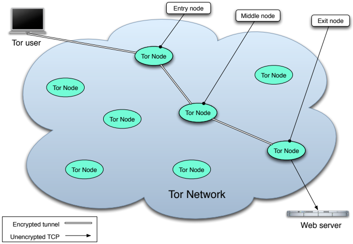
# Anonymity Systems Requirements and Architecture



Steven J. Murdoch

`http://www.cl.cam.ac.uk/users/sjm217/`

SecAppDev, 25 February 2010, Leuven, BE

# Anonymous communications

- Anonymous communication systems allow people to communicate without giving away their identity (in practice, IP address)
- Sometimes used in their own right: e.g. for browsing the Internet
- Sometimes used with other privacy enhancing technologies: e.g. Private Information Retrieval, Anonymous credentials
- One growing use is censorship resistance

# Construction of the Internet

- Internet Service Providers (ISPs) give people access to the Internet, and allow people to host services such as websites
- ISPs connect to other ISPs so the customers of one ISP can communicate with those of others
- Some ISPs have international connections, others use those of the bigger ISPs
- ISPs are typically based in one country and governed by the laws of that country
- Often governments control international Internet connections, either directly or via regulation

# Construction of the Internet

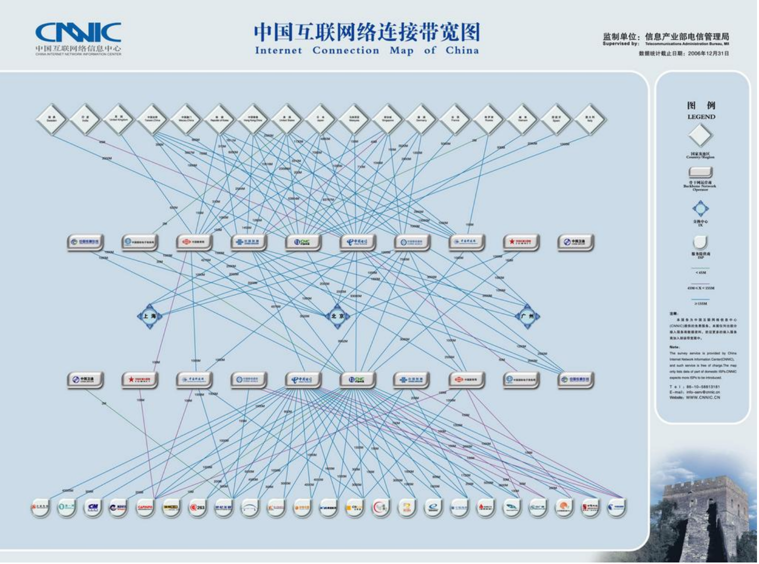

CNNIC
中国互联网络信息中心
CHINA INTERNET NETWORK INFORMATION CENTER
中国互联网络连接带宽图
Internet Connection Map of China
监制单位：信息产业部电信管理局
Supervised by: Telecommunications Administration Bureau, MII
数据统计截止日期：2006年12月31日
上海
北京
广州
图 例
LEGEND
国家及地区
Country/Region
骨干网运营商
Backbone Network Operator
交换中心
IX
服务提供商
ISP
<45M
45M≤X<155M
≥155M
Note:
The survey service is provided by China Internet Network Information Center(CNNIC), and such service is free of charge.The map only lists data of part of domestic ISPs.CNNIC expects more ISPs to be introduced.
Tel: 86-10-58813181
E-mail: info-serv@cnnic.cn
Website: WWW.CNNIC.CN

Diagram: China Internet Network Information Center

# What is being blocked, and why

- Out of the 40 countries studied by the OpenNet Initiative in 2006, 26 censored the Internet in some way
- The types of material censored varied depending on country, e.g.:
  - Human Rights (blocked in China)
  - Religion (blocked in Saudi Arabia, UAE, Iran, Bahrain)
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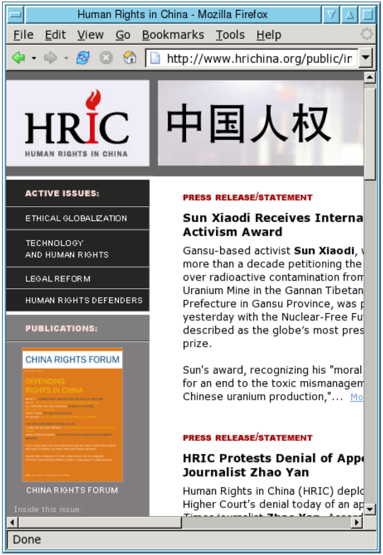
- Other issues censored include: military and militant websites; sex education, alcohol/drugs, music; gay and lesbian websites; news



PRESS RELEASE/STATEMENT

**Sun Xiaodi Receives Interna Activism Award**

Gansu-based activist **Sun Xiaodi**, v more than a decade petitioning the over radioactive contamination from Uranium Mine in the Gannan Tibetan Prefecture in Gansu Province, was p yesterday with the Nuclear-Free Fu described as the globe's most pres prize.

Sun's award, recognizing his "moral for an end to the toxic mismanagem Chinese uranium production,"... Mo

PRESS RELEASE/STATEMENT

**HRIC Protests Denial of Appe Journalist Zhao Yan**

Human Rights in China (HRIC) deplo Higher Court's denial today of an ap

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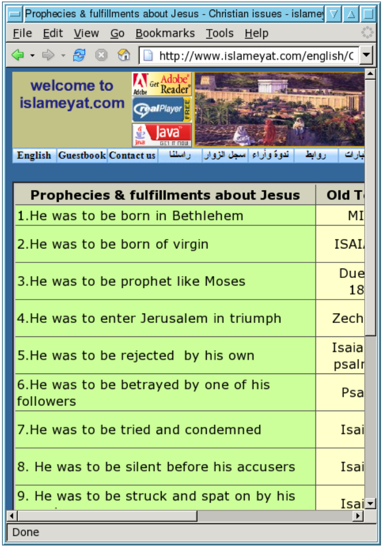
Prophecies & fulfillments about Jesus - Christian issues - islame
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RealPlayer FREE
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English
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Contact us
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سجل الزوار
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بارك
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| Prophecies & fulfillments about Jesus | Old T |
|---|---|
| 1.He was to be born in Bethlehem | MI |
| 2.He was to be born of virgin | ISAI |
| 3.He was to be prophet like Moses | Due<br>18 |
| 4.He was to enter Jerusalem in triumph | Zech |
| 5.He was to be rejected by his own | Isaia<br>psalr |
| 6.He was to be betrayed by one of his followers | Psa |
| 7.He was to be tried and condemned | Isai |
| 8. He was to be silent before his accusers | Isai |
| 9. He was to be struck and spat on by his | Isai |

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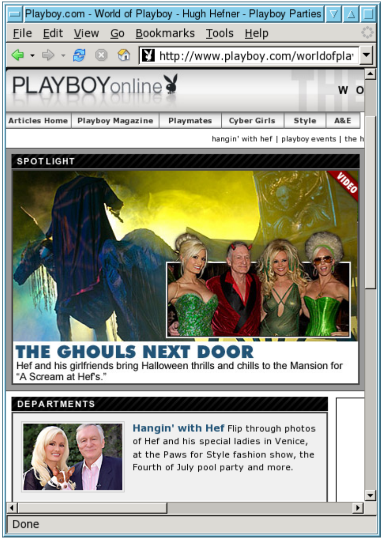
Playboy.com - World of Playboy - Hugh Hefner - Playboy Parties
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http://www.playboy.com/worldofpla
PLAYBOYonline
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Playboy Magazine
Playmates
Cyber Girls
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VIDEO
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THE GHOULS NEXT DOOR

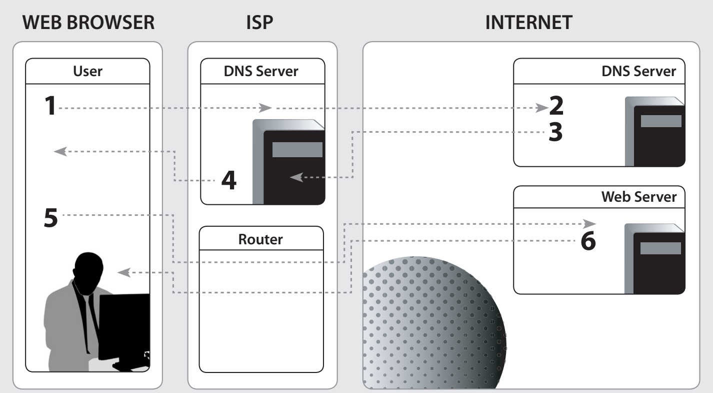
Hef and his girlfriends bring Halloween thrills and chills to the Mansion for "A Scream at Hef's."

**Hangin' with Hef** Flip through photos of Hef and his special ladies in Venice, at the Paws for Style fashion show, the Fourth of July pool party and more.

# Blocking with technology

- When a country’s government controls international connectivity, they can block requests for banned websites
- There are a number of different approaches (DNS blocking, IP address blocking, etc.)
- Software may be produced in-country, but often is an adapted commercial product
- These companies not only make the software, but provide a continuously updated list of websites to be blocked

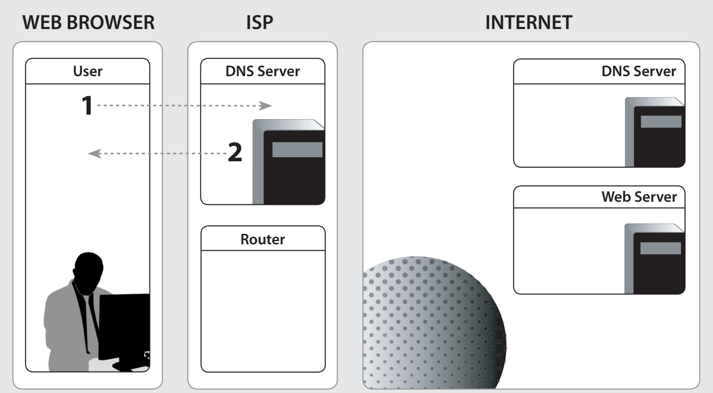
# Normal web browsing



1. User requests www.example.org/page.html
2. DNS lookup for www.example.org
3. Lookup response: www.example.org is 192.0.2.166
4. www.example.org is 192.0.2.166
5. Get web page: www.example.org/page.html at 192.0.2.166
6. Here is www.example.org/page.html

Diagram: Jane Gowan

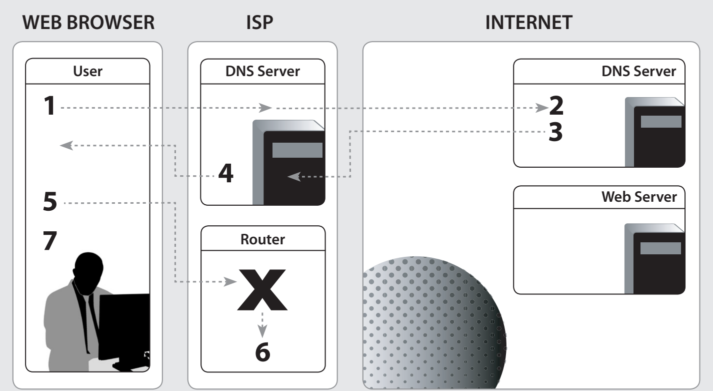
# DNS tampering



**1.** User requests www.example.org/page.html
**2.** DNS response: www.example.org does not exist

Diagram: Jane Gowan

# IP blocking



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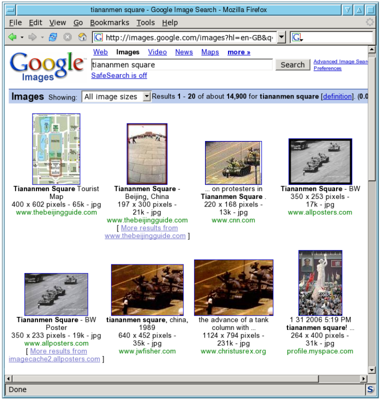
4. www.example.org is 192.0.2.166
5. Get web page: www.example.org/page.html at 192.0.2.166
6. Router drops all packets to 192.0.2.166
7. Browser concludes that www.example.org is inaccessible

Diagram: Jane Gowan

# Tradeoffs in blocking systems

- DNS blocking
  - Easy and cheap to implement
  - Blocks at domain name granularity – overblocks protocols, webpages
  - Trivial to bypass
- IP blocking
  - Easy and cheap to implement
  - Blocks at IP address (perhaps port) – overblocks virtual hosting
- Proxy blocking
  - Expensive to implement
  - Blocks at webpage level – low overblocking
- Hybrid blocking – IP based redirection to proxy
  - Tricky to get right, but cheap
  - Has some vulnerabilities
  - Blocks at webpage level – low overblocking

# Even if a site is accessible, it may be removed from search engine results


tiananmen square - Google Image Search - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
Web Images Video News Maps more »
Google Images
Search
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Preferences
Images
Showing:
All image sizes
Done

http://images.google.com/images?hl=en-GB&q=

tiananmen square

SafeSearch is off

Results **1** - **20** of about **14,900** for **tiananmen square** [definition]. (0.0

**Tiananmen Square** Tourist Map
400 x 602 pixels - 65k - jpg
www.thebeijingguide.com

**Tiananmen Square** - Beijing, China
197 x 300 pixels - 21k - jpg
www.thebeijingguide.com
[ More results from www.thebeijingguide.com ]

... on protesters in **Tiananmen Square** .
220 x 168 pixels - 13k - jpg
www.cnn.com

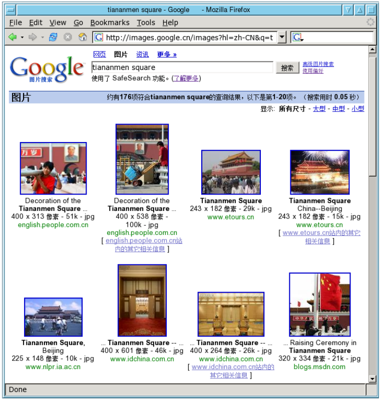
**Tiananmen Square** - BW
350 x 253 pixels - 17k - jpg
www.allposters.com

**Tiananmen Square** - BW Poster
350 x 233 pixels - 19k - jpg
www.allposters.com
[ More results from imagecache2.allposters.com ]

**tiananmen square**, china, 1989
640 x 452 pixels - 35k - jpg
www.jwfisher.com

the advance of a tank column with ...
1124 x 794 pixels - 231k - jpg
www.christusrex.org

1 31 2006 5:19 PM **tiananmen square**! ...
264 x 400 pixels - 31k - jpg
profile.myspace.com


tiananmen square - Google - Mozilla Firefox
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网页 图片 资讯 更多 »
Google 图片搜索
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http://images.google.cn/images?hl=zh-CN&q=t

tiananmen square

使用了 SafeSearch 功能。(了解更多)

约有**176**项符合**tiananmen square**的查询结果，以下是第**1**-**20**项。（搜索用时 **0.05** 秒）

显示: **所有尺寸** - 大型 - 中型 - 小型

Decoration of the **Tiananmen Square** ...
400 x 313 像素 - 51k - jpg
english.people.com.cn

Decoration of the **Tiananmen Square** ...
400 x 538 像素 - 100k - jpg
english.people.com.cn
[ english.people.com.cn站内的其它相关信息 ]

**Tiananmen Square**
243 x 182 像素 - 29k - jpg
www.etours.cn

**Tiananmen Square** China--Beijing
243 x 182 像素 - 15k - jpg
www.etours.cn
[ www.etours.cn站内的其它相关信息 ]

**Tiananmen Square,** Beijing
225 x 148 像素 - 10k - jpg
www.nlpr.ia.ac.cn

... **Tiananmen Square** -- ...
400 x 601 像素 - 46k - jpg
www.idchina.com.cn

... **Tiananmen Square** -- ...
400 x 264 像素 - 26k - jpg
www.idchina.com.cn
[ www.idchina.com.cn站内的其它相关信息 ]

... Raising Ceremony in **Tiananmen Square**
320 x 334 像素 - 21k - jpg
blogs.msdn.com

Searching for “Tiananmen Square” on Google.com and Google.cn

# Limitations of blocking

- Censorship systems block legitimate content and fail to block banned content
- It is fairly easy for readers and publishers to circumvent the technical measures
- Building and maintaining censorship systems is expensive
- Blocking one type of content encourages other types to be blocked
- Often the process of censorship is not transparent

Photograph: David Gaya

# Blocking through laws, fear, and intimidation

- ISPs may be forced to block sites themselves, or implement self-regulation
- People can be intimidated into not testing rules through fear of detection and retribution
- These may be through laws, social pressure or extra-legal punishment
- All these approaches may be used at the same time, and complement each other

# Censorship resistance system requirements

- Software to resist censorship should
  - Hide where user is visiting (to prevent blocking)
  - Hide who the user is (to protect them from intimidation)
- These properties should be maintained even if the censorship resistance system is partially compromised

Tor

The Freenet Project
http://freenetproject.org/

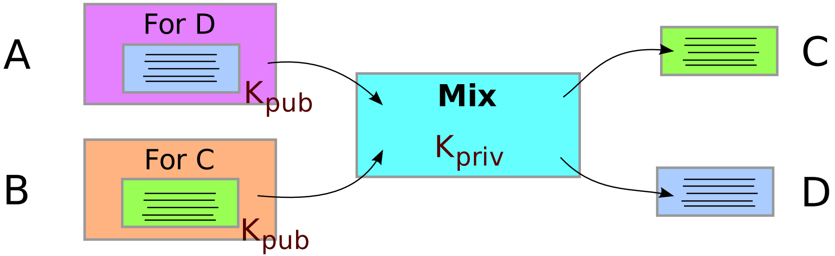
psiphon

# There are many other reasons why people might want privacy

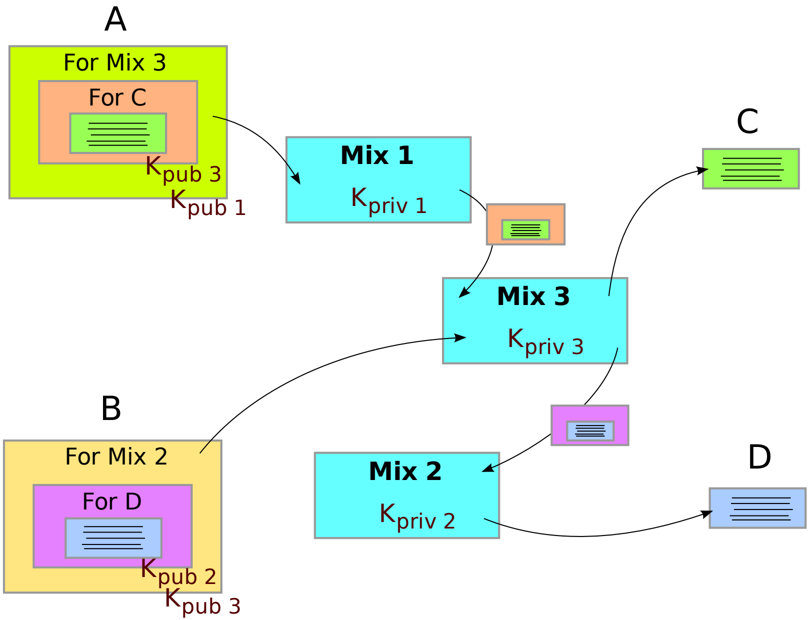
- Ordinary people
  - To avoid personal information being sold to marketers
  - Protect themselves when researching sensitive topics
- Militaries and law enforcement
  - To carry out intelligence gathering
  - Protect undercover field agents
  - Offer anonymous tip lines
- Journalists
  - To protect sources, such as whistle blowers
- Human rights workers
  - To publicise abuses and protect themselves from surveillance
  - Blogging about controversial subjects
- Businesses
  - To observe their competition and build anonymous collaborations

# Anonymous communication

- People have to hide in a crowd of other people ("anonymity loves company")
- The goal of the system is to make all users look as similar as possible, to give a bigger crowd
- Hide who is communicating with whom
- Layered encryption and random delays hide correlation between input traffic and output traffic



# Remailers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For Mix 3
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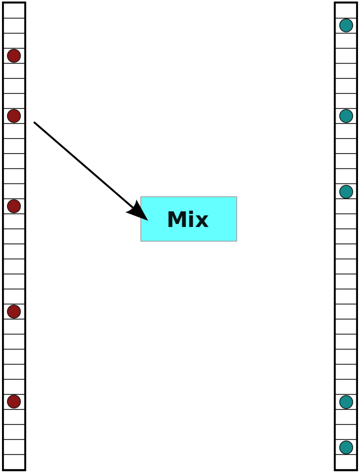
Mix 1
$K_{priv\ 1}$
C
Mix 3
$K_{priv\ 3}$
B
For Mix 2
For D
$K_{pub\ 2}$
$K_{pub\ 3}$
Mix 2
$K_{priv\ 2}$
D

# Threshold mix



- In each round, the “threshold mix” accepts a fixed number of messages
- Once the number of messages reaches the “batch size” the mix flushes and sends them all, in a random order
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- After observing one round, the attacker knows the set of senders and receivers, but not who sent each message

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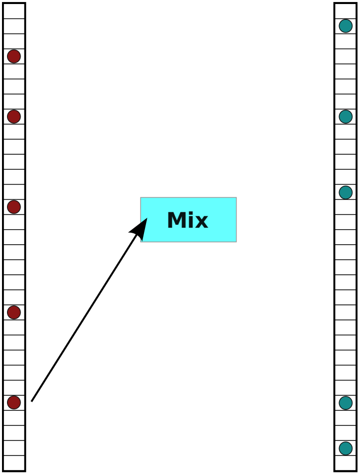

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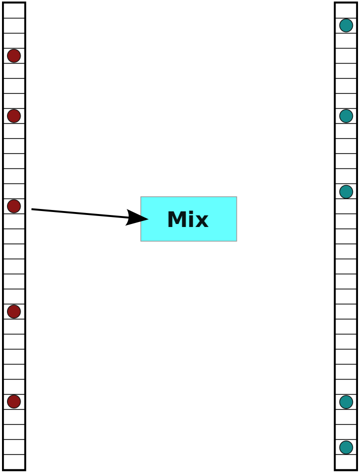

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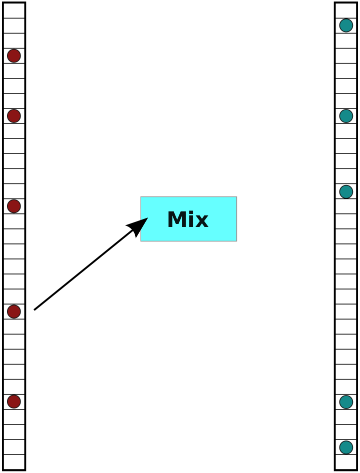

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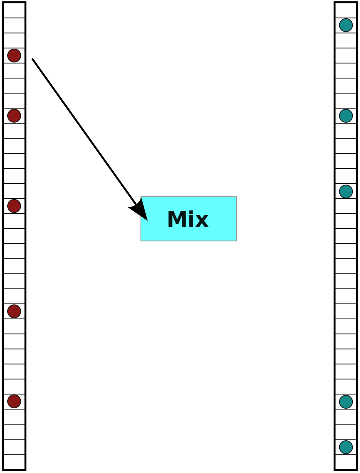

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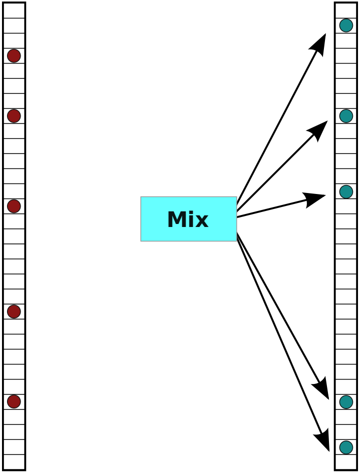

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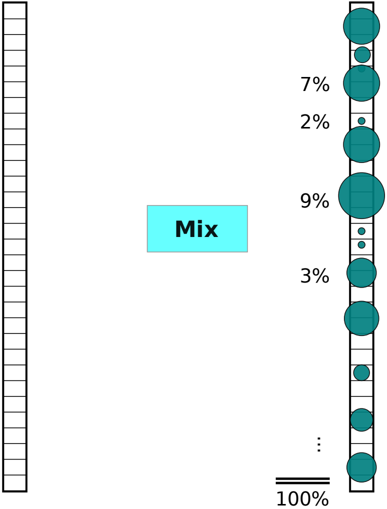
# Traffic Analysis

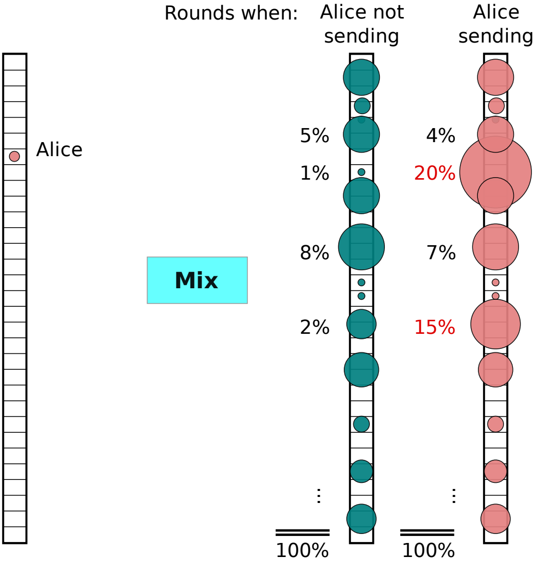


- By observing traffic over many rounds, the adversary can count each recipient's share of the messages received
- Some users will receive more messages than others
- These users may be of interest, so the target of further investigation
- e.g. Bob's share is:

$$\frac{\text{messages received by Bob}}{\text{messages received in total}}$$

over all rounds

# Tracking Alice’s Contacts



- Can observe each Bob’s share in both rounds where Alice was sending, and rounds where she was not
- Recipients whose share jumps when Alice is sending are likely Alice’s friends
- Score = (Bob’s share in rounds where Alice is sending) − (Bob’s share in rounds where Alice **not** sending)

# Anonymity systems exist for hiding both email and web traffic

- Hiding web traffic is a fundamentally more difficult problem than hiding email
- Anonymity is achieved by making all traffic look the same (padding) and hiding timing correlations (delays)
- Web traffic is very variable (few kB to few GB): so padding doesn't work well
- Long latencies would be intolerable for interactive traffic: so adding delays don't work well
- However it is not all bad: anonymity needs other users to hide in
- There is much more web traffic than there is email, so this partially makes up for the lower security

# Tor is a low-latency anonymity system

- Based on technology developed in the Onion Routing project
- Commonly used for web browsing (works for any TCP traffic)
- Originally built as a pure anonymity system (hides who is talking to whom)
- Now designed to resist censorship too (hides whether someone is using the system at all)
- Centralised directory authorities publish a list of all servers

# Tor hides communication patterns by relaying data through volunteer servers

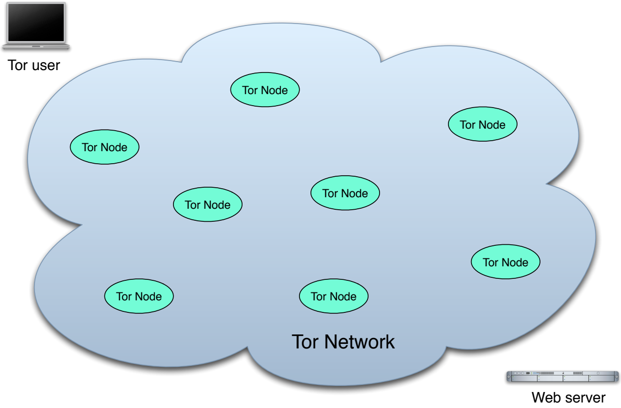


Diagram: Robert Watson

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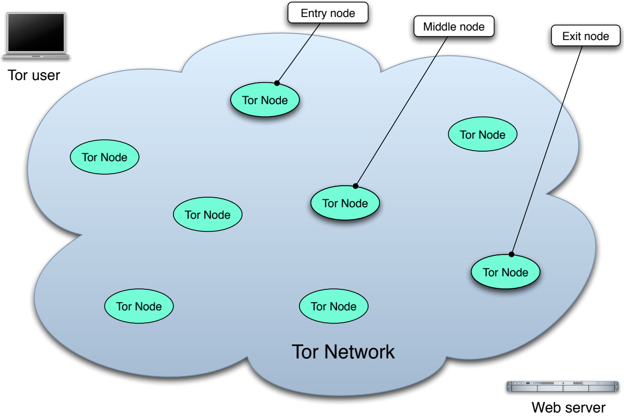

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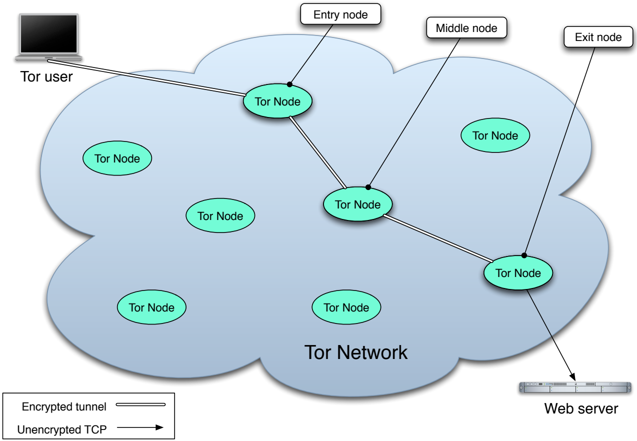
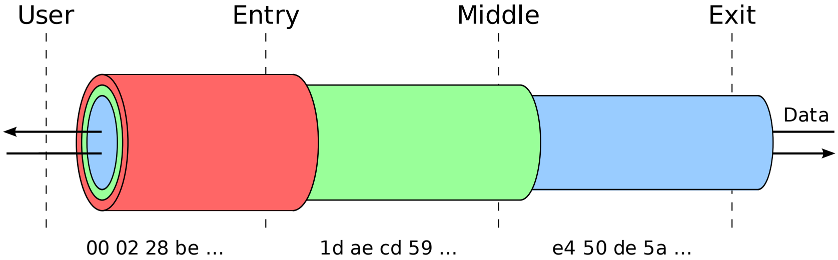


Diagram: Robert Watson

# Tor uses two types of encryption



Circuit encryption unlinks data entering and leaving a server

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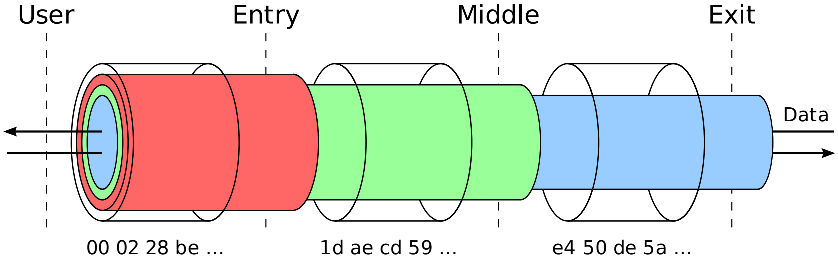

Circuit encryption unlinks data entering and leaving a server
Link encryption (TLS) disguises individual circuits

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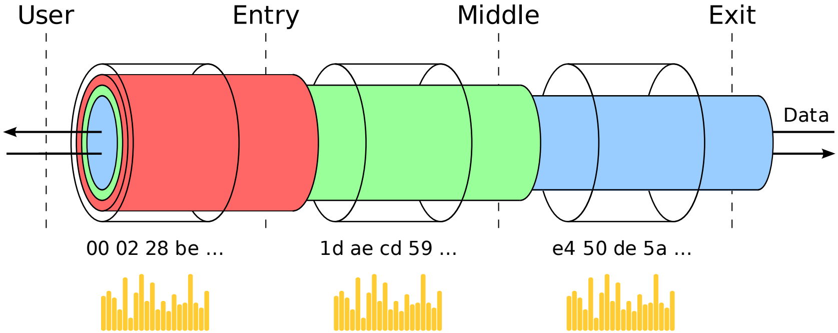
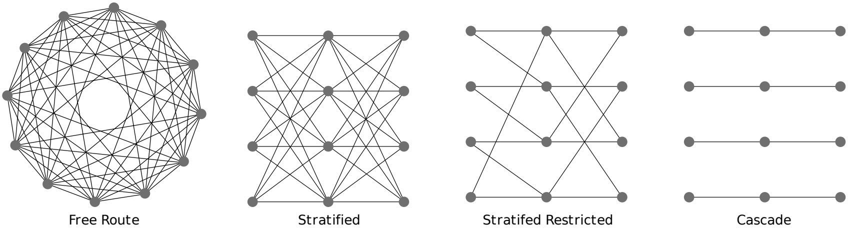


Circuit encryption unlinks data entering and leaving a server
Link encryption (TLS) disguises individual circuits
But data rate is unchanged so traffic analysis can correlate flows

# Architectural options: traffic analysis resistance

- Resisting traffic analysis comes with a cost
- It requires either long delays, lots of padding, dropping messages, or some combination of these
- Even performing these steps is not sufficient against an adversary who can infiltrate the network
- Delays are used for email anonymous communication systems (e.g. MixMinion and MixMaster)
- Padding and dropping are not used in any widely deployed system
- Tor gains resistance by being well used and widely distributed

# Architectural options: topology



Choosing how nodes can connect to other nodes affects:

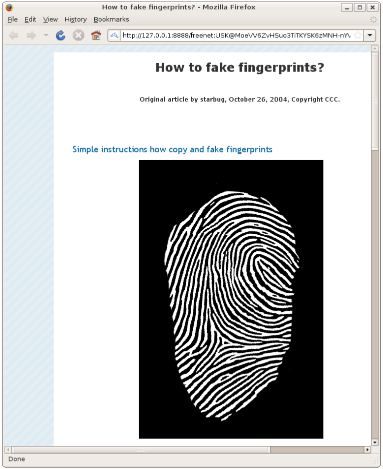
- Performance
- Security
- Scalability

# Architectural options: path selection

- Different anonymity systems take different approaches to path selection
- Tor and remailers have a central database and source routing
    - Implementation is easier
    - Central database is a point of vulnerability
- P2P systems let nodes choose next hop on path
    - Reduces resistance to compromised nodes
    - Other attacks become possible

# Freenet is an anonymous content distribution network

- While Tor allows access to the Internet, Freenet creates a private network
- Users can create websites, share files and send/receive emails between other members of the network
- Content is hosted by sharing it amongst users of the network
- Users cannot select what content they host, and it is stored in an encrypted form


How to fake fingerprints? - Mozilla Firefox
File Edit View History Bookmarks
http://127.0.0.1:8888/freenet:USK@MoeVV6ZvHSuo3TiTKYSK6zMNH-nYV
Done

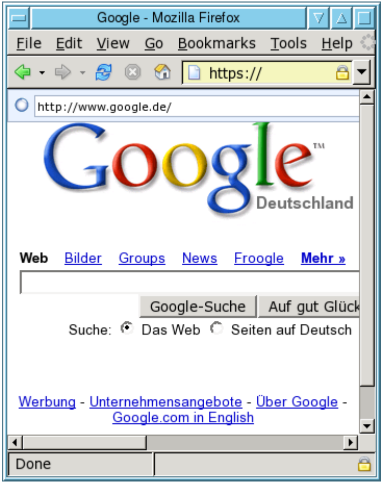
How to fake fingerprints?

Original article by starbug, October 26, 2004, Copyright CCC.

Simple instructions how copy and fake fingerprints

# Psiphon a is censorship resistance system with different tradeoffs to Tor

- There is no centralized control, so it is hard to block but also hard for user to find a server
- Users do not have to download software, but this limits the strength of protection
- If the user cannot modify browser settings or install software, Psiphon is still usable
- Users within a censored country can ask someone they trust outside of the country to install the Psiphon server


Google - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
https://
http://www.google.de/
Google
Deutschland
Web Bilder Groups News Froogle Mehr »
Google-Suche
Auf gut Glück
Suche: ● Das Web ○ Seiten auf Deutsch
Werbung - Unternehmensangebote - Über Google -
Google.com in English
Done

# Further information

“Tools and Technology of Internet Filtering”, a chapter in “Access Denied”.
`http://opennet.net/accessdenied`

“Security Engineering”, 2nd Edition (Chapter 23).
`http://www.cl.cam.ac.uk/~rja14/book.html`

The anonymity bibliography
`http://www.freehaven.net/anonbib/`

The Tor Project website
`https://www.torproject.org/`

A copy of these slides will be available
`http://www.cl.cam.ac.uk/~sjm217/`