Tor performance problems
...and how to solve them

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The Tor Project
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?
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- Private citizens: “It's privacy!”
- Businesses: “It's network security!”
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“Anonymity”

Governments

― Anonymity → Businesses

“It's traffic-analysis resistance!”

― Anonymity ← Private citizens

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- **Governments**
  - “It's traffic-analysis resistance!”

- **Private citizens**
  - “It's privacy!”

- **Businesses**
  - “It's network security!”

- **Blocked users**
  - “It's reachability!”
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
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 (cable modem, 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.
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.
Time to complete request (50 KiB, 5950 completed runs, 16 timeouts)
Time to complete request (1 MiB, 993 completed runs, 4 timeouts)
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
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

Node Percentiles

0  3  6  10  14  18  22  26  30  33  36  39  43  45  49  53  56  60  64  67  70  73  75  78
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.
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: network status consensus, plus individual descriptors
- Microdescriptor design: network status 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?