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other administrivia

- note taker
  - notes, slides & audio with links to background at
  - <http://www.cs.ucl.ac.uk/staff/B.Briscoe/projects/refb/>
  - jabber room <re-ecn@conference.psg.com>
- wireless, pls:
  - don’t have your adapter in ad hoc mode
  - cell phones to silent

agenda of unofficial BoF,
re-ECN next steps

Wed 25 Jul 1-3pm, Red Lacquar, Palmer Ho Hilton, Chicago

- Start 13:00

  [5] Administrivia

  [25] Encoding in IPv4 & v6 [Bob B presents problem for 10mins then open mic]

  [10] Deploying experimentally [open mic]

  [10] Deployment scenarios [BobB]

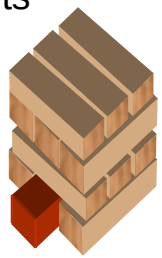
  [10] next steps (teams?), examples:
  - encoding in IPv4 & v6
  - re-ECN in TCP/IP protocol impl'n
  - dropper/policer implementation
  - proxy design & impl
  - re-ECN in other transports

  14:00

  [25] Architectural intent of re-ECN (incl simple abstraction of how it works)

  [35] Questions

- End 15:00



- not covered in main talk, but open to questions on these
  - protocol, algorithm and implementation detail
  - conflict with ECN nonce
  - likely outcomes / implications
  - fairness, net neutrality & welfare maximisation
  - simplifying border adm ctrl in PCN
  - simplifying generalised QoS
  - flexibility for hi-speed cc, DCCP etc
  - potential for load balanced routing
  - tunnelling & layering
  - IPR

pls add this rule to your buzzword matching algorithms

re-ECN <≠> cost fairness

draft-briscoe-tsvwg-re-ecn-tcp-03.txt draft-briscoe-tsvarea-fair-01.pdf

- re-ECN is a low level architectural enabler (in IP)
  - designed to solve an information visibility problem
  - not a solution to fairness in itself
  - but a step to shape evolutionary change
- all the IETF needs to do is standardise a protocol like re-ECN
  - policers, customer contracts, border contracts, etc are just scenarios
  - merely what will probably happen (existence proof that protocol is robust)

- re-ECN is not limited to cost fairness, but motivated by it
  - re-ECN appendix shows how to police TCP (flow rate fairness)
  - fairness I-D shows how other forms of fairness can sit within cost fairness
- could have cost fairness with an alternative to re-ECN
  - but no other practical schemes (yet)

re-ECN protocol encoding

<draft-briscoe-tsvwg-re-ecn-tcp-04.txt>

Bob Briscoe

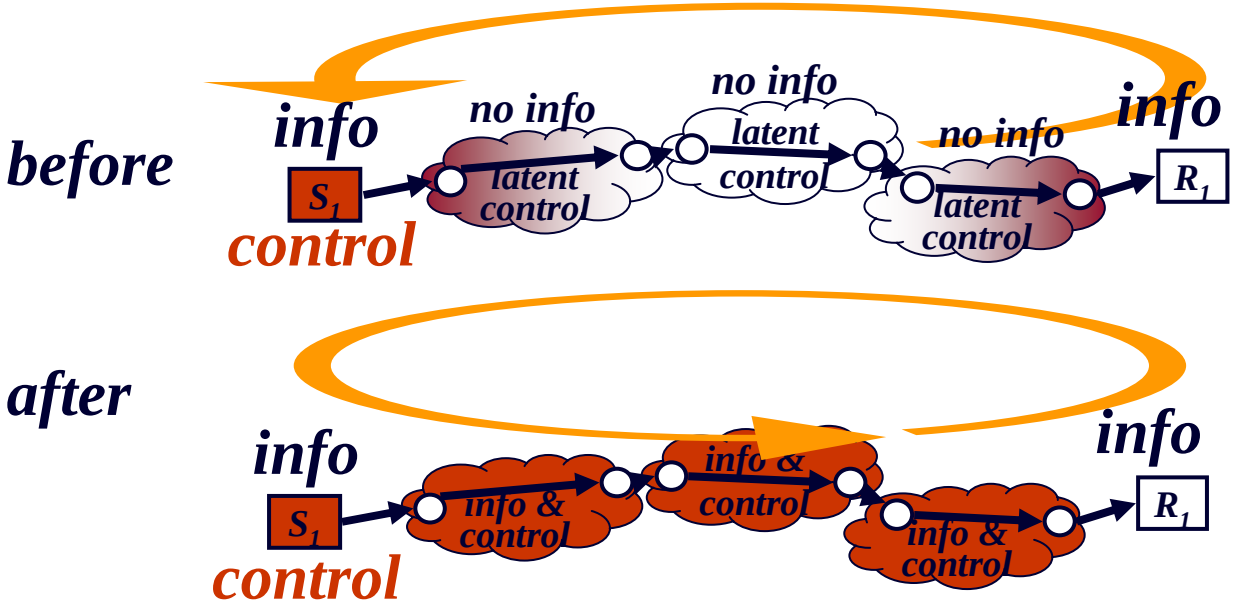
Chief Researcher, BT Group

unofficial Birds of a Feather at IETF-69

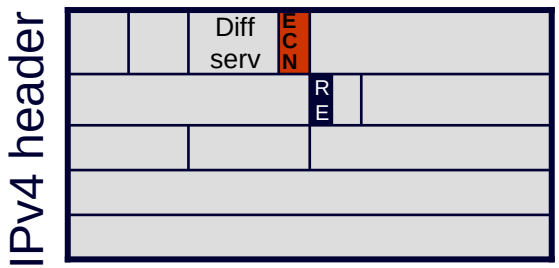
Jul 2007

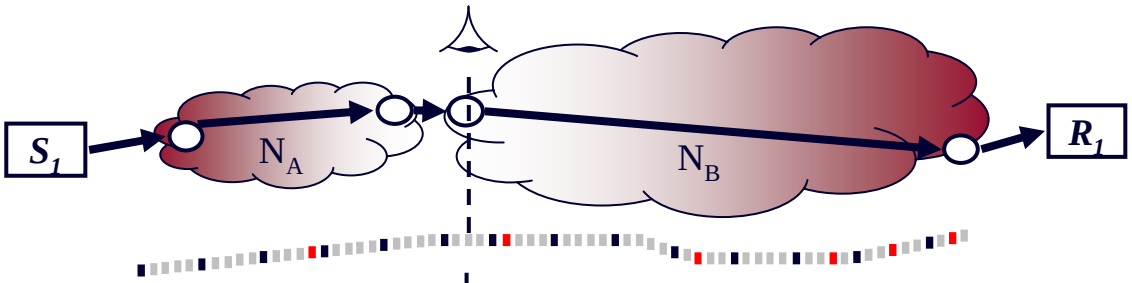
re-ECN in brief

- reinsert feedback
- packets arrive at each router predicting downstream path
- incremental deployment
  - only have to change sender (& turn on ECN)
- a simple idea for the Internet's accountability architecture



measurable downstream congestion

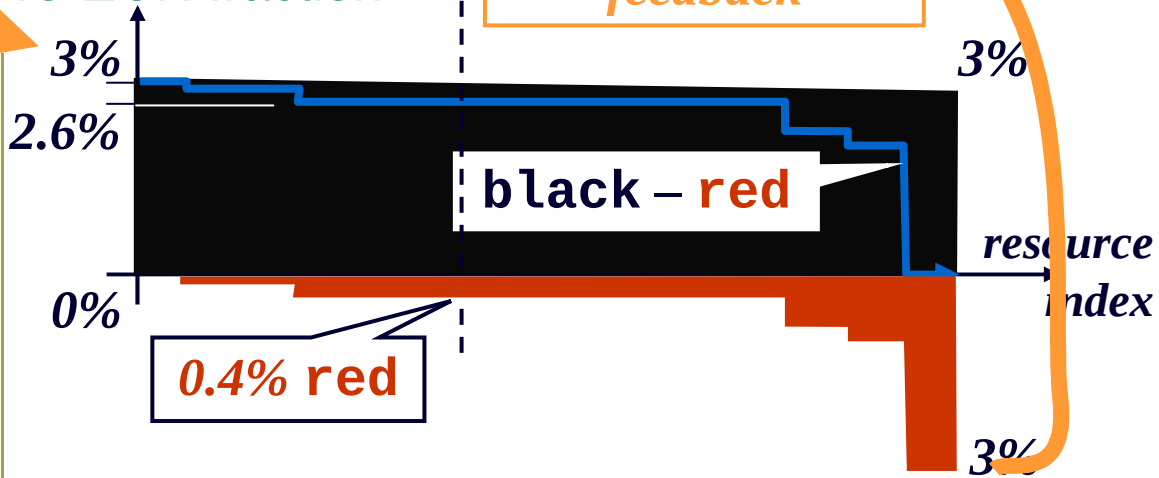




re-feedback

feedback

re-ECN fraction



- sender re-inserts feedback by marking packets **black**
- at any point on path,diff betw fractions of **black** & **red** bytes is downstream congestion
- ECN routers unchanged
- **black** marking e2e but visible at net layer for accountability

extended ECN codepoints: summary

- RE flag in different place in IPv4 (header) & IPv6 (extension)
- extra semantics backward compatible with ECN semantics

ECN code-point	ECN [RFC3168] codepoint	RE flag	Extended ECN codepoint	re-ECN meaning	`worth'
00	not-ECT	0	Not-RECT	Not re-ECN capable transport	
		1	FNE	Feedback not established	+1
01	ECT(1) nonce	0	Re-Echo	Re-echo congestion event	+1
		1	RECT	Re-ECN capable transport	0
10	ECT(0)	0	---	Not used	
		1	--CU--	Currently unused	
11	CE	0	CE(0)	Congestion experienced with Re-Echo	0
		1	CE(-1)	Congestion experienced	-1

re-ECN wire protocol in IPv4 (§3)

- propose Re-ECN Extension (RE) flag
  - for IPv4: propose to use (reserved) bit 48
  - set by sender, unchanged e2e
  - must be readable by network elements, preferably always in outer header

v4	IHL	Diffserv	ECN	Datagram Length
ID			RE / DMF	Fragment offset
TTL		Protocol		Header checksum
source addr				
dest addr				

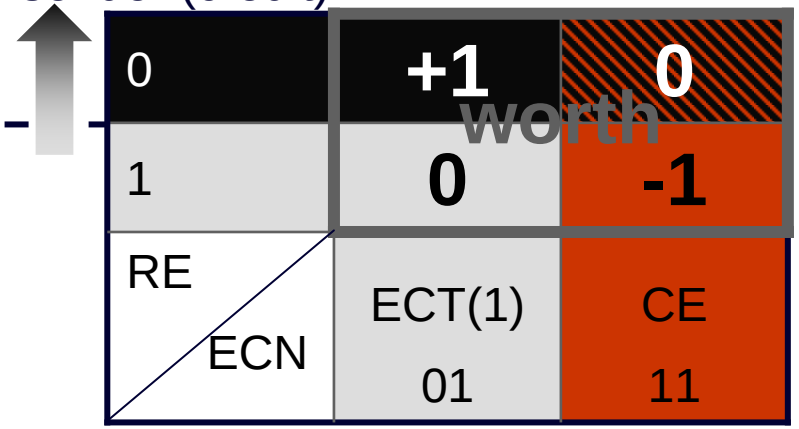
- once flow established
- sender re-inserts ECN feedback into forward data ("re-ECN") as follows
  - re-ECN sender always sets ECT(1)
  - on every **congestion event** from transport (e.g. TCP)

sender blanks **RE**
else sets RE

- conceptually, 'worth' of packet depends on 3 bit `codepoint'
- aim for zero balance of worth in flow

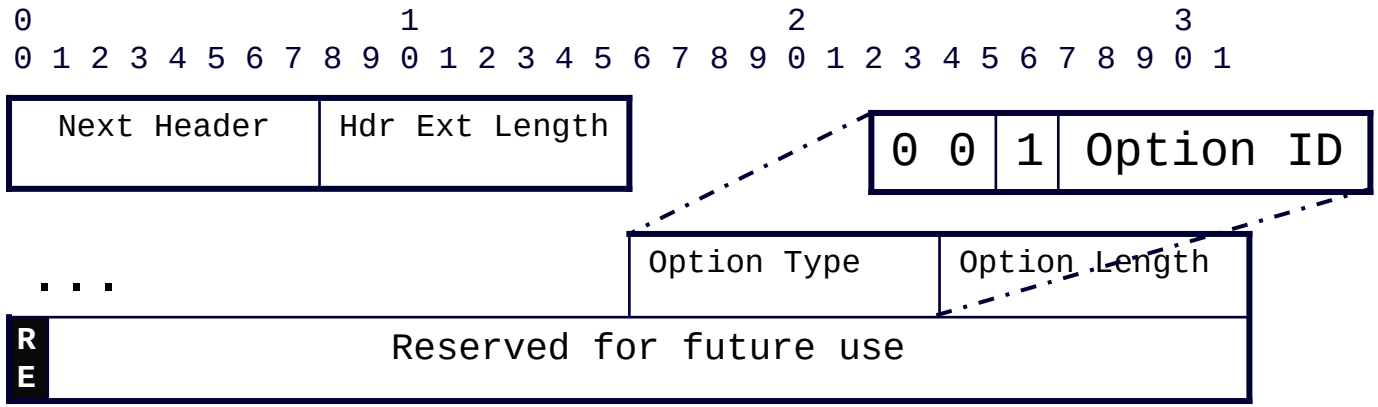
[RFC3168] ECN marking router (debit)

sender (credit)



IPv6 re-ECN protocol encoding (§3)

- IPv6 hop-by-hop options header extension
  - new Congestion hop-by-hop option type



  - action if unrecognized (AIU) = 00 ‘skip and continue’
  - changeable (C) flag = 1 ‘may change en route’
    - even tho RE flag shouldn’t change en route (AH would just tell attackers which packets not to attack)
- seems wasteful for 1 bit, but we plan:
  - future hi-speed congestion control I-D using multi-bit congestion field
  - other congestion-related fields possible
    - e.g. to distinguish wireless loss and per-packet vs per-bit congestion

re-ECN deployment scenarios

<draft-briscoe-tsvwg-re-ecn-tcp-04.txt>
<draft-briscoe-re-pcn-border-cheat-00.txt>

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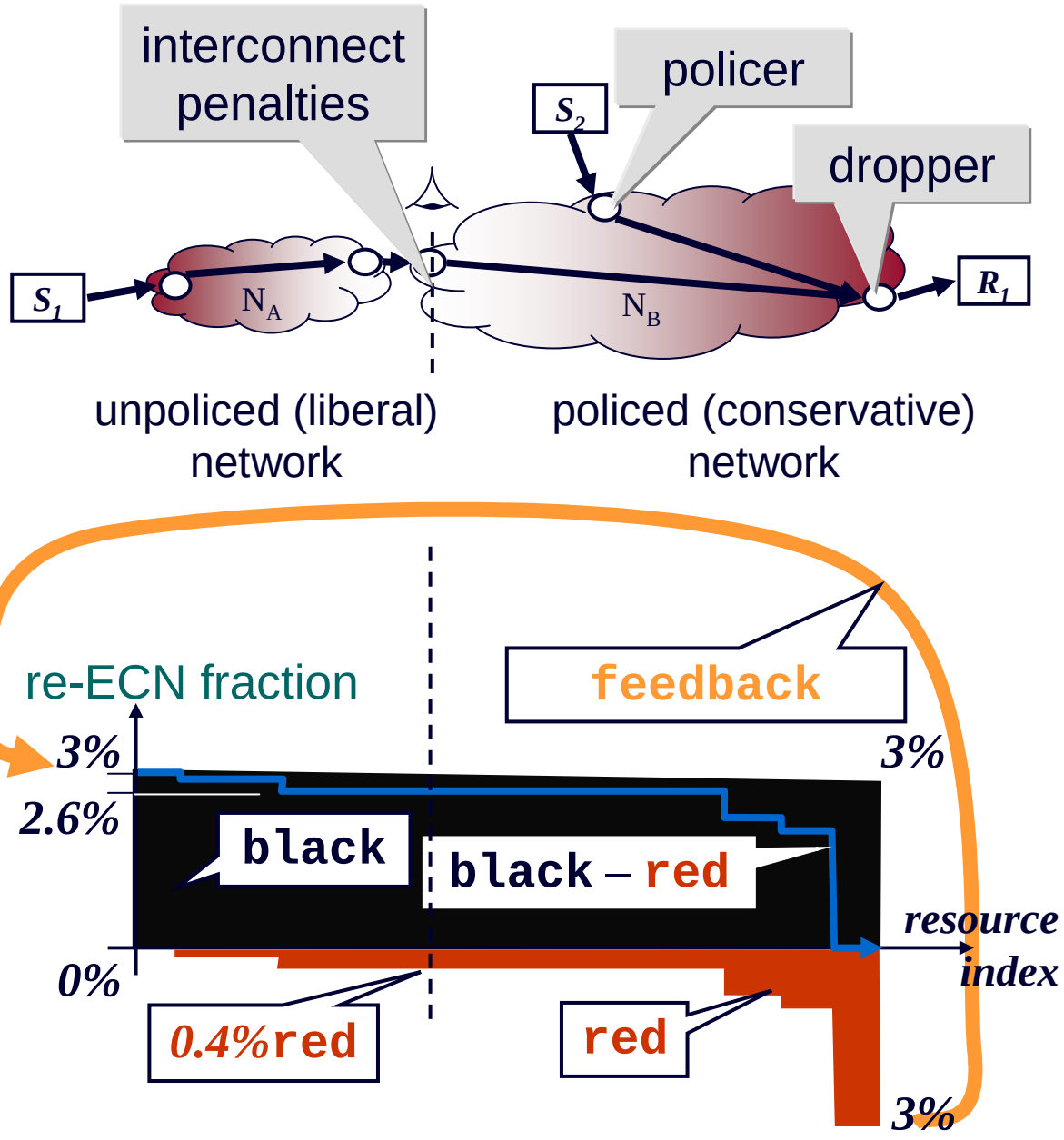
Jul 2007

various possible deployment scenarios

- permanently partial deployment
  - re-ECN codepoints effectively partition every DS PHB
  - subset of resources (queues etc) ECN-enabled
  - subset of operators deploy edge policing (ingress & egress)
  - subset of senders
  - subset of flows sender creates
  - subset of receivers
    - works nearly as well with RFC3168 ECN receivers
- sender proxy
- enforcing edge-edge congestion notification
  - e.g. extending PCN to multi-domain

re-ECN partial deployment



deployment incentives
bootstrap then chain reaction

- deployment effectively involves architectural change
  1. (minor) change to sender's Internet stack
  2. network deploys edge/border incentive functions
  - breaking the stand-off between 1 & 2 requires strong incentives
- re-feedback solves ISPs' main cost control problem
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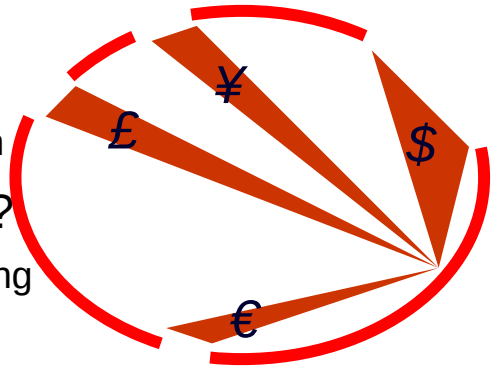
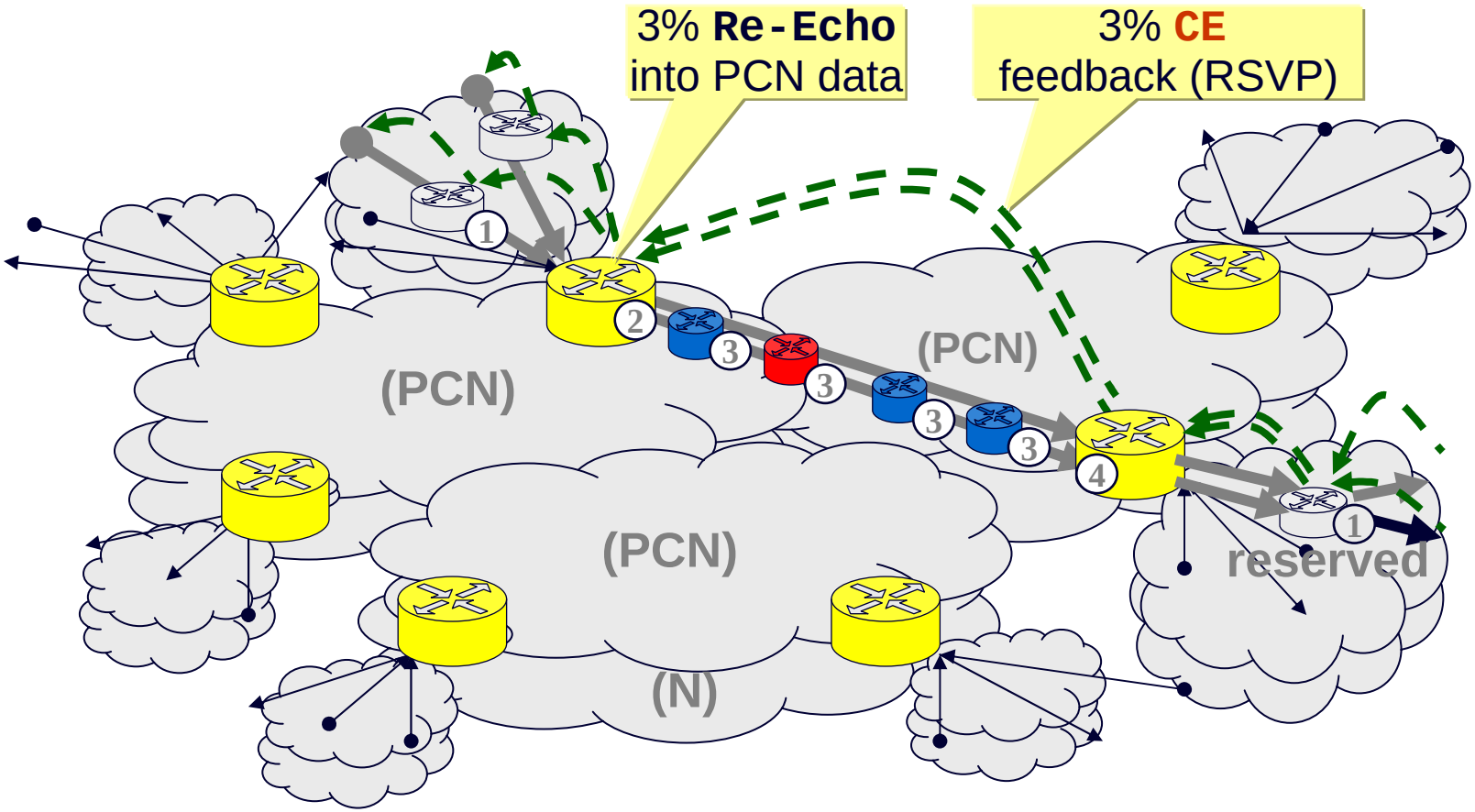
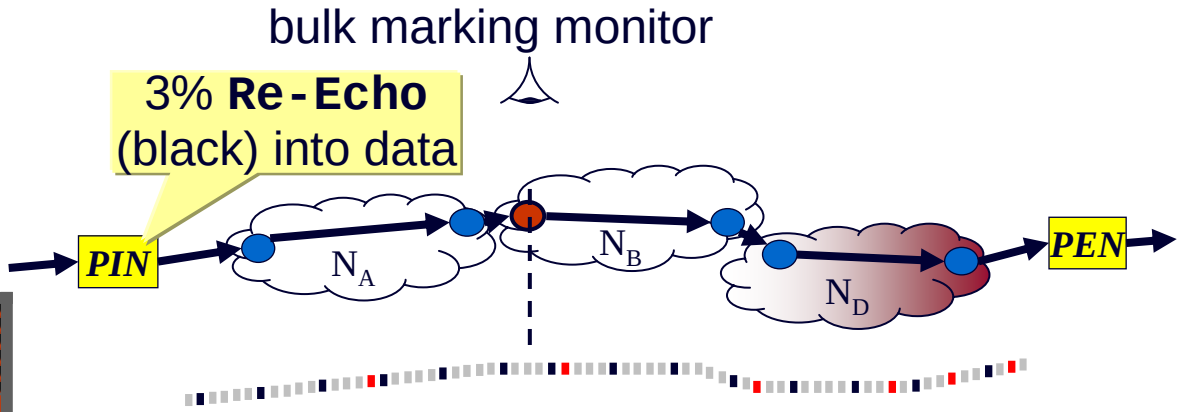


extending PCN to multi-domain

re-PCN: border anti-cheating solution

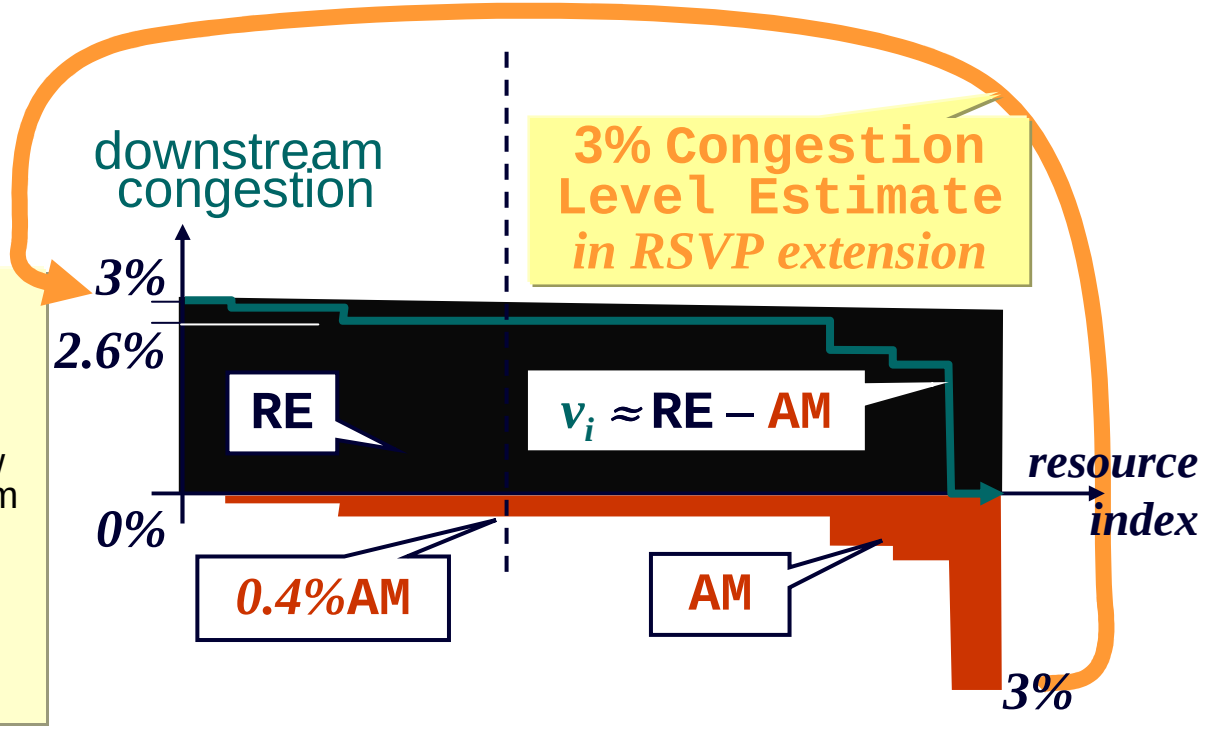


re-PCN

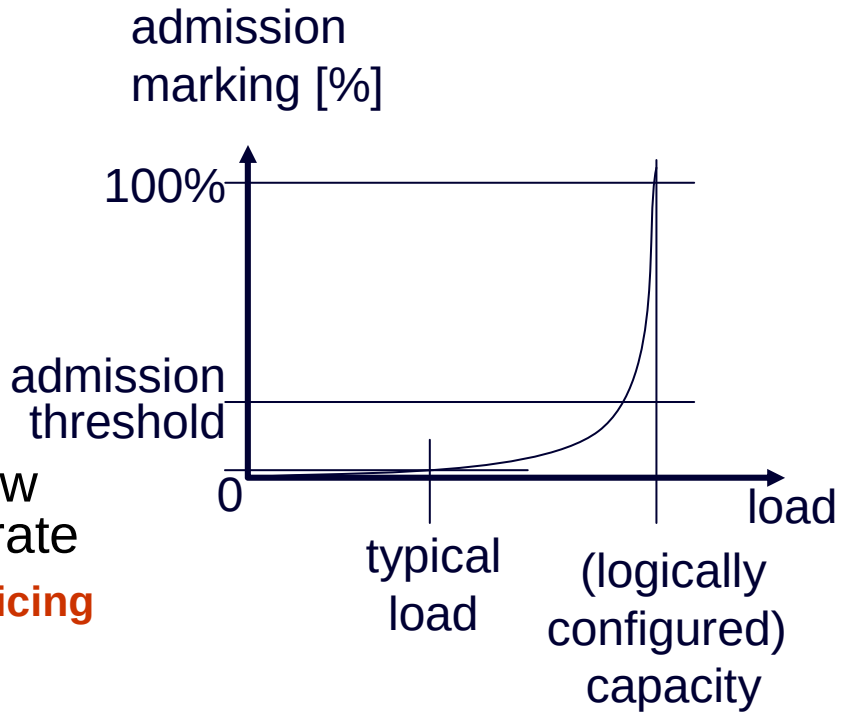


0	+1 worth	0
1	0	-1
RE / ECN	PCT 01	AM 10

- ingress gateway blanks **RE**, in same proportion as fraction of admission marking **AM** arriving at egress
- at any point on path, bulk diff betw fractions of **RE** & **AM** is downstream congestion
- routers unchanged
- same applies for termination marking, TM



solution rationale



- <0.01% packet marking at typical load
  - addition of any flow makes little difference to marking
- penalties to ingress of each flow appear proportionate to its bit rate
  - **emulates border flow rate policing**
- as load approaches capacity
  - penalties become unbearably high (~1000x typical)
  - insensitive to exact configuration of admission threshold
  - **emulates border admission control**
- neither is a perfect emulation
  - but should lead to the desired behaviour
  - fail-safes if networks behave irrationally (e.g. config errors) – see draft

re-ECN architectural intent

a step to shape evolutionary change

<draft-briscoe-tsvwg-re-ecn-tcp-04.txt>

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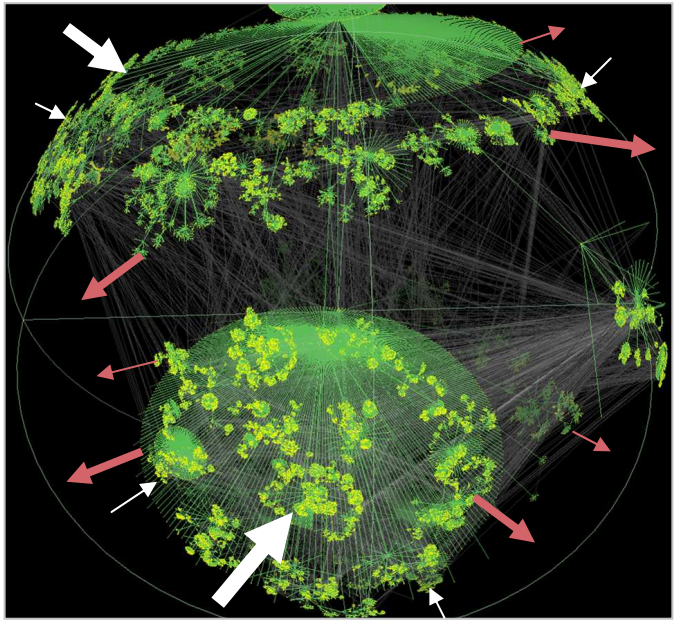
Jul 2007

known problem
since early days

- how to share all the parts of a huge, multi-provider packet multiplexer between competing processes
- keeping one-way datagrams
- allowing for
  - self-interest & malice
    - of users and of providers
  - evolvability
    - of new rate dynamics from apps
    - of new business models
  - viability of supply chain
  - simplicity

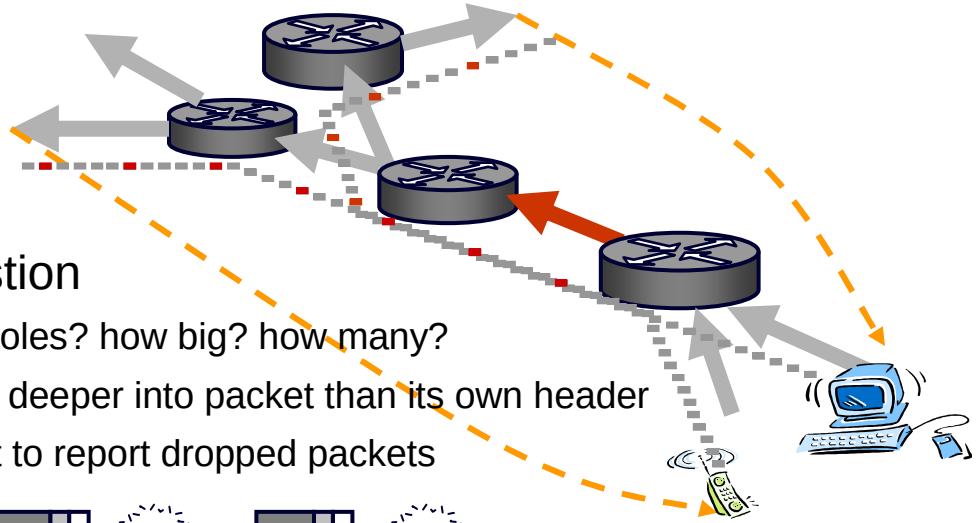


Internet topology visualization produced by Walrus (Courtesy of Young Hyun, CAIDA)

- if we do nothing
  - the few are ruining it for the many
  - massive capacity needed to keep interactive apps viable
  - poor incentives to invest in capacity
  - operators are kludging it with DPI
  - solely today's apps frozen into net
  - complex, ugly feature interactions

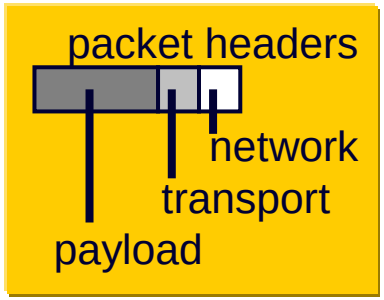
solution step #1: ECN

make congestion visible to network layer



- packet drop rate is a measure of congestion
  - but how does network at receiver measure holes? how big? how many?
  - can't presume network operator allowed any deeper into packet than its own header
  - not in other networks' (or endpoints') interest to report dropped packets

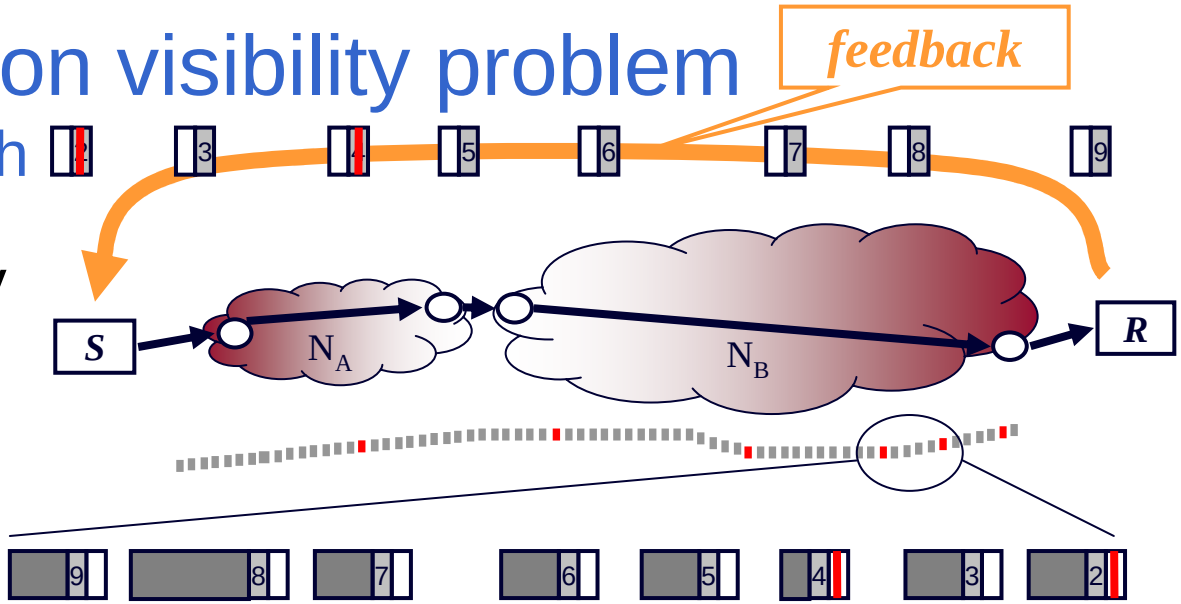
- solution: Explicit Congestion Notification (ECN)
  - mark packets as congestion ***approaches*** - to avoid drop
  - already standardised into IP (RFC3168 – 2001)
  - implemented by most router vendors – very lightweight mechanism
  - but rarely turned on by operators (yet) – mexican stand-off with OS vendors

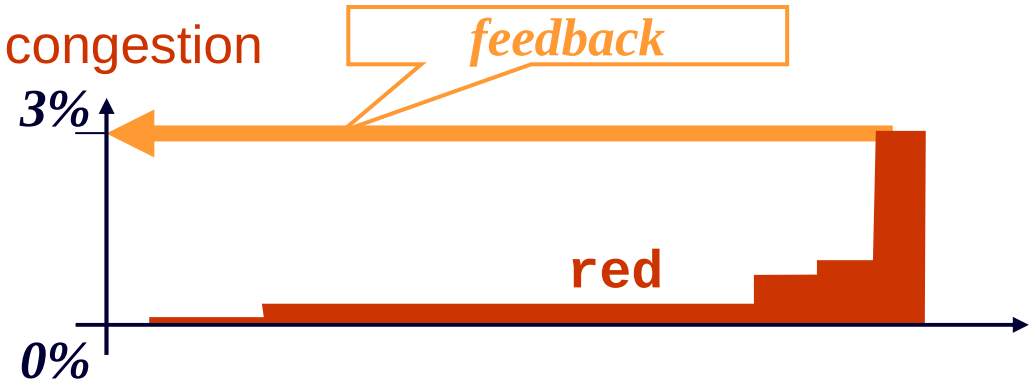


new information visibility problem

ECN is not enough

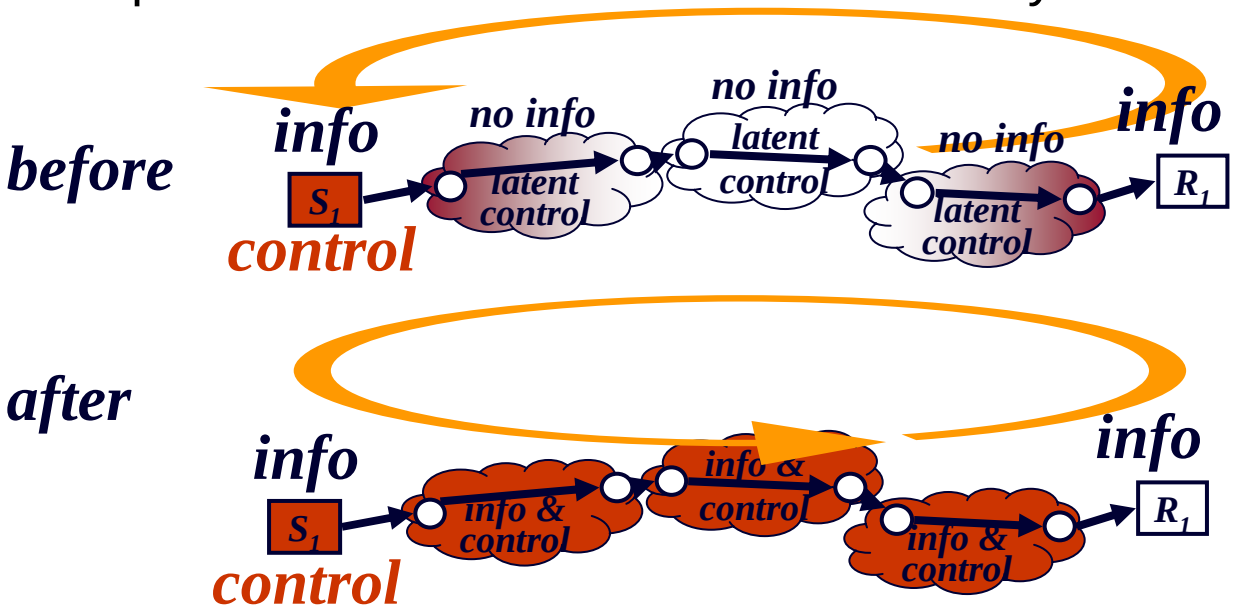
- path congestion only measurable at exit
- can't measure path congestion at entry
  - can't presume allowed deeper into feedback packets





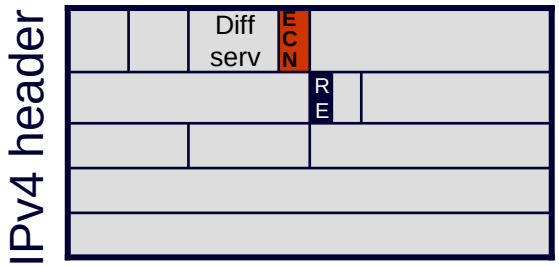
re-ECN in brief

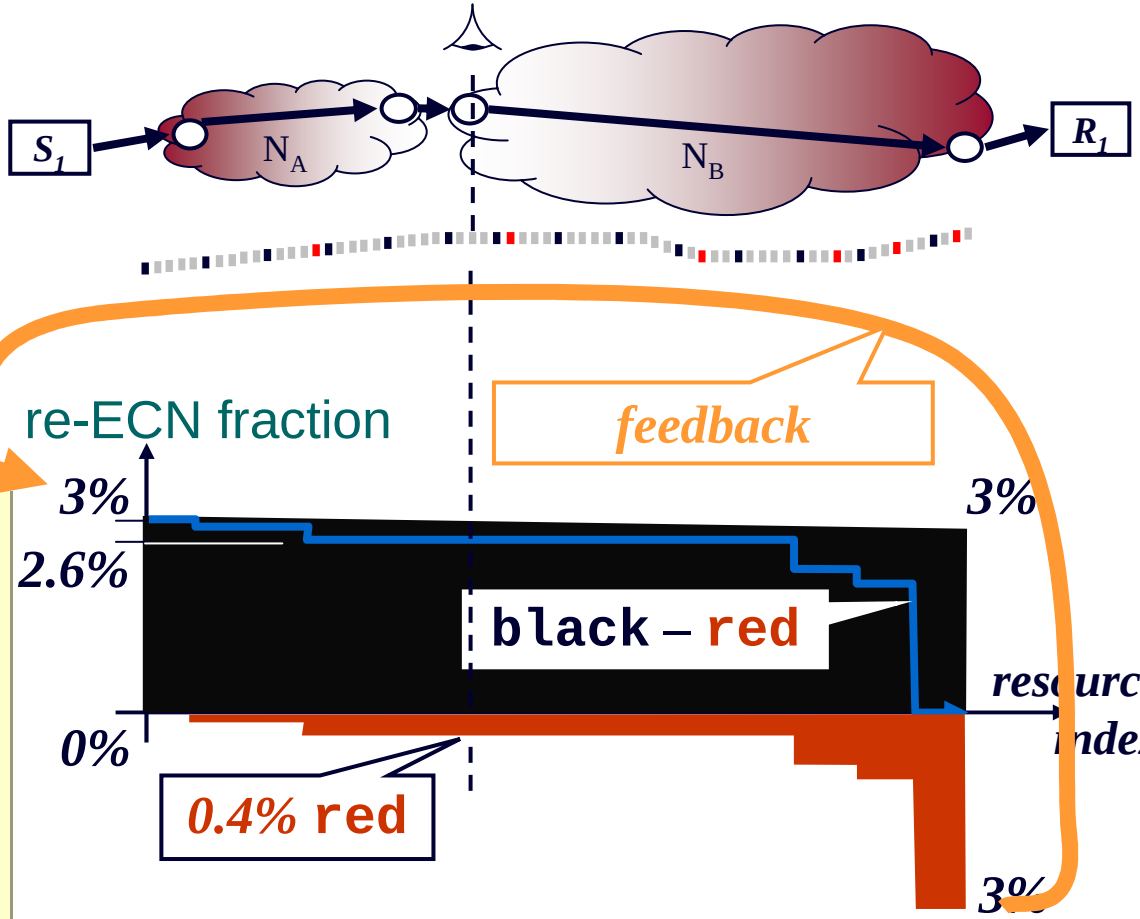
- reinsert feedback
- packets arrive at each router predicting downstream path
- incremental deployment + upgrade incentive knob
- hangs new capabilities on ECN deployment, not just performance
- a simple idea for the Internet's accountability architecture



measurable downstream congestion

solution step #2

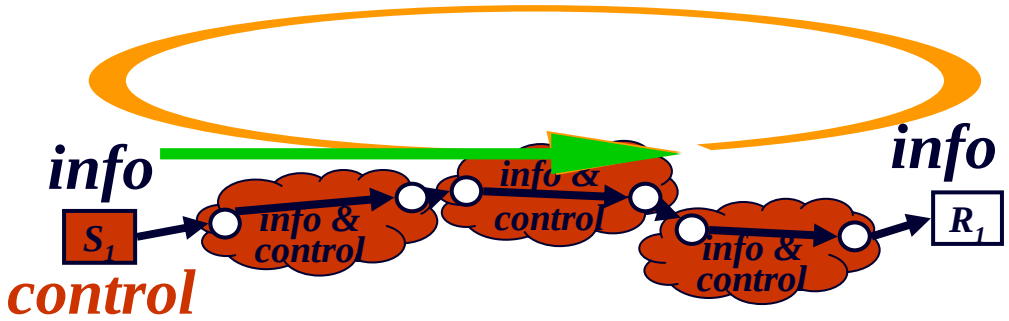




- sender re-inserts feedback by marking packets **black**
- at any point on path,diff betw fractions of **black** & **red** bytes is downstream congestion
- ECN routers unchanged
- **black** marking e2e but visible at net layer for accountability

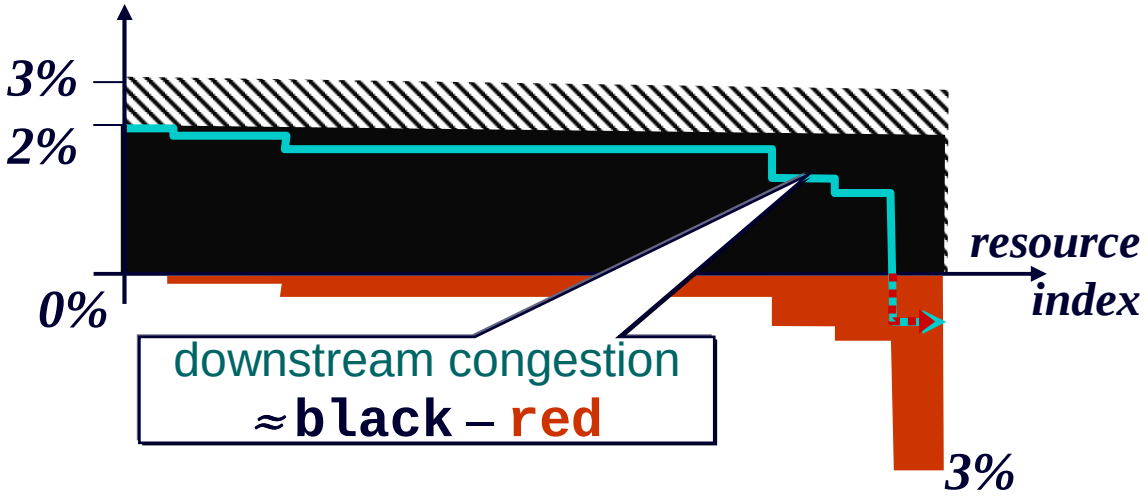
flow bootstrap ‘pre-feedback’

- at least one **green** packet(s) at start of flow or after >1sec idle
  - means “feedback not established”
  - ‘credit’ for safety due to lack of feedback
  - a **green** byte is ‘worth’ same as a **black** byte
- lots of powerful uses for a different colour from black
  - distinguishes conservatism from expected congestion based on experience
  - ability to vary the expected cost of jump-starting (research needed)
  - gives deterministic flow state mgmt (policers, droppers, firewalls, servers)

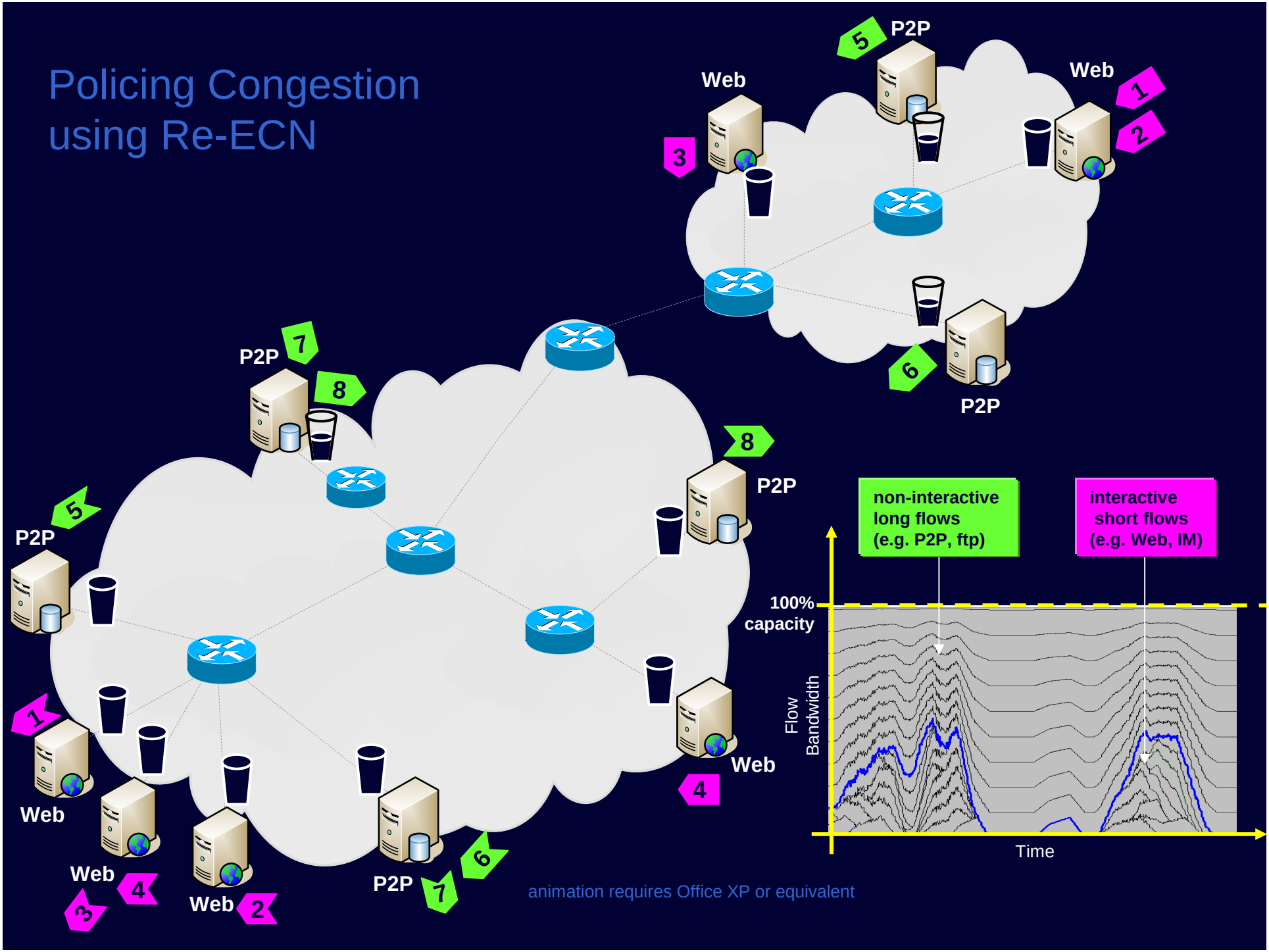


proposed re-ECN service model

- to encourage sender (or proxy) to indicate sufficient expected congestion...
- Internet won't try to deliver packet flows beyond the point where more congestion has been experienced than expected
  - if sender wants to communicate, has to reveal expected congestion
  - even if sender not trying to communicate (e.g. DoS) packets can be dropped rather than enqueued before they add to congestion

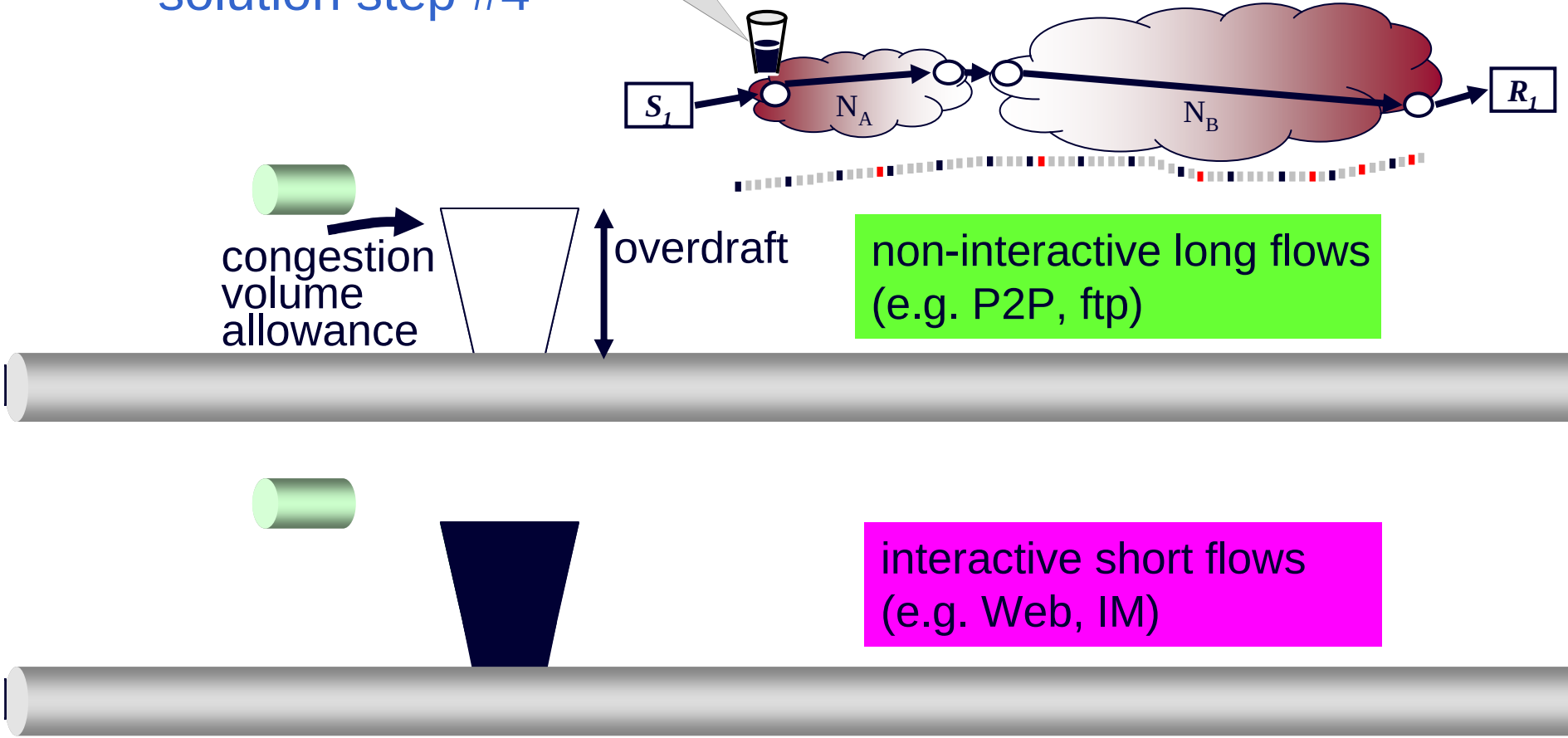


Policing Congestion using Re-ECN



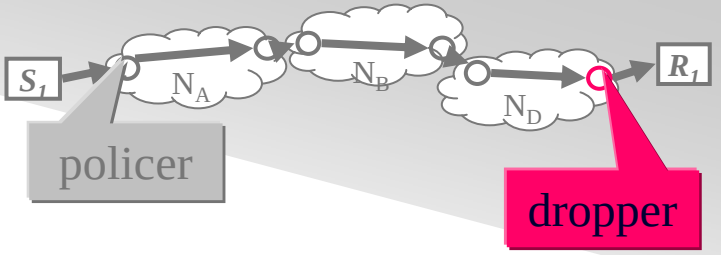
congestion policer – one example: per-user policer

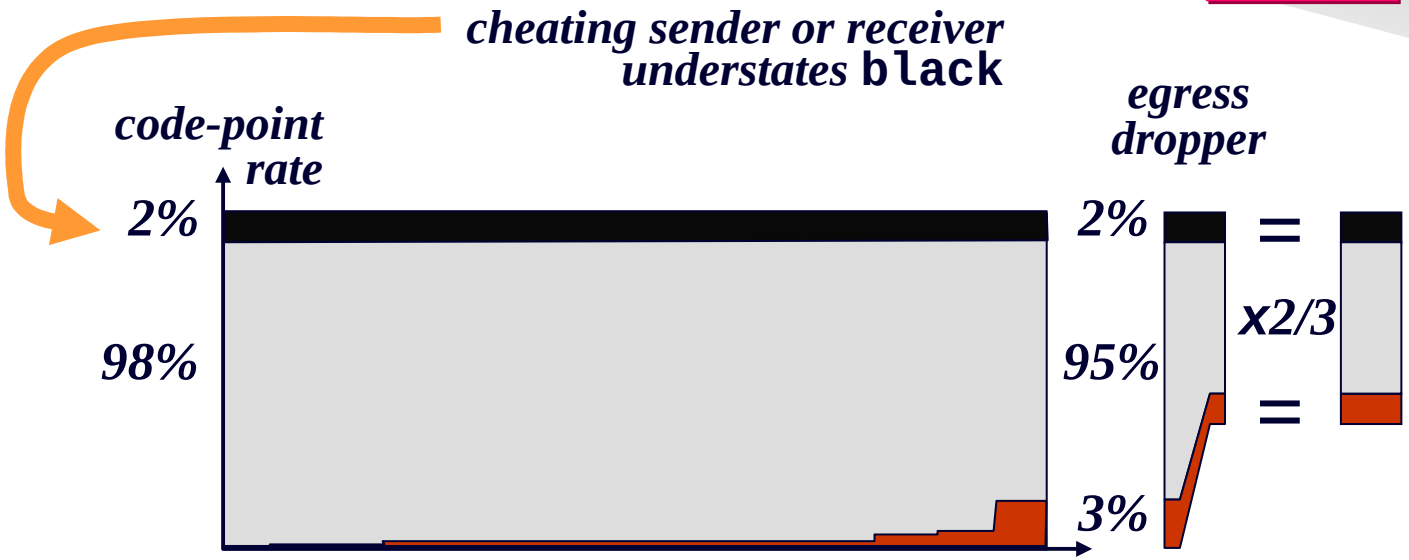
solution step #4



two different customers, same deal

egress dropper (sketch)

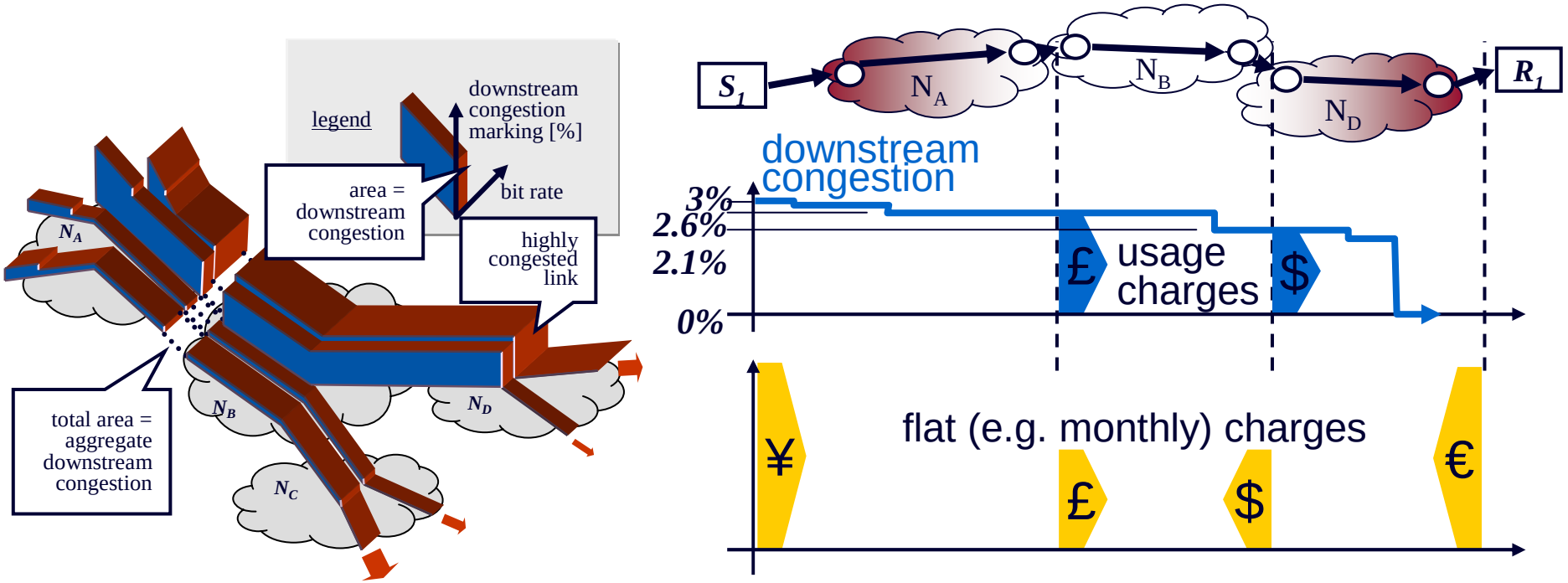




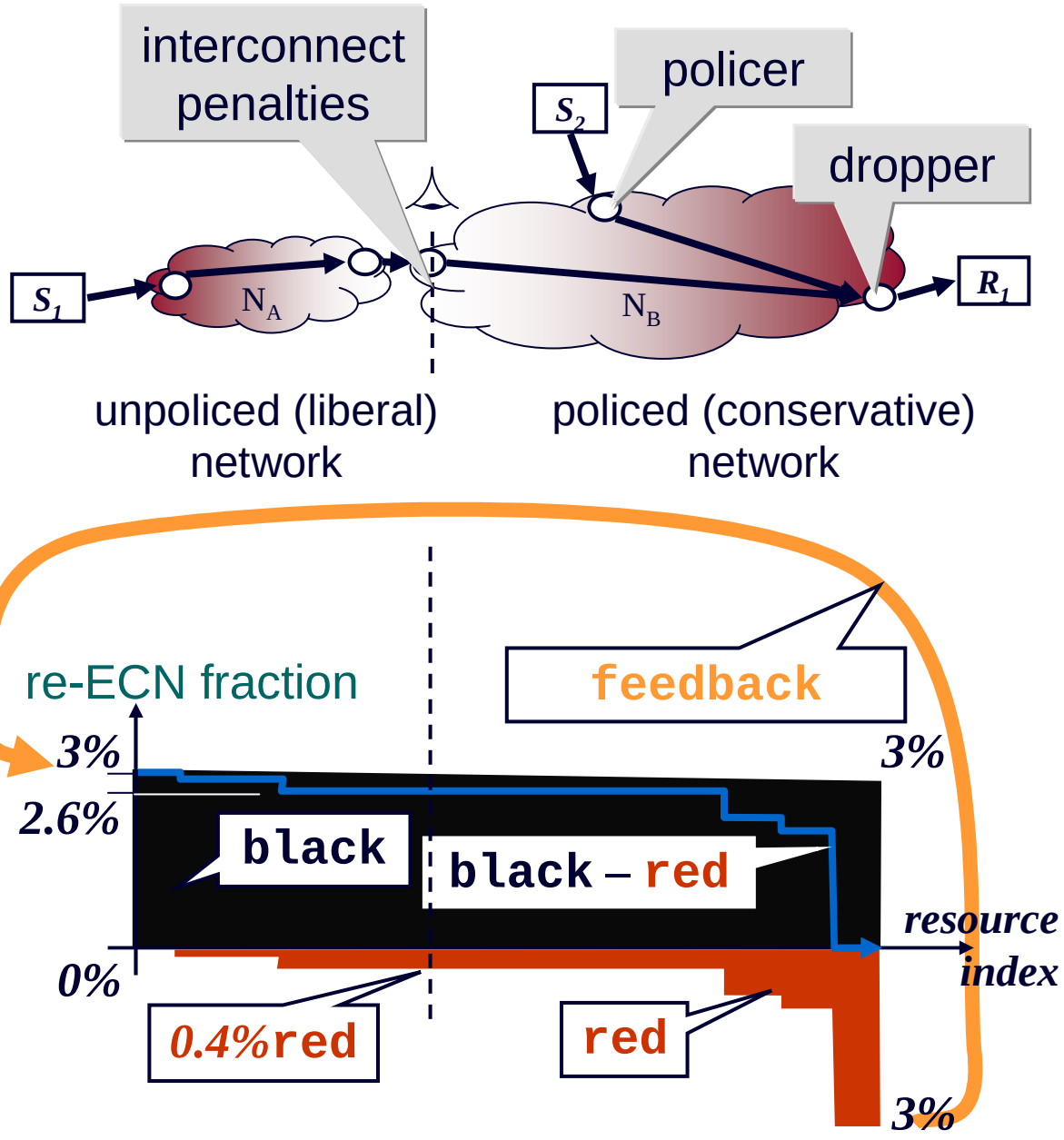
- drop enough traffic to make fraction of **red** = **black**
  - understatement allows gain through policer, but dropper always fully cancels it out
  - goodput best if rcvr & sender honest about feedback & re-feedback
- understate congestion to attack routers?
  - given overloaded routers, honest senders will be sending nearly all **black**
  - overloaded routers preferentially drop **grey** and **red** (next slide)
- important principle: attack traffic does no harm until it congests a router
  - re-ECN drops attack at first congested router (no push-back, no new attack vector)

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.
  - flows de-aggregate precisely to responsible networks



re-ECN partial deployment



deployment incentives
bootstrap then chain reaction

- deployment effectively involves architectural change
  1. (minor) change to sender's Internet stack
  2. network deploys edge/border incentive functions
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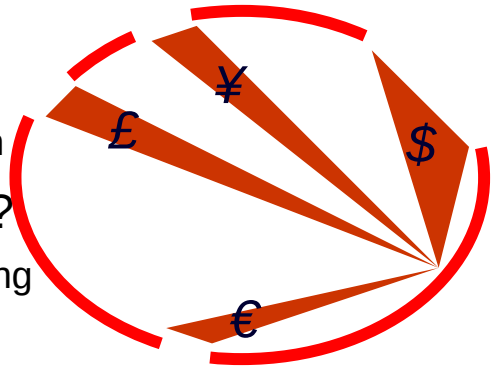


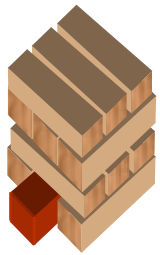
outstanding issues

- technical
  - ✗ a lot more verification of all the claims to do
  - ✗ community found a few nasty vulnerabilities over last two years
    - ✓ fixed (added minor complexity in only one case)
  - ✗ connection spoofing attack still outstanding
    - ✓ possible solution recently brainstormed
- religious
  - ✗ underlying problem has been dogma that equal flow rates are fair
    - ✓ groundswell change in community thinking since mid Oct‘06
    - ✗ dismantling a religion not so easy
- community
  - ✗ a lot of passive support but consensus needs a lot more active interest

a change to IP needs to be ‘owned’ by Internet community
please take it, break it, analyse it, re-design it, work out implications

conclusions

- resolution of tensions in fairness / net neutrality debate
  - freedom to use the Internet, until you congest freedom of others
  - proportionate restriction of freedom during congestion
- an architectural change with grand implications
  - simple management and control of fairness & QoS
  - naturally mitigates DDoS
  - generates correct capacity investment incentives and signals
- but conceptually simple and trivial to implement
- strong deployment incentives
  - bootstrap and onward chain reaction
- where’s the catch?
  - invite you to analyse it, break it, re-design it



Internet draft roadmap

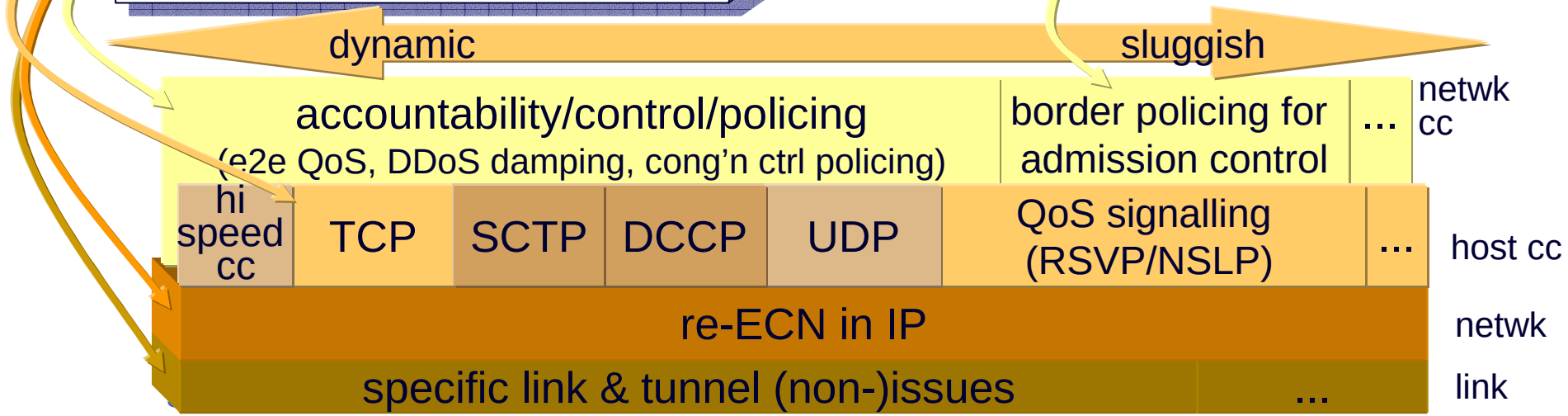
Re-ECN: Adding Accountability for Causing Congestion to TCP/IP
draft-briscoe-tsvwg-re-ecn-tcp-04

intent

§3: overview in TCP
§4: in TCP & other transports } *stds*
§5: in IP (v4 & v6)
§6: accountability apps *inform'l*

•more papers (PCN, QoS, DDoS etc): <http://www.cs.ucl.ac.uk/staff/B.Briscoe/projects/refb/>

Emulating Border Flow Policing using Re-ECN on Bulk Data
draft-briscoe-re-pcn-border-cheat-00
intent: informational



re-ECN architectural intent

<http://www.cs.ucl.ac.uk/staff/B.Briscoe/projects/refb/>

spare slides

more motivating problems

more architectural motivation

- (non)issues with layering & tunnelling
- bottleneck policing harmful
- independence from identifiers

mechanism

- IPv4 & v6 wire protocol
- drop preference semantics
- conflict with the ECN nonce

uses

- simplifying generalised QoS
- flexibility for hi-speed cc, DCCP etc
- adding re-ECN to various transports: TCP, SCTP, DCCP, PCN, UDP
- DDoS mitigation
- potential for load balanced routing

incentives and security

- attacks on re-ECN and fixes
- IPR

Q&A

UCL

BT

next steps

- build community
- simulations, implementation continues
- continue having ad hoc BoFs to maintain community
  - When ready
    - official IETF BoF
    - or IRTF Internet Congestion Control research group

designed for tussle

- current Internet gives freedom but no fairness
  - the more you take, the more you get; the more polite you are, the less you get
  - but we don't want to lose freedom by enforcing fairness
- solution: allow ISPs to enforce user-specific congestion control fairness

liberal acceptable use policies
  - open access, no restrictions

middle ground
  - might want to cap congestion caused per user (e.g. 24x7 heavy p2p sources, DDoS)
  - evolution of different congestion control (e.g. hi-dynamics; rate adaptive VoIP, video)

conservative acceptable use policies
  - might want to throttle if unresponsive to congestion (VoIP, video, DDoS)

- engineers shouldn't pre-judge answer to these socio-economic issues
  - Internet needs all these answers – balance to be determined by natural selection
  - 'do-nothing' doesn't maintain liberal status quo, we just get more middlebox kludges
- re-ECN at network layer: goals
  - just enough support for conservative policies without breaking 'net neutrality'
  - nets that allow their users to cause congestion in other nets can be held accountable

designed for tussle

Internet needs all these answers – market selection finds balance

demand side – freedom to degrade others

- the Internet is all about the freedom to get what I want (within my line rate)

limited by how much I impinge on the freedom of others

- enforceable congestion control

freedom within fairness

- differentiated quality of service

you'll get what you contract to have

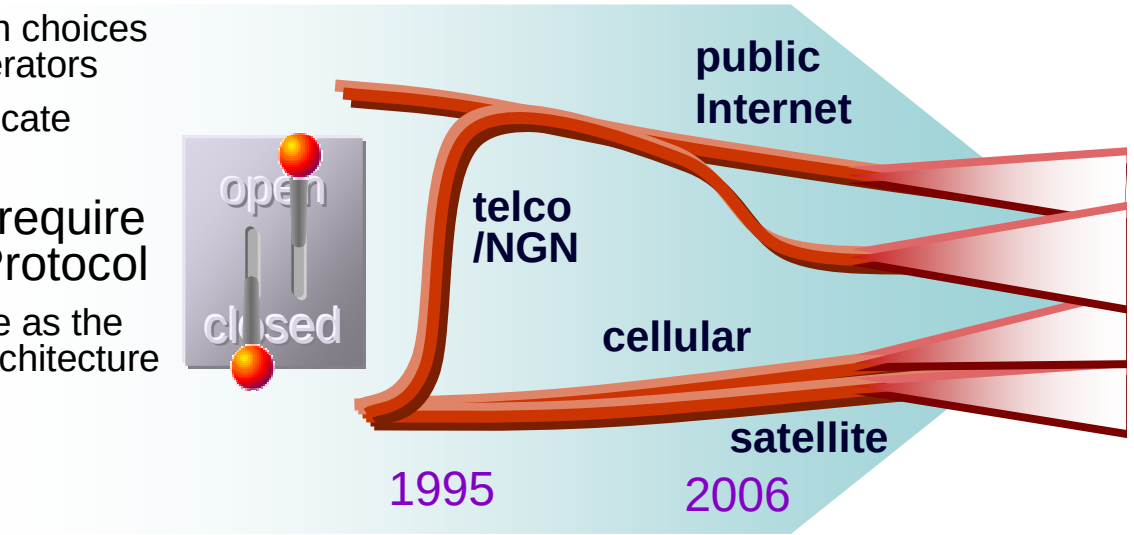
- you'll get what *we* infer you want given what you're doing

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

supply side – freedom to degrade competitors

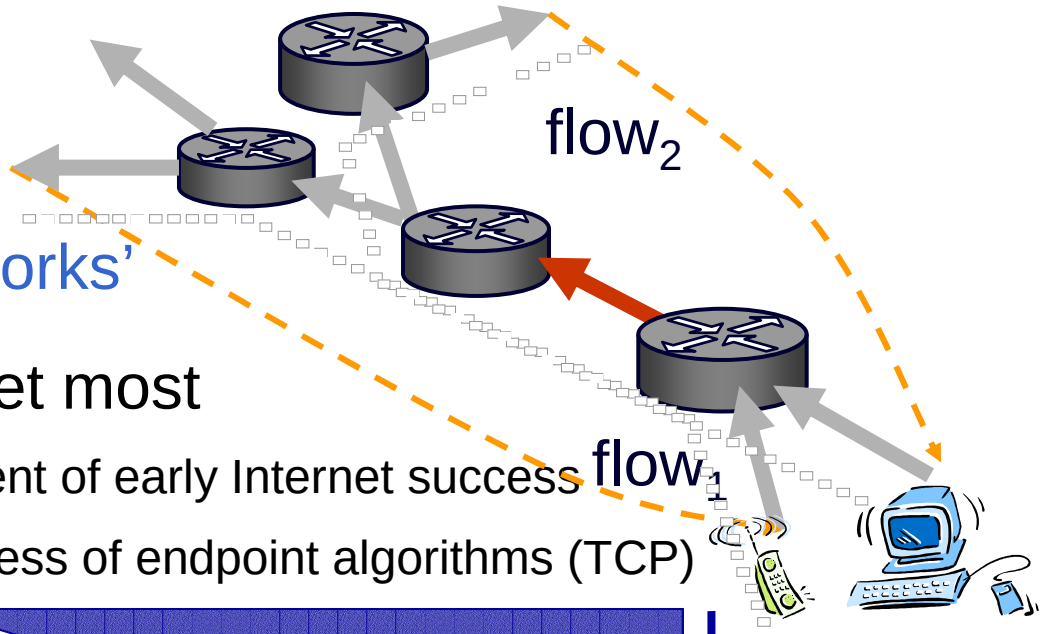
summary

- 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

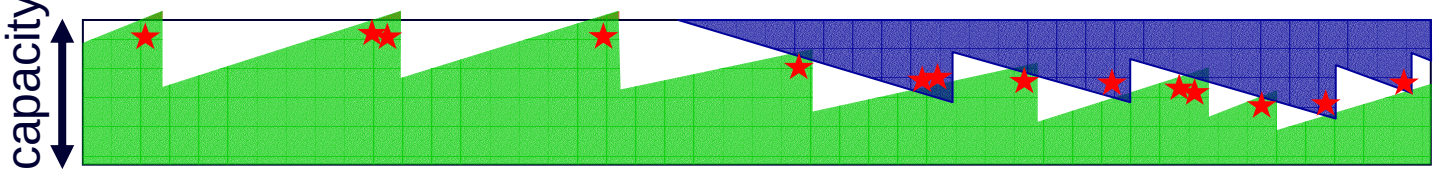


freedom

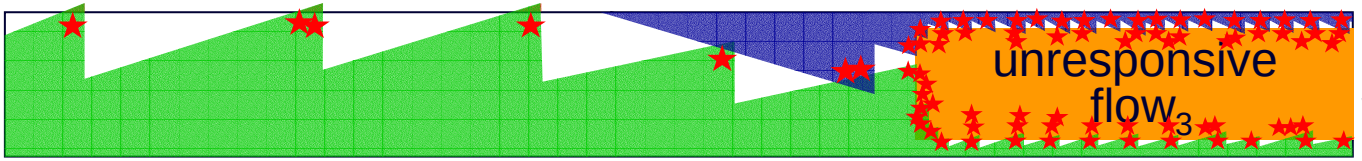
how Internet sharing ‘works’



- those who push most, get most
  - restraint: the other ingredient of early Internet success
  - reliant on voluntary politeness of endpoint algorithms (TCP)

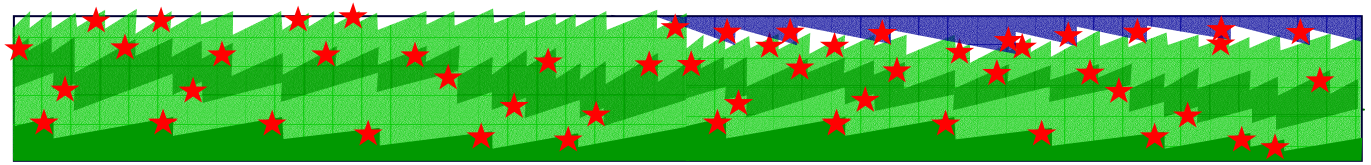


  - a game of chicken – taking all and holding your ground pays



(VoIP, video streaming)

  - or starting more ‘TCP-fair’ flows than anyone else

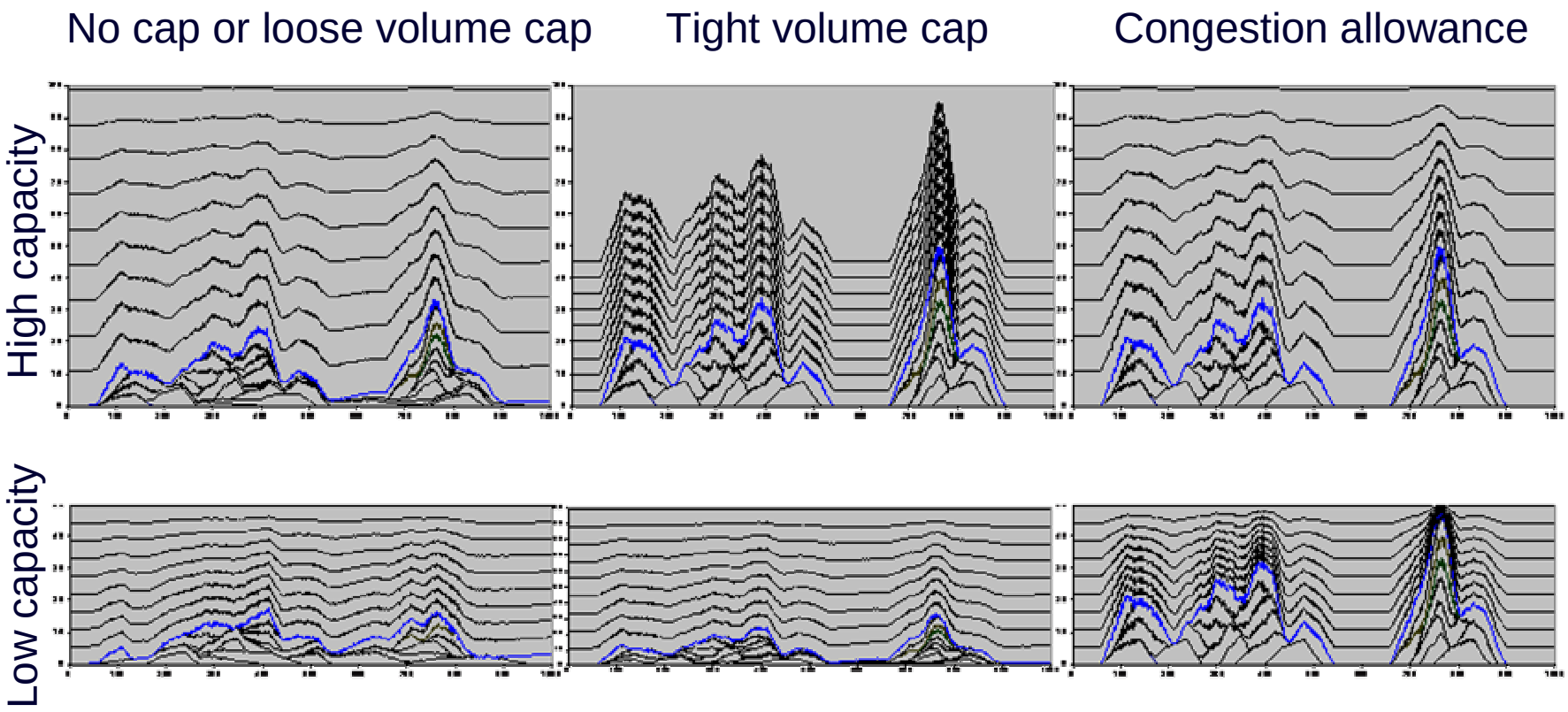


(browsers x4, bitTorrent x50)

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

congestion cap auto-adjusts

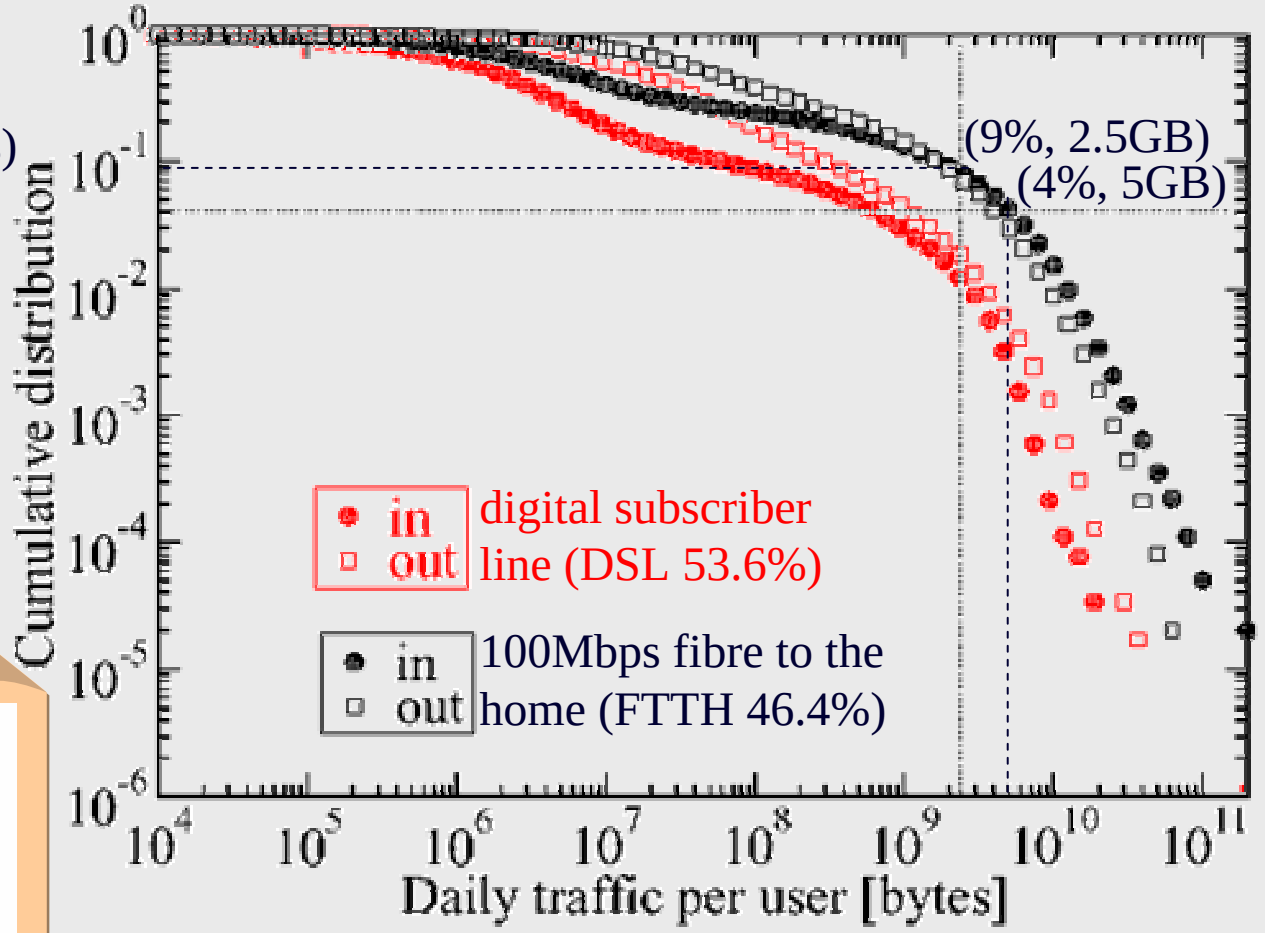
volume cap always a hard compromise



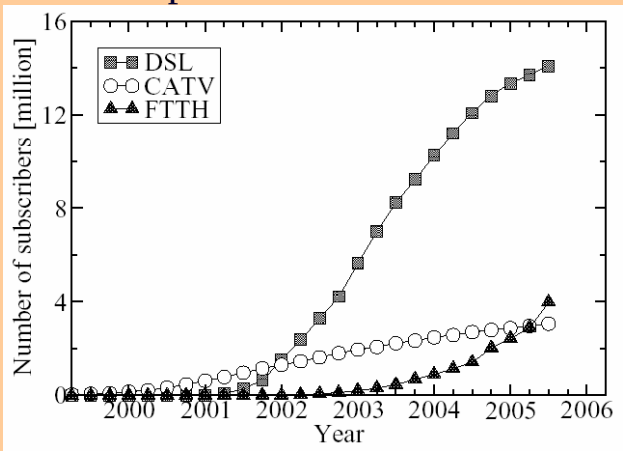
capacity growth will prevent congestion?

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

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



Changing technology shares of Japanese access market

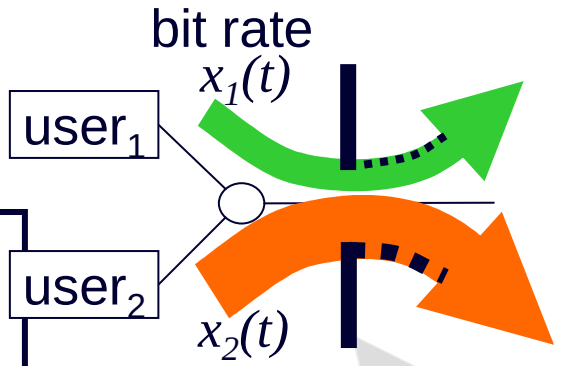


Courtesy of Kenjiro Cho et al
The Impact and Implications of the Growth in Residential User-to-User Traffic, SIGCOMM'06

hang on! solution step #0:

what's congestion got to do with the problem?

- can't solve a sharing problem without sharing costs
  - congestion is the cost of usage
  - cost of your behaviour on others
- NOTE WELL
  - IETF needs to provide the cost metric
  - don't need metric for value – leave that for industry to guess
- it's not what you get
  it's what you unsuccessfully tried to get
  - the bits each you contributed to excess load
  - loss/marking fraction $p(t)$ times your bit rate $x_i(t)$
  - only need dimensionless loss fraction $p(t)$ in wire protocol (ECN)
  - it subtly communicates your excess rate, because your own rate $x_i(t)$ is visible
- excess bits accumulate simply and correctly
  - over time, over flows and over network paths
  - congestion volume = bits of dropped/marked data you sent

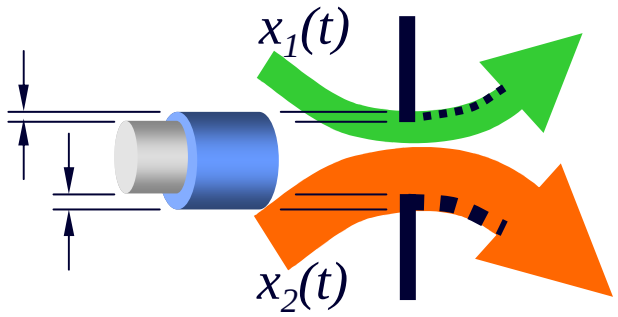


congestion or loss (marking) fraction [%]

$$p(t) \equiv \frac{\text{excess load}}{\text{offered load}}$$

calibrating ‘cost to other users’

- a monetary value can be put on ‘what you unsuccessfully tried to get’
  - the marginal cost of upgrading network equipment
    - so it wouldn’t have marked the volume it did
    - so your behaviour wouldn’t have affected others
- competitive market matches...
  - the cost of congestion volume
  - with the cost of alleviating it



note: diagram is conceptual

congestion volume would be accumulated over time

capital cost of equipment would be depreciated over time

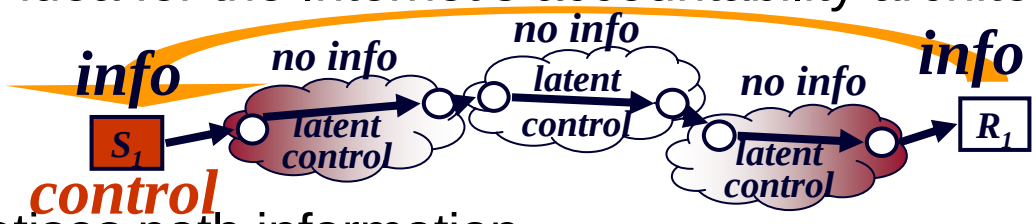
- congestion volume is not an extra cost
  - part of the flat charge we already pay
  - but we can’t measure who to blame for what
  - if we could, we ***might*** see pricing like this...

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

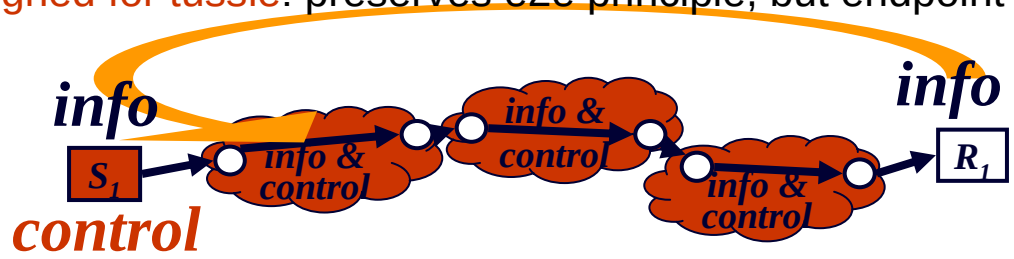
- NOTE WELL
  - IETF provides the metric
  - industry does the business models

re-feedback summary

- reinsert feedback to align path characterisations at receiver
- packets arrive at each router predicting downstream path
- arranged for dominant strategy of all parties to be honesty
- incremental deployment + upgrade incentive knob
- hangs new capabilities on ECN deployment, not just performance
- a simple idea for the Internet's accountability architecture



- democratises path information
  - either network or source can control (control requires timely information)
  - designed for tussle: preserves e2e principle, but endpoint control optional



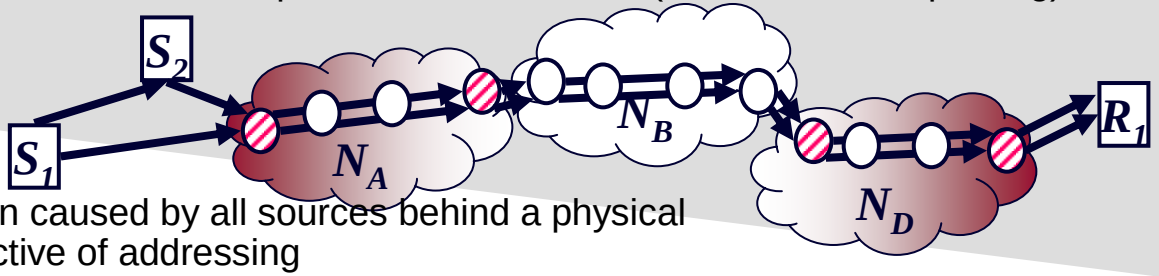
(non-)issues with layering & tunnels

- general non-issue
  - **RE** flag shouldn't change once set by sender (or proxy)
  - policers merely read **RE** to compare with **CE** introduced so far
  - OK as long as **CE** represents congestion since same origin that set **RE**
- IP in IP tunnels
  - OK if tunnel entry copies **RE** and **CE** to outer header
  - but full functionality RFC3168 ECN tunnel resets **CE** in outer header
    - RFC3168 only said reset because security folks thought copy might leak info
    - concern has been resolved – updated IPSec RFC4301 (Dec 05) copies ECN at ingress
    - RFC3168 tunnelling section needs updating to reflect later security thinking and practice
- IP payload encryption (e.g. IPSec ESP)
  - non-issue – re-ECN designed to work only in network layer header
  - flow-ID obfuscation also non-issue – re-ECN only uses flow ID uniqueness, if at all
- layer 2 congestion notification (ATM, Frame, ... MPLS, 802.3ar)
  - non-issue given IP layer should accumulate **CE** from each 'L2 network' into ECN

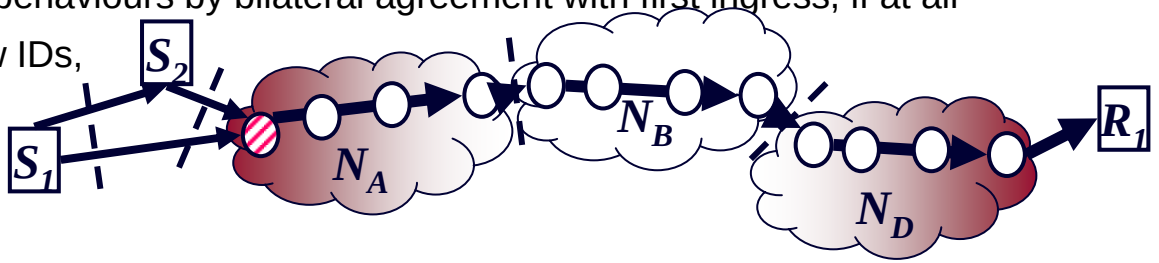
bottleneck policing harmful to evolvability

…and bypass-able anyway

- bottleneck policers: active research area since 1999
  - detect misbehaving flows causing ‘unfair’ share of congestion
  - located at each potentially congested routers
  - what right have these policers to assume a specific congestion response for a flow?
    - if they could police accurately, new congestion control evolution would require per-flow authorisation from all policers on the path (cf. IntServ)
  - malicious sources can bypass them by splitting flow IDs
    - even splitting flow across multiple intermediate hosts (or src address spoofing)



- re-ECN policing
  - polices congestion caused by all sources behind a physical interface, irrespective of addressing
  - within that, can also choose to police per-flow, per flow setup, per-destination etc.
  - evolution of new behaviours by bilateral agreement with first ingress, if at all
  - dropper uses flow IDs, but no advantage to split IDs



independence from identifiers

- controls congestion crossing any physical interface
  - user-network, network-network
  - congestion from network layer down to physical
  - not from a source address
- does have a dependency on source addresses
  - not to ***identify*** sources, merely to treat each flow separately
  - outstanding vulnerability
    - attacker spoofs another source's flow
    - deliberately brings down their joint average causing high drop

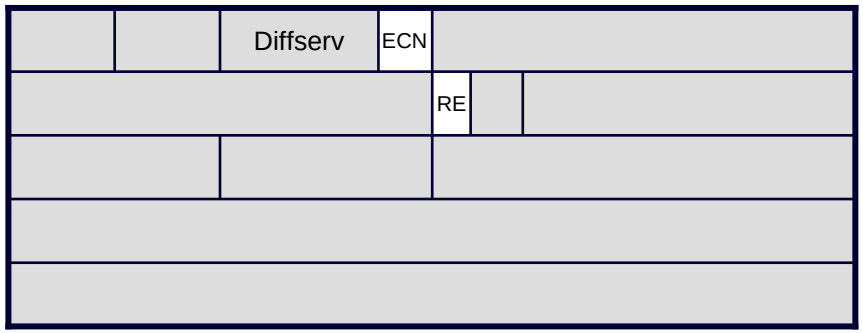
extended ECN codepoints: summary

- extra semantics backward compatible with previous ECN codepoint semantics

ECN code-point	ECN [RFC3168] codepoint	RE flag	Extended ECN codepoint	re-ECN meaning	`worth'
00	not-ECT	0	Not-RECT	Not re-ECN capable transport	
		1	FNE	Feedback not established	+1
01	ECT(1)	0	Re-Echo	Re-echo congestion event (ECN nonce conflict)	+1
		1	RECT	Re-ECN capable transport	0
10	ECT(0)	0	---	'Legacy' ECN use	
		1	--CU--	Currently unused	
11	CE	0	CE(0)	Congestion experienced with Re-Echo	0
		1	CE(-1)	Congestion experienced	-1

re-ECN wire protocol in IPv4 (§3)

- propose Re-ECN Extension (RE) flag
  - for IPv4: propose to use bit 48 (was reserved)
  - set by sender, unchanged e2e



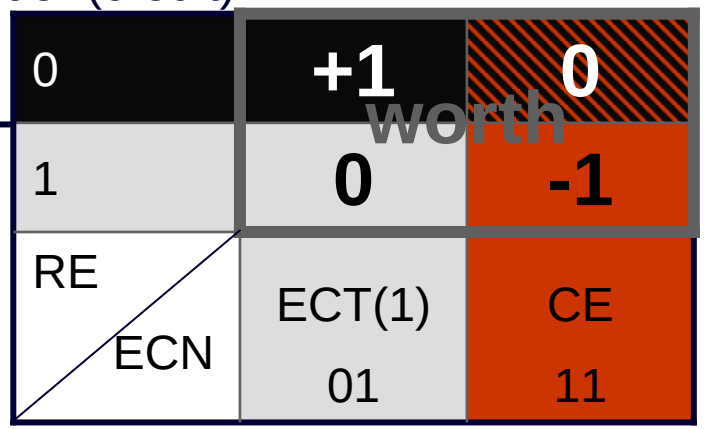
- once flow established
- sender re-inserts ECN feedback into forward data ("re-ECN") as follows
  - re-ECN sender always sets ECT(1)
  - on every **congestion event** from transport (e.g. TCP)

sender blanks **RE**
else sets RE

- conceptually, 'worth' of packet depends on 3 bit `codepoint'
- aim for zero balance of worth in flow

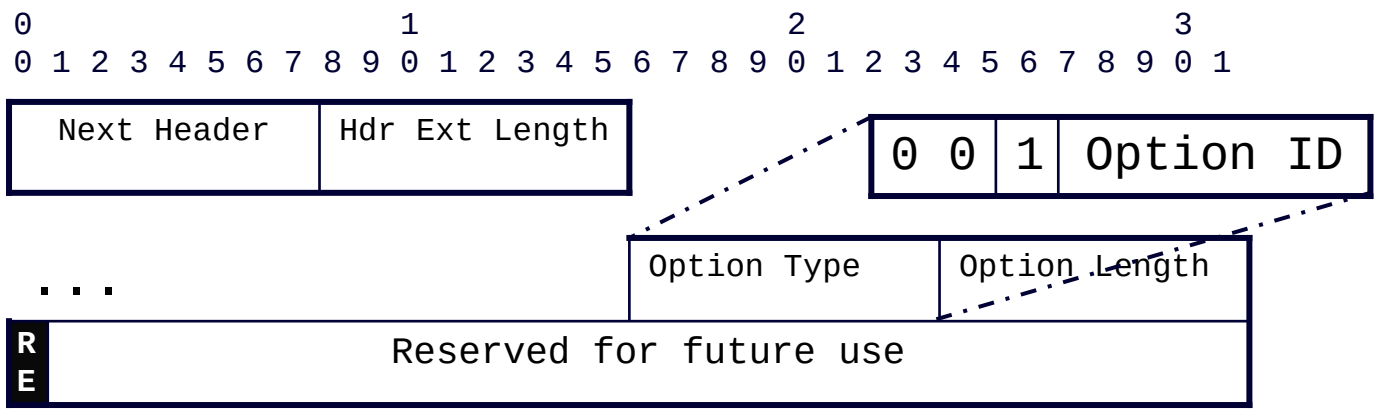
[RFC3168]
ECN marking
router (debit)

sender (credit)



IPv6 re-ECN protocol encoding

- IPv6 hop-by-hop options header extension
  - new Congestion hop-by-hop option type



  - action if unrecognized (AIU) = 00 ‘skip and continue’
  - changeable (C) flag = 1 ‘may change en route’
    - even tho RE flag shouldn’t change en route (AH would just tell attackers which packets not to attack)
- seems wasteful for 1 bit, but we plan:
  - future hi-speed congestion control I-D using multi-bit congestion field
  - other congestion-related fields possible
    - e.g. to distinguish wireless loss and per-packet vs per-bit congestion

OPTIONAL router forwarding changes

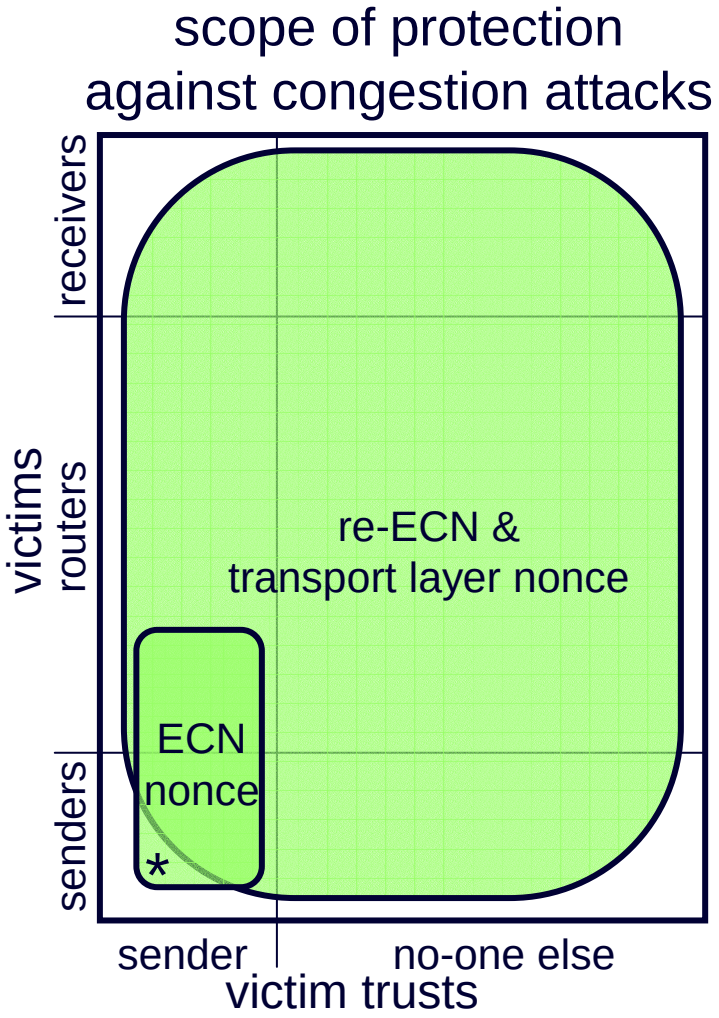
- preferential drop: improves robustness against DDoS
- **green** can be ECN marked rather than dropped (with caveat)

ECN code-point	ECN [RFC3168] codepoint	RE flag	Extended ECN codepoint	re-ECN meaning	`worth'	pref drop (1=drop 1st)
00	not-ECT	0	Not-RECT	Not re-ECN capable transport		1
		1	FNE	Feedback not established	+1	3
01	ECT(1)	0	Re-Echo	Re-echo congestion event	+1	3
		1	RECT	Re-ECN capable transport	0	2
10	ECT(0)	0	---	'Legacy' ECN use		1
		1	--CU--	Currently unused		1
11	CE	0	CE(0)	CE with Re-Echo	0	2
		1	CE(-1)	Congestion experienced	-1	2

new appendix “Argument for holding back the ECN nonce” (§AI)

ECN nonce usefulness

- re-ECN and a transport layer nonce defend against wide range of attacks
  - ECN nonce defends against a small subset
  - and only one outside re-ECN’s range (*)
    - a sender that uses network ECN to allocate its own resources, can limit a lying receiver
    - sender can contain this attack without nonce
- IP header bits used to do this:
  - ECN nonce $^1/_4$b (leaving last bit)
  - re-ECN $^3/_8$b (using last bit)
- one common codepoint
  - re-ECN negotiates its use, but ECN nonce doesn’t
- propose to hold back ECN nonce
  - to see if we can find a coding to do both
  - to see if we can prevent (*) another way
  - develop a transport layer solution



flow bootstrap

- at least one **green** packet(s) at start of flow or after >1sec idle
  - means “feedback not established”
  - ‘credit’ for safety due to lack of feedback
  - a **green** byte is ‘worth’ same as a **black** byte
- a different colour from black
  - distinguishes expected congestion based on experience from based on conservatism
  - gives deterministic flow state mgmt (policers, droppers, firewalls, servers)
  - rate limiting of state set-up
  - congestion control of memory exhaustion

- **green** also serves as state setup bit [Clark, Handley & Greenhalgh]
  - protocol-independent identification of flow state set-up
  - for servers, firewalls, tag switching, etc
  - don’t create state if not set
  - may drop packet if not set but matching state not found
  - firewalls can permit protocol evolution without knowing semantics
  - some validation of encrypted traffic, independent of transport
  - can limit outgoing rate of state setup
- to be precise **green** is ‘idempotent soft-state set-up codepoint’

guidelines for adding re-ECN to other transports

- main focus of <draft-briscoe-tsvwg-re-ecn-tcp-04>
  - IP (§5)
  - TCP (§4.1)
- added very brief sections giving guidelines for
  - DCCP (§4.2.3)
  - SCTP (§4.2.4)
  - spec would have to be a new I-D in each case
- focus of <draft-briscoe-re-pcn-border-cheat-00>
  - RSVP/NSIS transports ('re-PCN')
  - proposed technique to extend PCN-based admission control
    - Internet wide (edge-edge) – many untrusting domains
- our current focus
  - controlling fairness between current transports & hi-speed congestion control

differential quality of service (QoS) control
without all the complicated stuff

- QoS only relevant when there's a risk of congestion
- enforcing congestion control is equivalent to QoS (and to paying for it)
  - allowing one app's rate to slow down less than others in response to incipient congestion (ie. still low delay)
  - is equivalent to giving scheduling priority on routers*
- even if user pays a flat monthly fee
  - better QoS for some apps leaves less congestion 'quota' for rest
- purely by local (sender↔ingress) arrangement
  - no authorisation on any other network elements (equal marking)
- other networks reimbursed automagically
  - by inter-domain congestion pricing (SLA model also possible)
- incredible simplification of mechanisms for QoS control & mgmt
  - and, unlike other QoS mechanisms
  - it also prevents users 'stealing' QoS at everyone else's expense

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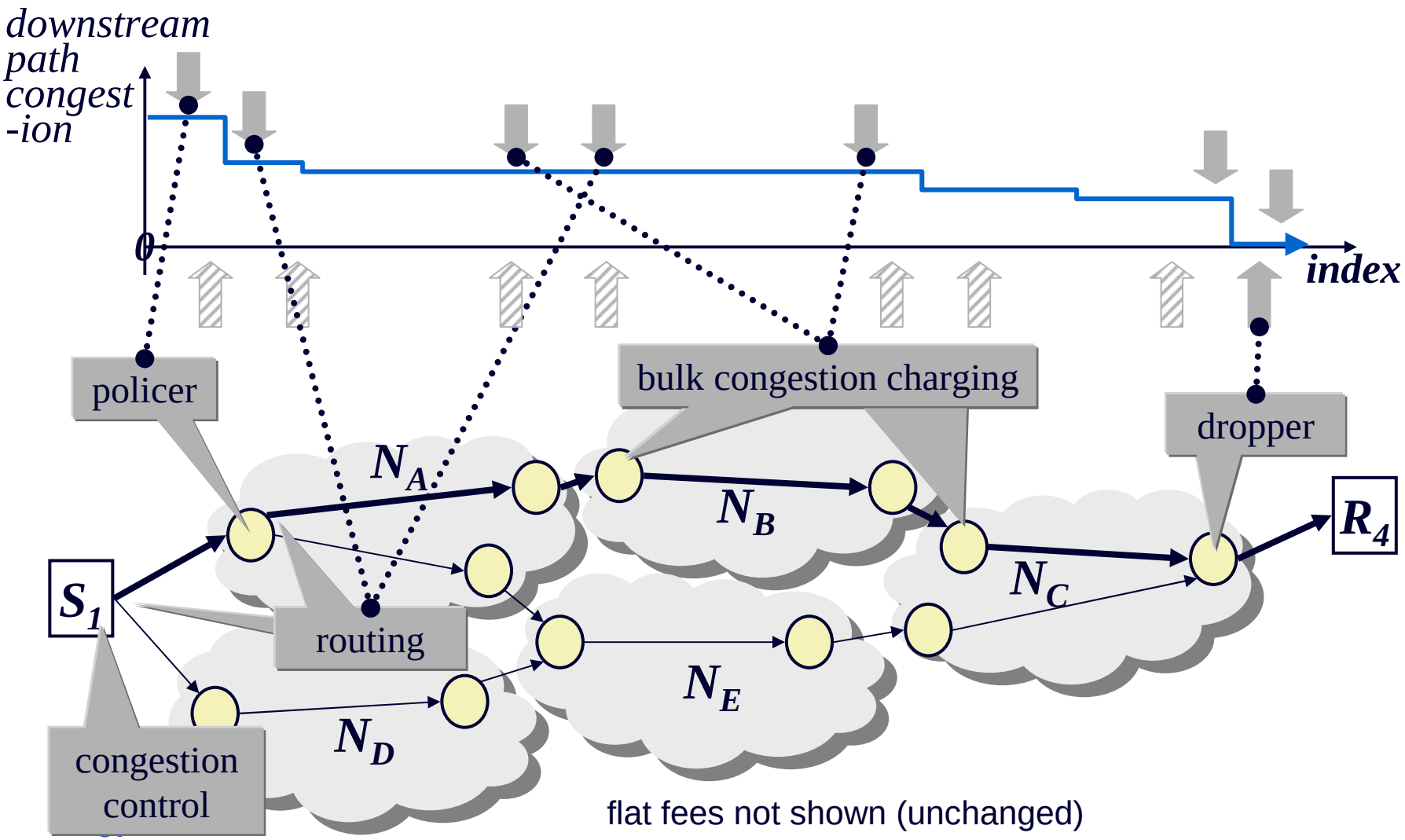
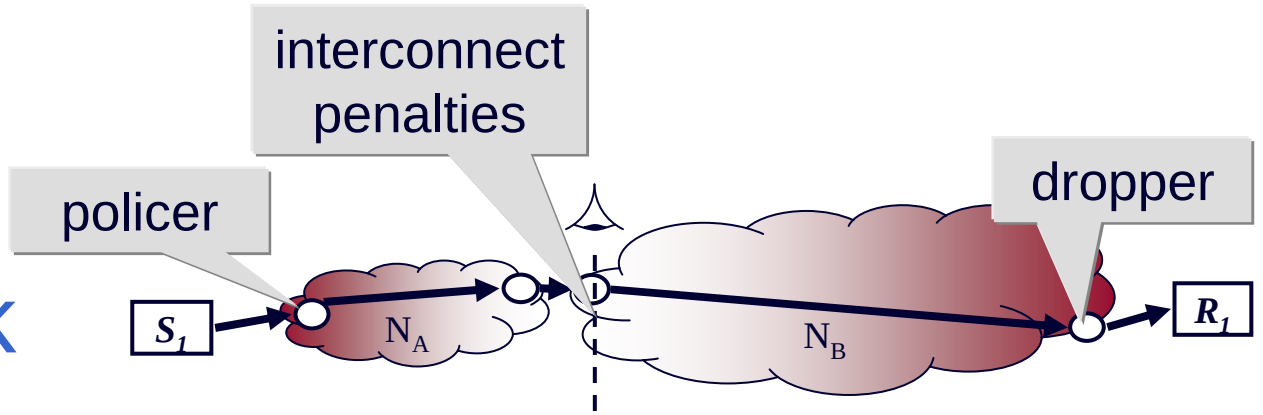
* except within a round trip time – implies two priority classes would be sufficient

(can also determine relative congestion marking rates of each class using economics)

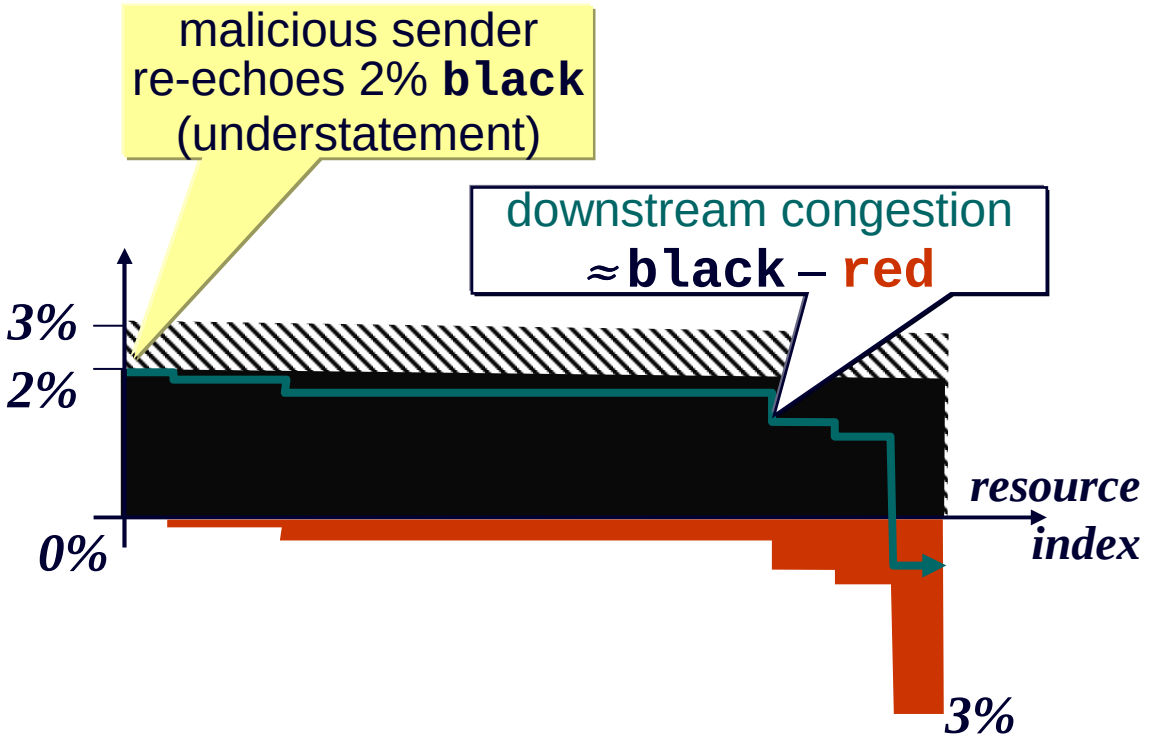
incentive framework



incentive framework

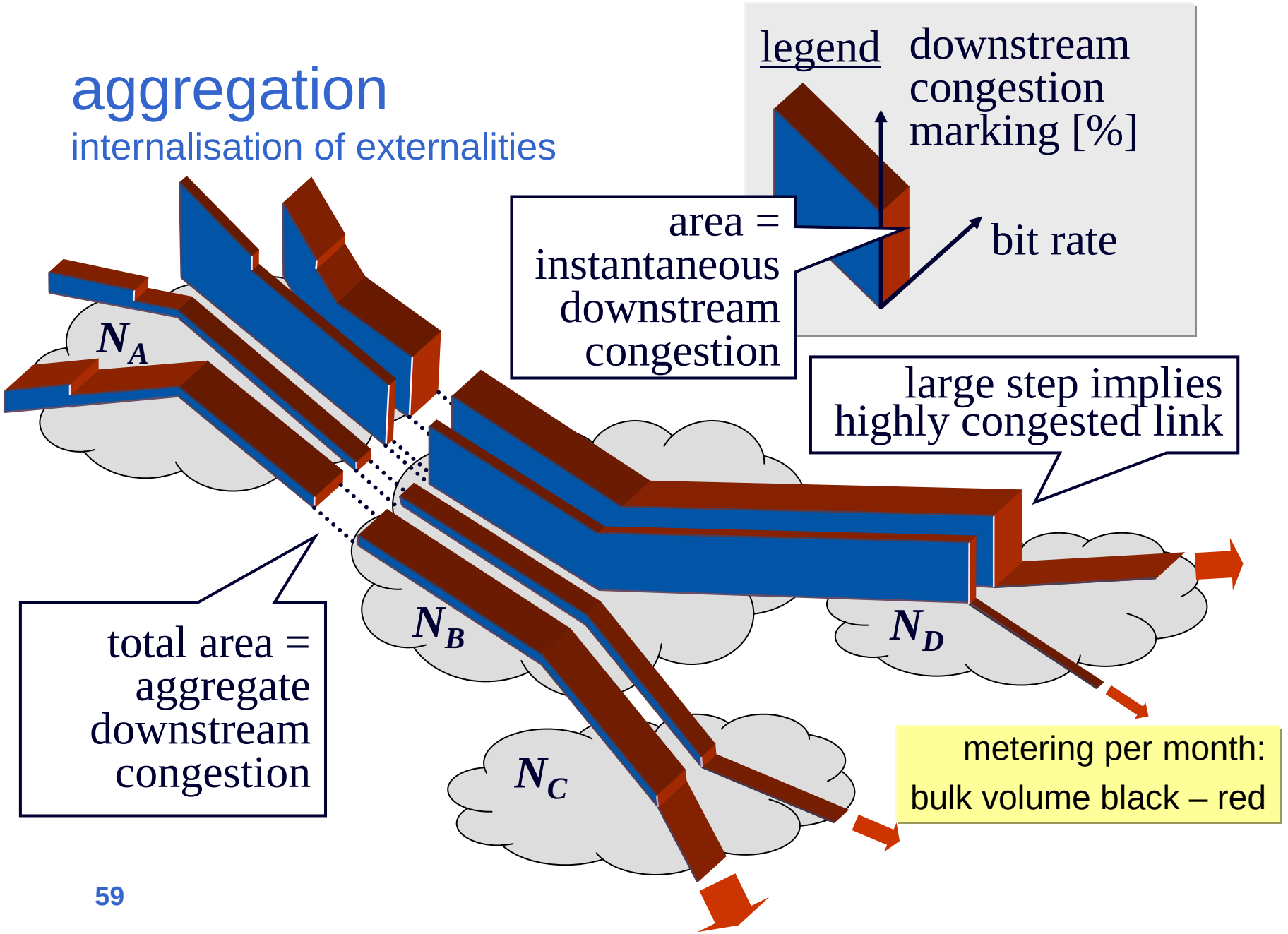


- packets carry view of downstream path congestion to each router
- using path congestion declared by sender
  - can police rate response
  - or enforce congestion quotas
- won't sender or rcvr just understate congestion?
  - egress drops negative balance (next slide)



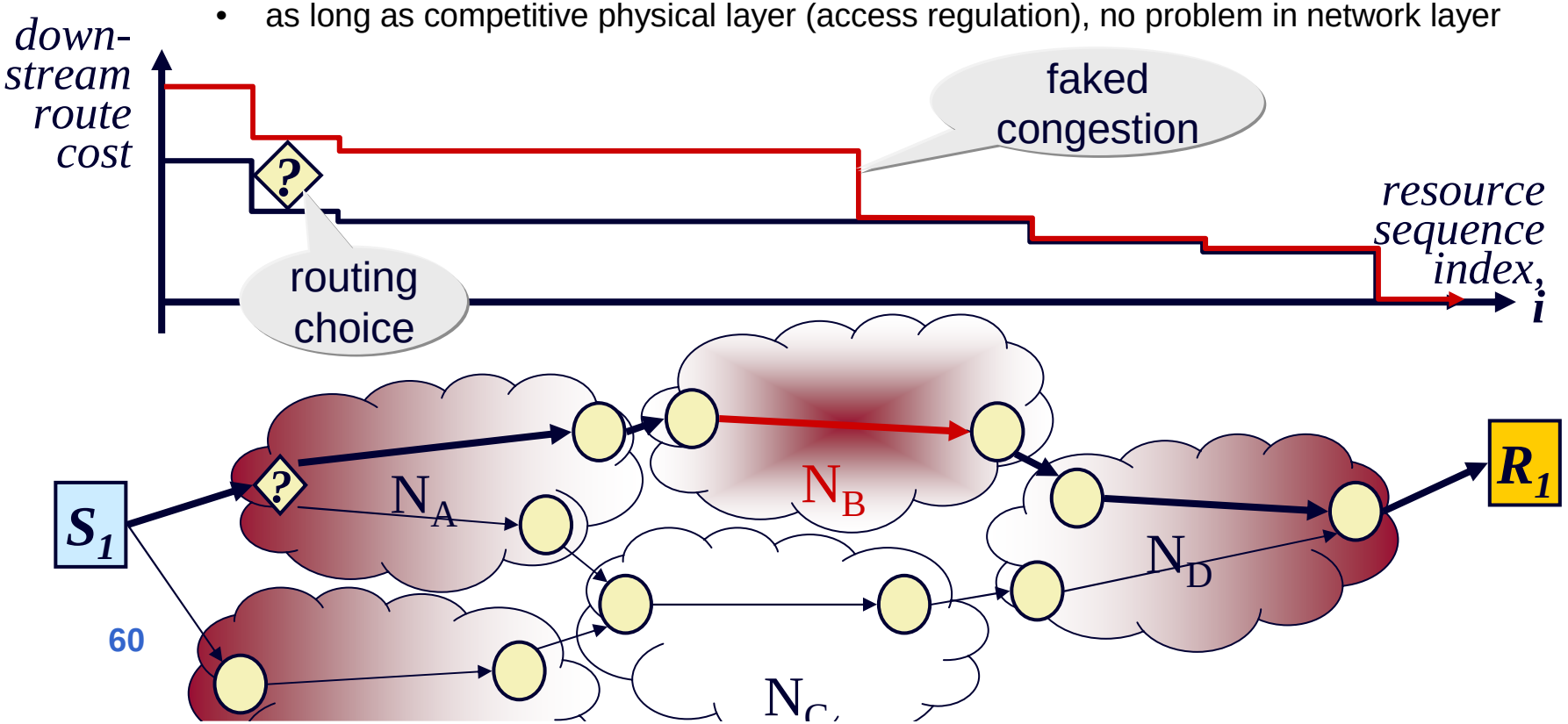
aggregation

internalisation of externalities



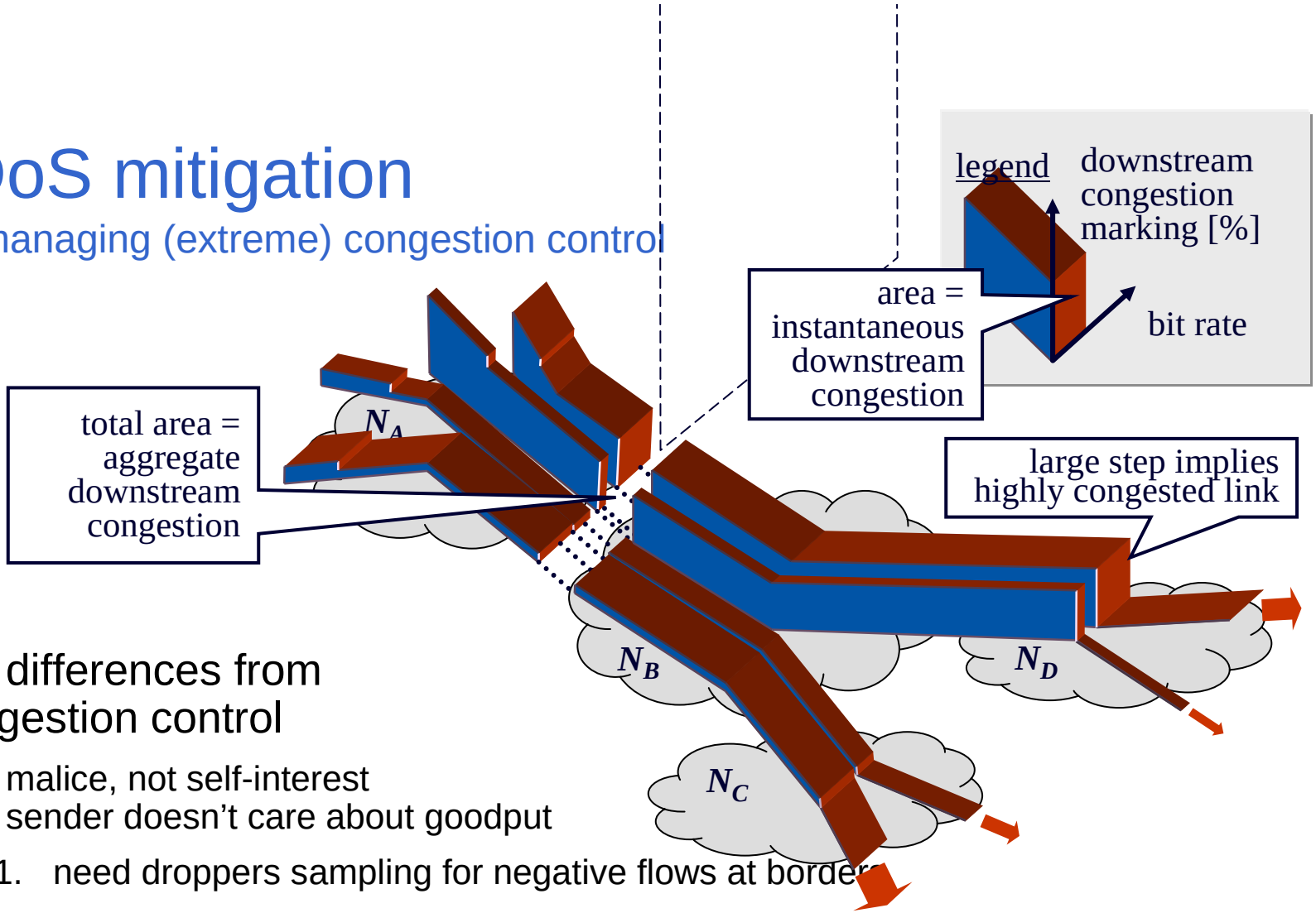
congestion competition – inter-domain routing

- if congestion → profit for a network, why not fake it?
  - upstream networks will route round more highly congested paths
  - N_A can see relative costs of paths to R_1 thru N_B & N_C
- the issue of monopoly paths
  - incentivise new provision
  - as long as competitive physical layer (access regulation), no problem in network layer



DDoS mitigation

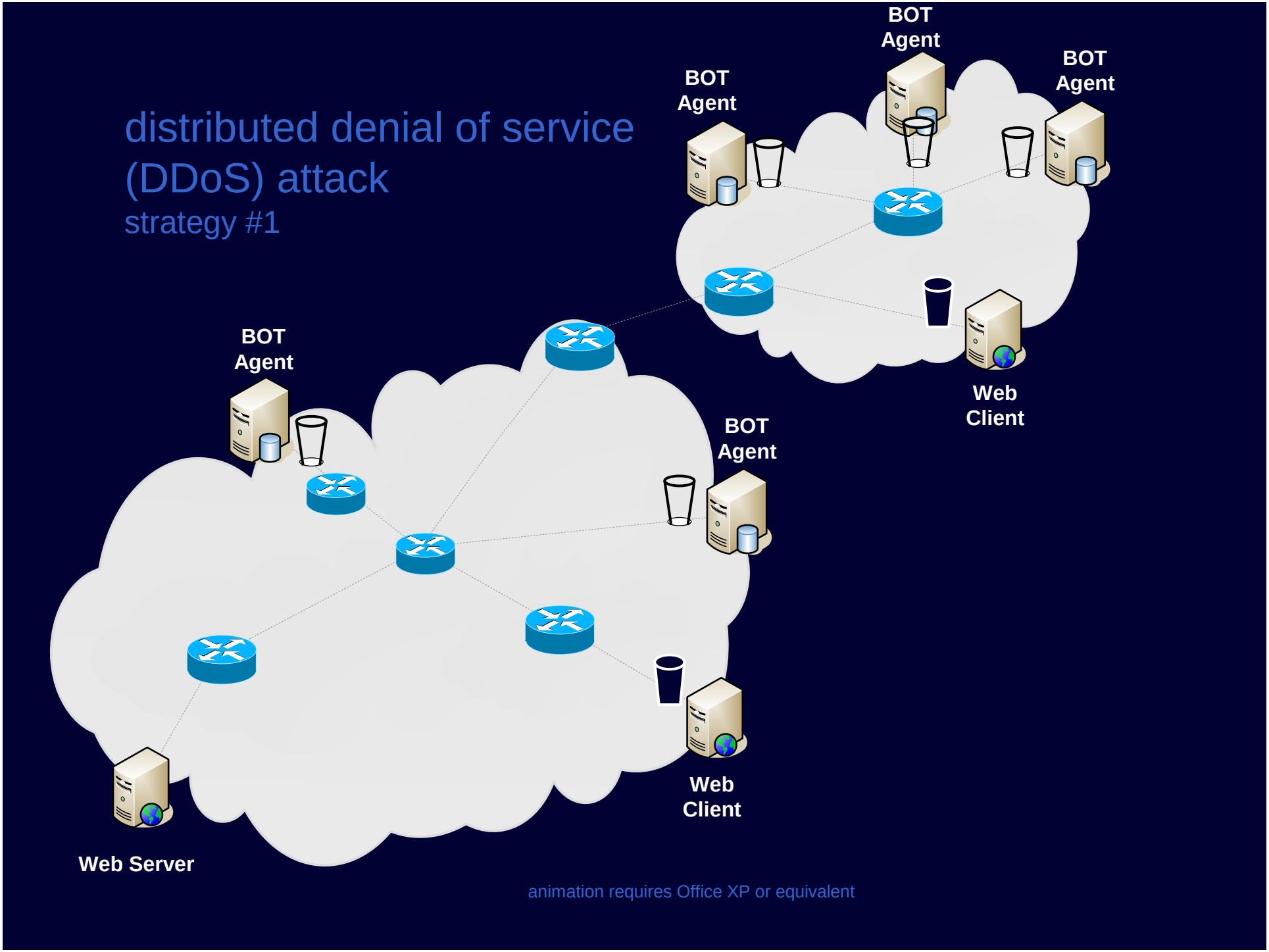
just managing (extreme) congestion control



- two differences from congestion control
  - malice, not self-interest
    sender doesn't care about goodput
    1. need droppers sampling for negative flows at borders
  - pushes beyond incipient congestion into heavy loss
    2. need preferential drop on routers
- provides incentives to deploy complementary DDoS solutions

distributed denial of service (DDoS) attack

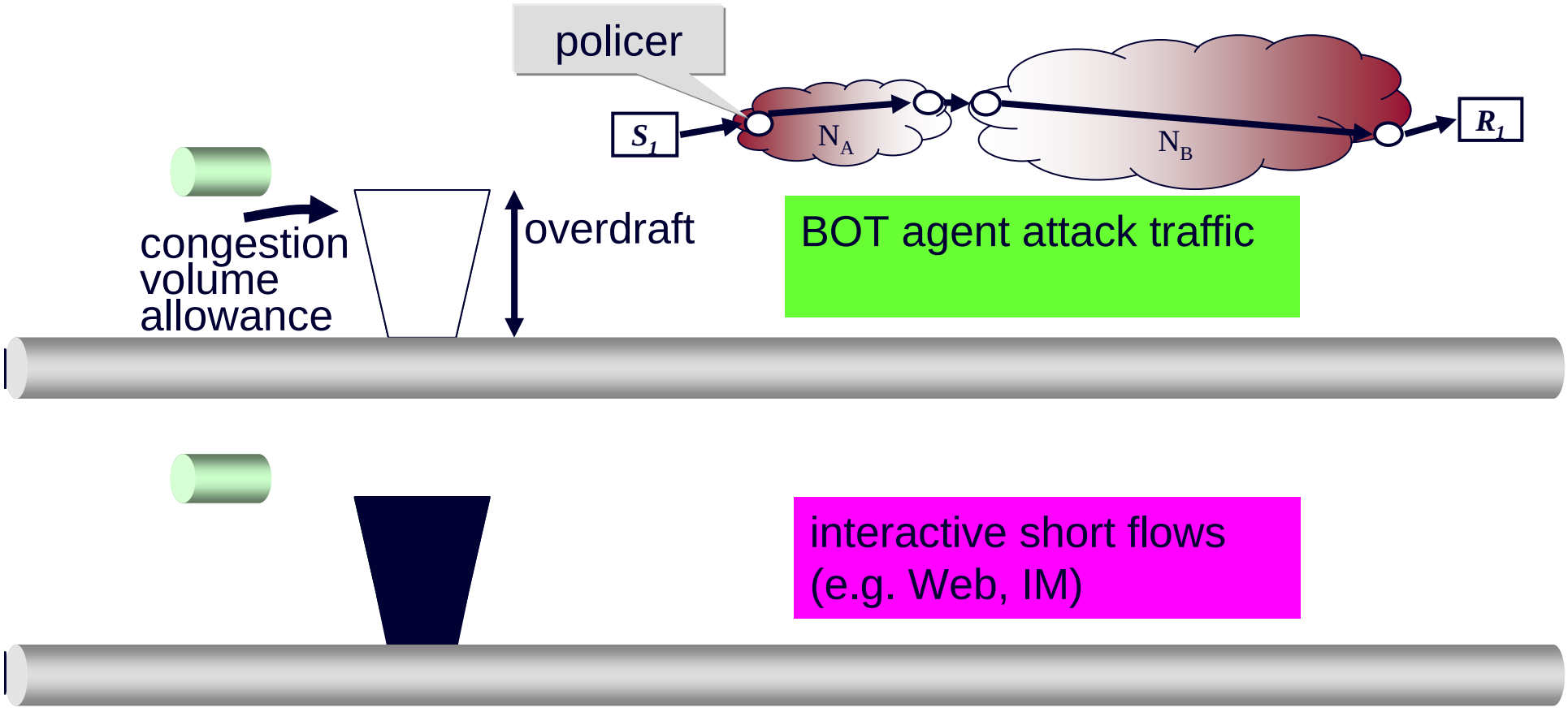
strategy #1



animation requires Office XP or equivalent

per-user congestion policer

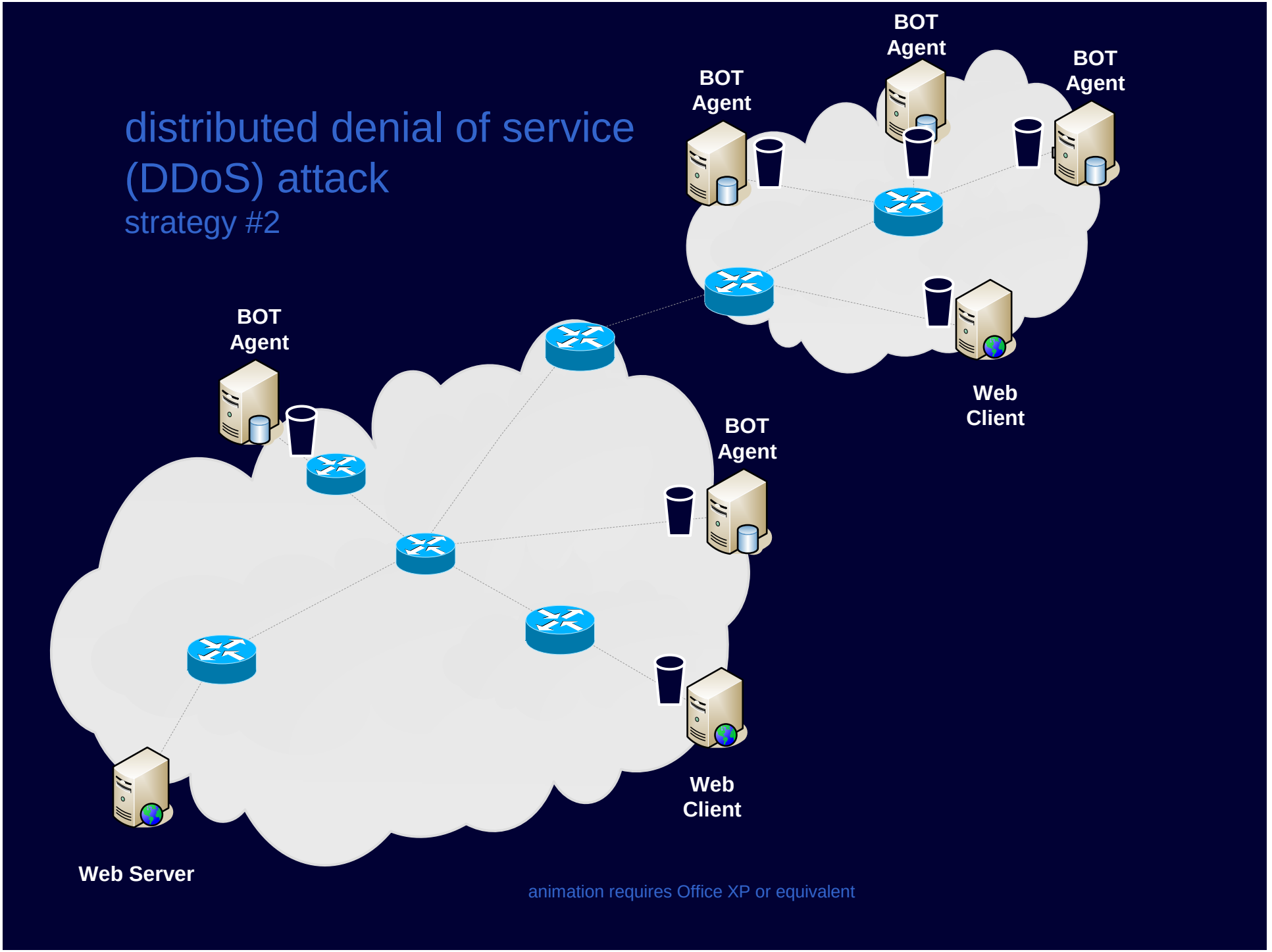
DDoS attack strategy #1



animation requires Office XP or equivalent

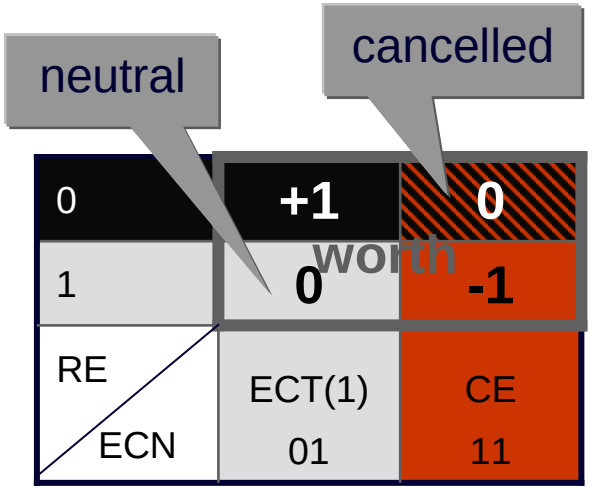
distributed denial of service (DDoS) attack

strategy #2



animation requires Office XP or equivalent

attacks on re-ECN & fixes



- recap: why two codepoints worth 0?
  - when no congestion send neutral (0)
  - packet marked ‘cancelled’ if network happens to mark a packet (-1) which the sender used to re-echo congestion (+1); +1 – 1 = 0
  - in draft 00, congestion marking of +1 packet turned it to -1 not 0, but networks could cheat by focusing marking on +1 (see §B)
- but now can’t attacker just send cancelled packets?
  - immune from congestion marking
  - simple fix: policer counts cancelled with +1 towards *path* congestion
    - should have specified this anyway, as both represent path congestion
    - also check proportion of cancelled to +1 packets same as -1 to neutral
- set of attacks using persistently negative dummy traffic flows
  - see next presentation for border policing fix
- one remaining known vulnerability if attacker can spoof another flow ID
  - known since early on – plan to focus effort on fixing this next

dummy traffic attacks on re-ECN

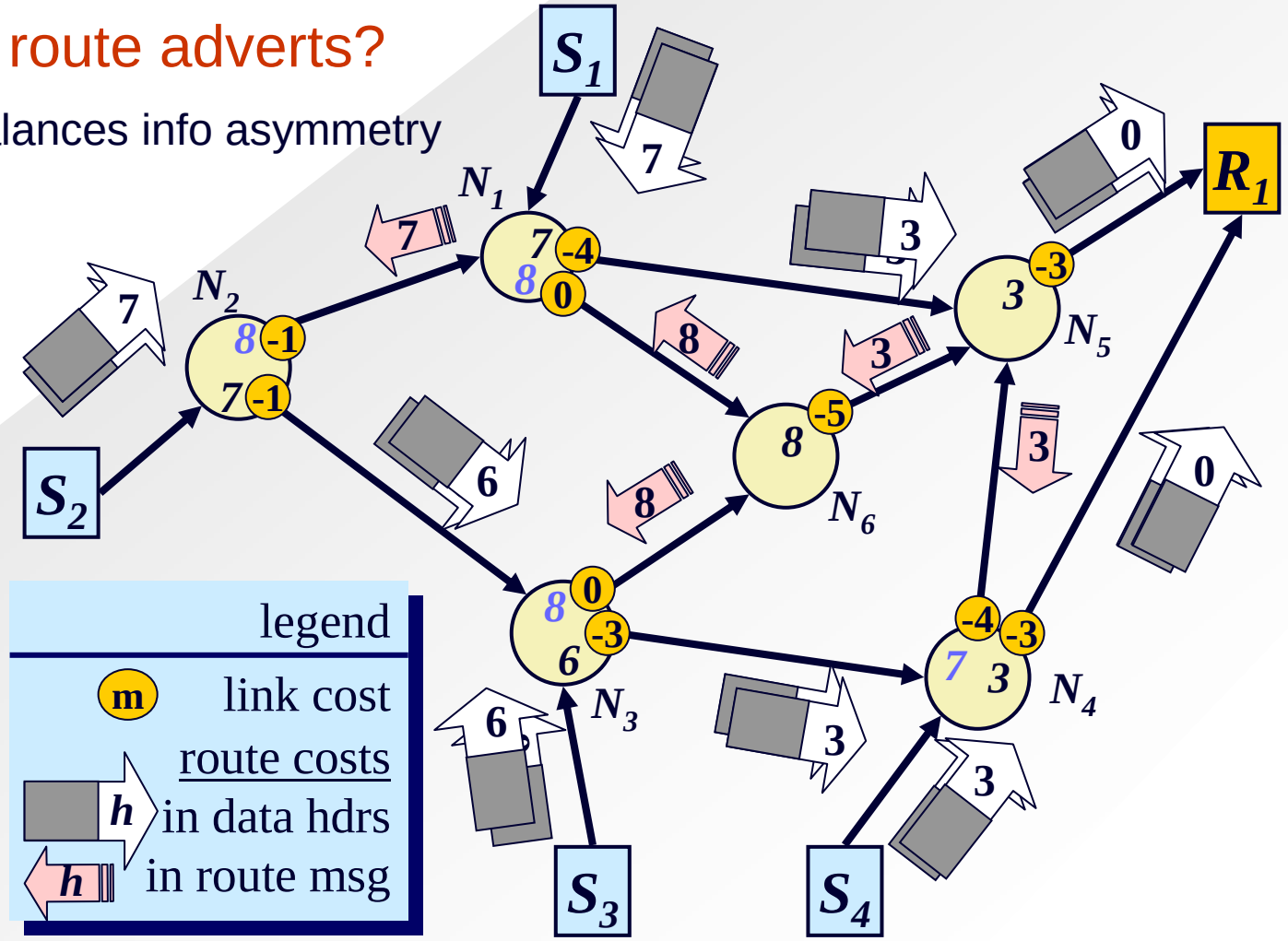
- sanctions against persistently negative flows may not discourage dummy traffic
- various attacks ([Salvatori, Bauer] see draft), eg.
  - a network sends negative dummy traffic with just enough TTL to cross border [Salvatori]
    - offsets penalties from other positive traffic
- fix is to estimate contribution from negative flows crossing border by sampling
  - inflate penalties accordingly – removes attack motivations
  - see draft for details and example algorithm in appendix

re-ECN security considerations (§10) and incentive framework limitations (§6.3)

- egress dropper
  - robust against attack that plays-off against ingress policing
  - robust against state exhaustion attacks (by design of **`green`**)
  - write-up of state aggregation implementation TBA
  - believe new protocol allows dropper to be robust against dynamic attacks
- collateral damage attack still possible → next slide
- re-ECN deliberately designed not to rely on crypto

load balanced routing support?

- automate inter-domain traffic engineering (damped)?
- validate route adverts?
  - re-balances info asymmetry



BT IPR related to draft-briscoe-tsvwg-re-ecn-tcp-00.txt

- See IPR declaration at https://datatracker.ietf.org/public/ipr_detail_show.cgi?&ipr_id=651 which overrides this slide if there is any conflict

1)	WO 2005/096566	30 Mar 2004	published
2)	WO 2005/096567	30 Mar 2004	published
3)	PCT/GB 2005/001737	07 May 2004	published
4)	GB 0501945.0 (EP 05355137.1)	31 Jan 2005	published
5)	GB 0502483.1 (EP 05255164.5)	07 Feb 2005	published

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more info...

- Fixing mindset on fairness
  - Flow Rate Fairness: Dismantling a Religion 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)
- Protocol Spec and rationale
  - Re-ECN: Adding Accountability for Causing Congestion to TCP/IP IETF Internet Draft (Oct 2006)
- Using re-ECN with pre-congestion notification (PCN)
  - Emulating Border Flow Policing using Re-ECN on Bulk Data IETF Internet draft (Jun 2006)
- Relation between re-ECN and inelastic QoS
  - Commercial Models for IP Quality of Service Interconnect BT Technology Journal (Apr 2005)
- Mitigating DDoS with re-ECN
  - Using Self-interest to Prevent Malice; Fixing the Denial of Service Flaw of the Internet Workshop on the Economics of Securing the Information Infrastructure (Oct 2006)
- more related papers and all the above: <http://www.cs.ucl.ac.uk/staff/B.Briscoe/projects/refb/>