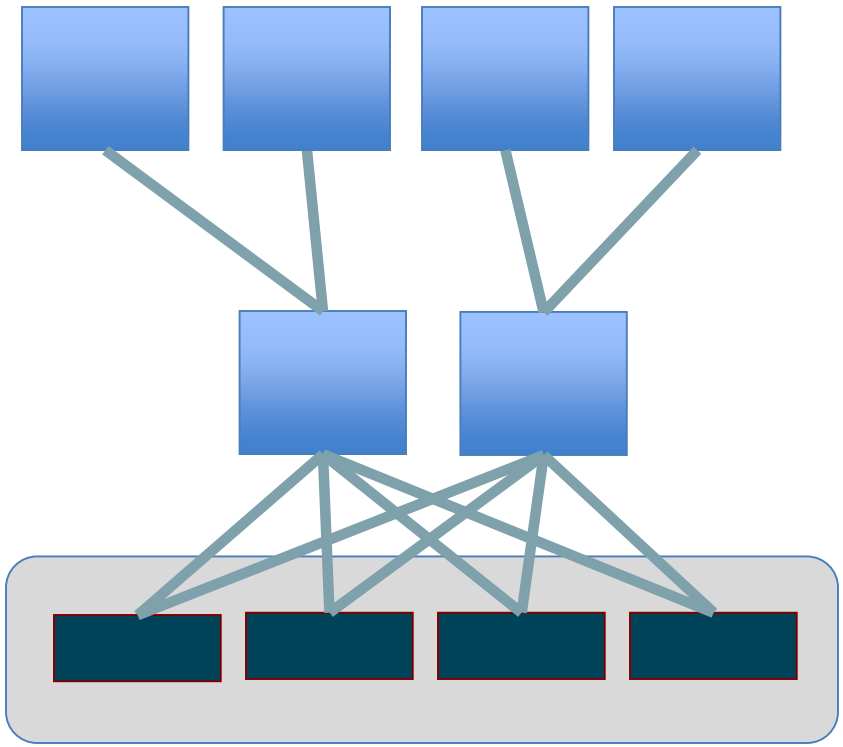


Upper Pod Switch

ToR Switch

Servers

Dual Homed Fat Tree Topology



Upper Pod Switch

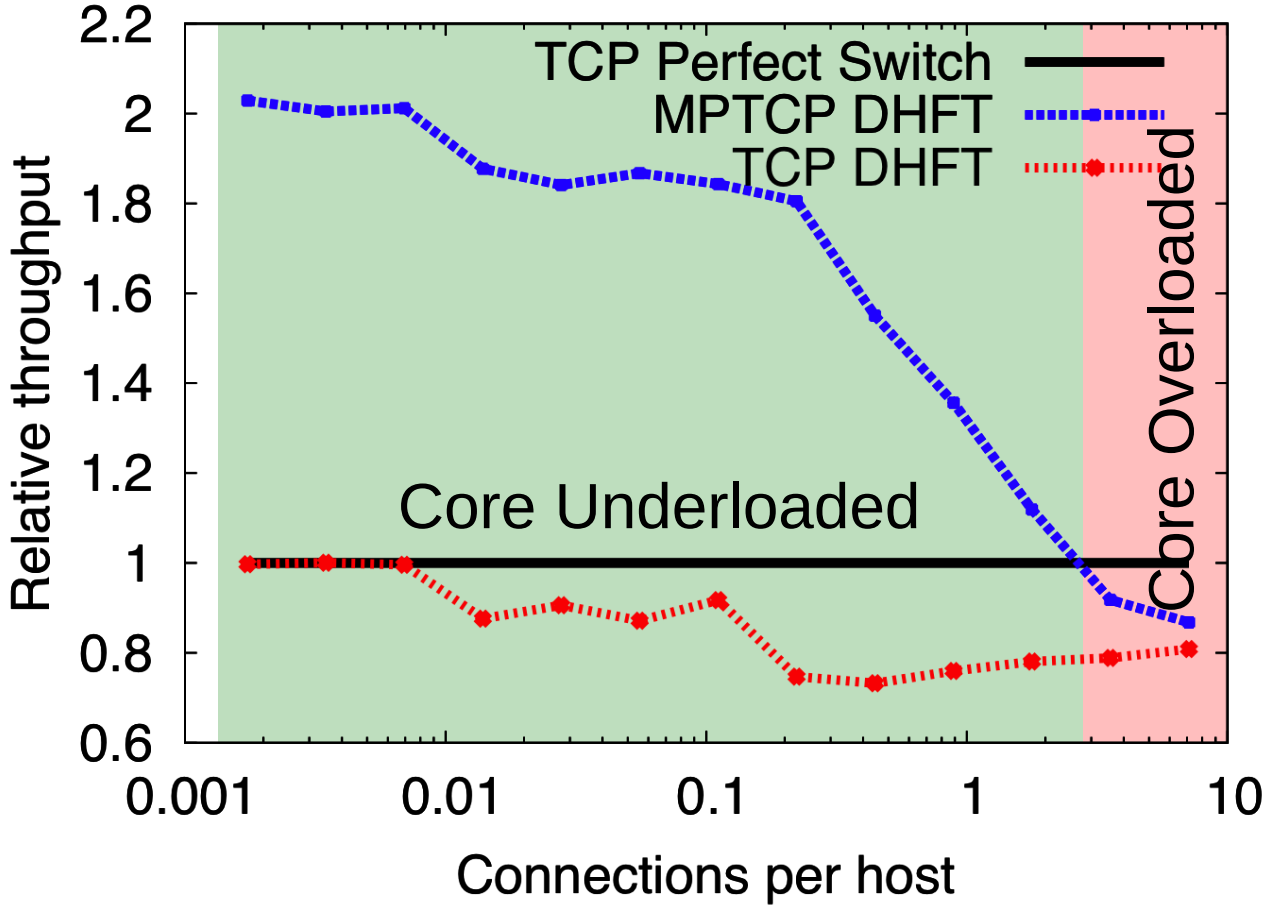
ToR Switch

Servers

Is DHFT any better than Fat Tree?

- Not for traffic matrices that fully utilize the core
- Let's examine random traffic patterns
  - Other TMs in the paper

DHFT provides significant improvements when core is not overloaded



Summary

- *"One flow, one path"* thinking has constrained datacenter design
  - Collisions, unfairness, limited utilization
- Multipath transport enables resource pooling in datacenter networks:
  - Improves throughput
  - Improves fairness
  - Improves robustness
- *"One flow, many paths"* frees designers to consider topologies that offer improved performance for similar cost

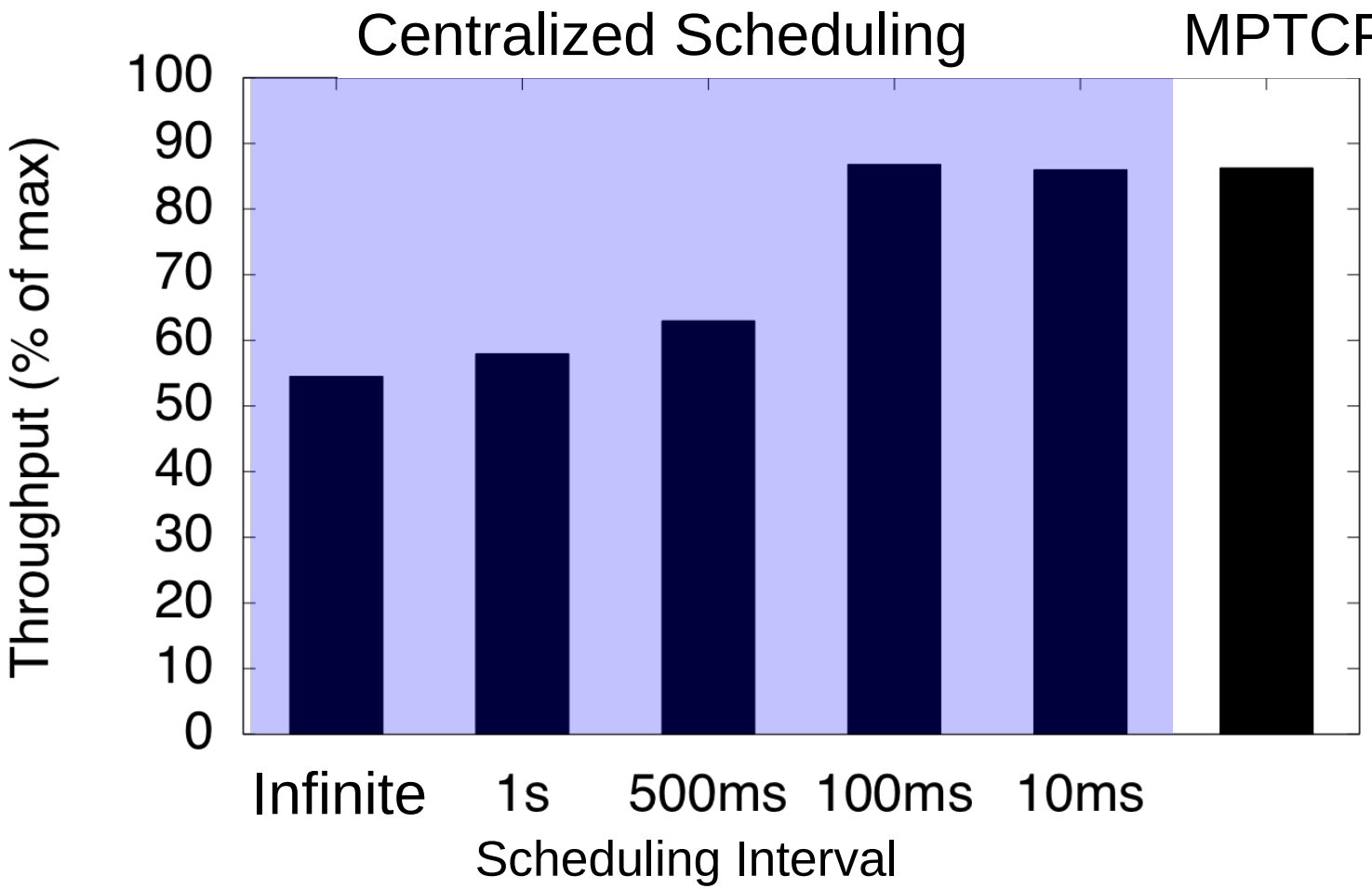
Backup Slides

Effect of MPTCP on short flows

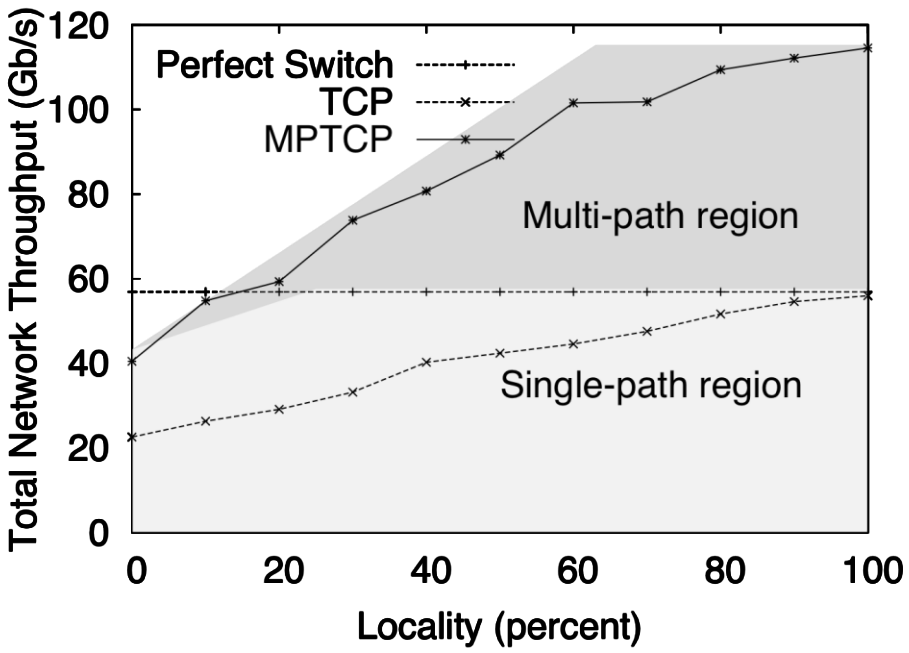
- Flow sizes from VL2 dataset
- MPTCP enabled for long flows only (timer)
- Oversubscribed Fat Tree topology
- Results:

	TCP/ECMP	MPTCP
Completion time:	79ms	97ms
Core Utilization:	25%	65%

MPTCP vs Centralized Dynamic Scheduling



Effect of Locality in the Dual Homed Fat Tree



Overloaded Fat Tree: better fairness with Multipath TCP