Linked Congestion Control

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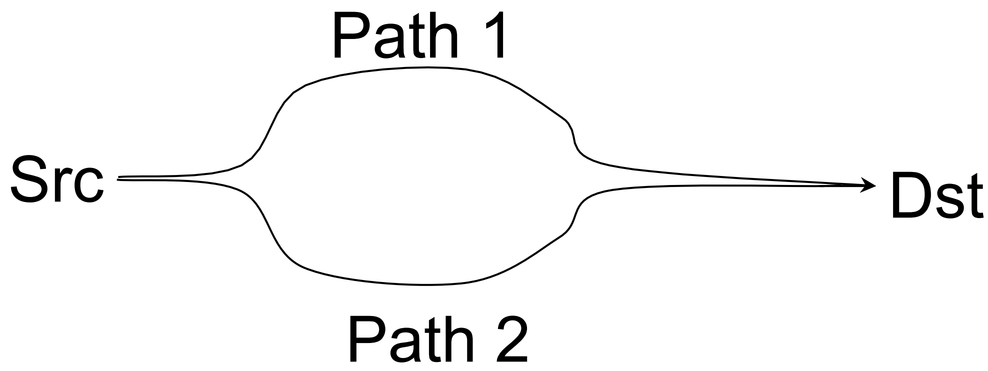
Where we are today

- We’ve studied practical aspects of multipath congestion control for 1.5 years
  – Solved issues with previous theoretical work (flappiness, RTT bias)
- Linked Increases algorithm
  – draft-raiciu-mptcp-congestion-00
  – Detailed analysis in tech report

Multipath TCP at work

- Source can use multiple paths to send traffic
- How should it allocate traffic to the two paths?
  - Using a window based protocol
  - Playing fair with TCP



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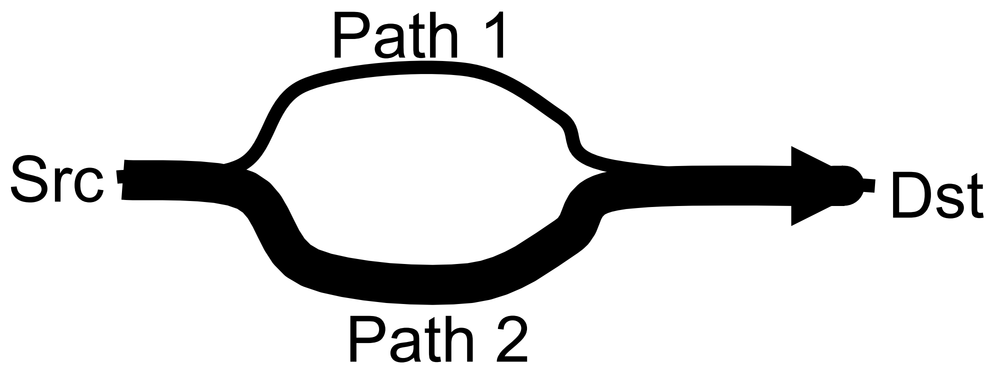

Aims

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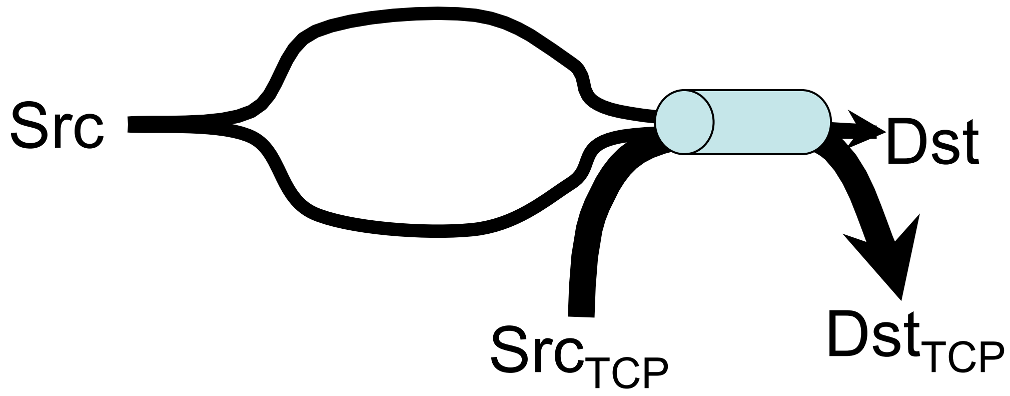
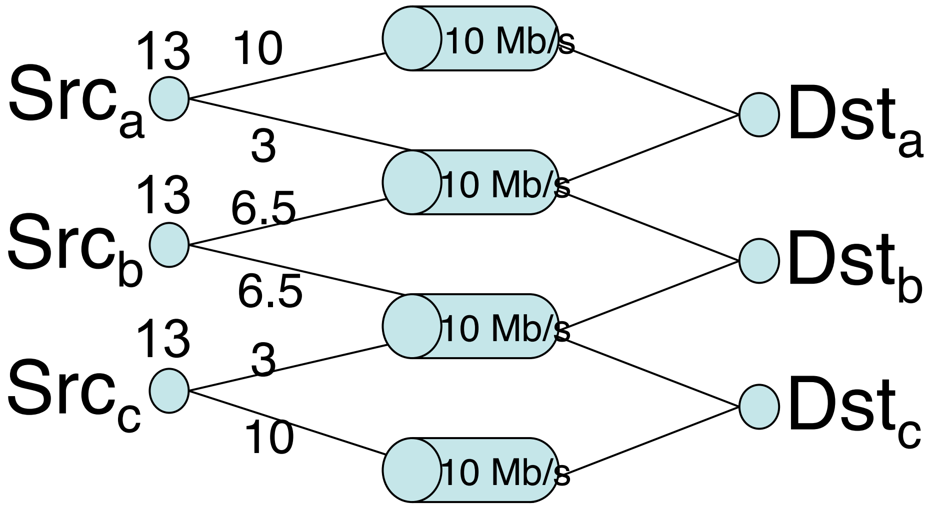
- **Goal 3** (balance congestion) move traffic onto least congested links as long as goals 1 and 2 are met

Goals 1&2 Imply Bottleneck Fairness



Goal 3 Implies Resource Pooling



Can we use existing algorithms?

- Independent TCP on each subflow
  – Breaks goals 2 and 3
- Theoretical work (Kelly et al)
  – Flappy – tends to allocate all traffic to a single subflow
  – Breaks goal 1 due to RTT dependence

Linked Increases Algorithm

- Preserves the basic window-based AIMD behavior that has kept the Internet running for ~20years
- Tweaks the increase phase

What is changing?

- We only change behavior in congestion avoidance phase
- All other algorithms are unchanged, and will run independently per subflow
  - Slow start
  - Fast retransmit/fast recovery
  - SACK
  - RTT estimation
  - …

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Tuning α

- We know loss rates and rtts
  - We know the throughput a TCP would get on the best path
  - We can compute α by solving a simple equation

Tuning α

- Formula

$$\alpha = tot\_cwnd \frac{\max_i \dfrac{cwnd_i \cdot mss_i^{\,2}}{rtt_i^2}}{\left(\sum_i \dfrac{cwnd_i \cdot mss_i}{rtt_i} \right)^2}$$

Is this practical?

- Compute α only when cwnd grows by one mss
  - Gives good precision at low cost
- We can do all operations with integers

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- α can be arbitrarily large
- On certain paths this may make multipath subflows be more aggressive than TCP
- To avoid this, just cap!

$$\min\left(\frac{\alpha \cdot bytes\_acked \cdot mss_i}{tot\_cwnd}, \frac{bytes\_acked \cdot mss_i}{cwnd_i}\right)$$

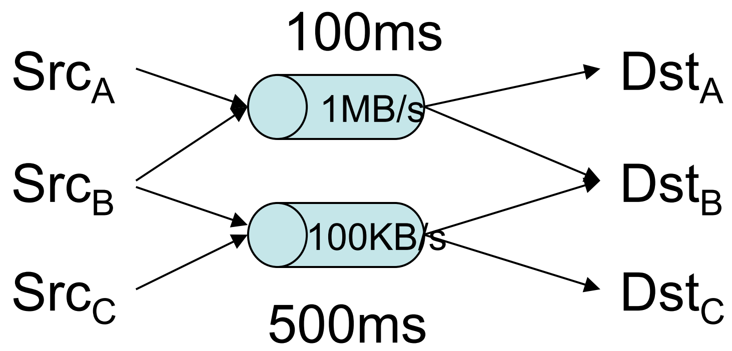
Emergent Behavior

- Linking the increase allocates proportionally more window to subflows with lower loss rates
- Tuning α scales the total window such that the desired throughput is achieved

Linked Increases Implementations

- Implemented in
  - Simple cwnd simulator, RTT based
  - Packet-level simulator [available soon]
  - Userland Linux stack [available on demand]
- Ran extensive experiments
  - Linked Increases gets throughput within +/-10% of best TCP

Experiment: Throughput



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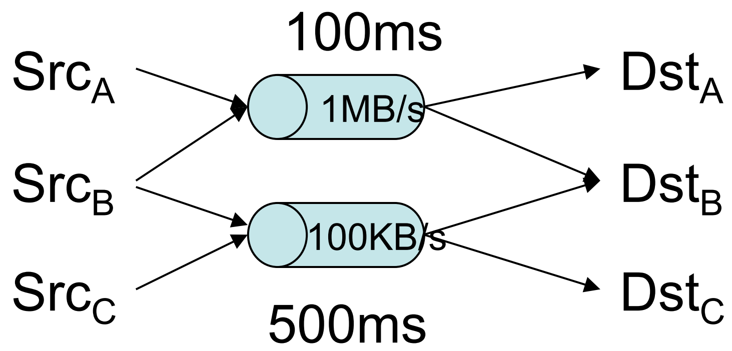
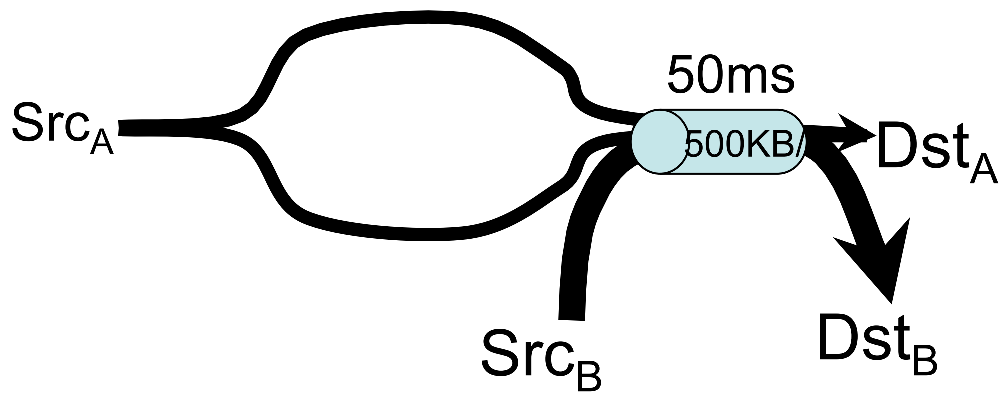


Throughput: Src_A 520KB/s
Src_B 510KB/s
Src_C 71KB/s

Experiment: Bottleneck



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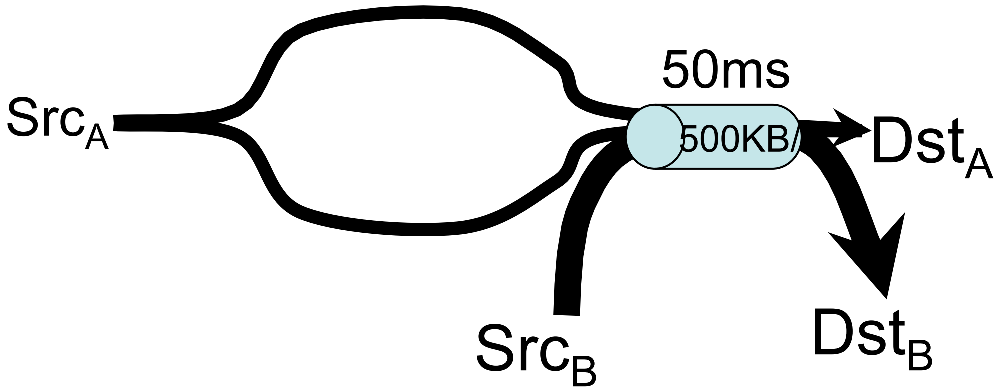
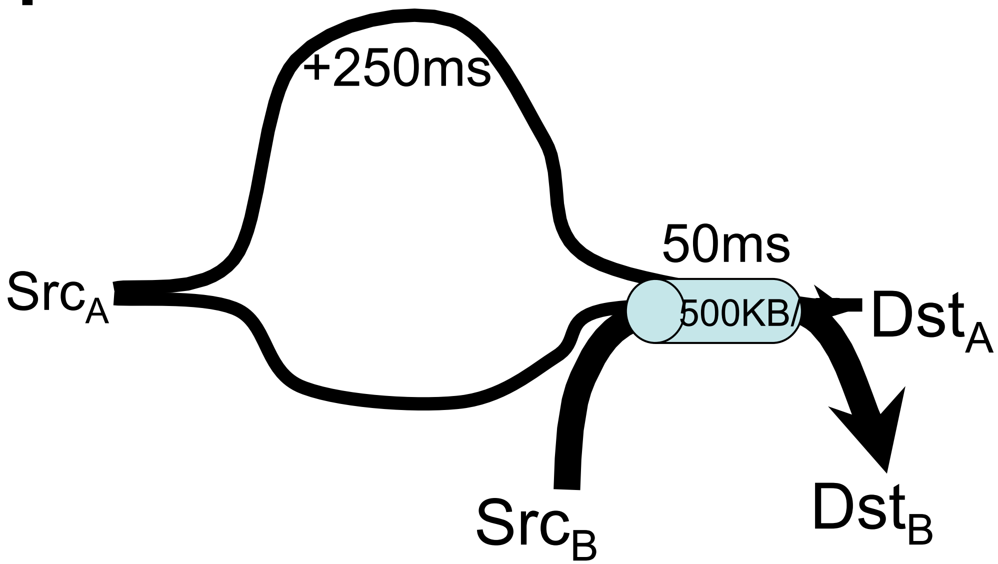


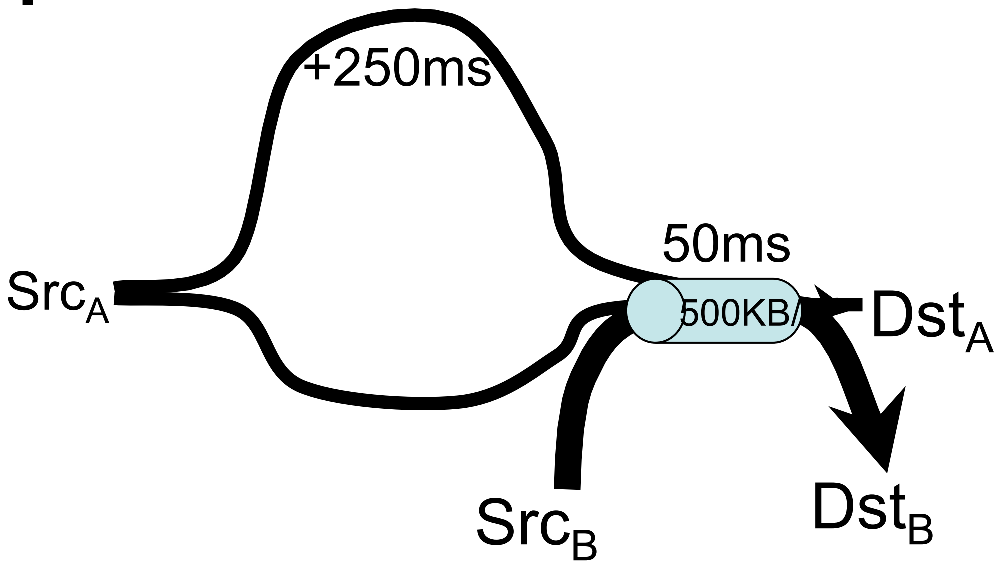
$cwnd_1$=$cwnd_2$ **α = 0.66**

Throughput: Src_A 240KB/s
Src_B 260KB/s

Experiment: Bottleneck [2]



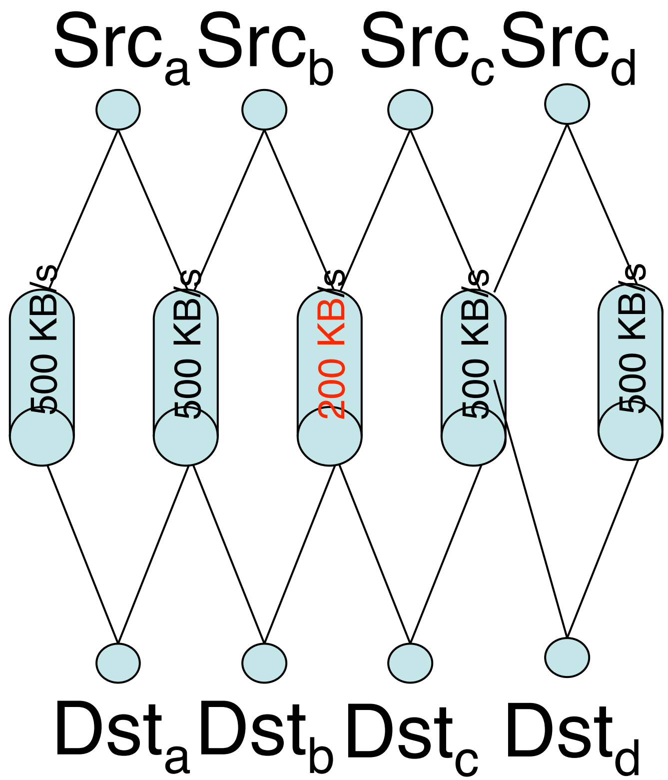
Experiment: Bottleneck [2]



$cwnd_1$=$cwnd_2$ **α = 0.89**

Result: Src_A 255KB/s
Src_B 245KB/s

Resource Pooling Experiment



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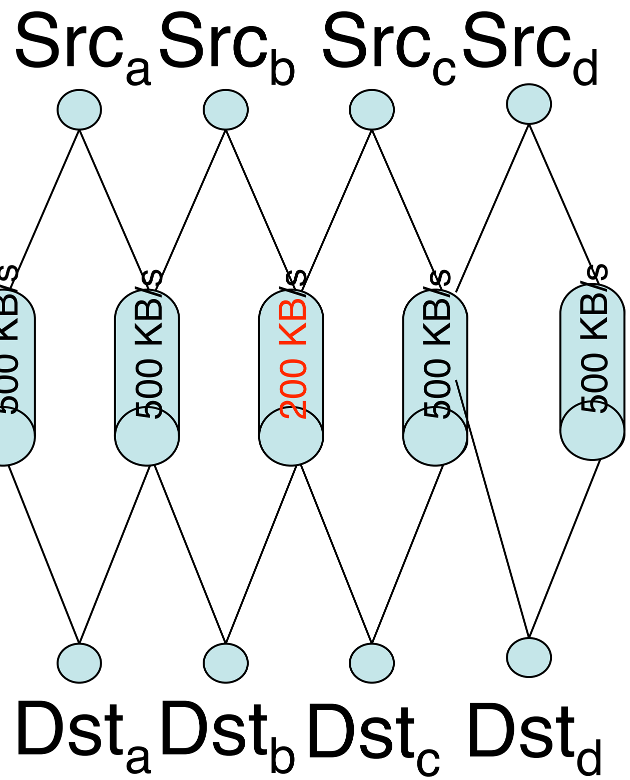

Throughput (KB/s):	**625**	**475**	**475**	**625**
Uncoupled TCP:	**750**	**350**	**350**	**750**
Perfect:	**550**	**550**	**550**	**550**

Summary

- We must couple congestion control loops to get resource pooling and bottleneck fairness
- Linked Increases [draft-raiciu-mptcp-congestion-00] achieves both
  - Simple and works
  - We have a working implementation
- Is this draft ready to become a working group document?