# Congestion control: recent perspectives

Brighten Godfrey
cs598pbg Sept 14 2010

# Where we are

| TCP Problem | Solution |
|---|---|
| Fills queues: adds loss, latency | RED (partial), XCP |
| Slow to converge | XCP (partial) |
| Loss ≠ congestion | XCP |
| May not utilize full bandwidth | XCP |
| Unfair to large-RTT | XCP |
| Unfair to short flows | ? |
| Is equal rates really "fair"? | ? |
| Vulnerable to selfishness | XCP & Fair Queueing (partial) |

# Today

RCP

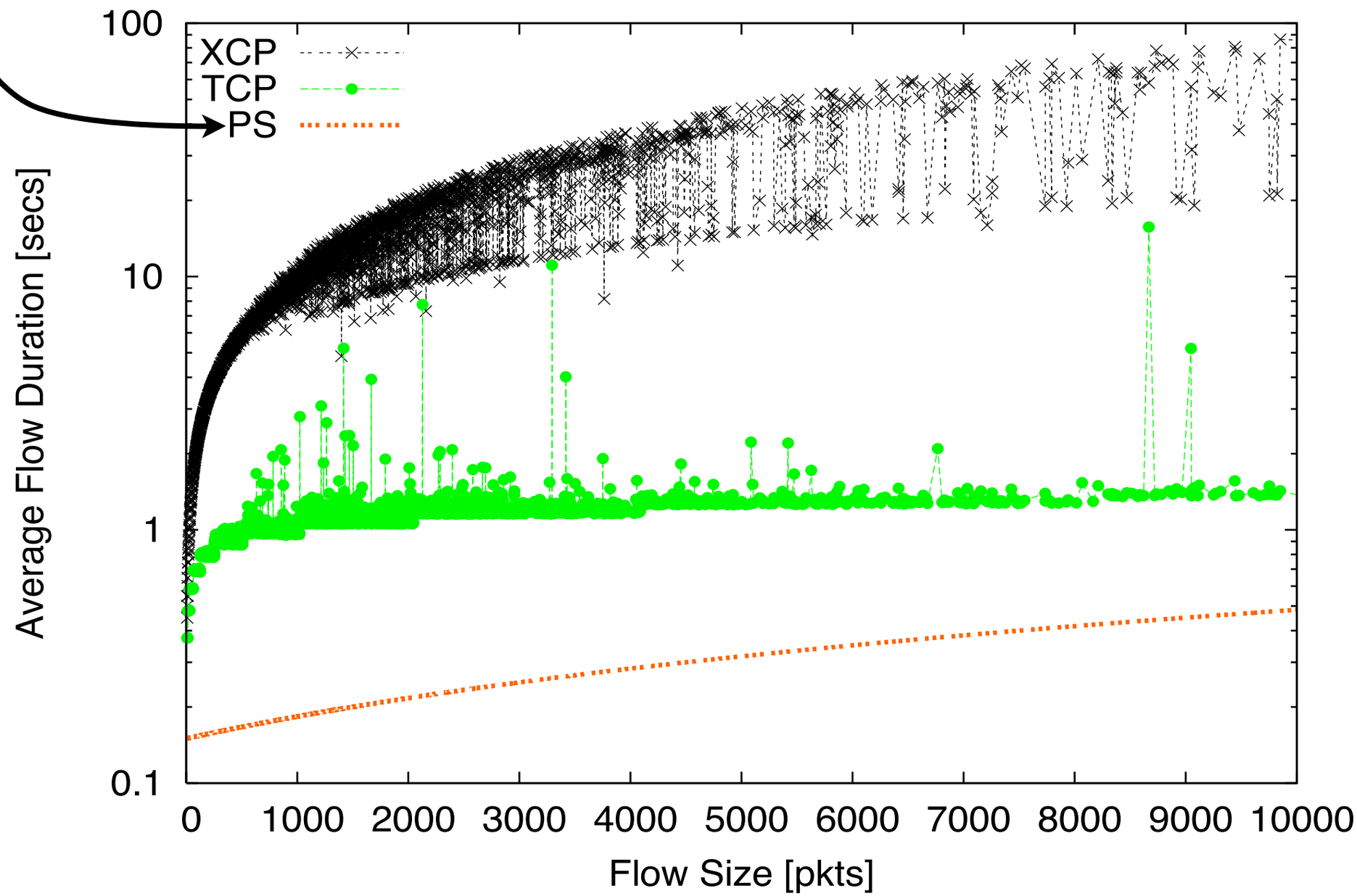
Congestion pricing

Announcements

# Flows finish slowly

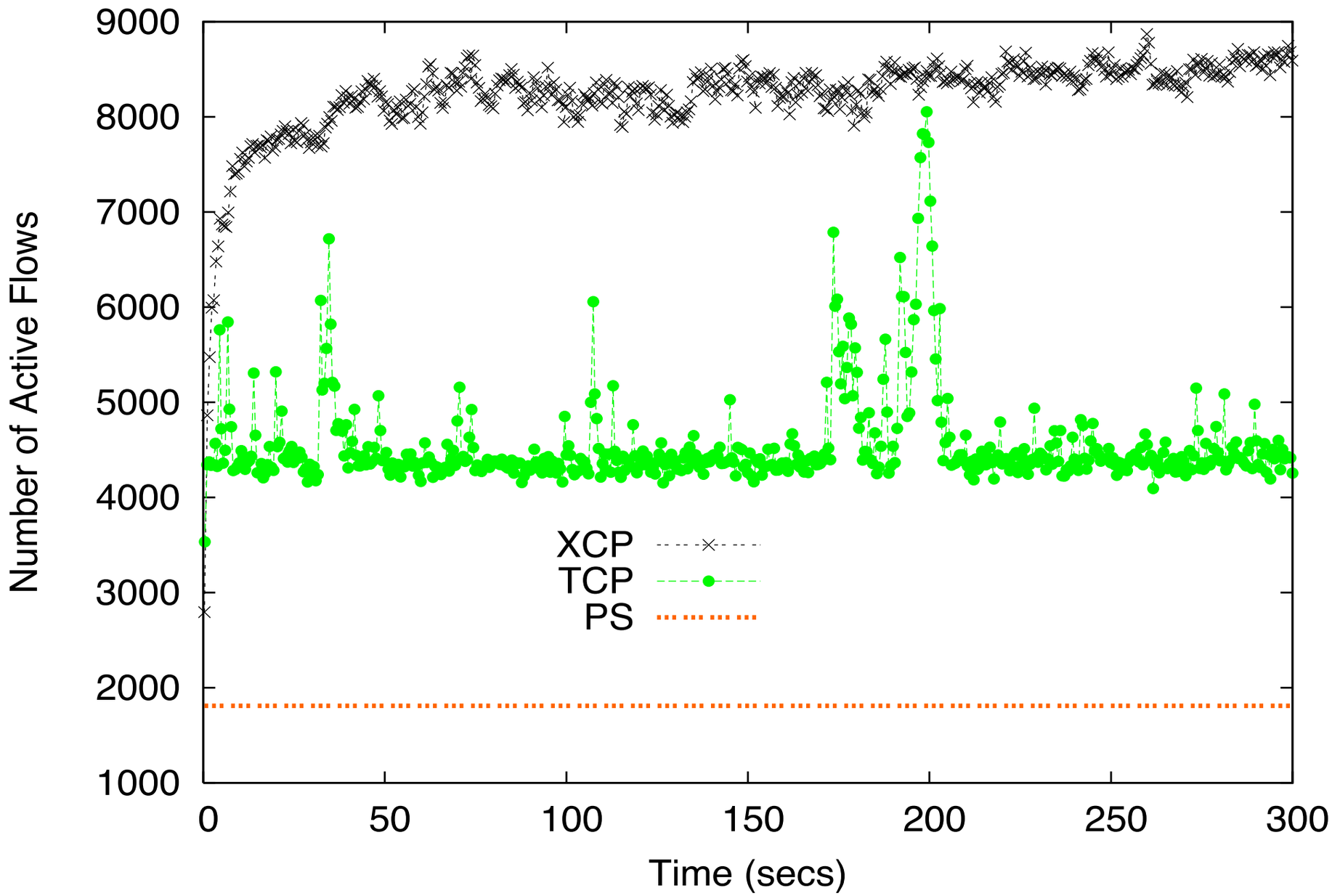
[Dukkipati & McKeown '05]

= fair queueing



# Many flows waiting

[Dukkipati & McKeown '05]



# RCP: finishing flows quickly

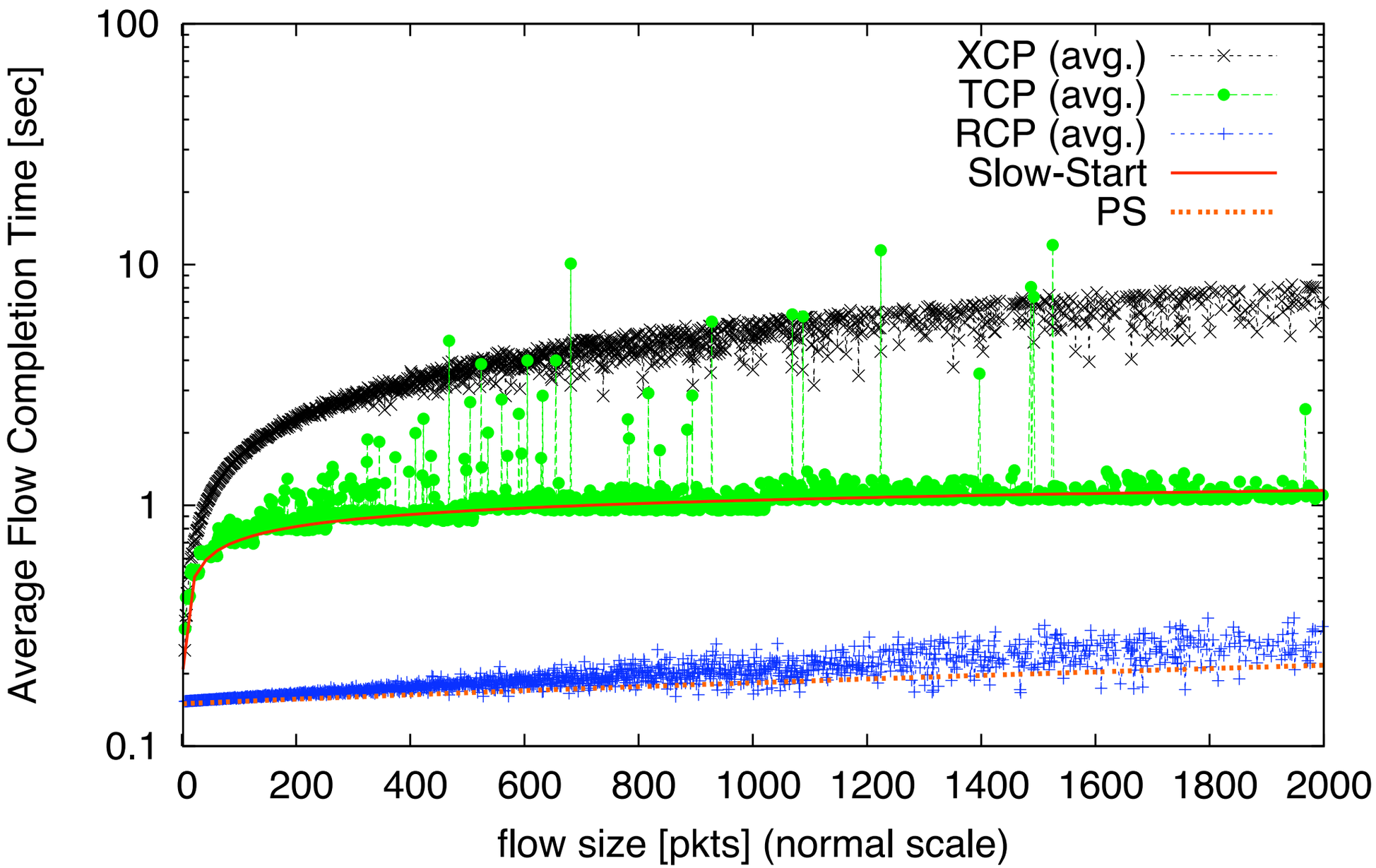
- Rate Control Protocol [Dukkipati, Kobayashi, Zhang-Shen, McKeown, IWQoS 2005]
- Algorithm:
  - Compute fair per-flow rate R(t) at time t as whatever will fill up the link capacity (roughly)
  - Similar to XCP, tell end-hosts about this by putting the value in packets, and recompute every RTT

# RCP rate computation

$$R(t) = \underbrace{R(t - d_0)}_{\text{old rate}} + \frac{\alpha(\overbrace{C - y(t)}^{\text{spare capacity}}) - \beta \overbrace{\frac{q(t)}{d_0}}^{\text{queue size}}}{\underbrace{\hat{N}(t)}_{\text{estimated \# of flows}}}$$

- (How can you estimate # flows?)
- Simpler than XCP:
  - rates instead of windows
  - thus, feedback doesn't depend on a flow's RTT
  - thus, same feedback to everyone

# RCP finishes flows quickly



# Today

RCP

Congestion pricing

Announcements

"The Internet routes money;
packets are just a side effect."

– Unknown, via Dave Clark

# What is “fair”?

- Flow rate equality!
- Easily circumvented
- Doesn’t even optimize for any metric of interest

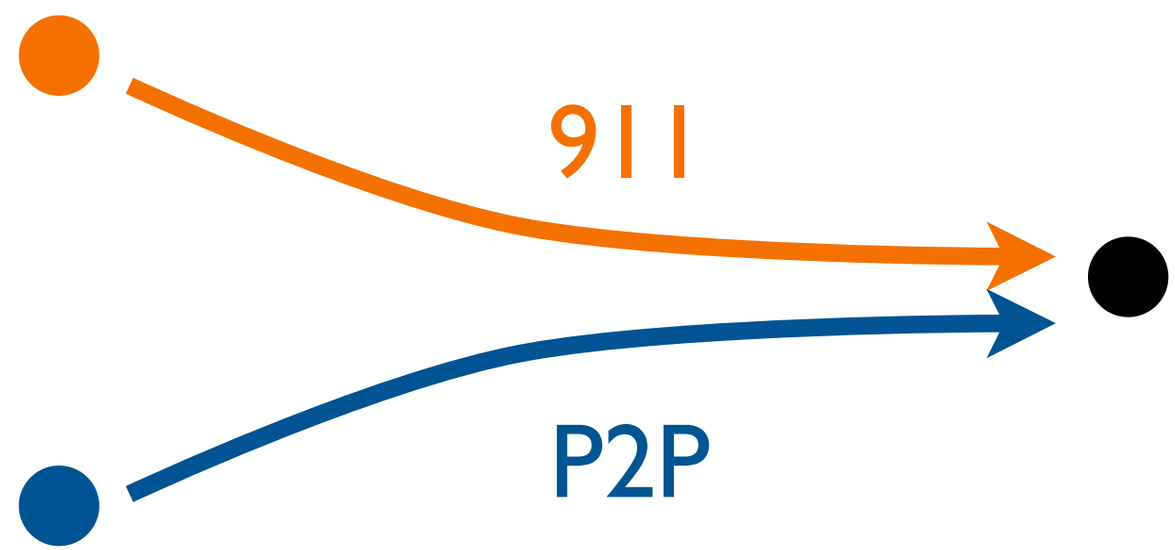



Fig. 1: Poppycock.

# Fairness in real life

- Plentiful resources: use as much as you want
  - e.g. air, advisor's grant money
- Scarce resources: pay for what you want
  - price set by market
  - result (under assumptions): socially optimal allocation

Fig. 2. Invisible hand of the market.

# Briscoe's main points

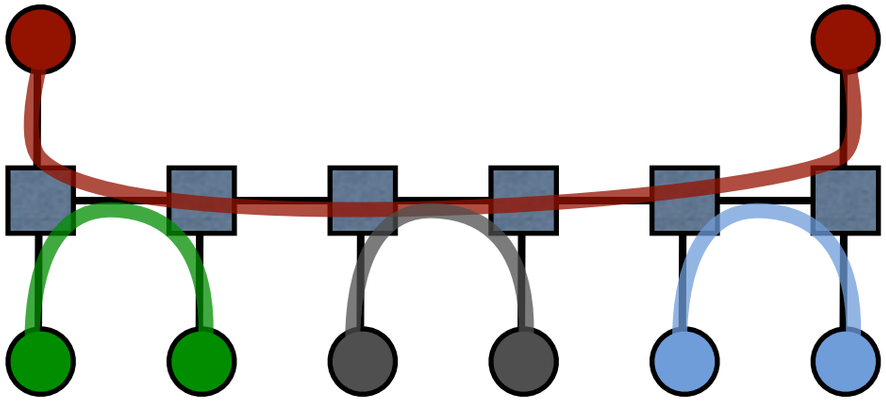
- Flow rate fairness (FRF) is not useful
- Cost fairness is useful

Briscoe

- Flow rate fairness is hard to enforce
- Cost fairness is feasible to enforce

# FRF not useful

- Doesn't measure benefits
  - e.g., SMS message vs. a packet of a video stream
- Doesn't measure costs
  - e.g., "parking lot" network: long flow causes significant congestion but is given equal rate by fair queueing



- Therefore, doesn't equalize cost or benefit

# FRF not useful

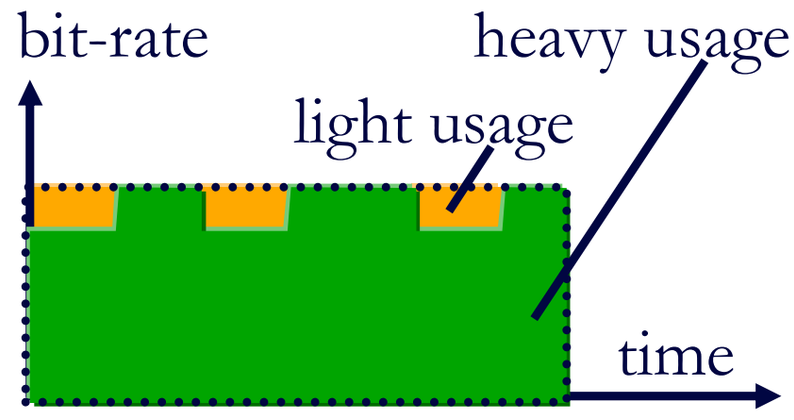
- Myopic: no notion of fairness across time
- In summary, FRF does not optimize utility (except for strange definitions of utility)
- So, even cooperating entities should not want to use it!

# Cost fairness is useful

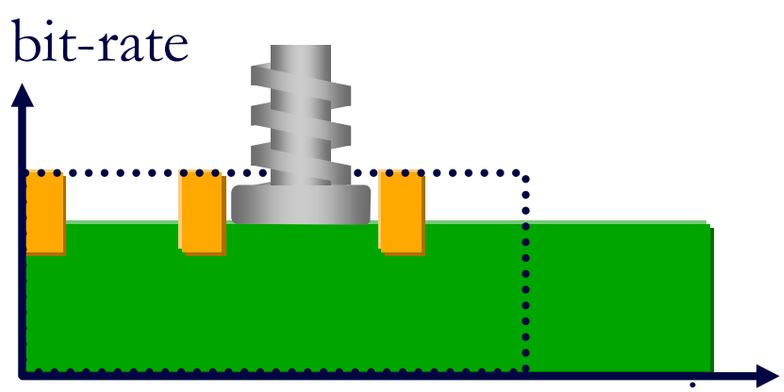
- Economic entities pay for the costs they incur
  - Note this is "fair" (in a real-world sense), not "equal"—and that's fine
- In other words, networks charge packets for the congestion they cause
  - Can networks lie about congestion?
  - Yes. So it's really a market price, not exactly congestion
- Result: senders want to maximize utility; they will balance benefit with cost (utility = benefit - cost)

# Example: light & heavy traffic

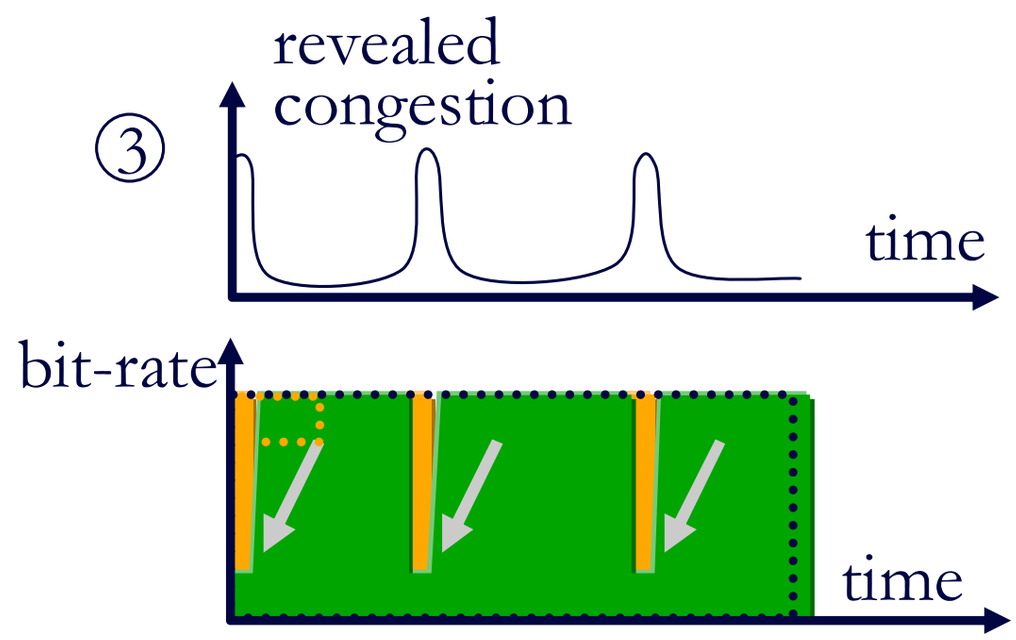
[Briscoe 2009]




'unfair' TCP sharing




throttling heavy usage




weighted TCP sharing

Key point: Benefit per bit is high for light flow and low for heavy flow.

# CF is provably useful

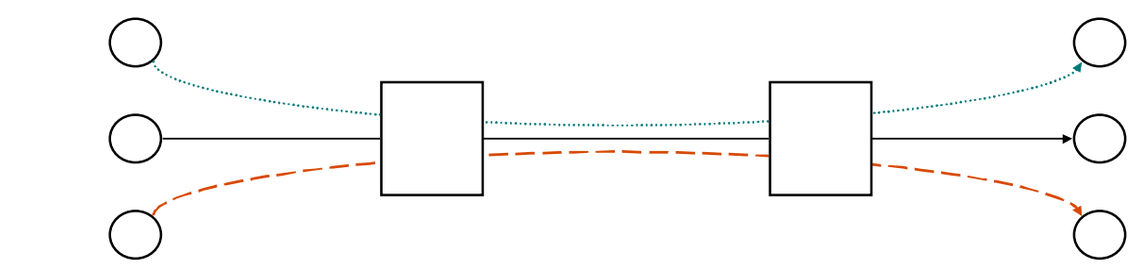
- Frank Kelly 1997: Cost fairness maximizes aggregate utility
- i.e.: any different outcome results in suboptimal utility
- Why won't anyone listen to Kelly? Hello??! ... where did everybody go?

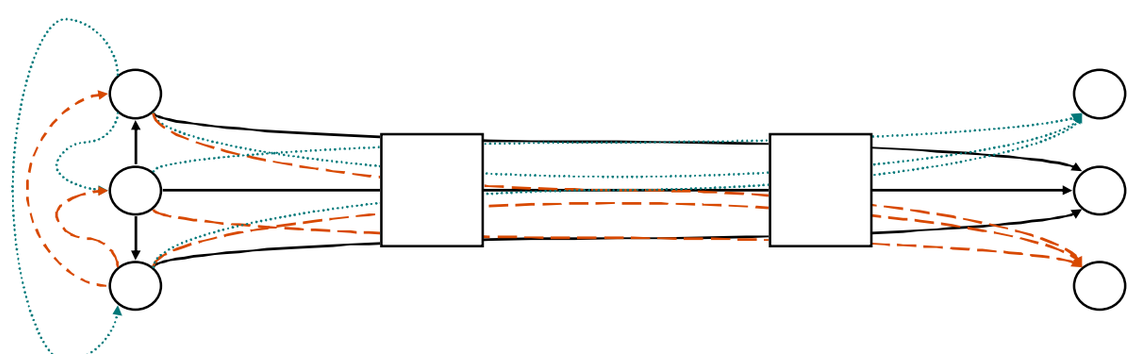
# Kelly's model

- Each user i has utility $U_i(r_i)$ for rate $r_i$
- Each user i pays wi for access to link (its own choice)
- Link sets price per unit bandwidth: $p = (\text{Sum } p_j) / C$
  - thus, $r_i = w_i / p = C\, p_i / (\text{Sum } p_j)$
- Theorem: assuming $U_i$ concave, strictly increasing, and continuously differentiable, then
  - A competitive equilibrium exists: no user can improve their utility given current price
  - This equilibrium maximizes Sum $U_i(r_i)$

# FRF is hard to enforce

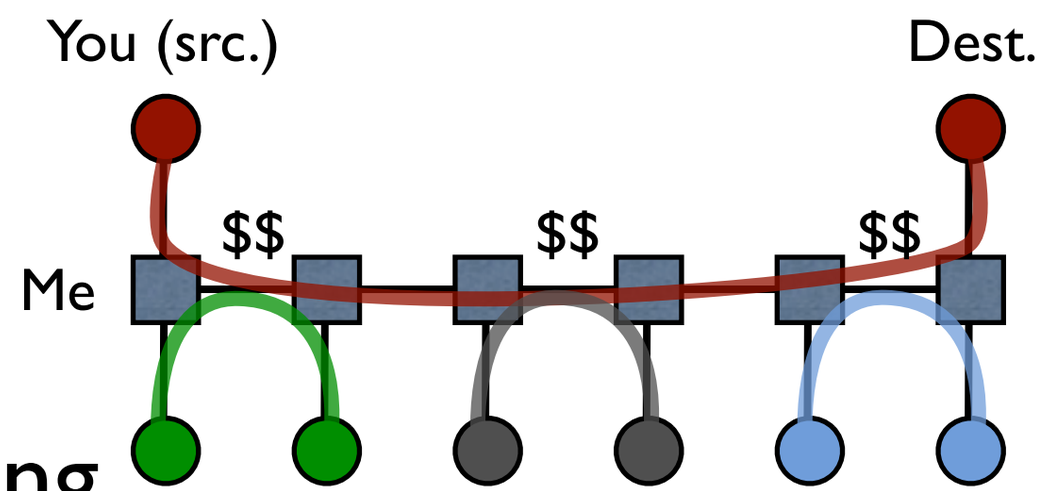
- Run your flow longer
- Create more flows (similar to sybil attack)
  - Multiple TCP connections between same source/ destination (web browsers)
  - Spoof source IP / MAC address
  - Multiple flows to other destinations (BitTorrent)





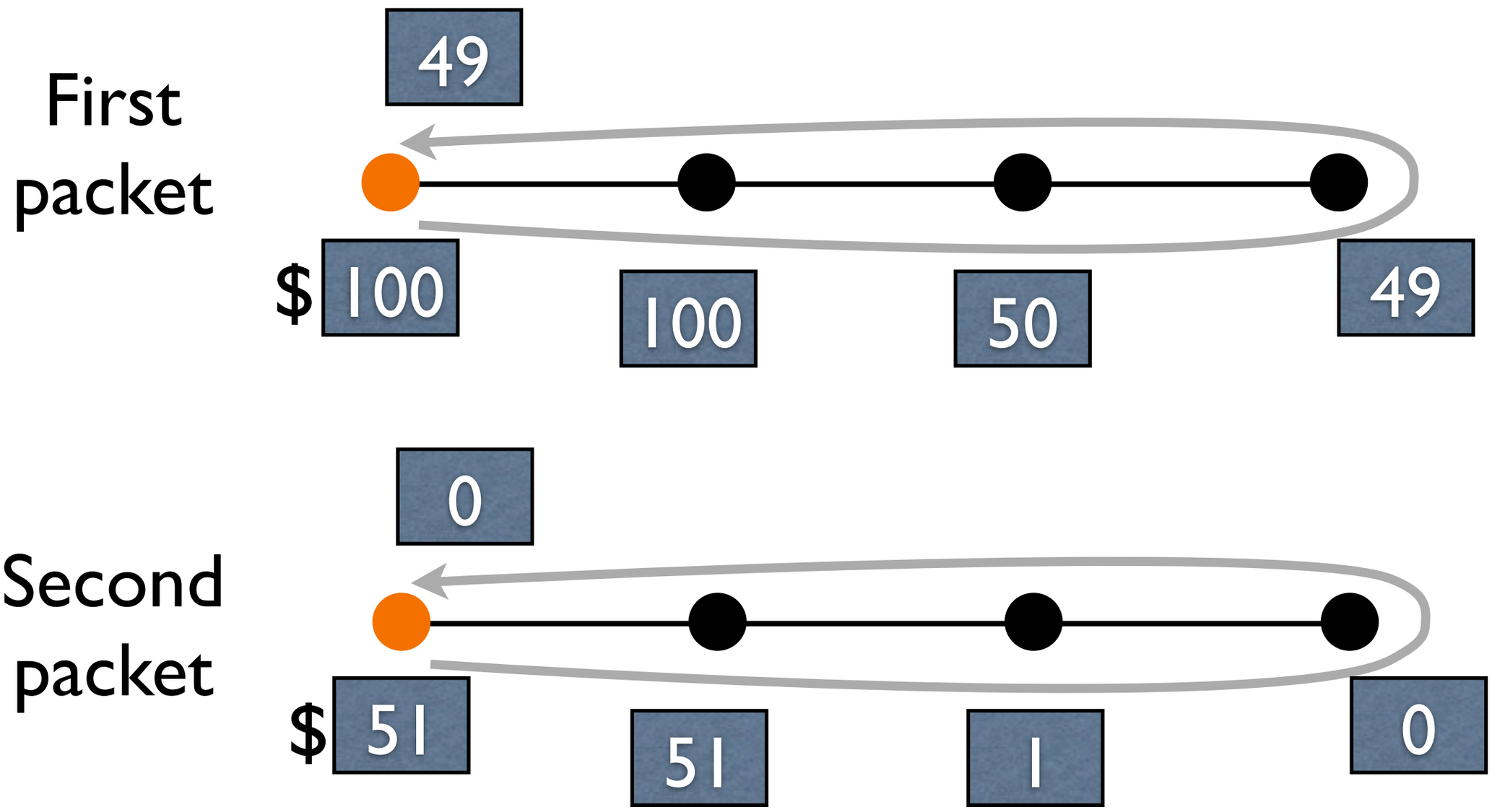
# Cost fairness is enforcable

- You send me a packet; I handle delivery and charge you for it
- How much do I charge? Depends on cost on entire remainder of path!
- Not the only way of arranging payments, but it is convenient: payments between neighbors that already have an economic relationship



# Mechanism: Re-Feedback

- Key property: every hop knows total congestion along downstream path



# Not necessarily about $$

- Previous explanation was in terms of money, but doesn't have to directly involve money
- Re-feedback is a mechanism; doesn't imply a particular way of implementing congestion pricing
  - pay per packet?
  - monthly allowance?
  - only at edges?
  - between all ISPs?

# Conclusion (Briscoe style)

- "It just isn't realistic to create a system the size of the Internet and define fairness within the system without reference to fairness outside the system."
- Cost fairness optimizes aggregate utility and is feasible to enforce
- Flow rate fairness does not optimize utility and is not feasible to enforce
  - Cease publication on the topic and stop teaching it in undergraduate courses

# Today

RCP

Congestion pricing

Announcements

# Announcements

- Reading schedule posted
  - 2 or 3 papers per week
  - Usually 2 for Tuesday, 1 for Thursday
- By 11:59 pm this Thursday, choose your preferred presentation topic