no share of the Internet is neutral
– we need a variety of outcomes

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degrading specific Internet applications

a trend with two confusable causes

- deficiencies in Internet technology: subject of this talk

- regulatory deficiency in some access markets (mostly US-specific)

- outline of talk – two technical deficiencies and a technical solution
  1. current resource sharing architecture gives most to those who take most (p2p, video)
     - resource provider cannot arbitrate, because key usage information inaccessible to it
     - lacking a proper remedy, operators kludge it by degrading likely culprit apps
  2. discrimination with confusable intentions – exploitable by either political camp:
     a) operators may be balancing causes of congestion
     b) operators may be degrading their competition
  3. proposed solution to both 1 & 2 (and more)
     - 1-bit app-neutral fix to the Internet Protocol, in early standards process

- purpose of talk
  - does the proposed solution create a playing field all sides would be happy with?

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freedom to limit the freedom of others?

- Internet designed to cope with endemic congestion

- no. of access lines that can congest *any* other Internet link
  - has stayed around 1,000 – 100,000

- shares of congested links:
  - continual conflict:
   - betw. real people
    - & between real businesses

Internet topology visualization produced by Walrus
(Courtesy of Young Hyun, CAIDA)
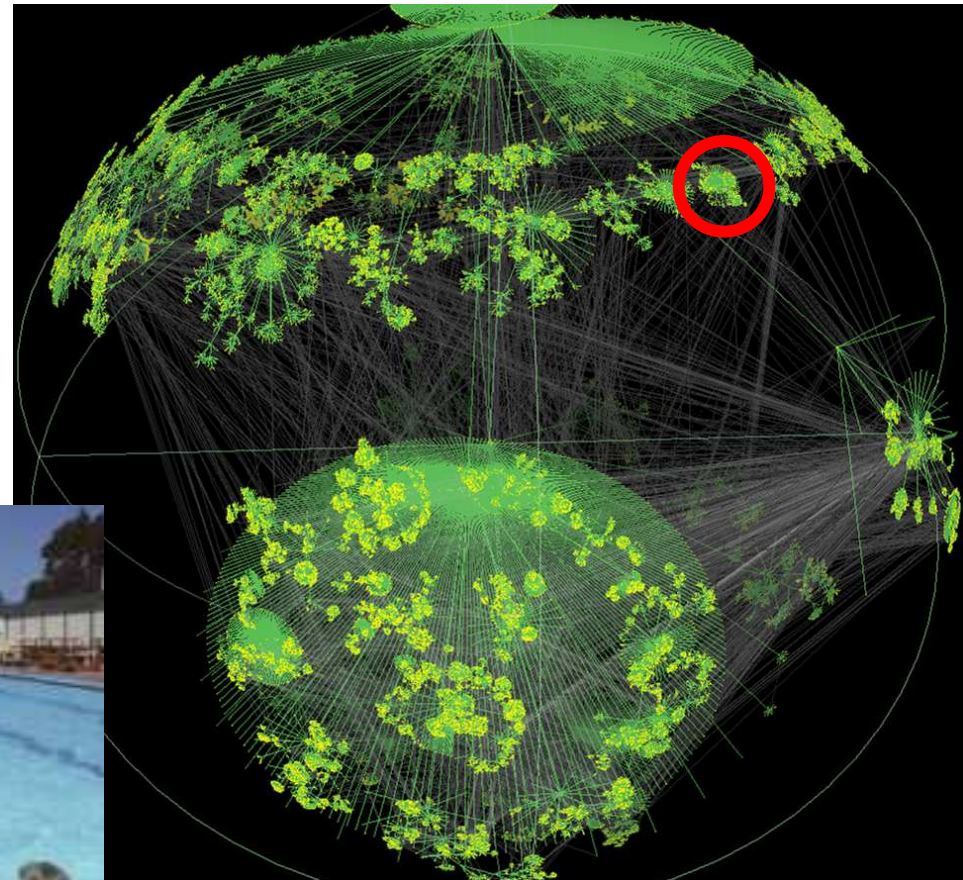
for comparison: ~10M lines ringed in red

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how Internet sharing 'works'
voluntary restraint

flow$_2$

flow$_1$
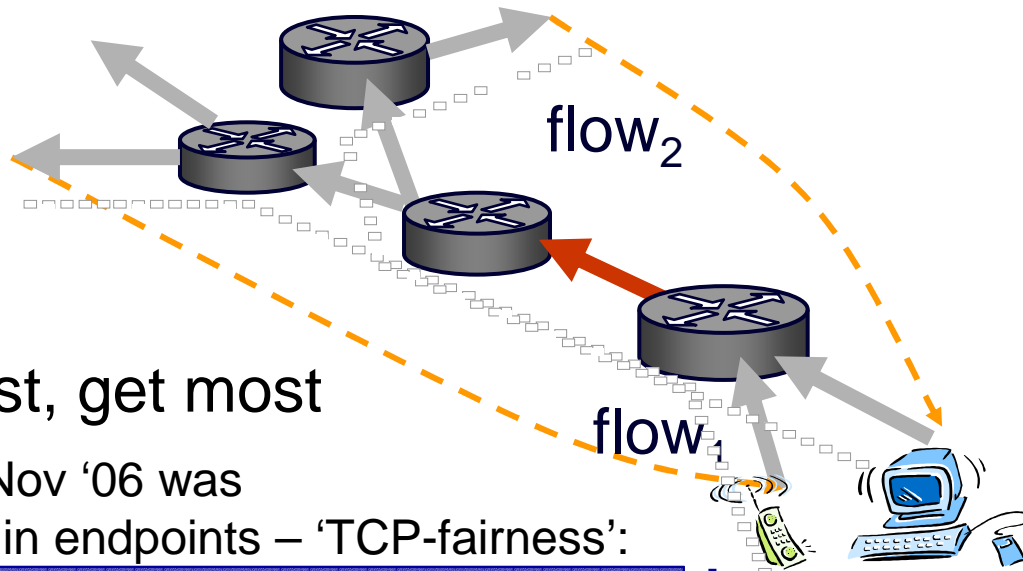
- ## aka. those who take most, get most

  - technical consensus until Nov '06 was
    voluntarily polite algorithm in endpoints – 'TCP-fairness':

capacity

↓bandwidth$_2$

↑bandwidth$_1$

time
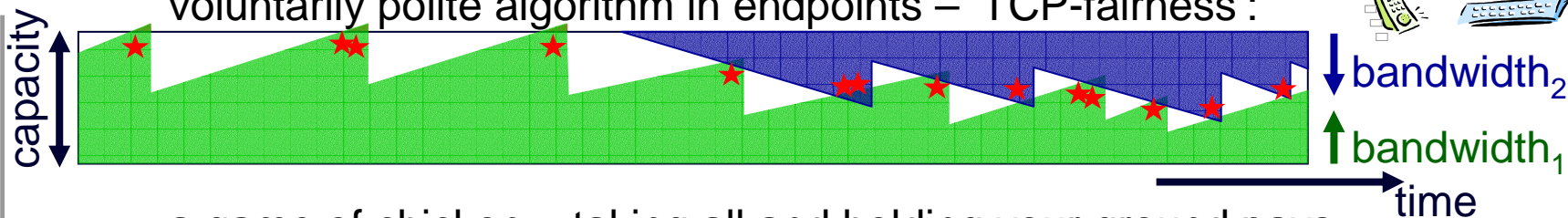
  - a game of chicken – taking all and holding your ground pays

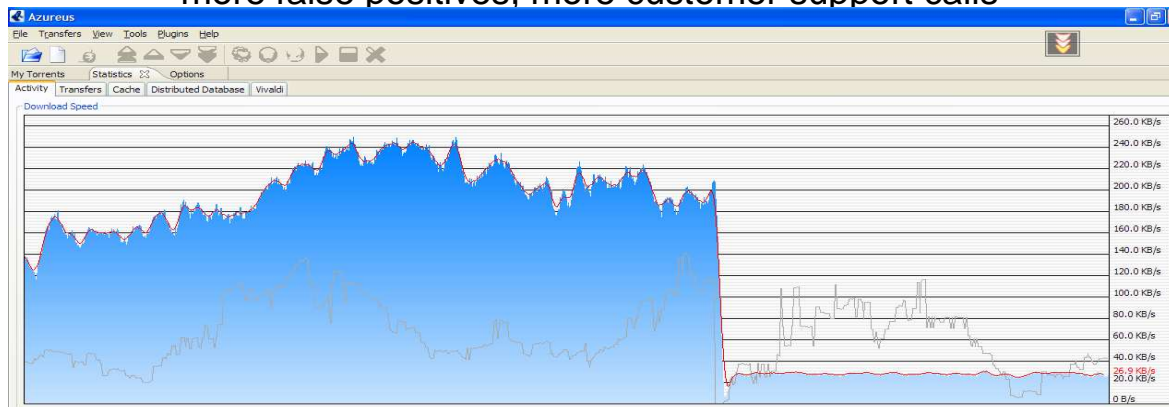unresponsive
flow$_3$

(VoIP,
video streaming)
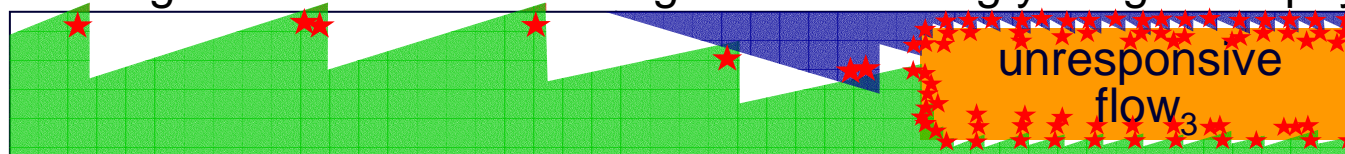
  - or starting more 'TCP-fair' flows than anyone else (x4, x50?)

  - or for much much longer than anyone else (p2p file-sharing)

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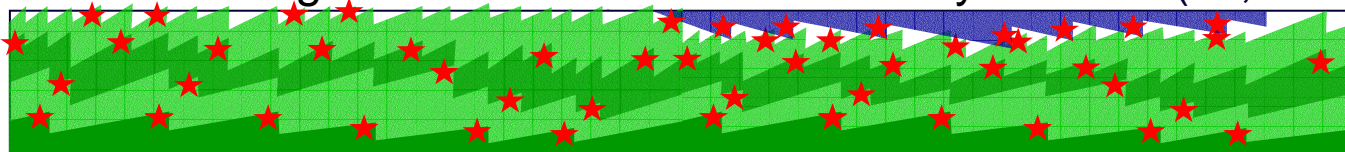
ineffective kludges are making matters worse
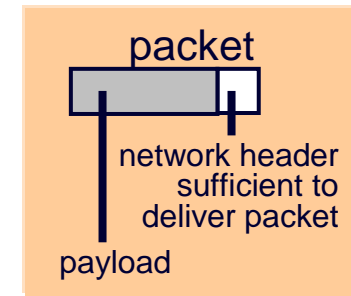## fuelling adversarial climate

- deep packet inspection (DPI) in an arms race against obfuscation
    - 80% of payloads now carry randomised app identifier
    - latest p2p apps use payload encryption & imitate other apps
    - more false positives, more customer support calls

packet

network header
sufficient to
deliver packet

payload

download bit rate

200kbps
(2M contended)

30kbps

summer 2006: customer of an ISP using DPI to throttle p2p turns *off* encryption in BitTorrent client

by winter 2007 DPI vendors could identify encrypted BitTorrent packets

- intentions might be honourable
    - protecting the many from the few
- but counter-productive
    - if easily bypassed and easily turned against itself
    - if (mis)interpretable as discriminating against competition

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the classic Internet is not a repeatable recipe for success

- yes, a thousand flowers bloomed because the 'net was dumb
  - but also because innovators exercised restraint ⬅
  - now the flowers are fruiting, greed and malice are dominating restraint

- net neutrality = "the shares of capacity that the classic Internet would give"?
  - that was just the arbitrary outcome of a certain amount of push and shove
  - legislating for that now would legitimise removing all restraint

- Mar '07: IETF dropped 'TCP-fairness' goal as meaningless
  - due to my arguments in 'Flow Rate Fairness: Dismantling a Religion'

- if you wanted legislative control over Internet sharing, uncontrolled sharing would no longer achieve your objective

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not volume, but
congestion volume: the missing metric

- not 'what you got'
  but 'what you unsuccessfully tried to get'
  - proportional to what you got
  - *and* to congestion at the time

1. congestion volume: cost to other users
   - the metric that *is* legitimate to discriminate on
   - rather than inferring which apps cause congestion
   - cost not value

2. the marginal cost of upgrading equipment
   - so it wouldn't have been congested
   - so your behaviour wouldn't have affected others

- competitive market matches 1 & 2

$x_1(t)$

$x_2(t)$
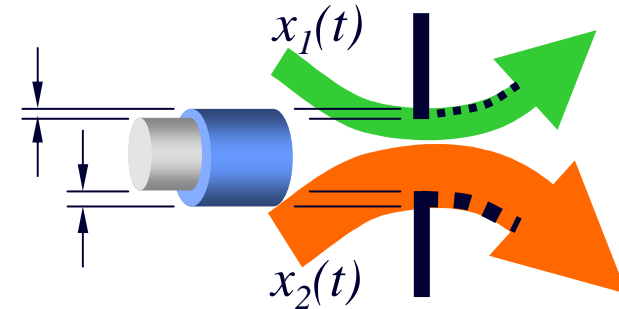
note: diagram is conceptual

congestion volume would be accumulated over time

capital cost of equipment would be depreciated over time

NOTE: congestion volume isn't an extra cost
- part of the flat charge we already pay
- if we could measure who to blame for what
- we *might* see pricing like this...

access link	congestion volume allow'ce	charge
100Mbps	50MB/month	€15/month
100Mbps	100MB/month	€20/month

NOTE: IETF provides the metric, industry invents the business models

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a practical congestion volume metric; step #1
congestion marking of packets

- **impractical to measure 'absence of bytes'**

- **explicit congestion notification (ECN)**

  - standardised into IP in 2001

  - mark 'packets that wouldn't have got through'
    if congestion got worse

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a practical congestion volume metric; step #2

expected downstream congestion

S_1 N_A N_B N_D R_1

black
*'re-feedback'
proposed for IP*

marking
fraction

feedback std in TCP

3%

**black
– red**

0%

resource
index

red *std in IP*

3%

- routers approaching congestion mark some packets **red** receiver **feeds back** to sender
  - already standardised & implemented
  - not generally turned on by operators

- sender re-inserts **feedback** by marking packets **black**
  - **re-feedback** requires standardisation

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designed for a range of outcomes

- current Internet gives freedom without fairness
  - we don't want fairness without freedom – we want different balances of both

- solution: different ISPs offer loose or tight fairness enforcement
  - and customers select between their offers

demand-side freedom – to degrade others

liberal acceptable use policies
  - open access, no restrictions

middle ground – manage congestion
  - limit how much I limit the freedom of others
    (e.g. 24x7 heavy p2p sources, DDoS)

conservative acceptable use policies
  - you'll get the network response you contract to have
    e.g. throttle if unresponsive to congestion (VoIP, video, DDoS)

supply-side freedom – to degrade competitors

architecture allows extremes
but doesn't help them and
provides handles for the market
to make it very hard for them

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goals

- not value, but cost is a necessary metric for competition to work

    - costs can be controlled in network
      without knowing value behind the cost

    - nets that allow their users to cause costs (congestion) in other nets
      can be held accountable

    - just enough support for conservative policies
      without app-specific controls

    - allows free innovation of new applications
      (e.g. hi-dynamics; enhanced reality, Internet of things)

- 'do-nothing' doesn't maintain allegedly liberal status quo

    - we just get more middlebox kludges

    - the end of innovation

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inter-domain accountability for congestion

- ## metric for inter-domain SLAs or usage charges

  - N_B applies penalty to N_A in proportion to bulk volume of **black** less bulk volume of **red** over, say, a month

  - could be tiered penalties, directly proportionate usage charge, etc.

  - penalties de-aggregate precisely to responsible networks & users

  - N_A can deploy policer to prevent S_1 costing more than revenue

summary

- Internet needs to be able to discriminate
    - against bits limiting the freedom of others – *bits* causing congestion
    - then wouldn't need to discriminate against *apps* causing congestion
- operators can choose not to limit their users' freedoms
    - but they take responsibility for congestion their users cause in other nets
- if operators do discriminate against apps
    - customers need enough choices to be able to switch operators
    - or apps can often obfuscate themselves anyway
- these economic effects require change to the Internet Protocol
    - making IP more suitable as the basis of a converged architecture
    - reached critical mass in standards process – link on next slide
    - please assess it urgently – would it have wide commercial & public policy support?

open

closed

public Internet

telco /NGN

cellular

satellite

1995

2006

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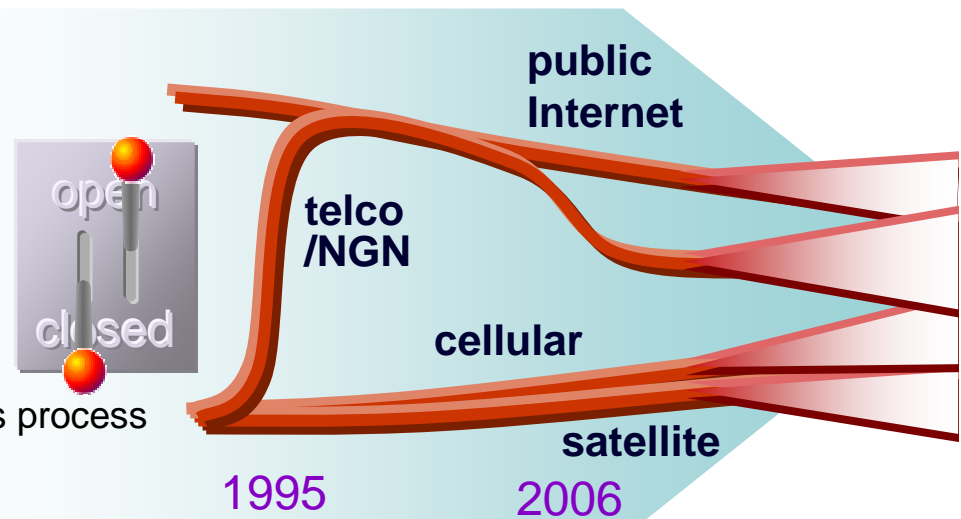
more info...

- more related papers and all the papers below:
  http://www.cs.ucl.ac.uk/staff/B.Briscoe/projects/refb/

- Fixing mindset on fairness
  - Flow Rate Fairness: Dismantling a Religion ACM Computer Communications Review 37(2) 63-74 (Apr 2007) – also IETF Internet draft (Mar 2007)

- Overall re-feedback idea, intention, policing, QoS, load balancing etc
  - Policing Congestion Response in an Inter-Network Using Re-Feedback (SIGCOMM'05 – mechanism outdated)

- Using congestion re-feedback to provide assured QoS reservations
  - Commercial Models for IP Quality of Service Interconnect BT Technology Journal (Apr 2005)

- Protocol Spec and rationale
  - Re-ECN: Adding Accountability for Causing Congestion to TCP/IP IETF Internet Draft (Oct 2006)

- Fixing the Denial of Service Flaw of the Internet
  - Using Self-interest to Prevent Malice Workshop on the Economics of Securing the Information Infrastructure (Oct 2006)

- Tussle in Cyberspace: Defining Tomorrow's Internet, David Clark, Karen Sollins, John Wroclawski and Robert Braden, Proc. ACM SIGCOMM'02, Computer Communication Review, 32(4) 347-356 (Oct 2002)

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no share of the Internet is neutral
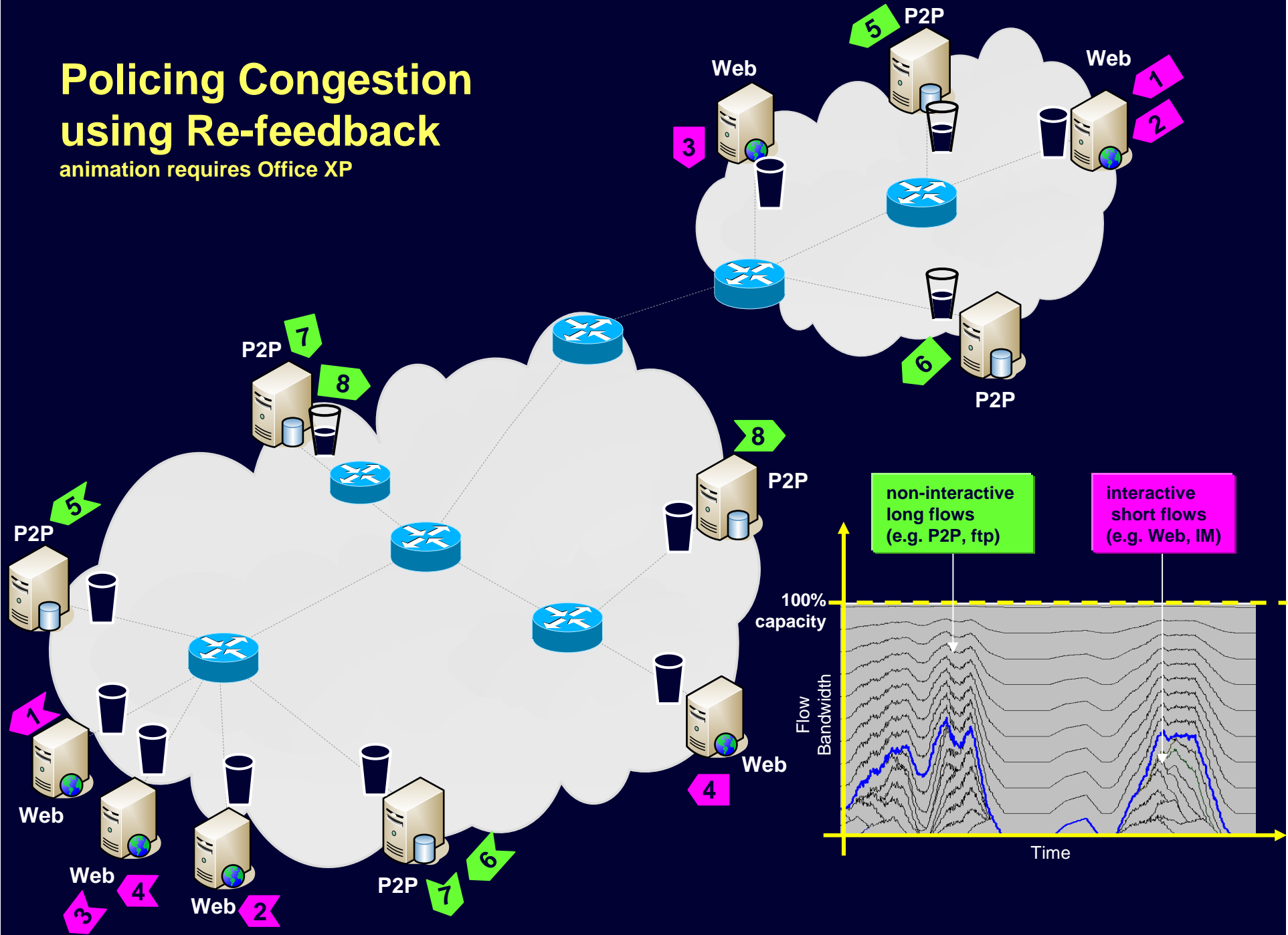<www.cs.ucl.ac.uk/staff/B.Briscoe/present.html>

Q&A
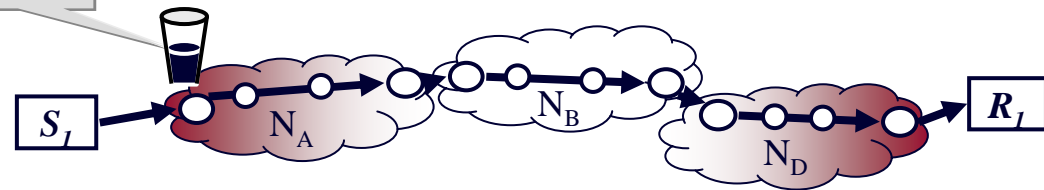& spare slides

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Policing Congestion using Re-feedback

animation requires Office XP

using the downstream congestion metric

one example: per-user policer

congestion volume allowance

overdraft

non-interactive long flows (e.g. P2P, ftp, DDoS)
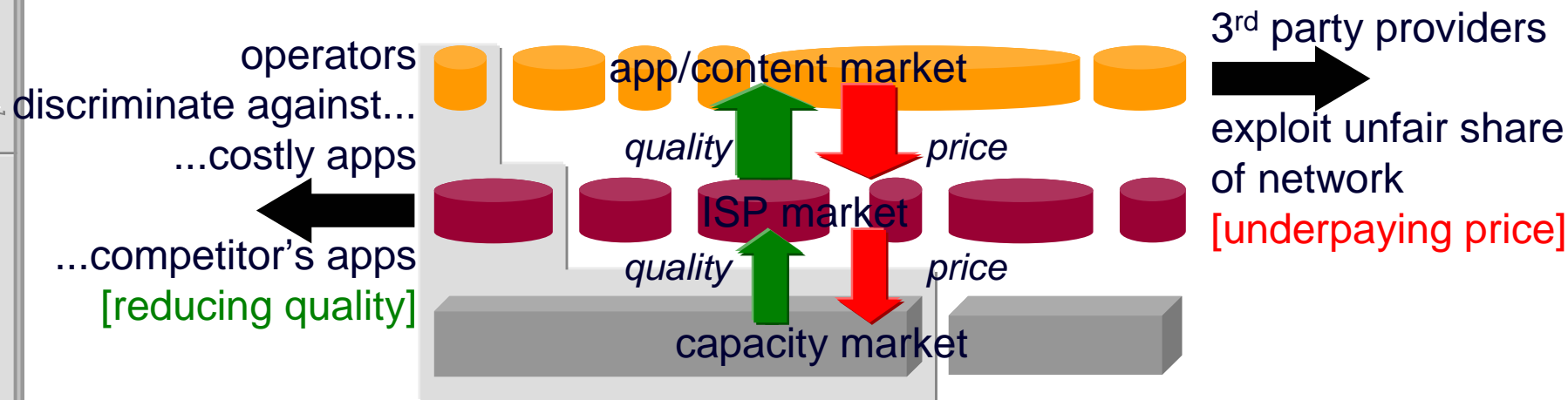
two different customers, same deal

interactive short flows (e.g. Web, IM)

other examples
- make flows respond to congestion (VoIP, video, DDoS)
- no policing at all

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degrading specific Internet applications
wider market context

operators
discriminate against...

...costly apps

...competitor's apps
[reducing quality]

app/content market

quality   *price*

ISP market

quality   *price*

capacity market

3rd party providers

exploit unfair share
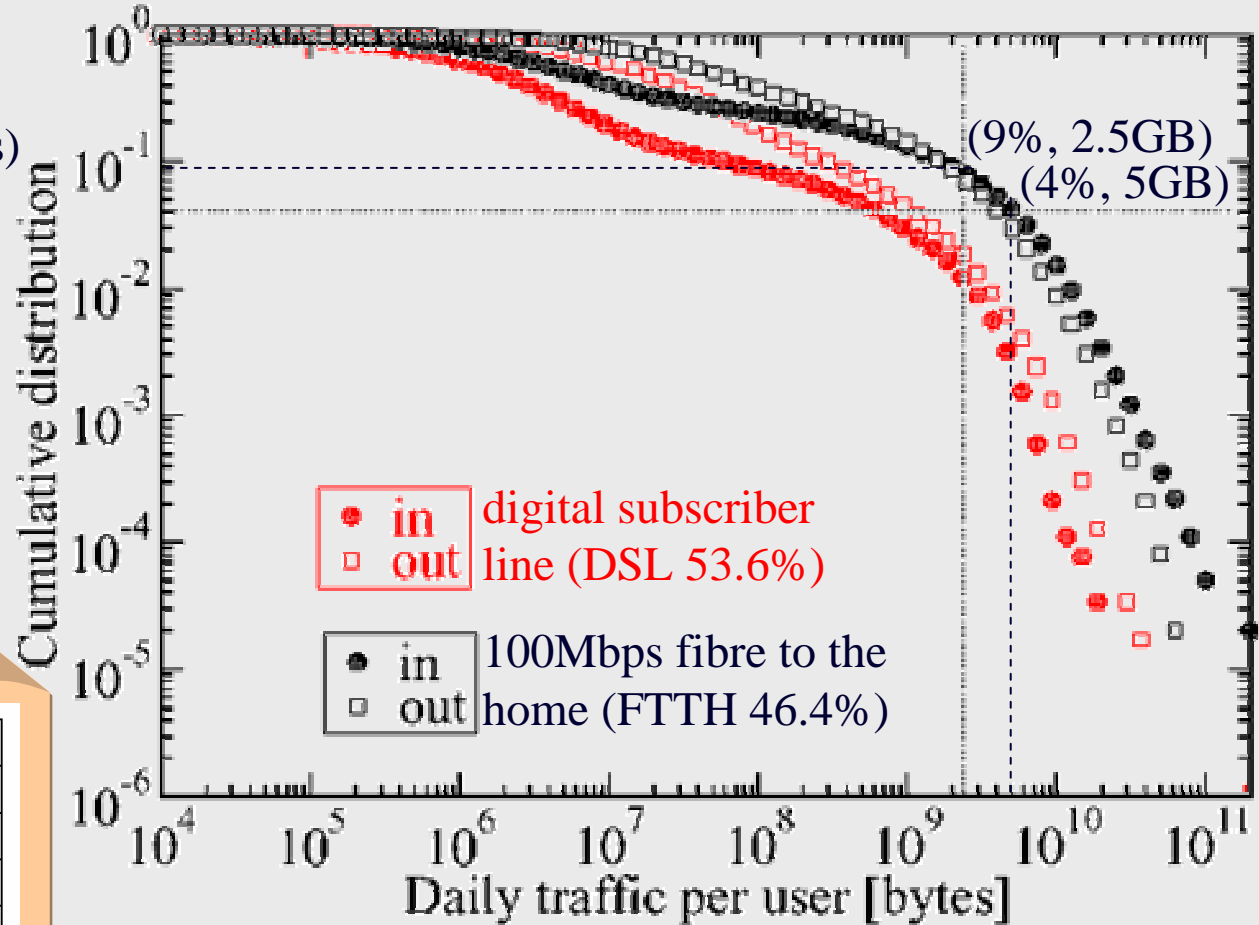of network
[underpaying price]

- solution: identify costly *bits*
  - then quality can rise to match willingness to pay

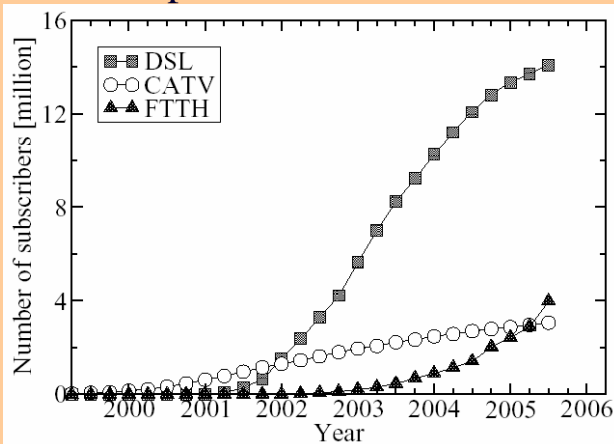| market	problem	appropriate remedy	inappropriate remedy
Internet	architecture	fix architecture	US net neutrality regulation
access	weak competition (US)	fix US access regulation	US net neutrality regulation
	going well (e.g. UK)	no change	

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capacity growth will prevent congestion?

Distribution of customers' daily traffic into & out of a Japanese ISP (Feb 2005)

(5GB/day equivalent to
0.46Mbps if continuous)

(9%, 2.5GB)
(4%, 5GB)

in digital subscriber
out line (DSL 53.6%)

in 100Mbps fibre to the
out home (FTTH 46.4%)

Changing technology shares
of Japanese access market

Courtesy of Kenjiro Cho et al
The Impact and Implications of the Growth
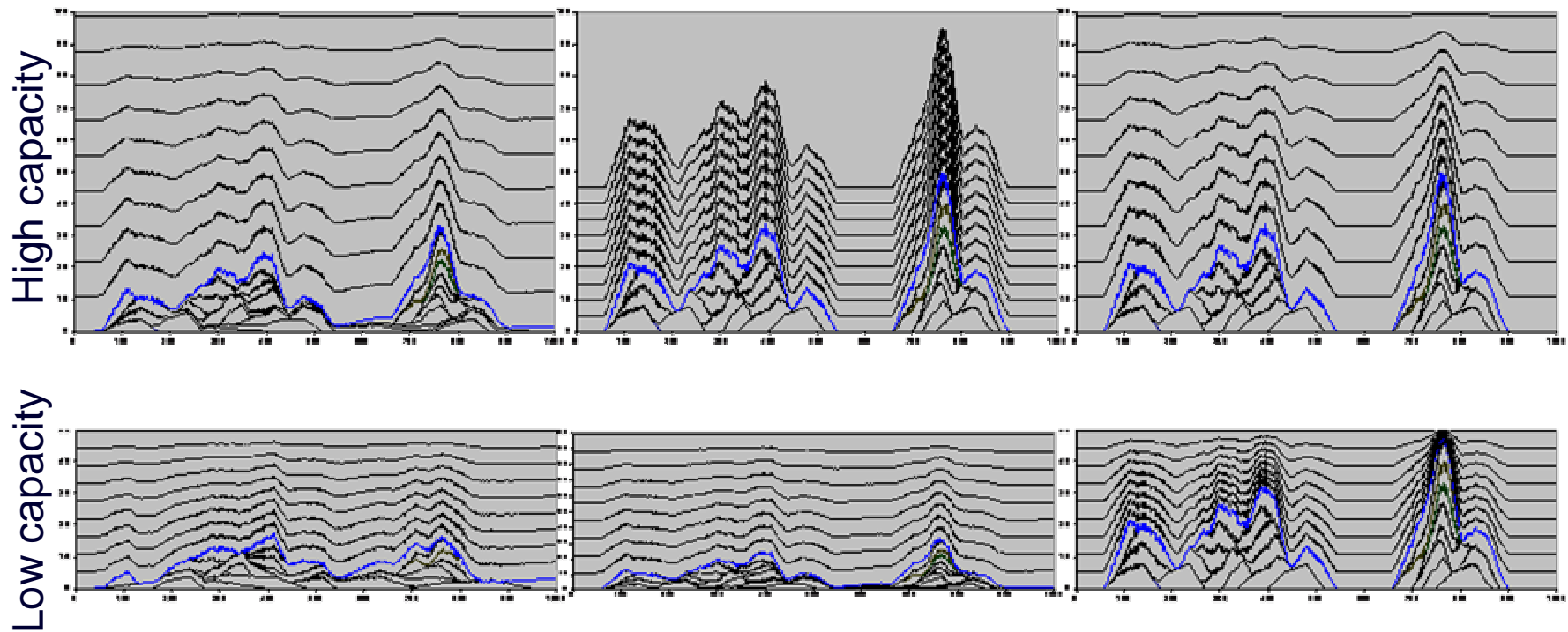in Residential User-to-User Traffic, SIGCOMM'06

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congestion cap auto-adjusts
volume cap always a hard compromise
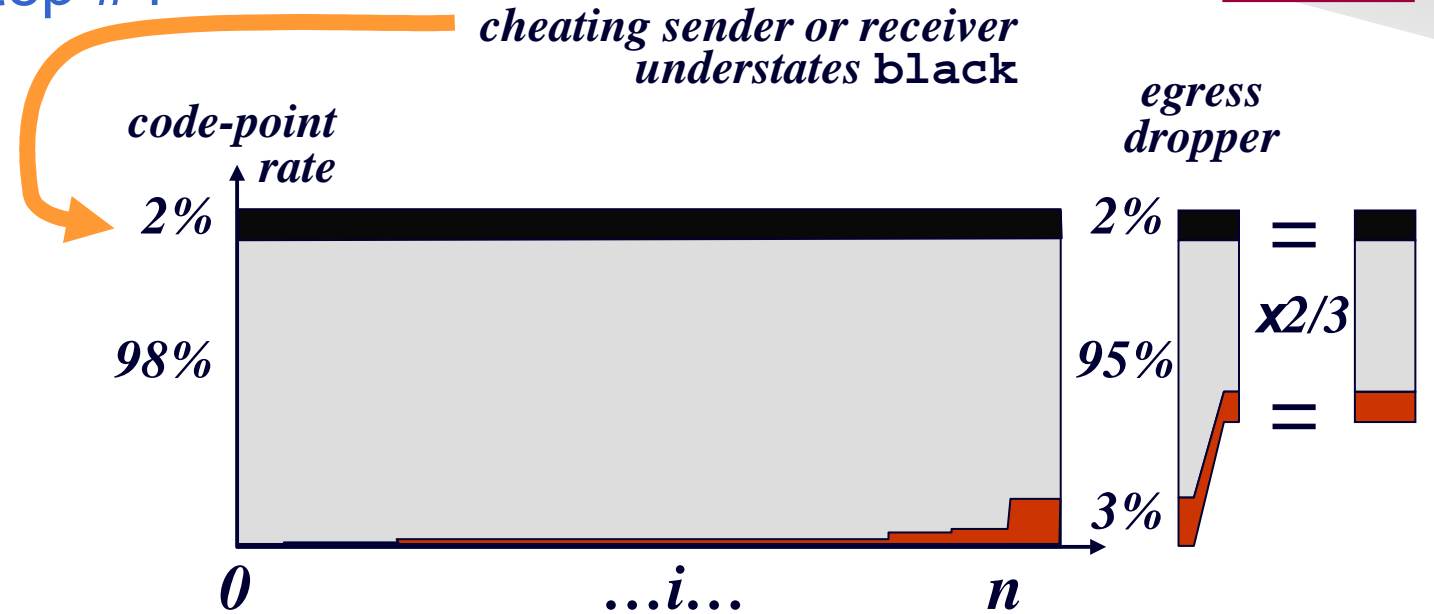
No cap or loose volume cap   Tight volume cap   Congestion allowance

High capacity

Low capacity

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incentives
solution step #4

S_1 N_A N_B N_D R_1

policer

dropper

cheating sender or receiver
understates `black`

egress
dropper

code-point
rate

2%

98%

0   **...i...**   **n**

2%

95%

3%

=

x2/3

=

- won't sender or receiver simply understate congestion?

- no – drop enough traffic to make fraction of `red` = `black`

- goodput best if rcvr & sender honest about feedback & re-feedback

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aggregation
internalisation of externalities

legend downstream congestion marking [%]

area = instantaneous downstream congestion

bit rate

large step implies highly congested link

N_A

N_B

N_D

N_C

total area = aggregate downstream congestion

metering per month: bulk volume black – red