Resource Pooling across the Internet

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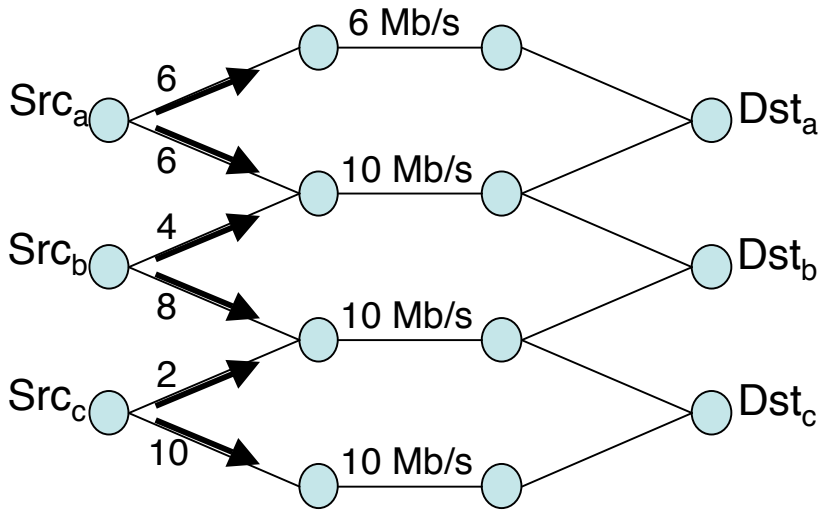
Resource Pooling

Make a network's resources behave like a **single pooled resource**.

- Aim is to increase reliability, flexibility and efficiency.
- Method is to build mechanisms for shifting load between the various parts of the network.



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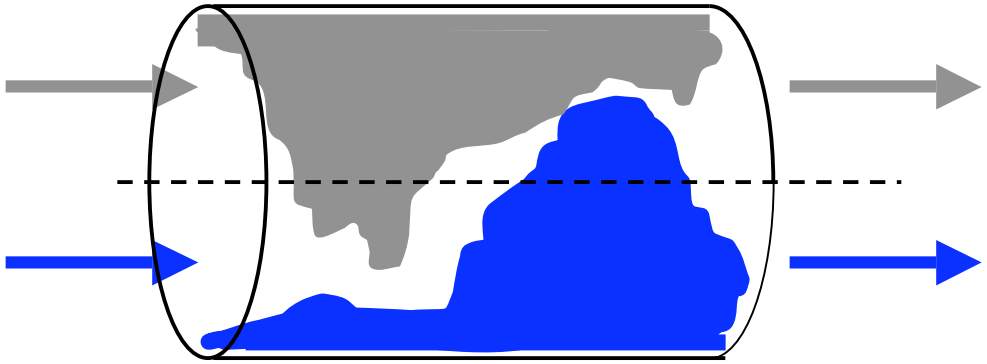
Everyone keeps reinventing resource pooling to solve their own local problems.

Resource Pooling is not new…

Computer communication is bursty, so a virtual circuit-based model with rate allocations gives poor utilization.

- A packet-switched network pools the capacity of a single link.
  - Goal: high utilization
- Router queues pool capacity from one time interval to the next
  - Goal: high utilization, robustness to arrival patterns



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We're doing resource pooling in routing

- **BGP traffic engineering:**
  - Slow manual process to pool resources across peering links.
- **OSPF/MPLS traffic engineering:**
  - Slow mostly manual process to pool resources across internal ISP links.
- **BT, AT&T (and others) dynamic alternative routing**

Recent resource pooling trends

- **Multihoming**
  - Primary goal: pool reliability.
  - Secondary goal: pool capacity

- **Google, Akamai, content distribution networks**
  - Pool reliability of servers, datacenters, ISPs.
  - Pool bandwidth.

- **Bittorrent**
  - Overall: Pool upstream capacity (over space and time)
  - Per-chunk: pool for reliability from unreliable servers.

Summary:
Motivations for Resource Pooling

- Robustness
- Increased capacity or utilization

Currently two main resource pooling mechanisms:

- **Routing-based traffic engineering.**
  - Either slow, or potentially unstable.
  - There are many examples where no network-based flow-based mechanism can achieve pooling.

- **Application-based load-balancing between multiple servers.**
  - Pretty effective, but strong tussle with what the network operators are doing.

The requirements have changed

- Need a **more robust** Internet than we can get from simply making better components.
  - Traditional routing can't solve this in a scalable way.
- Applications are becoming **more demanding**:
  - VoIP, TV, Games.
- Most of the end-systems will be **mobile, with multiple radios** that can be used simultaneously.

So what might work?

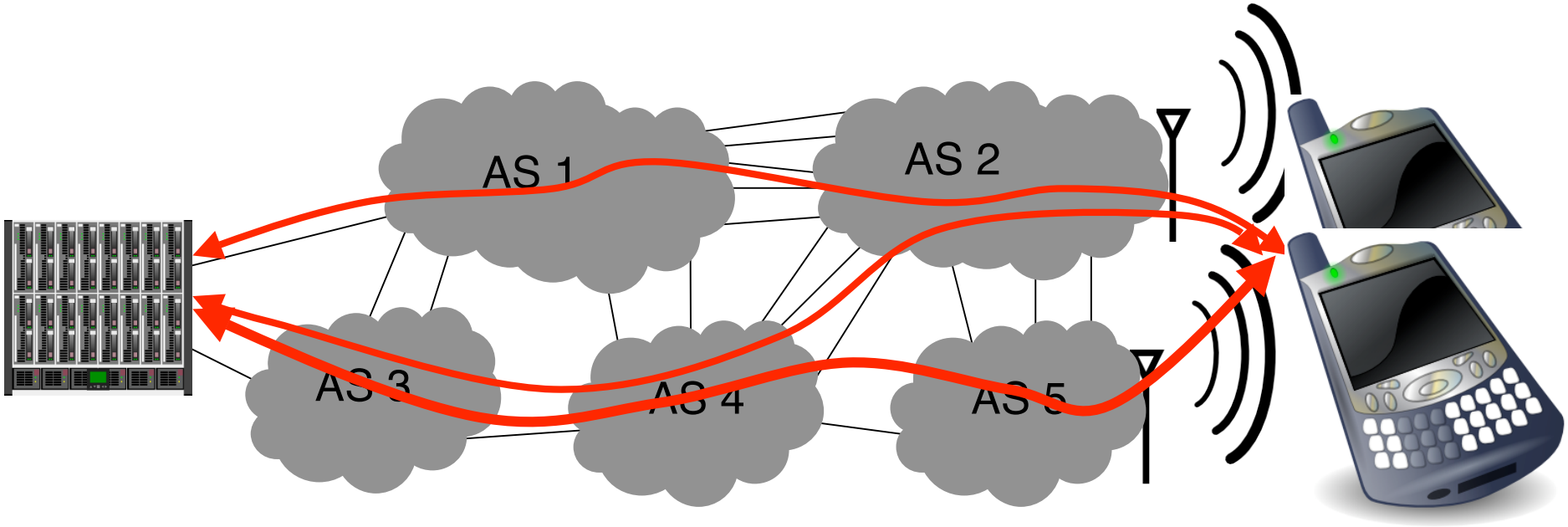
- **Multihoming**, via multiple addresses.
- **Mobility**, via adding and removing addresses, so upper layers can see and adapt to this.

Then use these to do:

- **Multipath**.
  - Use multiple paths simultaneously for each transfer.
  - Only real way to get robustness is redundancy.

So what might work?

- **Multipath-capable transport layers.**
  - Use multiple subflows within each connection.
  - Congestion control the subflows, not the connection.



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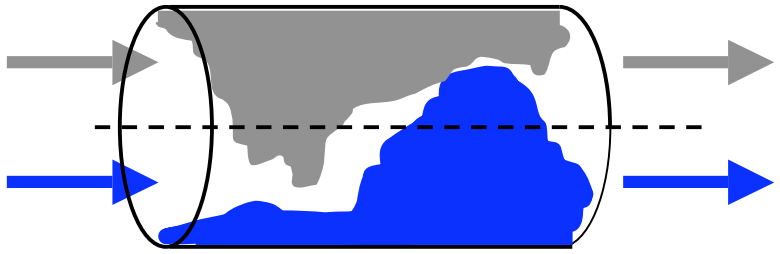
Multipath transport

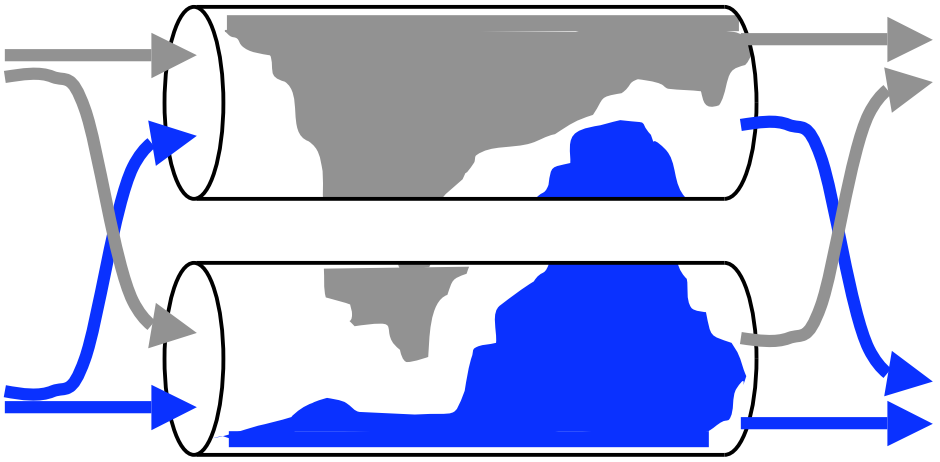
- Multipath transport allows multiple links to be treated as a single pooled resource.

- Traffic moves away from congested links.
- Larger bursts can be accommodated.

ARPAnet resource pooling:



Multipath resource pooling:



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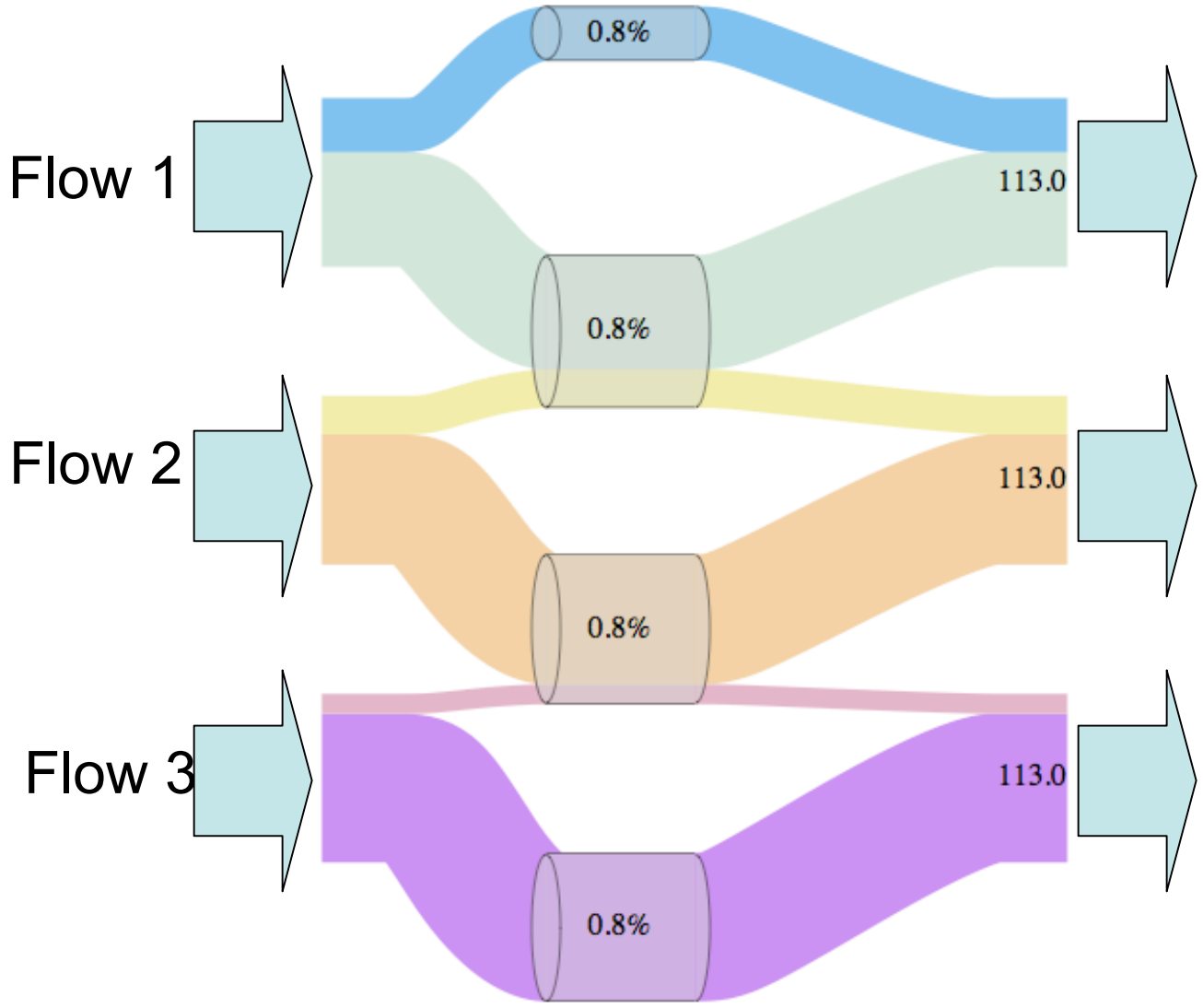
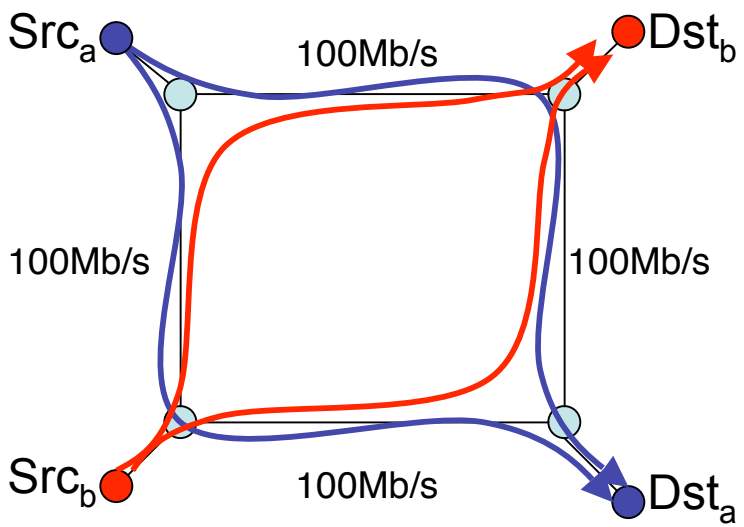
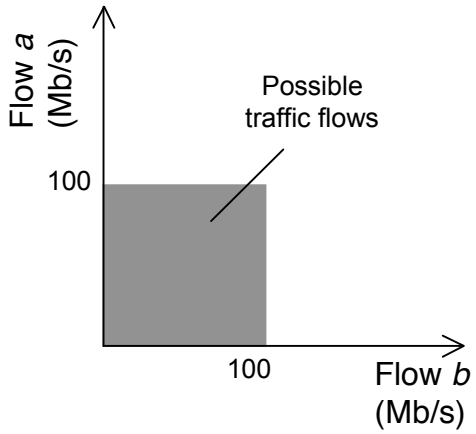
Traffic moves away from congestion

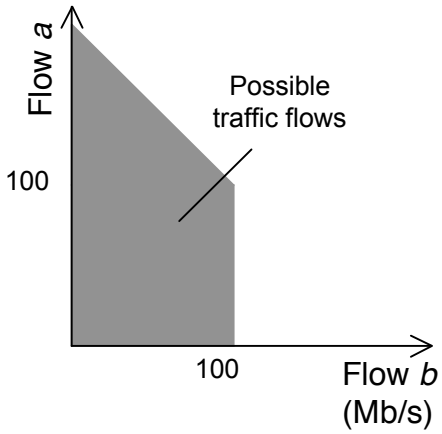


Resource pooling allows a wider range of traffic matrices

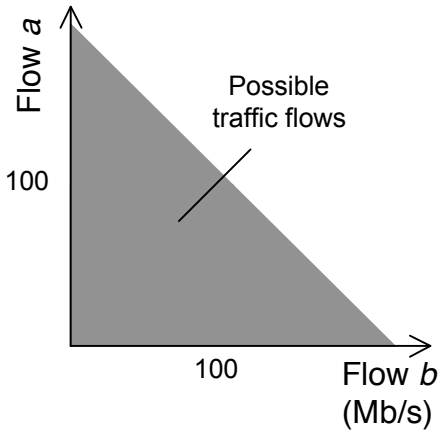




No multi-path flows



Only flow *a* is multi-path.



Both flows are multi-path

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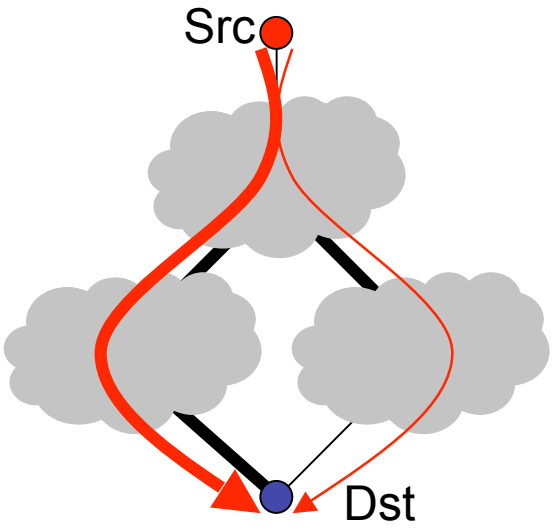
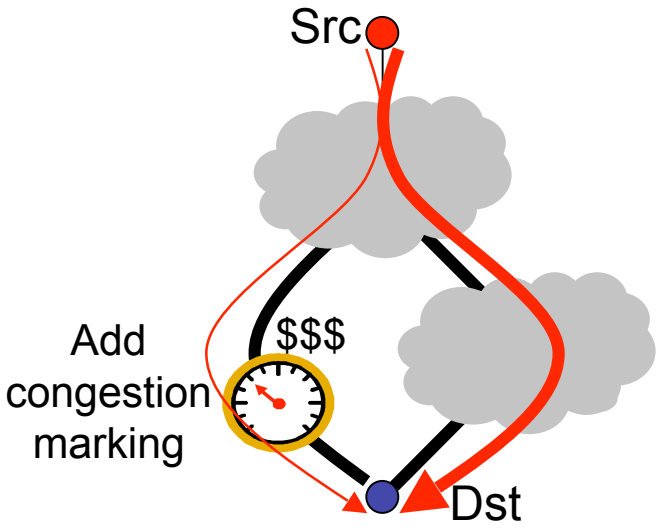
Multipath Traffic Engineering



- Balancing across dissimilar speed links



- Balancing across dissimilar cost links

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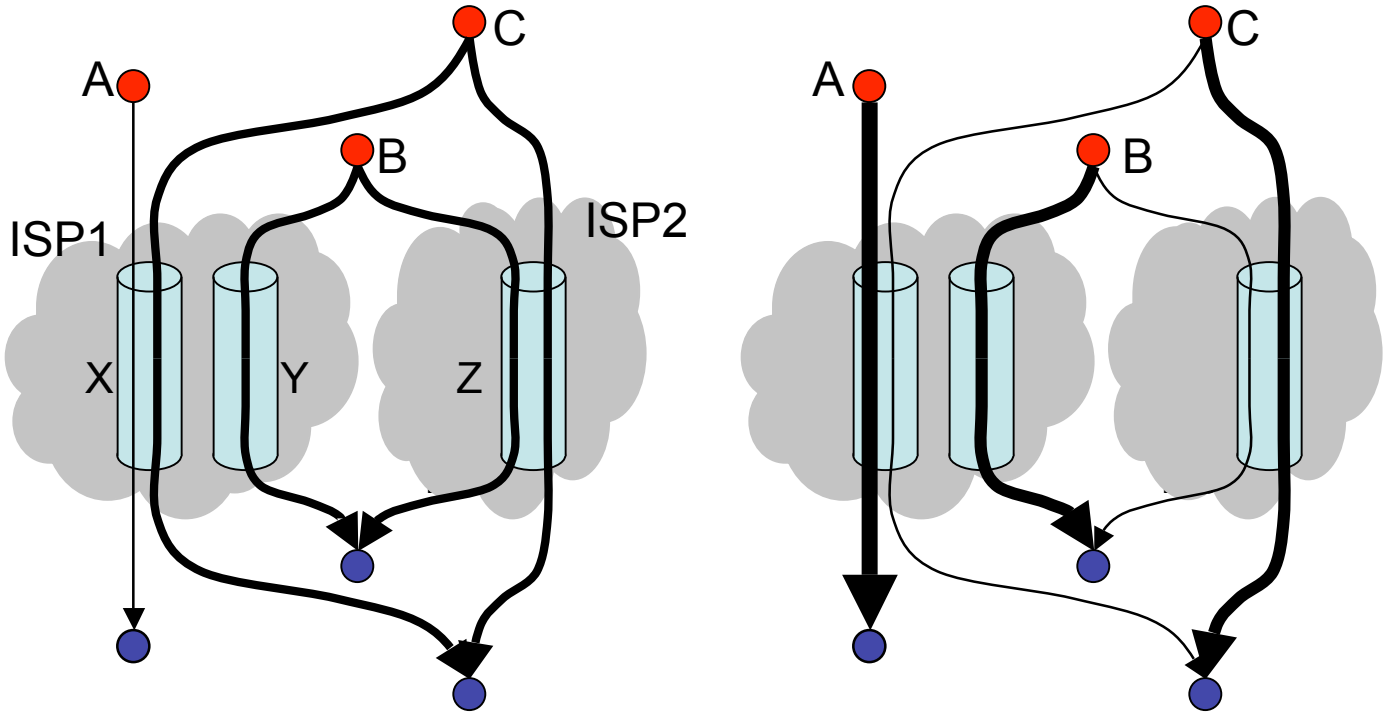
End-systems can optimize globally (often ISPs cannot)



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Existing Multipath Transport

We already have it: BitTorrent.

Providing traffic engineering for free to ISPs who don't want that sort of traffic engineering :-)

If flows were accountable for congestion, BitTorrent would be optimizing for cost.

The problem for ISPs is that it reveals their pricing model is somewhat suboptimal.

Robustness at an Affordable Price

- What if all flows looked a bit like BitTorrent?
  - Fetch from the best place right now.
- Can we build an extremely robust and cost effective network for billions of mobile hosts based on multipath transport and multi-server services?
  - Must build in controls to allow networks to tune traffic.

Multipath Transport Design Space

Multipath TCP

Add multi-path capability to the Transmission Control Protocol

Multi-server HTTP

Allow browsers to fetch simultaneously from multiple mirror servers.

P2P interactions with ISPs

Impact

- Robustness
  - To link failures before routing can react
  - To ISP issues
  - To unexpected traffic patterns
- Seamless mobility (*really* use multiple radios)
- Multihoming
  - Link sharing (use my DSL and my neighbour's Cable (via Wifi) simultaneously.
- Reactive ends give the middle control to move traffic around.