Tor performance problems ...and how to solve them

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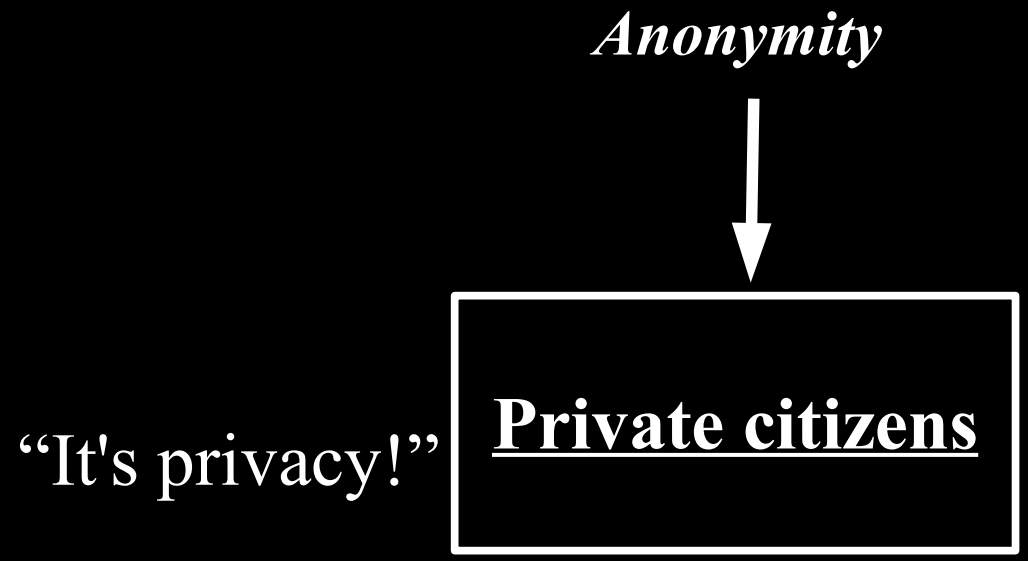
https://www.torproject.org/

Tor: Big Picture

- Freely available (Open Source), unencumbered.
- Comes with a spec and full documentation: Dresden and Aachen implemented compatible Java Tor clients; researchers use it to study anonymity.
- 1800 active relays, 200000+ active users, >1Gbit/s.
- Official US 501(c)(3) nonprofit. Eight+ funded developers, dozens more dedicated volunteers.
- Funding from US DoD, Electronic Frontier Foundation, Voice of America, Human Rights Watch, Google, NLnet, ...you?

Anonymity serves different interests for different user groups.



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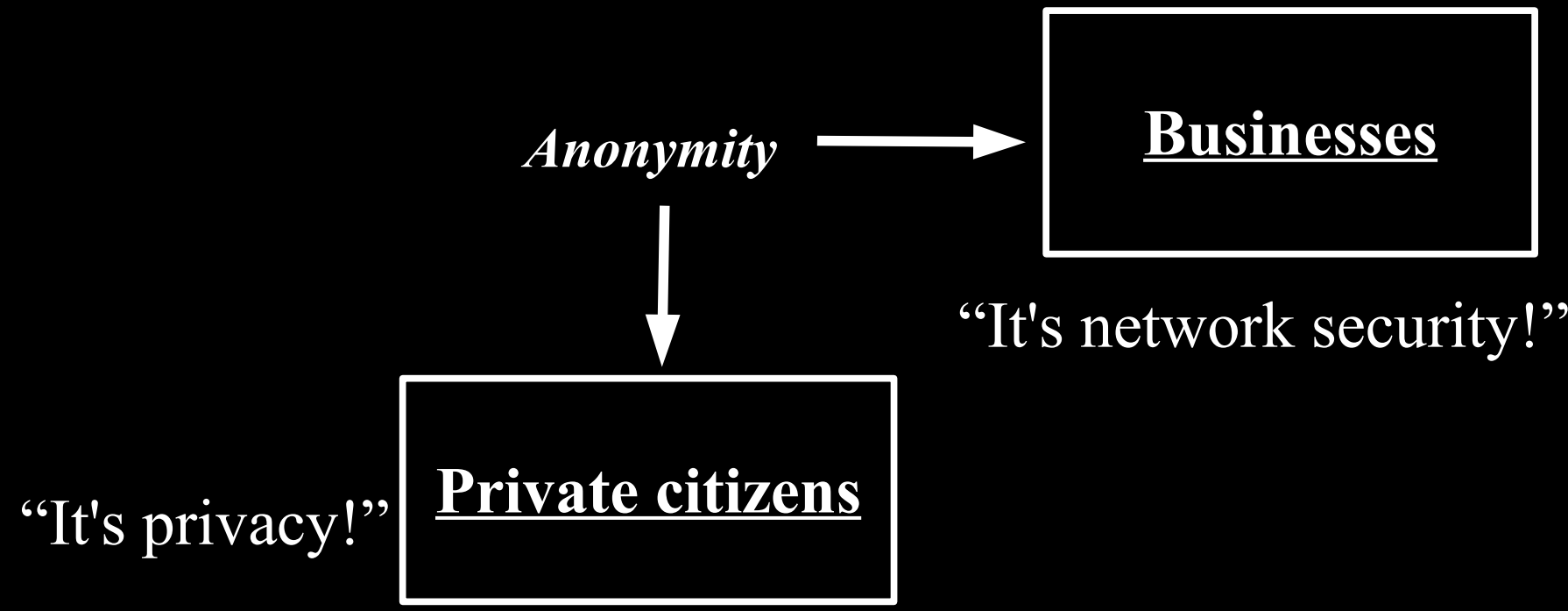

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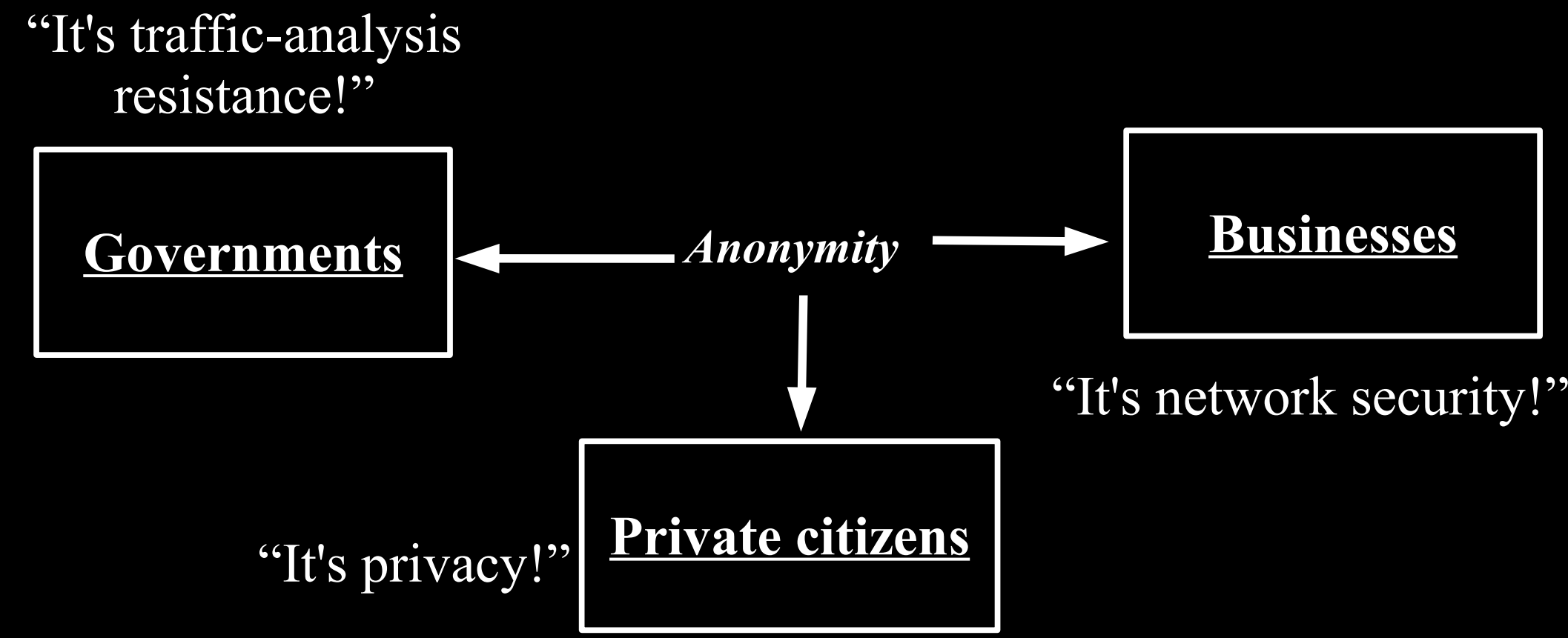

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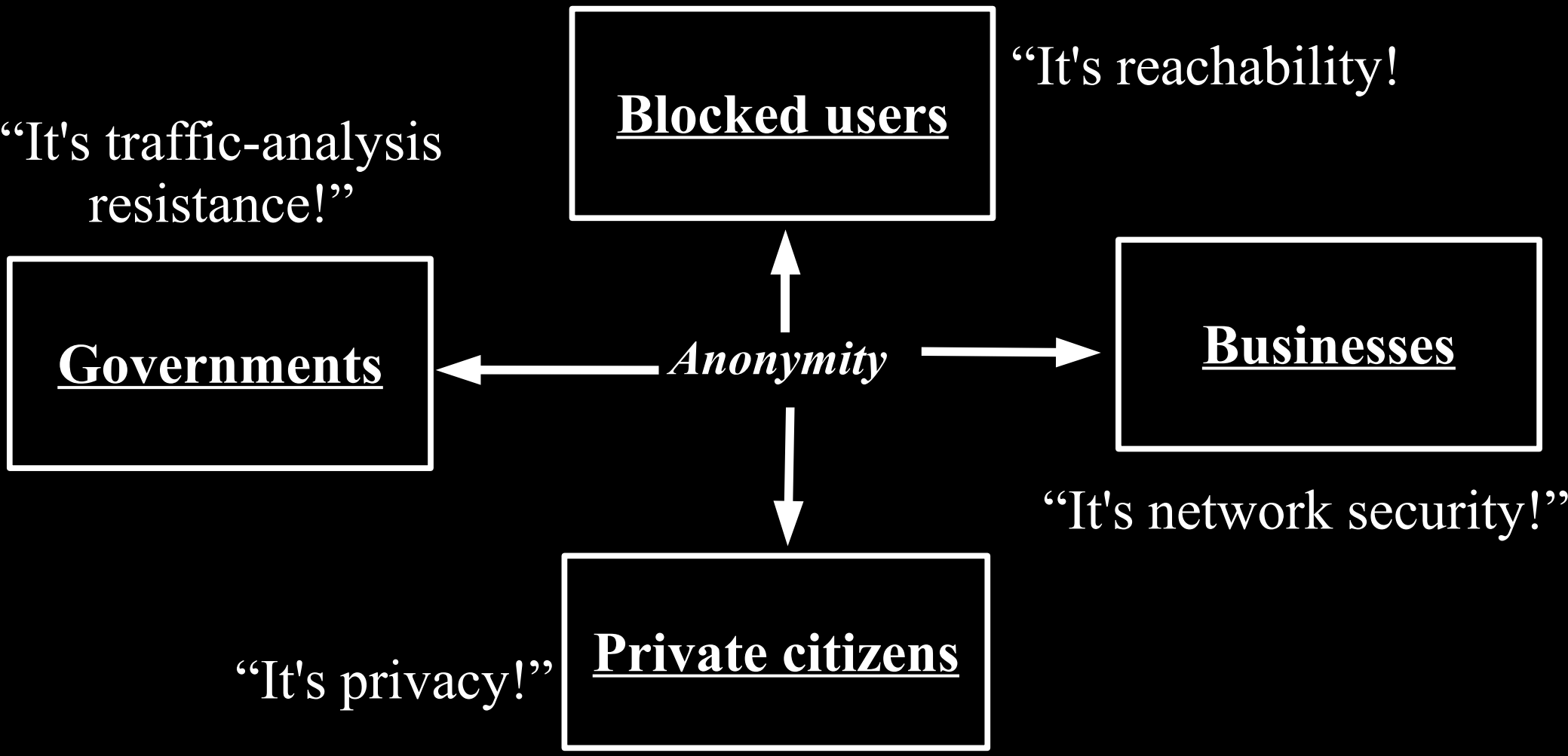
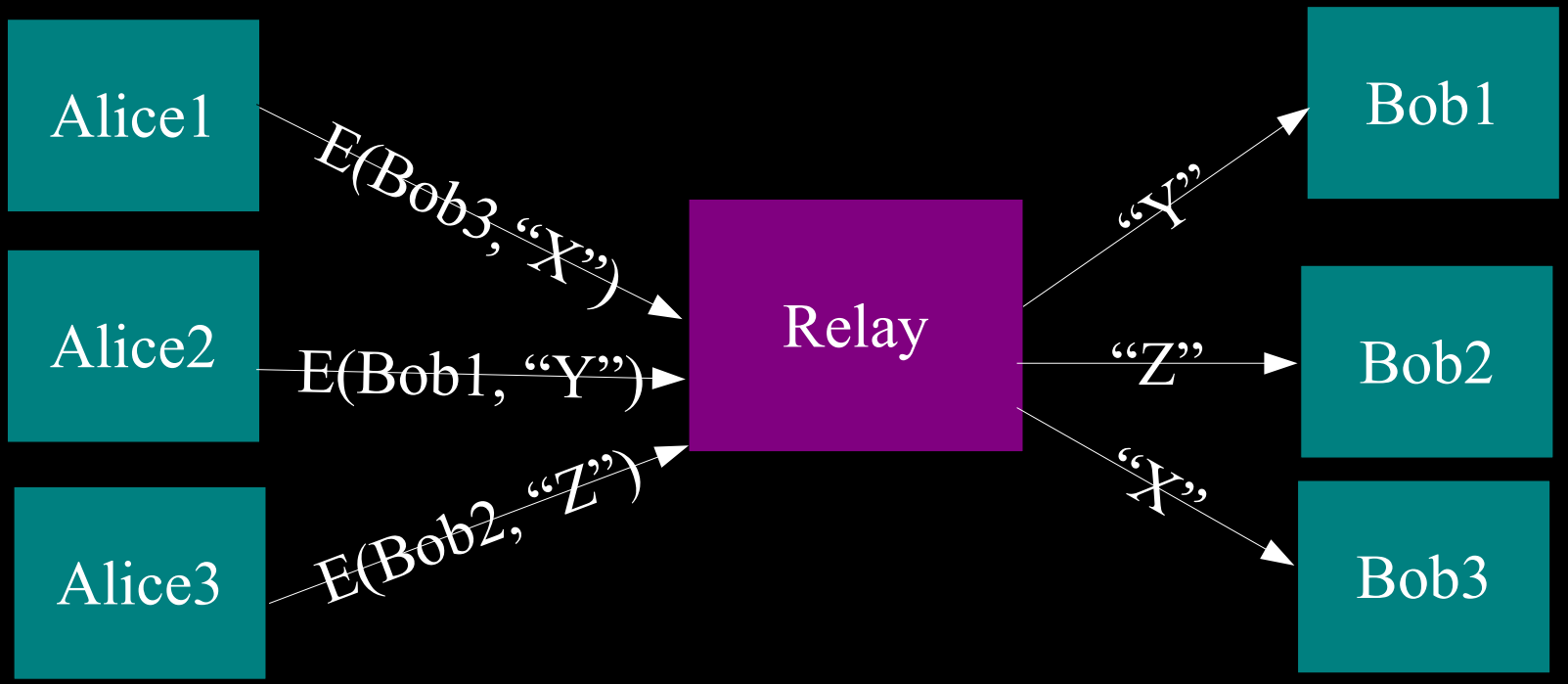
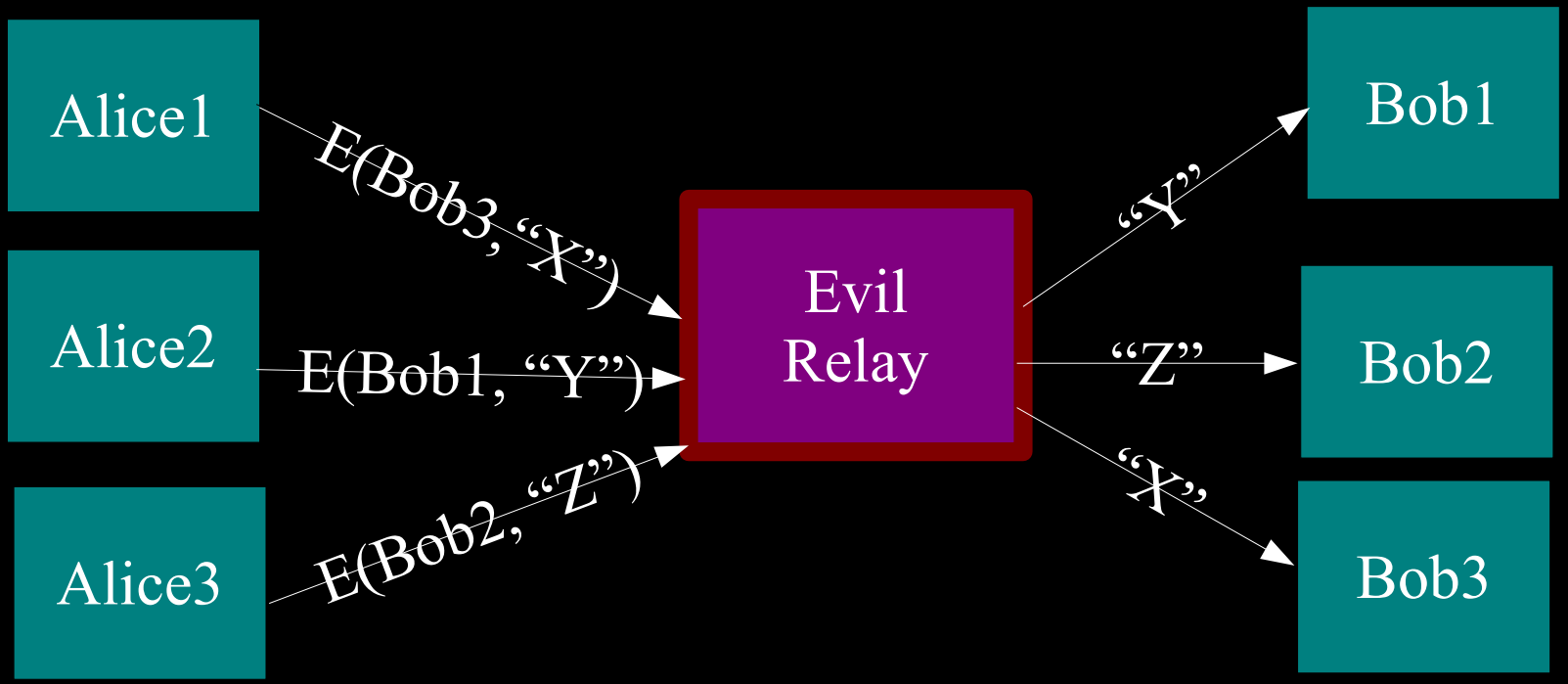


The simplest designs use a single relay to hide connections.

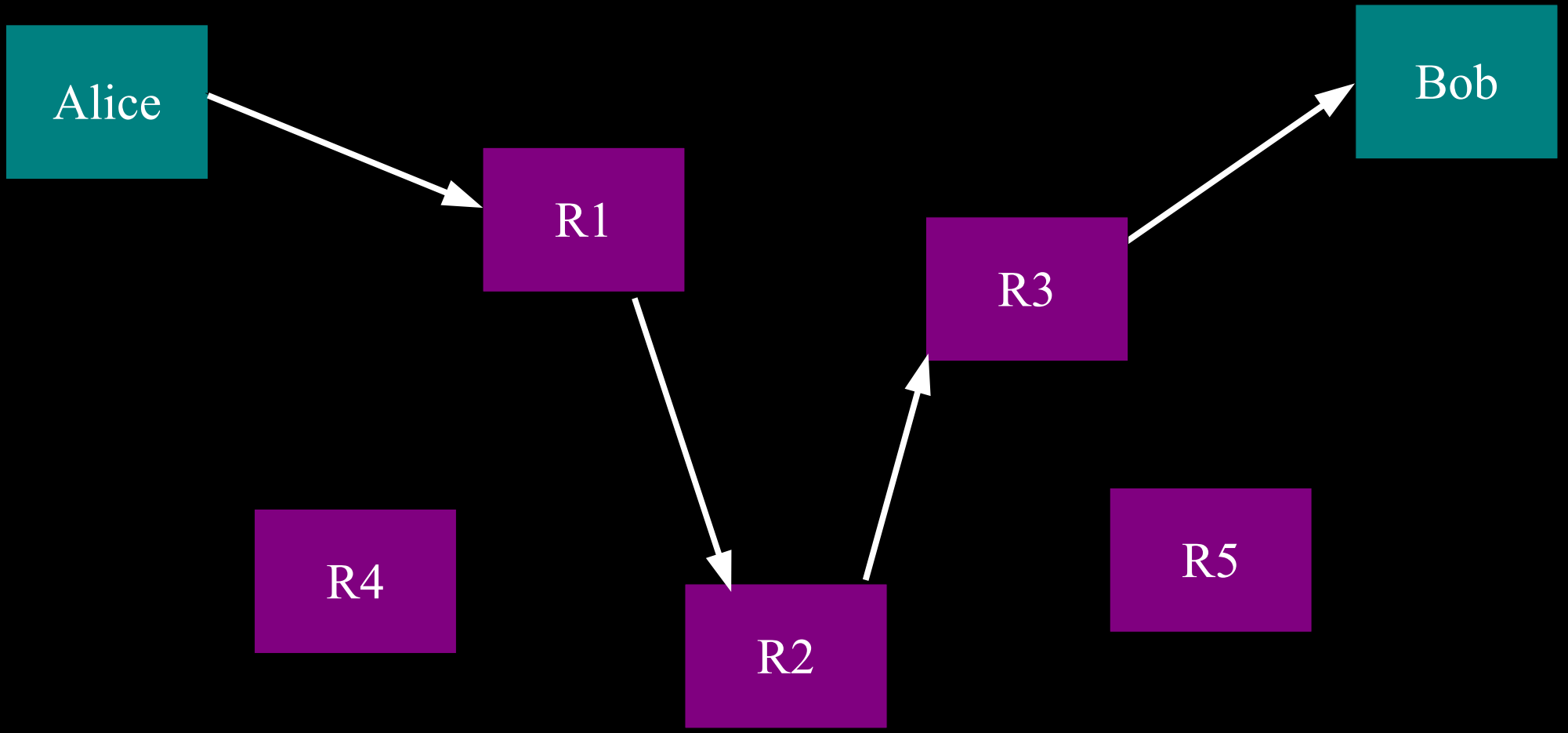


(example: some commercial proxy providers)

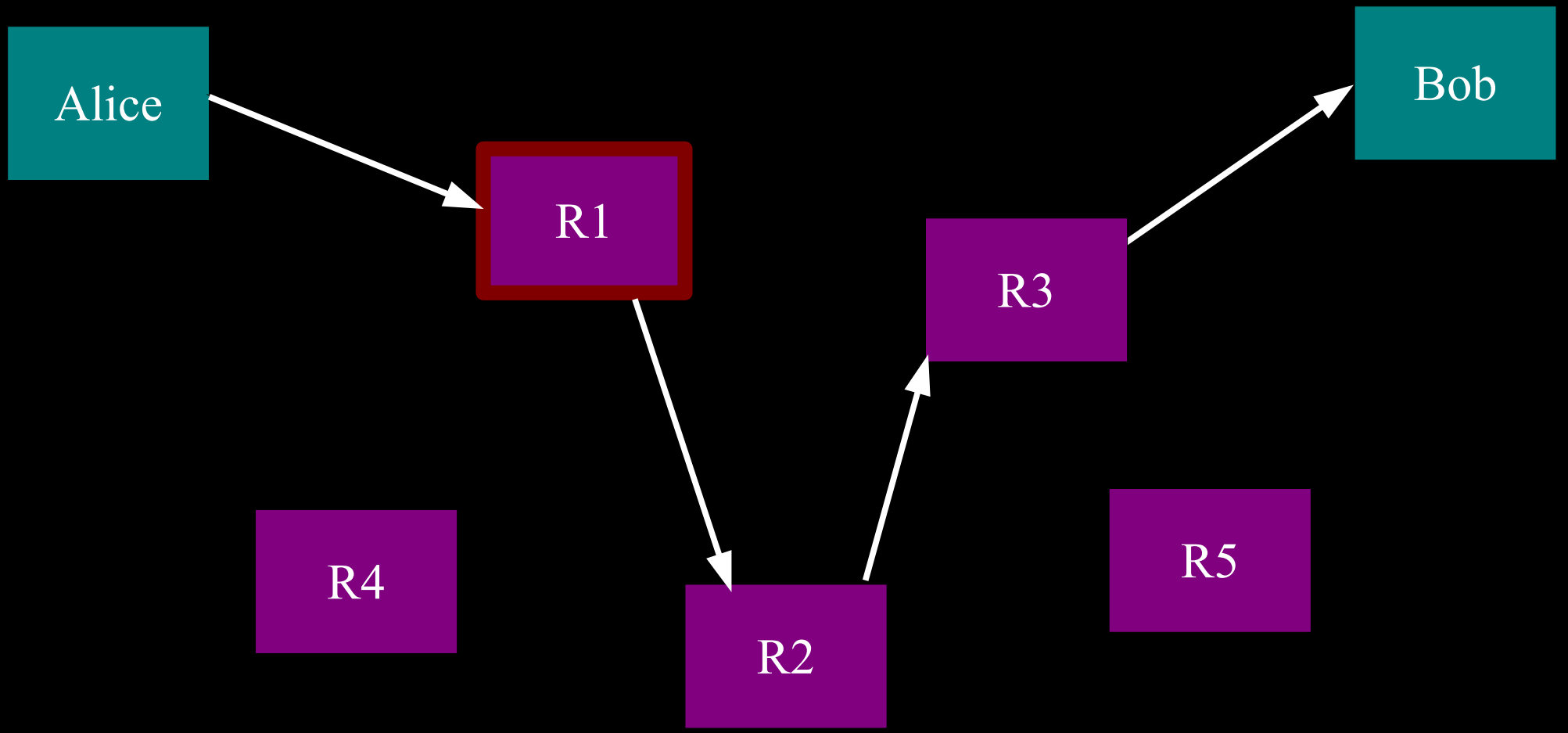
But a single relay (or eavesdropper!) is a single point of failure.



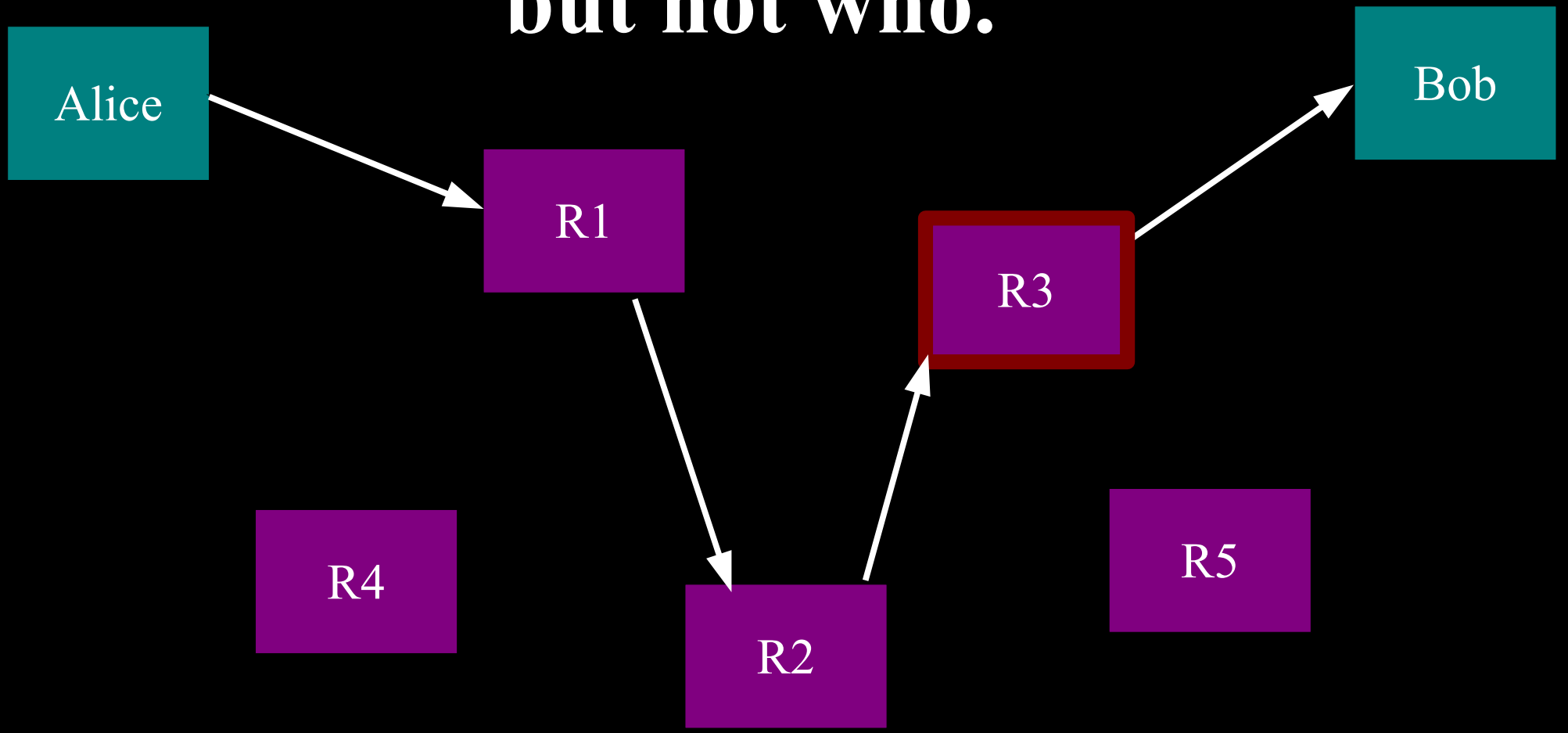
So, add multiple relays so that no single one can betray Alice.



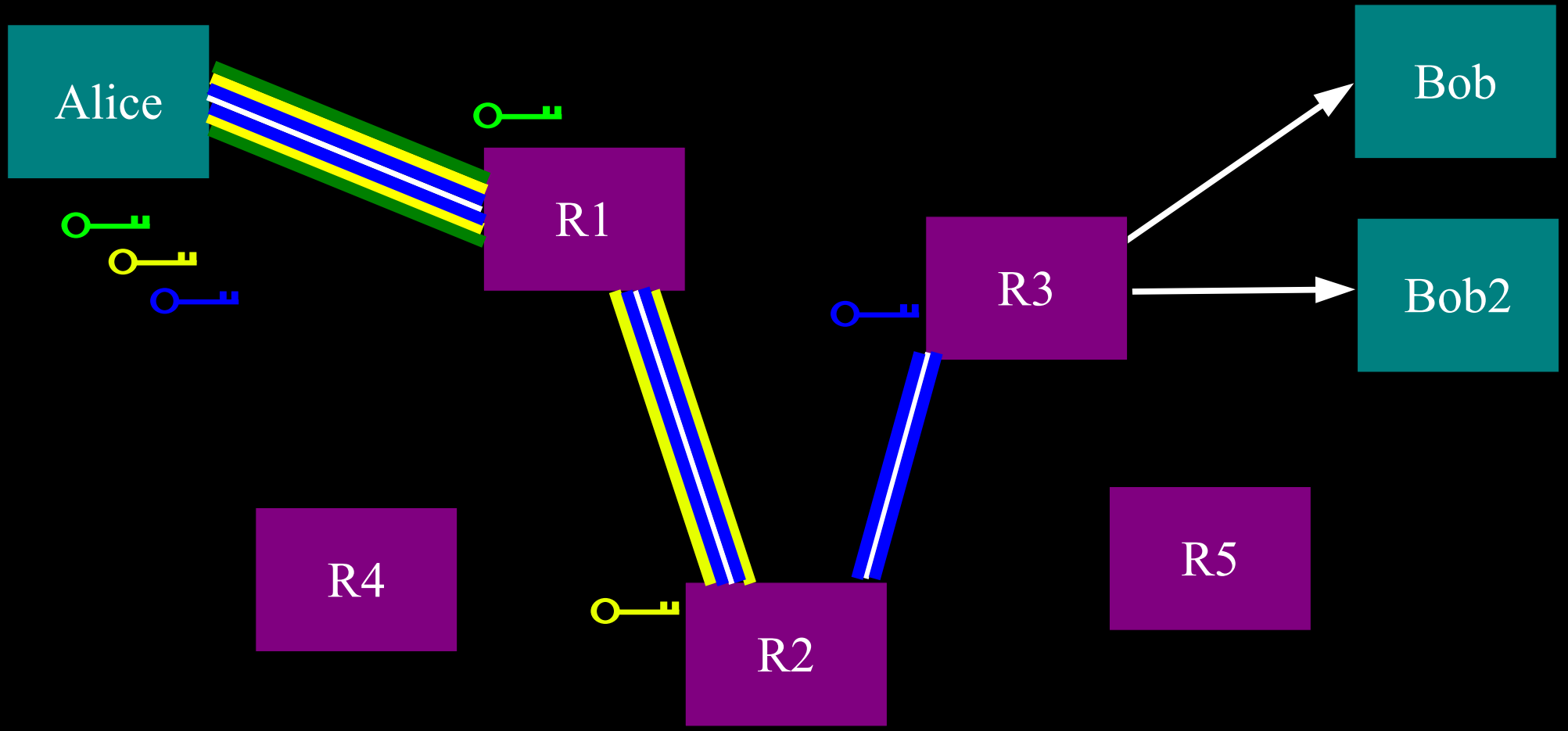
A corrupt first hop can tell that Alice is talking, but not to whom.

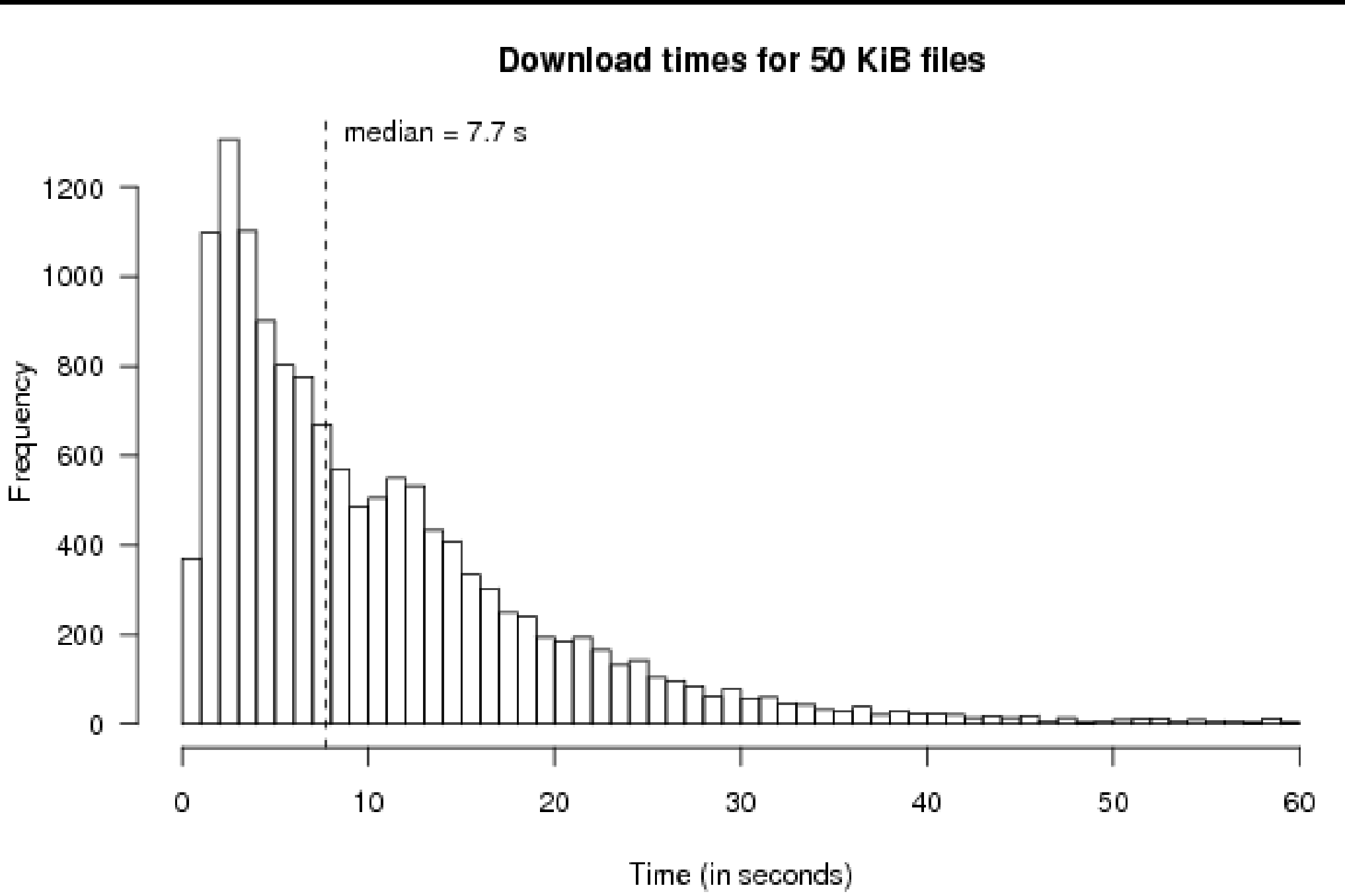


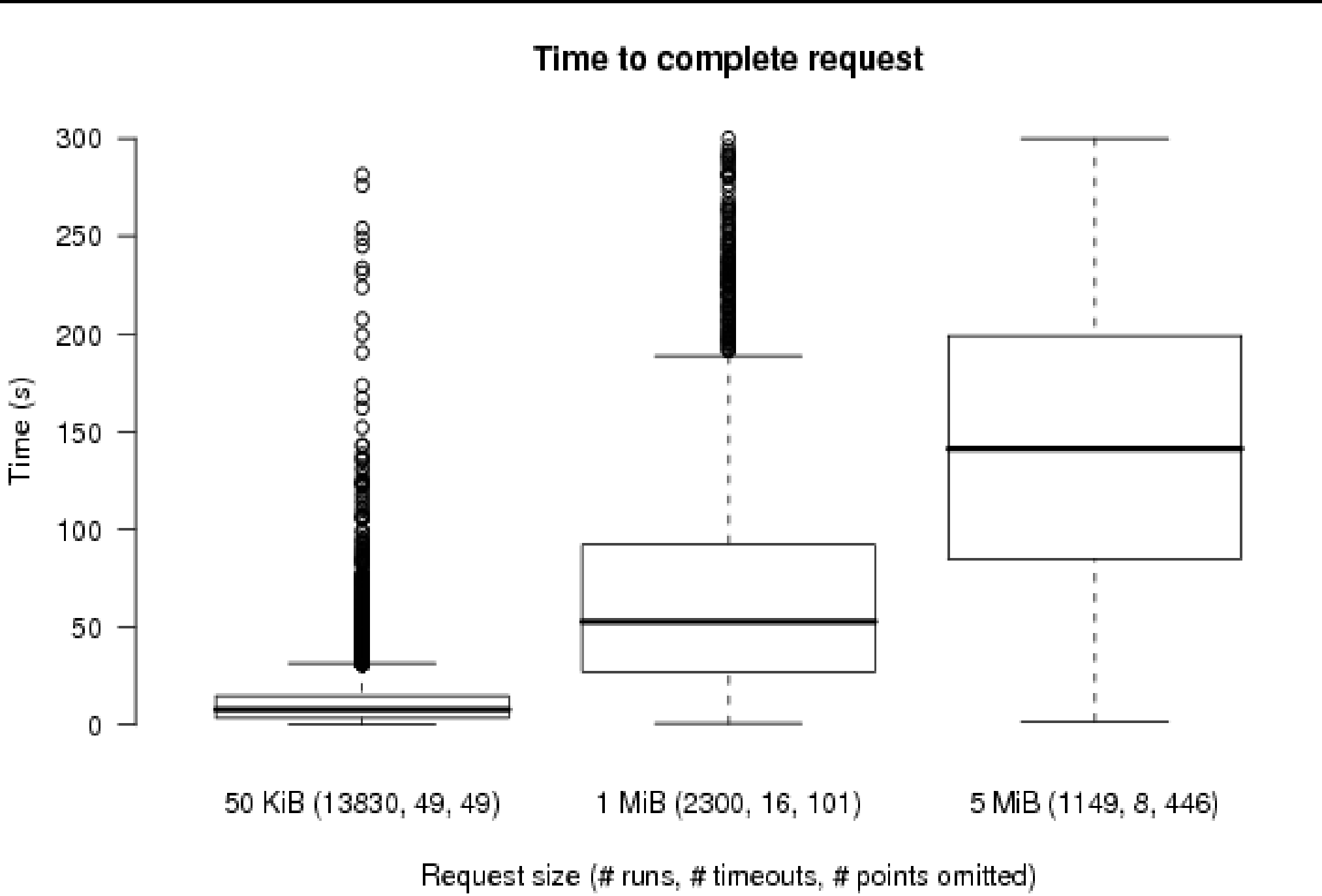
A corrupt final hop can tell that somebody is talking to Bob, but not who.



Alice makes a session key with R1 ...And then tunnels to R2...and to R3




Download times for 50 KiB files
median = 7.7 s
Frequency
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
Time (in seconds)


Time to complete request
Time (s)
300
250
200
150
100
50
0
50 KiB (13830, 49, 49)
1 MiB (2300, 16, 101)
5 MiB (1149, 8, 446)
Request size (# runs, # timeouts, # points omitted)

Six performance problems

- Tor's congestion/flow control is not good
- Some users bulk-transfer over Tor
- Not enough capacity (run a relay!)
- Load balancing isn't right
- Not just high latency, but high variability
- High directory downloading overhead

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TCP backoff slows down every circuit at once (1)

- Tor multiplexes many circuits over a given TCP connection
- The only trick TCP has to slow one down is to slow them all down
- Especially bad on asymmetric bandwidth links (cablemodem, DSL, ...)

TCP backoff slows down every circuit at once (2)

- The solution: switch to a datagram protocol (e.g. UDP) and layer end-to-end flow control on top of it.
- Needs a secure maintained free-software portable user-space TCP stack? Yuck.
- Maybe other datagram protocols have better congestion control. SCTP? Delay-based backoff rather than drop-based?

Circuit window sizes too big?

- Tor does flow control with end-to-end "circ window" plus "sendme" ack cells
- Fixed-size window of 1000 cells (512KB)
- Cutting the window size to 100 reduces buffer sizes (and queues), but increases roundtrips

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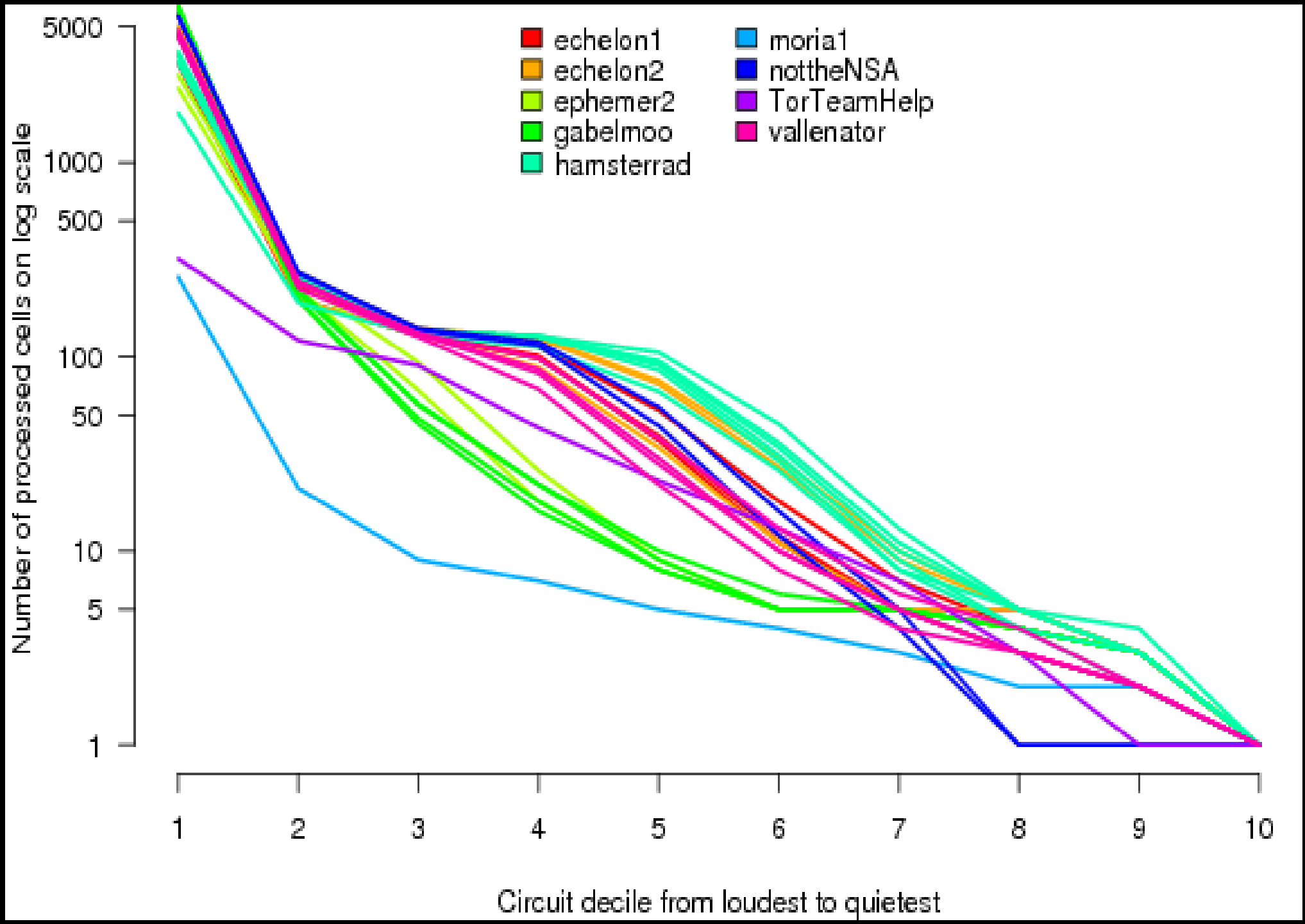
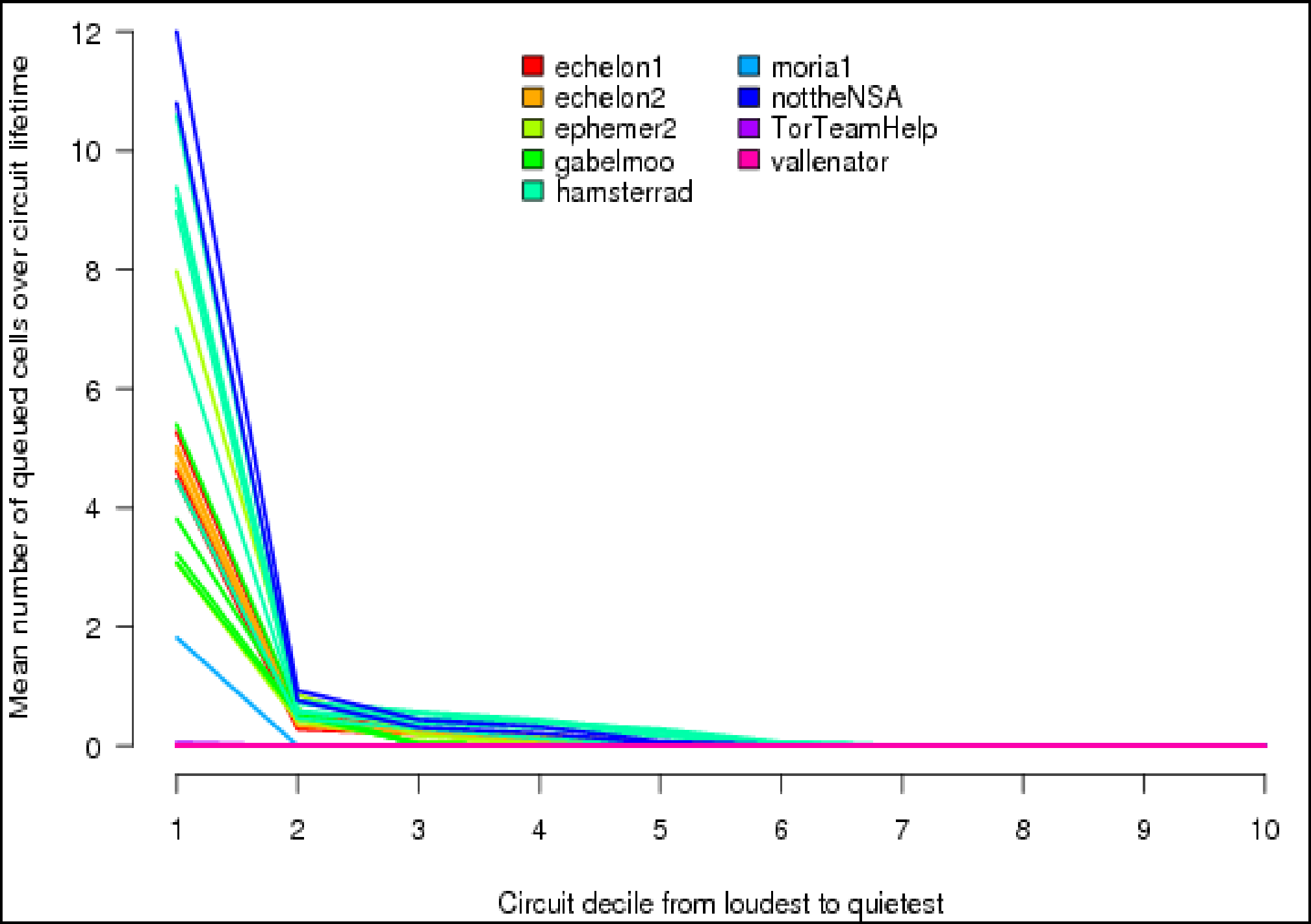
Lessons from economics

- Increase in supply (network capacity) means increase in demand (users)
- We used to think there would be an equilibrium
- But file-sharing users have a different tolerance for latency than web browsing users

Squeeze over-active circuits (1)

- Right now we round-robin among all "active" circuits when choosing next cell
- Most relays rate-limit: they'll only deliver a certain number of cells per second
- So circuits that are always active end up sending more cells.


5000
1000
500
100
50
10
5
1
Number of processed cells on log scale
echelon1
echelon2
ephemer2
gabelmoo
hamsterrad
moria1
nottheNSA
TorTeamHelp
vallenator
1
2
3
4
5
6
7
8
9
10
Circuit decile from loudest to quietest


Mean number of queued cells over circuit lifetime
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
9
10
Circuit decile from loudest to quietest
echelon1
echelon2
ephemer2
gabelmoo
hamsterrad
moria1
nottheNSA
TorTeamHelp
vallenator

Squeeze over-active circuits (2)

- So we should pick from the really loud circuits less often.
- But using what algorithm?
- And how do we know whether we'll actually make it better?

Throttle bandwidth in client

- Not really a stable solution, since users could “fix” their client
- But can't do it at the relay, since the relays would need to coordinate what they see
- Throttling bandwidth at the client can actually make you more secure, too! Cf. the paper that Columbia is working on

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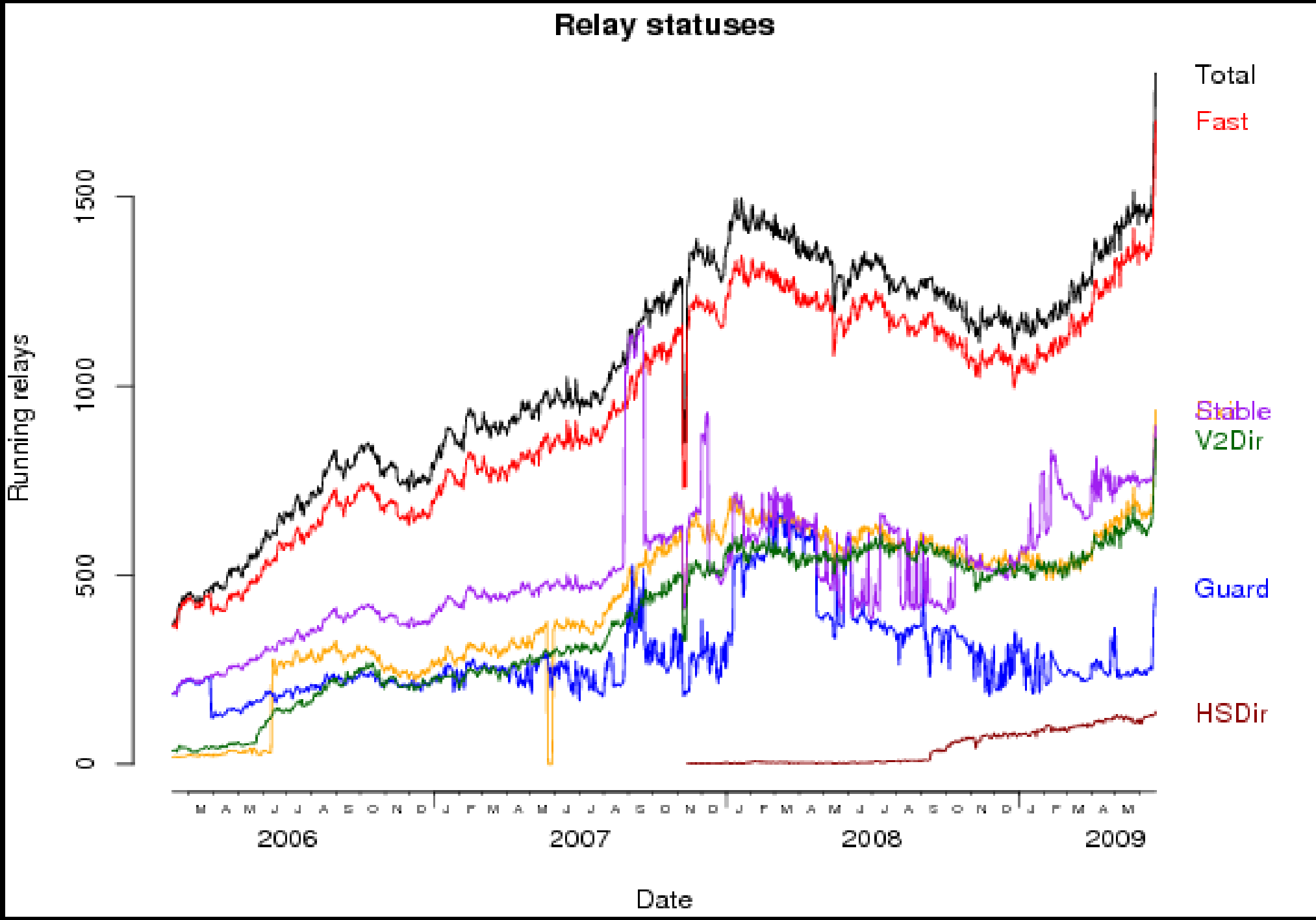
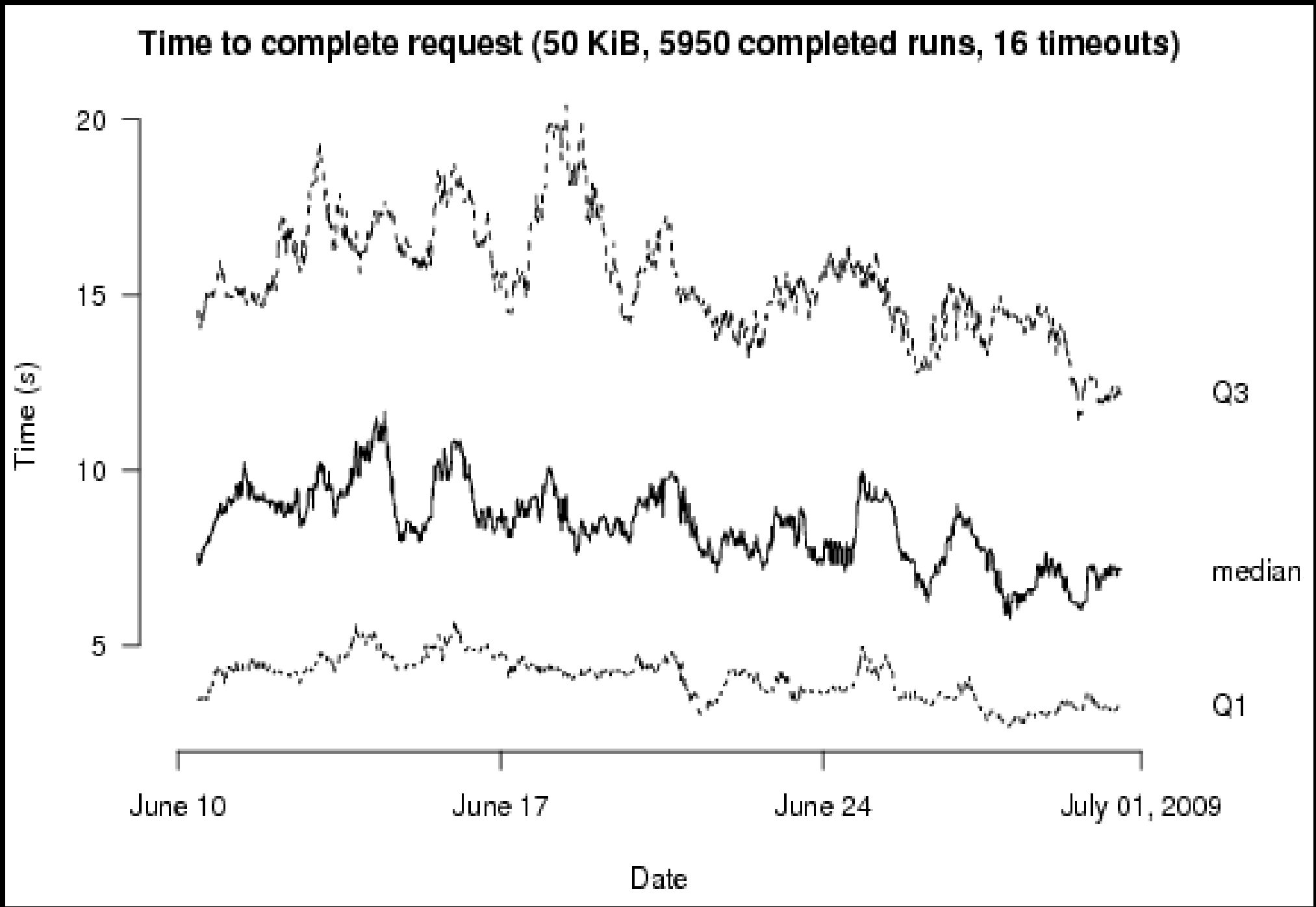
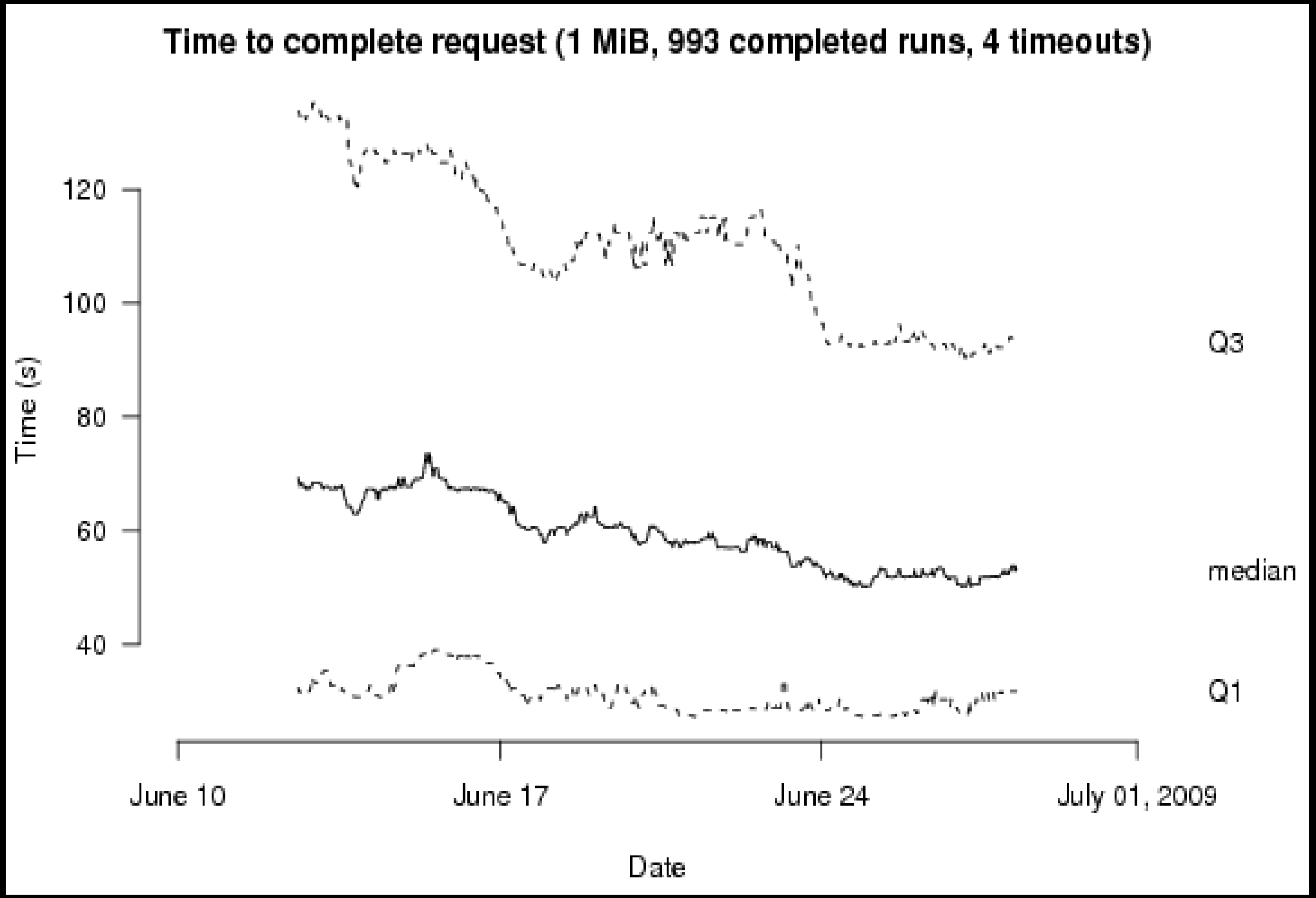
Why is capacity only #3?

- If congestion control continues to be poor, getting more relays won't solve that
- Won't bulk-transfer users expand to fill our new capacity?
- Remember our economic argument

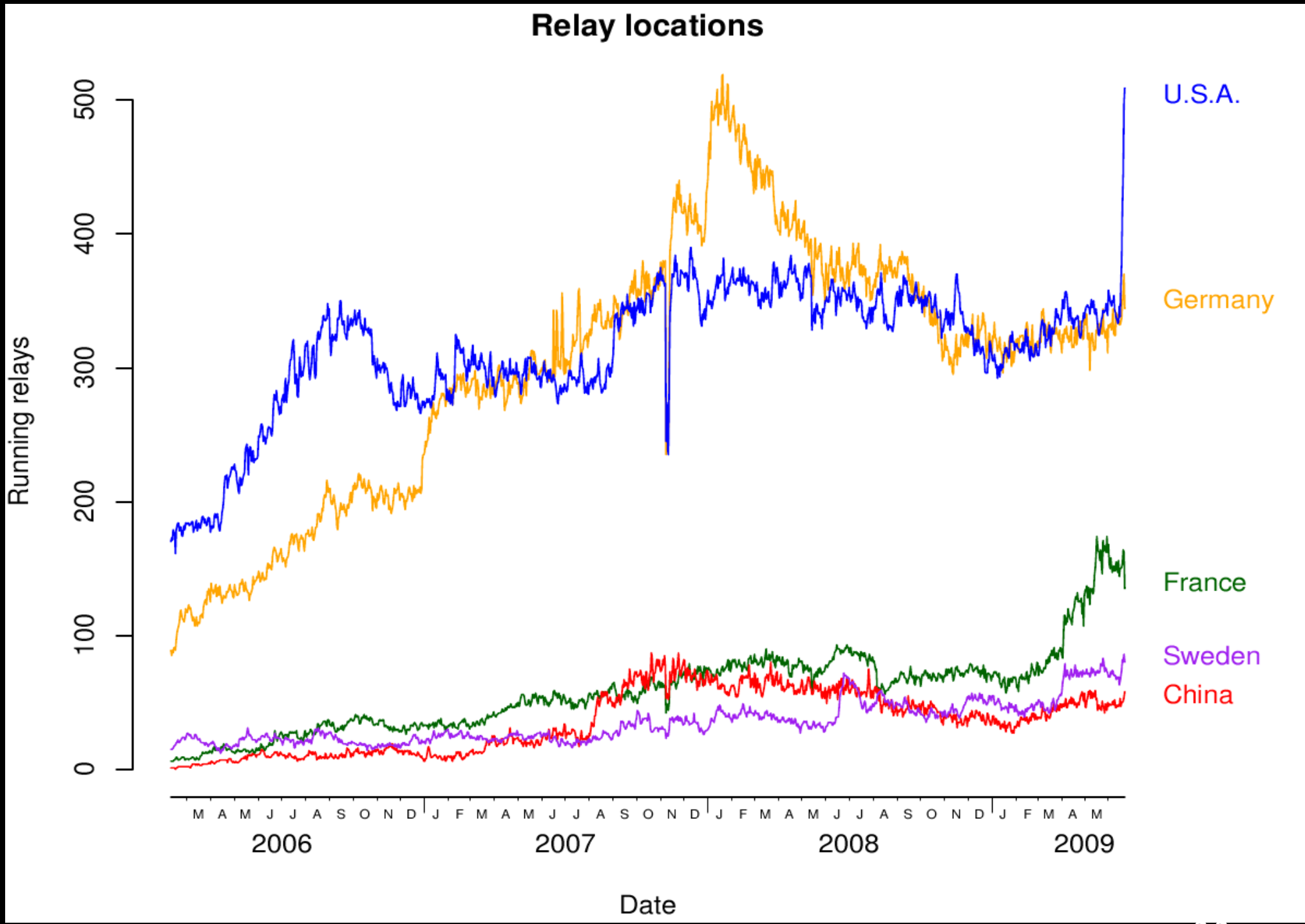

Relay statuses
Total
Fast
Stable
V2Dir
Guard
HSDir
Running relays
0
500
1000
1500
2006
2007
2008
2009
Date


Time to complete request (50 KiB, 5950 completed runs, 16 timeouts)
20
15
10
5
Time (s)
Q3
median
Q1
June 10
June 17
June 24
July 01, 2009
Date


Time to complete request (1 MiB, 993 completed runs, 4 timeouts)
120
100
80
60
40
Time (s)
Q3
median
Q1
June 10
June 17
June 24
July 01, 2009
Date

Relay advocacy

- Jake and I keep doing talks and trainings all over the world
- Need better support for relay operators
  - Mailing list just for them?
  - "Tor weather" cgi to mail them when their relay goes down


Relay locations
Running relays
0
100
200
300
400
500
U.S.A.
Germany
France
Sweden
China
M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
2008
2009
Date

Incentive mechanisms

- Gold-star reputation design: be a relay, get rewarded with better performance.
- Micropayment approaches
- But: intersection attacks on the lists of which relays are running whenever our target user connects

Everybody-a-relay

- Need to support fast Tor windows relays (Nick has spent the past months hacking libevent / openssl)
- Automatically configure rate limiting?
- Need a directory design that scales
- Anonymity risks from letting the attacker relay traffic through you

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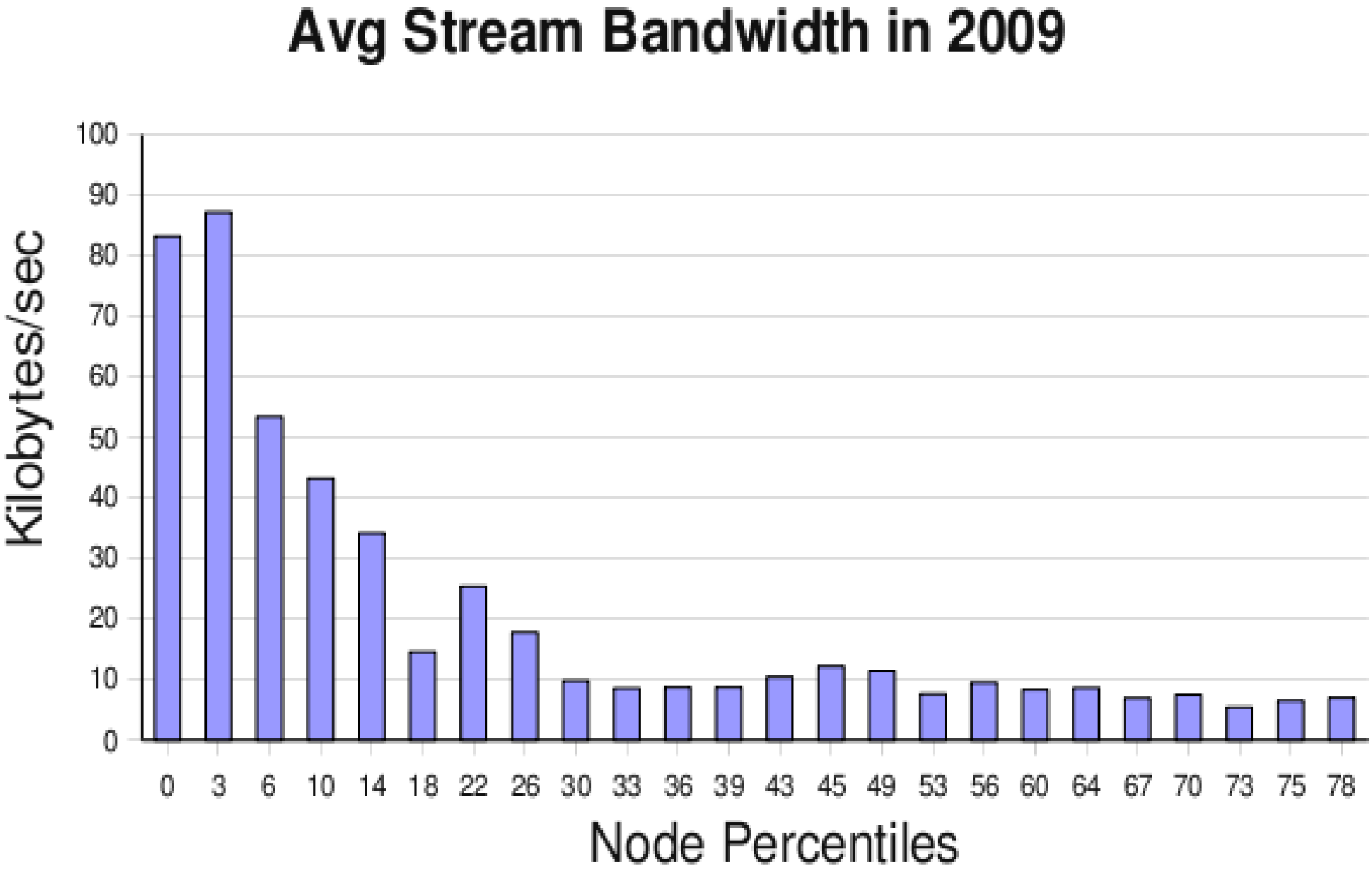
Avg Stream Bandwidth in 2009
Kilobytes/sec
100
90
80
70
60
50
40
30
20
10
0
0 3 6 10 14 18 22 26 30 33 36 39 43 45 49 53 56 60 64 67 70 73 75 78
Node Percentiles

Torflow: better bandwidth weights via measuring

- Bandwidth self-measuring not so good
- And we had to cap it at 10MB/s to resist cheaters
- Now we actively measure, and put the results in the consensus for clients
- Still a tradeoff between optimal network use vs anonymity

Old entry guards are overloaded

- The longer you're an entry guard, the more clients you accumulate
- Now clients expire each guard after a month
- (This issue also means that brand new entry guards have no users, so aren't used efficiently)

What about one-hop paths?

- It used to be a bad idea because it would screw up load balancing. Not so bad now.
- They're clearly way worse for anonymity.
- If exits are scarce, would it actually help?
- The main stumbling block is exit relay exposure: they'd become juicy targets, since no more guaranteed distributed trust

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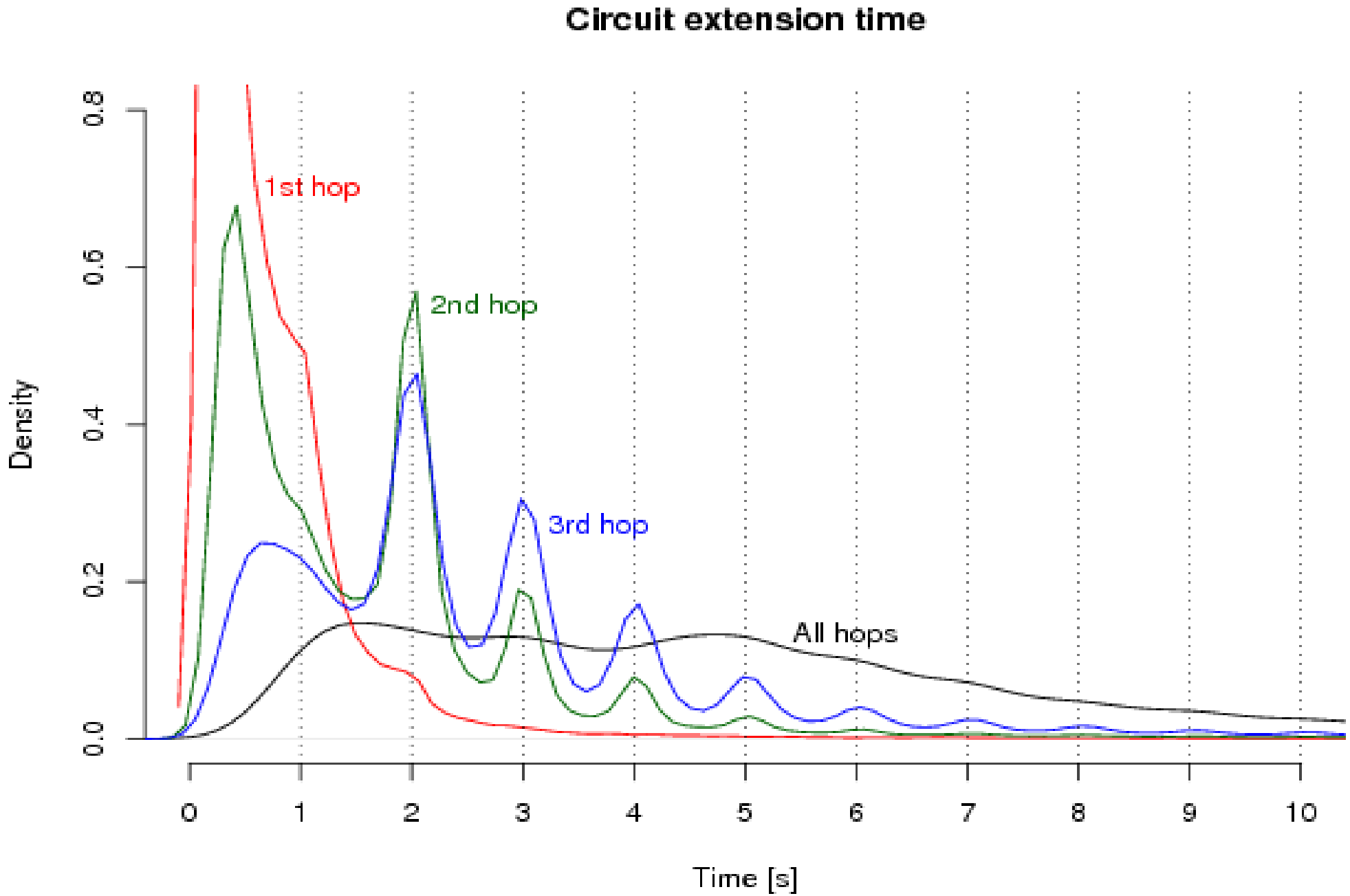
Per-second rate limiting

- Tor uses a token bucket for its rate limiting. It refills the bucket each second.
- Now that relays are overloaded, that means a burst of traffic at the beginning of each second, and then silence.


Circuit extension time
Density
0.0
0.2
0.4
0.6
0.8
1st hop
2nd hop
3rd hop
All hops
0
1
2
3
4
5
6
7
8
9
10
Time [s]

Adaptive circuit build timeouts

- Some circuits finish building in a few seconds. Some take 15-20 seconds.
- Circuits that build slowly also have bad performance. We should discard them.
- We can't just lower the timeouts: folks in Zimbabwe would never finish a circuit
- Need to measure build times at the client and dynamically adapt the timeouts

Same thing for stream timeouts?

- Right now our stream timeouts are hard-coded at 10sec for the first two attempts, 15sec for later attempts.
- This is way too low for people on modems in Iran.
- So even if the user is really patient, their Tor client isn't.

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Clients need to learn about available relays

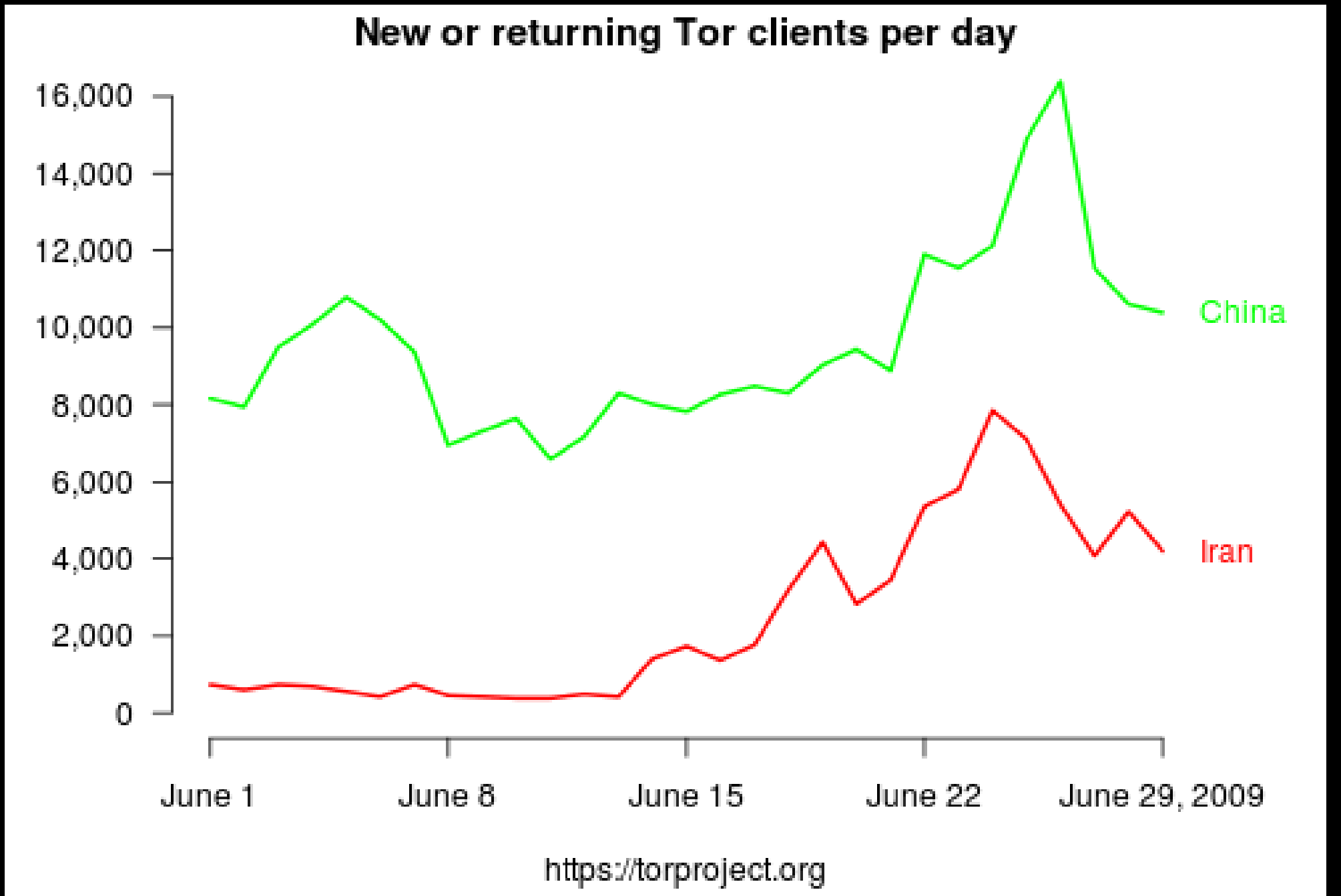
- The quicker the client learns, the more use we get from short-term relays
- Clients need to share the same view of the network to prevent partitioning attacks
- We want it to scale to many thousands of relays

Scaling directory info

- V1 directory design: big list of descriptors
- V3 directory design: networkstatus consensus, plus individual descriptors
- Microdescriptor design: networkstatus consensus, plus mostly static microdescs
- Consensus diffs?

Last thoughts

- How do we decide whether a given design change will actually help?
- Tor network simulator sure would be nice
- Doing measurements is also a good start
  - We've got data!
- What about anonymity implications of our changes?


New or returning Tor clients per day
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
China
Iran
June 1
June 8
June 15
June 22
June 29, 2009
https://torproject.org