Network Security V

CSE 565: Fall 2024
Computer Security

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Disclaimer

- We don’t claim any originality of the slides. The content is developed heavily based on
  - Slides from Prof. Dan Boneh and Prof. Zakir Durumeric’s lecture on Computer Security (https://cs155.stanford.edu/syllabus.html)
  - Slides from Prof Nick McKeown’s lecture on Computer Network (https://vixbob.github.io/cs144-web-page/)
  - Slides from Prof Ziming Zhao’s past offering of CSE565 (https://zzm7000.github.io/teaching/2023springcse410565/index.html)
  - Slides from Prof Hongxin Hu’s past offering of CSE565

Announcement

- HW3 and Project3 **due Tue, Nov 12, 23:59 pm**.

Review of Last Week

- DDoS Attack
  - Two major types: Amplification & Flooding
  - Defense: Rate limiting; Anycast network (IP multiplexing); Reverse Proxy.
- Network Defense
  - IPSec: securing the Network Layer. Default in IPv6
    - AH (Integrity of the whole packet) , ESP (Confidentiality & Integrity of the payload), & IKE (secure session establishment).
  - VPN: Secure tunneling protocols.
  - TLS: Securing the Transport Layer.
    - The go-to solution for implementing secure channel: HTTPS, QUIC, VPNs
  - Firewall / IDS
    - Packet filtering

Today's topic

- Privacy in web browsing
  - Tracking and how to stop it
- Anonymity
  - Hide your identity (and/or your actions)
- Secure messaging

Privacy

(Not only) Big brother is watching you

- Individual's data are constantly being collected (legally or illegally) by all kinds of parties.

Government agencies

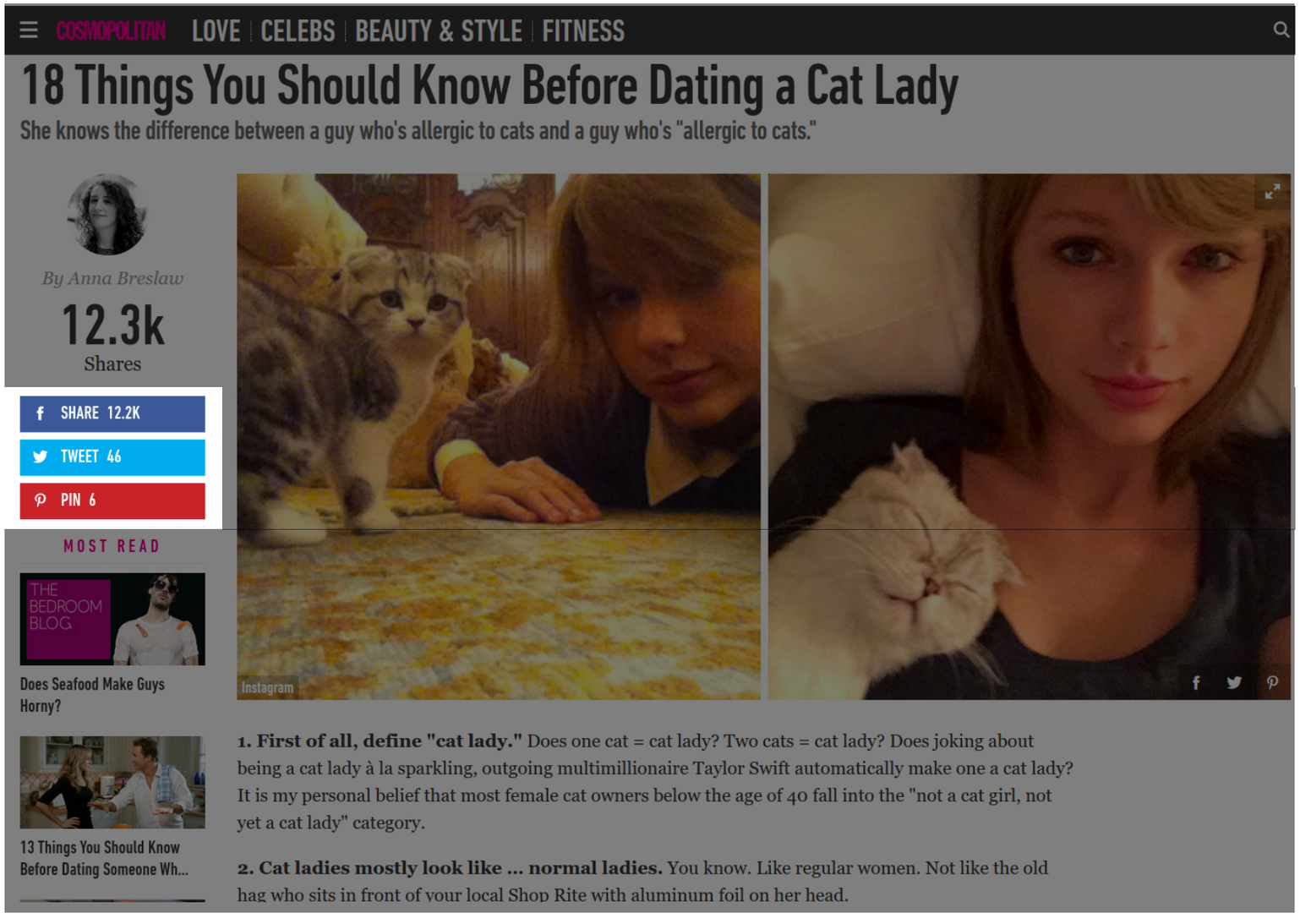
Hackers

Big techs

(Not only) Big brother is watching you

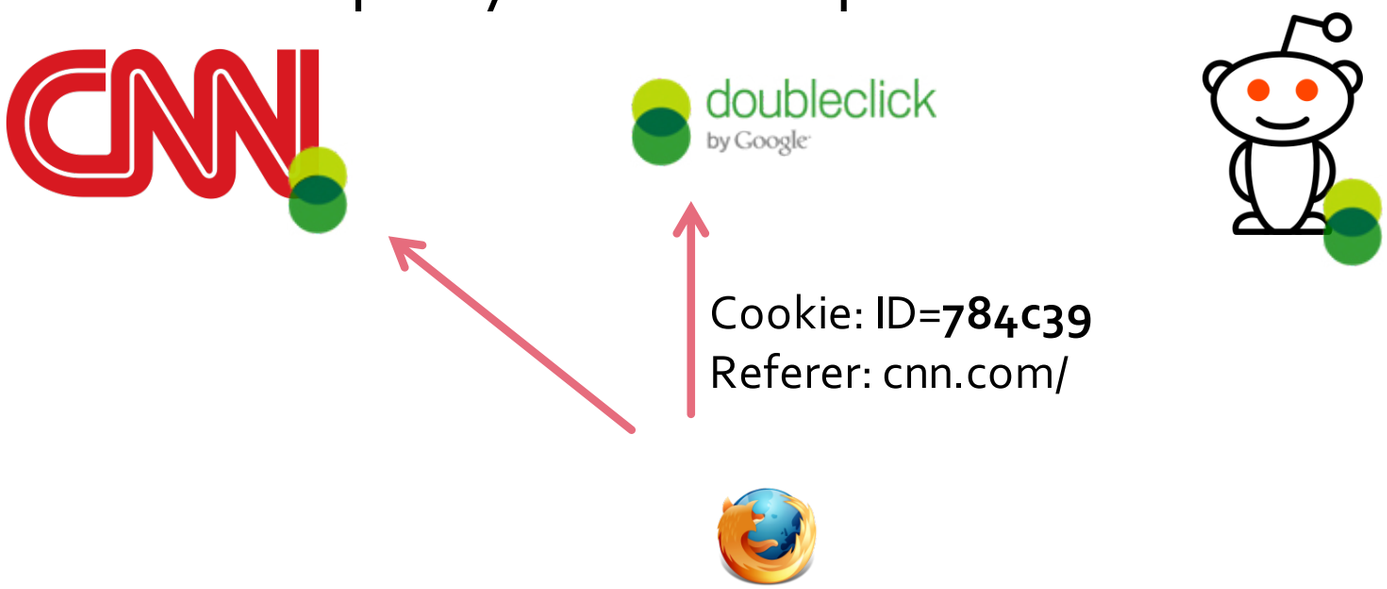
- Individual's data are constantly being collected (legally or illegally) by all kinds of parties.
- What for?
  - **Advertising**: primary reason why Google/Meta/Amazon … want your data. (E.g. to train ad recommendation models)
  - **National Security** (or not?): thanks to Edward Snowden, we now know the extent of surveillance.
  - **Money**
    - There are simply too many (illegal) ways to exploit people's data

Third Party Tracking



Third Party Cookies

- Site A's page requests a third-party resource (image, script, iframe)
  - Normally, browser sends cookie associated with that third-party in that request

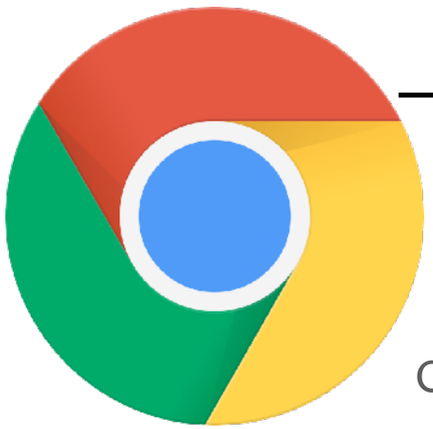


A third-party cookie is a cookie *set* by a website other than the one you are currently visiting.

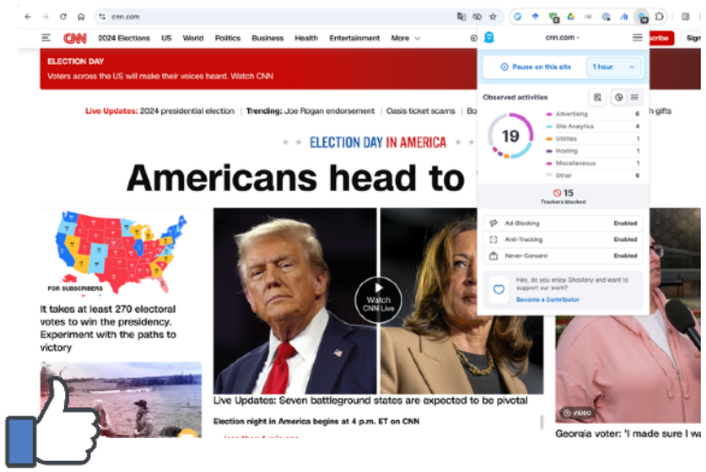
Third-Party Web Tracking

Cookies and Code

(CNN)



`GET / HTTP/3`



`GET /facebook-like.js HTTP/3`

`Cookie: User=Alice, Referer=cnn.com`

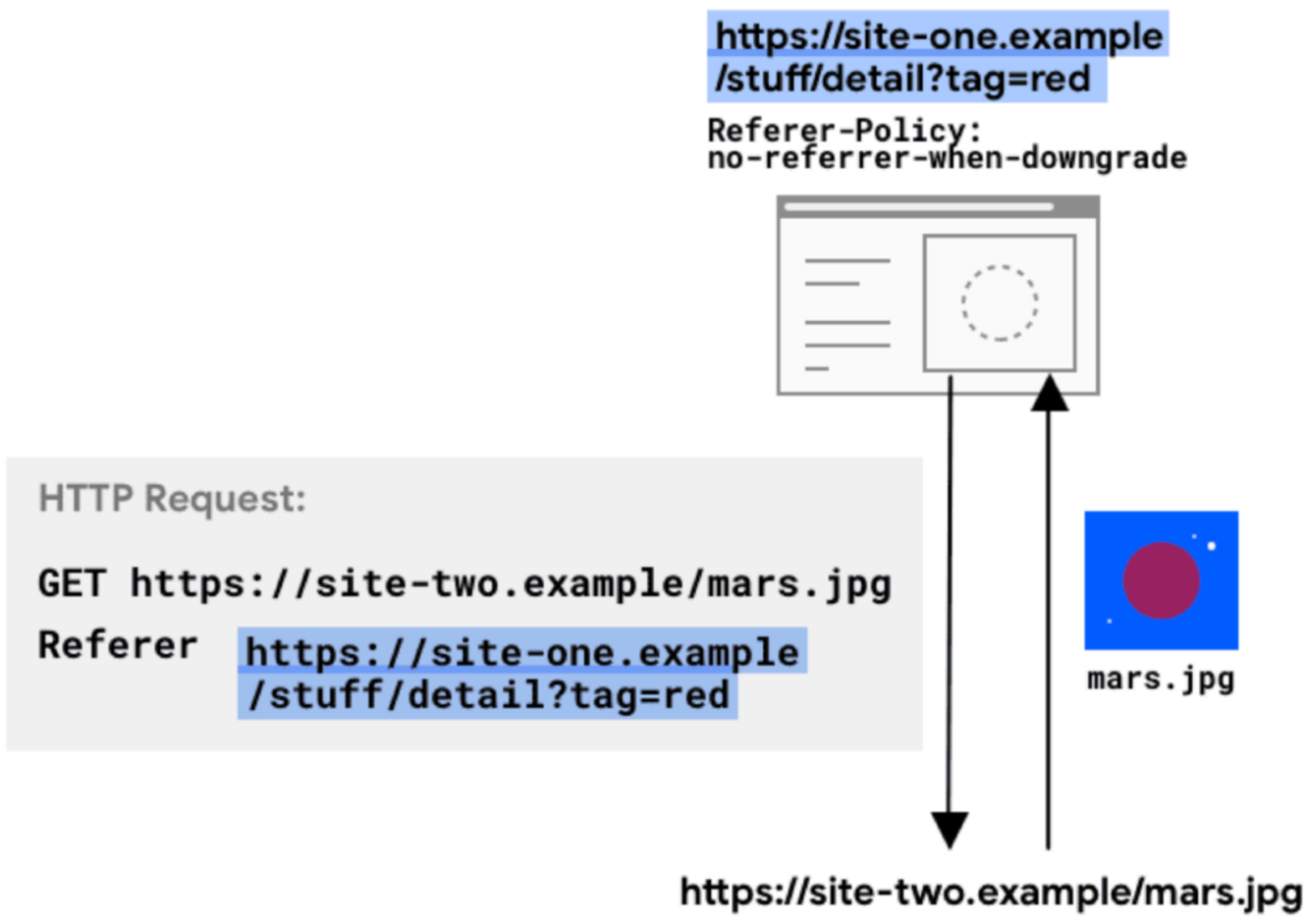
(Facebook)

- With this request, companies can link your cookie to your browsing data (e.g., through **`Referer`** header, **`Host`** headers, Origin, or just JavaScript)

Third-Party Web Tracking

Cookies and Code

- What exactly is sent in the referer?



cnn.com

CNN 2024 Elections US World Politics Business Health Entertainment

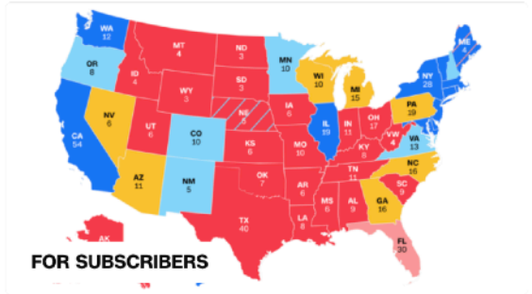
ELECTION DAY

Voters across the US will make their voices heard. Watch CNN

Live Updates: 2024 presidential election | **Trending:** Joe Rogan endorsement |

★ ★ ELECTION DAY

Americans hea



It takes at least 270 electoral votes to win the presidency. Experiment with the paths to victory

Live Updates: Seven battleground sta

Election night in America begins at 4 p.m. E

less than 1 min ago

cnn.com

Pause on this site 1 hour

Observed activities

Advertising 6

Nativo 1

OneTag 1

Google 2

Outbrain 1

DoubleClick 1

Adobe Audience Manager 3

Site Analytics 4

Georgia voter: 'I made sure I wa

CNN.COM

87

OBSERVED ACTIVITIES (87)

This chart shows the total unique trackers seen on this website. Rather than an exact count per page, it shows the diversity of trackers seen over multiple visits.

Filter the list by category to view subset tracker types.

All | Advertising | Site Analytics | Consent Management | Hosting | Customer Interaction | Audio/Video Player | Misc | Social Media

Sorted by frequency of appearance on domain subpages

1. ChartBeat
87.64% · CHARTBEAT · SITE A...

2. OneTag
85.86% · ONETAG · ADVERTISI...

3. Optimizely
85.23% · OPTIMIZELY · SITE AN...

4. Datadog
80.84% · · MISC

5. DoubleClick
76.98% · GOOGLE · ADVERTISI...

6. Google
71.27% · GOOGLE · ADVERTISI...

7. videoplayerhub.com
68.67% · · MISC

8. Warner Media
67.28% · AT&T · SITE ANALYTICS

9. Outbrain
66.84% · OUTBRAIN · ADVERTI...

10. Nativo
65.37% · NATIVO · ADVERTISI...

11. Amazon Advertising
63.14% · AMAZON · ADVERTI...

12. FreeWheel
61.98% · COMCAST · ADVERTI...

13. Integral Ad Science
60.16% · INTEGRAL AD SCIEN...

14. ComScore, Inc.
60.15% · COMSCORE, INC. · SI...

15. Index Exchange
54.09% · INDEX EXCHANGE, I...

16. PubMatic
50.44% · PUBMATIC, INC. · AD...

17. Tremor Video
50.23% · TREMOR VIDEO · AU...

18. Rubicon
49.58% · THE RUBICON PROJ...

19. AppNexus
46.21% · MICROSOFT · ADVER...

20. Cloudflare
43.85% · CLOUDFLARE · HOST...

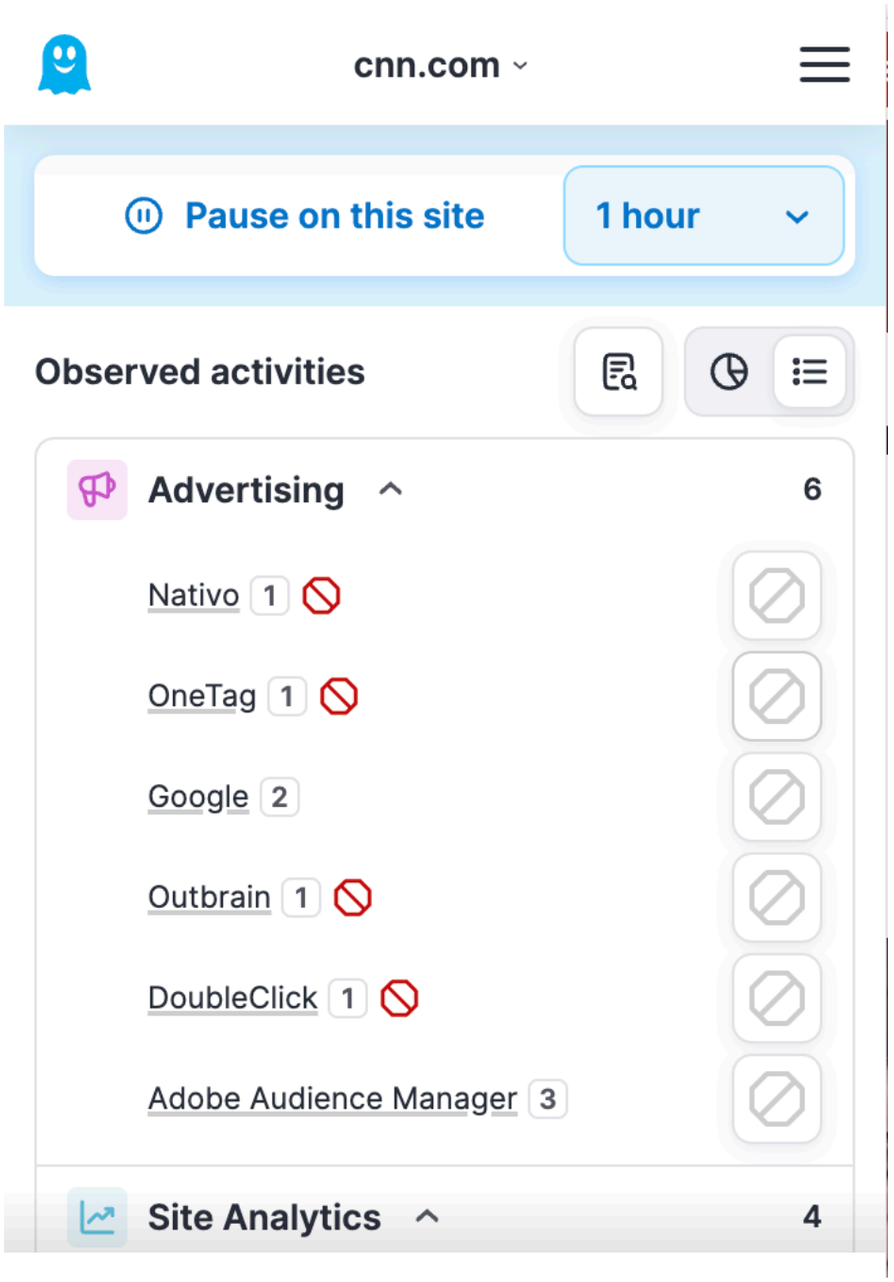
Third Party Cookies

Facebook, DoubleClick, etc. know much more about you than actual website does because they can track you across websites.

Domain	Top 1M	Domain	Top 1M
google-analytics.com	67.8%	ajax.googleapis.com	23.1%
gstatic.com	50.1%	googlesyndication.com	19.6%
fonts.googleapis.com	42.8%	googleadservices.com	14.1%
doubleclick.net	40.5%	twitter.com	12.8%
facebook.com	33.7%	fbcdn.net	10.7%
google.com	33.2%	adnxs.com	10.5%
facebook.net	27.4%		

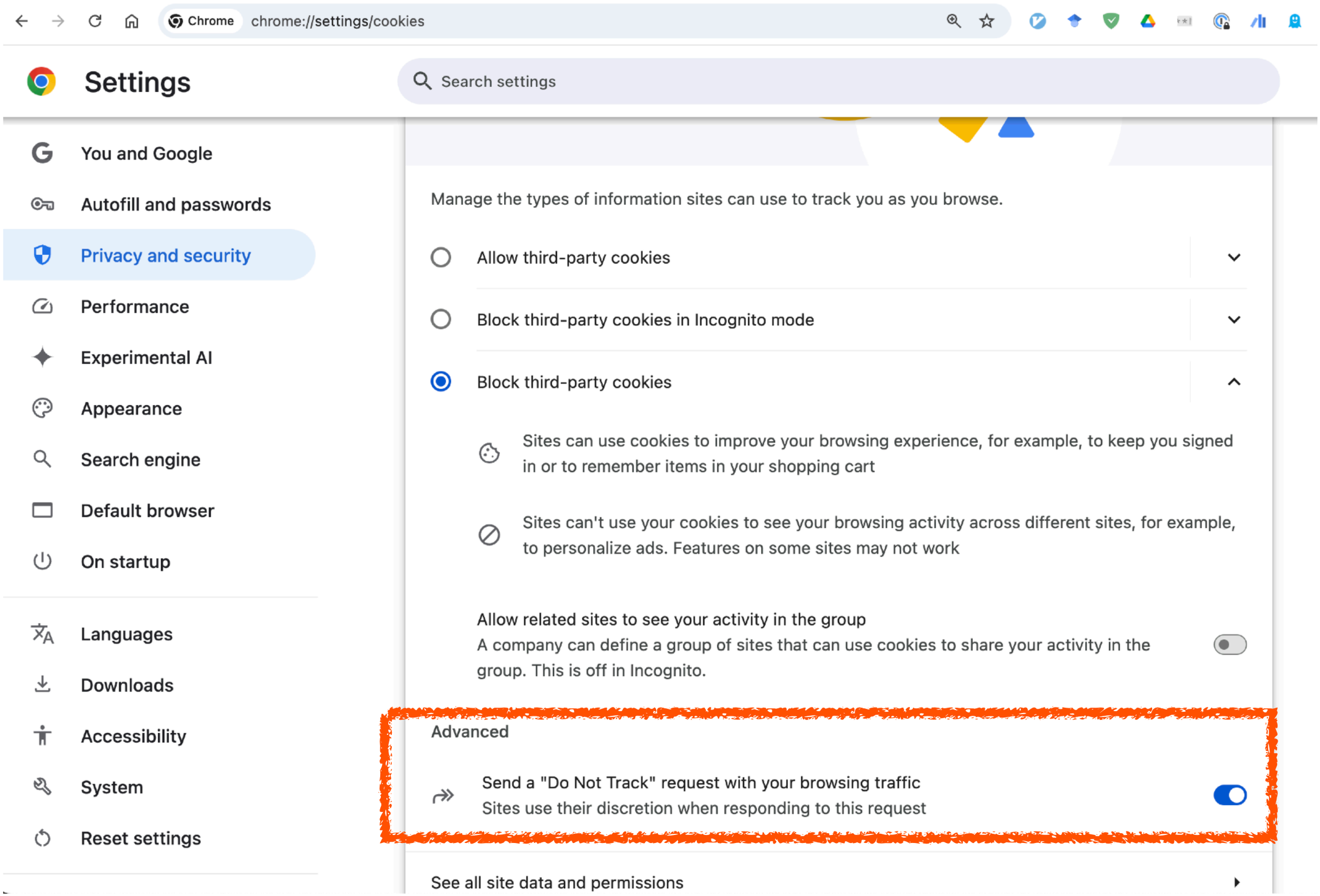
Ghostery

Browser extension to prevent tracking



Do Not Track (DNT)

Browser settings to prevent tracking



2024 — The Year of the End of Third Party Cookies?

- **Firefox**:
  - Third-Party Cookies from known trackers are dropped
  - Third-party cookies use separate cookie jar per site, so they can't be used to track users across sites
- **Safari**: Blocks third-party cookies
- **IE** (*anyone still use this?*): blocks some third-party cookies based on baked-in blacklist
- **Edge** does not block third-party cookies by default
- **Chrome** announced that they will drop support for third party cookies by the end of 2024

Google Topics

Privacy-preserving Advertising

User's browser	User's browser	Site that displays ads	Adtech code	Adtech code	Adtech code
					
User visits websites	Browser infers topics of interest	User visits site displaying ads	Topics are retrieved	Ad is requested	Ad is displayed
The user visits websites about a range of topics, for example: "Country Music", "Makeup & Cosmetics", "Vegetarian Cuisine"	The browser calculates the most frequently visited topics from the user's recent browsing history	The user visits a site whose adtech platform needs to select an ad for them	The adtech platform gets topics of interest to the user by calling the Topics API function `browsingTopics()`	The adtech platform uses the topics provided by the Topics API as part of the input to help select an ad	An ad is displayed to the user

Topics are selected from a taxonomy consisting of hierarchical categories such as /Arts & Entertainment/Music & Audio/Soul & R&B and /Business & Industrial/Agriculture & Forestry.

The (maximum) three topics returned for a user are chosen at random from the top five for the past three epochs (with a 5% chance of getting a random topic).

Browser Fingerprinting

- Websites can also track you effectively with *browser fingerprinting*, which is a technique that leverages all your settings to identify you~~, and stores this in a cookie on your browser~~
  - https://amiunique.org/
- So long as JavaScript can run (by third-parties), you run the risk of being "followed" on the web


```
{
 "user-agent": "Mozilla/5.0 (Macintosh; Intel Mac OS X 10.15; rv:93.0) Gecko/20100101 Firefox/93.0",
 "accept": "text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,*/*;q=0.8",
 "accept-encoding": "gzip, deflate, br",
 "accept-language": "en-US,en;q=0.5",
 "upgrade-insecure-requests": "1",
 "referer": "https://amiunique.org/",
"userAgent-js": "Mozilla/5.0 (Macintosh; Intel Mac OS X 10.15; rv:93.0) Gecko/20100101 Firefox/93.0",
"platform": "MacIntel",
"cookies": "yes",
"timezone": 420,
"languages-js": "en-US,en",
"ad": "no",
"doNotTrack": "NC",
"navigator_properties": [
 "vibrate",
 "javaEnabled",
 "getGamepads",
 "getVRDdisplays",
 "mozGetUserMedia",
 "sendBeacon",
 "requestMediaKeySystemAccess",
 "registerProtocolHandler",
 "taintEnabled",
```

MY BROWSER FINGERPRINT

SEE YOUR BROWSER FINGERPRINT PROPERTIES

ARE YOU UNIQUE ?

DOWNLOAD | TIMELINE

TODAY | 7 DAYS | 15 DAYS | 30 DAYS | 90 DAYS | ALL TIME

Yes! You are unique among the 2382170 fingerprints in our entire dataset.

The following informations reveal your OS, browser, browser version as well as your timezone and preferred language. Moreover, we show the proportion of users sharing the same elements.

mac os	chrome	en	UTC-08:00
Operating system	Web browser	Language	Timezone
MacOS		en	UTC-08:00
10.11 %	43.12 %	75.07 %	1.88 %

HTTP HEADERS ATTRIBUTES

Search for an attribute

Attribute	Similarity ratio	Value
1 - User agent	0.10 %	Mozilla/5.0 (Macintosh; Intel Mac OS X 10_15_7) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/121.0.0.0 Safari/537.36
2 - Accept	12.02 %	text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3;q=0.7
3 - Content encoding	96.52 %	gzip, deflate, br
4 - Content language	19.94 %	en-US,en;q=0.9
5 - Upgrade Insecure Requests	91.00 %	1

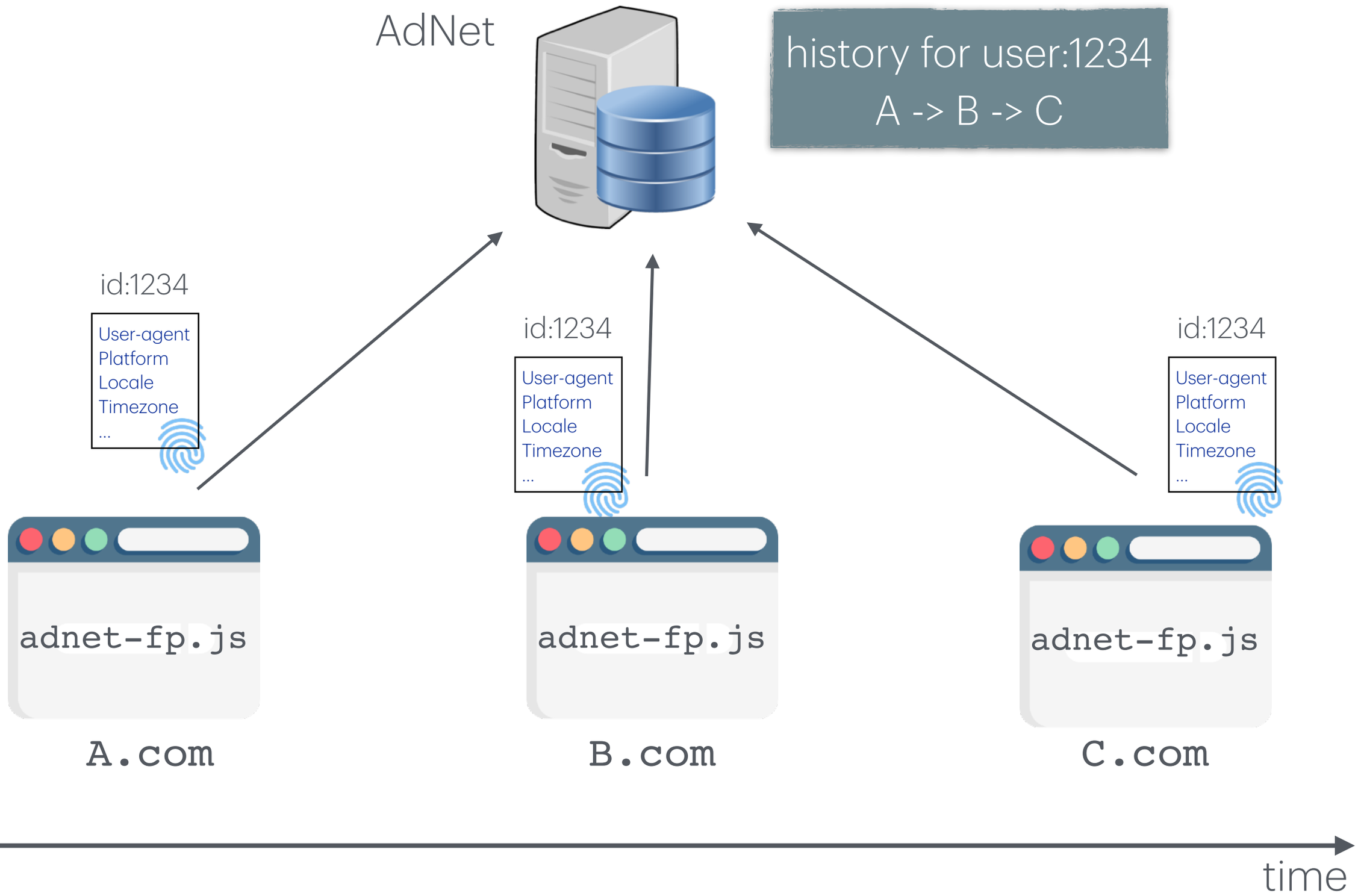
JAVASCRIPT ATTRIBUTES

Search for an attribute

Attribute	Similarity ratio	Value
1 - User agent	0.09 %	Mozilla/5.0 (Macintosh; Intel Mac OS X 10_15_7) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/121.0.0.0 Safari/537.36
2 - Platform	10.01 %	MacIntel
3 - Cookies enabled	89.14 %	✓
4 - Timezone	1.88 %	UTC-08:00

		pdf-viewer.
20 - Screen width	4.25 %	2560
21 - Screen height	4.58 %	1440
22 - Screen depth	3.64 %	30
23 - Screen available top	3.32 %	25
24 - Screen available Left	83.26 %	0
25 - Screen available Height	0.01 %	1346
26 - Screen available width	4.07 %	2560
27 - Permissions	6.24 %	**accelerometer** : granted **accessibility** : Not supported **ambient-light-sensor** : Not supported **camera** : prompt **clipboard-read** : prompt **clipboard-write** : granted **geolocation** : prompt **background-sync** : granted **magnetometer** : granted **microphone** : prompt **midi** : granted **notifications** : prompt **payment-handler** : granted **persistent-storage** : prompt **push** : Not supported
28 - WebGL Vendor	1.83 %	Google Inc. (Apple)
29 - WebGL Renderer	0.01 %	ANGLE (Apple, ANGLE Metal Renderer: Apple M2 Max, Unspecified Version)
30 - WebGL Data	0.13 %	
31 - WebGL Parameters	0.03 %	35 different extensions 25 different general parameters analyzed 36 different shaders precisions analyzed

Cross-Site Fingerprinting



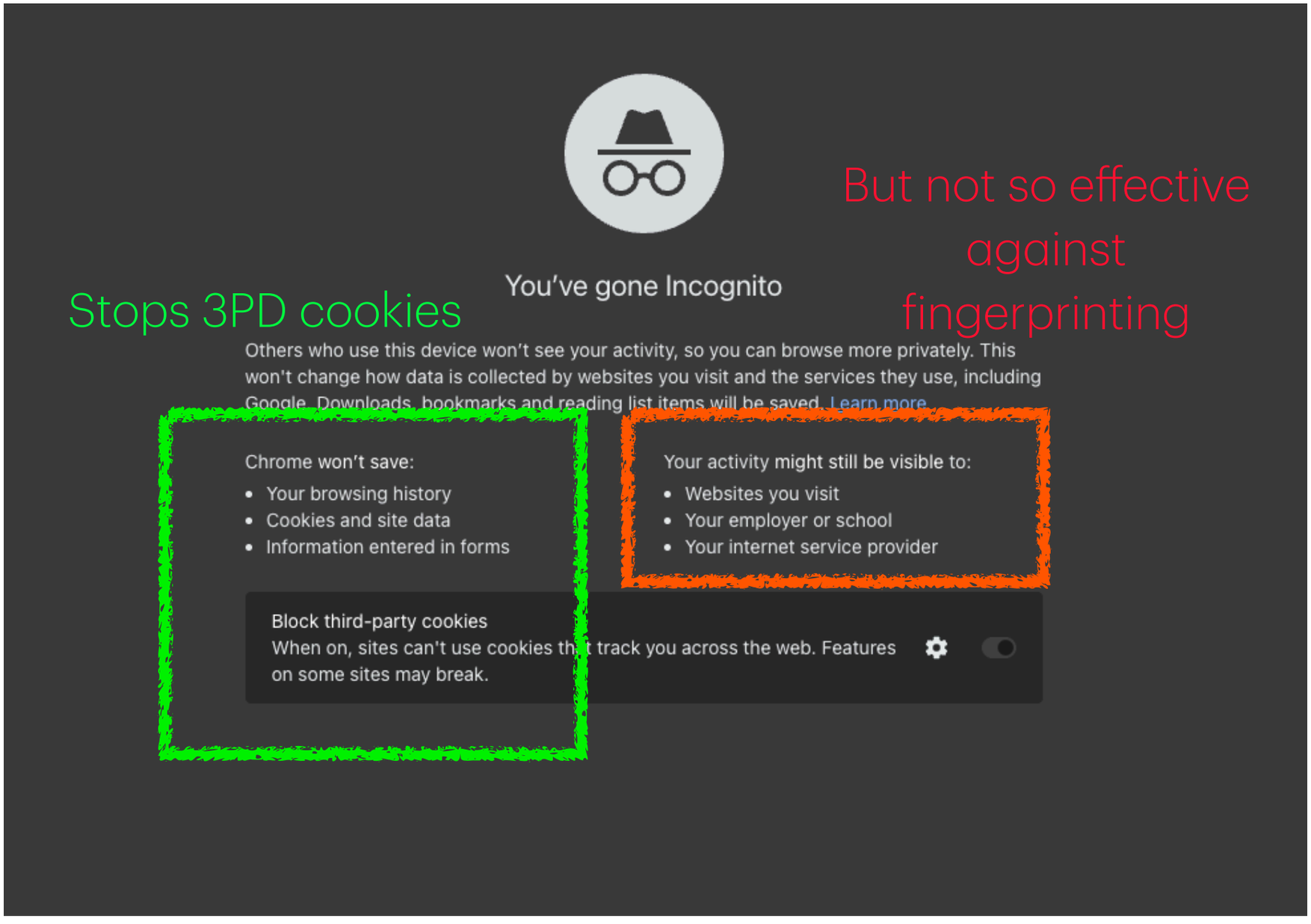
Fingerprinting is Hard to Block

- **No dependency on cookies**: does not *store* any data on the user's device, so cookie-blocking tools do not stop it.

- **Inherent device characteristics**: relies on information that browsers naturally provide (e.g., screen resolution and browser type), which are often needed for the website to function correctly.

- **Consistency across websites**: As long as multiple websites use the same third-party service, the fingerprint identifier will be the same, allowing seamless tracking.

Incognito?



Stops 3PD cookies

But not so effective against fingerprinting

My Fingerprint- Am I Unique ?

amiunique.org/fingerprint

AM I UNIQUE ?

MY FINGERPRINT | MY EXTENSION | GLOBAL STATISTICS | SURVEY | BLOG | USEFUL LINKS | LANGUAGE

MY BROWSER FINGERPRINT

SEE YOUR BROWSER FINGERPRINT PROPERTIES

ARE YOU UNIQUE ?

DOWNLOAD | TIMELINE

TODAY | 7 DAYS | 15 DAYS | 30 DAYS | 90 DAYS | ALL TIME

Yes! You are unique among the 2974298 fingerprints in our entire dataset.

The following informations reveal your OS, browser, browser version as well as your timezone and preferred language. Moreover, we show the proportion of users sharing the same elements.

mac os

Operating system

MacOS

10.70 %

My Fingerprint- Am I Unique ?

amiunique.org/fingerprint

AM I UNIQUE ?

MY FINGERPRINT | MY EXTENSION | GLOBAL STATISTICS | SURVEY | BLOG | USEFUL LINKS | LANGUAGE

MY BROWSER FINGERPRINT

SEE YOUR BROWSER FINGERPRINT PROPERTIES

ARE YOU UNIQUE ?

DOWNLOAD | TIMELINE

TODAY | 7 DAYS | 15 DAYS | 30 DAYS | 90 DAYS | ALL TIME

Incognito (3)

Yes! You are unique among the 2975612 fingerprints in our entire dataset.

The following informations reveal your OS, browser, browser version as well as your timezone and preferred language. Moreover, we show the proportion of users sharing the same elements.

mac os

Operating system

MacOS

10.70 %

chrome

Web browser

44.08 %

en

Language

en

73.59 %

UTC-05:00

Timezone

UTC-05:00

5.61 %

Evading fingerprinting

- **VPN**: only hide your IP, but *not* browser fingerprints
- **Privacy-enhanced Browsers**
  - Tor Browser (next section): Hide IP & obfuscate browser attribute
  - Firefox, Brave Browser
- **Browser extensions**: uBlock Origin, NoScript, Privacy Badger
- **Privacy-enhanced OS**: Tail OS
  - Not for everyday use.

Other reasons for privacy?

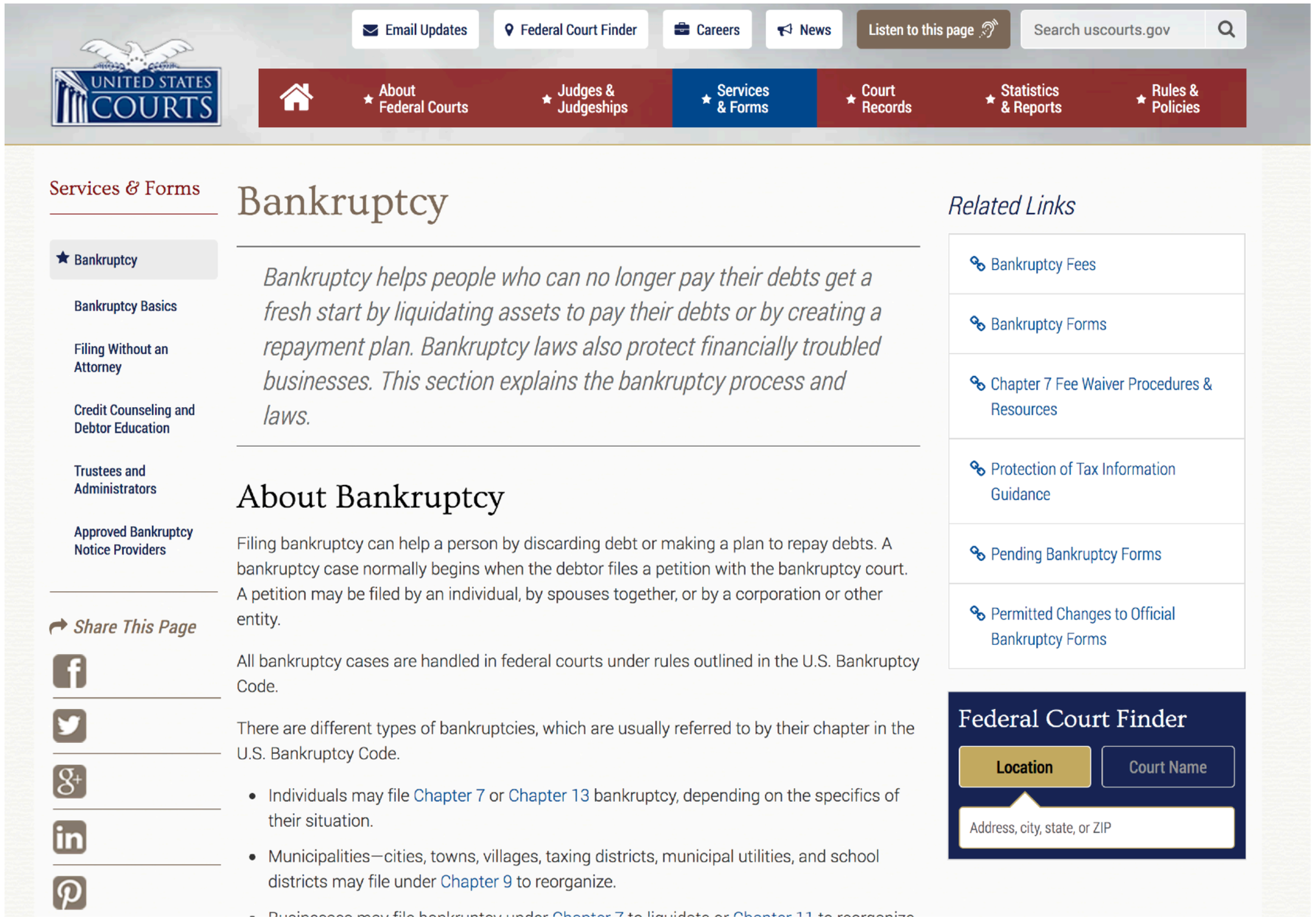
- Tracked by ad companies: annoying but does not seem to be much harmful (really?)

- Monitored by government:
  - *“I’m just a nobody / I’m not a criminal. What bad could the government do with my data?”*

    - Governments are not always doing good.

- … but there are more reasons for not being tracked

What if banks know you searched for this?



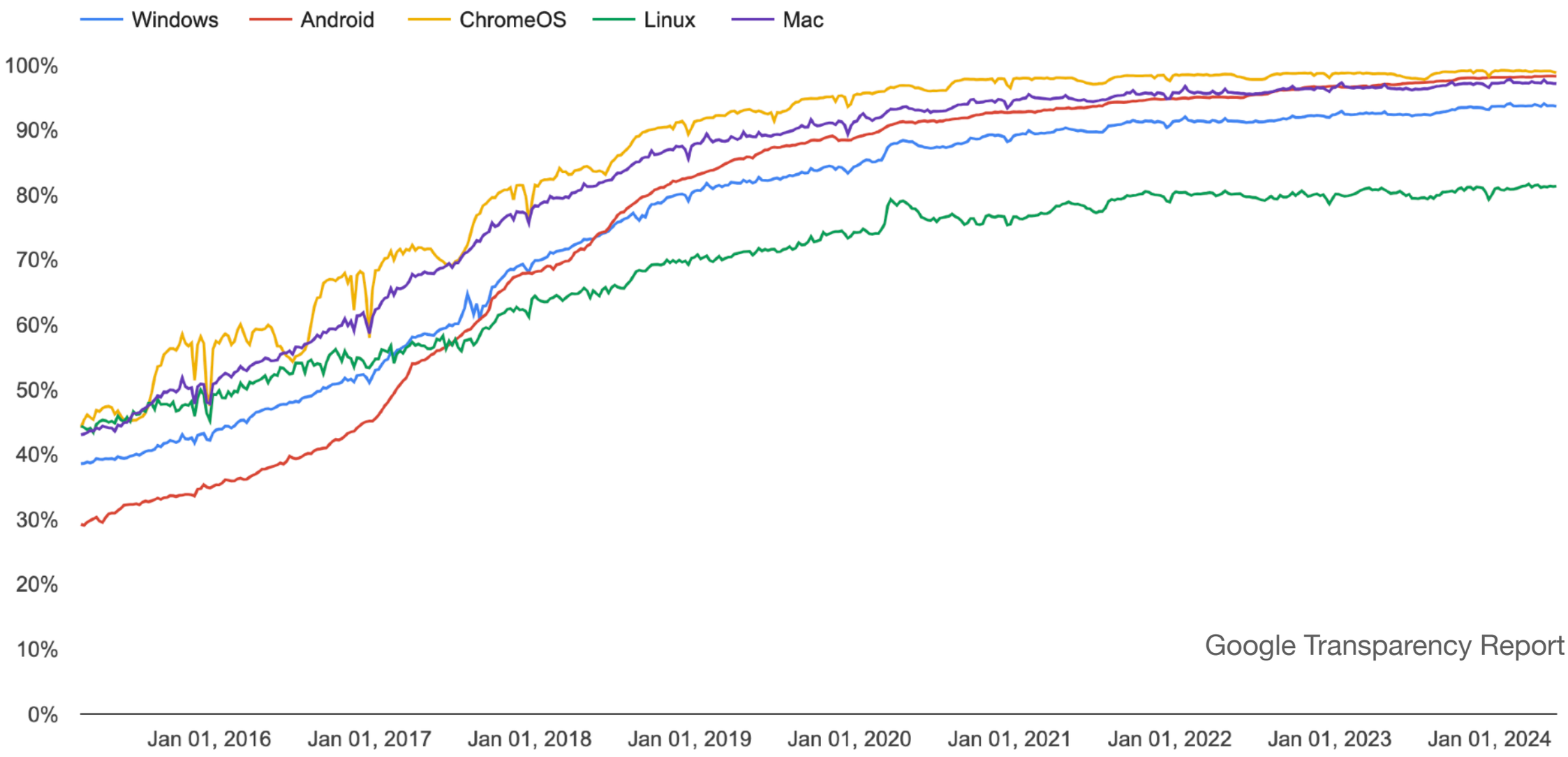
Privacy Enhancing Technologies

- Methods for protecting personal data
- Most Common/Successful? **TLS**.
- Comes with browser. Also used for protecting email. It just works, without you having to configure anything.
    - Protects *contents* of communication from passive eavesdroppers and active MITM attacks.
- Tools that provide confidentiality also provide some privacy. You probably don't want your landlord or coffee shop customers to learn things about you.

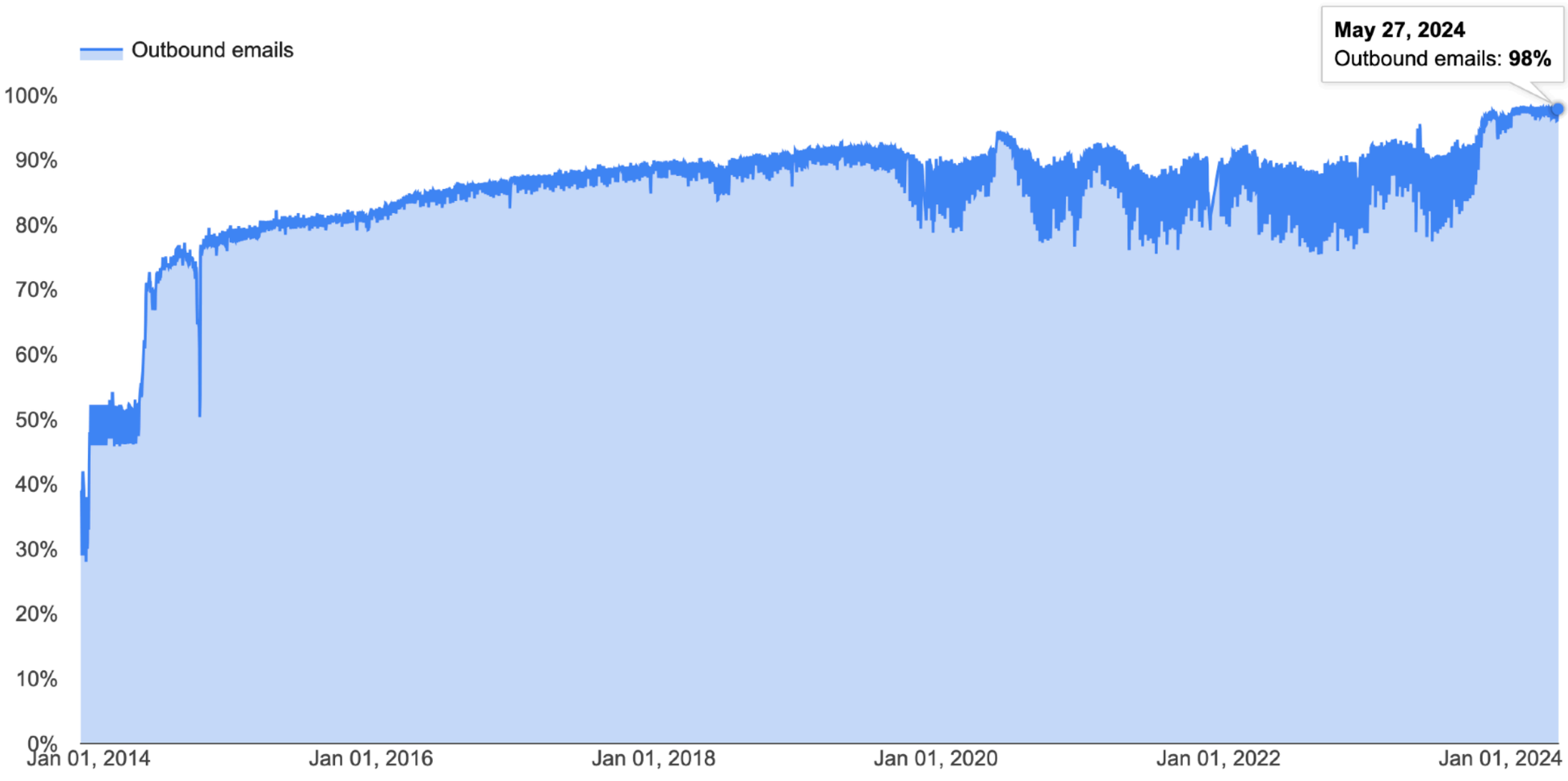
Encouraging HTTPS Adoption

- **2014:** HTTPS used as a page rank indicator
- **Early 2018:** Mozilla announces that new features will require HTTPS
- **Late 2018:** New Chrome HTTPS indicators

Chrome Page Loads over HTTPS



STARTTLS seen by Gmail



Protecting Metadata

- TLS only protects content. What doesn't TLS protect against?
- **We may want to protect metadata:**
  - Who is visiting what websites? Who is sending messages to whom?
  - Gov't might not like that you're visiting Human Rights Watch website
  - Gov't might not be amused that you're sending messages to Human Rights Watch
  - We may want to hide the existence of the message (maybe sending an encrypted message at all is going to cause you problems)

Anonymity

What is Anonymity?

- Anonymity (“without name”) means that a person is not identifiable within a set of subjects

- **Unlinkability** of action and identity

  - For example, sender and his email are no more related after adversary’s observations than they were before

  - Who talks to whom

- **Unobservability**

  - Adversary cannot tell whether someone is using a particular system and/or protocol

Why Anonymity?

- **To protect privacy:**
  - Avoid tracking by advertising companies
  - Viewing sensitive content
    - Information on medical conditions
    - Advice on bankruptcy
- **Protection from prosecution**
  - Not every country guarantees free speech
- **To prevent chilling-effects**
  - It’s easier to voice unpopular or controversial opinions if you are anonymous

Anonymity is Hard

- **Internet anonymity is hard**…
- Right there in every packet is the source and destination IP address
- ISPs store communications records
  - Law enforcement can subpoena these records
  - Wireless traffic can be trivially intercepted
  - Tier 1 ASs and ISPs are compromised — NSA, GCHQ, “Five Eyes”

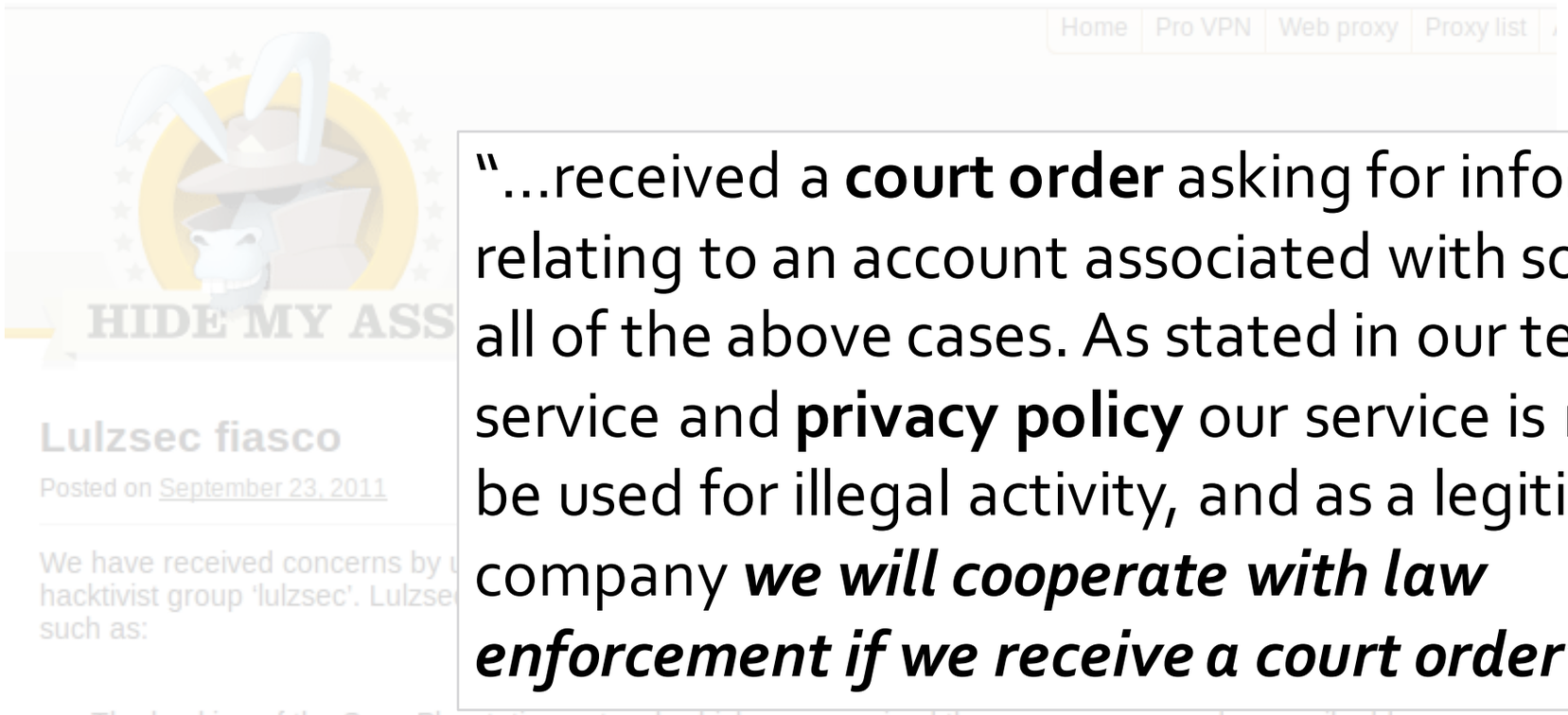
Anonymity

- Difficult if not impossible to achieve on your own
- You generally need help.
- **State of the art technique:** Ask someone else to send it for you

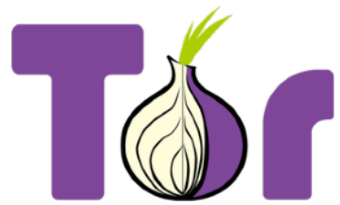
Naive approach .... VPNs

Naive approach .... VPNs

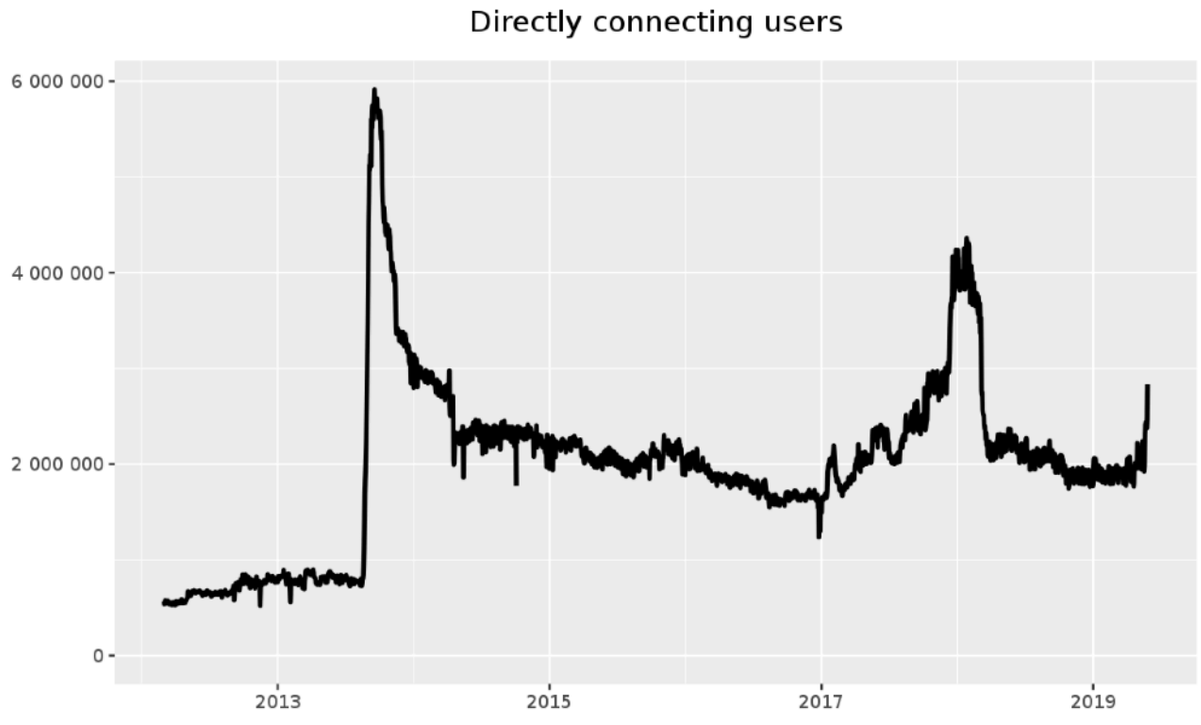
Naive approach …. VPNs



"…received a **court order** asking for information relating to an account associated with some or all of the above cases. As stated in our terms of service and **privacy policy** our service is not to be used for illegal activity, and as a legitimate company ***we will cooperate with law enforcement if we receive a court order***"

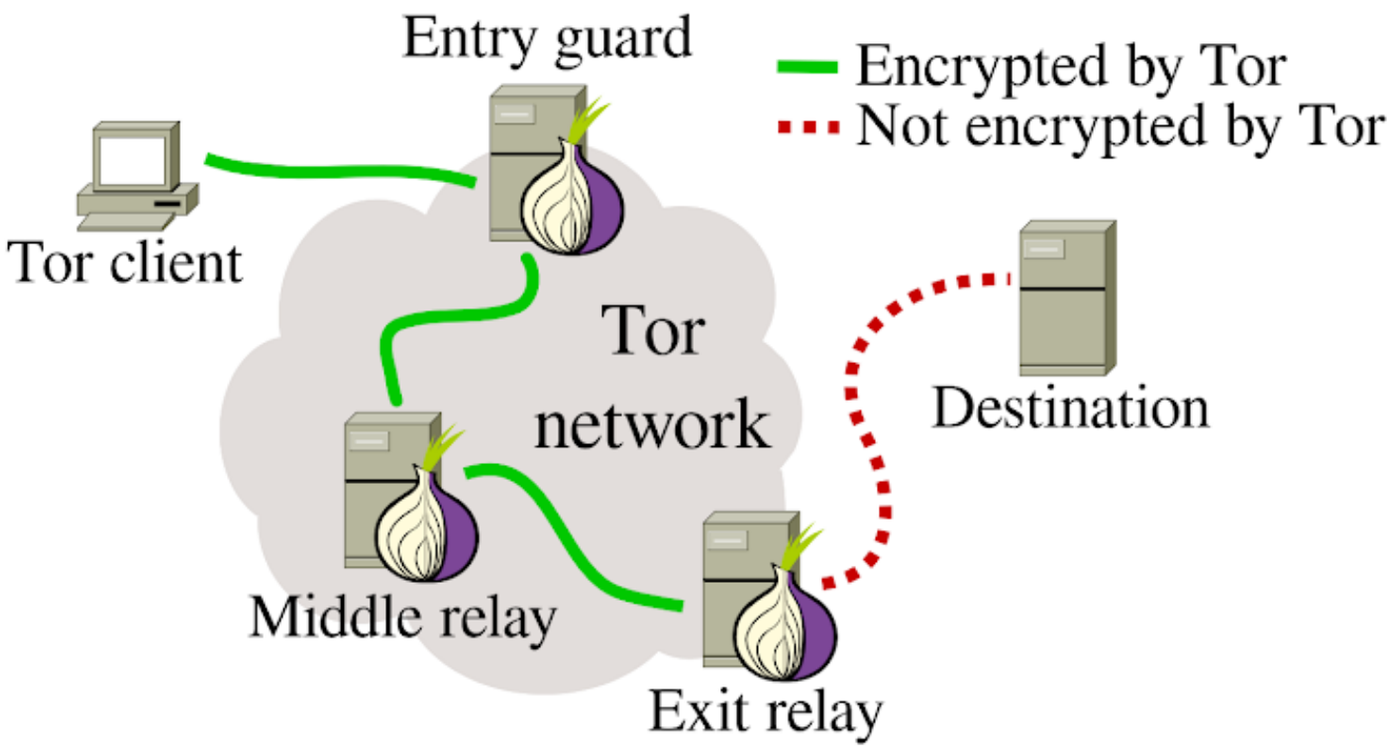


- Tor is a successful privacy enhancing technology that works at the transport layer
- Millions of active users.
- Normally, a TCP connection reveals your IP address
- Tor allows TCP connections without revealing your IP



Tor (“The Onion Router”)

Tor operates by tunneling traffic through multiple “onion routers” using public key cryptography



Who Knows What?

- **Entry node:** knows Alice is using Tor, and identity of middle node, but not destination
- **Exit node:** knows some Tor user is connecting to destination, but not which user
- **Destination:** knows a Tor user is connecting to it via the exit node
- Tor does not provide encryption between exit and destination (use HTTPS!)

Does Tor Provide Anonymity?

- Tor provides for anonymity in TCP connections over the Internet, both unlinkably (long-term) and linkably (short-term).

- **What does this mean?**
  - There's no *long-term identifier* for a Tor user
    - If a web server gets a connection from Tor today, and another one tomorrow, it won't be able to tell whether those are from the same person
  - But two connections in quick succession from the same Tor node are more likely to in fact be from the same person

Tor Challenges

- **Performance**: message bounces around a lot (can be slow)
- **Attack:** government can coerce server operates in one country
  - Defense: use mix servers in different legal jurisdictions
- **Attack**: adversary operates all of the mixes
  - Defense: have lots of mix servers (Tor has ~7,000 onion routers today). Use diverse set.
- **Attack:** adversary observes when Alice sends and when Bob receives, links the two together
  - A side channel attack – exploits timing information
  - Defenses: pad messages, introduce significant delays
  - Tor does the former, but notes that it's not enough for defense

Guard Relays

- How do you protect against an adversary creating a large number of onion routers and performing timing observation at entrance and exits?

- Limit the servers used for initial connection to a subset of trusted nodes:

  - Have long and consistent uptimes...

  - Have high bandwidth...

  - Are manually vetted by the Tor community

- Tor client selects 3 guard relays and uses them for 3 months

Exit Nodes

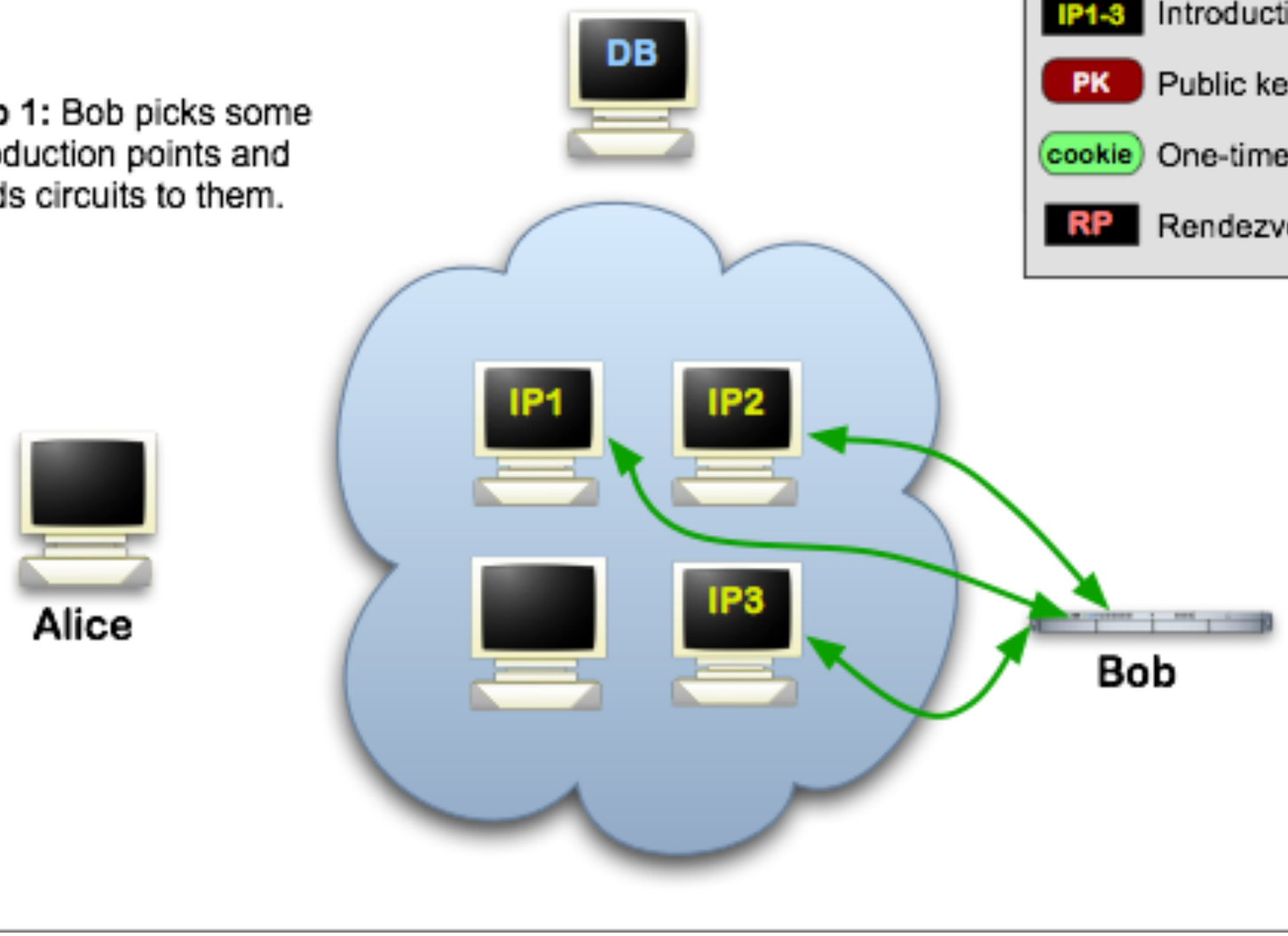
- Relays must *self-elect* to be exit nodes. Why?
  - Legal problems
  - If someone does something malicious or illegal using Tor and the police trace the traffic, the trace leads to the exit node

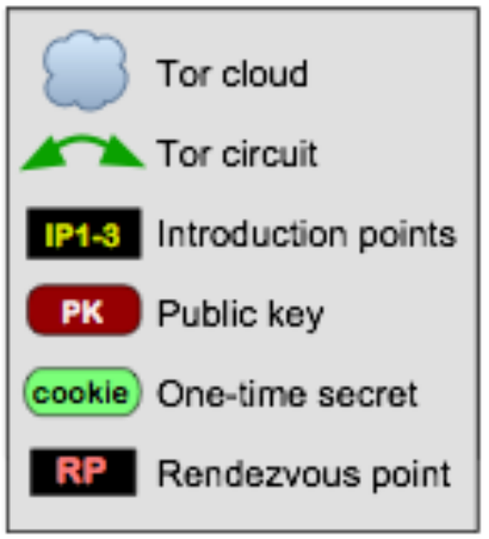
Tor Hidden Services

- As described, Tor protects the identity of the client, but not the server
- What if we want to run an anonymous service?
  - a website, where nobody knows the IP address?
- Tor supports Hidden Services...
  - Allows you to run a server without disclosing the IP or DNS name
- Many hidden services
  - Duck Duck Go, Tor Chat, Wikileaks

Hidden Services: 1

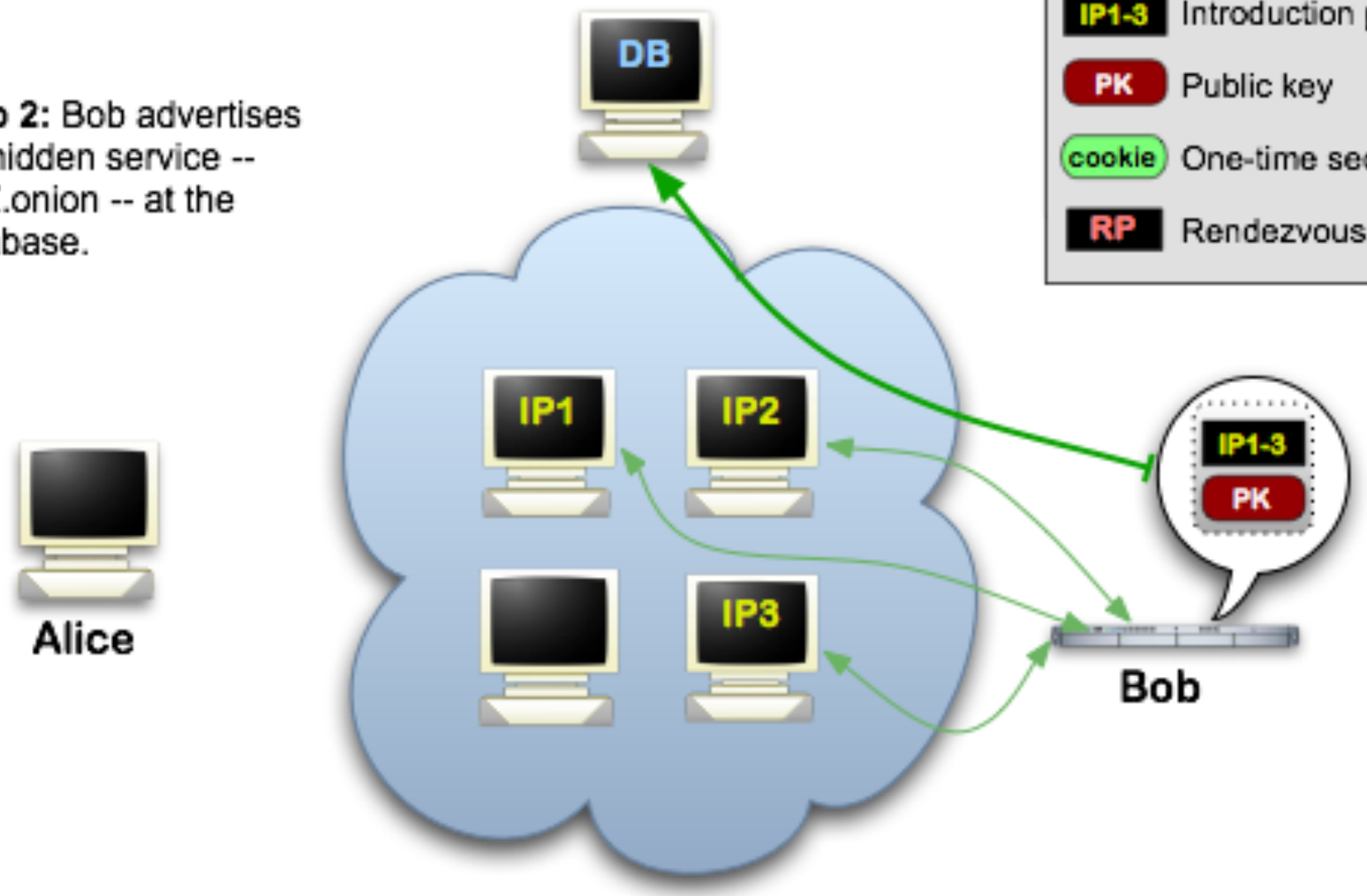
Step 1: Bob picks some introduction points and builds circuits to them.





Tor Hidden Services: 2

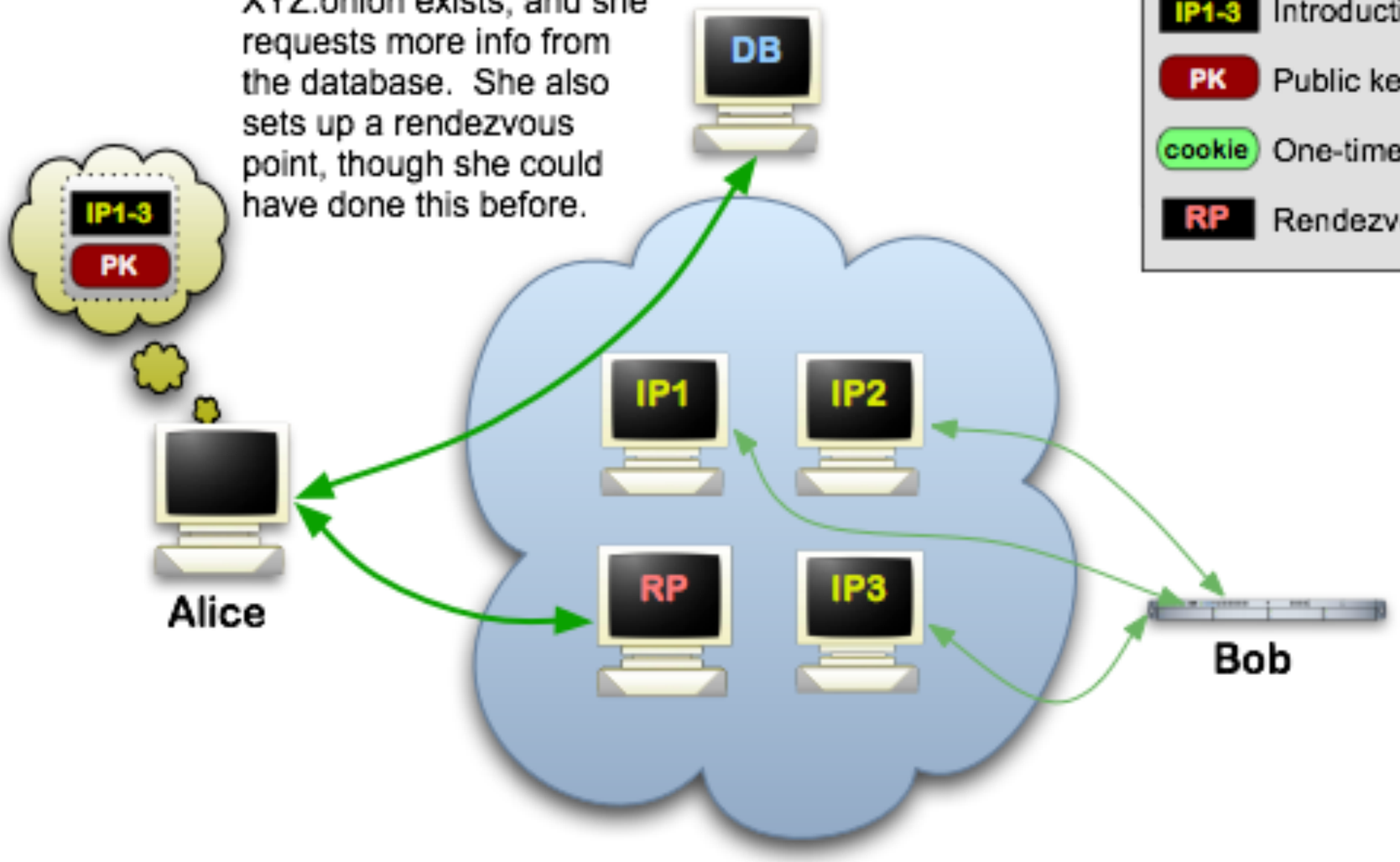
Step 2: Bob advertises his hidden service -- XYZ.onion -- at the database.

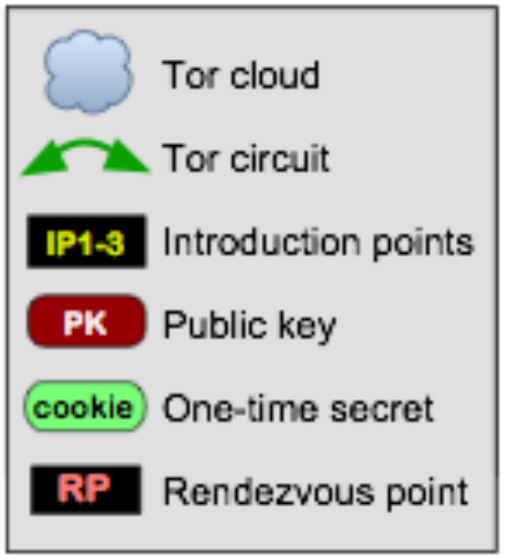


Tor cloud
Tor circuit
IP1-3 Introduction points
PK Public key
cookie One-time secret
RP Rendezvous point

Hidden Services: 3

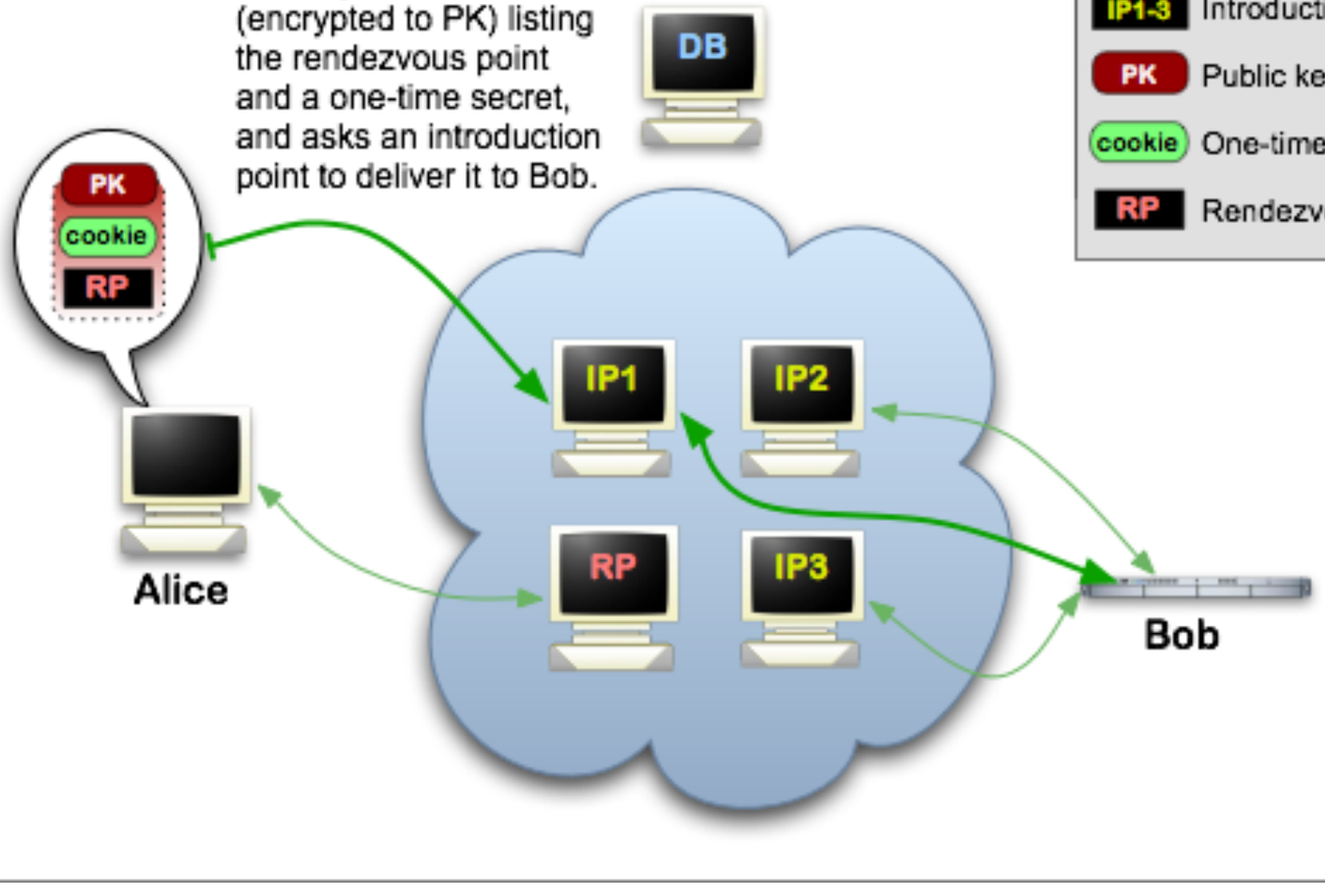
Step 3: Alice hears that XYZ.onion exists, and she requests more info from the database. She also sets up a rendezvous point, though she could have done this before.





Tor Hidden Services: 4

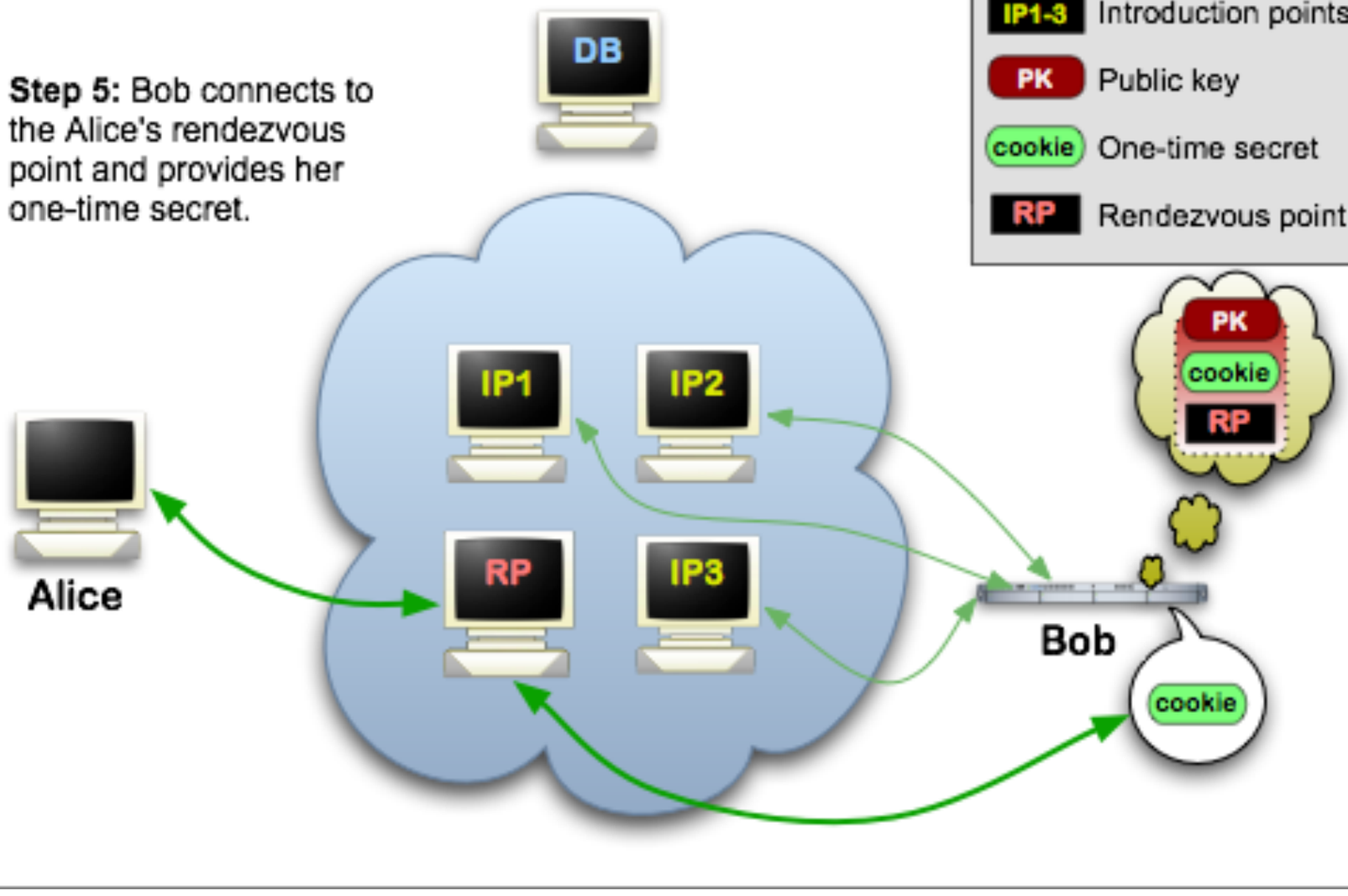
Step 4: Alice writes a message to Bob (encrypted to PK) listing the rendezvous point and a one-time secret, and asks an introduction point to deliver it to Bob.



- Tor cloud
- Tor circuit
- IP1-3 Introduction points
- PK Public key
- cookie One-time secret
- RP Rendezvous point

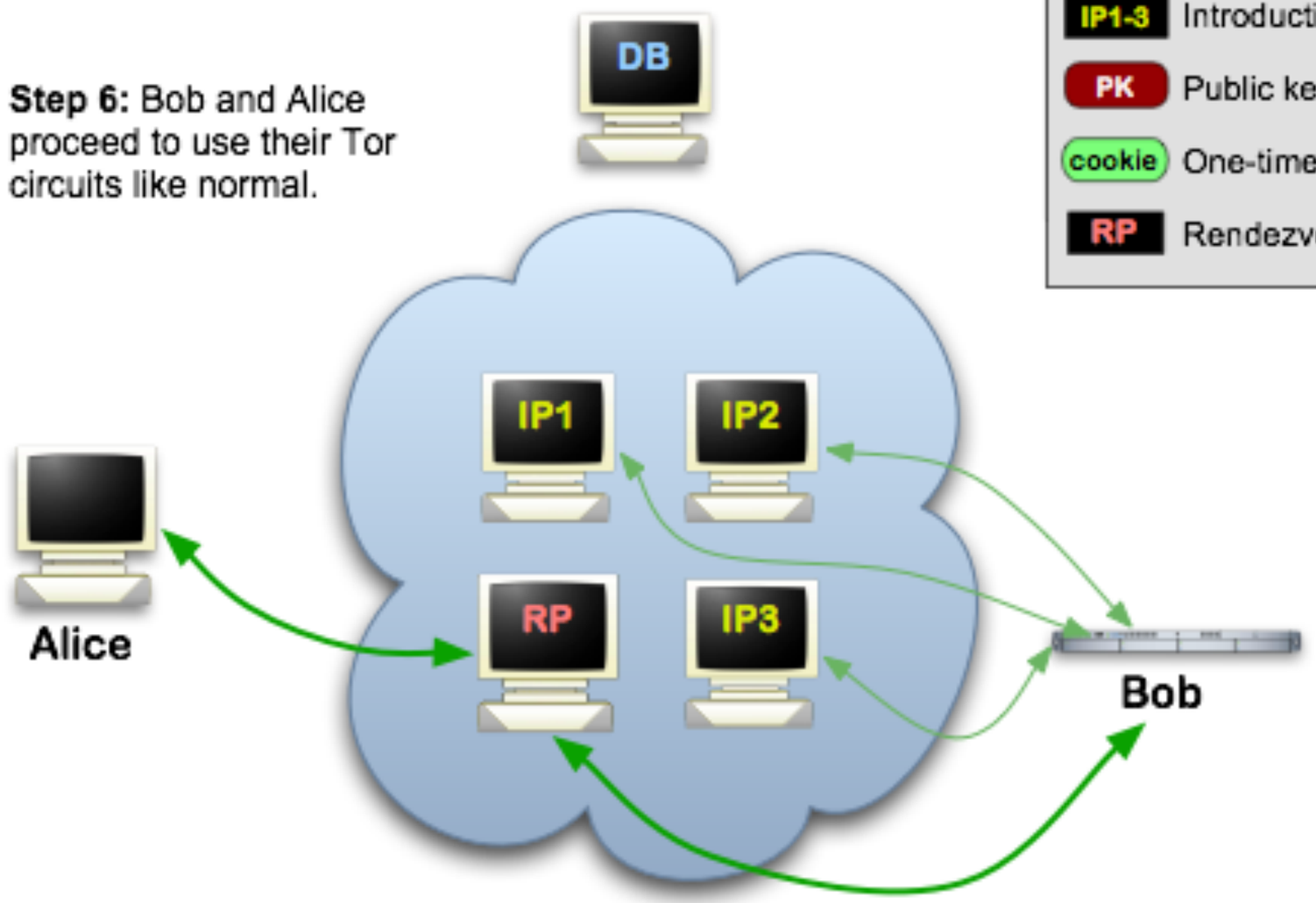
Hidden Services: 5

Step 5: Bob connects to the Alice's rendezvous point and provides her one-time secret.



Hidden Services: 6

Step 6: Bob and Alice proceed to use their Tor circuits like normal.



Tor cloud

Tor circuit

IP1-3 Introduction points

PK Public key

cookie One-time secret

RP Rendezvous point

Silk Road

anonymous marketplace

Welcome **now0pen**!

messages(0) | **orders(0)** | **account(฿0)** | **settings** | **log out**

search | **(0)**

Shop by category:

- Drugs(752)
  - Cannabis(280)
  - Ecstasy(35)
  - Dissociatives(11)
  - Psychedelics(84)
  - Opioids(62)
  - Stimulants(53)
  - Other(107)
  - Benzos(70)
- Lab Supplies(6)
- Digital goods(98)
- Services(48)
- Money(55)
- Weaponry(15)
- Home & Garden(14)
- Food(4)
- Electronics(5)
- Books(49)
- Drug paraphernalia(28)
- XXX(30)
- Medical(3)
- Computer equipment(4)
- Apparel(4)
- Musical instruments(2)
- Tickets(1)
- Forgeries(13)

5 Marijuana Butter Chocolate Chip...

฿8.53

4mg. TIZANIDINE (zanaflex) x25

฿2.09

US customers only Express...

฿2.79

4 x 20MG Original Lily Cialis

฿7.85

(1g) High-grade Crystal Meth

฿11.95

MindFood - Protect your brain!...

฿3.69

to US 1/4 lb (qp) BC Master Kush...

฿121.37

How to Grow Mushrooms

฿0.14

Mushroom Indoor Growing - Easy...

฿0.29

News:

- Escrow hedging **update**
- New feature to help protect **sellers**
- We are **hiring**! Get paid for a referral, too...
- Reclaim lost coins from **MyBitcoin.com**
- Seller ranking and feedback **overhaul**
- Change your Mt. Gox **password**

recent feedback:

Silk Road Marketplace

Who uses anonymity systems?

- *"If you're not doing anything wrong, you shouldn't have anything to hide."*
  - Implies that anonymous communication is for criminals
- The truth: who uses Tor?
  - Journalists, Law Enforcement, Human Rights Activists, Business Executives, Intelligence/Military, Normal People

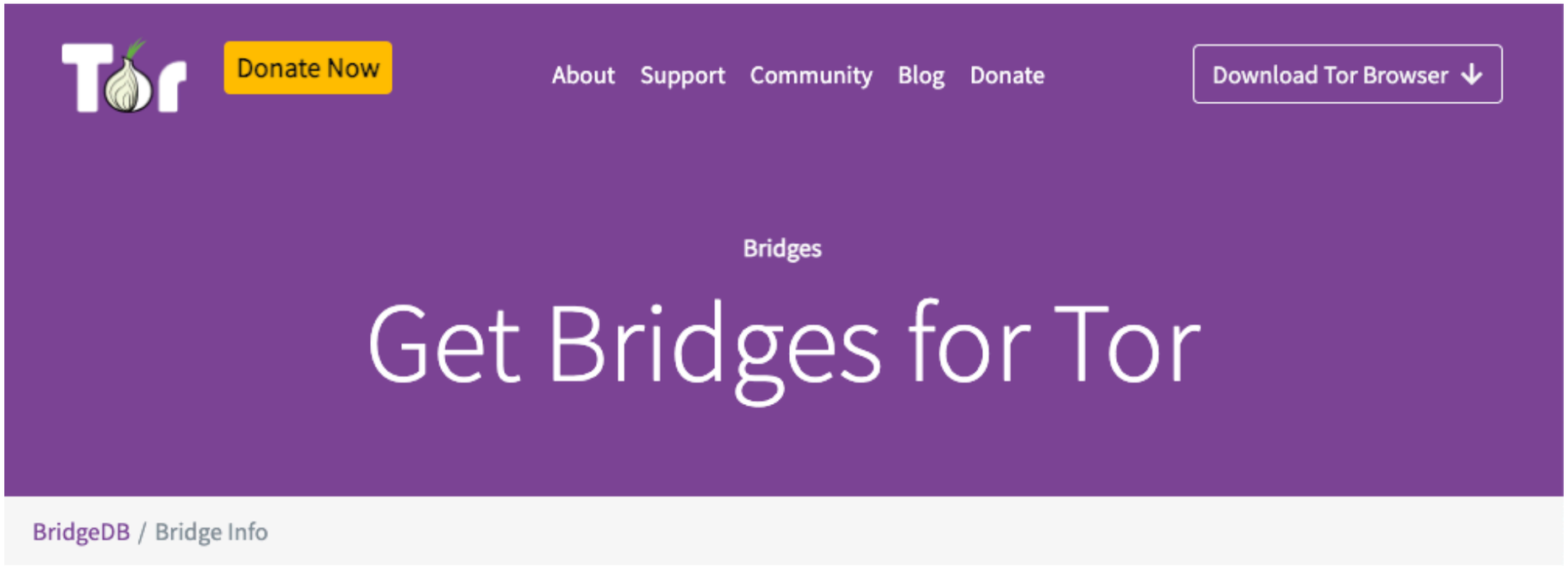
Internet Censorship

- **Government censors**
  - Block websites containing “offensive” content
  - Commonly employ blacklist approach
- **Observed techniques**
  - IP blocking, DNS blackholes, forged RST packets
- **Popular countermeasures**
  - Mostly proxy based — Tor, Freenet, Ultrasurf, ...
  - Problem: Cat-and-mouse game

Tor Bridges

- Anyone can look up the IP addresses of Tor relays
  - Public information in the consensus file
- Many countries block traffic to these IPs
  - Essentially a denial-of-service against Tor
- Solution: Tor Bridges
  - Tor proxies that are not publicly known

Tor Bridges



Here are your bridge lines:

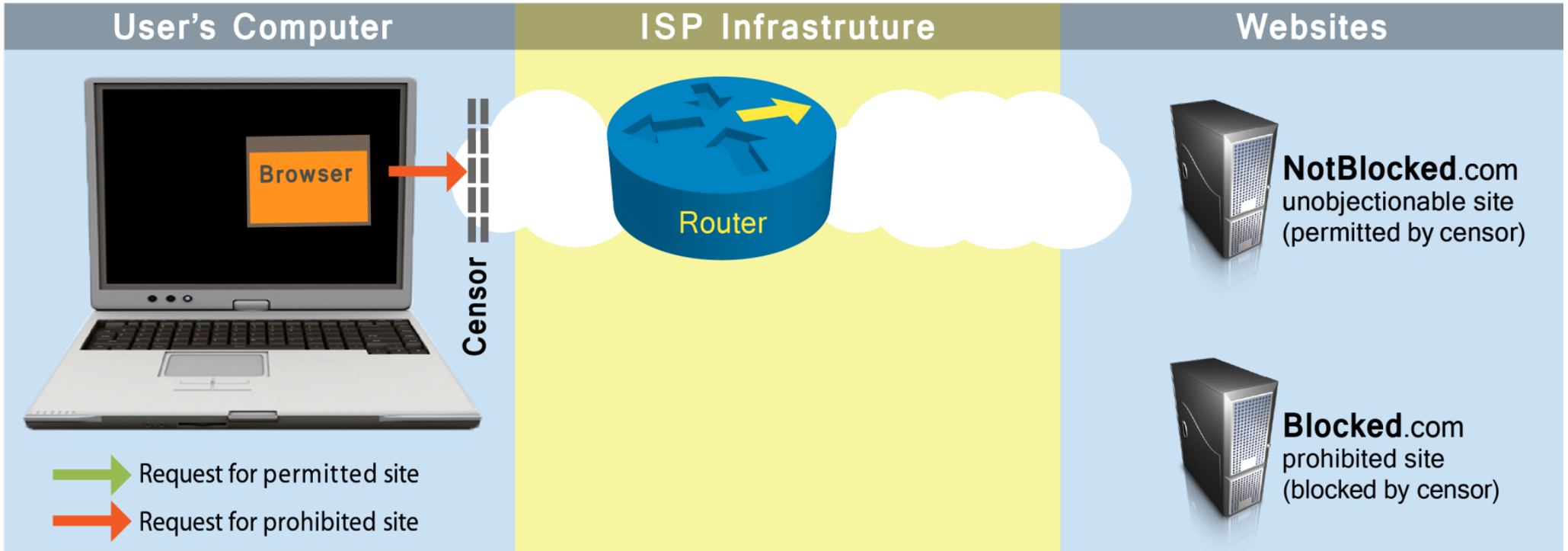
```
obfs4 98.16.155.208:7001 9E48072D43FFD90D53665C08E68A2FEBEC4F8856
obfs4 83.219.181.35:9443 E7A080574A671C6346322CEC8AE278B1F1CED7F7
```

Copy All

Obfuscating Tor Traffic

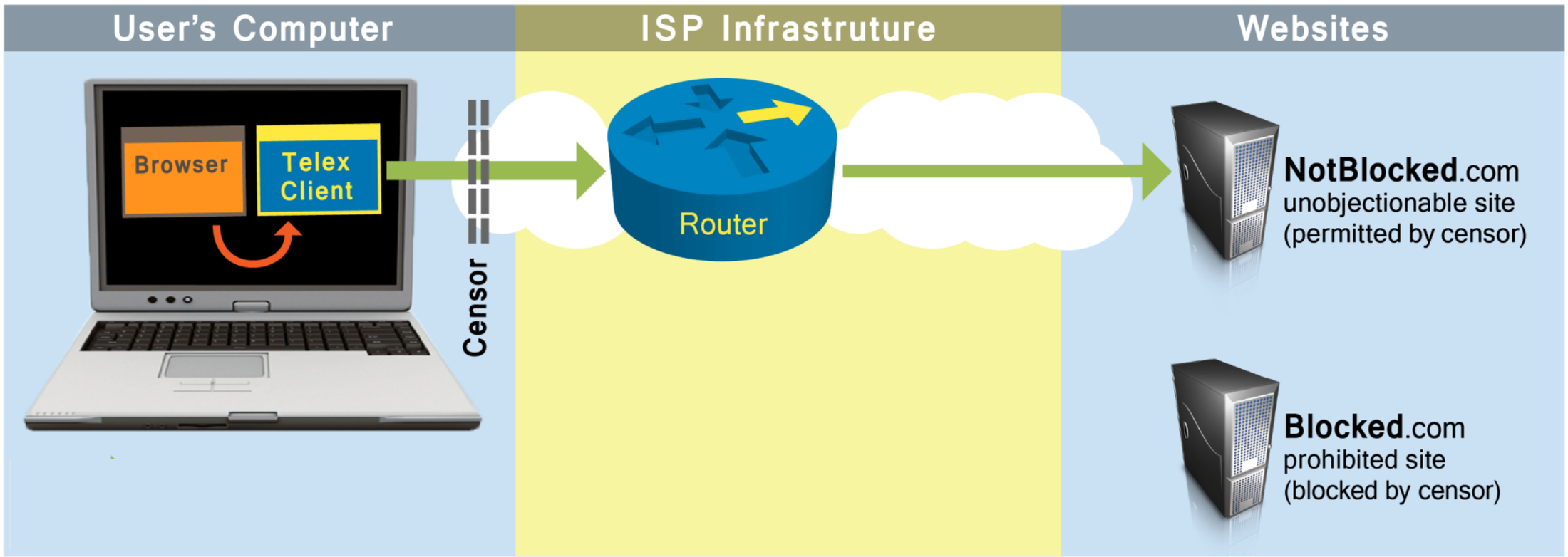
- Bridges alone may be insufficient to get around all types of censorship
  - DPI can be used to locate and drop Tor frames
- Countries would passively detect and block bridges
  - Single use bridges
- Tor adopts a pluggable transport design
  - Tor traffic is forwarded to an obfuscation program
  - Obfuscator transforms the Tor traffic to look like some other protocol
  - BitTorrent, Skype, HTTP, streaming audio, etc.

Decoy Routing (Telex)



Request for **permitted** site Request for **prohibited** site

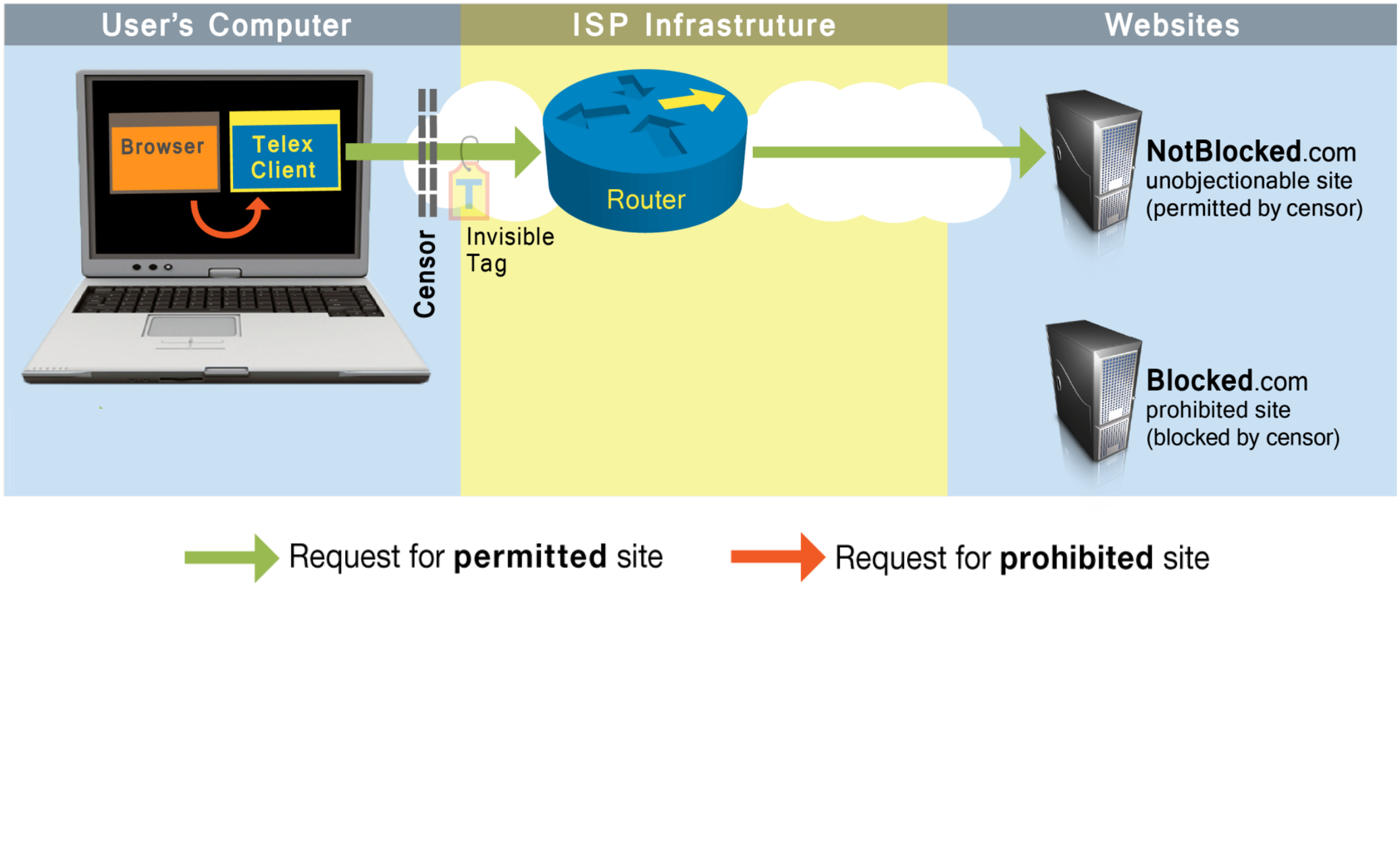
Decoy Routing (Telex)



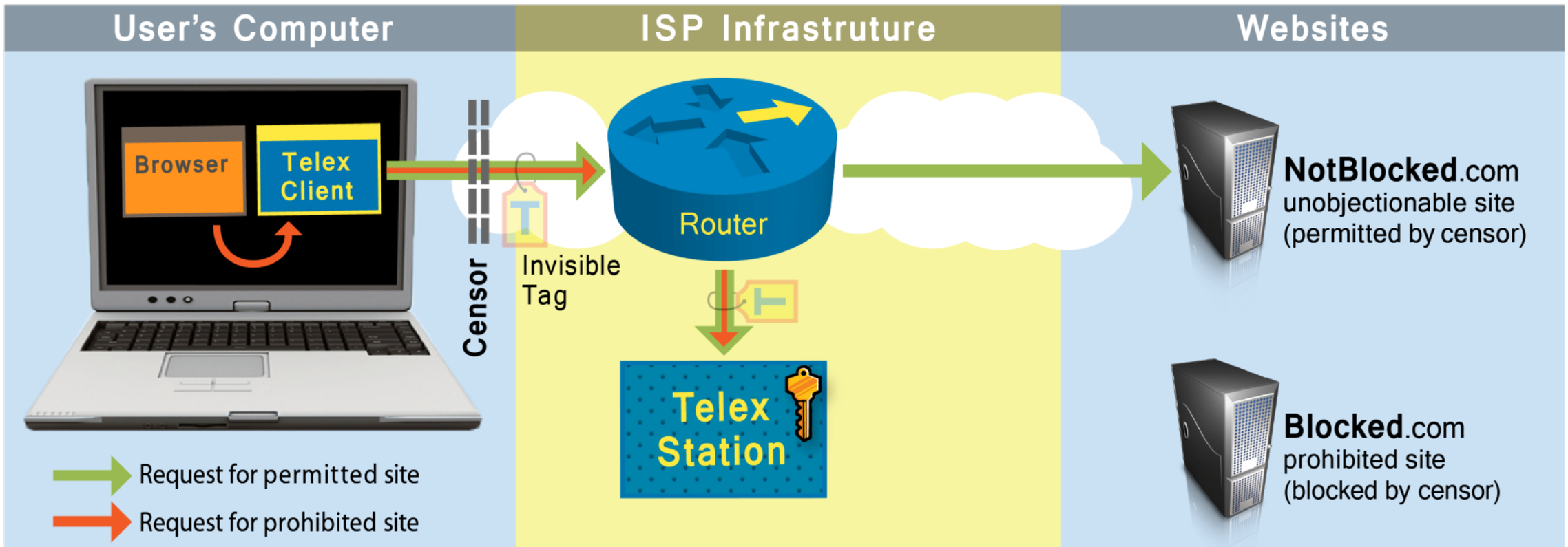
Request for **permitted** site

Request for **prohibited** site

Decoy Routing (Telex)



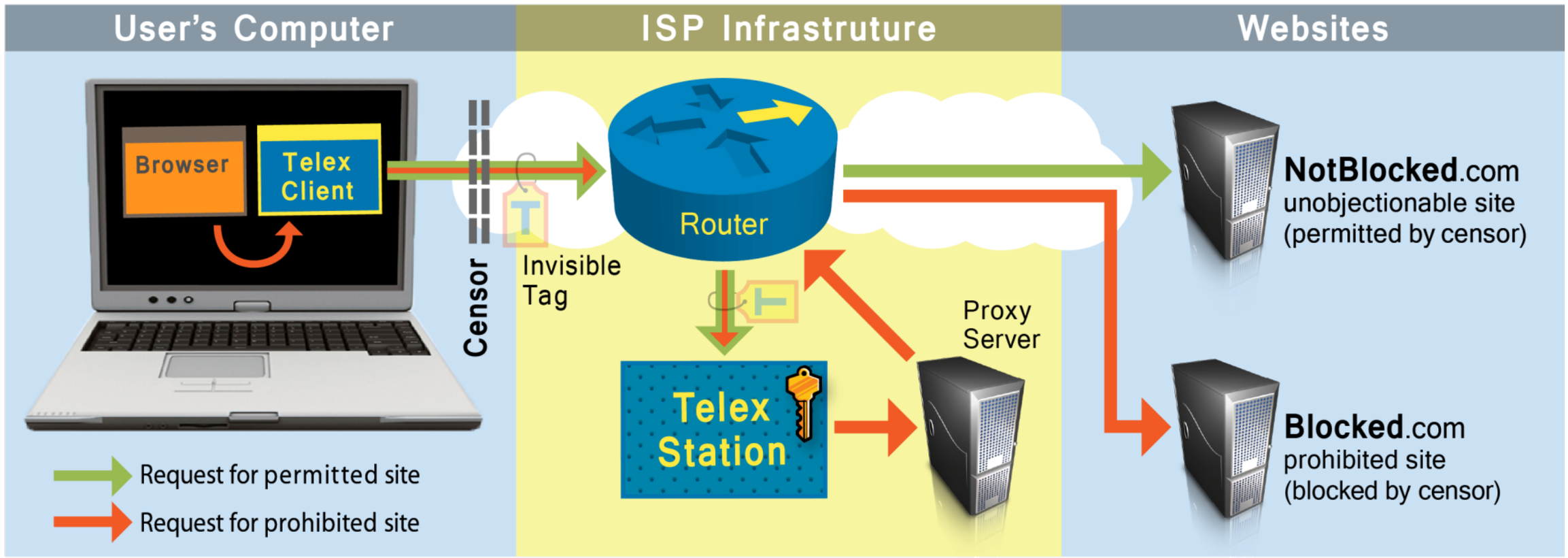
Decoy Routing (Telex)



Request for **permitted** site

Request for **prohibited** site

Decoy Routing (Telex)



Request for **permitted** site Request for **prohibited** site

Secure Messaging

Secure Messaging

- Most communications today are through some (instant) messaging apps.
- Unique challenges:
  - Chats are highly sensitive, containing lots of personal info.
    - Authenticated (between the two) but Deniable (to any third party)
  - Chats are sporadic in short-term, but can persist in long-term.
    - Forward-secrecy and post-compromise security?
  - Need to establish a secure channel even when the receiver is offline.
  - You really want End-to-End encryption: no one (even the *service provider*) other than the sender & receiver should be able to read a message.

Deniability

- **Def**: Even if a communication is intercepted or recovered, neither the sender nor the recipient can prove (or *be forced to prove*) that they sent or received the message

- Opposite to the non-repudiability provided by digital signatures

- Crucial for privacy & anonymity

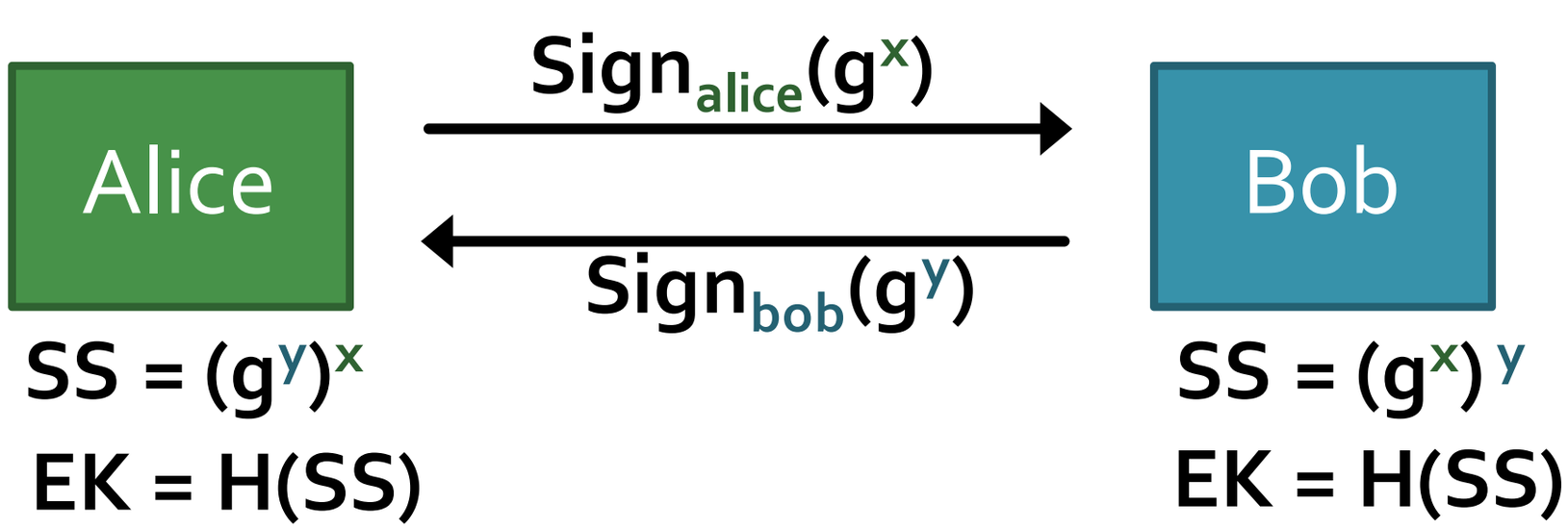
  - Similar to secret verbal conversation

  - Reduce the value of compromised communications

  - Prevents (out-of-context) misuse of messages

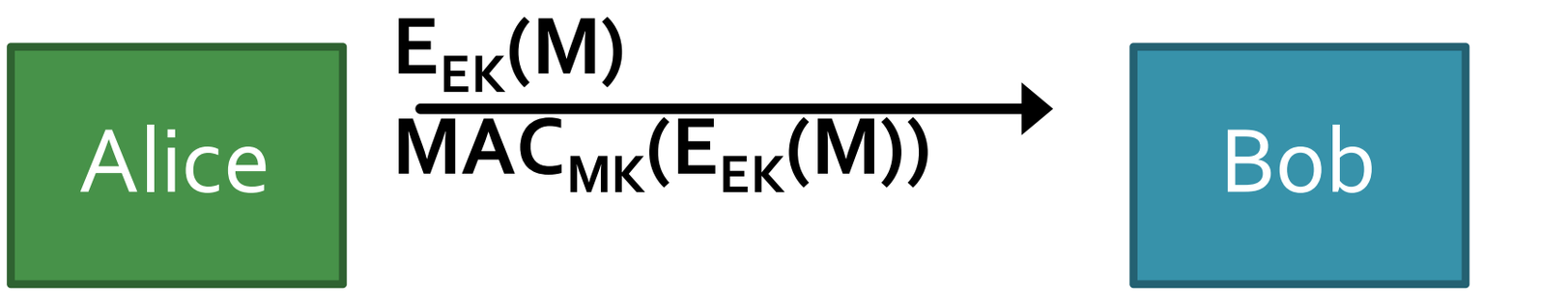
OTR: Off the Record Chat

1. Use authenticated Diffie-Hellman to establish a (short-lived) session key EK



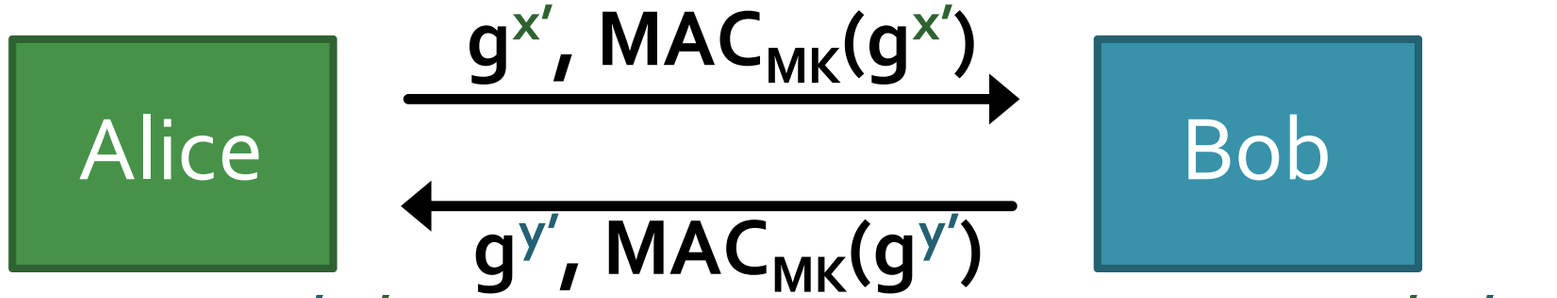
OTR: Off the Record Chat

2. Then use symmetric encryption on message M
… and authenticate using a MAC



OTR: Off the Record Chat

3. Re-key using Diffie-Hellman



$SS' = (g^{y'})^{x'}$

$EK' = H(SS')$

$MK' = H(EK')$

$MK = H(EK)$

$SS' = (g^{x'})^{y'}$

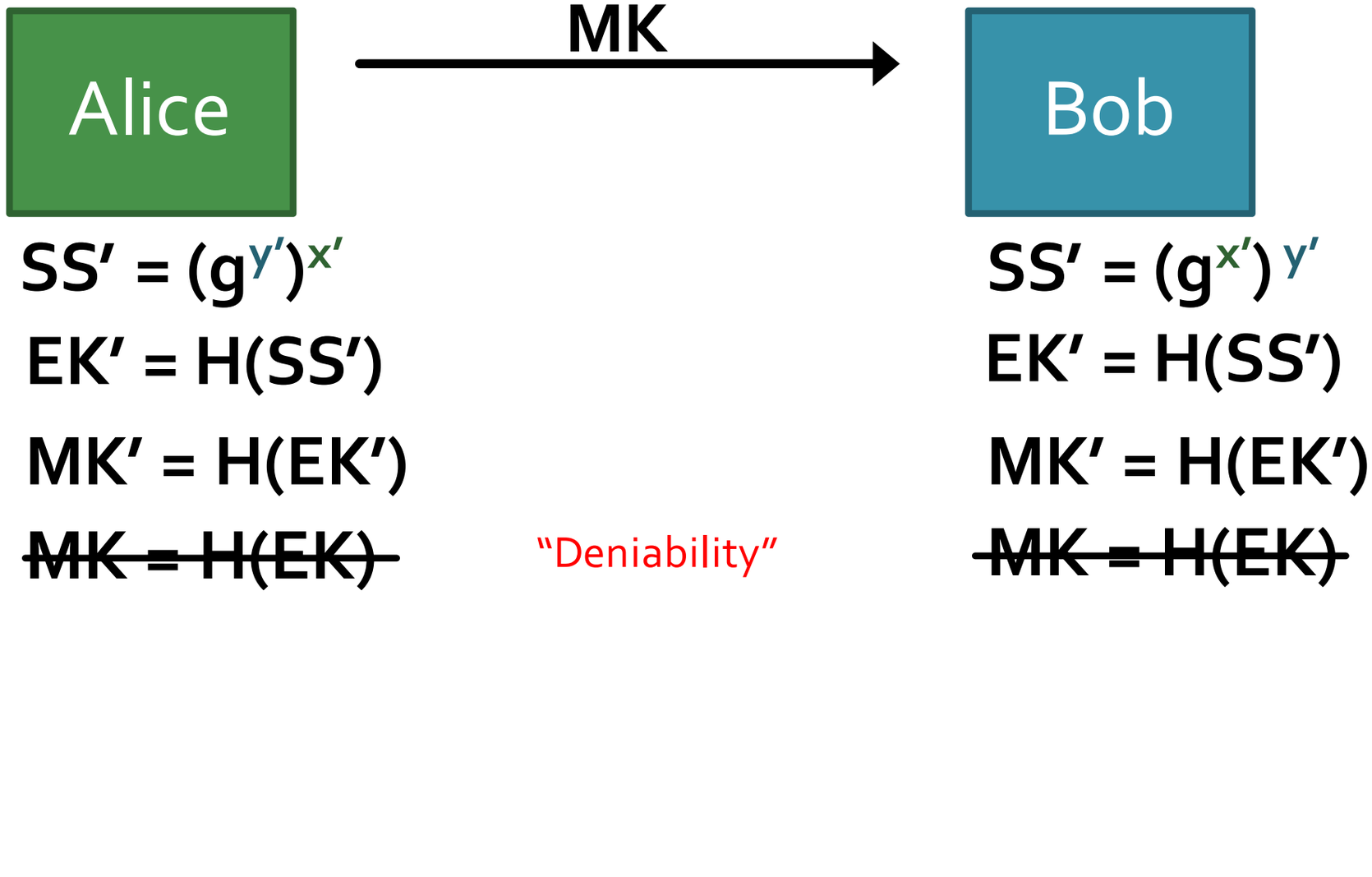
$EK' = H(SS')$

$MK' = H(EK')$

$MK = H(EK)$

OTR: Off the Record Chat

4. Publish old MK



Signal / WhatsApp

A successor to OTR

- **End-to-End Encryption:**
  - Messages are encrypted on the sender's device and only decrypted on the recipient's device. Even Signal's servers can't access message content.
- **Double Ratchet Algorithm:**
  - The "ratcheting" process ensures that each new message has a unique encryption key, meaning past and future messages remain secure *even if a key is compromised*.
- **Asynchronous (Pre-Key) Messaging:**
  - Pre-keys are temporary public keys stored on the server. When Alice sends a message to Bob (*who is offline*), Alice can encrypt it using one of Bob's pre-keys, which is later decrypted by Bob's device.
- **X3DH (Extended Triple Diffie-Hellman) Key Agreement Protocol:**
  - Allows authenticated, async key exchange.

Telegram

- **MTProto**: Telegram's proprietary protocol. Hasn't undergone the same level of peer review and scrutiny as the Signal Protocol.

- **Default Chats**: By default, Telegram stores all messages on its servers with standard client-server encryption.

- **Secret Chats**: Implements end-to-end encryption: encrypted on the device level and are not stored on Telegram's servers

- **Group Chats**: No end-to-end encryption for group chats, so all group conversations are stored on Telegram's servers with only client-server encryption.

Questions?