

Contracts: Practical Contribution Incentives for P2P Live Streaming

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Live streaming with PPLive

- **P2P** distribution
- Over **20 million active users** worldwide
- Current design offers **no reward for capacity contributions**



How to provide contribution incentives?

Overview

1. Challenges for *live streaming incentives*

2. *Contracts* design

3. Evaluating *PPLive with Contracts*

PPLive design



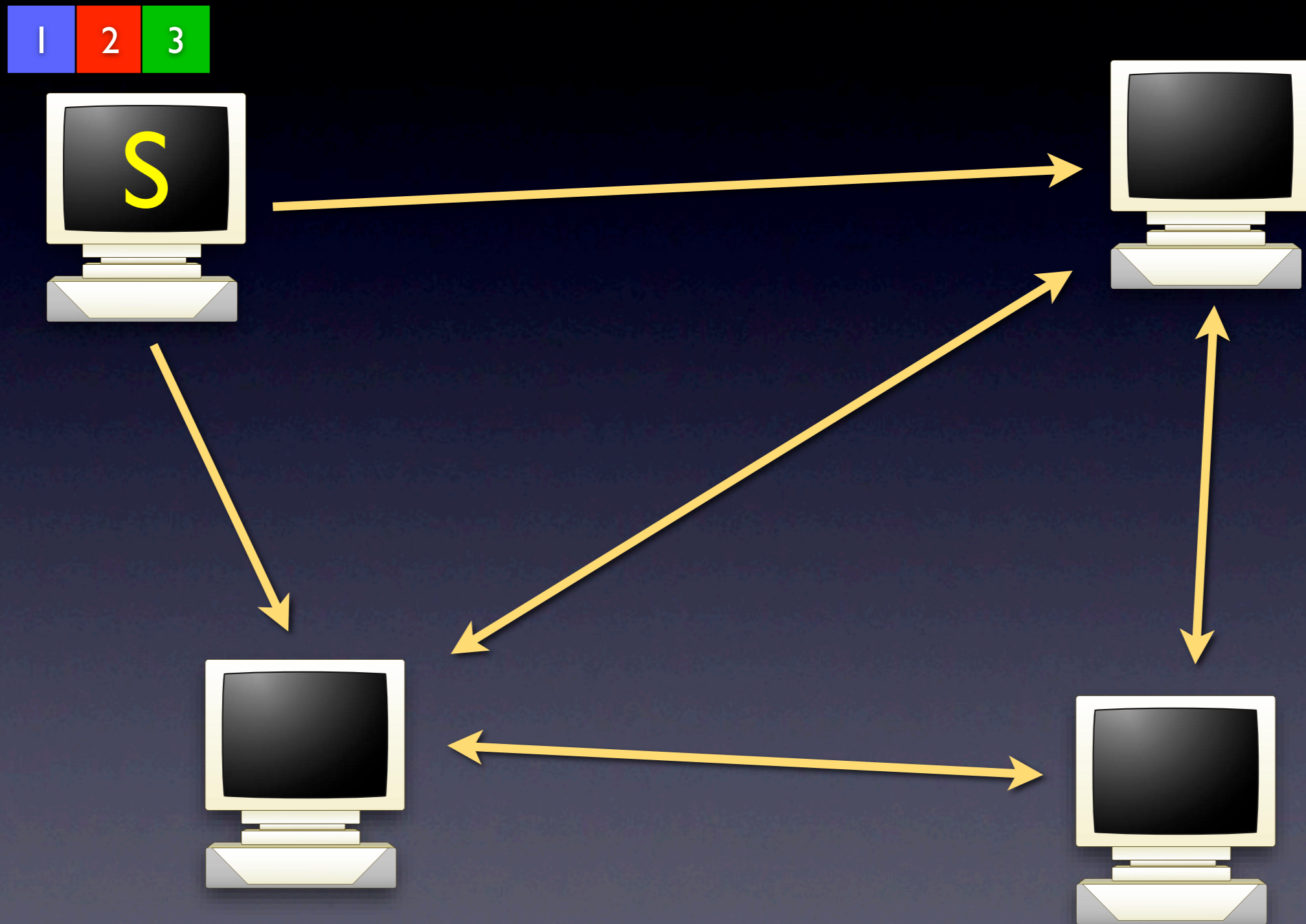
PPLive design



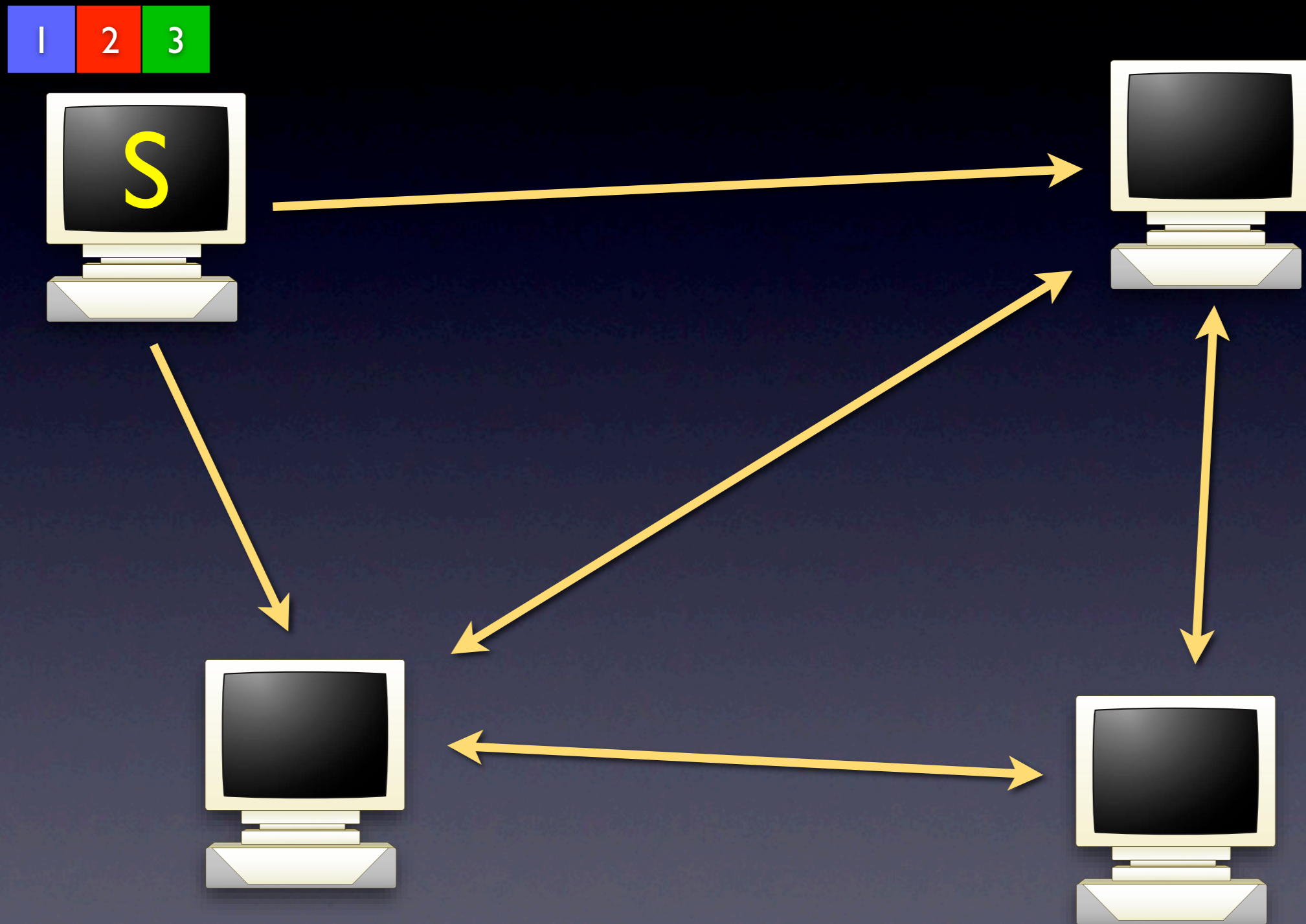
PPLive design



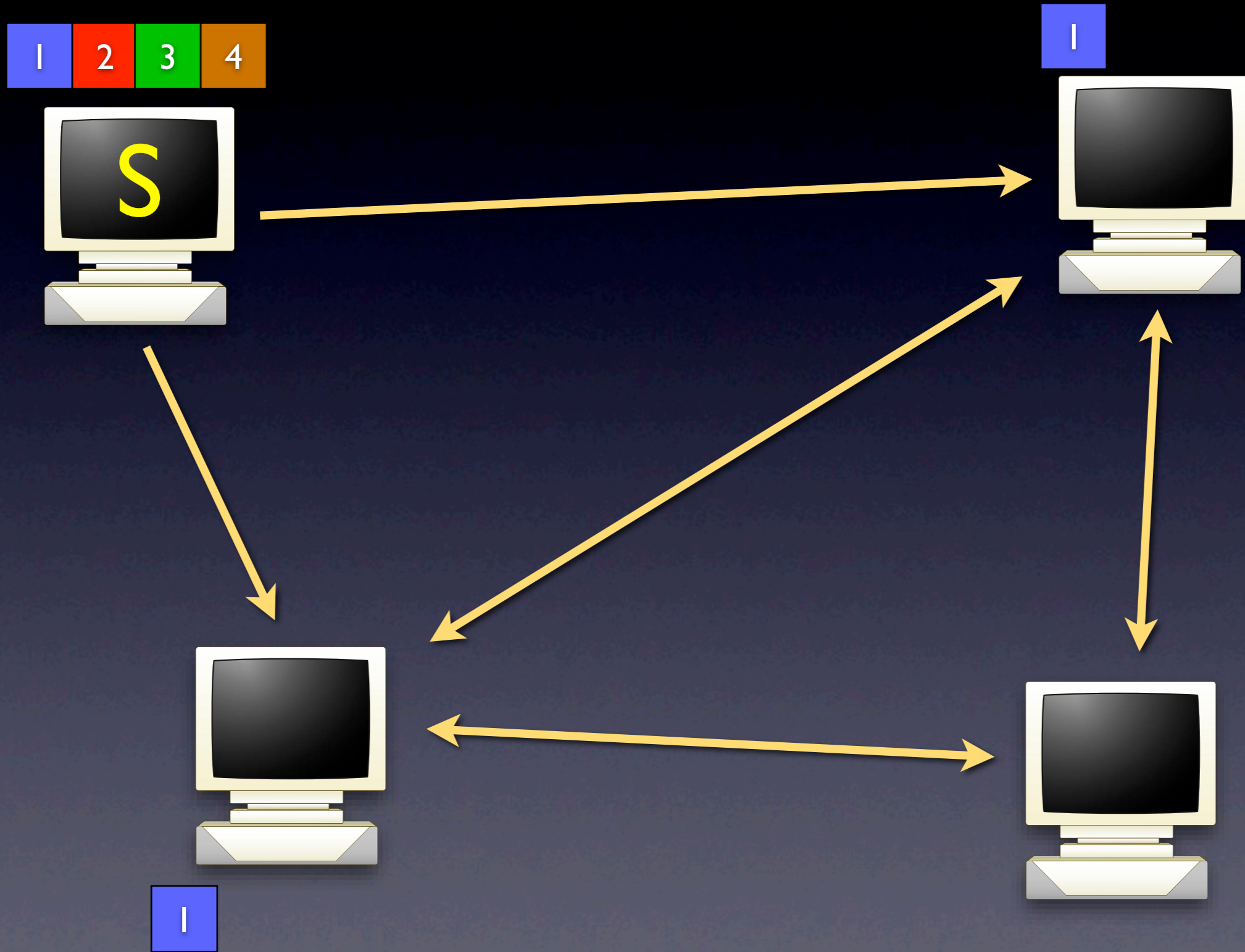
PPLive design



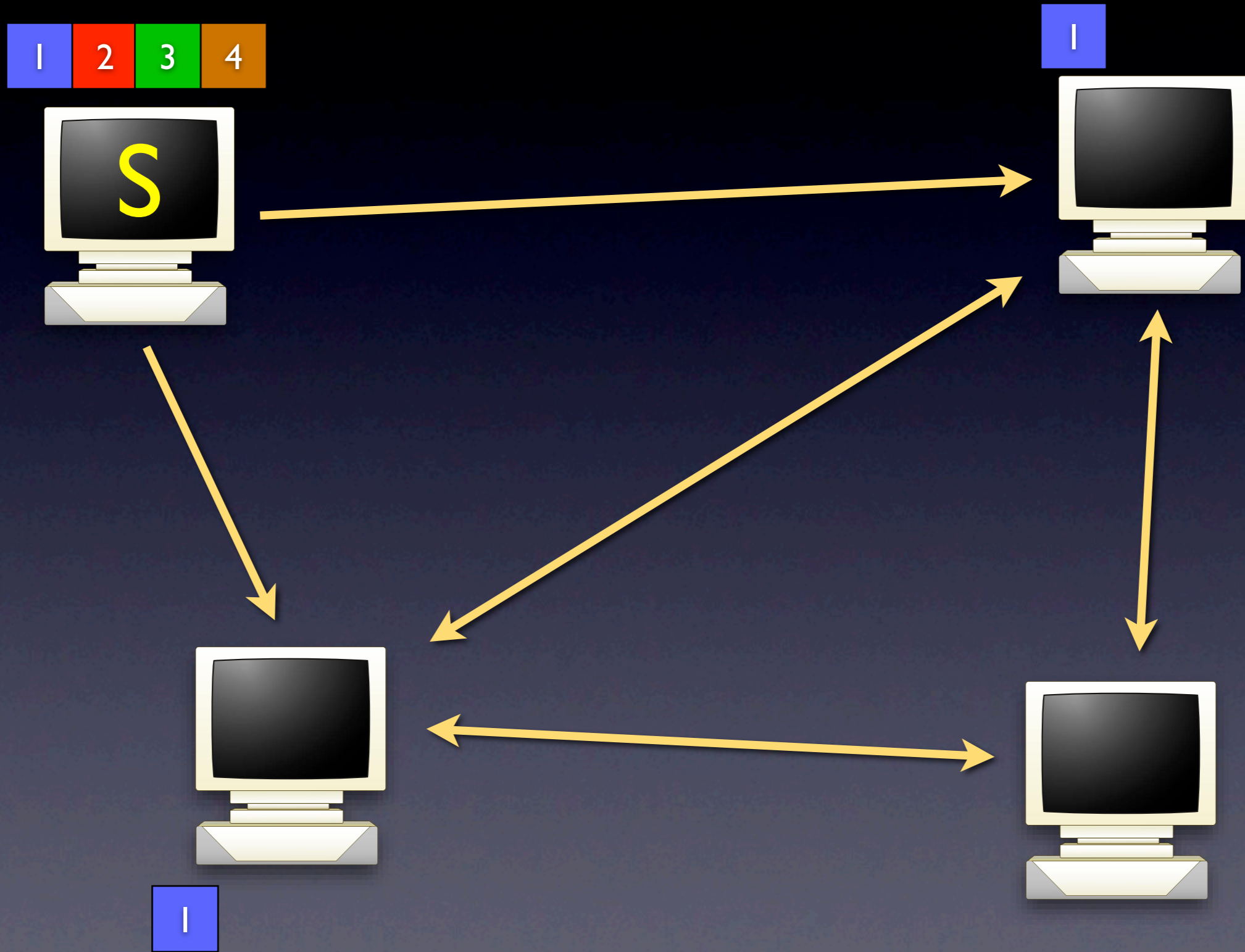
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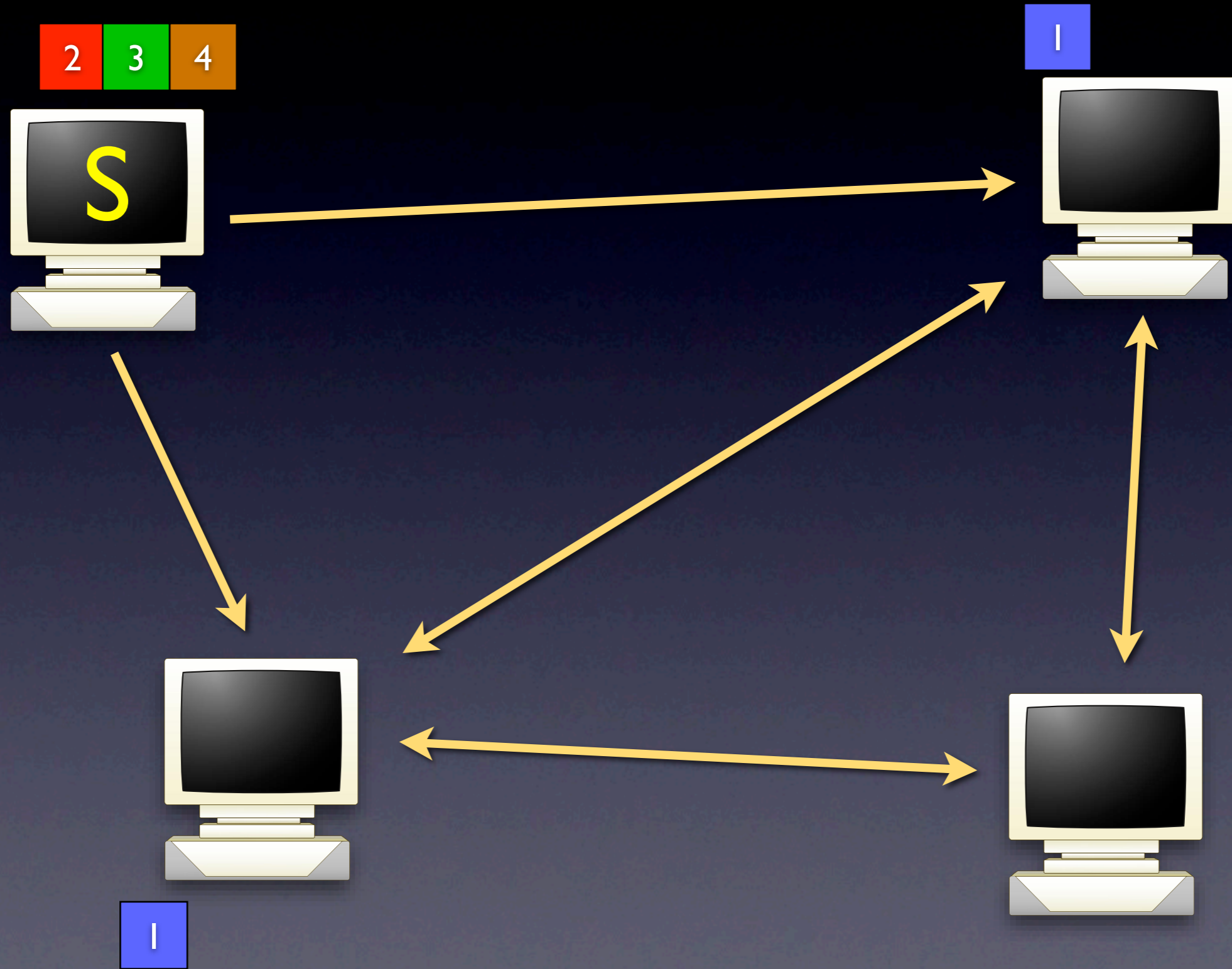
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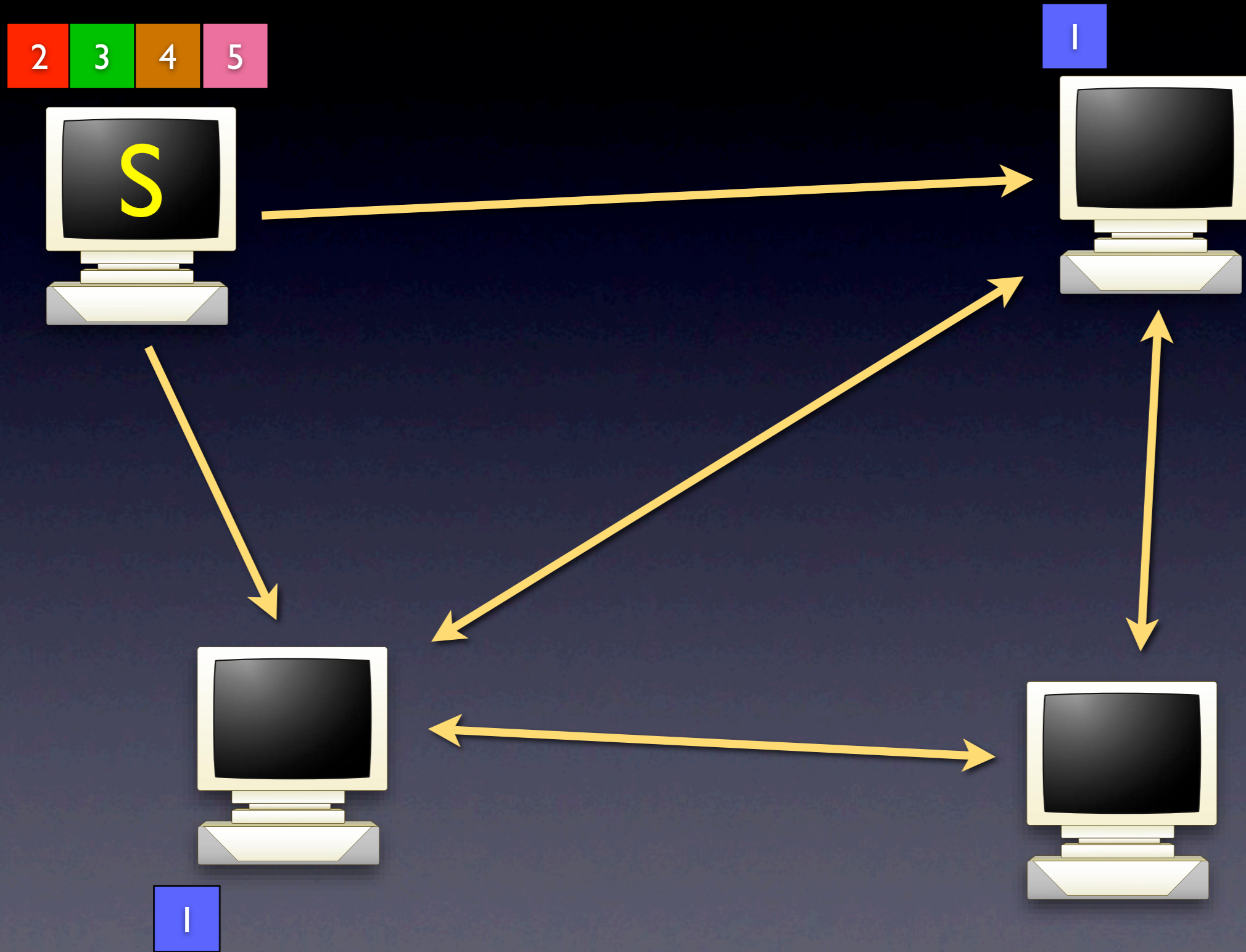
PPLive design



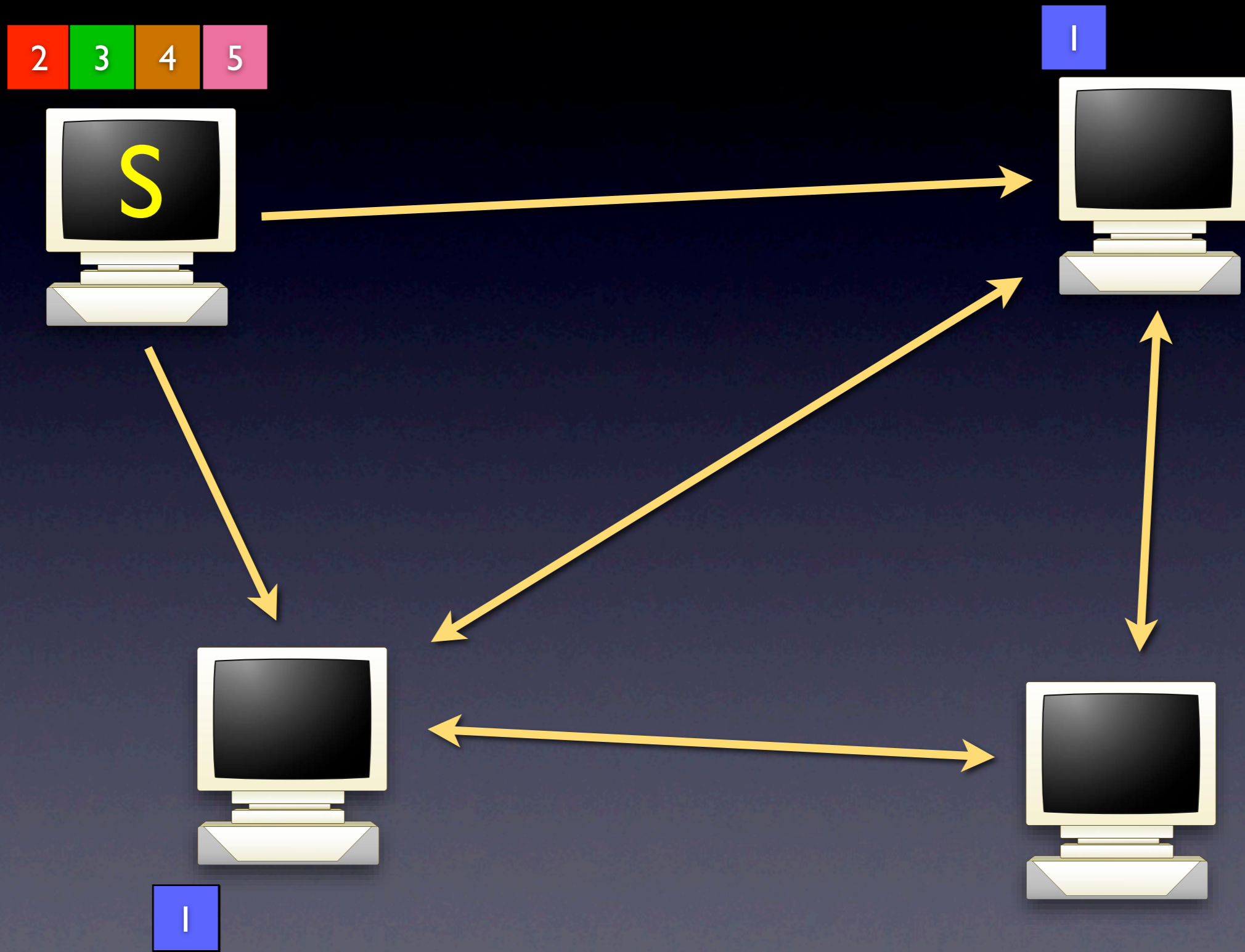
PPLive design



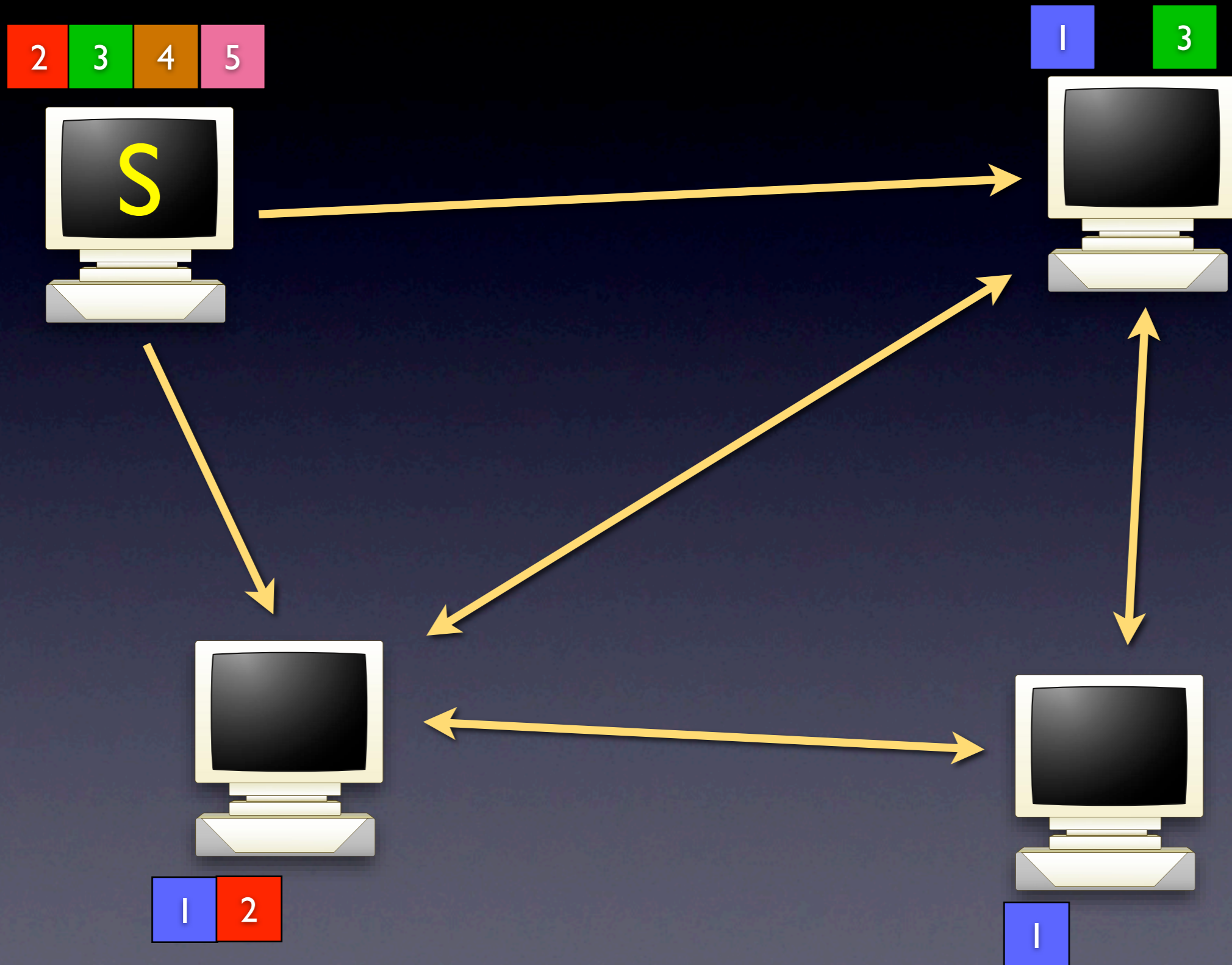
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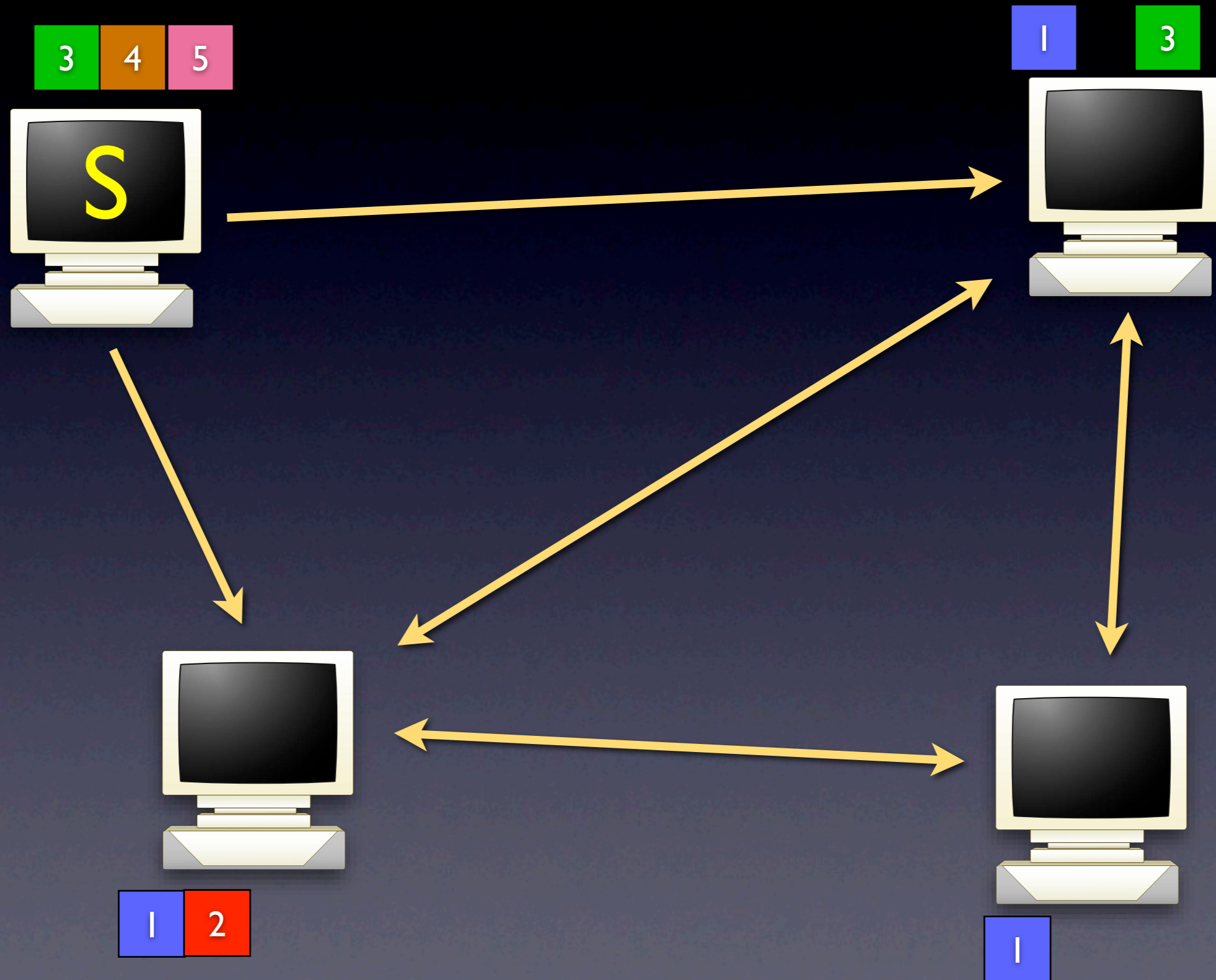
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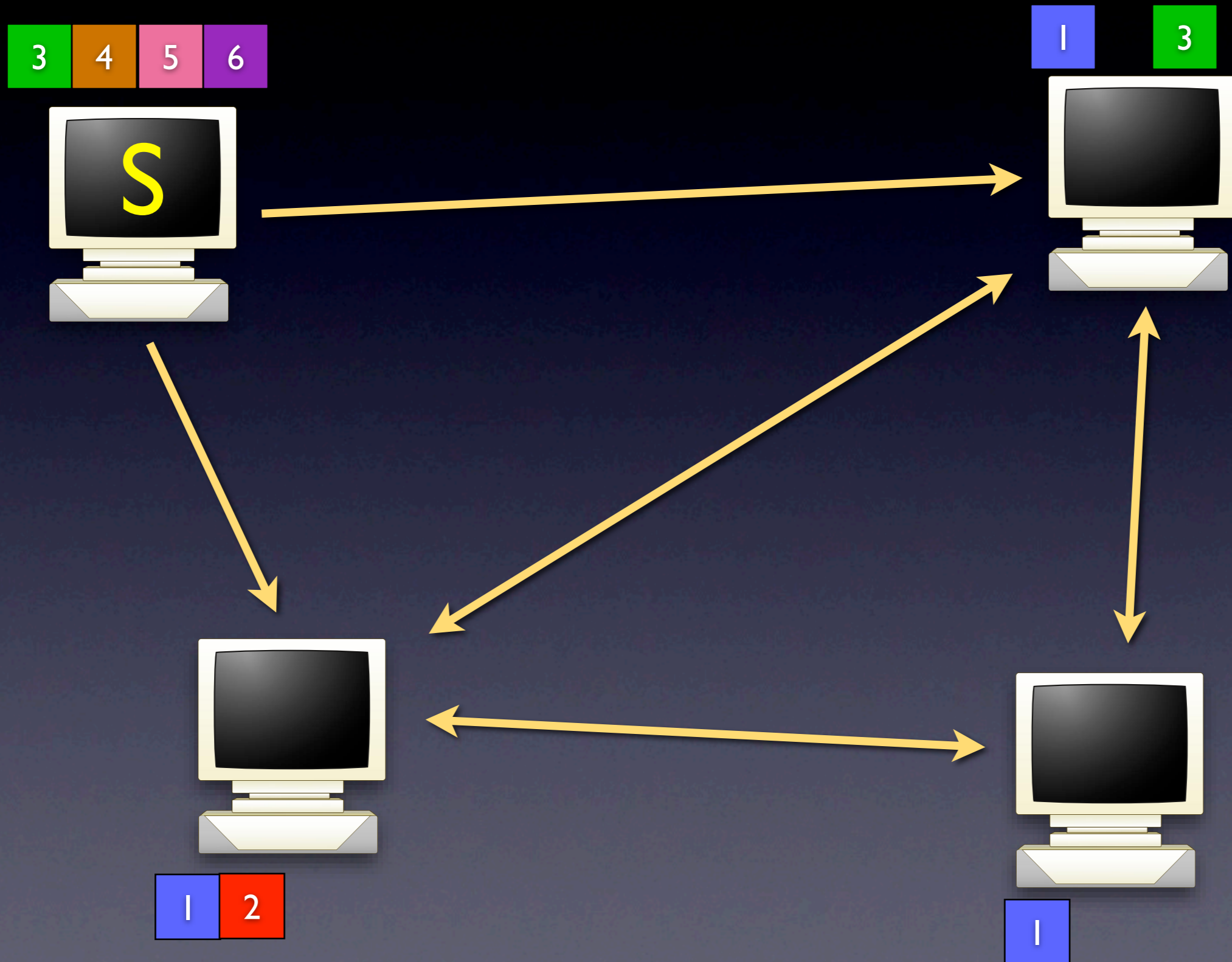
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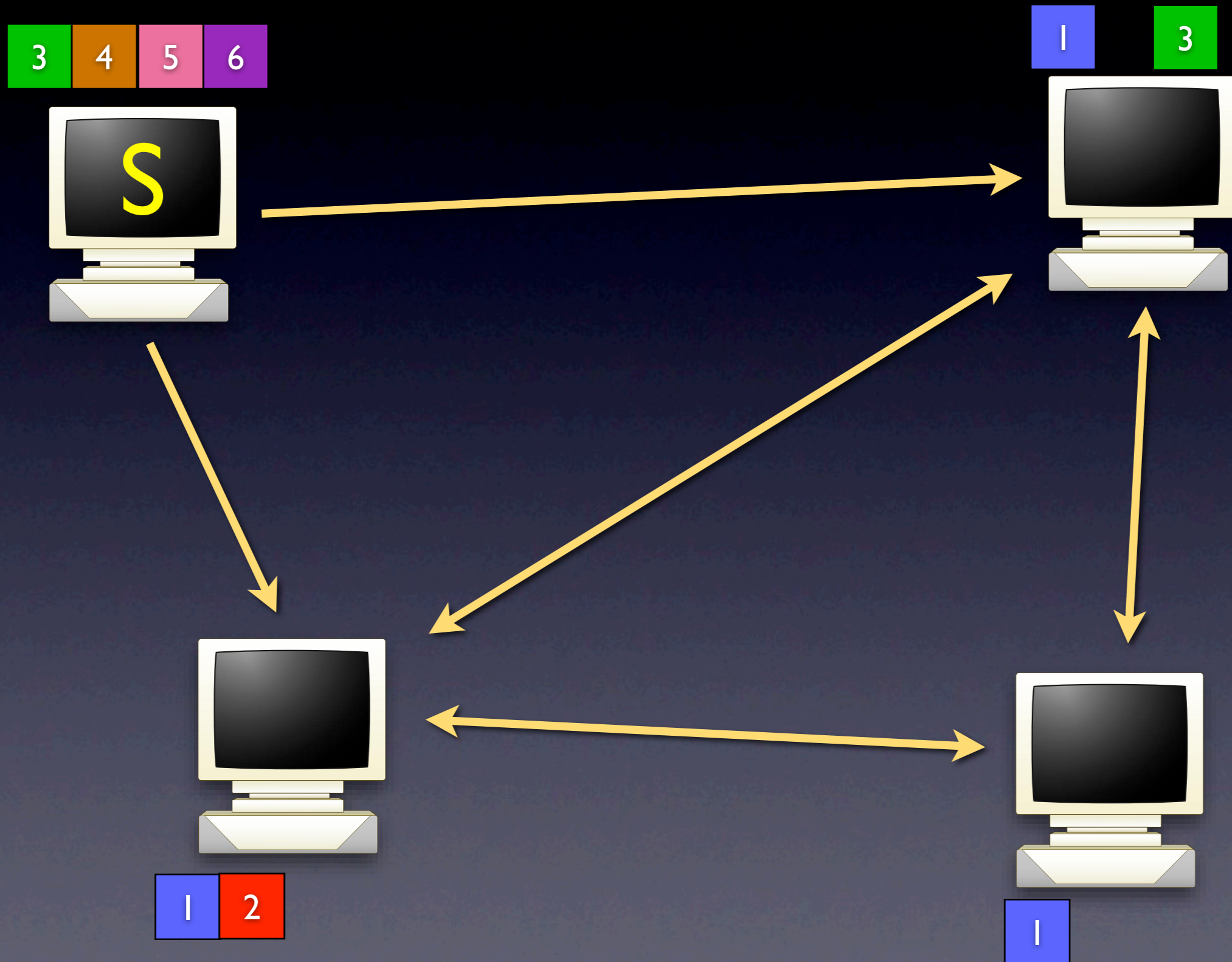
PPLive design



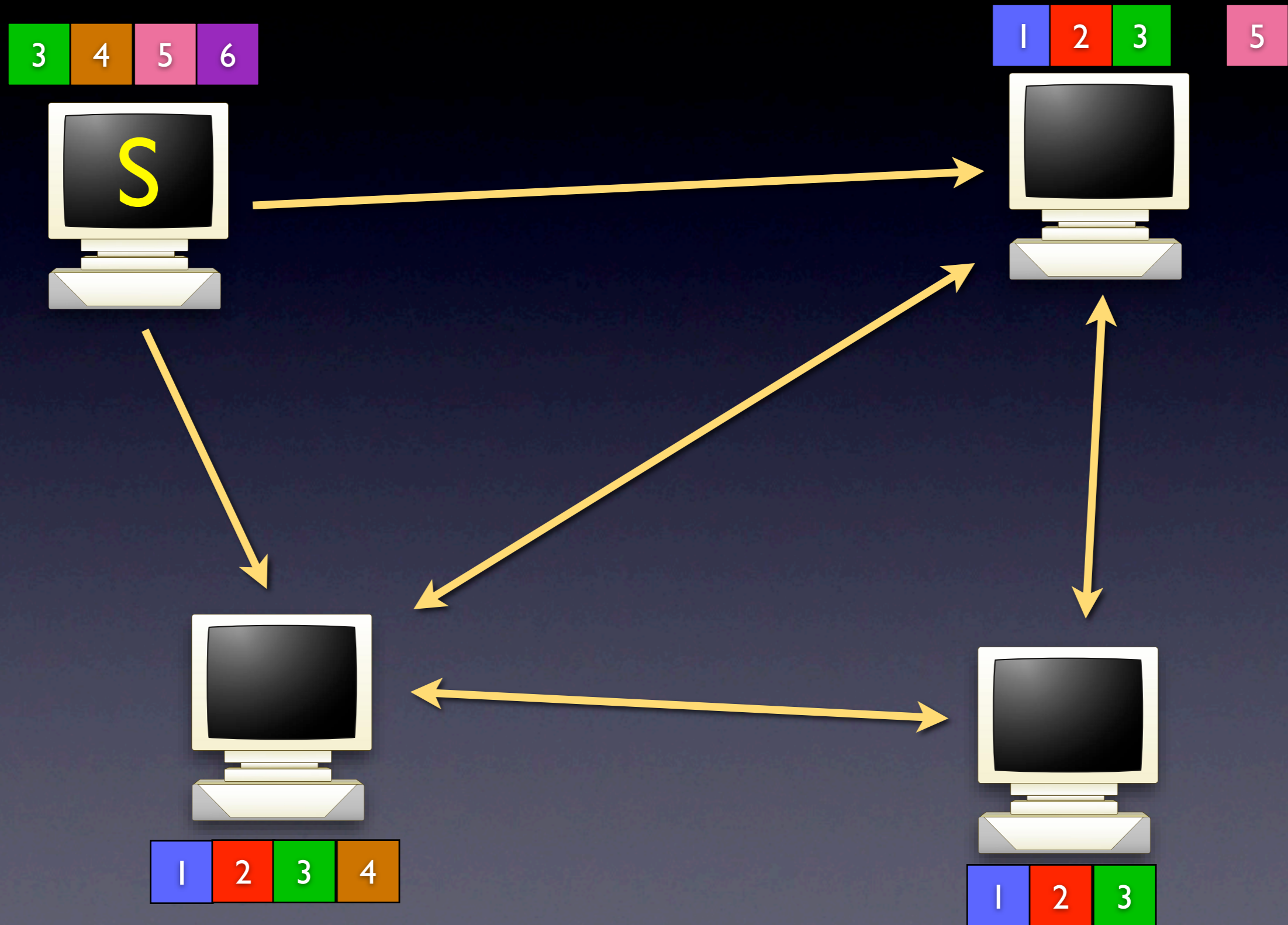
PPLive design



PPLive design



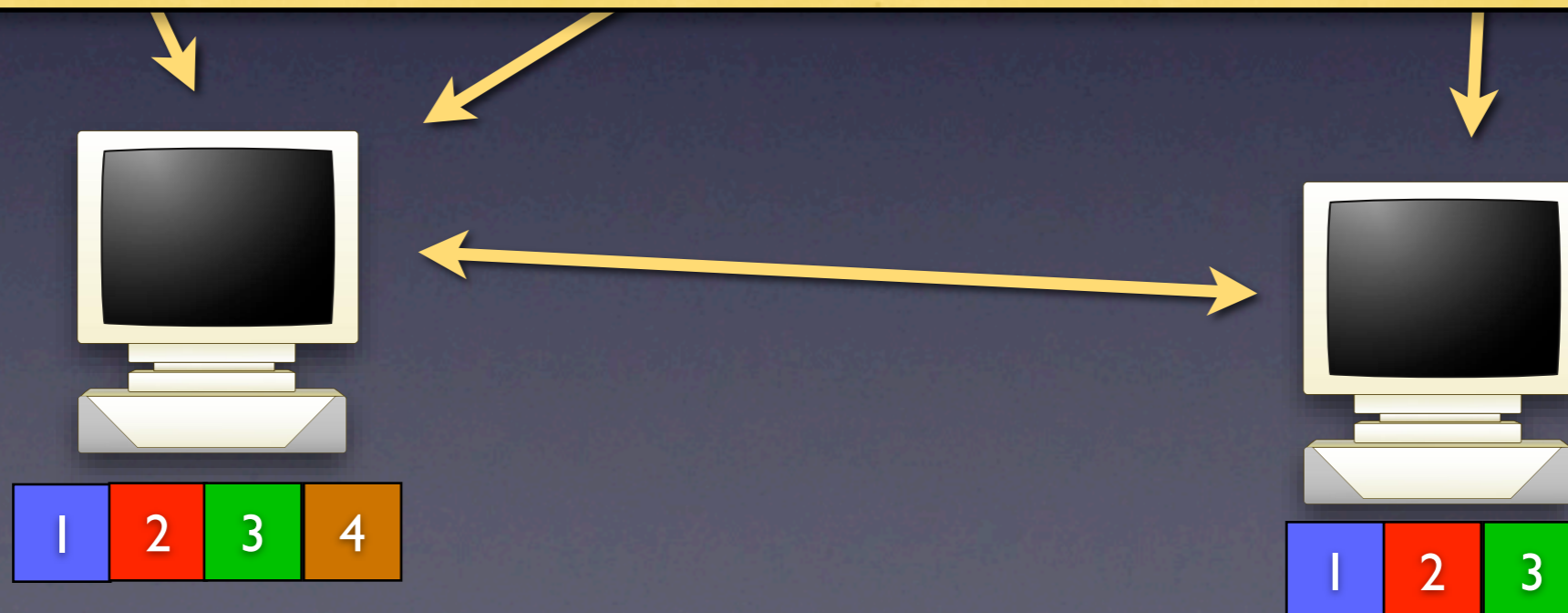
PPLive design



PPLive design



Wire-level protocol very similar to BitTorrent



Can we apply tit-for-tat?

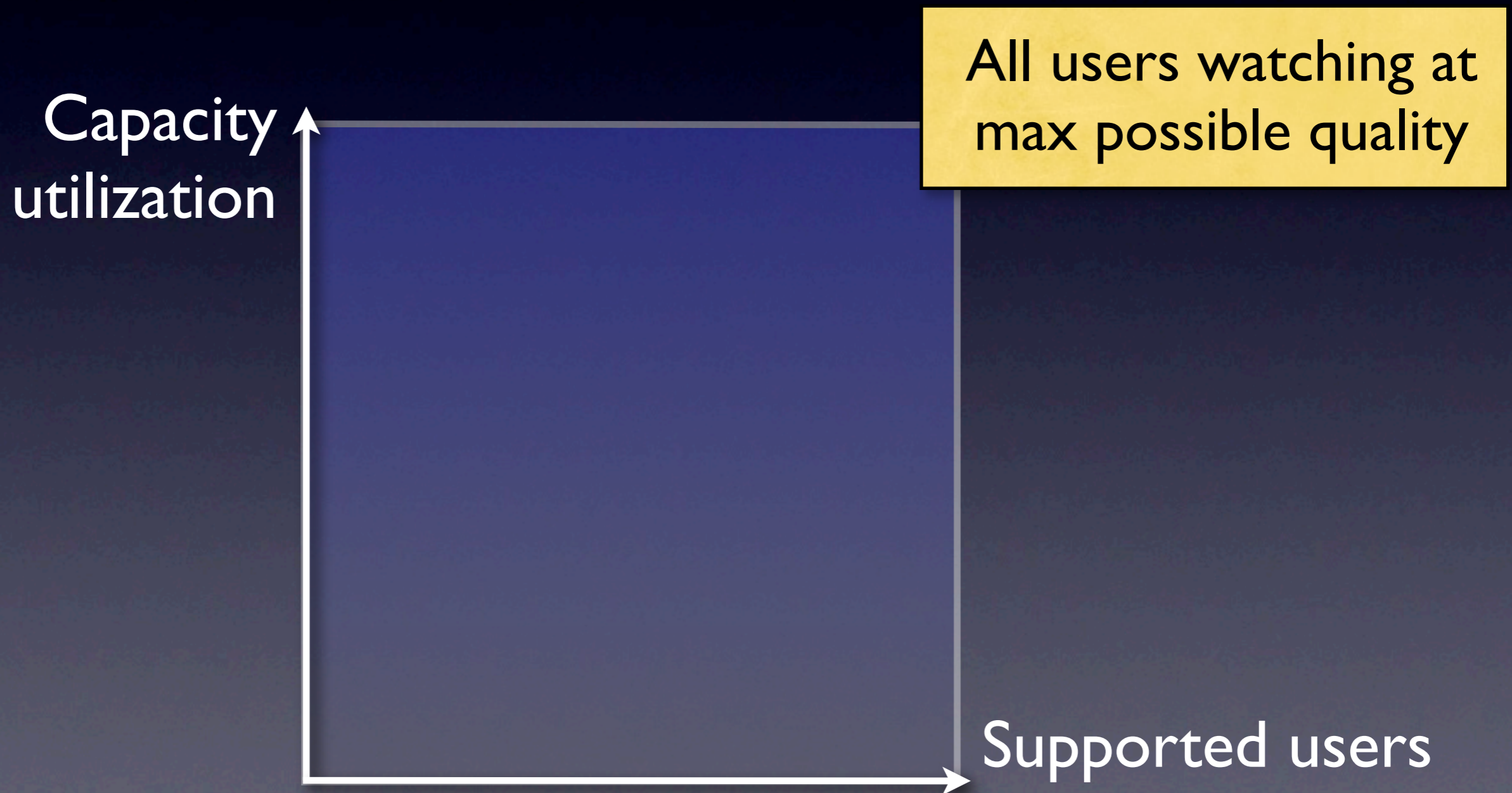
- *Bilateral reciprocation*:
Contribute to peers that contributed to you
- *Challenges* for live streaming:
 - Capacity *heterogeneity*
 - Limited *trading opportunities*
 - No *compelling reward*

Capacity heterogeneity

- *Top 10%* of users contribute *58% of total capacity*

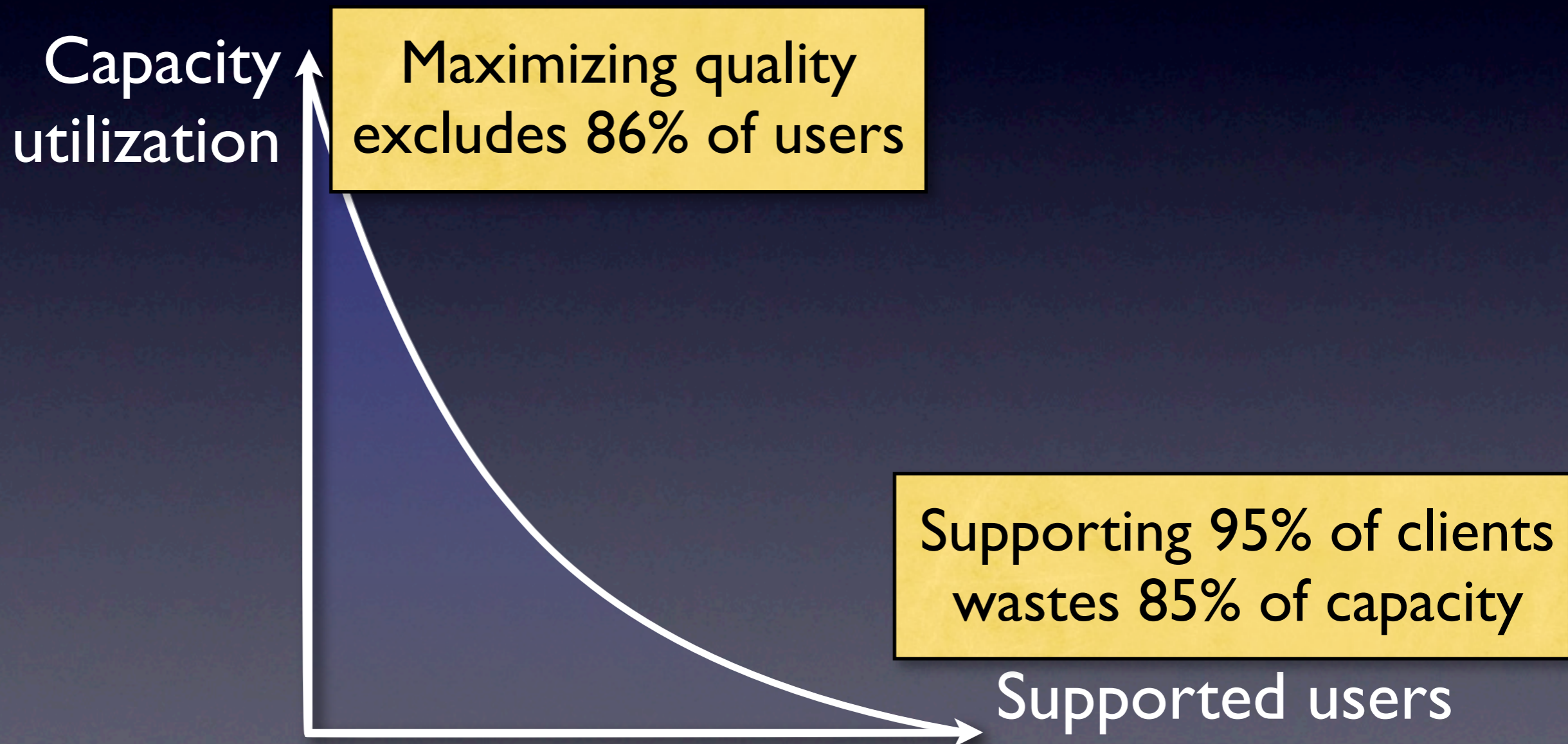
Capacity heterogeneity

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Capacity heterogeneity

- *Top 10%* of users contribute *58% of total capacity*
- With *balanced exchange*:



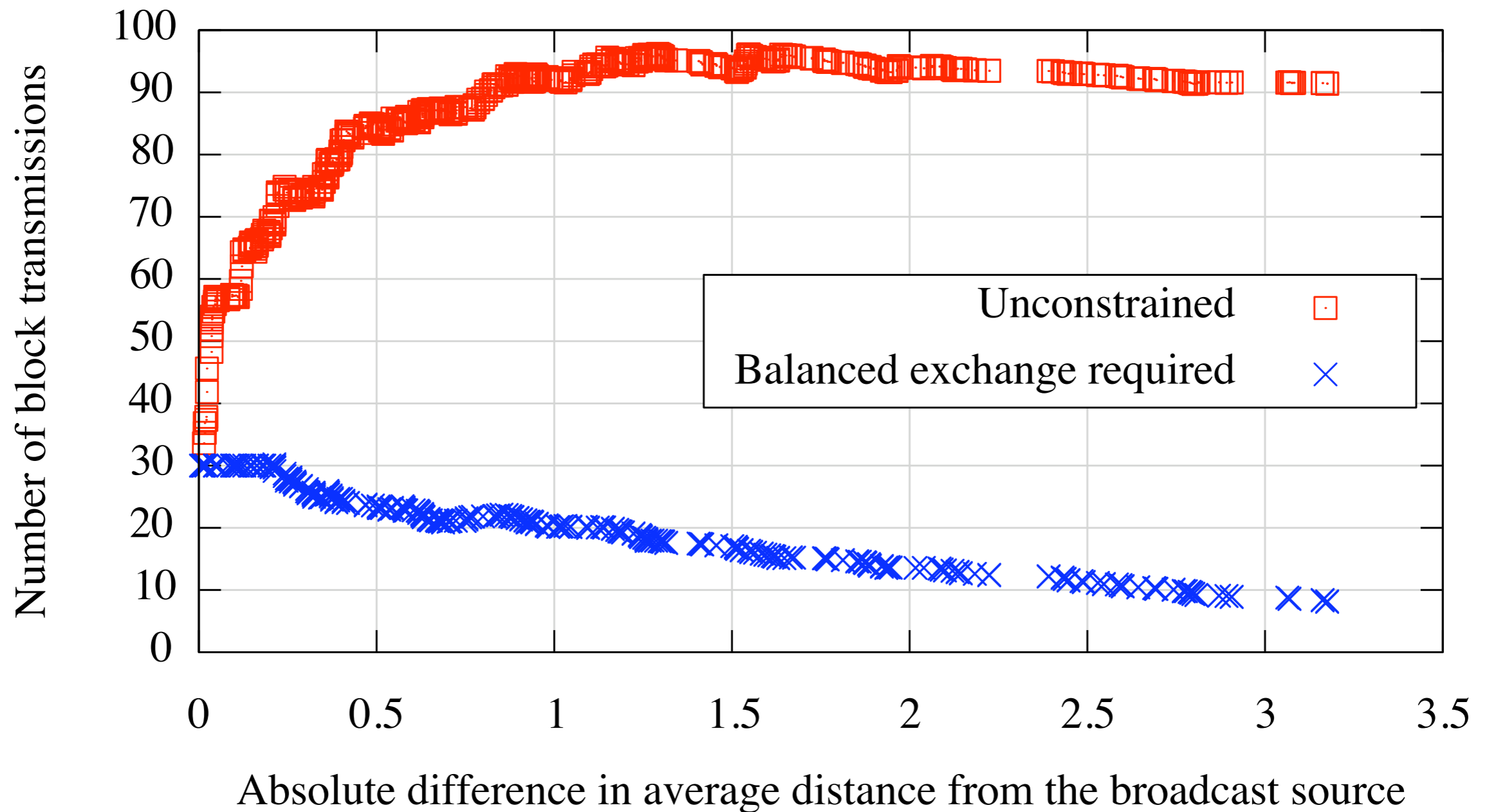
Imbalanced exchange?

- Is *relaxing balance* sufficient?
- Reciprocation depends on *trading opportunities*

- But, live streams *swarm over few blocks*
 - Clients near the source: *block monopoly*
 - Distant clients: *perpetual trade imbalance*

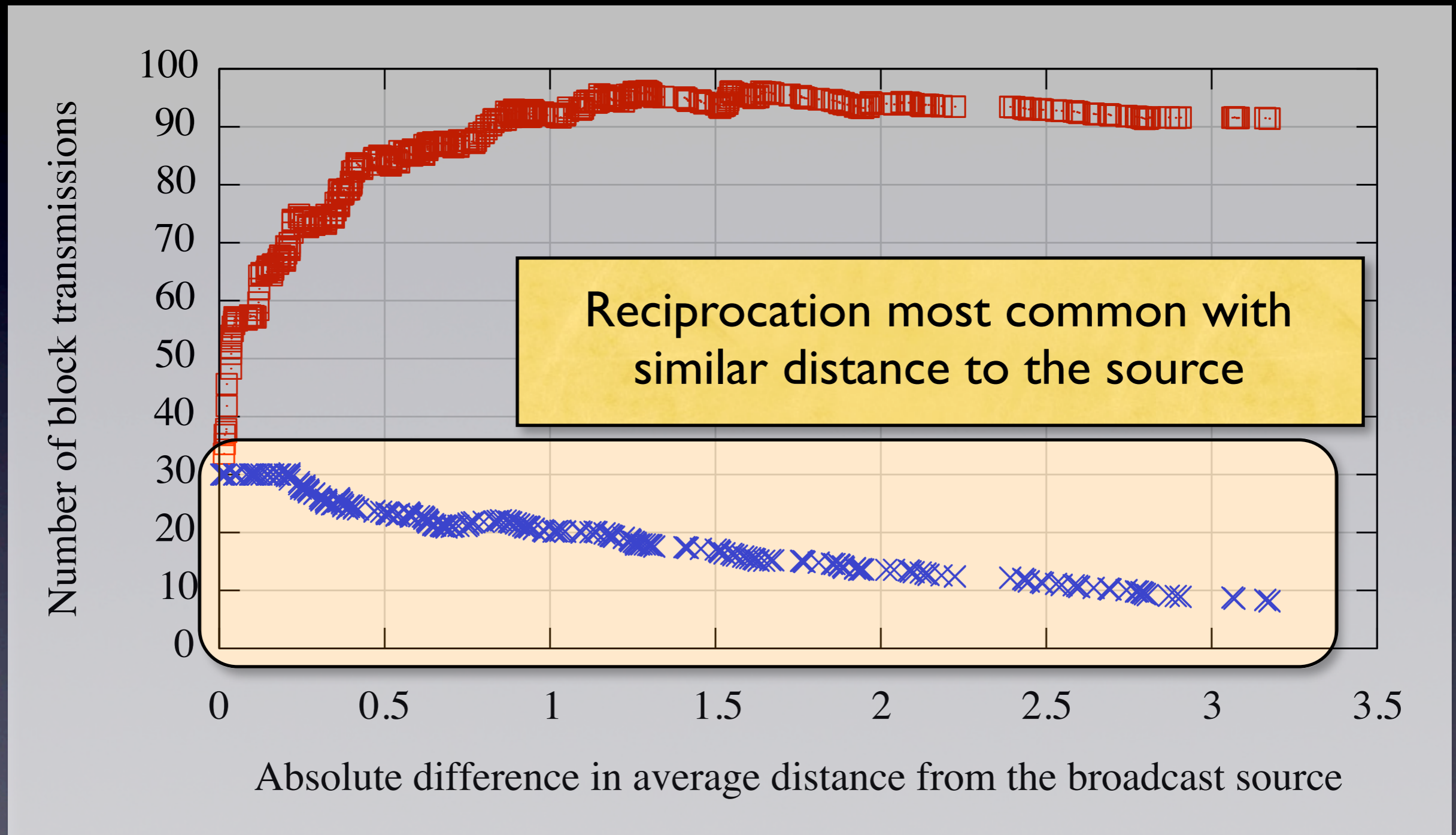
- Outcome: *few trading opportunities*

Transfer opportunities



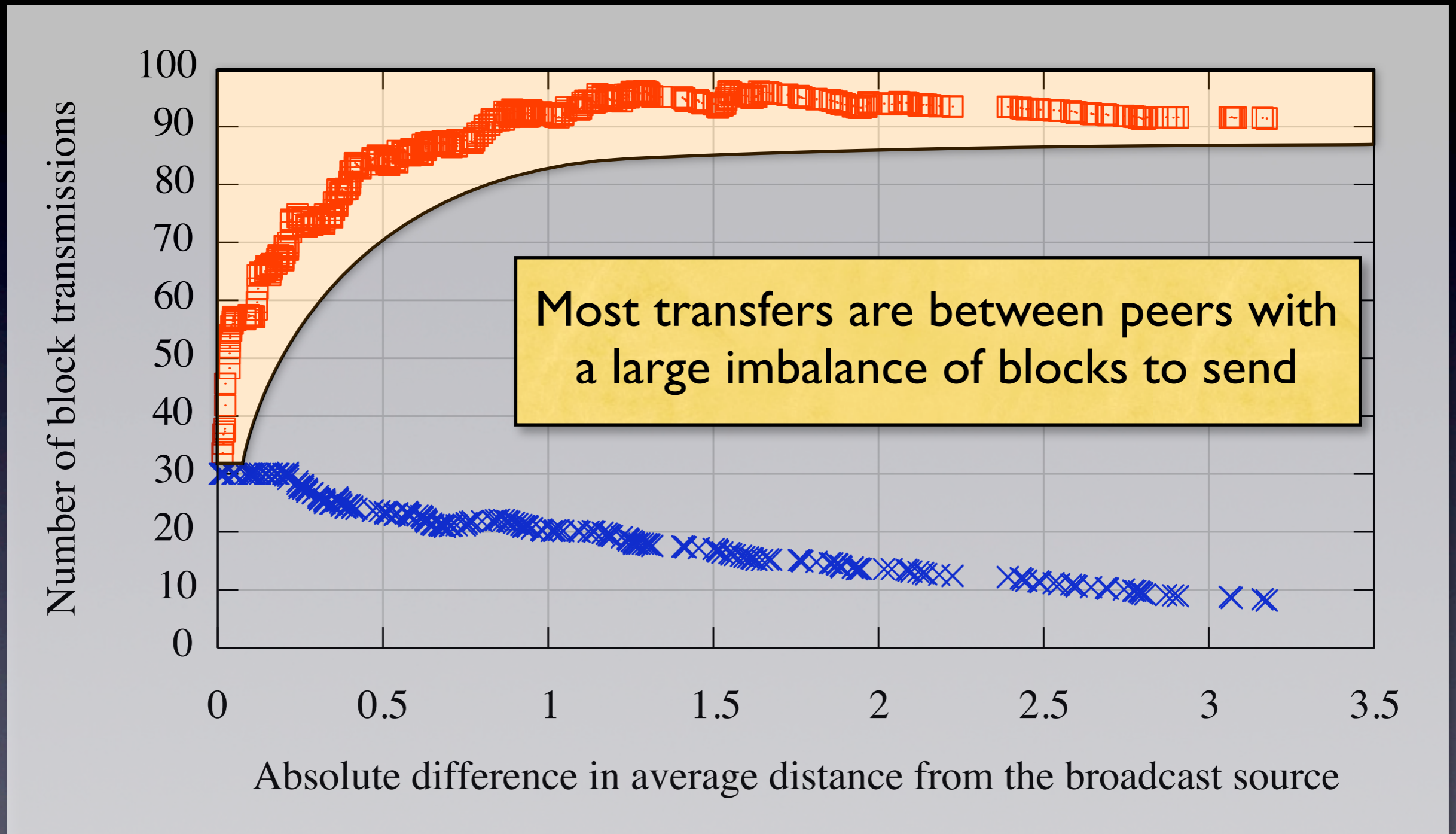
Data availability from a snapshot of client buffer states

Transfer opportunities



Data availability from a snapshot of client buffer states

Transfer opportunities



Data availability from a snapshot of client buffer states

Rewarding contribution

- For bulk data:
Increase contribution rate → *increase download rate*
- Live streaming: *inelastic*
All users download at the stream rate

How to create a compelling reward?

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Contracts design overview

Global evaluation *contract* rather than
bilateral reciprocation

- Recognizes *globally effective contributions*

Reward contributions with robustness by
optimizing the overlay topology

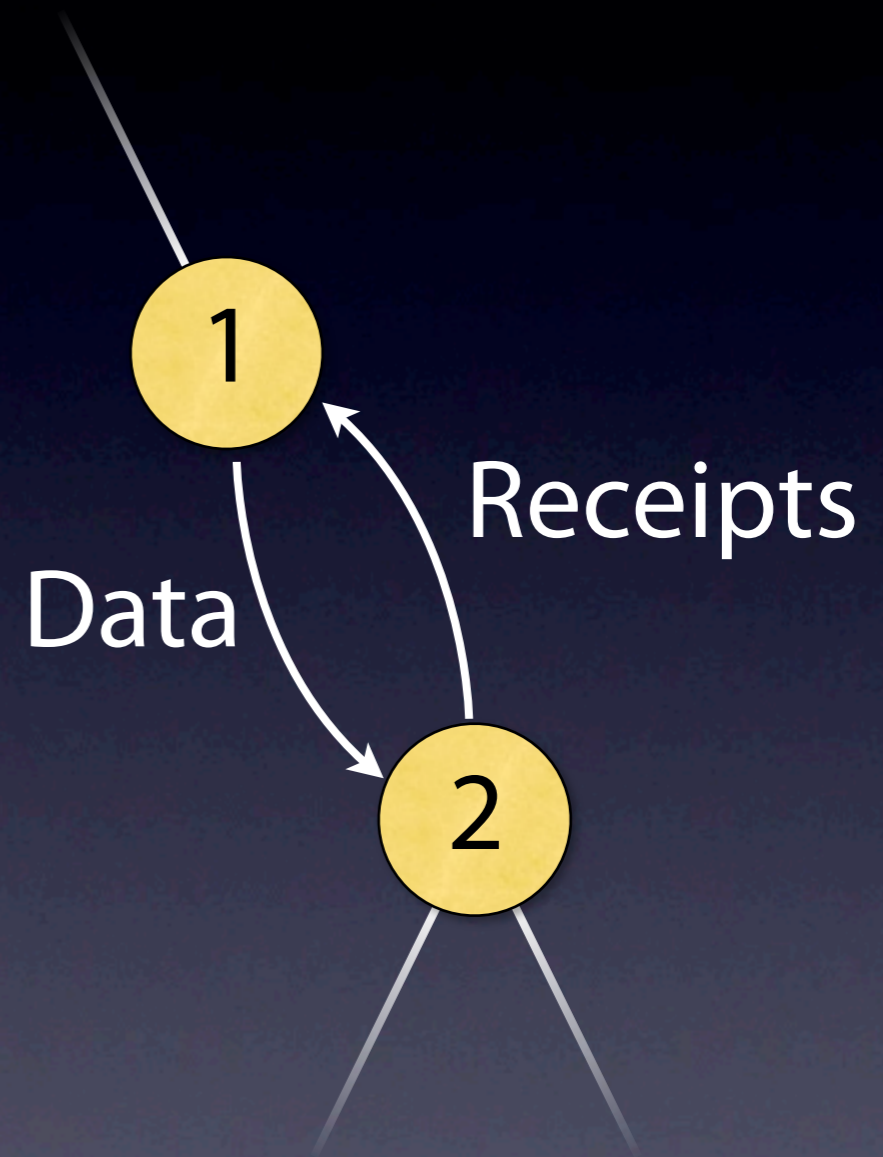
- If the system becomes capacity constrained,
contributors fail last

Evaluating contributions

- Goals:
 1. *Contribute capacity*
 - As in any P2P system, contributions required
 2. *Choose effective peers*
 - Live streaming has playback deadlines
 - Prioritize peers that replicate data quickly

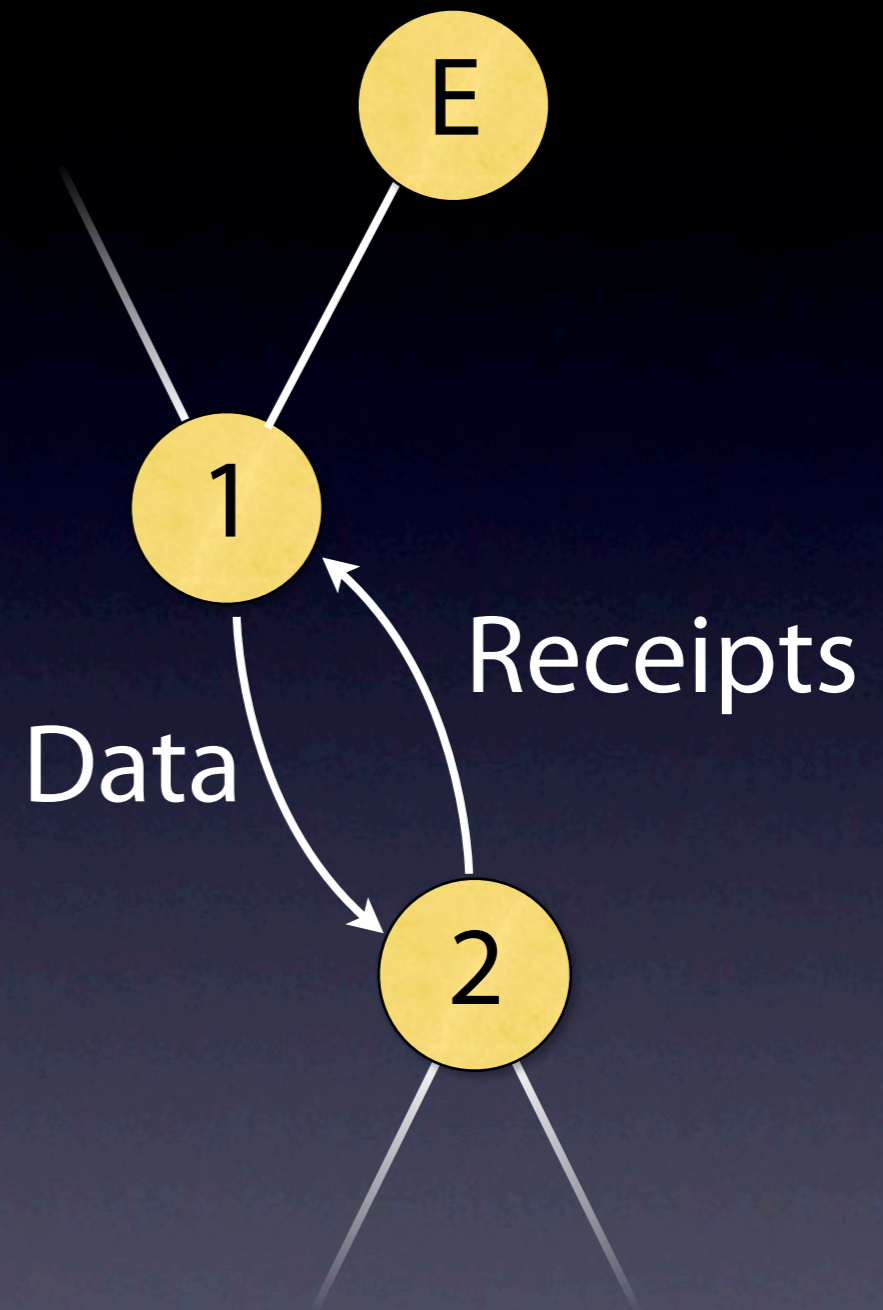
Tracking contributions

- *Cryptographic receipts* attest to the contributions of peers
- Presented to other peers to *demonstrate contributions*



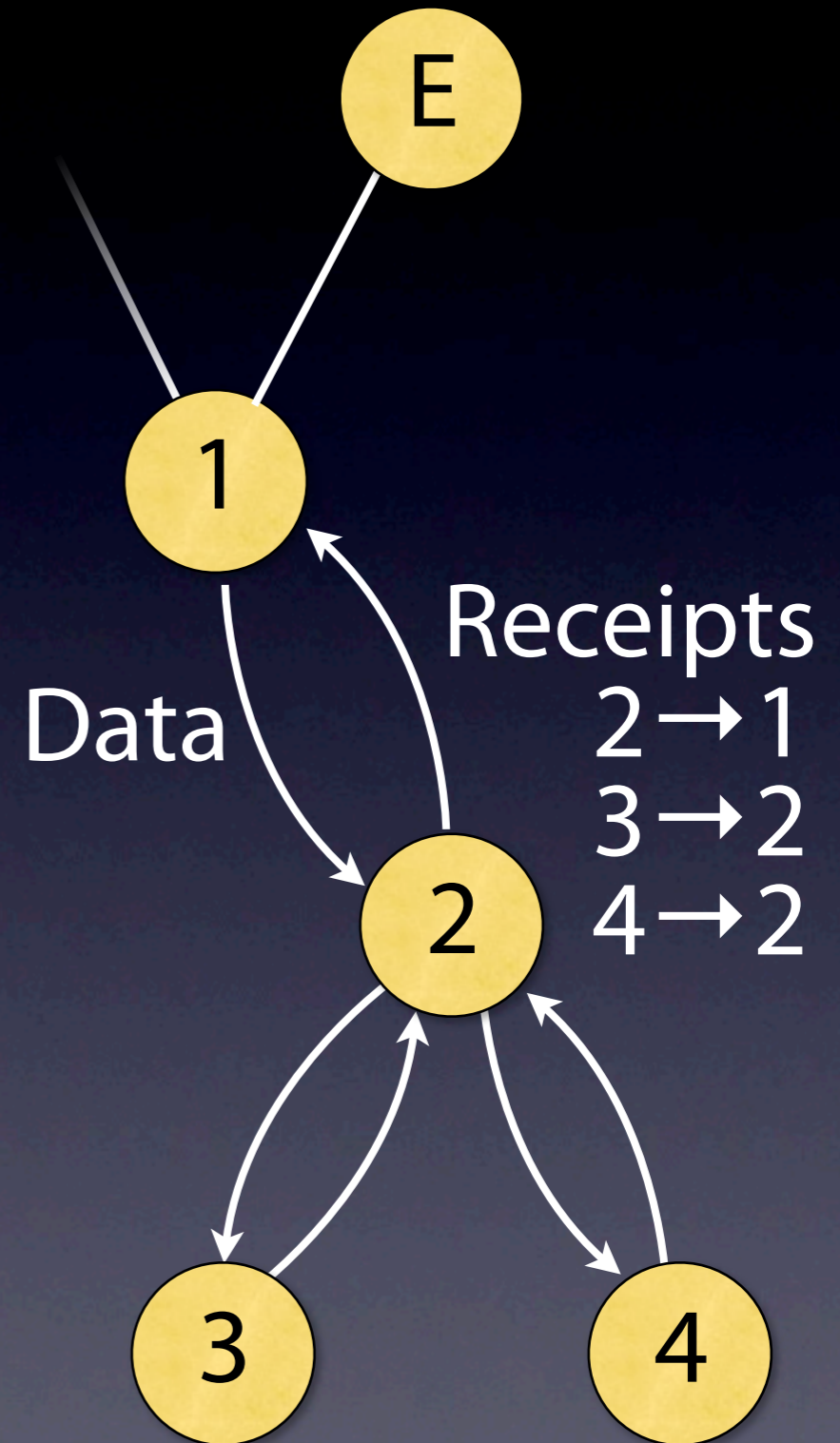
Tracking contributions

- *Cryptographic receipts* attest to the contributions of peers
- Presented to other peers to *demonstrate contributions*
(From 1 to E, for example)



Tracking effectiveness

- *Gossip receipts* in a one hop neighborhood
- Allows **E** to compute:
 - *Effectiveness* of peers (**1**)
 - *Contributions* of peers of peers (**2**)
- Clients *prioritize effective peers*



Evolving the topology

- *Compute contributions* of distant peers using forwarded receipts
- Preferentially *connect to highest capacity* peers
Prune unproductive peers
- *High capacity peers:* percolate towards the source
- *Low capacity peers:* pushed to mesh periphery

Evolving the topology

- *Compute contributions* of distant peers using forwarded receipts

Because failures cascade, proximity to the source improves quality of service

- *High capacity peers:* percolate towards the source
- *Low capacity peers:* pushed to mesh periphery

Collusion defenses

- *Limit identity creation* at PPLive coordinator
- Weight contributions by *diversity of network addresses*
- *Flow integrity check* –
Incoming data rate cannot exceed stream rate
Outgoing data rate cannot exceed capacity

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Evaluation overview

This talk

- Contracts improves performance
- Contracts strengthens contribution incentives

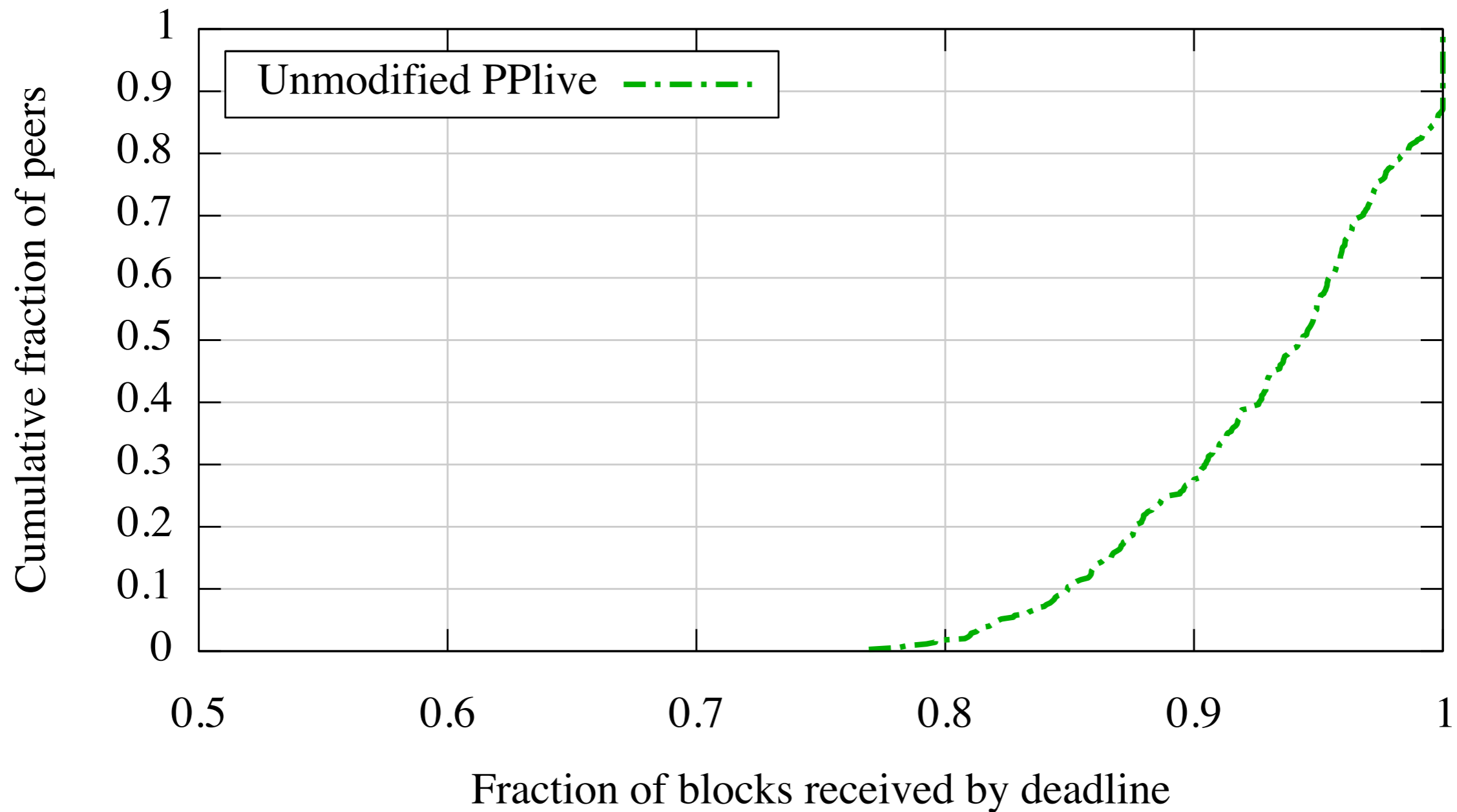
Paper

- Computational and network overhead
- Comparison with FlightPath [OSDI'08]
- Topology convergence
- Over-provisioning and loss-rate

Experimental setup

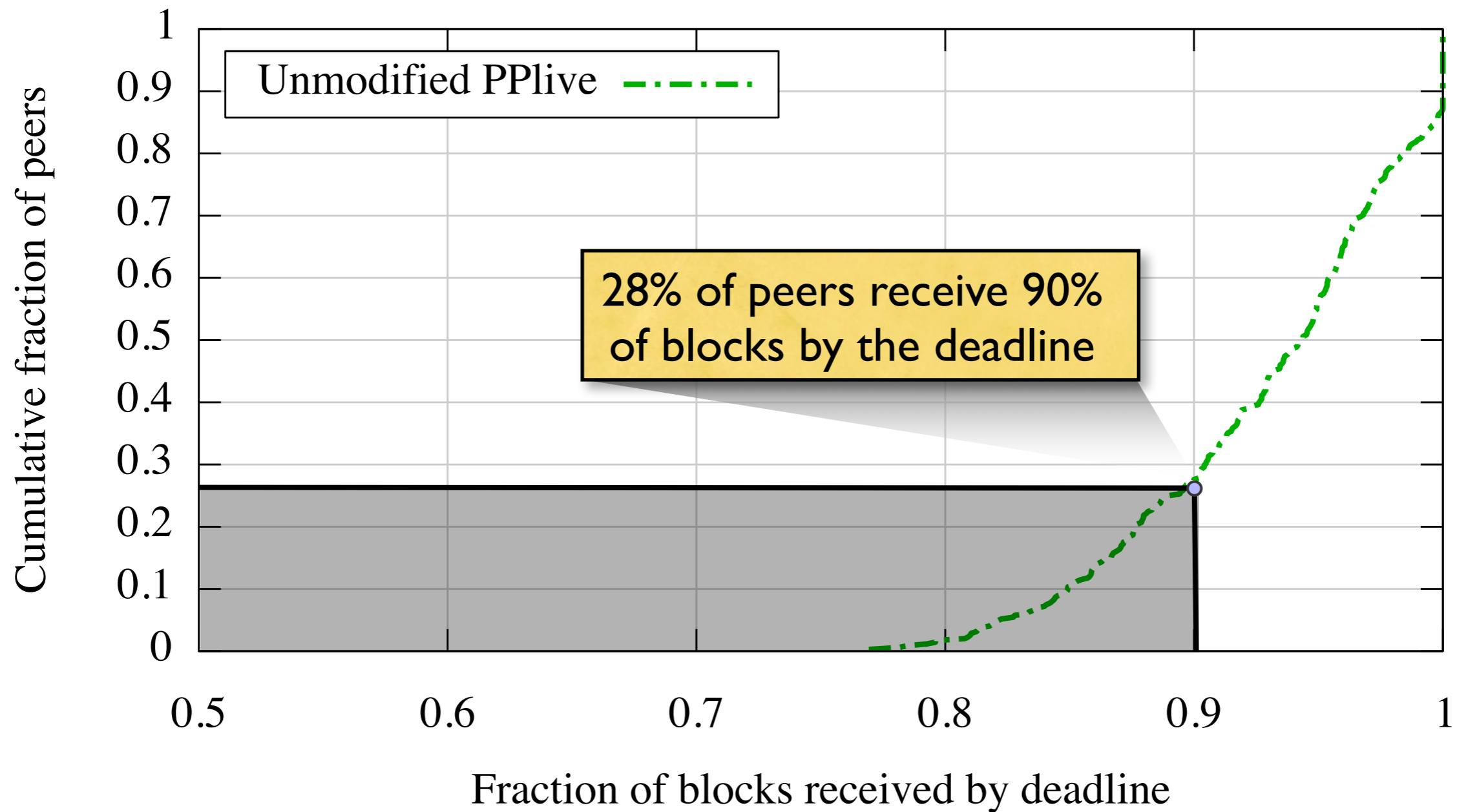
- Modified PPLive to support *Contracts* and rate-based *tit-for-tat*
- Synthetic broadcast on *100 Emulab machines*
- *Churn* from clients joining at 10 second intervals, remaining for 20 minutes, repeating for 2 hours
- *Capacities* from measured distribution of over 90,000 PPLive users

PPLive performance



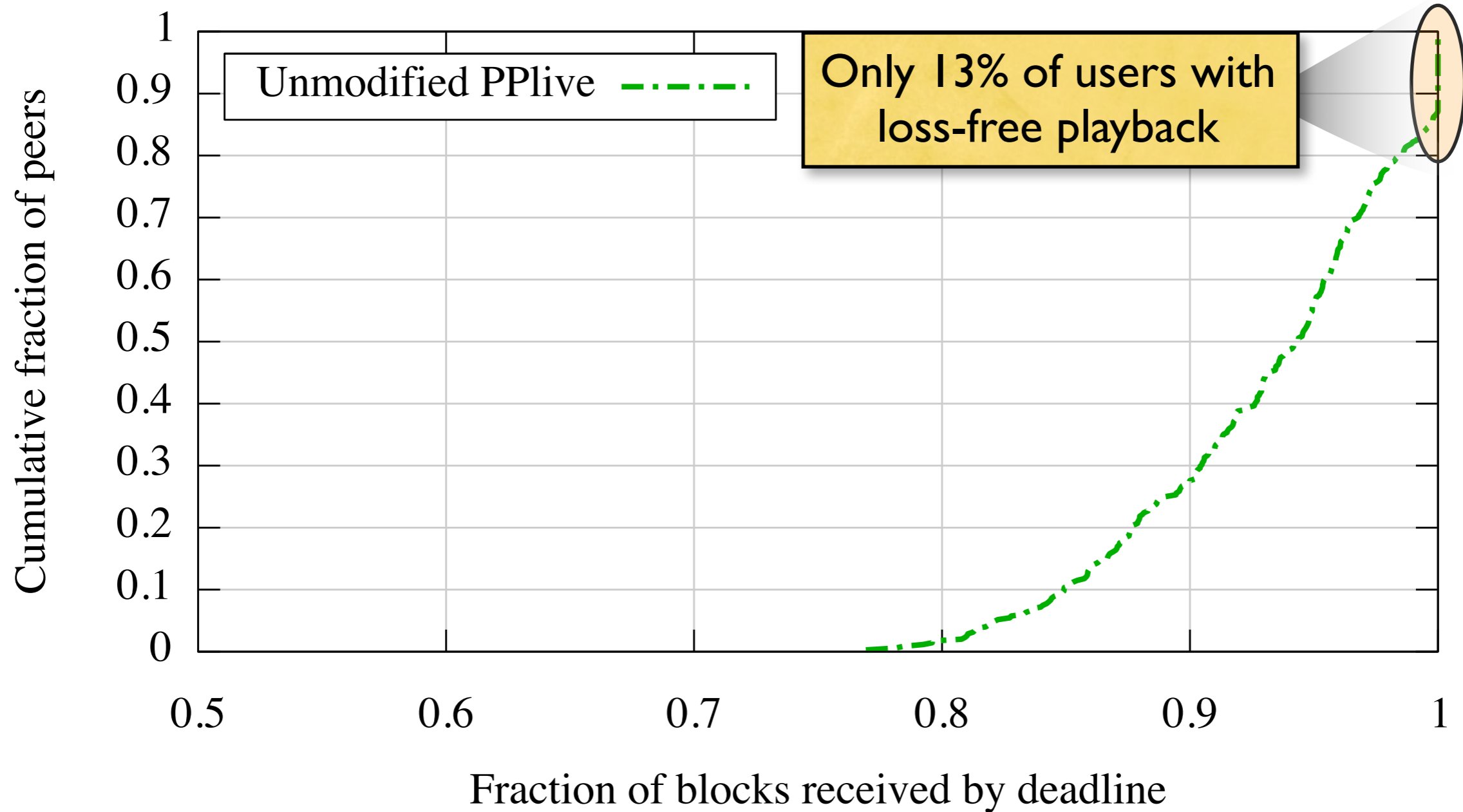
Stream rate chosen to induce capacity constraints

PPLive performance



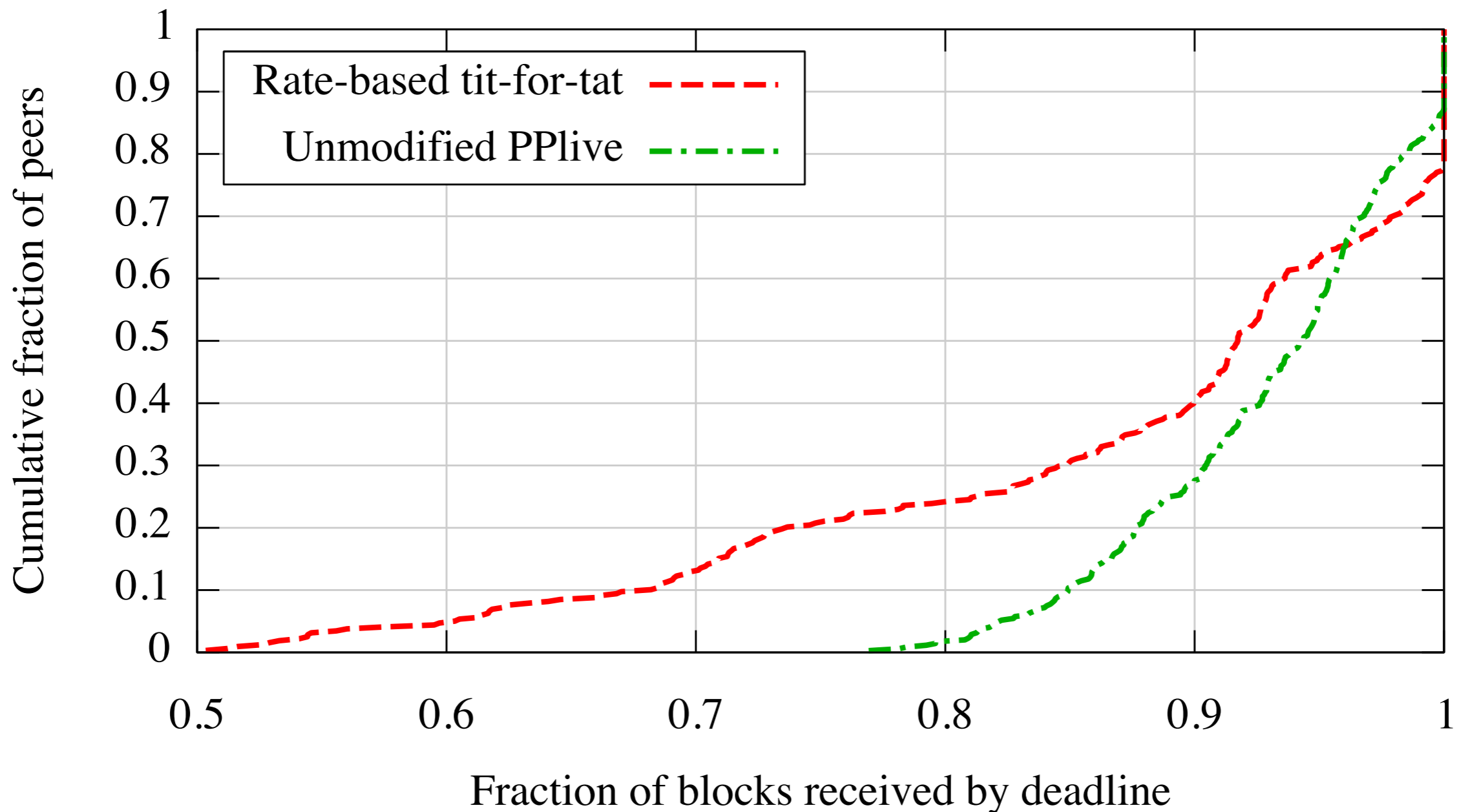
Stream rate chosen to induce capacity constraints

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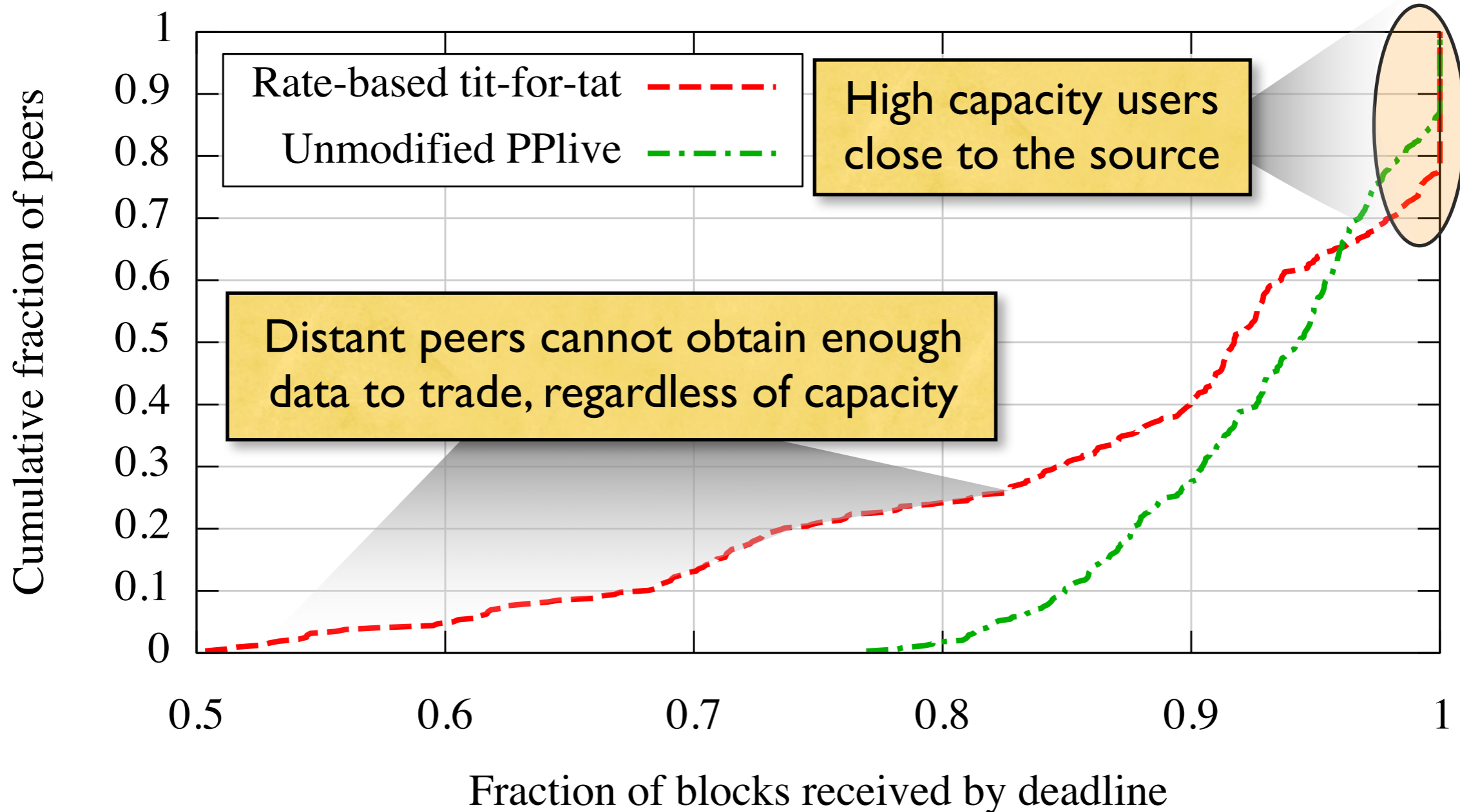
Stream rate chosen to induce capacity constraints

PPLive + tit-for-tat



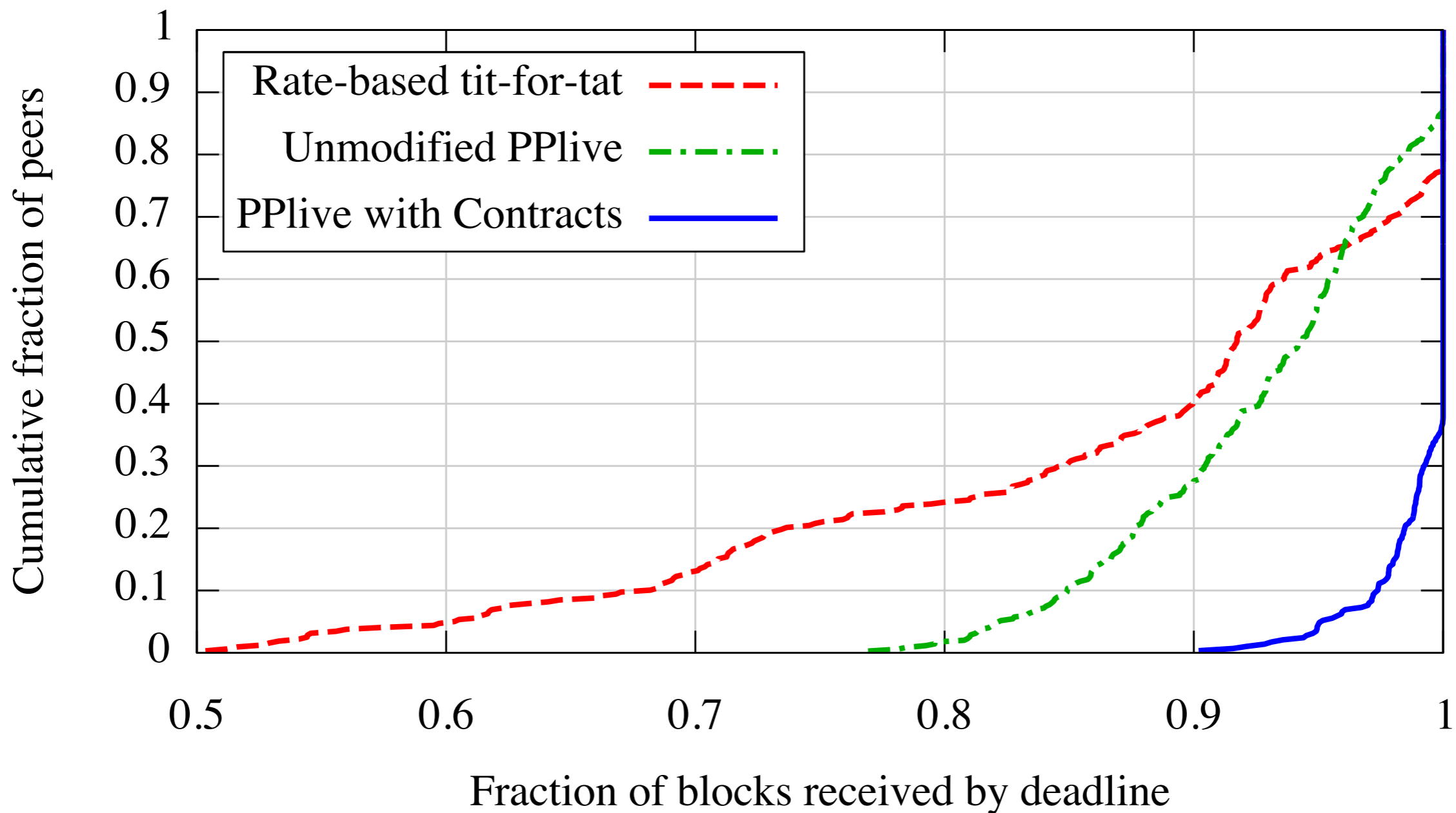
Tit-for-tat reduces performance for live streaming

PPLive + tit-for-tat



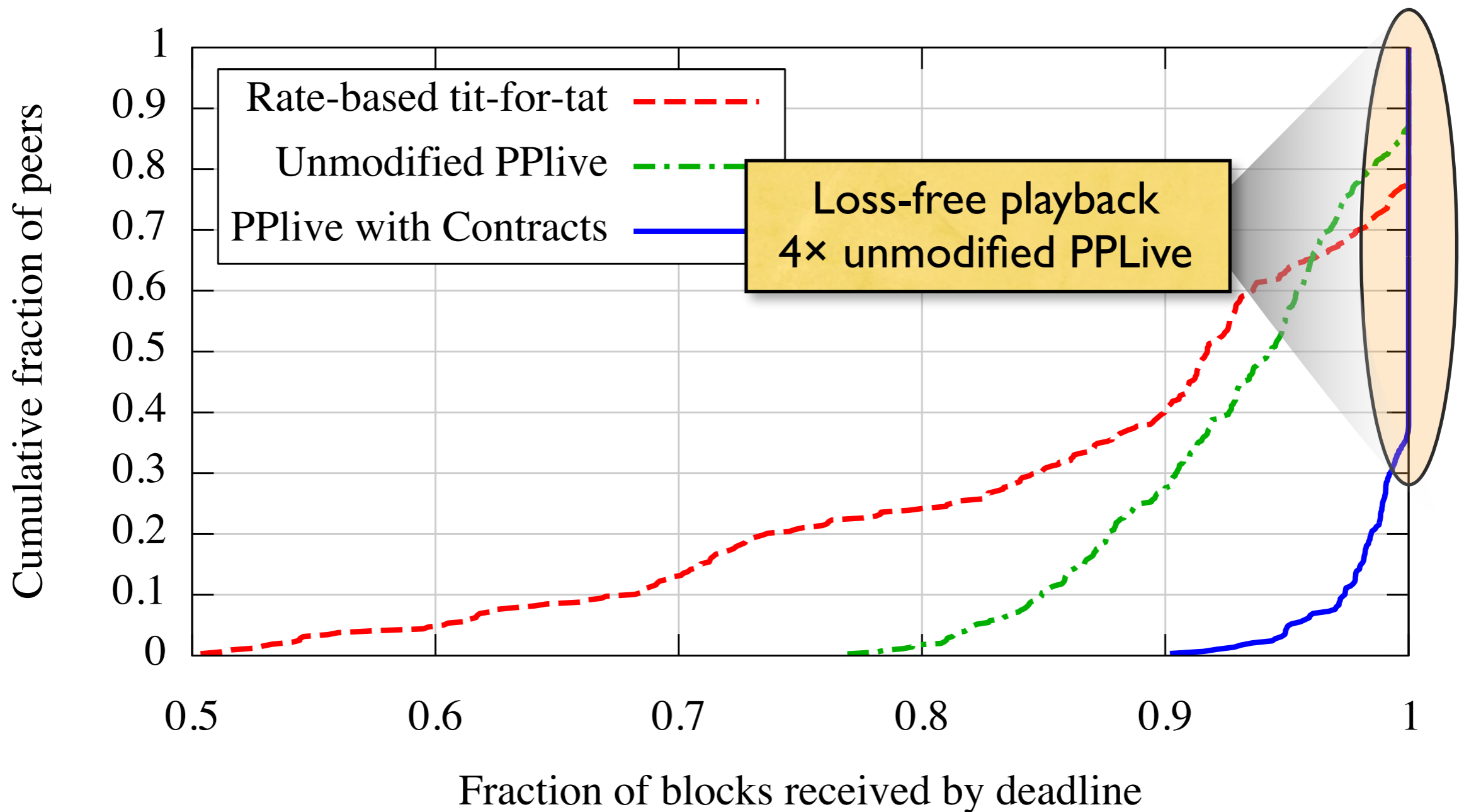
Tit-for-tat reduces performance for live streaming

PPLive + Contracts



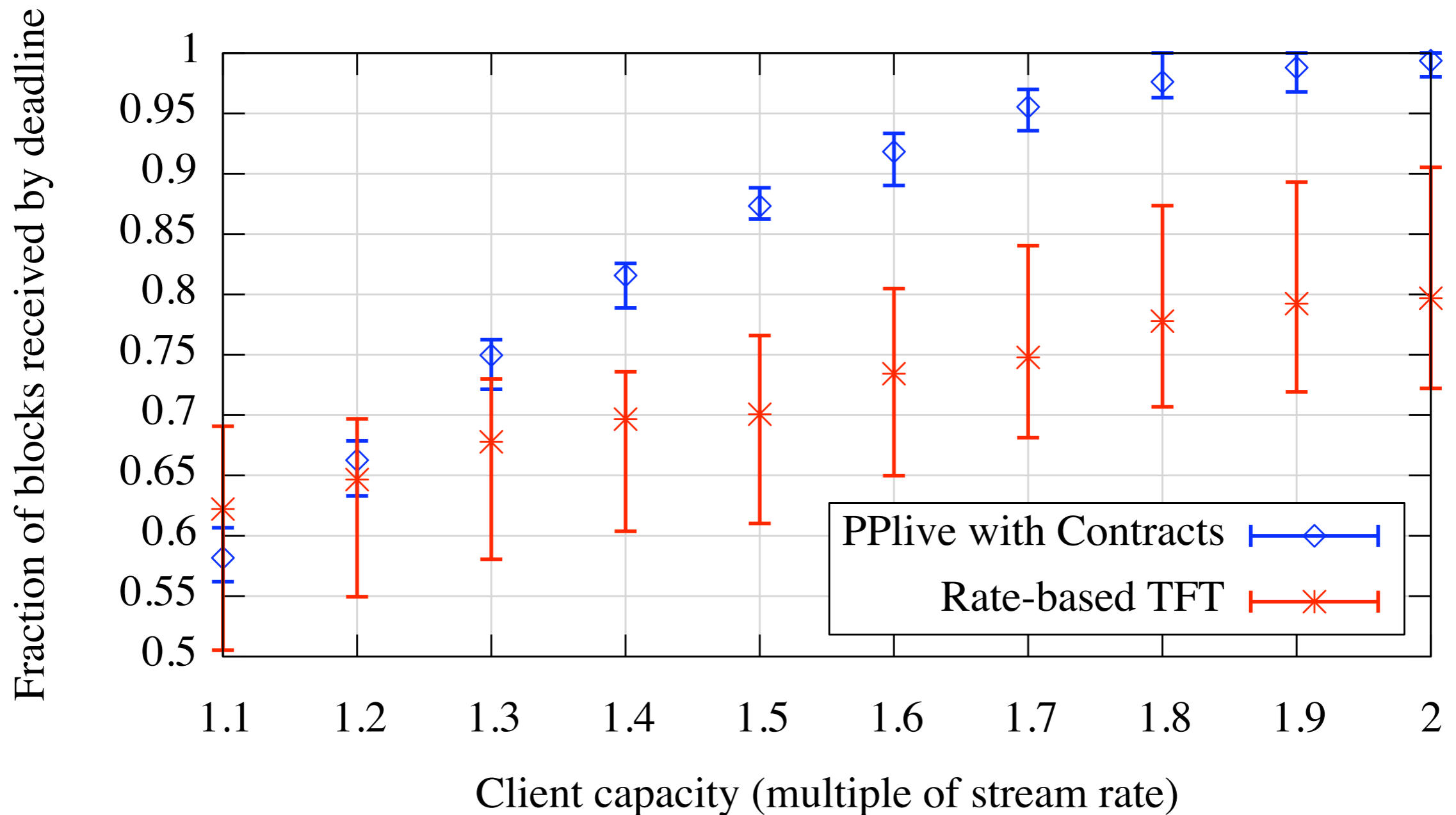
Contracts substantially improves performance

PPLive + Contracts



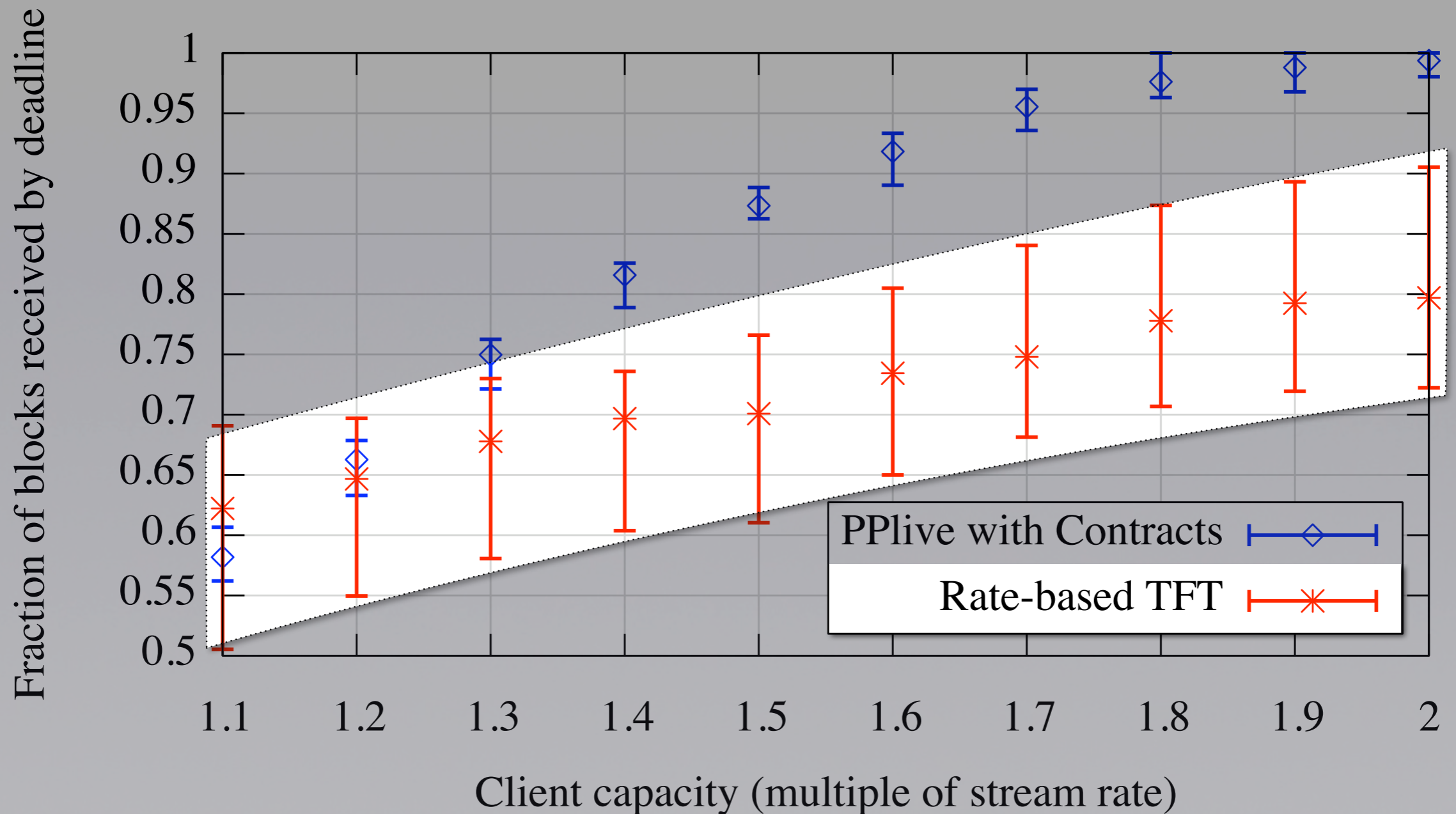
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Incentives



Contracts strengthens contribution incentives

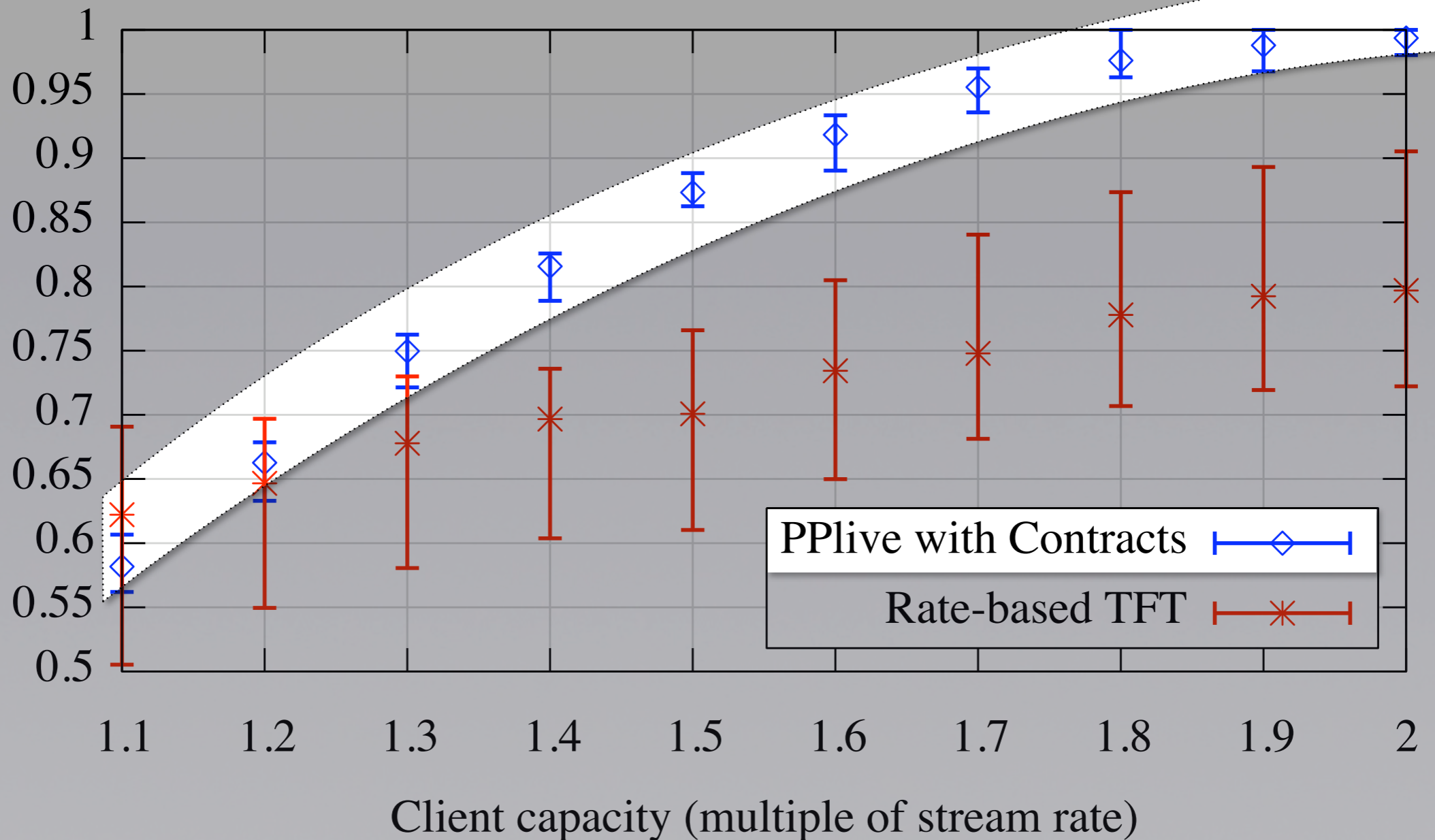
Incentives



Tit-for-tat reward increases slowly, varies widely

Incentives

Fraction of blocks received by deadline



Contracts strengthens contribution incentives

Conclusions

- Live streaming exhibits *new challenges* for fostering P2P contribution incentives
- Contracts improves *performance* and *incentives*
 - *Evaluation contract* rather than bilateral exchange
 - Restructure topology to *reward contributions with quality of service*