the speed of sharing
stretching Internet access

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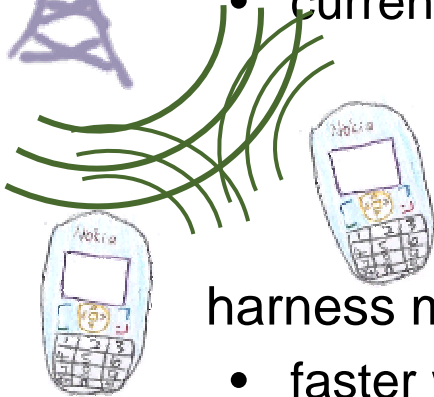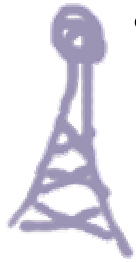Apr 2009

shared access

- India: 11,000 new mobile contracts /hr
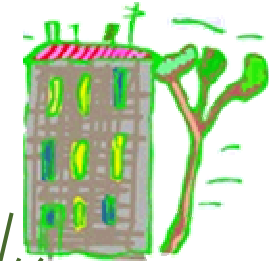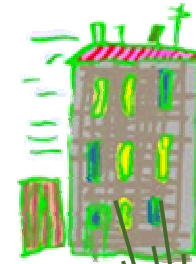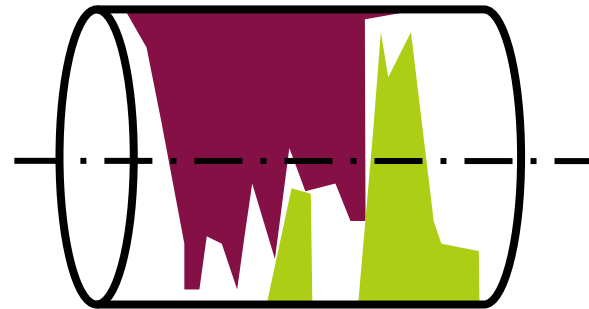- given best available access technology
  - huge gains from sorting out sharing properly
 - currently a disaster area

  harness mutual flexibility
  - faster when you really need it
- greater value, better quality of experience
- gentler entry ramp to the Internet
  - share infrastructure cost between more people
- inability to prevent free-riding kills capacity investment [CFP06]

how to share a bandwidth cloud?

Broadband Usage Distribution

45% 27% 40%
15% 20% 20%
5% 16% 8% 4%

■ % of subscribers ■ % traffic
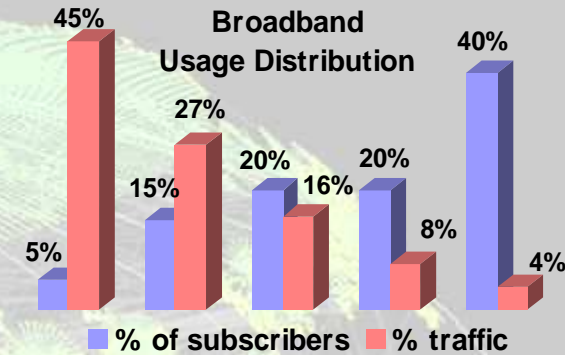
- since 1988: misplaced belief that 'TCP-friendly' sharing is good
  - but ISP's homespun alternatives have silently overridden TCP
- since 2006 IETF support for TCP-friendly sharing has collapsed
  - Van Jacobson agrees the shares his TCP aimed for were wrong & supports our new direction
  - rewrite of IETF capacity sharing architecture in process
- the invisible hand of the market
  - favours ISPs that share capacity in their customers' best interests
  - based on theory of Hal Varian, now Chief Economist, Google
  - made practical by my team: congestion limiting within a flat fee
  - need to tweak TCP & IP (no change required to IP forwarding)

how to share an access cloud?

- once TCP/IP protocols can share internetwork capacity properly
  - partitioning access separately will be counter-productive

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endemic congestion & voluntary restraint

flow$_2$

flow$_1$
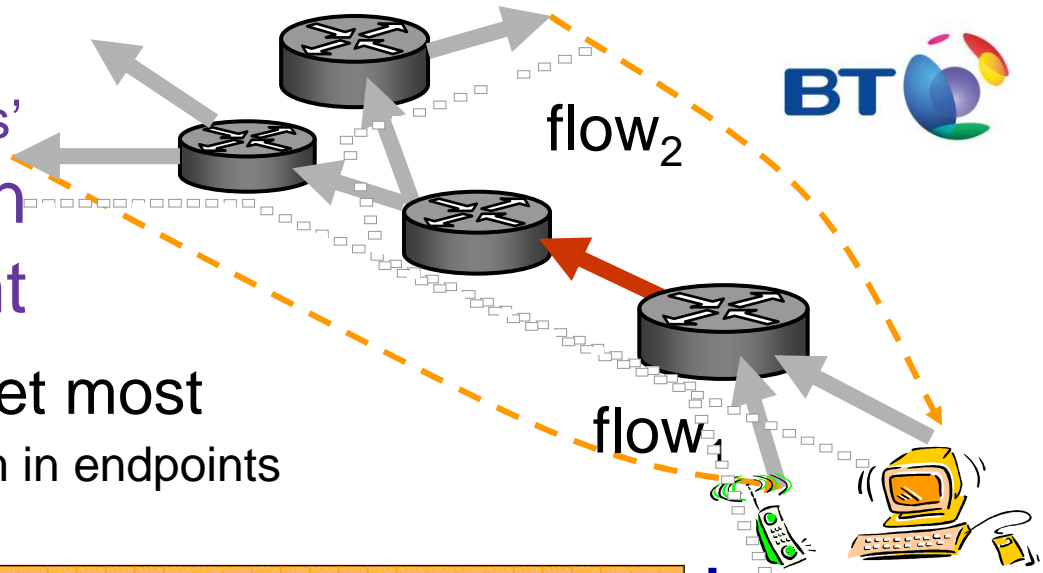
- those who take most, get most
  - voluntarily polite algorithm in endpoints
  - 'TCP-friendliness':

capacity

$\downarrow$bandwidth$_2$

$\uparrow$bandwidth$_1$

time

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

unresponsive flow$_3$

(VoIP, VoD Joost 700kbps)
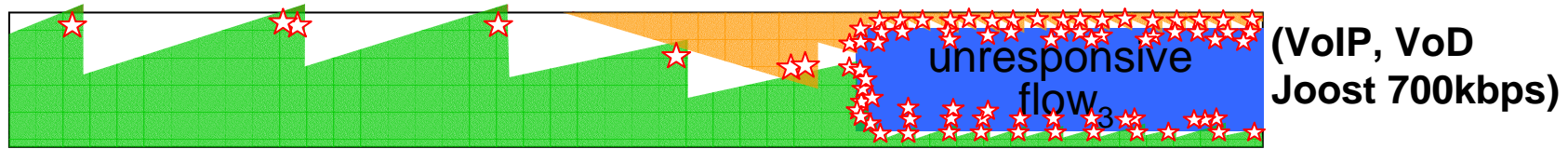
  - or start more 'TCP-friendly' flows than anyone else **(Web: x2, p2p: x5-100)**
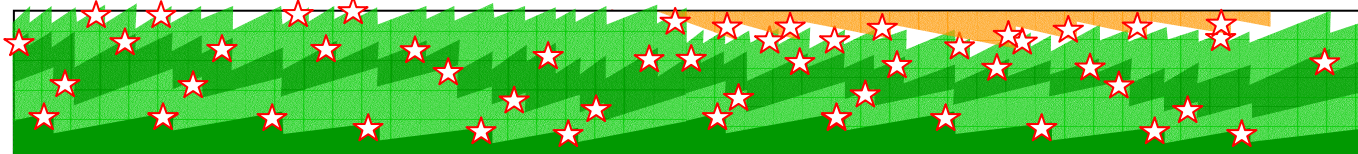
  - or for much longer than anyone else (p2p file-sharing x200)
  - net effect of both (p2p: x1,000-20,000 higher traffic intensity)

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who is the fairest of them all?

1. equal bottleneck flow rates
   (TCP)?

2. access rate shared between active users,
   but weighted by fee (WFQ)?

3. volume caps
   tiered by fee?

4. heaviest applications of heaviest users
   throttled at peak times by deep packet inspection (DPI)?

none of the above
harness end-system flexibility

1. TCP

2. WFQ

3. volume cap

4. DPI
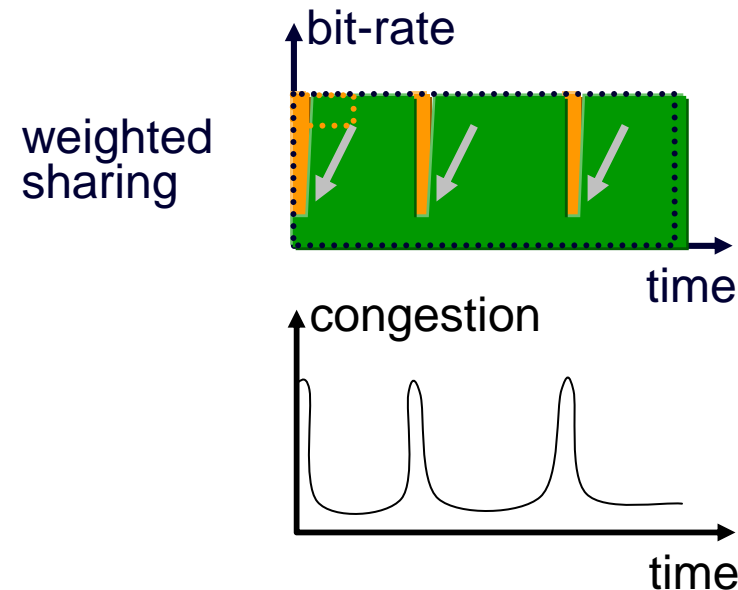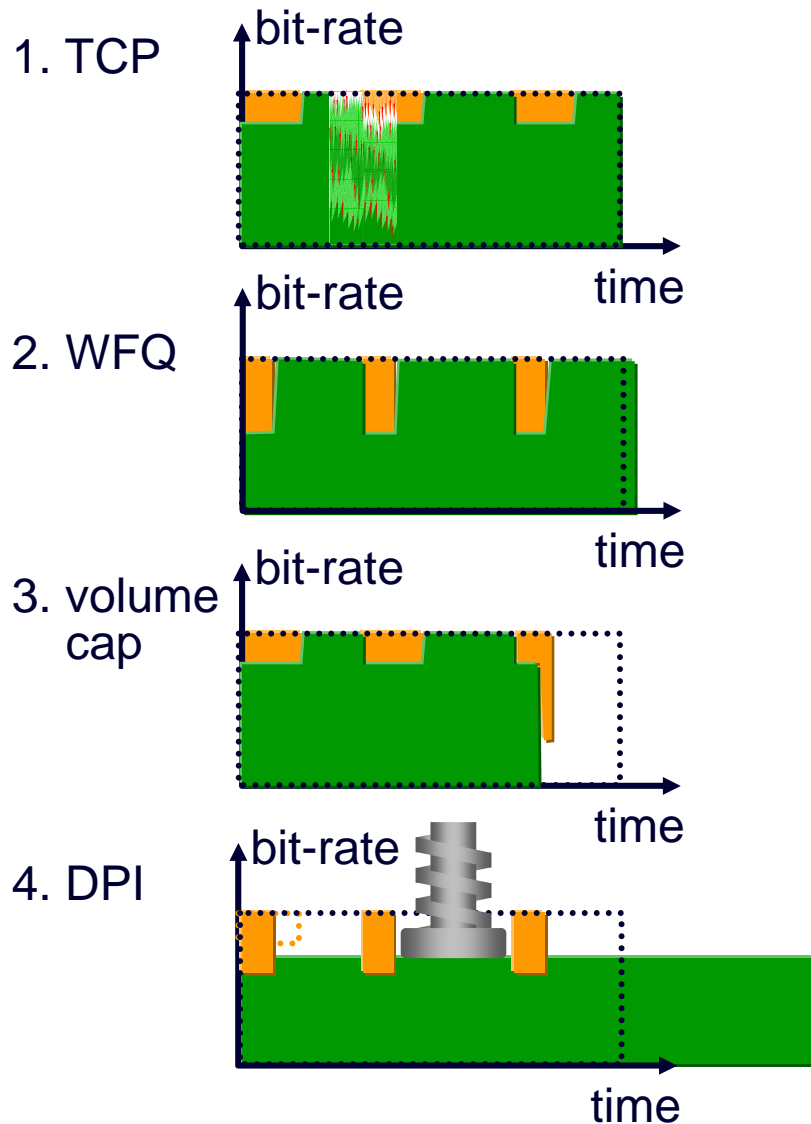
weighted sharing

- light usage can go much faster
- hardly affects completion time of heavy usage

NOTE: weighted sharing doesn't imply differentiated network service

- just weighted aggressiveness of end-system's rate response to congestion

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a new resource accountability metric
– a bandwidth trading unit

- how to measure
  - volume that is marked with explicit congestion notification (ECN)
  - can't be gamed by strategising machines

- a resource accountability metric
  - of customers to ISPs (too much traffic)
  - and ISPs to customers (too little capacity)

a) cost to other users of your traffic
b) marginal cost of equipment upgrade
  - so it wouldn't have been congested
  - so traffic wouldn't have affected others
- competitive market matches a) & b)

- cost of network usage
  - unforgivable for a business not to understand its costs

- answer: congestion-volume
  - volume weighted by congestion when it was sent

- takes into account all three factors

	congestion-volume	TCP	WFQ	Vol	DPI
bit-rate	✓	✓	✓	✓	✓
weighted by congestion	✓	~	~	✗	~
activity over time	✓	✗	✗	✓	✓

bit-rate$_a$

bit-rate$_b$

congestion = loss or marking fraction

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note: diagram is conceptual
congestion volume & capital cost of equipment would be accumulated over time
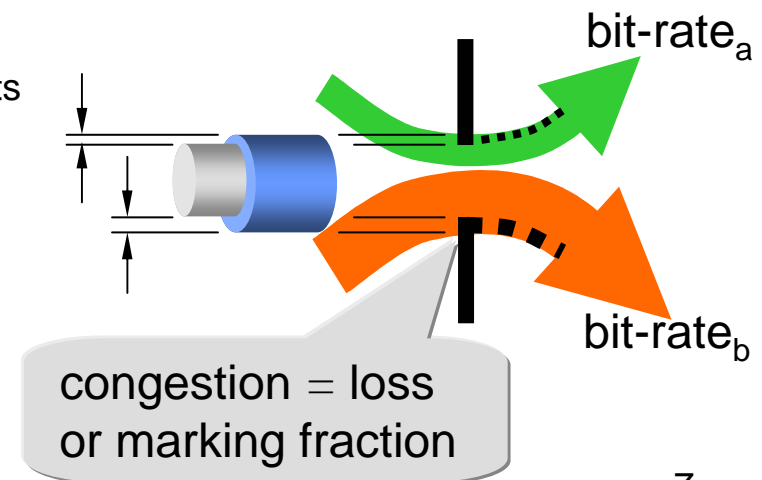
flat fee congestion policing

if ingress net could see congestion...

Acceptable Use Policy

'congestion-volume' allowance: 1GB/month

@ £15/month

Allows **~70GB per day** of data in typical conditions

- incentive to avoid congestion
- simple invisible QoS mechanism
  - apps that need more, just go faster
- side-effect: stops denial of service
- only throttles traffic when your contribution to congestion in the cloud exceeds your allowance

bulk congestion policer

Internet

0%

0.3% congestion

0.1%

2 Mb/s
0.3Mb/s
6 Mb/s
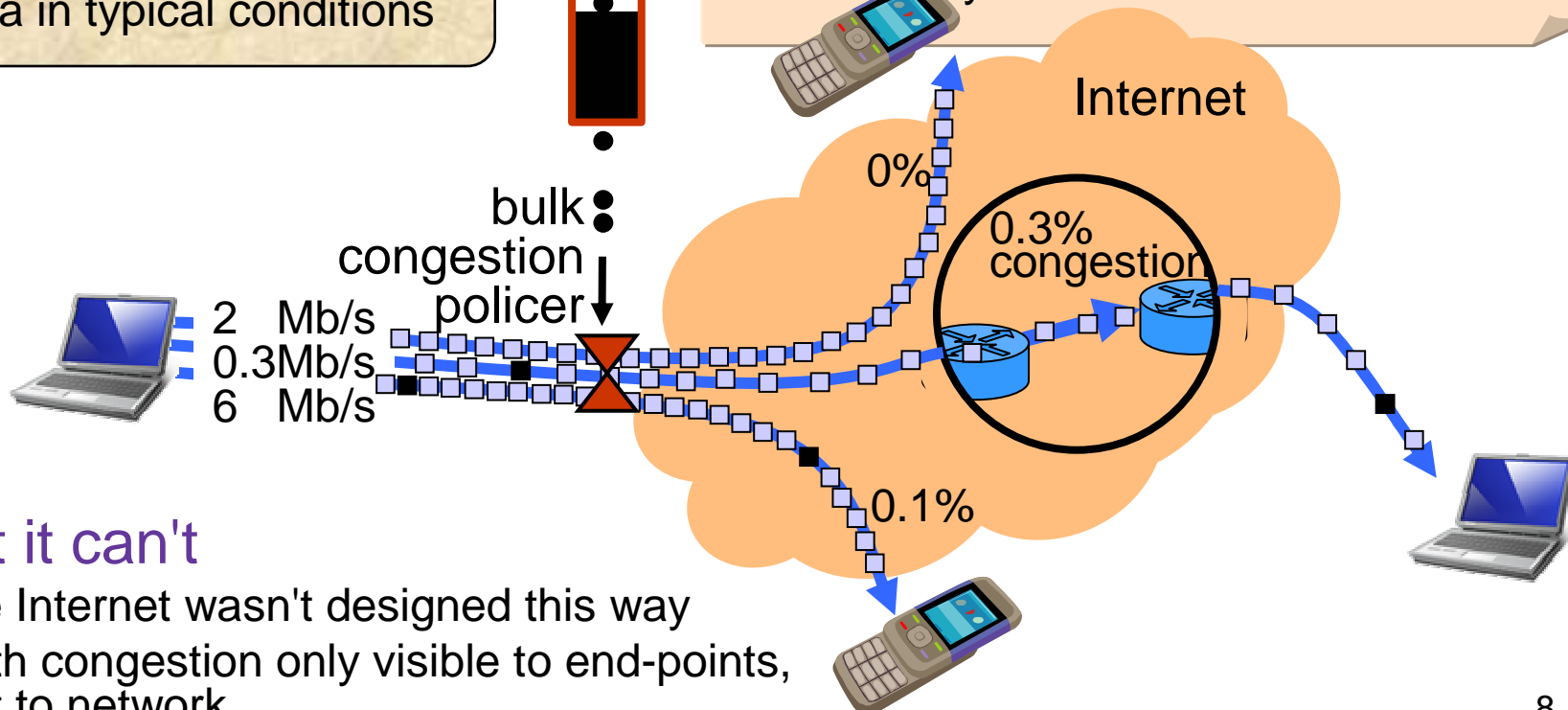
...but it can't

- the Internet wasn't designed this way
- path congestion only visible to end-points, not to network

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one bit opens up the future

BT

IPv4 header

		Diff serv	ECN	
			R E	

3 Sender re-inserts feedback (re-feedback) into the forward data flow as credit marks

1 Congested queue debit marks some packets

2 Receiver feeds back debit marks

Feedback path

Networks

Routers

+1   +1   +1   -1   +1   -1

Sender

Data packet flow

Receiver

4 Outcome:
End-points still do congestion control
But sender has to reveal congestion it will cause
Then networks can limit excessive congestion

5 Cheaters will be persistently in debt
So network can discard their packets
(In this diagram no-one is cheating)

no changes required to IP data forwarding

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guaranteed bit-rate?
or much faster 99.9% of the time?
harnessing flexibility

constant quality video encoding (qp=28)
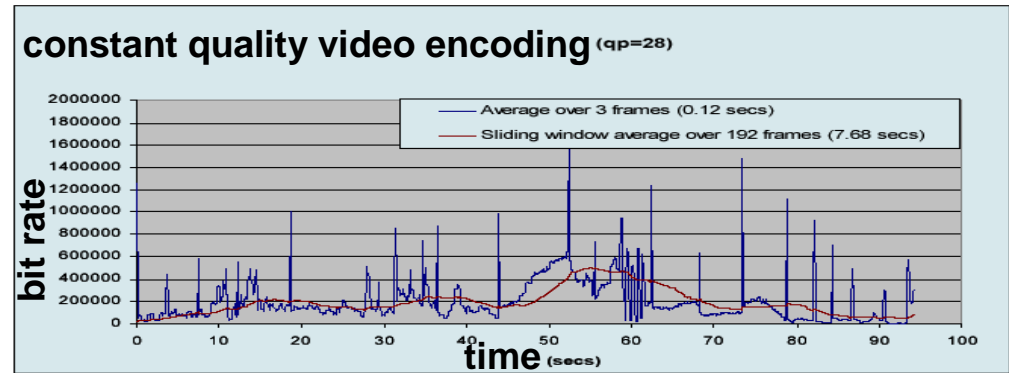
- the idea that humans want to buy a known fixed bit-rate
  - comes from the needs of media delivery technology
  - hardly ever a human need or desire

- services want freedom & flexibility
  - access to a large shared pool, not a pipe
- when freedoms collide, congestion results
  - many services can adapt to congestion
  - shift around resource pool in time/space
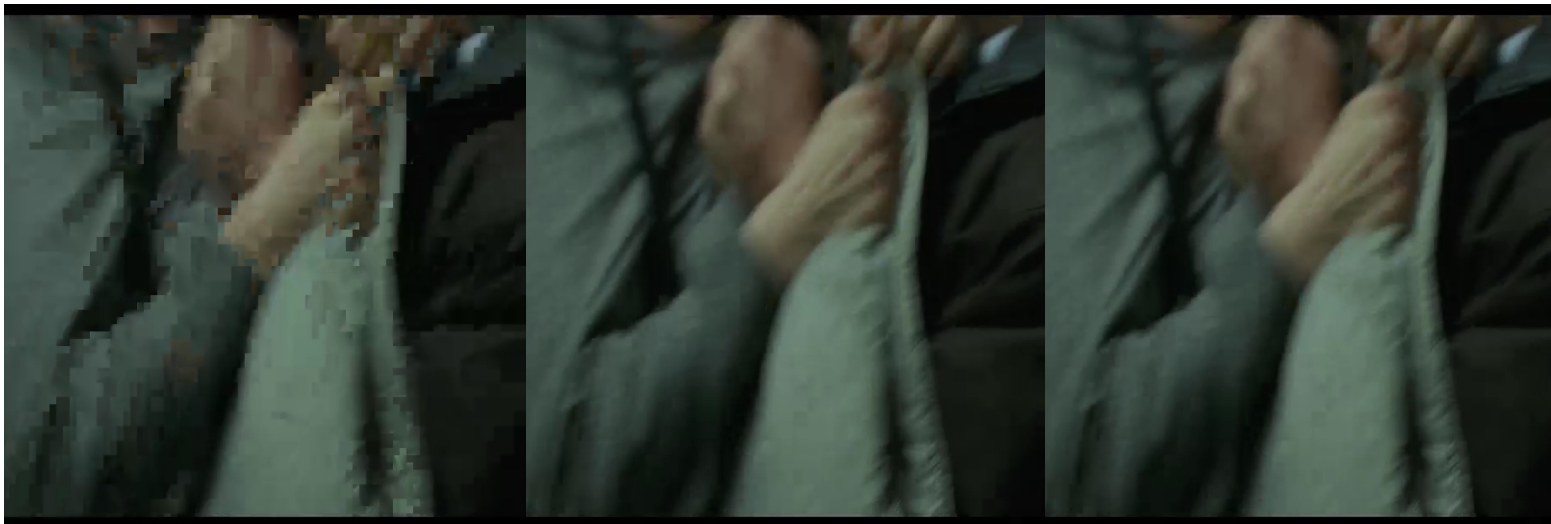
% figures = no. of videos that fit into the same capacity

Constant Bit Rate **100%**   Constant Quality **125%**   Equitable Quality **216%**
sequences encoded at same average of 500kb/s   [Crabtree09]

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closing off the future

- ISPs must have a role in bandwidth sharing
  - minimally, incentivise end-systems to manage congestion
  - can't today, because ISPs can't see path congestion
- without correct metric, ISPs resort to application analysis
  - getting impossible to deploy a new use of the Internet
  - must negotiate the arbitrary blocks and throttles en route
- two confusable motives
  - fairer cost sharing
  - competitive advantage to own services

- how to deconfuse: make cost of usage transparent
  - fixing Internet technology should avoid need for legislation

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bringing information to the control point

- no control without information
  - re-ECN packets reveal real-time cost
- flat fee policer was just one example...
- huge space for business & technical innovation at the control point
  - cost based, value-cost based
  - bulk, per flow, per session
  - call admission control
  - policing, charging
  - tiers, continuous
  - wholesale, retail

open

closed

telco /NGN

Internet

cable

cellular

satellite

1995

2009

Internet

- truly converged architecture
  - can apply different industry cultures
  - through policies at the control point
  - not embedded in each technology

BT

the future of access?

a) integrated part of a clean transparent global infrastructure for all to share?

b) a jumble of conflicting opaque ways to carve up the infrastructure?

- recommendations
  - Internet fairness architecture: support IETF/IRTF rework
  - access technologies: commit to new IETF interface
- prospect
  - release innovative new application behaviours

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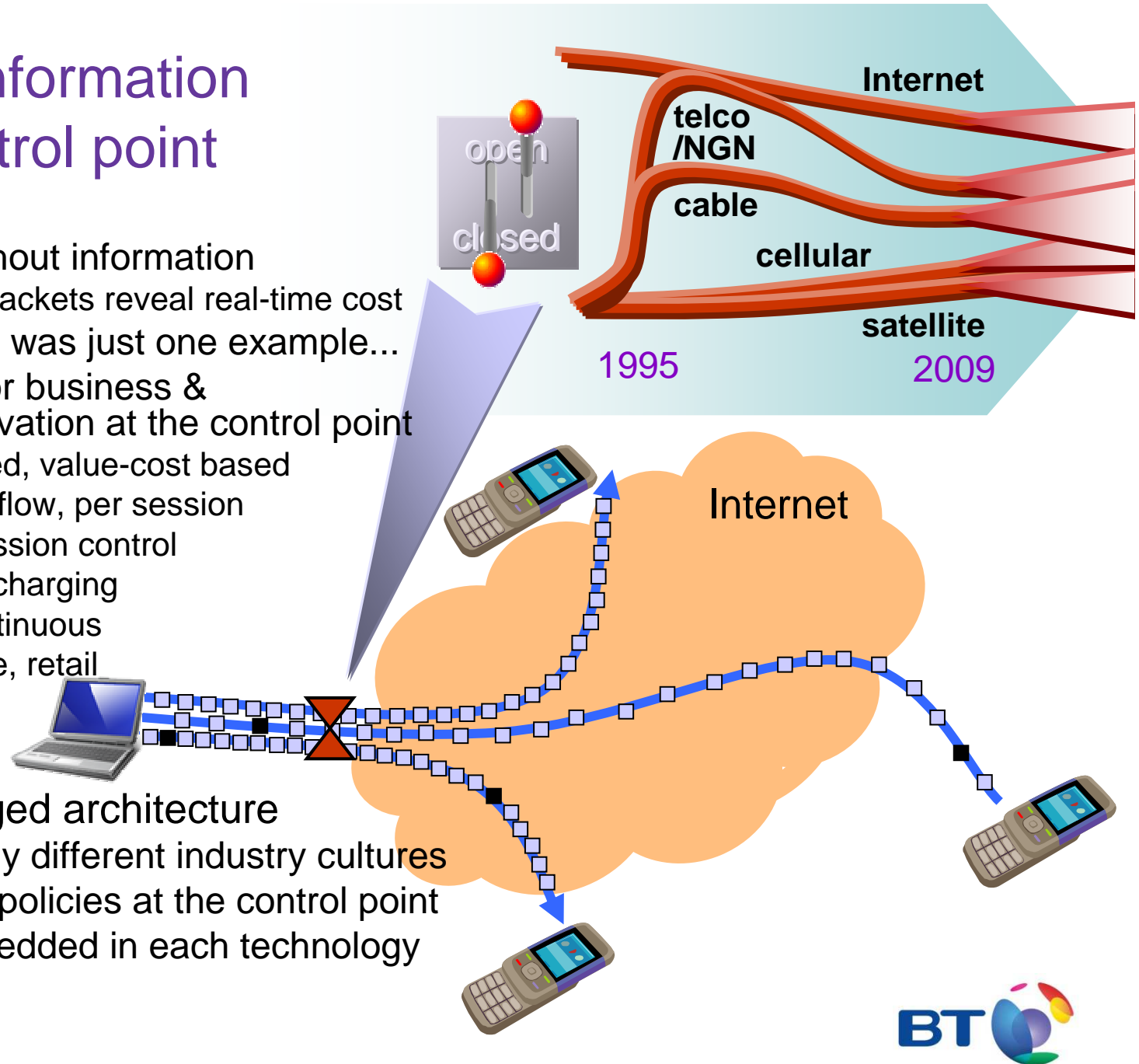
more info...

- The whole story in 5 pages
  - Bob Briscoe, "A Fairer, Faster Internet Protocol", IEEE Spectrum (Dec 2008)
- Inevitability of policing
  - [CFP06] The Broadband Incentives Problem, Broadband Working Group, MIT, BT, Cisco, Comcast, Deutsche Telekom / T-Mobile, France Telecom, Intel, Motorola, Nokia, Nortel (May '05 & follow-up Jul '06) <cfp.mit.edu>
- Slaying myths about fair sharing of capacity
  - [Briscoe07] Bob Briscoe, "Flow Rate Fairness: Dismantling a Religion" ACM Computer Communications Review 37(2) 63-74 (Apr 2007)
- How wrong Internet capacity sharing is and why it's causing an arms race
  - Bob Briscoe et al, "Problem Statement: Transport Protocols Don't Have To Do Fairness", IETF Internet Draft (Jul 2008)
- Understanding why QoS interconnect is better understood as a congestion issue
  - Bob Briscoe and Steve Rudkin "Commercial Models for IP Quality of Service Interconnect" BT Technology Journal 23 (2) pp. 171--195 (April, 2005)
- Equitable quality video streaming
  - [Crabtree09] B. Crabtree, M. Nilsson, P. Mulroy and S. Appleby "Equitable quality video streaming" Computer Communications and Networking Conference, Las Vegas, (January 2009)

Re-architecting the Internet:
    The Trilogy project <www.trilogy-project.org>

re-ECN & re-feedback project page:
    http://www.cs.ucl.ac.uk/staff/B.Briscoe/projects/refb/

bob.briscoe@bt.com

the speed of sharing
stretching Internet access

discuss...

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main steps to deploy re-feedback / re-ECN

summary
rather than control sharing in the access links,
pass congestion info & control upwards

- network
  - turn on explicit congestion notification in data forwarding
    - already standardised in IP & MPLS
    - standards required for meshed network technologies at layer 2
      (ECN in IP sufficient for point to point links)
  - deploy simple active policing functions at customer interfaces around participating networks
  - passive metering functions at inter-domain borders
- terminal devices
  - (minor) addition to TCP/IP stack of sending device
  - or sender proxy in network
- then new phase of Internet evolution can start
  - customer contracts & interconnect contracts
  - endpoint applications and transports

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routing money
and simple internalisation of all externalities

lightly congested link

legend: re-ECN downstream congestion marking [%]

area = instantaneous downstream congestion-volume

bit rate

N_A

highly congested link

€

€

0|0|2|7|6|0|5

just two counters at border, one for each direction

meter monthly bulk volume of packet markings

= aggregate money in flows

without measuring flows

N_B

€

N_D

N_C

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