

Protocols for anonymity

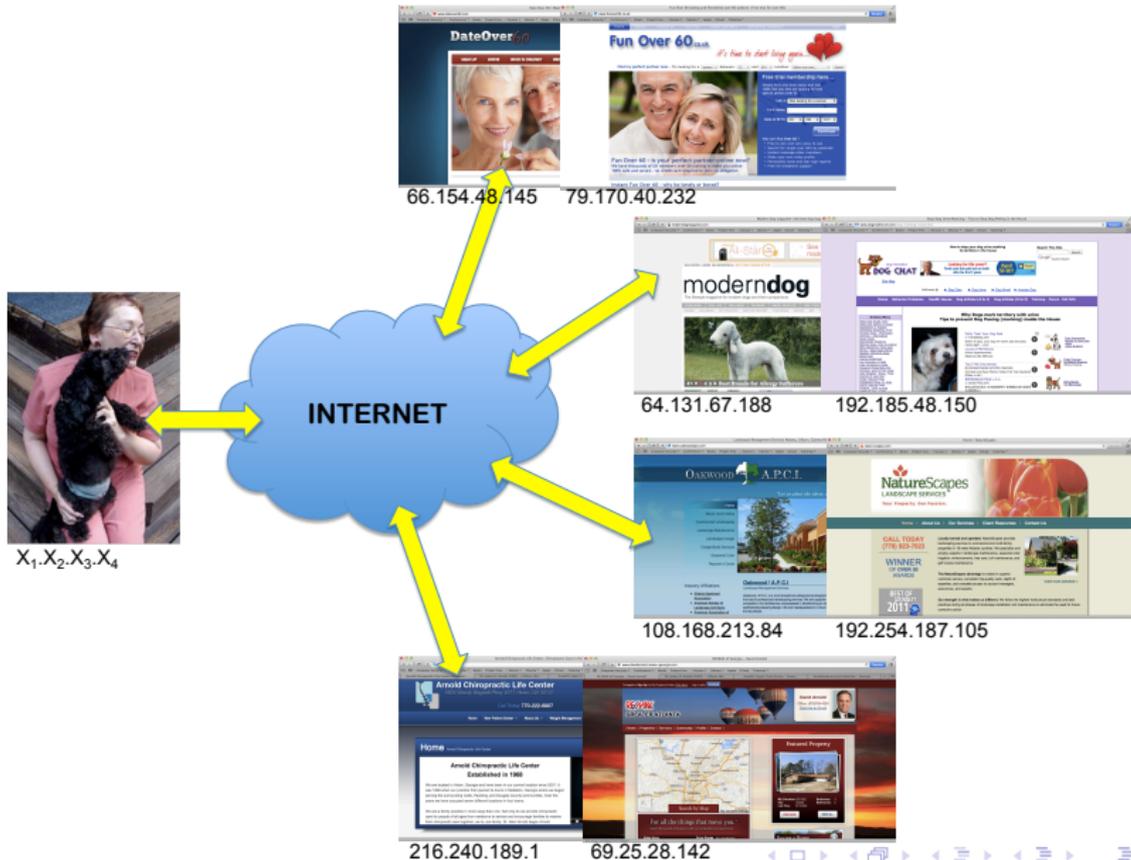
Myrto Arapinis
School of Informatics
University of Edinburgh

October 31, 2017

Context

- ▶ The Internet is a public network:
 - ▶ network routers see all traffic that passes through them
- ▶ Routing information is public:
 - ▶ IP packet headers contain source and destination of packets
- ▶ Encryption does not hide identities:
 - ▶ encryption hides payload, but not routing information

Routing information can reveal who you are!



Routing information can reveal who you are!

A Face Is Exposed for AOL Searcher No. 4417749 - New York Times

www.nytimes.com/2006/08/09/technology/09aol.html?pagewanted=all&_r=0

Computer Security ▾ Conferences ▾ Books ▾ Project Free ... ▾ Season 1 ▾ Ubuntu ▾ Apple ▾ iCloud ▾ Tutoring ▾

HOME PAGE | MY TIMES | TODAY'S PAPER | VIDEO | MOST POPULAR | TIMES TOPICS

SUBSCRIBE NOW | Log In | Register Now

The New York Times **Technology** Technology ▾ All NYT Search

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION | ARTS | STYLE | TRAVEL | JOBS | REAL ESTATE | AUTOS

CAMCORDERS | CAMERAS | CELLPHONES | COMPUTERS | HANDHELD | HOME VIDEO | MUSIC | PERIPHERALS | WI-FI

A Face Is Exposed for AOL Searcher No. 4417749

By MICHAEL BARBARO and TOM ZELLER Jr.
Published: August 9, 2006

Buried in a list of 20 million Web search queries collected by AOL and recently released on the Internet is user No. 4417749. The number was assigned by the company to protect the searcher's anonymity, but it was not much of a shield.

No. 4417749 conducted hundreds of searches over a three-month period on topics ranging from "numb fingers" to "60 single men" to "dog that urinates on everything."

And search by search, click by click, the identity of AOL user No. 4417749 became easier to discern. There are queries for "landscapers in Lilburn, Ga.," several people with the last name Arnold and "homes sold in shadow lake subdivision gwinnett county georgia."

It did not take much investigating to follow that data trail to Thelma Arnold, a 62-year-old widow who lives in Lilburn, Ga., frequently researches her friends' medical ailments and loves her three dogs. "Those are my searches," she said, after a reporter read part of the list to her.

AOL removed the search data from its site over the weekend and apologized for its release, saying it was an



Erin S. Lessor for The New York Times

Thelma Arnold's identity was betrayed by AOL records of her Web searches, like ones for her dog, Dudley, who clearly has a problem.

Multimedia

Graphic: What Revealing Search Data Reveals

SIGN IN TO E-MAIL THIS
PRINT
REPRINTS



More Articles in Technology >



Video Gallery | Latest Thinking | Ad Spotlight

The Accenture Digital Difference

Digital Business is Changing

Accenture Digital-Defining Digital Business

Daily Report: Web-Could Computing, Companies Face a World of Tech Choices >
Maps That Use and Abuse Web Data >
Detroit, Embracing New Auto Technologies, Sets App Builders >
The New York Times The reproduction of these articles is permitted by America's Open Access Act of the New York Times

Routing information can reveal who you are!

Safari File Edit View History Bookmarks Develop Window Help
What Is My IP Address? IP Address Tools and More

whatismyipaddress.com

ComputerSecurity SimSec C5exam La cryptogra... ts dévoilés Conferences ResearchProfiles Security-Club Teaching Tutoring

IP Address Search Search

How you **connect** to the world

MY IP IP LOOKUP SPEED TEST BLACKLIST CHECK TRACE EMAIL CHANGE IP HIDE IP IP TOOLS LEARN COMMUNITY

IP Lookup
Know the IP address of another computer? You can find where in the world it is—and more.

Trace Email
Track down the geographical location and origin of an email you received.

Hide IP
Learn how to use a high-tech "mask" to shield your real IP address on the Internet.

VPN Comparison
Compare top rated VPN service providers that meet your needs and budget.

Blacklist Check
Have you been blacklisted because of the IP address you use? Check to see here.

Speed Test
Is your Internet connection up to speed? Find out for free with a quick click.

IP Tools
Have the right tool for any job. That goes for your Internet connection, too.

Your IPv4 Address Is:
89.241.168.239

WhatIsMyIPAddress.c...
Like Page 244k likes

Your IP Details:

ISP: TalkTalk
City: Edinburgh
Region: Edinburgh
Country: United Kingdom

Don't want this known? [Hide your IP details](#)

Click for more details about 89.241.168.239

Location not accurate? [Update your IP location](#)

[Learn More About This IP](#)

Tweet Share

This Christmas, people will search for a business like yours.

Google AdWords

Check out our new Learning Center

Learn more about IP addresses, staying safe online, general computer topics and more, including a look at IPv6.

[Start Here](#)

It's not personal — It's just your connection.

Routing information can reveal who you are!



"With your permission, you give us more information about you, about your friends, and we can improve the quality of your searches. We don't need you to type at all. We know where you are. We know where you've been. We can more or less know what you're thinking about."

Eric Schmidt, CEO Google, 2010

Your IP address is your ID

Your IP address is Your ID.



Your IP address leaves behind digital tracks that can be used to identify you and invade your privacy

The McNealy argument



"You have zero privacy anyway. Get over it"
Scott McNealy, CEO Sun Microsystems, 1999

The Schmidt argument



"If you have something that you don't want anyone to know maybe you shouldn't be doing it in the first place"
Eric Schmidt, CEO Google, 2009

Anonymity

Definition (ISO/IEC standard 15408)

A user may use a service or resource without disclosing the users identity.

Anonymity

Definition (ISO/IEC standard 15408)

A user may use a service or resource without disclosing the users identity.

→ this can be achieved by **hiding one's activities among others' similar activities**

- Dining cryptographers
- Crowds
- Chaum's mix
- Onion routing

Three-party dining cryptographers (3DC) protocol

Three cryptographers are having dinner. Either NSA paid for the dinner, or one of the cryptographers. They want to know if it is the NSA that paid, but without revealing the identity of the cryptographer that paid in the case the NSA did not pay.

3DC protocol:

1. Each cryptographer flips a coin and shows it to his left neighbor:
 - ▶ each cryptographer will see his own coin and his right neighbor's
2. Each cryptographer announces whether the two coins he saw are the same. If he is the payer, he lies
3. odd number of "same" \Rightarrow the NSA paid
even number of "same" \Rightarrow one of the cryptographers paid
 - ▶ only the payer knows he is the one who paid

Superposed sending

- ▶ 3DC protocol generalises to any group size n (nDC)
- ▶ Sender wants to anonymously broadcast a message m :
 1. for each bit of the m , every user generates a random bit and sends it to his left neighbor
 - ▶ every user learns two bits: his own, and his right neighbor's
 2. each user (except the sender) announces (own_bit XOR neighbor's_bit)
 3. the sender announces (own_bit XOR neighbor's_bit XOR message_bit)
 4. XOR of all announcements = message_bit
 - ▶ every randomly generated bit occurs in this sum twice (and is canceled by XOR)
 - ▶ message_bit occurs only once

Limitations of the DC protocol

The DC protocol is impractical:

- ▶ Requires pair-wise shared secret keys (secure channels) between the participants (to share random bits)
- ▶ Requires large amounts of randomness

Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

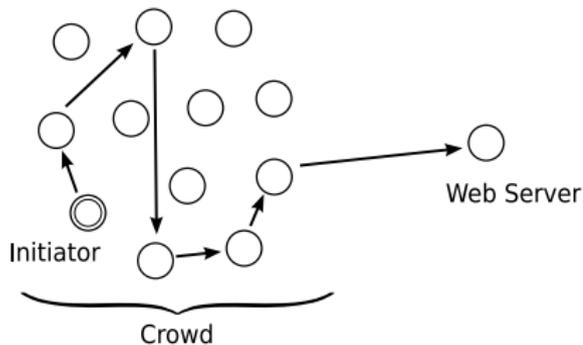
Idea: randomly route the request through a crowd of users

Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

Idea: randomly route the request through a crowd of users

- ▶ a crowd is a group of m users; c out of m users may be corrupted

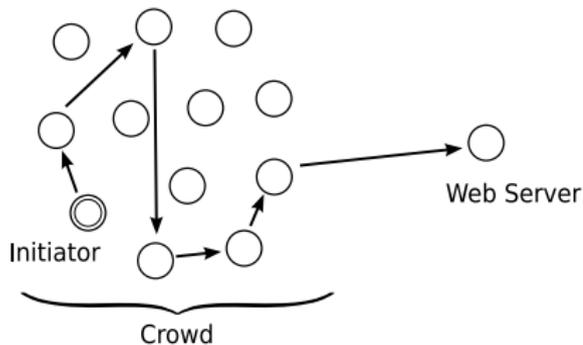


Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

Idea: randomly route the request through a crowd of users

- ▶ a crowd is a group of m users; c out of m users may be corrupted
- ▶ an initiator that wants to request a webpage creates a path between him and the server:

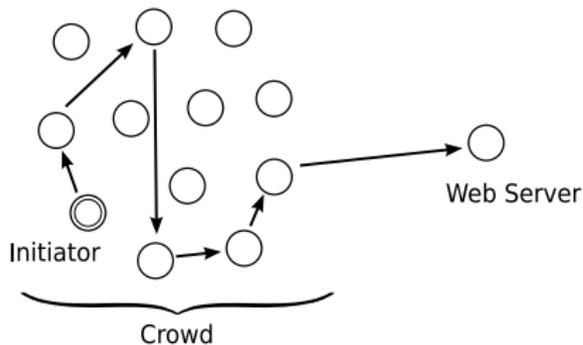


Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

Idea: randomly route the request through a crowd of users

- ▶ a crowd is a group of m users; c out of m users may be corrupted
- ▶ an initiator that wants to request a webpage creates a path between him and the server:
 1. the initiator selects a forwarder from the crowd and sends his request

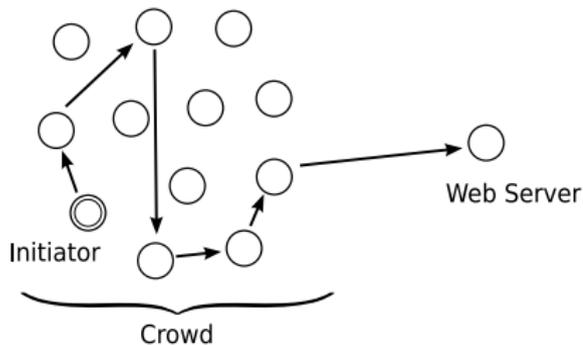


Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

Idea: randomly route the request through a crowd of users

- ▶ a crowd is a group of m users; c out of m users may be corrupted
- ▶ an initiator that wants to request a webpage creates a path between him and the server:
 1. the initiator selects a forwarder from the crowd and sends him his request
 2. a forwarder delivers the request directly to the server with probability $1 - p_f$; he forwards the request to a randomly selected new forwarder from the crowd with probability p_f ; the new forwarder repeats the procedure

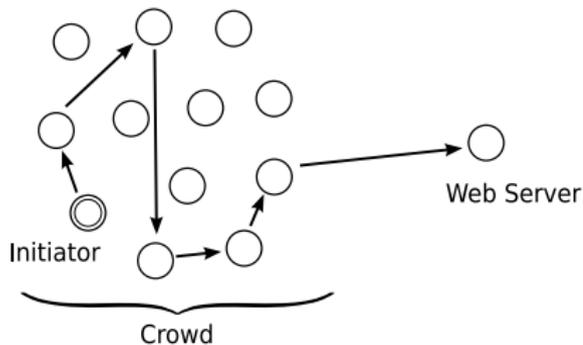


Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

Idea: randomly route the request through a crowd of users

- ▶ a crowd is a group of m users; c out of m users may be corrupted
- ▶ an initiator that wants to request a webpage creates a path between him and the server:
 1. the initiator selects a forwarder from the crowd and sends him his request
 2. a forwarder delivers the request directly to the server with probability $1 - p_f$; he forwards the request to a randomly selected new forwarder from the crowd with probability p_f ; the new forwarder repeats the procedure
 3. the response from the server follows same route in opposite direction

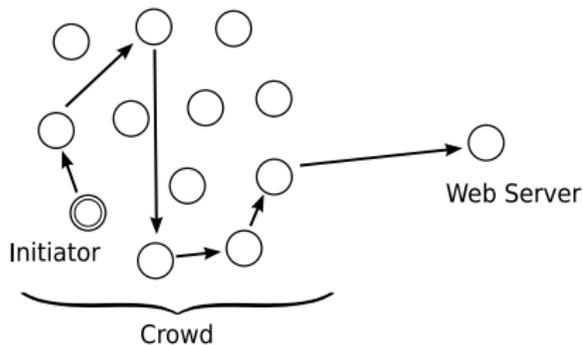


Crowds

[M. K. Reiter and A. D. Rubin, "Crowds: anonymity for Web transactions". ACM Transactions on Information and System Security.]

Idea: randomly route the request through a crowd of users

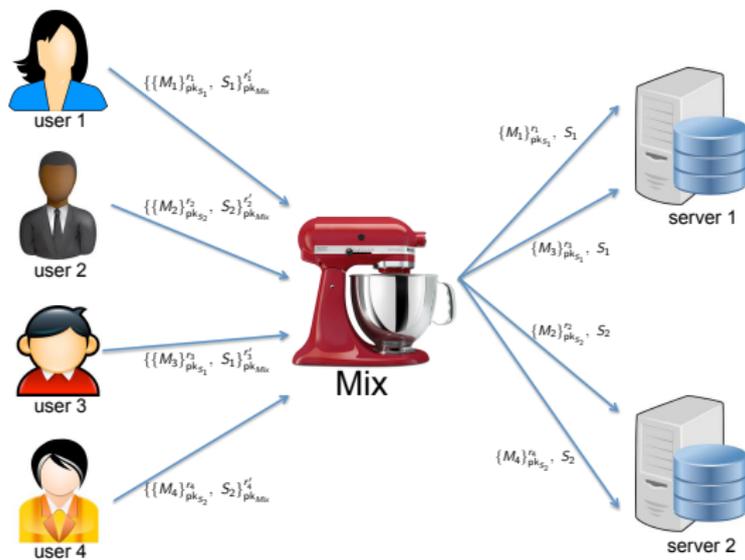
- ▶ a crowd is a group of m users; c out of m users may be corrupted
- ▶ an initiator that wants to request a webpage creates a path between him and the server:
 1. the initiator selects a forwarder from the crowd and sends him his request
 2. a forwarder delivers the request directly to the server with probability $1 - p_f$; he forwards the request to a randomly selected new forwarder from the crowd with probability p_f ; the new forwarder repeats the procedure
 3. the response from the server follows same route in opposite direction



Crowd IS NOT resistant against an attacker that sees the whole network traffic!

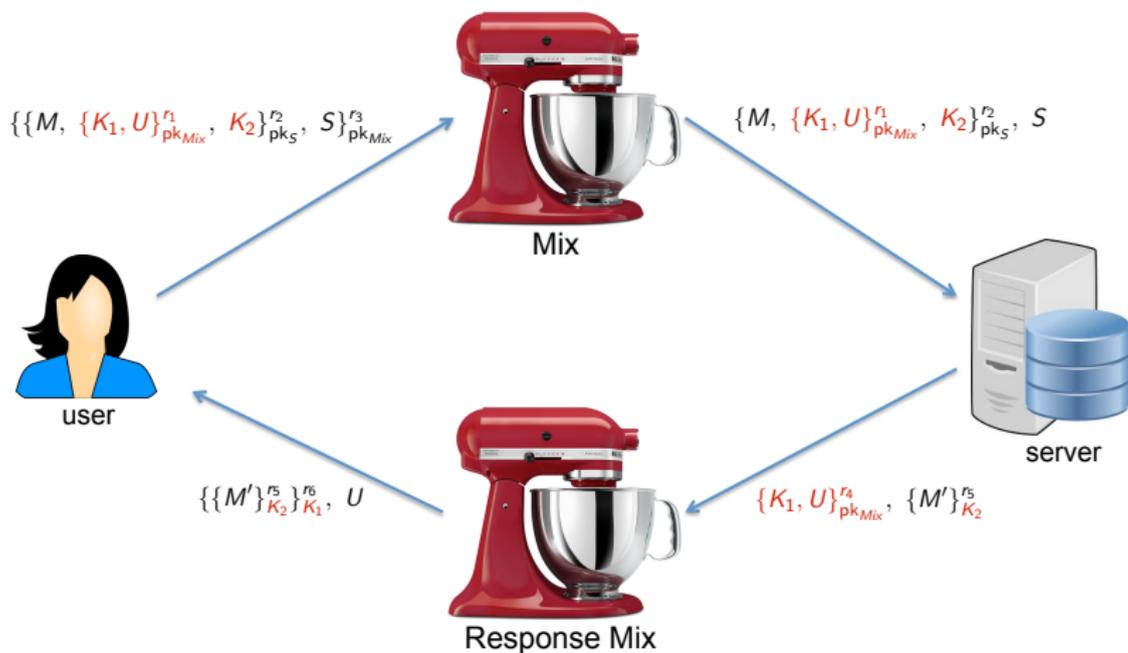
Chaum's mix

[D. Chaum, "Untraceable electronic mail, return addresses, and digital pseudonyms", Communications of the ACM, February 1981.]

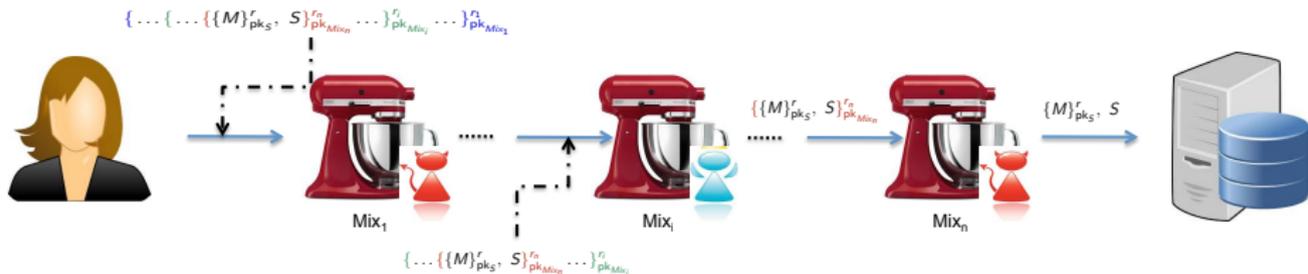


- ▶ **message padding** and **buffering** to avoid time correlation attacks
- ▶ **dummy messages** are generated by the mixes themselves to prevent an attacker sending $n - 1$ messages to a mix with capacity n , allowing him to then link the sender of the n^{th} message with its recipient

Anonymous return addresses



Mix cascade



- ▶ messages are sent through a sequence of mixes
- ▶ some of the mixes may be corrupted
- ▶ a single honest mix guarantees anonymity against an attacker controlling the whole network provided it applies:
 - ▶ message padding
 - ▶ buffering
 - ▶ dummy messages

Limitations of Chaum's mixnets

- ▶ Asymmetric encryption is not efficient
- ▶ Dummy messages are inefficient
- ▶ Buffering is not efficient

Onion routing

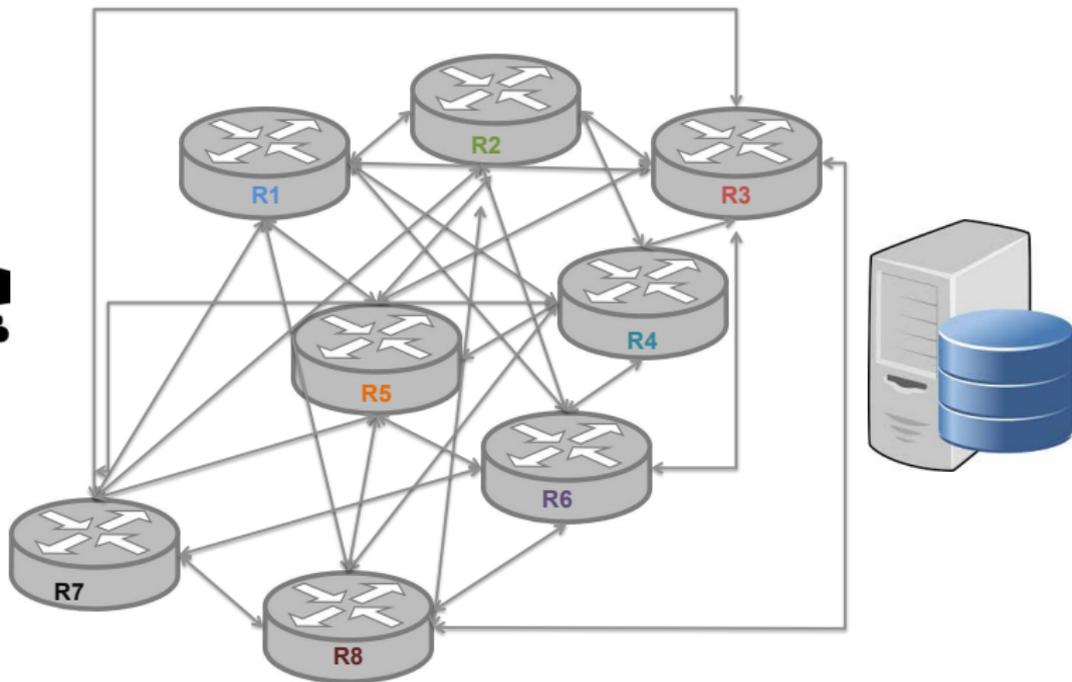
[R. Dingledine, N. Mathewson, and P. F. Syverson: “Tor: The Second-Generation Onion Router”, USENIX Security Symposium 2004]

Idea: combine advantages of mixes and proxies

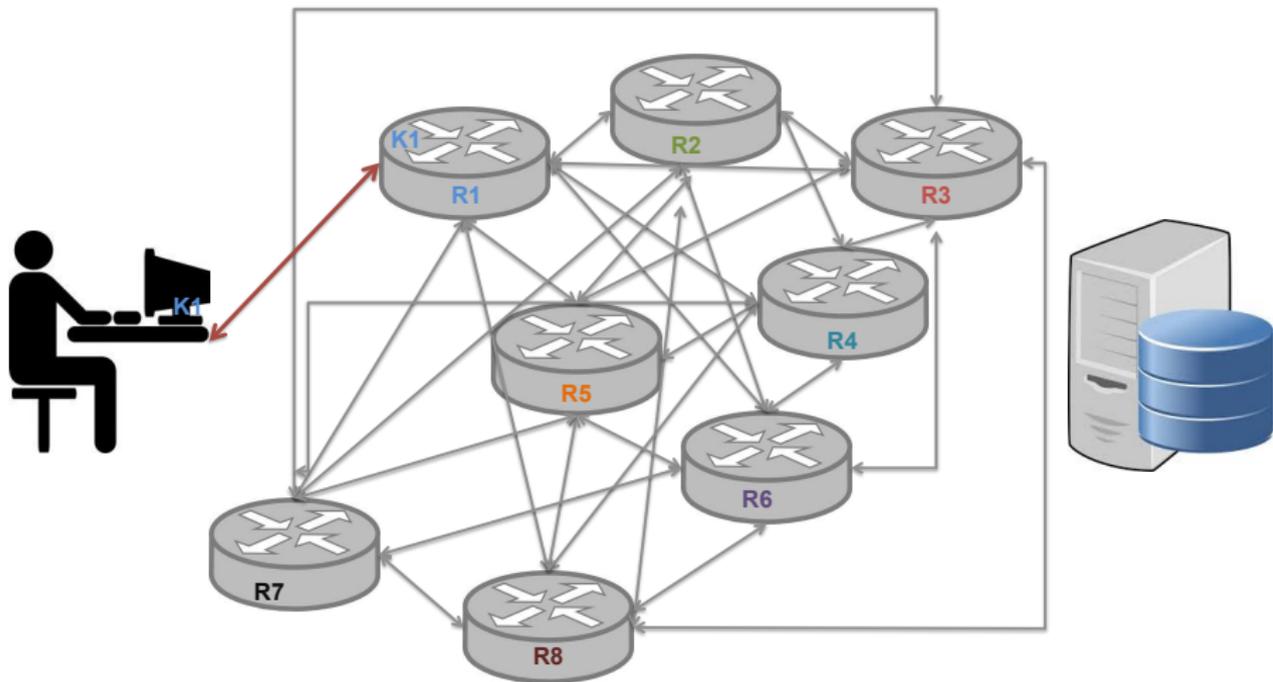
- ▶ use public-key crypto only to establish circuit
- ▶ use symmetric-key crypto to exchange data
- ▶ distribute trust like mixes

But does not defend against attackers that control the whole network

TOR circuit setup

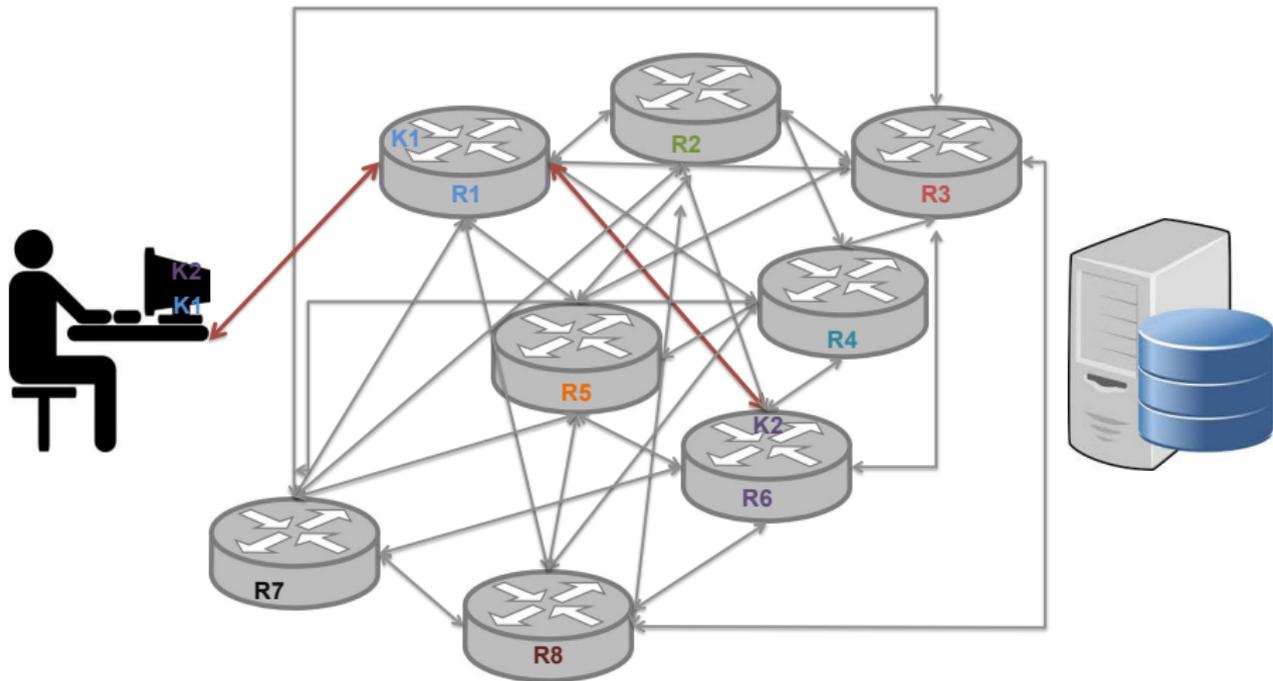


TOR circuit setup



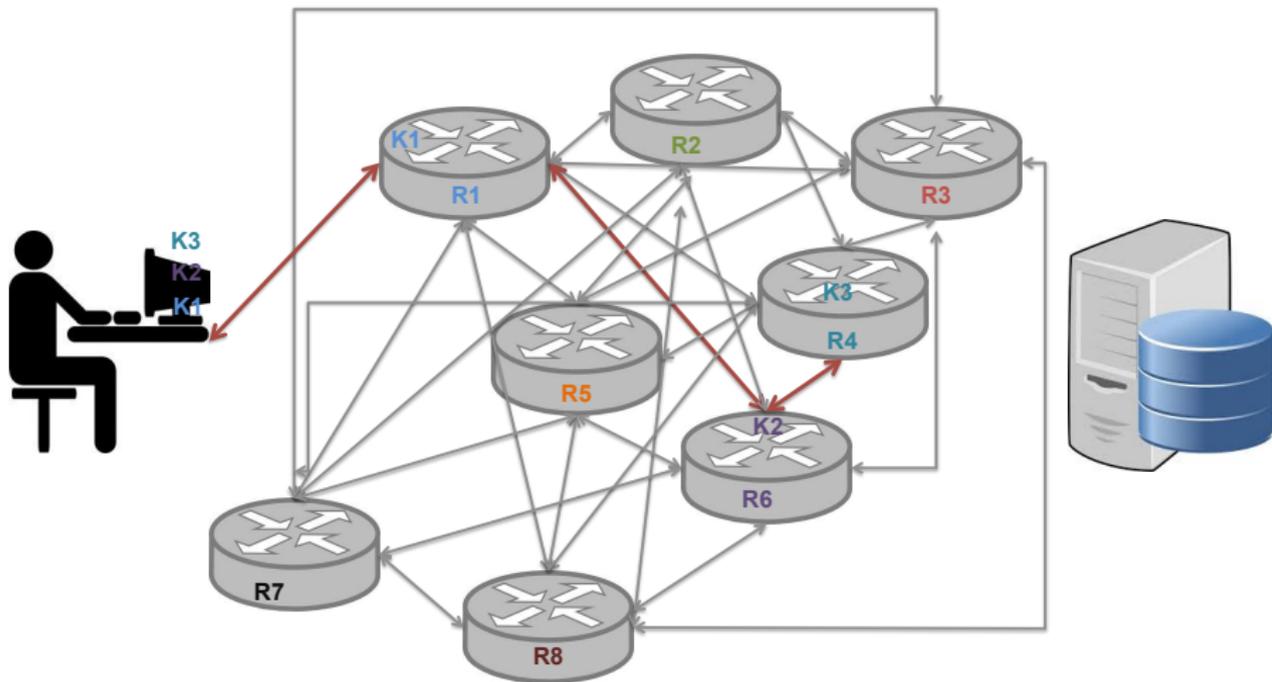
- ▶ client establishes session key **K1** and circuit with Onion Router **R1**

TOR circuit setup



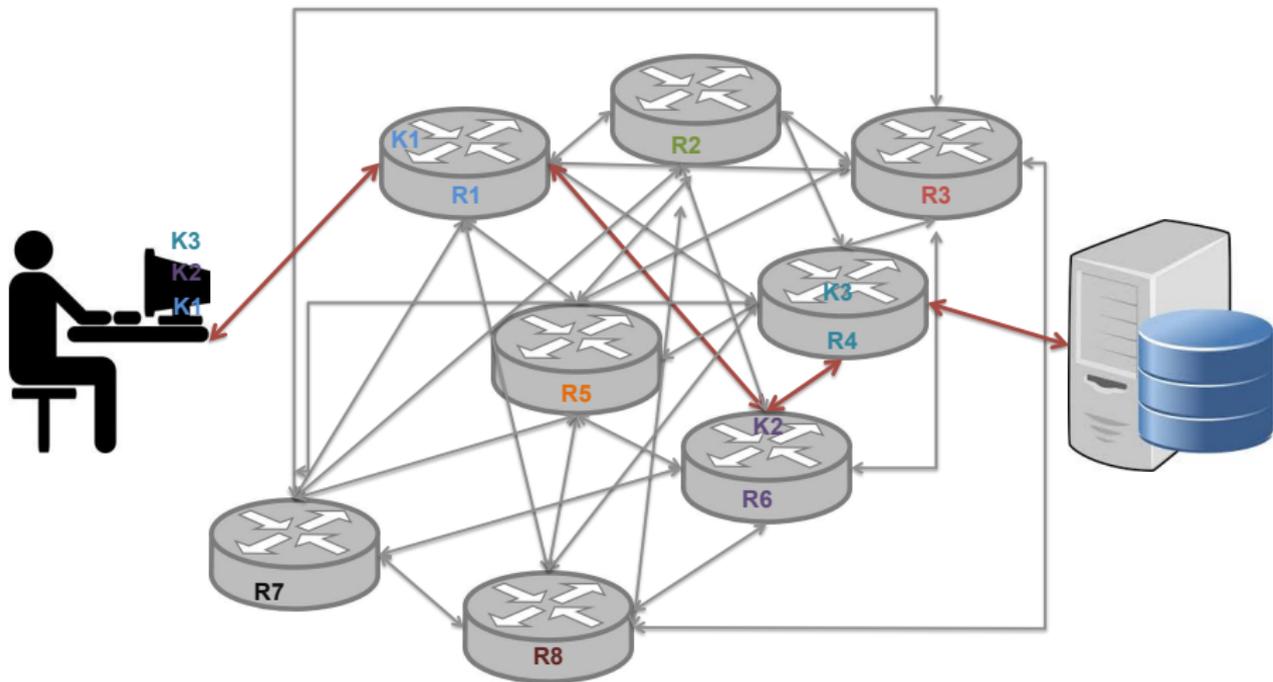
- ▶ client tunnels through that circuit to extend to Onion Router R6

TOR circuit setup



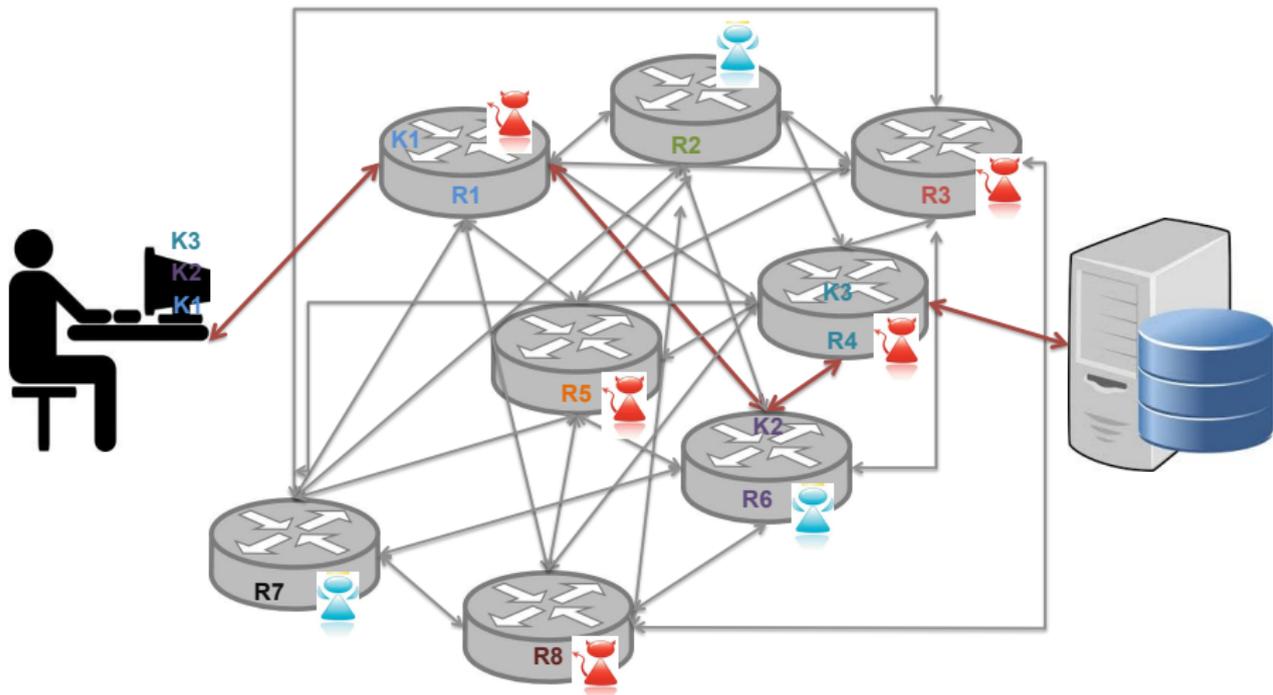
- ▶ client tunnels through that extended circuit to extend to Onion Router **R4**

TOR circuit setup



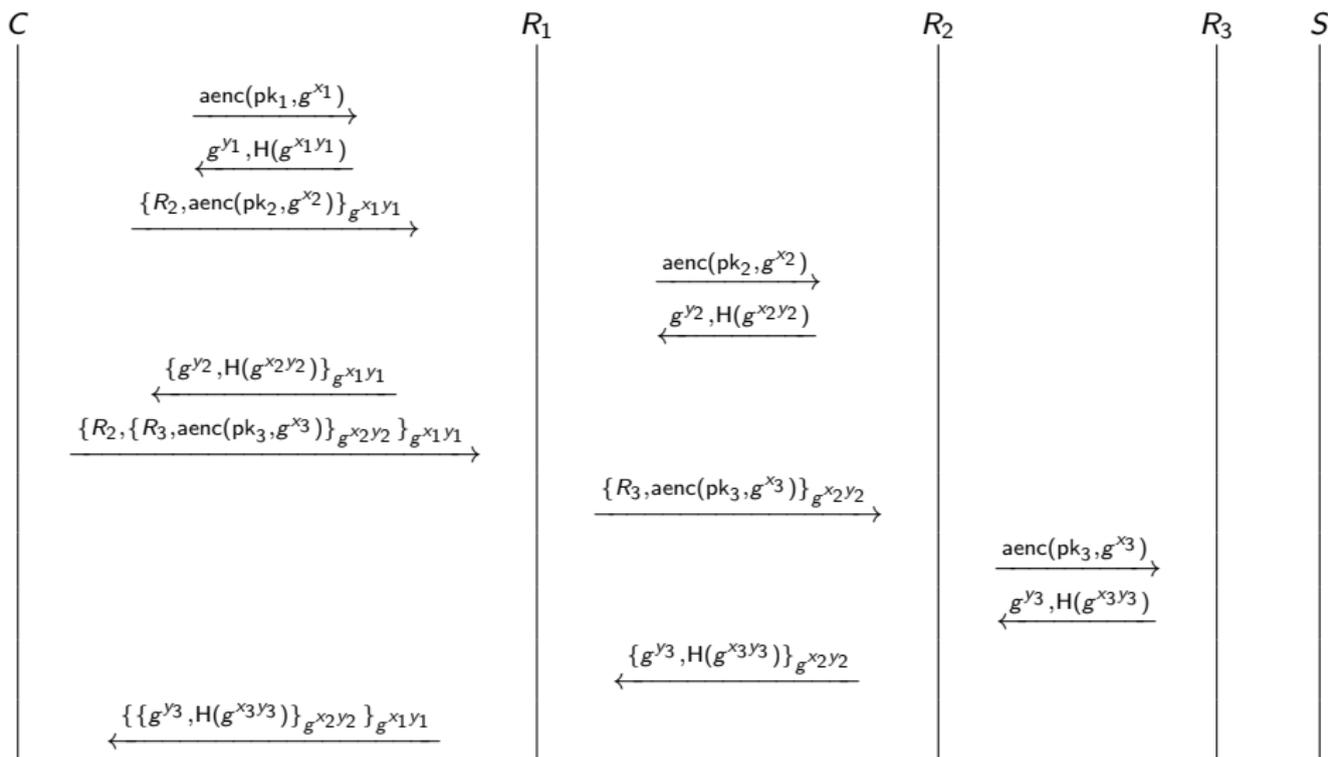
- ▶ client applications connect and communicate of established TOR circuit

TOR circuit setup

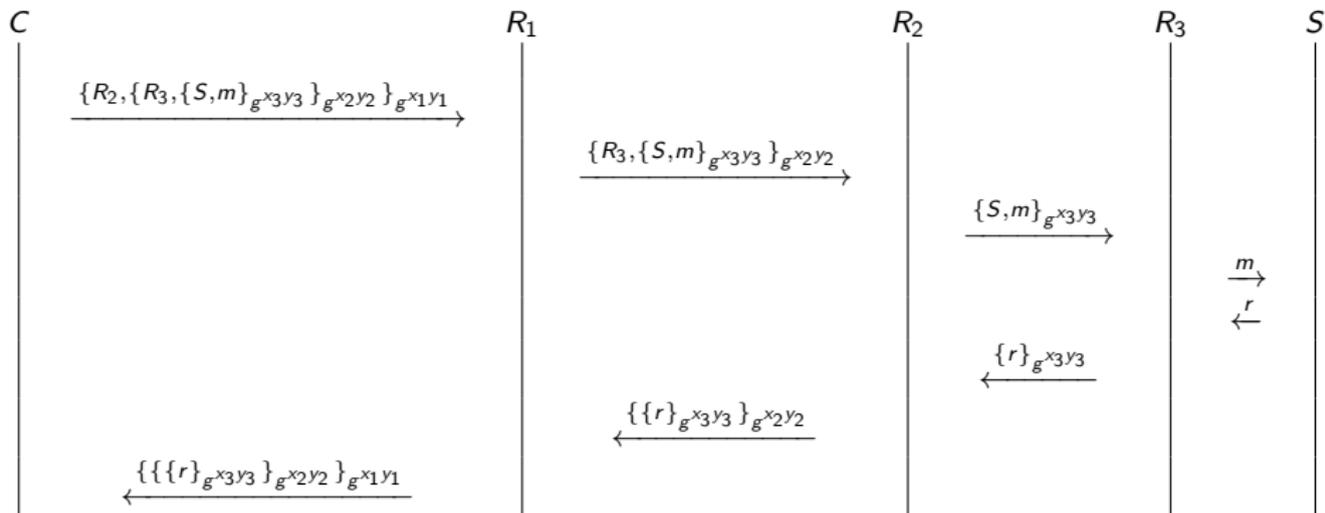


a single honest Onion Router on the TOR circuit guarantees anonymity against an attacker controlling some Onion Routers

The (simplified) TOR message flow - circuit setup



The (simplified) TOR message flow - actual communication



TOR only provides privacy - not confidentiality

- ▶ TOR anonymises the origin of the traffic
- ▶ TOR encrypts everything inside the TOR network
- ▶ but TOR **DOES NOT encrypt all traffic through the Internet**
- ▶ for confidentiality you still need to use end-to-end encryption such as **SSL/TLS**

TOR takes care of DNS resolution

- ▶ TOR only anonymises TCP streams
- ▶ But, DNS resolution is executed over UDP
- ▶ So, DNS resolution if handled by the client browser defeats the purpose of using TOR
- ▶ To avoid privacy breaches due to DNS resolution, the TOR browser delegates DNS resolution to the exit node

Avoiding censorship

- ▶ TOR relays are listed on the public TOR directory
- ▶ So your local ISP can observe that you are communicating with TOR nodes
- ▶ ISPs and governments can try to block access to the TOR network by blocking TOR relays
- ▶ TOR bridge relays are relays not listed on the public TOR directory
- ▶ Entering the TOR network through a TOR bridge relay can prevent ISPs and governments blocking access to the TOR network

Limitations of TOR

- ▶ TOR does not provide protection against end-to-end timing attacks
- ▶ If the attacker can see both ends of the communication channel, he can correlate volume and timing information on the two sides

whatismyipaddress.com cannot tell where am I using TOR

The screenshot shows the website whatismyipaddress.com in a browser window. The page title is "How you connect to the world". The navigation menu includes: MY IP, IP LOOKUP, SPEED TEST, BLACKLIST CHECK, TRACE EMAIL, CHANGE IP, HIDE IP, IP TOOLS, LEARN, and COMMUNITY. On the left sidebar, there are links for IP Lookup, Trace Email, Hide IP, VPN Comparison, Blacklist Check, Speed Test, and IP Tools. The main content area displays "Your IPv4 Address Is: 89.234.157.254" under the heading "Your IP Details:". Below this, it lists "ISP: OPDOP SCIC" and "Services: Tor Exit Node". A yellow banner says "Don't want this known? Hide your IP details". A blue box contains the message "Javascript disabled or geolocation map not available." Below this, it says "Location not accurate? Update your IP location" and provides a "Learn More About This IP" link. On the right, there is a social media section for "WhatsMyIPAddress.c..." with "Like Page" and "244K likes". At the bottom right, there is a "Check out our new Learning Center" link and a "Learn more about IP addresses, staying safe online, general computer" text next to a globe icon.

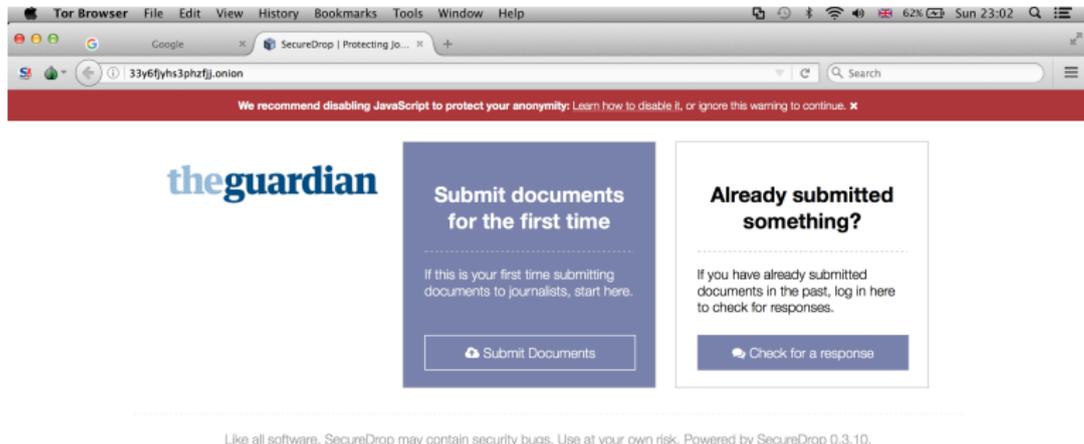
google.com thinks I'm in the Netherlands using TOR

The screenshot shows a Tor Browser window with the Google.de search page. A tooltip is open, displaying the selected Tor circuit for the site (google.de):

- This browser
- United Kingdom (163.172.21.117)
- France (91.121.23.100)
- Netherlands (46.166.148.177)
- Internet

The search page features a search bar, a search button, and a "Google-Suche" button. Below the search bar, there is a link to "Google.de angeboten auf: English". At the bottom of the page, there is a "Hinweise zum Datenschutz bei Google" section with buttons for "SPÄTER ERINNERN" and "JETZT ANSEHEN". The footer contains links for "Werbeprogramme", "Unternehmen", "Über Google", "Datenschutzerklärung", "Nutzungsbedingungen", and "Einstellungen".

TOR hidden services



The screenshot shows a Tor Browser window with the address bar displaying "SecureDrop | Protecting Jo...". The page content includes the Guardian logo, a "Submit documents for the first time" button, and an "Already submitted something?" button. A red warning banner at the top of the page reads: "We recommend disabling JavaScript to protect your anonymity: Learn how to disable it, or ignore this warning to continue. X". Below the main content, a disclaimer states: "Like all software, SecureDrop may contain security bugs. Use at your own risk. Powered by SecureDrop 0.3.10."

- ▶ TOR can also provide anonymity to websites and servers
- ▶ `www.torproject.org/docs/hidden-services.html`