Design of a blocking-resistant anonymity system

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The Tor Project

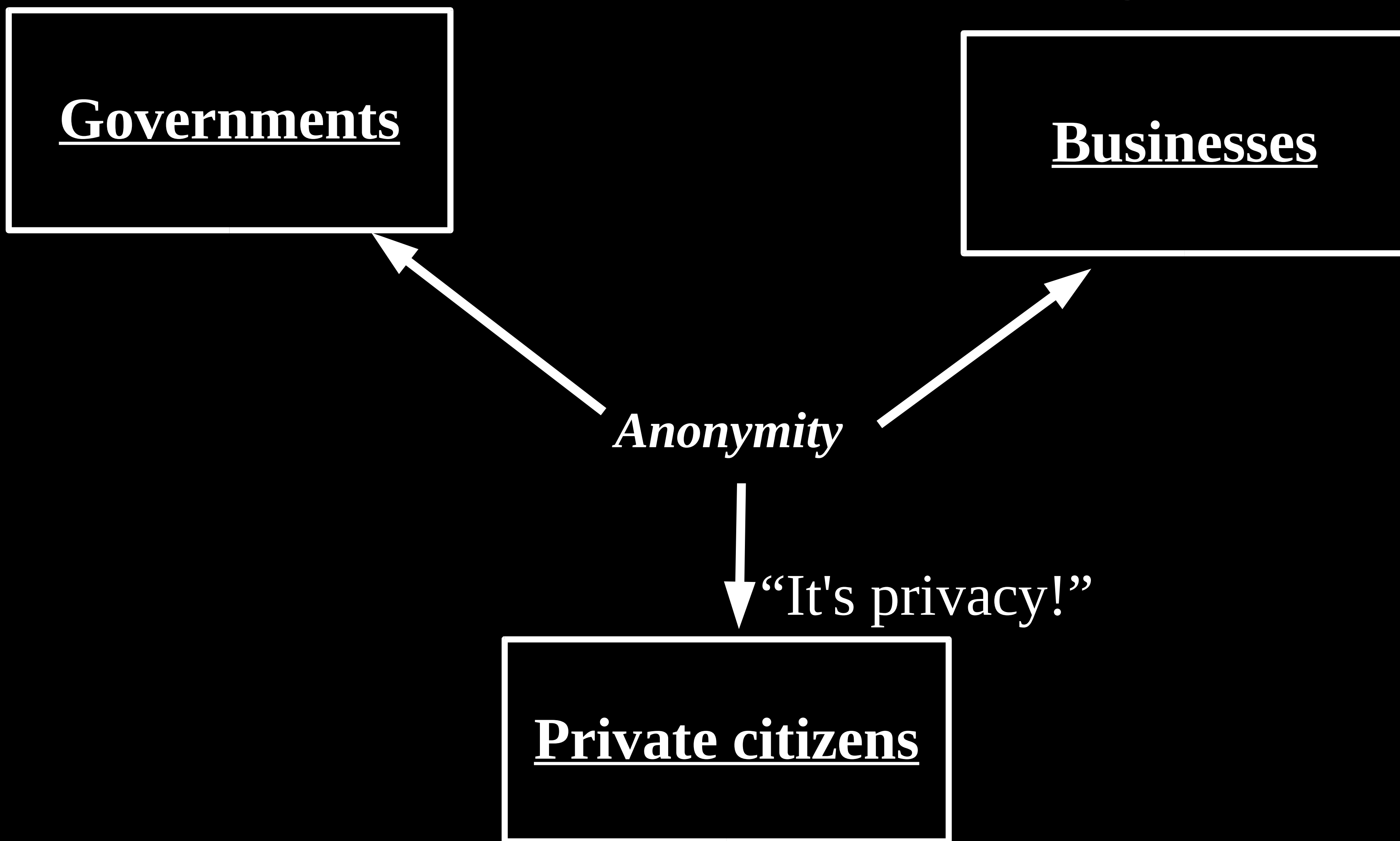
Outline

- Crash course on Tor
- Goals for blocking resistance
- Assumptions (threat model)
- What Tor offers now
- Current proxy solutions
- What we need to add to Tor
- All the other issues that come up

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.
- Chosen as anonymity layer for EU PRIME project.
- 200000+ (?) active users.
- PC World magazine named Tor one of the Top 100 Products of 2005.

Anonymity serves different interests for different user groups.



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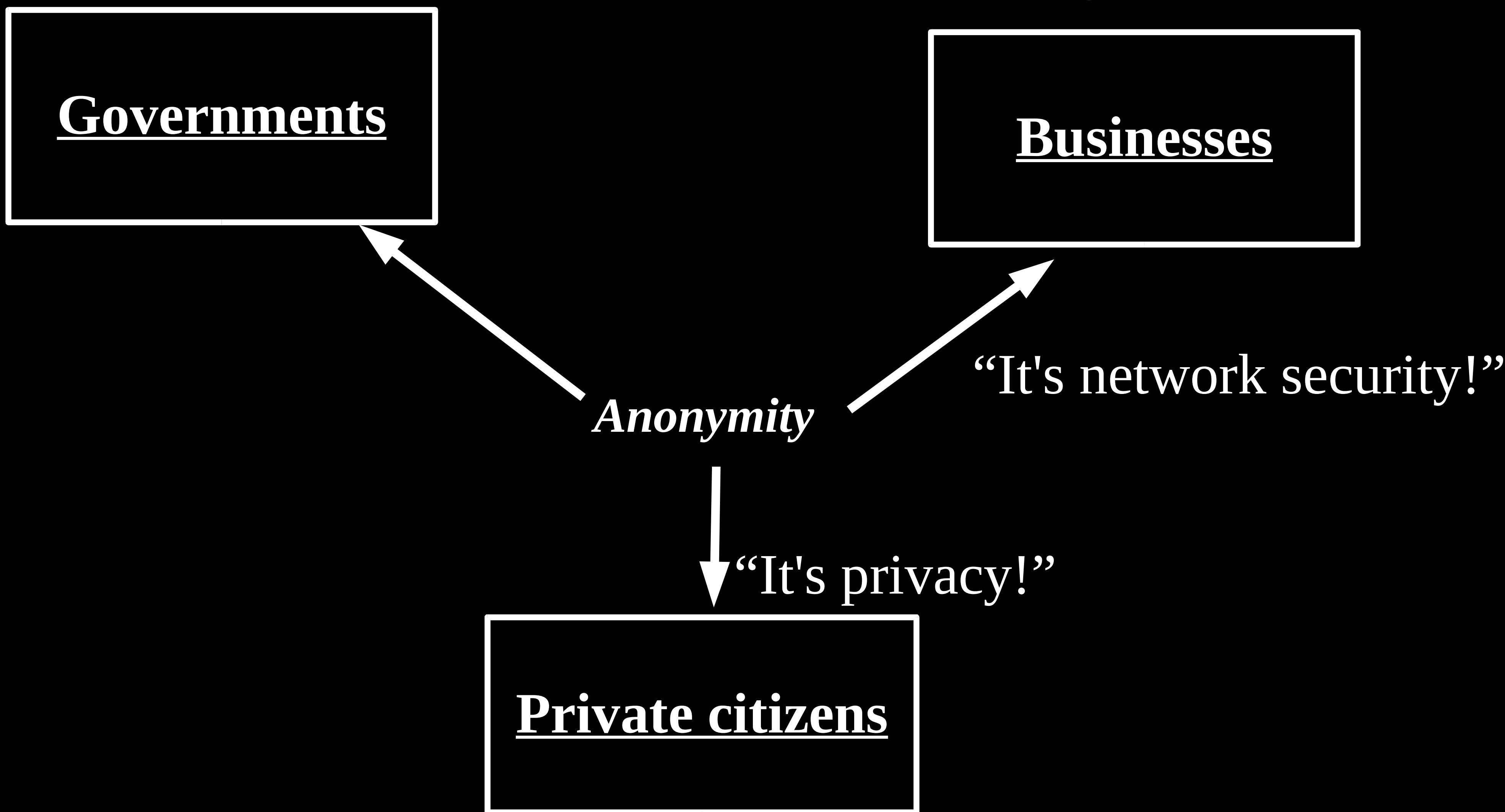

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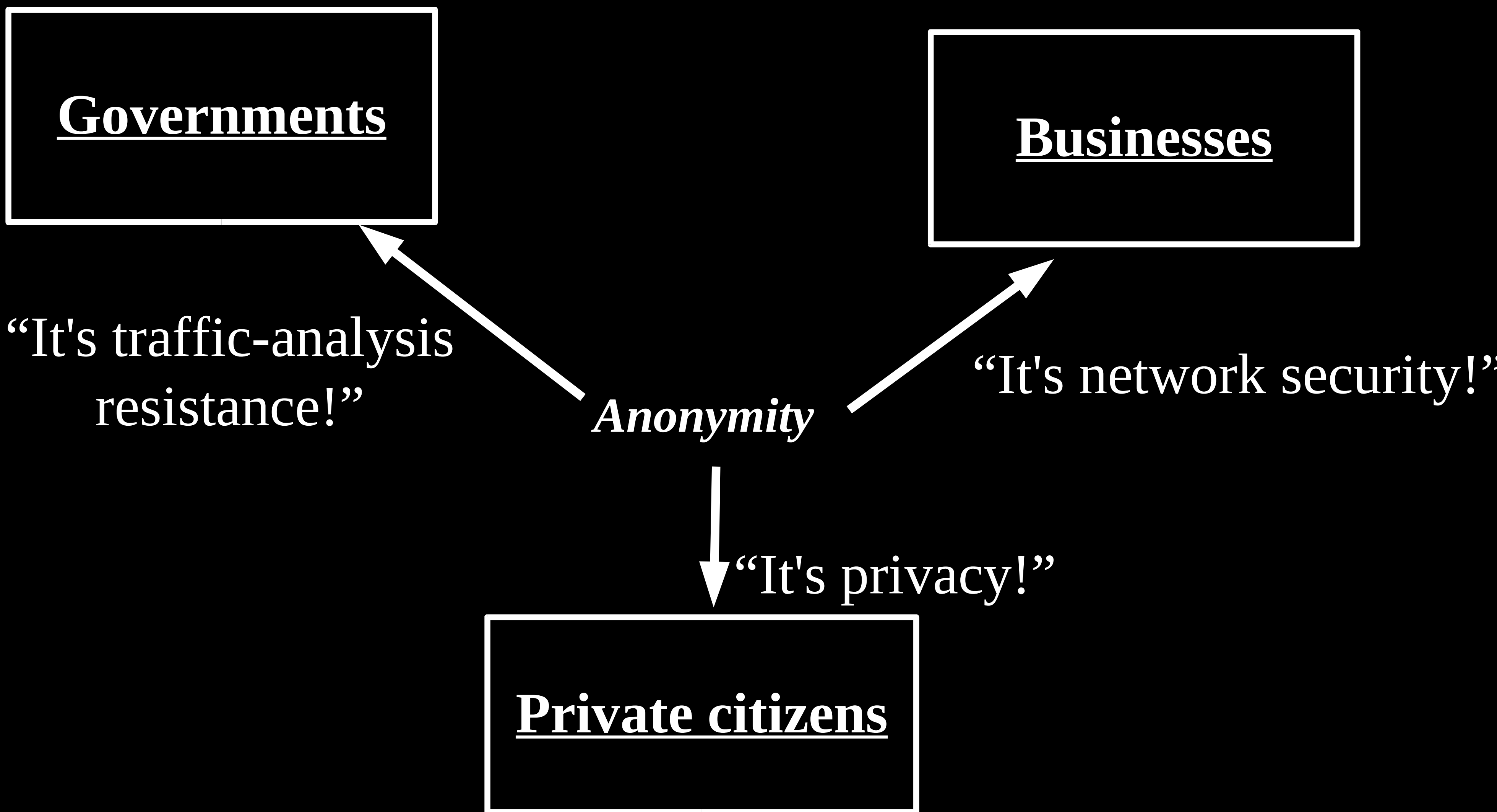
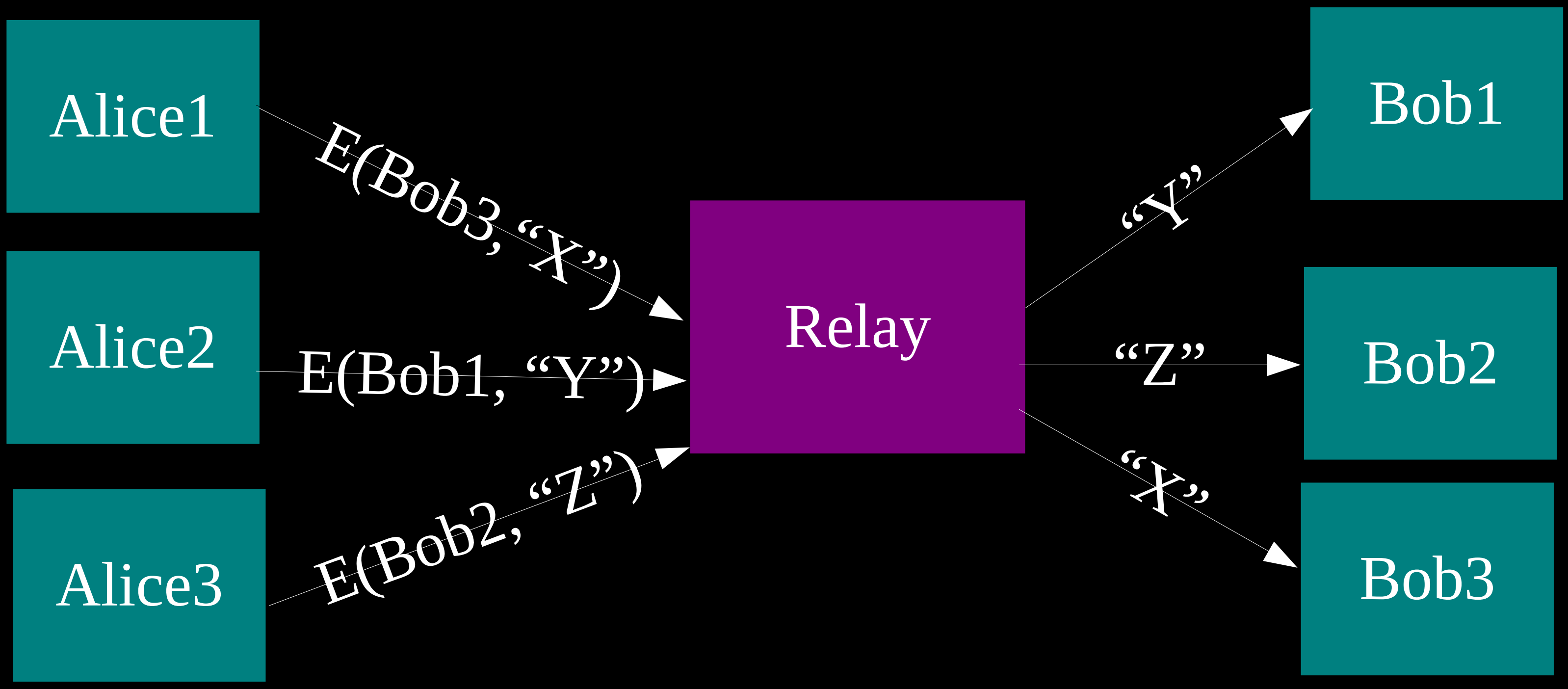
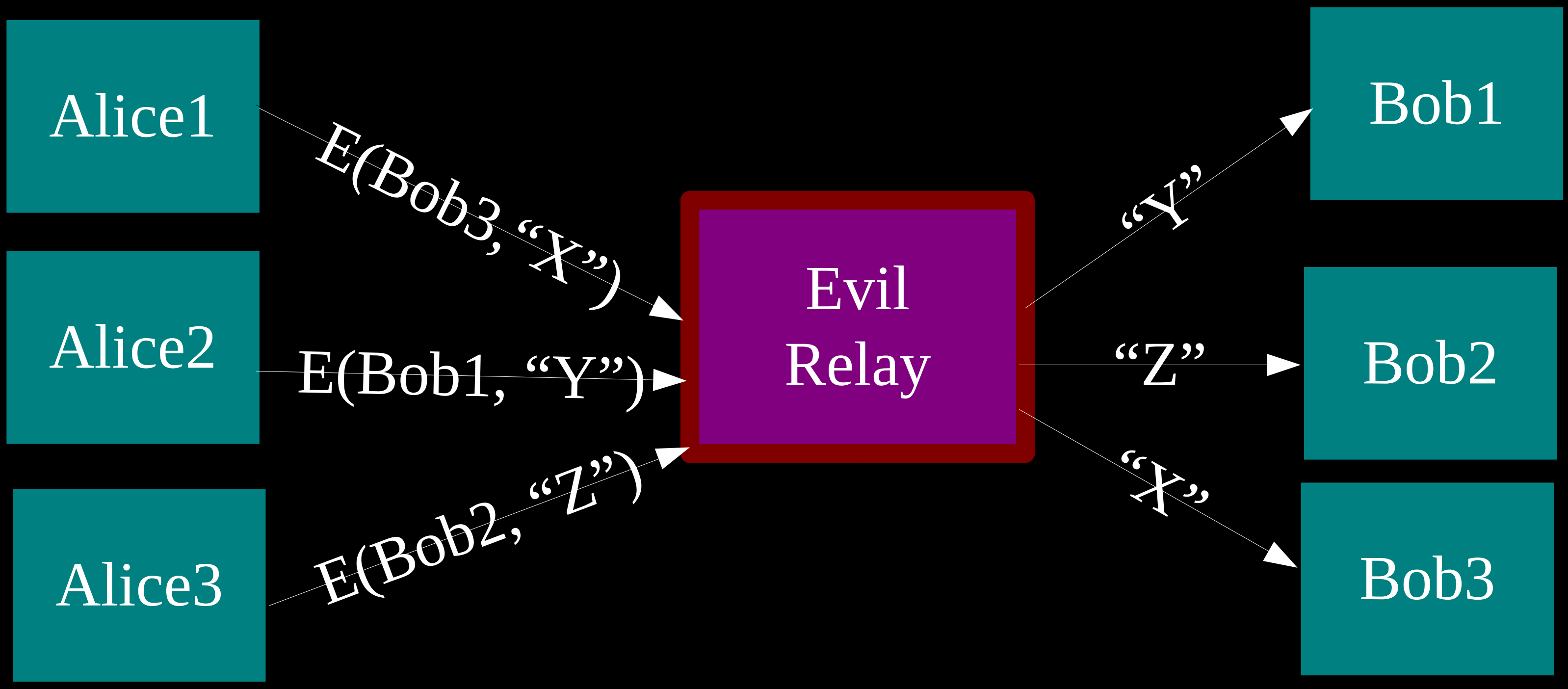


The simplest designs use a single relay to hide connections.



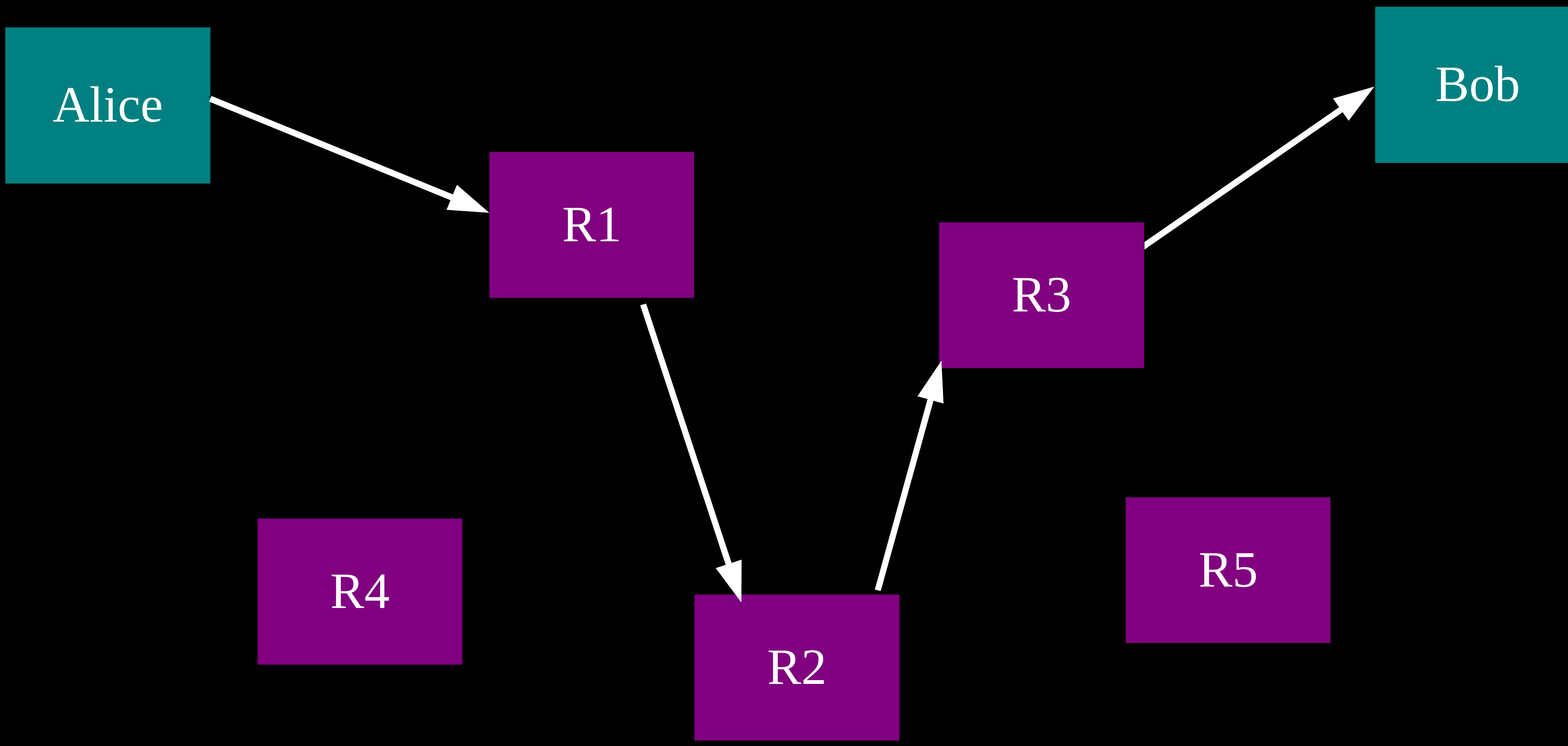
(example: some commercial proxy providers)

But a single relay is a single point of failure.

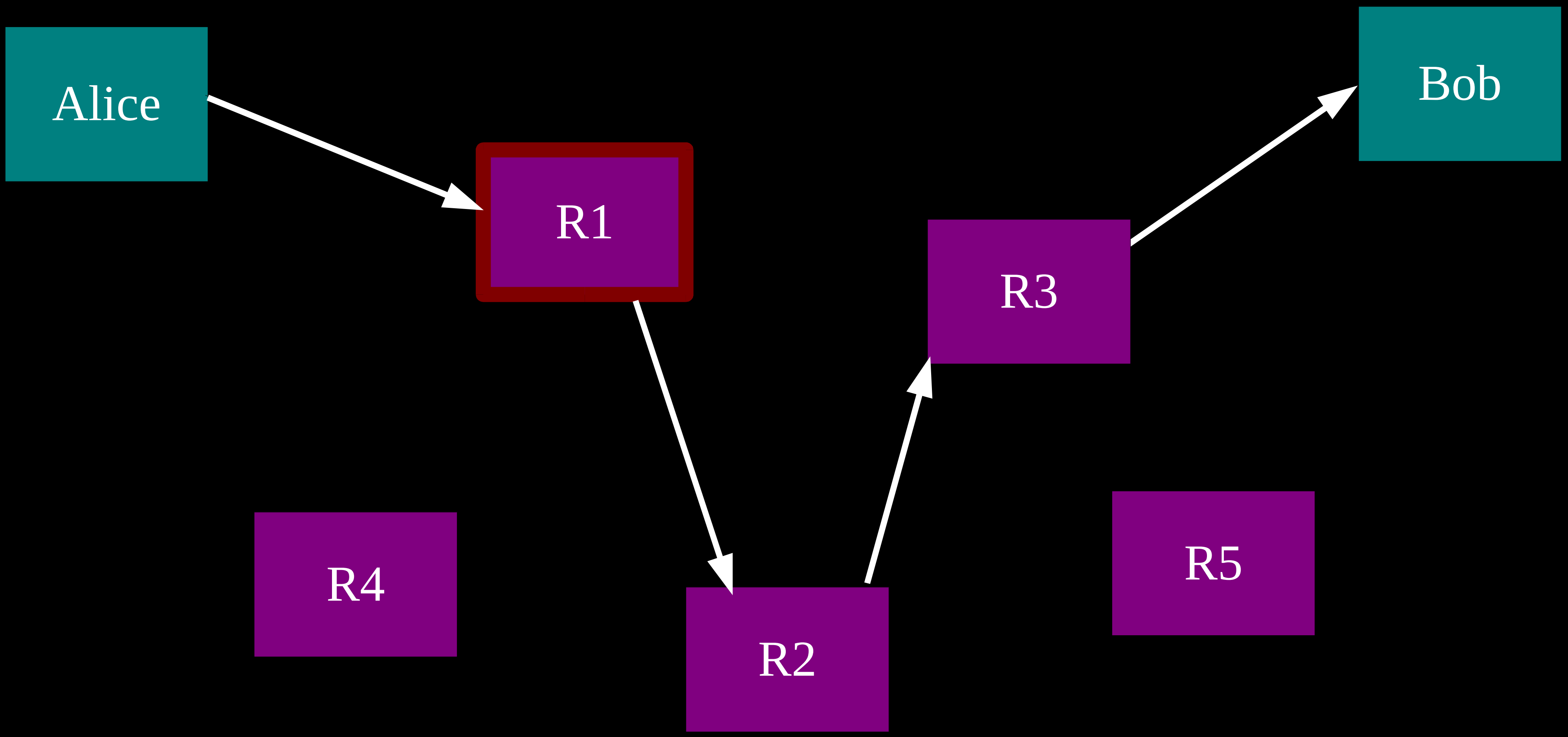


Eavesdropping on the relay works too.

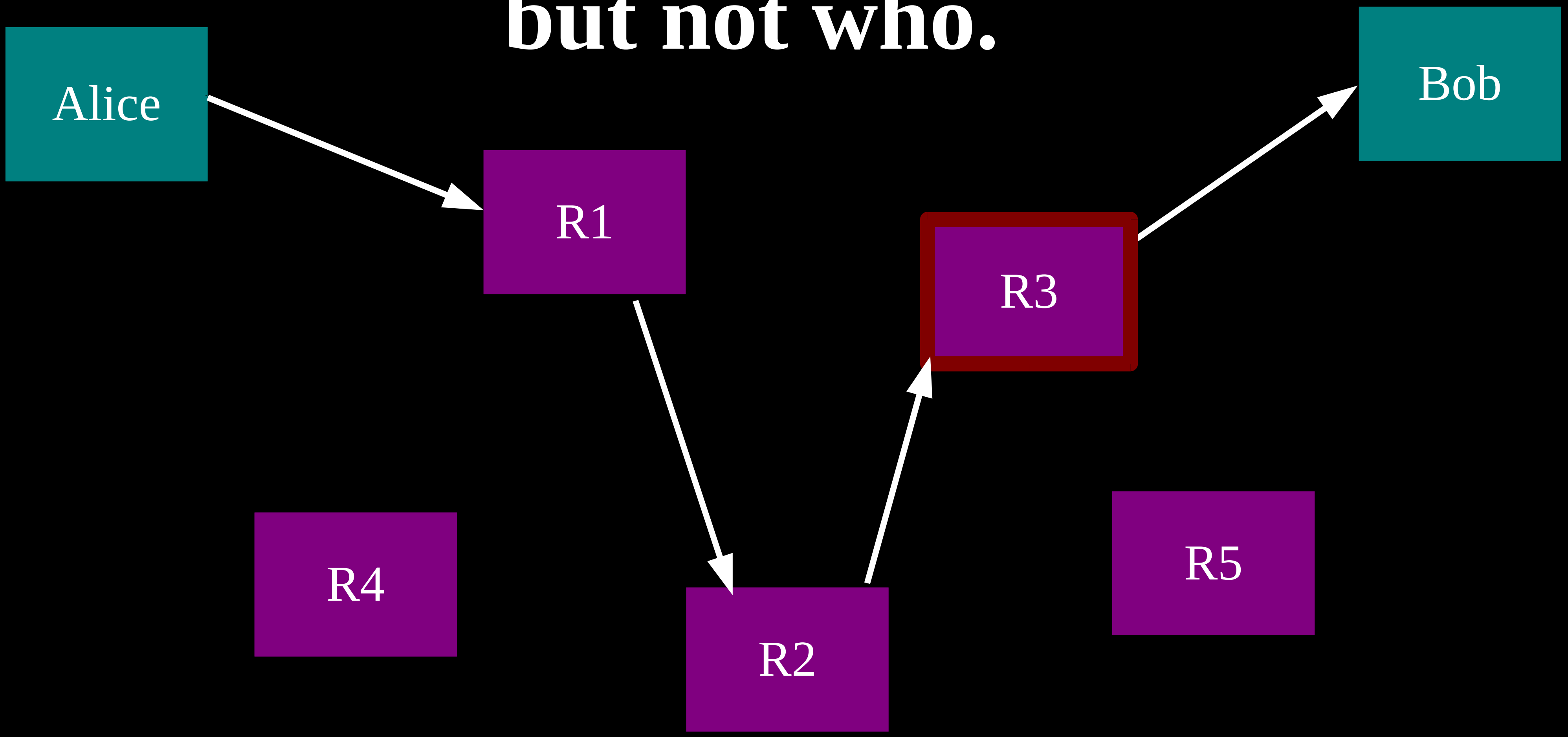
So, add multiple relays so that no single one can betray Alice.



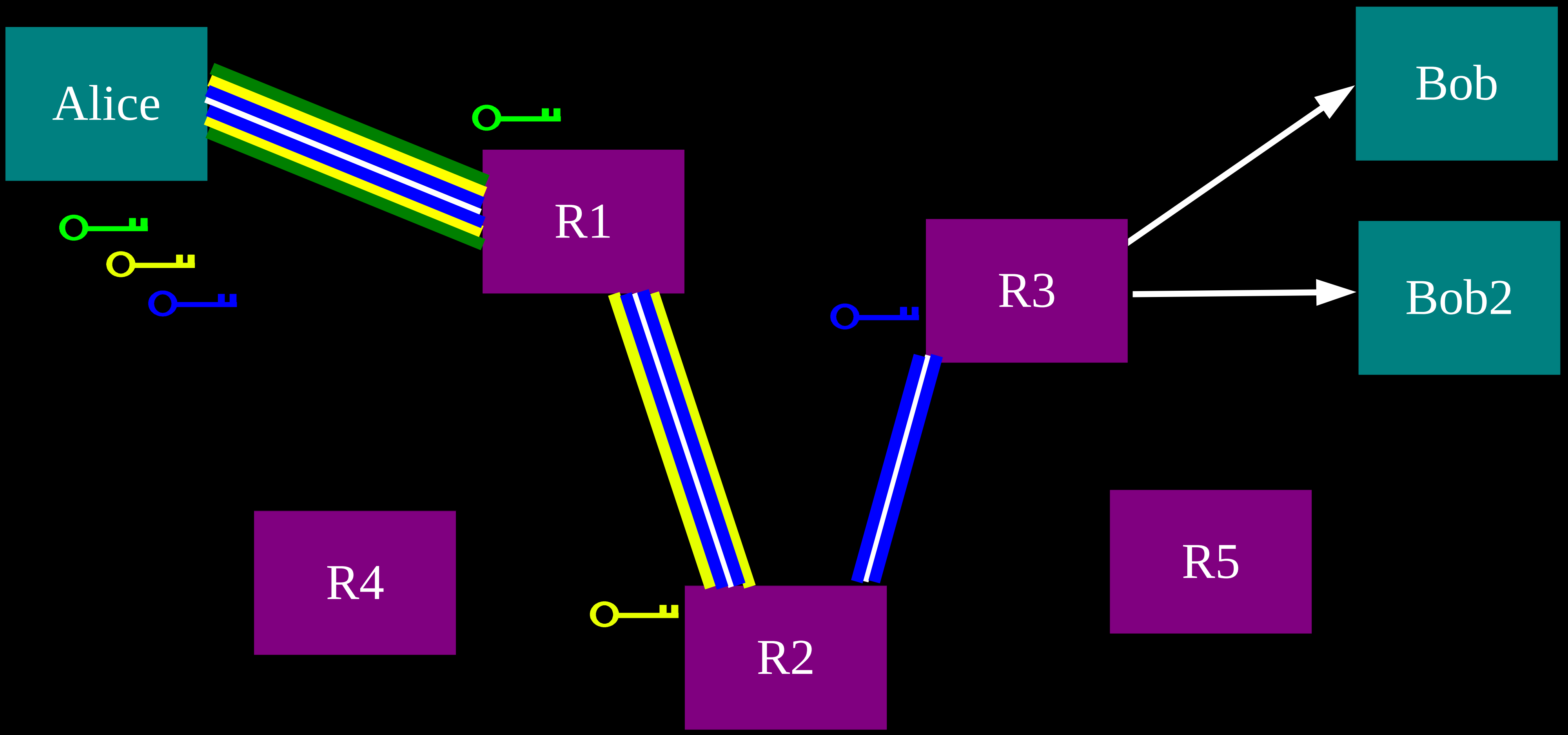
A corrupt first hop can tell that Alice is talking, but not to whom.



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



Attackers can block users from connecting to the Tor network

- By blocking the directory authorities
- By blocking all the server IP addresses in the directory
- By filtering based on Tor's network fingerprint

Goals

- Attract, and figure out how to use, more relay addresses
- Normalize Tor's network fingerprint
- Solve the discovery problem: how to find relay addresses safely
- Don't screw up our anonymity properties in the process

Adversary assumptions aka Threat model

- Aim to defend against a strong attacker
  - so we inherit defense against weaker attackers
- Have a variety of users in mind
  - Citizens in China, Thailand, ...
  - Whistleblowers in corporate networks
  - Future oppressive situations
- Attackers will be in different stages of the arms race

Attacker's goals (1)

- Restrict the flow of certain kinds of information
  - Embarrassing (rights violations, corruption)
  - Opposing (opposition movements, sites that organize protests)
- Chill behavior by *impression* that online activities are monitored

Attacker's goals (2)

- Complete blocking is not a goal. It's not even necessary.
- Similarly, no need to shut down or block *every* circumvention tool. Just ones that are
  - popular and effective (the ones that work)
  - highly visible (make censors look bad to citizens -- and to bosses)

Attacker's goals (3)

- Little reprisal against passive consumers of information.
  - Producers and distributors of information in greater danger.
- Censors (actually, govts) have economic, political, social incentives not to block the whole Internet.
  - But they don't mind collateral damage.

Main network attacks

- Block by IP address at firewall
- Keyword searching in TCP packets
- Intercept DNS requests and give bogus responses or redirects

Design assumptions (1)

- Network firewall has limited CPU and memory per connection
  - full steganography not needed, thankfully
- Time lag between attackers sharing notes
  - Most commonly by commercial providers of filtering tools
  - Insider threat not a worry initially

Design assumptions (2)

- Censorship is not uniform even within each country, often due to different ISP policies
- Attacker can influence other countries and companies to help them censor or track users.

Design assumptions (3)

- Assume the users aren't attacked by their hardware and software
  - No spyware installed, no cameras watching their screens, etc
- Assume the users can fetch a genuine copy of Tor: use GPG signatures, etc.

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Tor gives three anonymity properties

- #1: A local network attacker can't learn, or influence, your destination
  - Clearly useful for blocking resistance
- #2: No single router can link you to your destination
  - The attacker can't sign up relays to trace users
- #3: The destination, or somebody watching it, can't learn your location
  - So they can't reveal you; or treat you differently.

Other Tor design features (1)

- Well-analyzed, well-understood discovery mechanism: directory authorities.
- They automatically aggregate, test, and publish signed summaries of the available routers.
- Tor clients fetch these summaries to learn which routers have what properties.
- Directory information is cached throughout the Tor network.

Other Tor design features (2)

- The list of dir authorities is not hard-wired.
- There are defaults, but you can easily specify your own to start using a different (or even overlapping!) Tor network.
- For example, somebody could run a separate Tor network in China.
- (But splitting up our users is bad for anonymity.)

Other Tor design features (3)

- Tor automatically builds paths, and rebuilds and rotates them as needed.
- More broadly, Tor is just a tool to build paths given a set of routers.
- Harvard's “Blossom” project makes this flexibility more concrete:
  - It lets users view Internet resources from any point in the Blossom network.

Other Tor design features (4)

- Tor separates the role of “internal relay” from the role of “exit relay”.
- Because we don't force all volunteers to play both roles, we end up with more relays.
- This increased diversity is what gives Tor users their anonymity.

Other Tor design features (5)

- Tor is sustainable. It has a community of developers and volunteers.
- Commercial anonymity systems have flopped or constantly need more funding for bandwidth.
- Our sustainability is rooted in Tor's open design: clear documentation, modularity, and open source.

Other Tor design features (6)

- Tor has an established user base of hundreds of thousands of people around the world.
- Ordinary citizens, activists, corporations, law enforcement, even govt and military users.
- This diversity contributes to sustainability.
- It also provides many many IP addresses!

Anonymity is useful for censorship-resistance too!

- If a Chinese worker blogs about a problem at her factory, and she routes through her uncle's computer in Ohio to do it, ...?
- If any relay can expose dissident bloggers or compile profiles of user behavior, attacker should attack relays.
- ...Or just spread suspicion that they have, to chill users.

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Relay versus Discovery

- There are two pieces to “proxying” schemes:
- a relay component: building circuits, sending traffic over them
- a discovery component: learning what routers are available

Centrally-controller shared proxies

- Existing commercial anonymizers are based on a set of single-hop proxies.
- Typically characterized by two features:
  - They control and operate the proxies centrally.
  - Many different users get assigned to each proxy.
- Weak security compared to distributed-trust.
- But easier to deploy, and users don't need new software because they completely trust the proxy already.

Independent personal proxies

- Circumventor, CGIProxy, Psiphon
- Same relay strategy, new discovery strategy: “Find a friend to install the relay for you.”
- Great for blocking-resistance, but huge scalability question:
- How does the user in China find a volunteer in Ohio?
- How does the volunteer in Ohio find a user in China?

Open proxies

- Google for “open proxy list”.
- Companies sell refined lists.
- Downsides:
  - Widely varying bandwidth, stability, reachability.
  - Legally questionable.
  - Not encrypted in most cases; keyword filtering still works.
  - “Too convenient” Are they run by the adversary?

JAP and blocking-resistance

- Stefan Kopsell's paper from WPES 2004
- This is the idea that we started from in this blocking-resistance design.
- Uses the JAP anonymity network rather than Tor.
- Discovery is handled by making users solve a CAPTCHA in order to learn a relay address.

Internal caching networks

- Run a Freenet network inside China or other countries.
- Many users can fetch content without ever needing to cross the national firewall.
- Usability issues? and anonymity issues.

Skype

- Port switching and encryption avoid the simple blocking and filtering attacks.
- Still has a central login server?

...and Tor itself

- Tor's website is blocked in many places, but not the Tor network. Why?
- Tens of thousands of users? “Nobody cares.”
- Perception: “Tor is for experts.”
- We haven't publicly threatened their control: “Tor is for civil liberties in free countries.”
- Realize that we're *already* in the arms race. These constraints teach us about priorities and capabilities of our various attackers.

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Bridge relays

- Hundreds of thousands of Tor users, already self-selected for caring about privacy.
- Add a “Tor for Freedom” button to Vidalia (the most popular Tor GUI).
- Rate limit to 10KB/s.
- They can be internal relays, and don't have to be exit relays.

Bridge directory authorities

- Specialized dir authorities that aggregate and track bridges, but don't provide a public list:
  - You can keep up-to-date about a bridge once you know its key, but can't just grab list of all bridges.
- Identity key and address for default bridge authorities ship with Tor.
- Bridges publish via Tor, in case somebody is monitoring the authority's network.

One working bridge is enough

- Connect via that bridge to the bridge authority.
- ...and to the main Tor network.
- Remember, all of this happens in the background.
- “How to circumvent for all transactions (and trust the pages you get)”
  is now reduced to
  “How to learn about a working bridge”.

Hiding Tor's network fingerprint

- [Skipping details since I only have an hour]
- Get rid of plaintext HTTP (used by directories)
- Pick a good default port like 443.
- Make the TLS handshake look more like an ordinary HTTPS certificate exchange.
- Better understand timing and volume fingerprint attacks.

Discovering working bridge relays

- Tor's modular design means we can separate the relay component from the discovery component.
- So we can use any discovery approach we like. Great!
- ...But alas, we still don't have any perfect ones.

Discovery: bootstrapping

- We assume users already have some way of bypassing the firewall to bootstrap.
- Open proxy servers, instant messaging, Skype, WoW, ...
- Or they know a friend who can.

Independent bridges, no central discovery

- Like CGIProxy.
- Users could bootstrap by
  - knowing the bridge's operator, or
  - learning about the bridge from a local friend.
- “Telling a friend” has interesting incentives:
  - If he gets it blocked, you can't use it either now.
  - You're mapping your social network for the adversary.

Families of bridges, no central discovery

- Volunteers run several bridges at once, or coordinate with other volunteers.
- The goal is that some bridges will be available at any given time.
- Each family has a bridge authority, to add new bridges to the pool, expire abandoned or blocked bridges, etc.
- Remember: this is all automated by the Tor client.

Public bridges, central discovery

- What about bridges who don't know users?
  Or users who don't know any bridges?
- Divide bridges into pools based on identity key.
- Each pool corresponds to a *distribution strategy*. We start with eight strategies.
- Each strategy is designed to exercise a different scarce resource or property of the user.

Distribution strategy #1

- Time-release bridge addresses.
- Divide available bridges into partitions, and each partition is deterministically available only in certain time windows.
- This pool will be first to get blocked, but
  - it will help to bootstrap until it *is* blocked
  - it won't be blocked by *every* adversary

Distribution strategy #2

- Publish bridge addresses based on IP address of requester.
- Divide bridges into partitions, hash the requester's IP address, choose a random bridge from the appropriate partition.
- (Don't use entire IP address, just first 3 octets.)
- As a special case, treat all Tor exit IP addresses as being on the same network.

Distribution strategy #3

- Combine time-based and location-based strategies.
- The bridge address provided in a given time slot is deterministic within the partition, rather than chosen randomly each time.
- So later requests during that time slot from a given network are given the same bridge address as the first request.

Distribution strategy #4

- Use Circumventor's “mailing list trick”.
- Start a mailing list, let people sign up, send out a few new bridge addresses every few days.
- The adversary will block them, but not immediately.
- Every three or four days seems to be sufficient for Circumventor for now.

Distribution strategy #5

- Users provide an email address and we mail them a bridge address.
- Limit one response per email address?
- Require a CAPTCHA.
  - We can leverage Yahoo and Gmail CAPTCHAs!

Distribution strategy #6

- Social network reputation system.
- Pick some seeds (trusted people in blocked areas) and give them a few dozen bridge addresses and a few "delegation tokens".
- Run a database near the bridge authority; Tor clients log in to learn more bridge addresses.
- Users can delegate trust to other people by giving them a token, which can be exchanged for a new account in the database.

Distribution strategy #6 (cont)

- Accounts “in good standing” then accrue new bridge addresses and new tokens.
- How do we decide we like an account? If the bridges it knows don't end up blocked.
- Could track reputation between accounts, or use blinded tokens to prevent even the database from mapping the social network.
- Gets really messy. Future work.

Distribution strategies #7 and #8

- Held in reserve, in case all our tricks fail at once and we need to deploy new strategies quickly.
- Please come up with new strategies and tell us! For example, SMS messages?

Deploying all solutions at once

- Finally, we're not in the position of defender: We only need one scheme that works!
- The attacker must guess how to allocate his resources between all the discovery strategies.
- By deploying all of them at once, we make *all* of them more likely to succeed.

How do we learn if a bridge has been blocked? (1)

- Active testing via users
  - Can use Blossom-like system to build circuits through them to test.
  - If we pick random users, the adversary should sign up users.
  - Even if we have trusted users, adversary can still discover them and monitor them.

How do we learn if a bridge has been blocked? (2)

- Passive testing via bridges
  - Bridges install GeoIP database, periodically report countries and traffic load.
  - But: If we don't see activity from Burma, does that mean it's blocked, or they're just asleep?

How do we learn if a bridge has been blocked? (3)

- Different zones of the Internet are blocked in different ways – not just one per country.
- Lots of different possible locations for the fault: at bridge, at user, in between?
- Attacker could poison our bridge DB by signing up already-blocked bridges.
- Eventual solution will probably involve a combination of active and passive testing.

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Using Tor in oppressed areas

- Common assumption: risk of using Tor increases as firewall gets more restrictive.
- But as firewall gets more restrictive, more ordinary people use Tor too, for more mainstream activities.
- So the “median” use becomes more acceptable?

Trusting local hardware/software

- Internet cafes
- USB-based Tor package
- CD-based Tor package (LiveCD)

How many bridges do you need to know about to stay connected?

- Cablemodem / DSL bridges will disappear or move periodically.
- Already a tough problem with natural churn, but they can also get blocked.
- Related: how often should users fetch updates?

Cablemodems don't usually run big websites

- So the attacker can just block all connections to Comcast, Verizon, ...
- We need to get bridges on both “consumer” and “producer” addresses.
- Also have to worry about economic pressure, E.g. from China on Verizon.

Publicity attracts attention

- Many circumvention tools launch with huge media splashes. (The media loves this.)
- But publicity attracts attention of the censors.
- We threaten their *appearance* of control, so they must respond.
- We can control the pace of the arms race.

Next steps

- Technical solutions won't solve the whole censorship problem. After all, firewalls are *socially* very successful in these countries.
- But a strong technical solution is still a critical puzzle piece.
- Next steps: deploy prototype bridges and bridge authorities, implement some discovery strategies, and get more intuition about what should come next.

And Tor itself needs to survive

- Ongoing discussion around the world: is anonymity useful for the world?
- Data retention threatens privacy and safety, but won't catch the bad guys.
- We need help!
  More Tor servers, more volunteers, more funding, ...