Multipath Congestion Control for Shared Bottleneck

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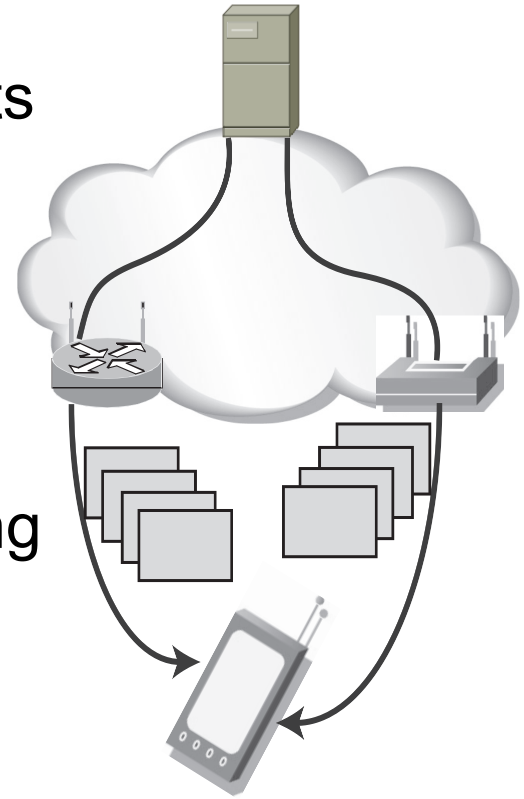
Outline

- Introduction
- Problem statements for multipath congestion control
- Approach
- Designing Multipath Congestion Control
- Experimental results
- Conclusion and ongoing work

Introduction

- Multiple paths between end-to-end hosts
  - Many hosts are equipped with multiple network interfaces
- Transmitting data over multiple paths
  - Increase resource allocation with improved reliability and load balancing



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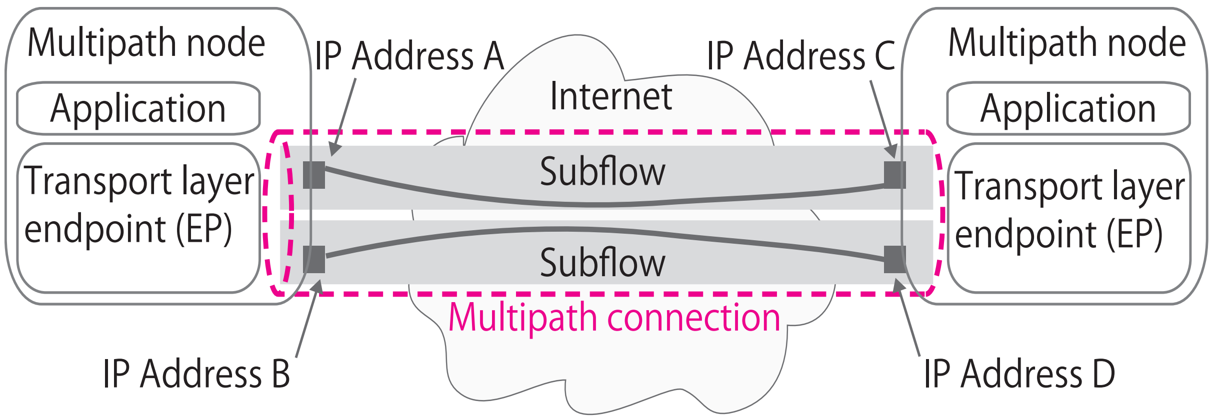
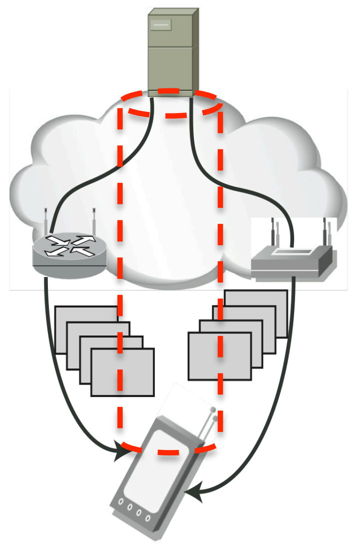
Multipath Transport Protocols

- Multipath connection
  - An entity over which applications communicate between transport layer endpoints (EP)
  - Provide the same communication primitive through the socket as well as general transport protocols (i.e., a reliable and ordered byte stream)
- Subflow
  - An entity over which the endpoint transmits a flow along a path





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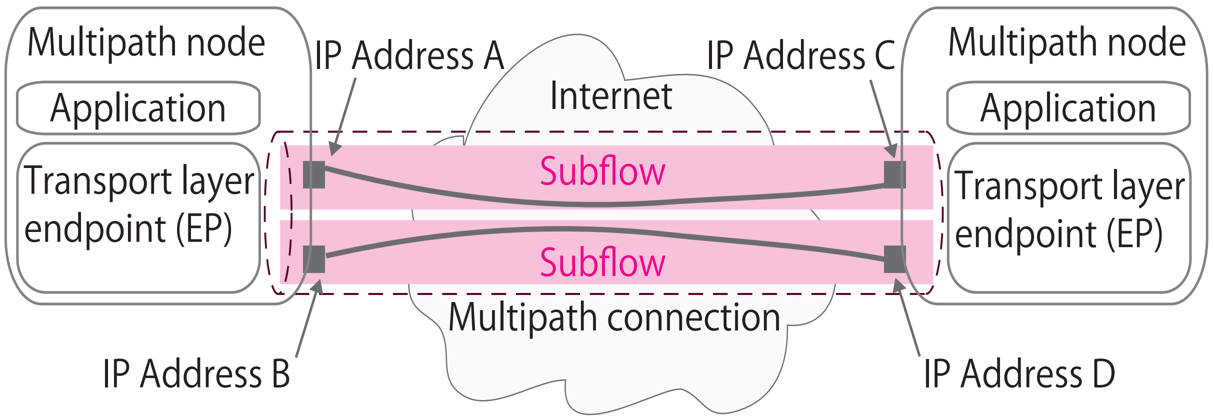
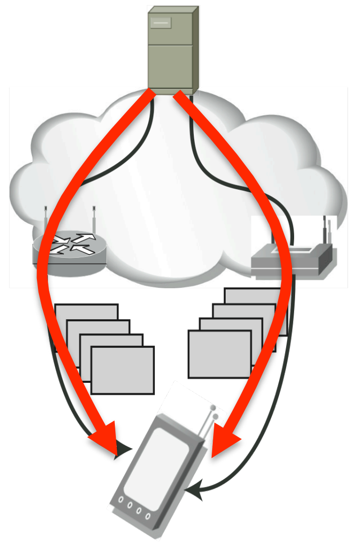
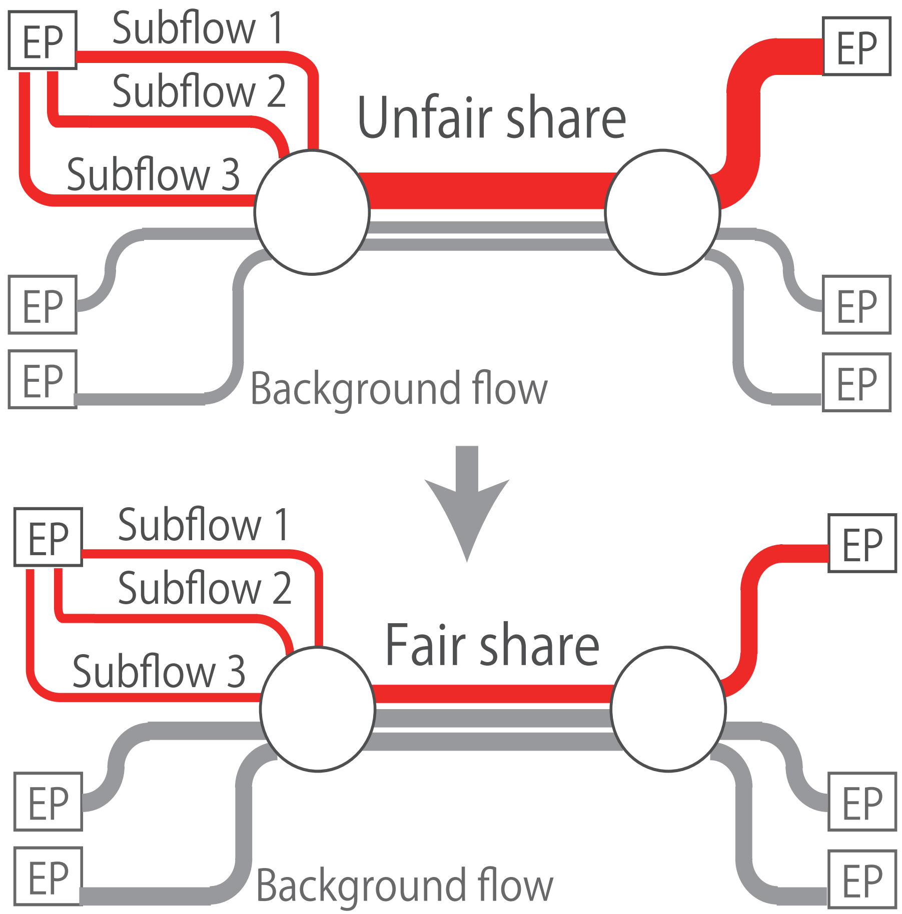
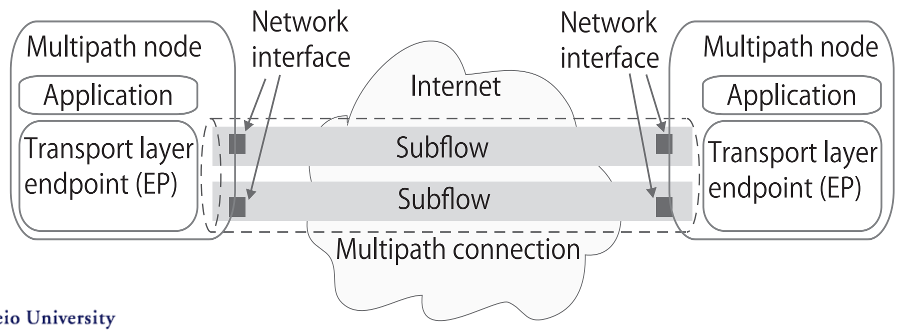




Problem Statement

- Existing multipath transport protocols adopt TCP's algorithm to each subflow (e.g., pTCP, mTCP, CMT)
- The endpoint of the multipath connection uses the shared bottleneck unfairly





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Approaching fair utilization of the shared bottleneck

- How do we achieve TCP-friendly multipath connections?
- Aggregate congestion control approach (e.g., E-TCP, CM)
  - Share the congestion information between subflows
    - Don't work between subflows along different paths
    - Cause performance issue
- Shared bottleneck detection approach (e.g., mTCP)
  - Take time to detect shared bottleneck
- <u>Weighted congestion control approach</u>
  - Apply the weight to congestion control of subflows
    - Each subflow independently behaves based on its own congestion information (i.e., cwnd, RTT measurement)
    - Work even if each subflow traverses distinct paths

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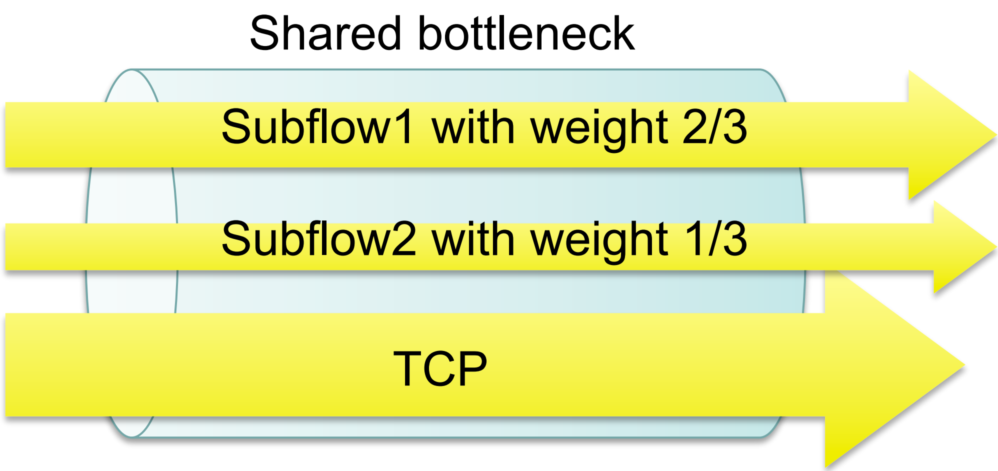
Approaching fair utilization of the shared bottleneck

- The sum of the throughput of subflows should be equal with TCP at the shared bottleneck
- We define the weight of TCP is 1, so maintain the sum of weight of subflows to 1 in the multipath connection
  - One subflow with the weight *D* achieves *D* times throughput TCP



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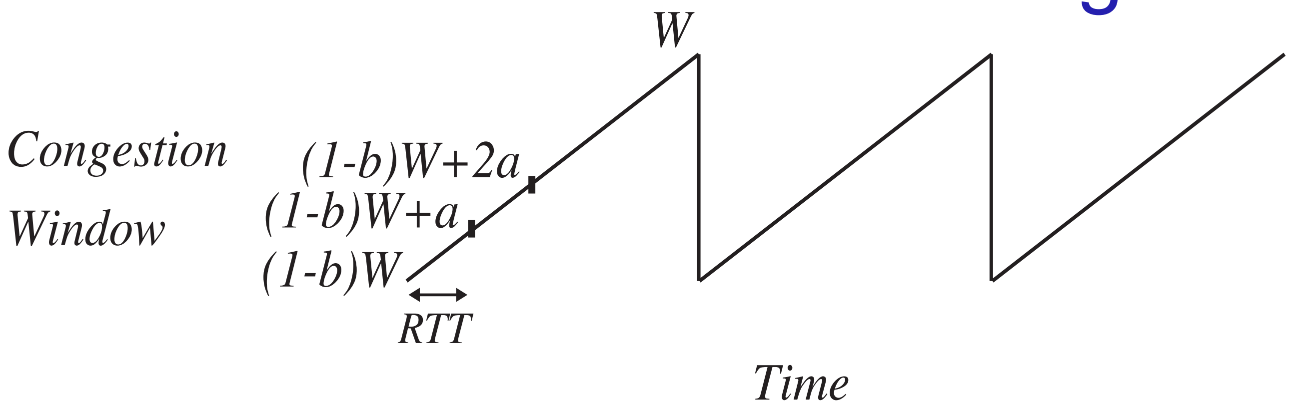
Applying the AIMD parameters for each subflow based on the weight



Window size of *AIMD(a, b)*

- Based on the weight of the subflow (*D*), we determine its AIMD parameter (additive increase parameter "*a*" and multiple decrease parameter "*b*")

$$a = \frac{3b}{2-b} D^2$$

- We adopt AIMD(D^2, 1/2) for *D* times throughput compared to TCP (using AIMD(1, 1/2))
  - based on the response function and simulation results (MulTCP and PA-MulTCP cannot fit $D<1$)

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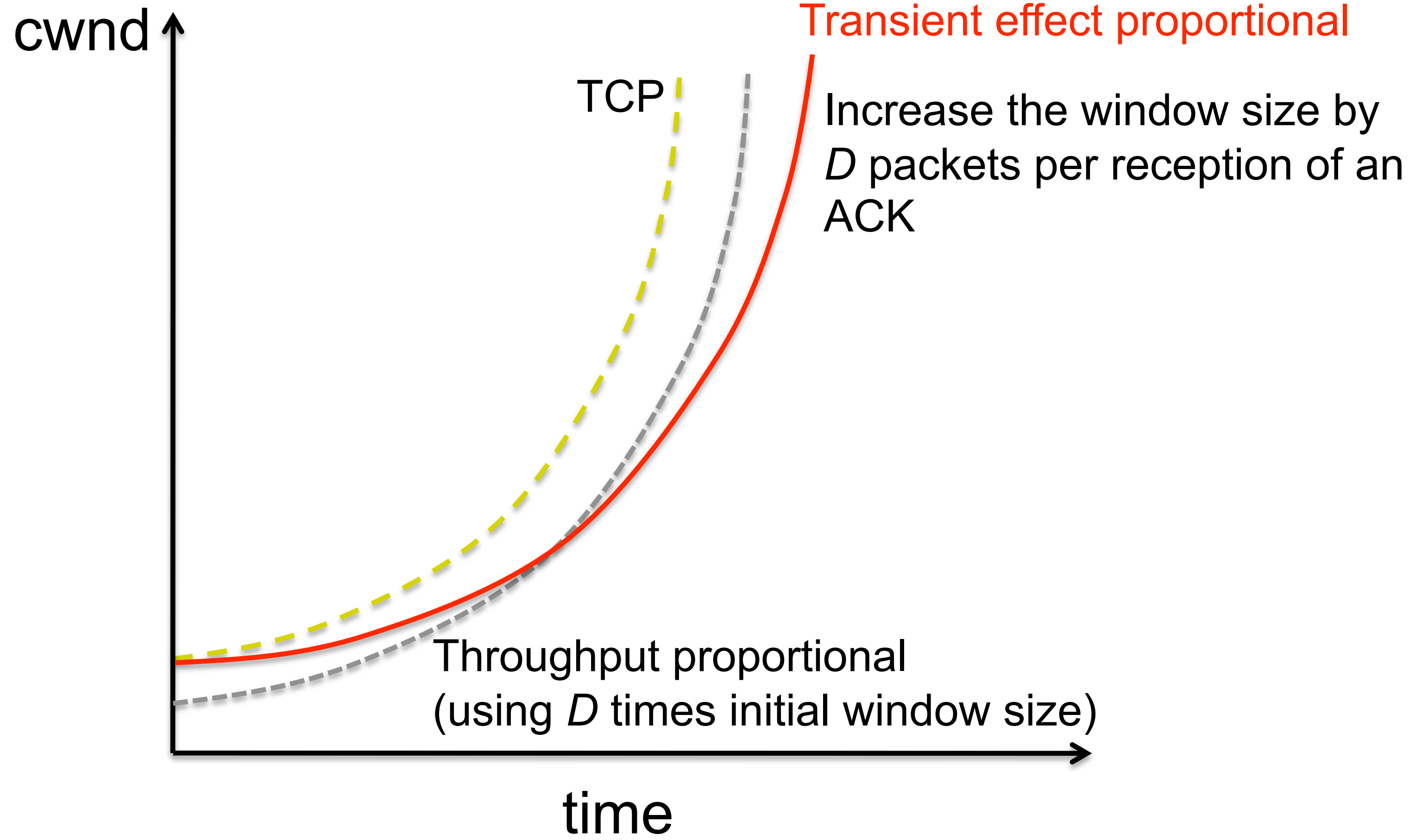
Slow-start behavior of subflows

- We use conservative increase behavior with the same window size of TCP at the beginning of the transmission and after RTO



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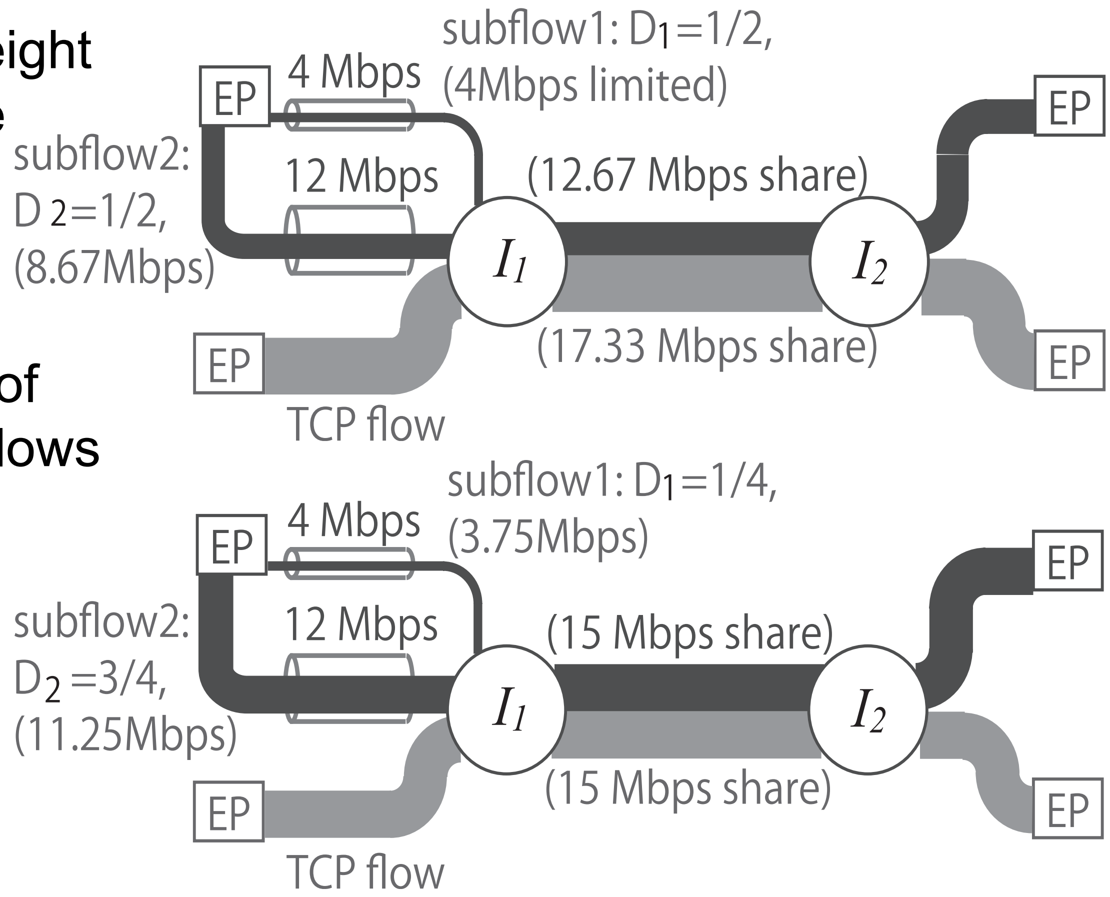
How do we use spare bandwidth of disjoint links?

- Disjoint links can have different spare bandwidth
- We have to adjust the weight of subflows to bypass the limitation of spare bandwidth
- Detect spare bandwidth limitation by comparison of throughput between subflows



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Detection of spare bandwidth limitation

- Comparison of each subflow based on the value which has deducted the effect of the weight and RTT

$$T_{wr} = \frac{RTT}{weight} T_{measured}$$

- We reduce the weight of the subflow with the smallest *Twr*
  - At the same time increase the weight of the highest *Twr*
- We change the weight of subflow with more outstanding weight more conservatively

$$D^{dec}_{new} = (D^{dec}_{cur})^2$$

  - Maintain aggressiveness of subflows achieving better throughput

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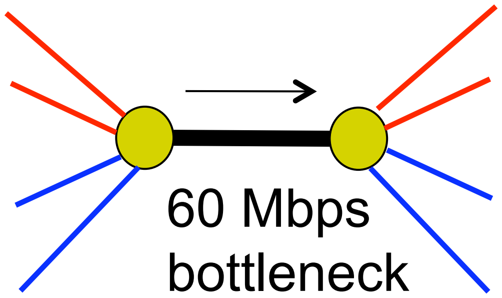
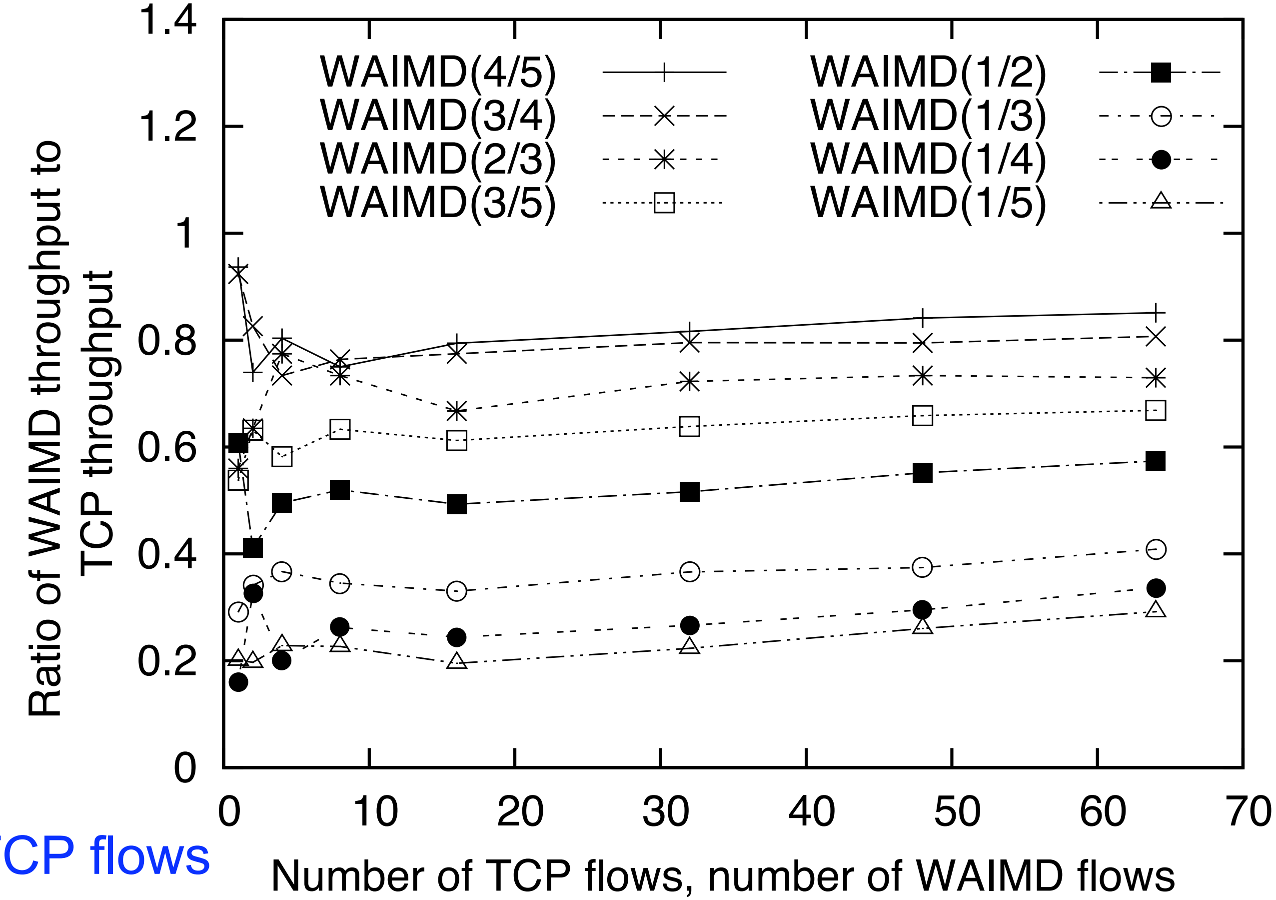
Experimental results (Weighted AIMD flows v.s. TCP flows)

- Throughput proportion of weighted AIMD (weight < 1) flows compared to TCP



N WAIMD flows
and N standard TCP flows



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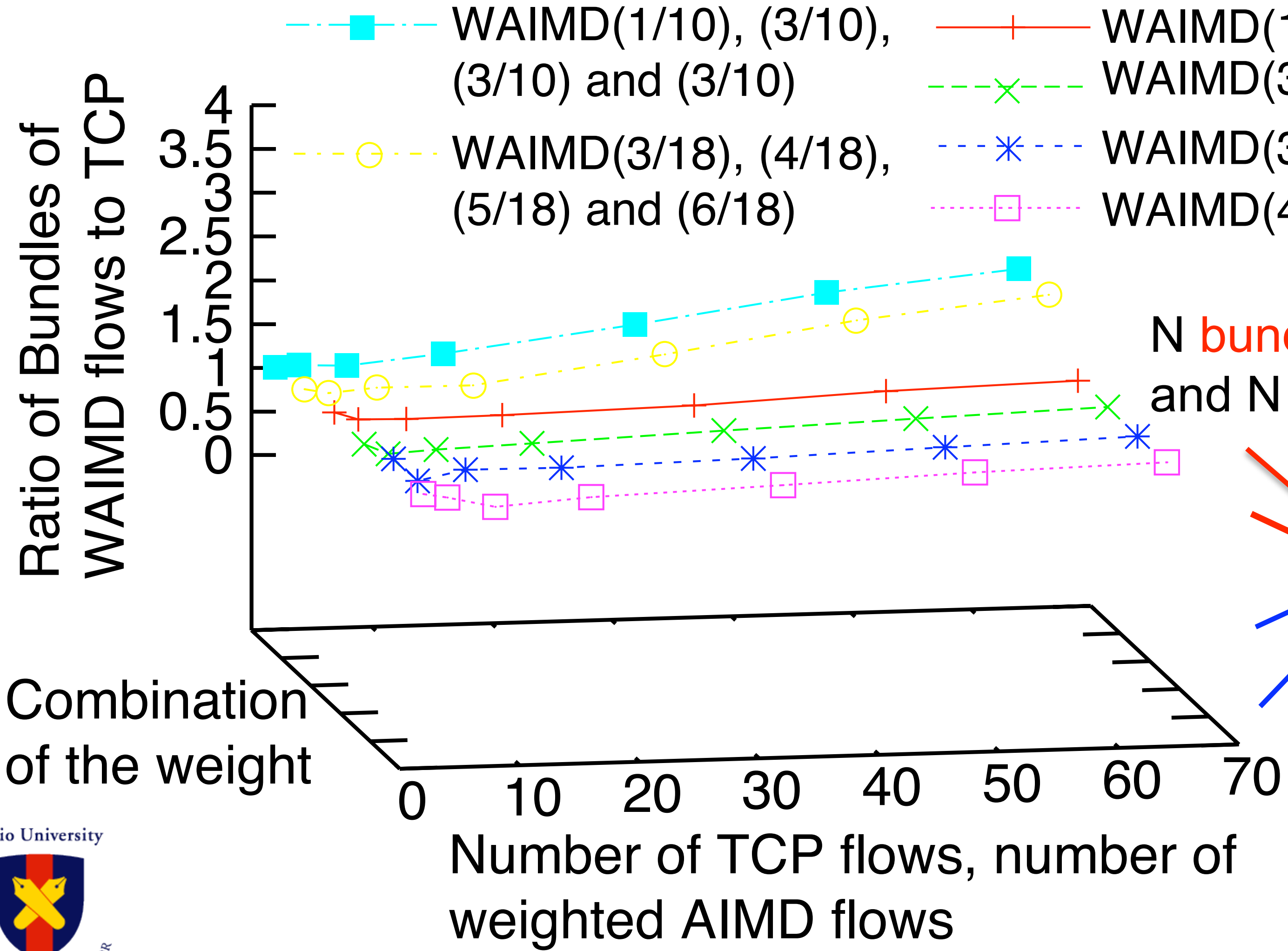
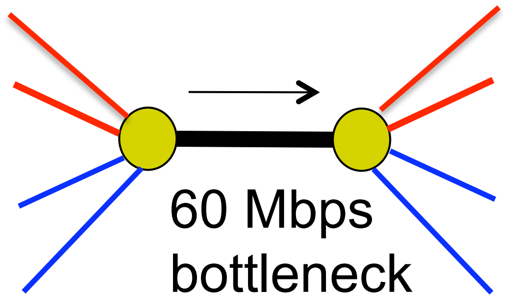
Experimental results (Bundles of WAIMD flows v.s. TCP flows)

- Comparison between aggregate of WAIMD flows and TCP



N bundles of WAIMD flows and N standard TCP flows



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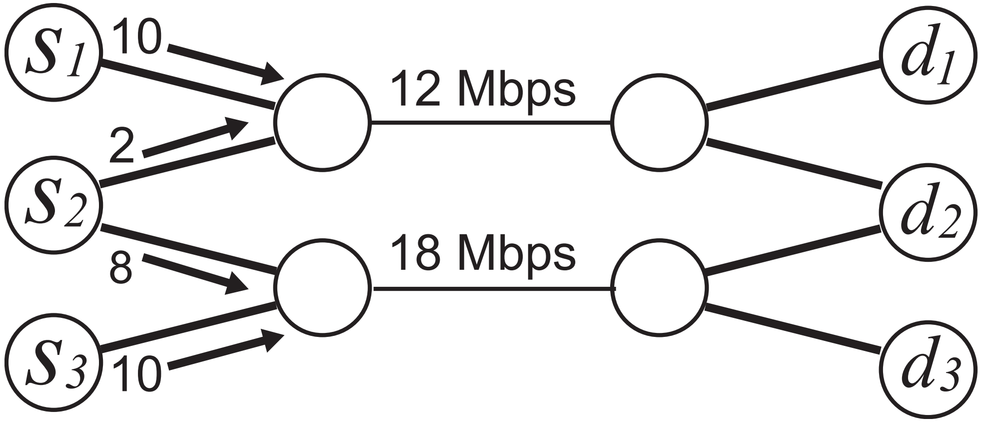
Behavior on disjoint bottlenecks



- Our algorithm converges to equal resource allocation between endpoints across bottlenecks, similarly to Kelly's and Key's resource pooling (but equal window allocation)
  - Discussion: Should we achieve an equal resource allocation for per-flow fairness? or per-connection?

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Conclusion and Ongoing work

- Conclusion
  - Our scheme achieves TCP-friendliness of multipath communication for coexistence of TCP and multipath transport protocols
    - Weighted congestion control approach
  - We find out that our scheme achieves TCP friendliness of the bundle of multiple subflows through experiments
- Ongoing work
  - Evaluation and optimization of convergence speed and stability
  - Investigation for the other fairness metric (e.g., proportional fairness, cost fairness)

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