Examining How
The Great Firewall Discovers
Hidden Circumvention Servers

Roya Ensafi, David Fifield, Philipp Winter, Nick Feamster,
Nicholas Weaver, and Vern Paxson

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How do governments find these proxies?
How GFW Discovers Hidden Circumvention Servers

We focus on the **GFW** and **Tor**

- GFW is a *sophisticated censorship system*
- Tor has a long history of being used for *circumventing* government censorship
Censorship Arms Race: GFW vs. Tor

Use public Tor network to circumvent GFW
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Download consensus and block relays
Censorship Arms Race: GFW vs. Tor

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Introduce **private bridges**, whose distribution is **rate-limited**

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Censorship Arms Race: GFW vs. Tor

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- Introduce **private bridges**, whose distribution is **rate-limited**
- Download consensus and **block relays**
- Use **DPI** to detect Tor **TLS handshake**
Fingerprinting the Tor TLS Handshake

● TLS handshake is unencrypted and leaks information

● Tor’s use of TLS has some peculiarities
  ○ X.509 certificate life times
  ○ Cipher suites
  ○ Randomly generated server name indication (e.g., www.6qgoz6epdi6im5rvxn1x.com)

● GFW looks (at least) for cipher suites in the TLS client hello
Censorship Arms Race: GFW vs. Tor

Use **public Tor network** to circumvent GFW

Introduce **private bridges**, whose distribution is **rate-limited**

Introduce **pluggable transports** to hide the handshake such as obfs2, obfs3

Download consensus and **block relays**

Use DPI to detect Tor **TLS handshake**
Tor Pluggable Transport

- Pluggable transports are drop-in modules for traffic obfuscation
- Many modules have been written, but we focus on
  - **obfs2** (First deployed module)
    - First 20 bytes can be used to detect Tor traffic with high confidence.
  - **obfs3** (obfs2’s successor)
    - Makes Tor traffic look like a uniformly random byte stream
Censorship Arms Race: GFW vs. Tor

- Detection of pluggable transports is **uncertain**
  - Implies false positives → collateral damage
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GFW added **active probing** to complement the DPI fingerprinting
How does GFW Block Tor Hidden Circumvention Servers?

1. Network monitoring (e.g., switch mirror port)
2. DPI for suspicious traffic (e.g., cipher suite)
3. **Actively probing server to verify suspicion**
4. Blocking server
Censorship Arms Race: GFW vs. Tor

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Introduce private bridges, whose distribution is rate-limited

Introduce pluggable transports to hide the handshake such as obfs2, obfs3

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Use DPI to detect Tor TLS handshake

Use DPI + Active probing
Many Questions about Active Probing are Unanswered!

- Only two blog posts and Winter’s FOCI’12 paper
- We lack a comprehensive picture of more complicated questions

We want to know:

- **Implementation**, i.e., how does it block?
- **Architecture**, i.e., how is a system added to China’s backbone?
- **Policy**, i.e., what kind of protocols does it block?
- **Effectiveness**, i.e., what’s the degree of success at discovering Tor bridges?
Overview of Our Datasets:

Shadow Infrastructure

Amazon AWS

EC2-Vanilla
EC2-Obfs2
EC2-Obfs3

CERNET Network

Unicom ISP

Clients in China

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Sybil Infrastructure

30000
30300
30600

Forwarding 600 ports to Tor port

Vanilla Tor

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**Clients in China**

**Sybil Infrastructure**
- 30000
- 30300
- 30600

**Client in China**

**Vanilla Tor**
Forwarding 600 ports to Tor port

**Server Log Analysis**
Application logs of a web server that also runs a Tor bridge since 2010.
Overview of Our Datasets:

- For the Shadow and the Sybil datasets:
  - We had pcap files of both the clients and the bridges.
- For the Log dataset, we only had application logs.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Time span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shadow</td>
<td>Dec 2014 -- Feb 2015 (3 months)</td>
</tr>
<tr>
<td>Sybil</td>
<td>Jan 29, 2015 -- Jan 30, 2015 (20 hours)</td>
</tr>
<tr>
<td>Log</td>
<td>Jan 2010 -- Aug 2015 (5 years)</td>
</tr>
</tbody>
</table>
How to Distinguish Probers from Genuine Clients?
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  - Visited our vanilla Tor bridge after our client established connections
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● For the other datasets, we adopt an algorithm:
  ○ If the cipher suites is in the TLS client hello => Vanilla bridge probes
  ○ If the first 20 bytes can reveal Obfs2 => Obfs2 bridges probers
  ○ ...
How Many Unique Probers did We Find?

27
How Many Unique Probers did We Find?

- Using **Sybil**, **Shadow** and **Log** dataset
  - In total, we collected **16,083** unique prober IP addresses
Can We Fingerprint Active Probers?
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- **TCP layer**
  - TSval slope: timestamp clock rate
  - TSval intercept: (rough) system uptime
  - GFW likely operate a handful of physical probing systems

Shadow exp. with **158** Prober IPs

Sybil exp. with **1,182** Prober IPs

Log dataset with **14,912** Prober IPs
Can We Fingerprint Active Probers?

- **TCP layer**
  - Striking pattern in initial sequence numbers (derived from time) of 1,182 probes
  - Shared pattern in TSval for all three datasets
What do These Patterns Mean?

- Active probing connections leak shared state
  - ISNs, TSval, source ports, ...
- GFW likely operates only few physical systems
- Thousands of IP addresses are controlled by central source
How Quickly do Active Probes Show Up?
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- Sybil dataset shows that system now works in **real time**
  - Median delay between Tor connection and subsequent probing connection is ~500ms
  - 1,182 distinct probes showed up in 22 hours
Is Active Probing Successful?
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- **obfs2** and **obfs3 (~98%)** were almost always reachable for clients
  - Surprising because GFW can probe and block obfs2 and obfs3
Takeaway messages

Our results show that the active probing system

- Makes use of a large amount of IP addresses, clearly centrally controlled
  - We can not just blacklist probers’ IP addresses
- Operates in real time
- Probes Vanilla, Obfs2, and Obfs3 Bridge

Tor’s pluggable transports led to GFW’s “pluggable censorship”
Q&A

- **Project page:** [https://nymity.ch/active-probing/](https://nymity.ch/active-probing/)
- **Log** and **Sybil** data sets are available online
- **Contact:** rensafi@cs.princeton.edu
What Is the Characteristic of the Probing System?

- Sensor responsible for triggering probes operates **single-sidedly**:  
  - SYN, followed by ACK, then Tor’s TLS client hello) => trigger probe.
- The sensor does **not** seem to **robustly reassemble** TCP:  
  - The fragmented data did not trigger an active probe, which differs from the GFW
- **Traceroute** to the sensors suggested:  
  - Unicom’s sensor appears to operate on the same link as the GFW  
  - CERNET sensor appears one hop closer to our server