TCP Congestion Control Fairness
Current Issues and an Economics Proposal

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CS 555: Introduction to Networks and Communications
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Outline

1. Background
   - Jacobson’s Algorithm and Its Descendents
   - Problem, What Problem?

2. What Is “Fair” Anyway?
   - “Traditional” TCP Congestion Control Fairness.
   - “Human” Fairness

3. An Economics Approach
   - Economics?
   - The Wrong Way
   - The Right Way
   - Other Fairness Issues
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October 1986: Internet experienced as series of congestion-driven meltdowns [?].

1988: Van Jacobson consolidated ideas and changed the BSD UNIX TCP protocol [?]
(TCP Tahoe).

1990: Jacobson added triple duplicate ACK [?]
(TCP Reno).

1994: Brakmo, et. al. added per-segment timeouts, better triple ACKs, congestion detection by expected vs. actual [?]
(TCP Vegas).

Others, ...
TCP congestion control has been evolving with the Internet — so, what is the problem?
It appears to work, but under the covers there are big problems [?, ?].
There is a new breed of application [?]:
- Peer-to-peer is best known.
- BitTorrent.
Problem, What Problem?
TCP Applications: 1986 and Today.

(a) Flow-Rate Fairness with Single-Connection Applications

Note: Illustrations inspired by G. Ou. [?]

Scott Ainsworth  TCP Congestion Control Fairness
### BitTorrent Screenshot

![Image of µTorrent interface](image-url)

#### File Information

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- D: 458.7 kB/s
- T: 19.4 MB
- U: 5.5 kB/s
Problem, What Problem?
TCP Applications: 1986 and Today.

(a) Flow-Rate Fairness with Single-Connection Applications

(b) Flow-Rate (Un)fairness with Single- and Multi-Connection Applications

Note: Illustrations inspired by G. Ou. [?]
When traditional network applications and contemporary applications are mixed, the 1988 flow-rate fairness model is inadequate.

TCP Congestion Control is Broken!

*It is no longer fair.*
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What is “Fair” Anyway?

“Traditional” TCP Congestion Control Fairness.

- Based on flows.
- Is based on engineering principles.
- Easily subverted by opening multiple or long-running connections.
- But how do humans determine fairness?
  — Certainly not by engineering!
What is “Fair” Anyway?
How do we determine fairness?

- Humans have been studying fairness for millenia.
- But not as an engineering discipline.
- Instead, we study...

**Markets & Economics**
Economists have been studying fairness for centuries. Kelly was first to proffer an economics solution [?], [?]. Briscoe has taken up the cause [?] and produced draft RFCs.
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What Is “Fair” Anyway?
Engineering vs. “human” fairness.

“Traditional” TCP fairness
- Flow-rate parity
- Discrete TCP connections
- Created from an engineering perspective
- Made sense in 1986 — broken in 2008 [?]

“Human” fairness [?]
- Stability is an engineering problem
- Fairness is a philosophy or economics problem
- Current model should be replaced with “human” models
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What can economics teach us about fairness?

- Economists study distribution of scarce resources
- Cost and utility closely related in human affairs
- Supply, demand, and equilibrium — Sound familiar?
- Centuries of study — far outdates computer science

  - 362 BCE: Xenophon, *Economicus*
The Wrong Way
Bad assumptions about economic utility.

- Several ISPs experimenting
- Focus on high-visibility streams such as music and video
- COMCAST — negative news for interfering with BitTorrent

These approaches are misguided because

- Assume music and video have high economic utility to all users, which is not the case
- It is impossible to determine economic utility from the data stream alone

Therefore, congestion control algorithms cannot easily consider economic utility
Cost not Benefit
Since utility is not viable...

- Since utility is not a viable option, only cost can be used.
- Cost = total volume of data transmitted — not number of flows!
- Approach: weighted proportional fairness
- Flows are weighted based on importance to the user (Probably automatically by the operating system)
Weighted Proportional Fairness

(a) Weighted TCP Fairness with Single-Connection Applications

(b) Weighted TCP Fairness with Single- and Multi-Connection Applications

Single flow: weight = 64

16 flows: weight = 4 each
The 1986 congestion control model has not stood the test of time
Its insufficiencies are causing ISPs to make bad choices
We need a cost-based solution
Weighted proportional fairness is the approach
Weighted TCP is being championed by Briscoe [?]
Questions?