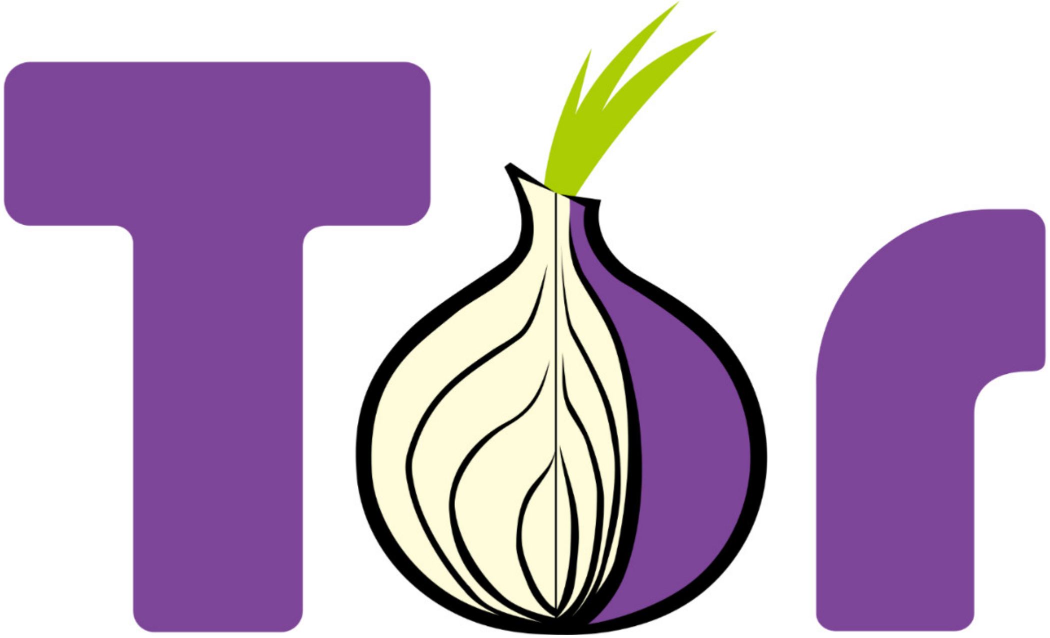

Tor

Topics

- Brief History
- What is Onion Routing?
- What is Tor?
    - How it works
    - Why do we need Tor?
    - Who uses Tor?
- Vulnerabilities
- Onion Services
- Talking to Tor
- Other privacy tools
- References

Brief History

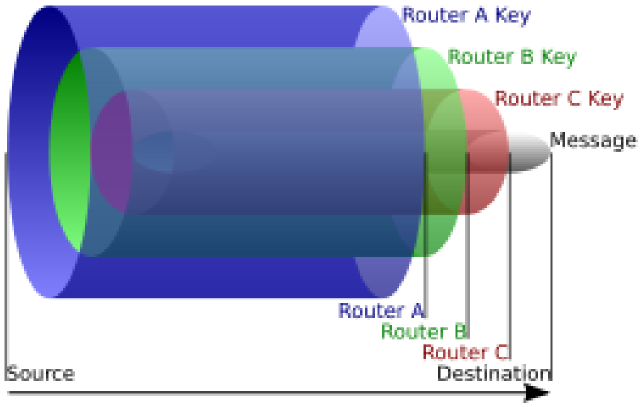
- 1995
  - Work on Onion Routing begins by the Office of Naval Research (ONR) to secure U.S. intelligence communications (Generation 0).
  - Principals involved are Paul Syverson, Michael G. Reed and David Goldschlag.
- 1996
  - Work on Generation 1 begins.
- 1998
  - Several Generation 0 and 1 networks are established. One such is a distributed network of 13 nodes with an average of over 50,000 hits a day, which maxes out the usage.
  - A commercial network called Freedom Networks was established with many similarities to Onion Routing. Differences:
    - Ran over UDP
    - Commercially funded rather than volunteer-based
    - Management to limit use to a paid subscription model
- 1999
  - Development is suspended on Onion Routing due to lack of funding and principal developers moving on to other pursuits.
- 2001
  - Development resumes after renewed funding from DARPA.
  - Freedom Network shutters from lack of commercial interest.
- 2002
  - Generation 1 code abandoned as too crufty, work begins on Generation 2.
- 2003
  - Tor deployed in October by Syverson, Roger Dingledine and Nick Mathewson with ~12 volunteer nodes, all in the U.S. but one (in Germany). All code is publicly available under the MIT license.
- 2004
  - Hidden services are deployed and the Tor design paper is published.
  - By the end of the year, there are 100 Tor nodes on three continents.
- 2006
  - Dingledine, Mathewson, et al. founded the Tor Project as a non-profit.

What is Onion Routing?

Onion Routing Design

- An overlay network.
- Onion proxy client downloads list of nodes from a directory node.
- A route is chosen at random to the destination.

  This is called the circuit and can be any number of hops.
- A layer of encryption wraps the data for each node in the circuit.
- No node knows how many nodes constitute the circuit.



- No node knows if the preceding one was the initiator or just another node in the circuit.
- Every node only knows the nodes directly before and after it.
- The only node that knows the destination address is the last, the exit node. Similarly, it's the only node that knows its place in the circuit.
- If the responder (remote host) uses TLS, the no nodes in the circuit ever knows the contents of the payload. Otherwise, the exit node can read the data.

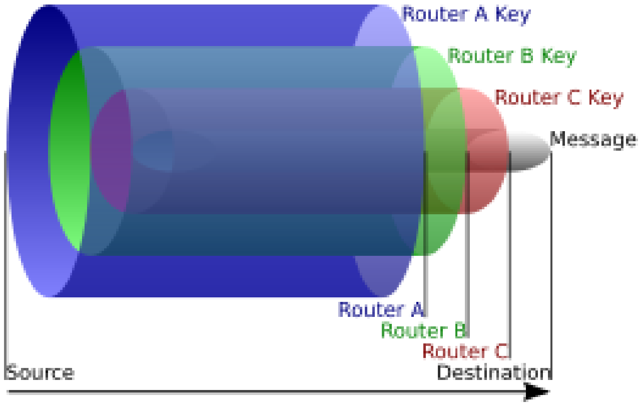
What is Tor?

The Tor Project

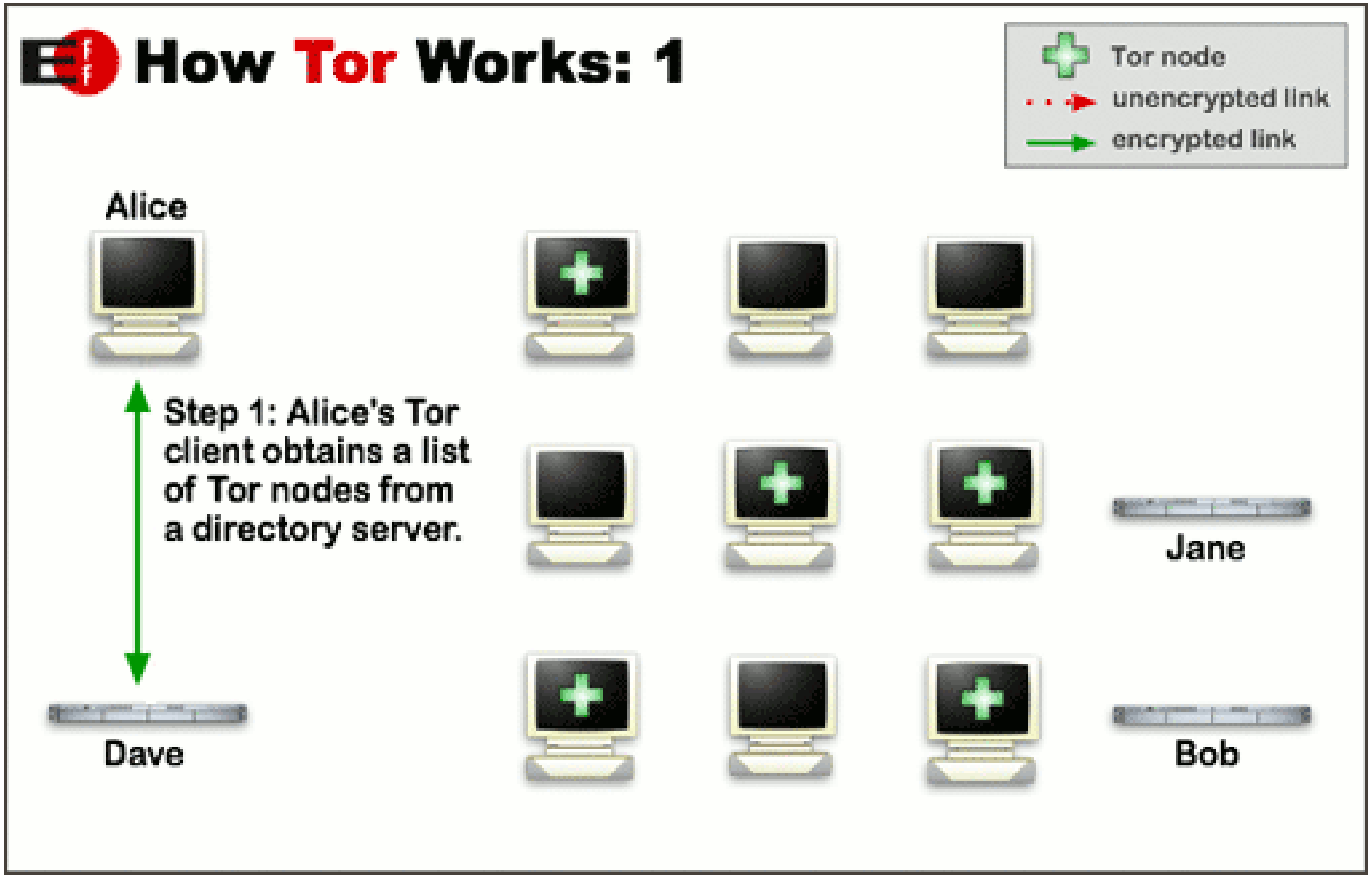
- A Massachusetts-based non-profit with a respected and well-known Board of Directors:
  - Bruce Schneier (Blowfish)
  - Matt Blaze
  - Et. al
- Funding:
  - Personal donations
  - Mozilla
  - U.S. Government (U.S. Department of State: Bureau of Democracy, Human Rights, and Labor; National Science Foundation)
  - Et. al
- An implementation of Onion Routing (2nd generation)
- Run by volunteers that donate bandwidth and processing power, i.e., relays (servers) that route the traffic through the Tor network
- Projects:
  - Tor Browser
  - Tails
  - Orbot
  - Et. al
- Open source

How it works

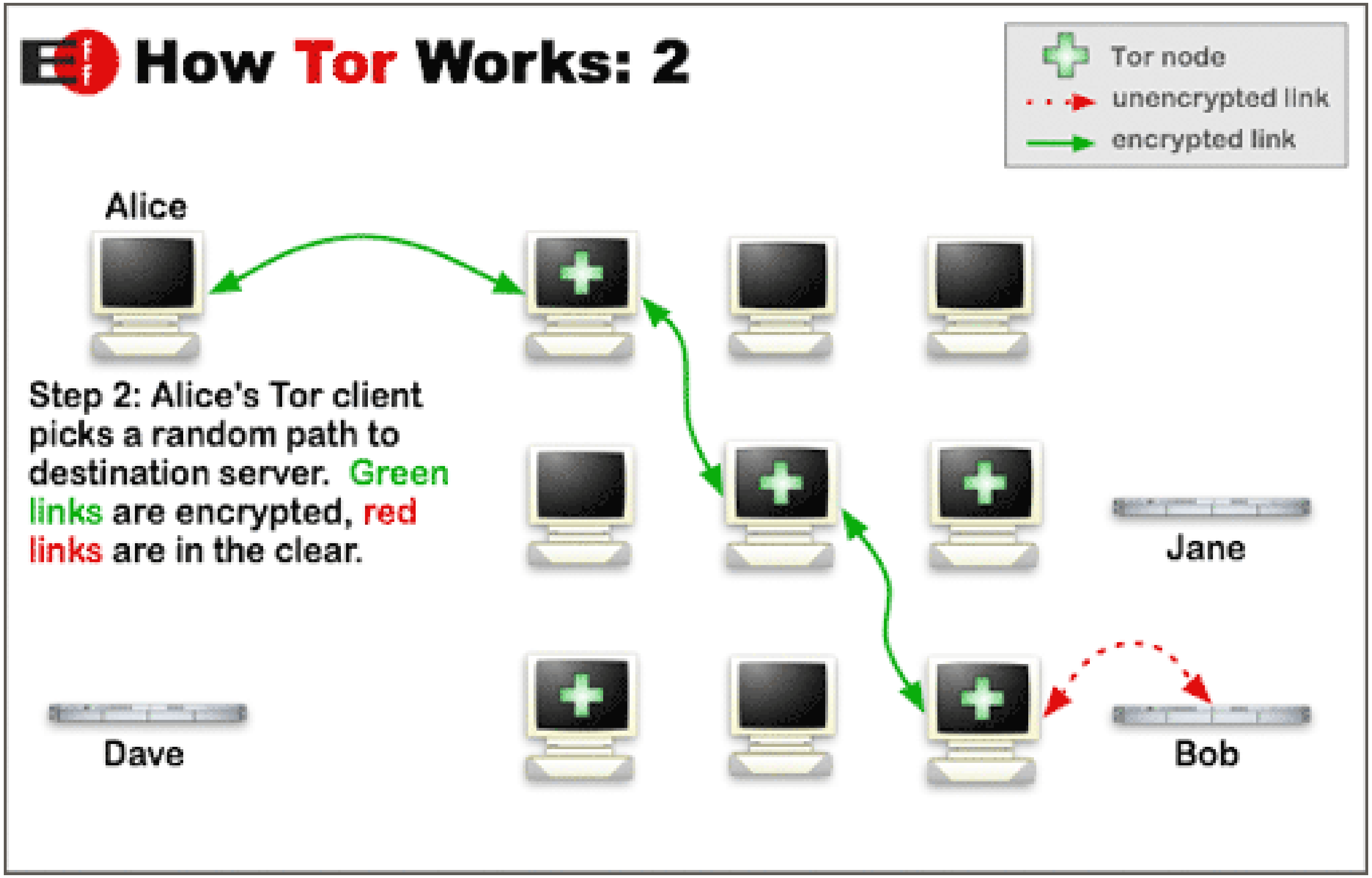
- When started, Tor will create a hidden `.tor` directory in the user's home directory, the contents of which depends upon the contents of `torrc`
- Builds a circuit of three relays (guard, middle and exit relays) between the initiator and the responder (Internet)
- Each node only knows about the relay before and after
  - The guard or entry node is the only relay that knows the true IP address of the initiator
  - The exit node is the only node that knows the destination of the responder
- Layers of encryption (*onion* routing) are generated by initiator before leaving host machine
  - Onion proxy picks a random path (circuit) to responder and generates shared keys with each onion router.
  - Onion proxy wraps layers of encryption around payload, one for each onion router.
  - Each relay unwraps a layer of encryption using shared symmetric key on transit.
  - Exit node decrypts final encryption layer and is able to read destination `TCP/IP` headers. Sends to responder over open Internet.
  - Each packet (cell) is uniform in length.



How Tor Works, Part 1

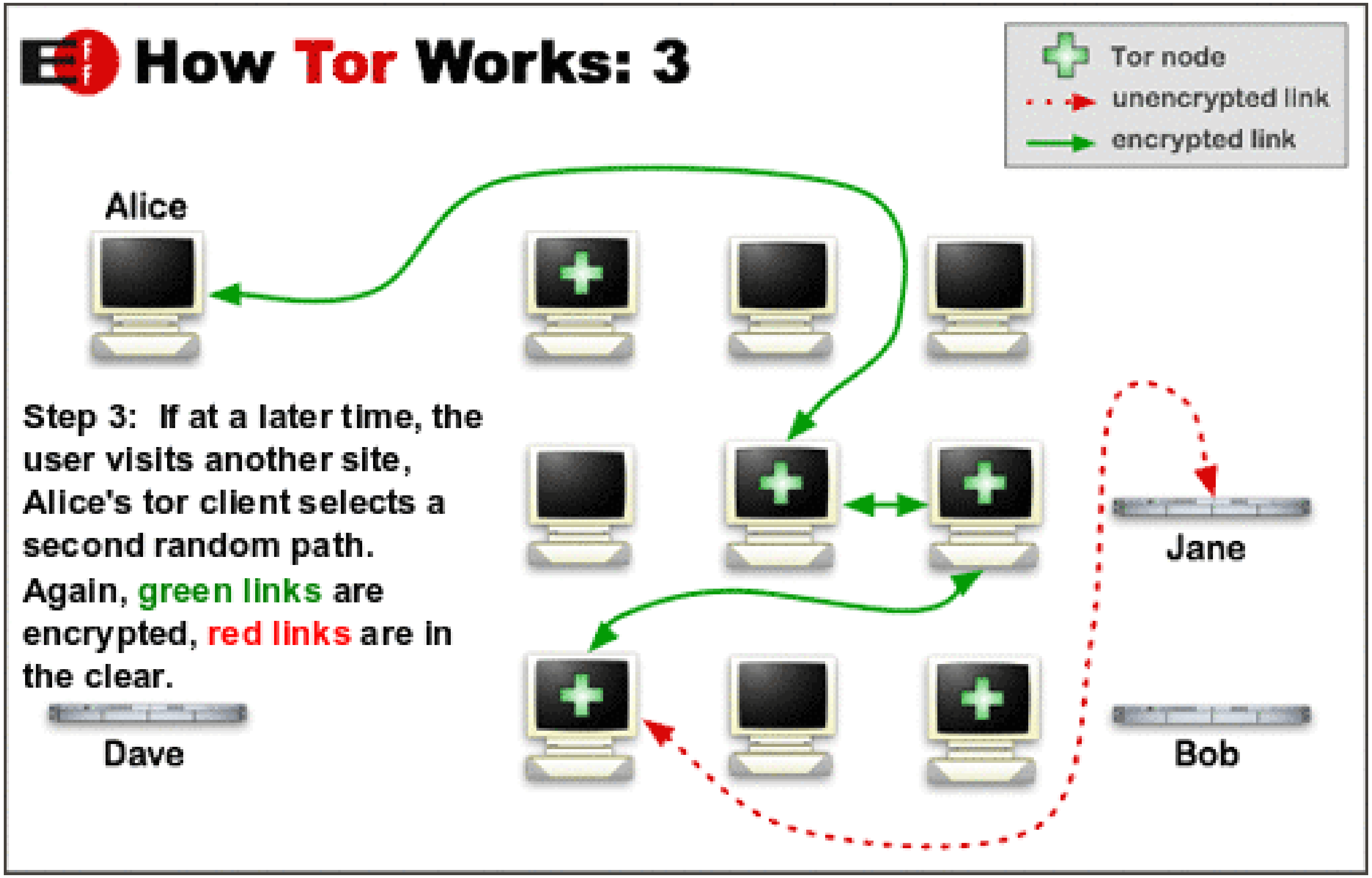

How Tor Works: 1
Tor node
unencrypted link
encrypted link
Alice
Step 1: Alice's Tor client obtains a list of Tor nodes from a directory server.
Jane
Dave
Bob

How Tor Works, Part 2



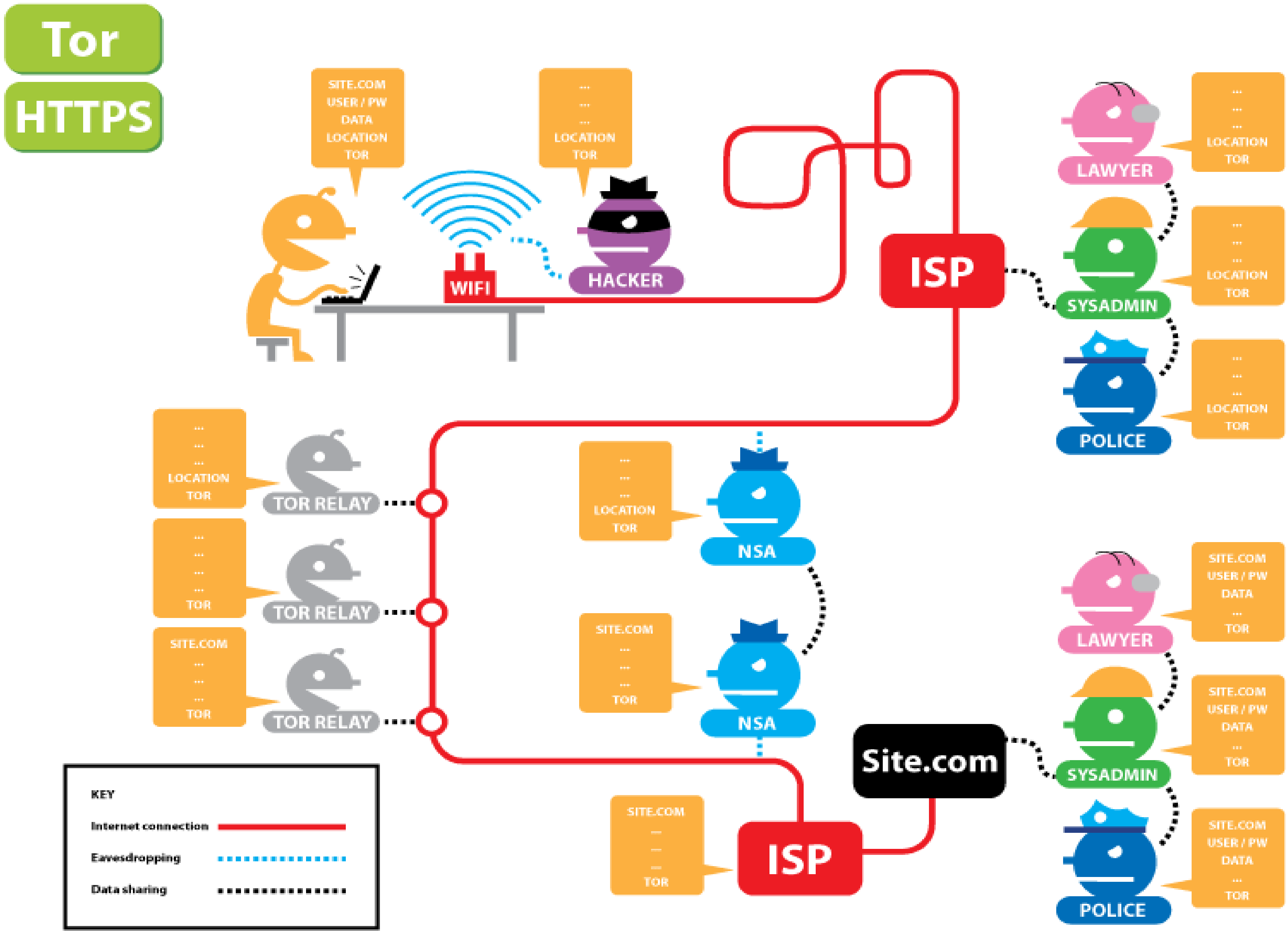
Step 2: Alice's Tor client picks a random path to destination server. Green links are encrypted, red links are in the clear.

How Tor Works, Part 3



How Tor Works: 3
Tor node
unencrypted link
encrypted link
Alice
Step 3: If at a later time, the user visits another site, Alice's tor client selects a second random path. Again, green links are encrypted, red links are in the clear.
Jane
Dave
Bob

Who can see the traffic?



Why do we need Tor?

- Provides anonymity and privacy
- First Amendment protection
- Connections should be private by default
- Best strategy currently available*

* What about VPNs? Services often lie about what they log and for how long, and they are subject to FISA warrants.

Who uses Tor?

- Regular people
  - Anyone who values privacy
  - Citizens in repressive regimes
  - Programmers and sysadmins
  - Mom and Dad
- Journalists
- Activists
- Whistleblowers and dissidents
- Governments
- Law enforcement
- Bad actors

How do I know Tor is working?

- If using Tor browser:
  - Visit https://check.torproject.org/
  - Verify IP address of exit node:
    - IP Chicken
- Verify IP address of exit node in server logs:
  - `sudo tail -f /var/log/nginx/access.log`
- Sniff traffic network traffic:
  - Localhost
    - `sudo tcpdump -nX host <ip.of.guard.node> and port 443`
  - Remote
    - `sudo tcpdump -nX host <ip.of.exit.node> and port 80`

Tor traffic can be censored

- The IP addresses of all Tor exit nodes are published, so it’s trivial to blacklist those IPs.
  - Tor bridges are the solution!
- Censors can perform deep packet inspection between the sender and the guard relay.
- Tor has developed pluggable transports so traffic between the initiator and the first hop (guard relay) can’t be identified as Tor network traffic.

What not to do when using Tor

- Use a browser other than the Tor browser!
- Download browser plugins
- Download files, i.e., pdf and Word docs whose loader programs could then leak your true IP address if the docs contain links to other resources
- Use BitTorrent
- Et al.

Vulnerabilities

Common Attack Vectors

- **Passive**
  - End-to-end timing correlation
    - An attacker watching patterns of traffic at the initiator and the responder in an attempt to correlate the two.
  - End-to-end size (packet counting) correlation
  - Website fingerprinting
    - Attacker watches encrypted traffic patterns between initiator and guard node in an attempt to identify the user.
    - Attacker builds up a database of “fingerprints” of websites containing file sizes and access patterns.
- **Active**
  - Run a hostile onion router
    - A hostile node must be immediately adjacent to both endpoints to compromise the anonymity of a circuit.
    - Occasionally, an adversary controls both end nodes but can still only correlate at most .4444% of all circuit traffic.
  - Introduce timing into messages
  - Smear attacks
    - An attacker could do socially disapproved acts to bring the network into disrepute and get its operators to shut it down.
    - Exit policies reduce the possibilities for abuse.

Traffic-Analysis Attack

- Timing-analysis attack
- Try to deduce information from patterns in data flows, i.e., timing, size (packet counting), etc. on one side of the network and look for the same patterns on the other side. This will tell an attacker the circuit a particular user is using.
    - Passive attack– Simply observe packets
    - Active attack – Alter timings of packets, inject extra packets into a data flow in a specific pattern (watermarking), etc.
- Some successful attacks of Tor have occurred in highly controlled academic environments with no timing noise added to the packets.
- Successful counter-measures include encryption, masking whereby data is continuously sent whether or not traffic is actually being transmitted (dummy traffic) and buffering to introduce delays to thwart timing analysis.
    - Adaptive Padding – add packets to flow
    - Defensive Dropping – remove added packets from flow
    - Gamma Buffering – buffer at node

Mouse Fingerprinting Attack

- Mouse movements can be unique (a fingerprint) and then used to correlate and identify a user.
- The user would have had to visit the same fingerprinting site with both the Tor browser and a non-Tor browser.
- The same researcher demonstrated that a machine can also be fingerprinted by the time it takes to run a CPU-intensive task in JavaScript.
- There are currently multiple open bug reports on the Tor bug tracker to address this.
- The best solution is to turn off JavaScript, which is a branch (or at least a leaf) on the tree of evil.

DNS Leaks

- Not an Onion Routing problem, it’s an Internet problem!
- Tor-aware applications **must** resolve DNS lookups through the Tor network.
  - Tor browser
  - tor-resolve
- What will leak?
  - Using a browser other than the Tor browser
  - Everything else that’s not torified!
    - dig, host, et al.
    - cURL
    - Etc.
  - Colanders

DNS Examples

- Leaks!

  1) dig +short benjamtoll.com
  2) curl www.benjamintoll.com
  3) curl --socks5 localhost:1080 www.benjamintoll.com
  4) curl --socks5 localhost:9050 www.benjamintoll.com

- Doesn’t leak!

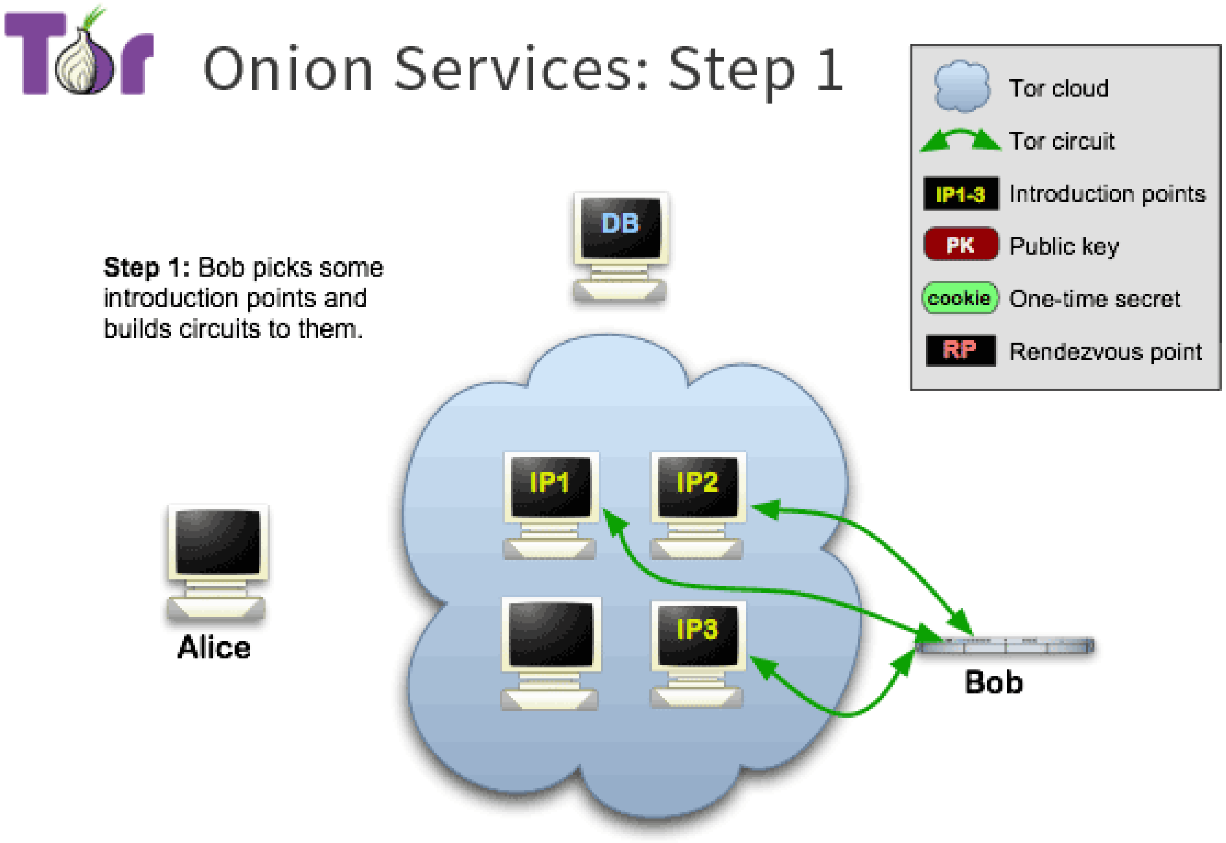
  1) tor-resolve benjamintoll.com
  2) torsocks curl www.benjamintoll.com
  3) Send through Tor network!
  4) curl --socks5-hostname localhost:9050 www.benjamintoll.com

Onion Services

http://lgewyajrjxytj4z6.onion/

- Formerly known as hidden services
- Provides end-to-end anonymity
    - Traffic never leaves the Tor network.
    - The responder is anonymous in addition to the initiator.
- Rendezvous point doesn’t know initiator, responder or message!
- Protects against DDoS attacks
    - Responder (server) is anonymized, no IP to target.
- No DNS
    - Although applications not configured properly will still leak DNS by doing a lookup!
- Harder to find sites. Most onion addresses are passed by word-of-mouth, email, posted on individual sites , etc.
    - Here are some well-known ones:
        - ProPublica
        - The Intercept SecureDrop server
        - DuckDuckGo
        - Ahmia
        - Silk Road (defunct)
- The “Dark Web”

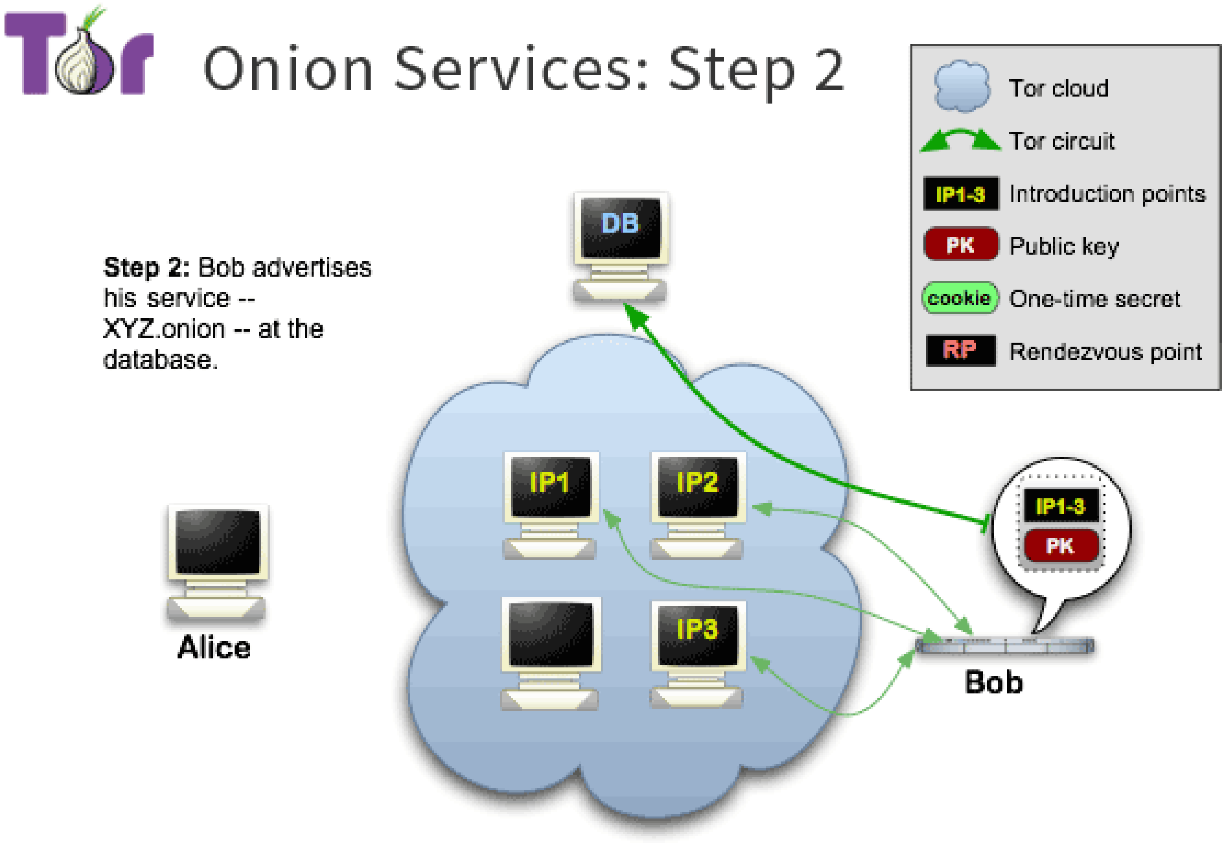
1) Select the introduction points



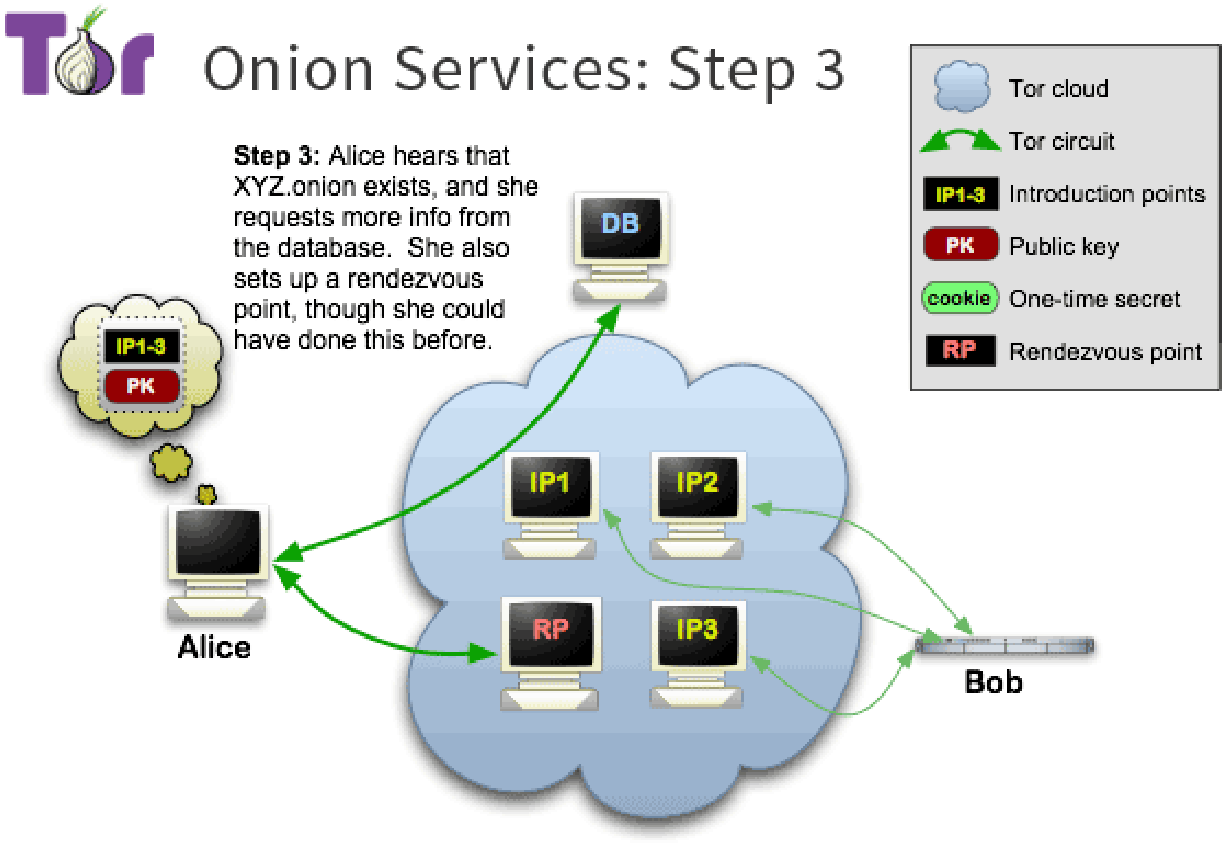
Onion Services: Step 1

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

2) Advertise that the service is available



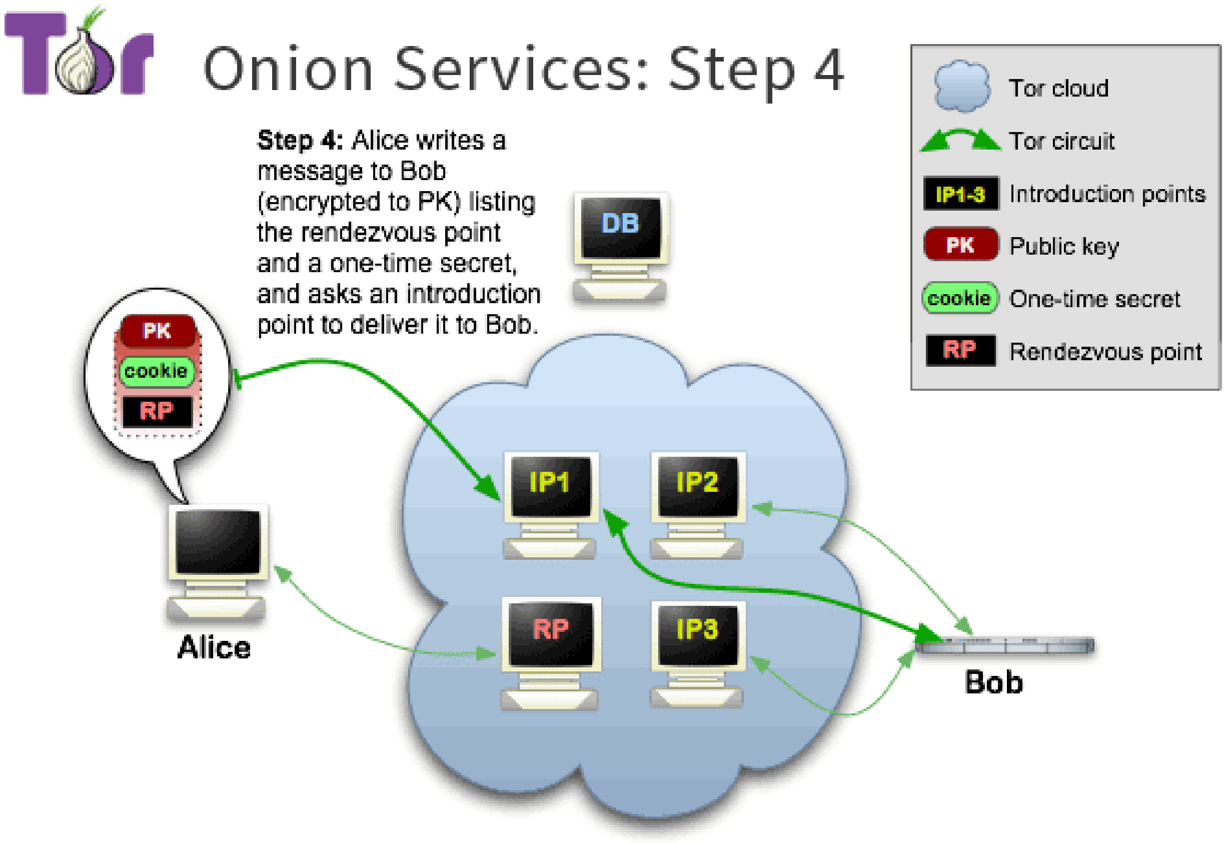
3) The client downloads the descriptor and sets up a rendezvous point



Onion Services: Step 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.

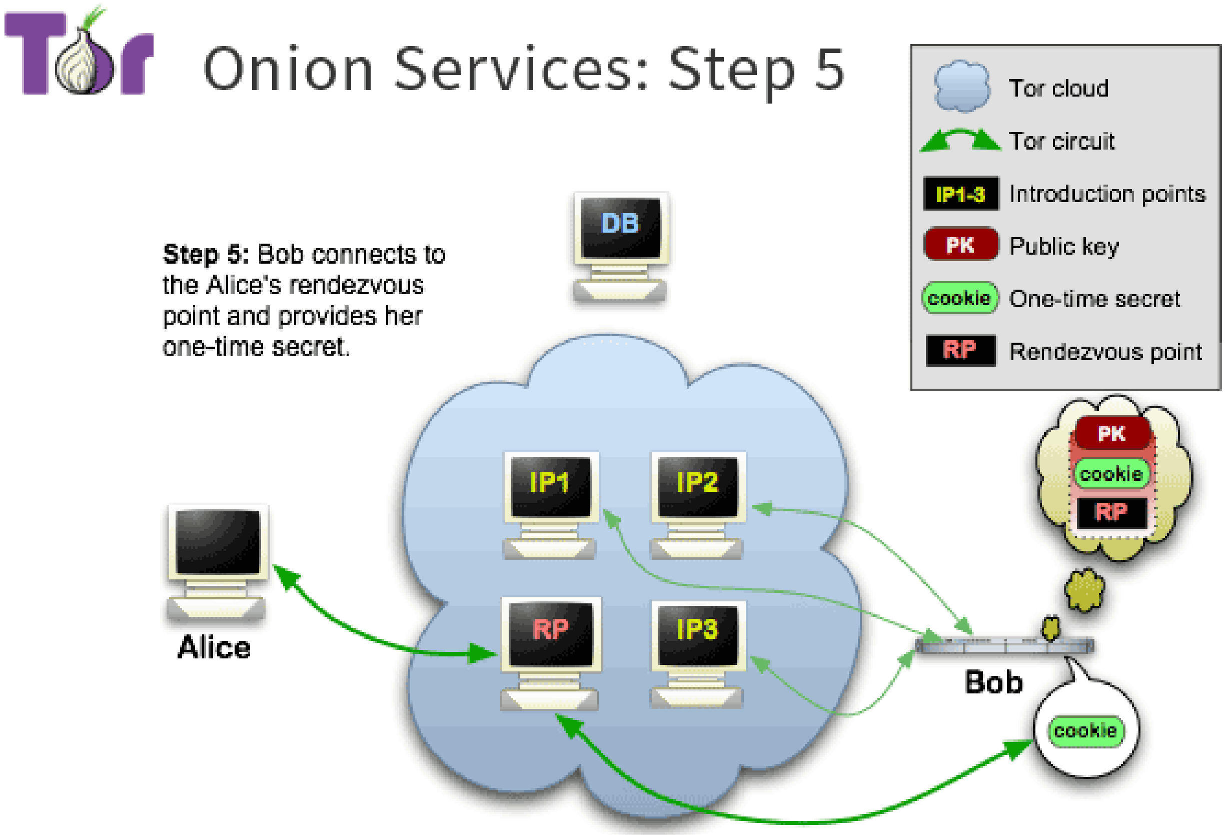
4) The client requests an introduction of the host



Onion Services: Step 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.

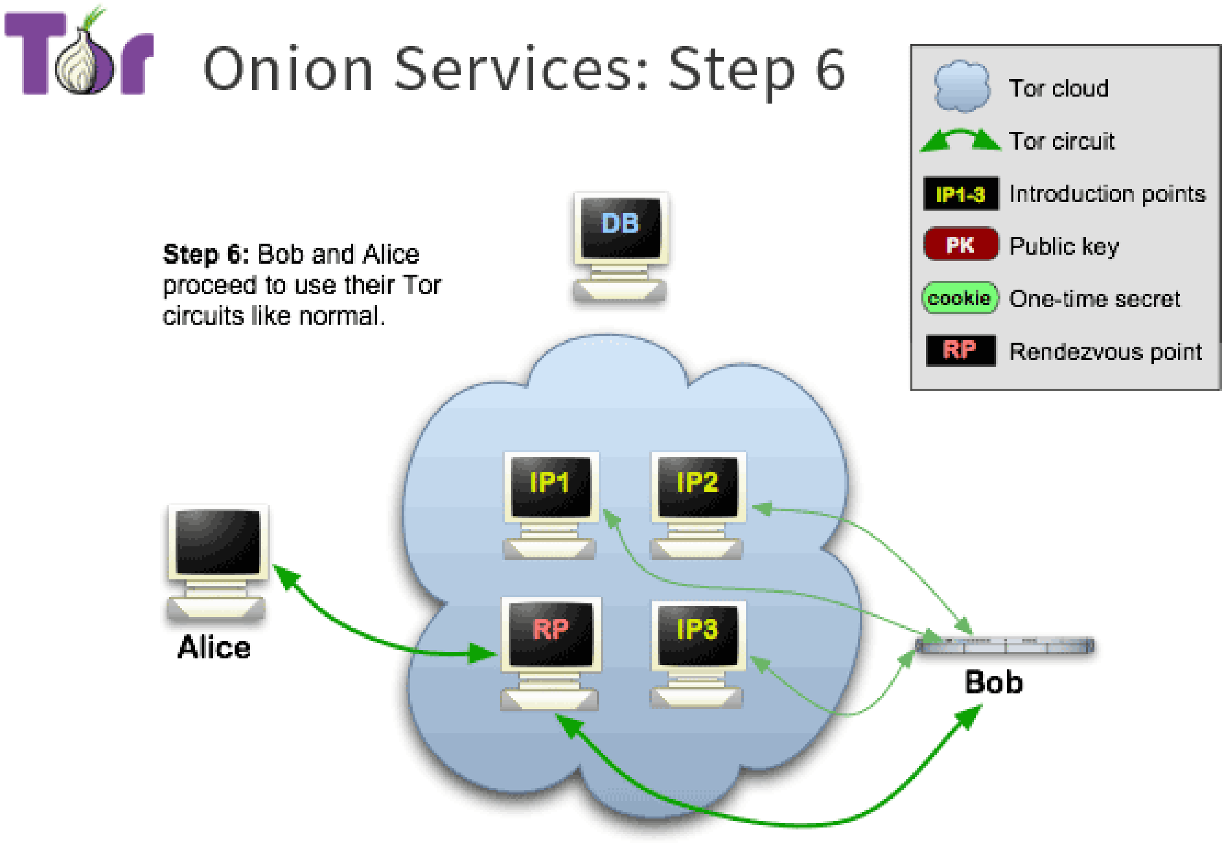
5) The onion service creates a circuit to the rendezvous point



Onion Services: Step 5

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

6) The client and service communicate via the rendezvous point

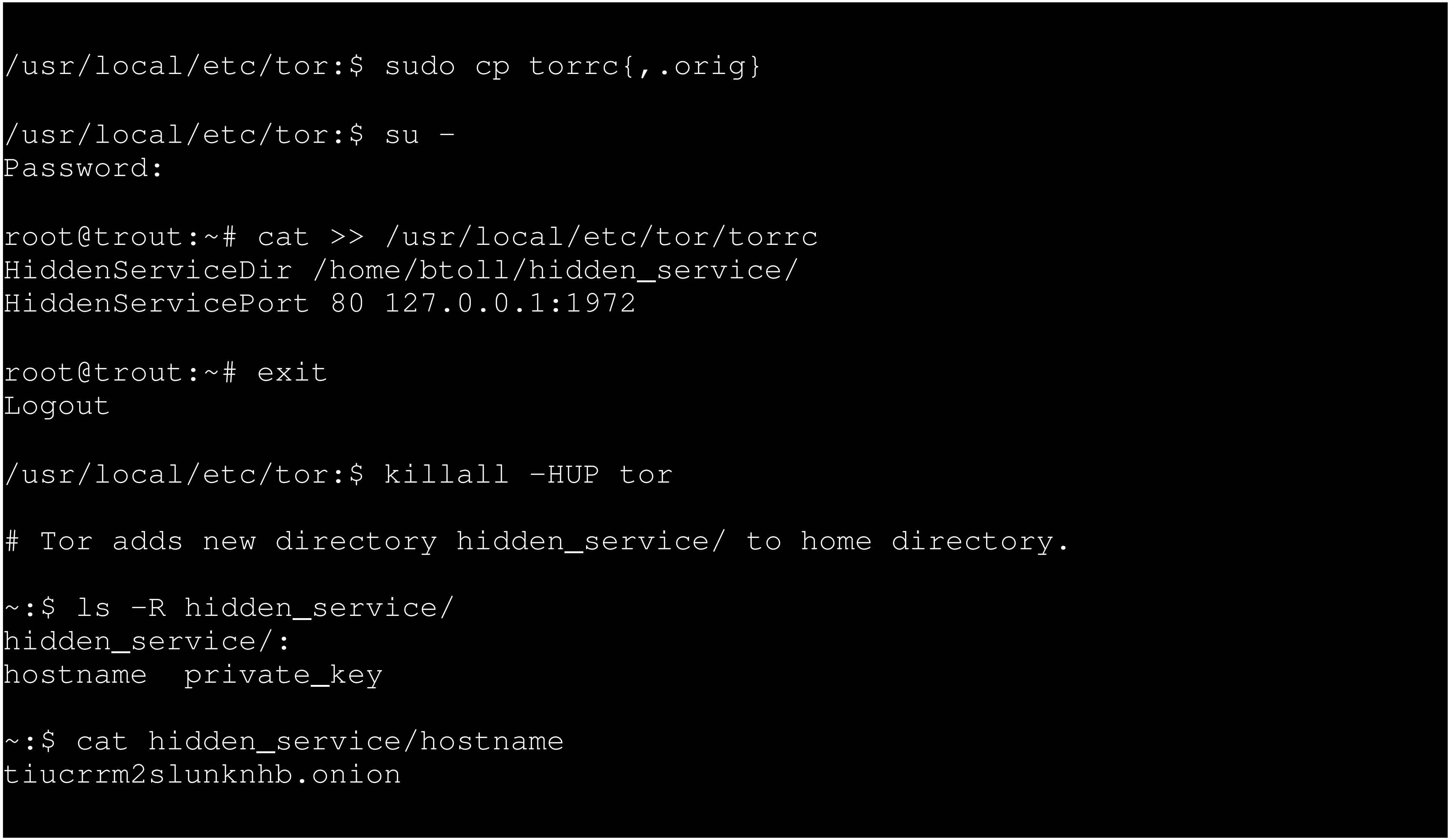


Onion Services: Step 6

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

This is great, how do I set one up?

Add HiddenService* directives to torrc



```
/usr/local/etc/tor:$ sudo cp torrc{,.orig}

/usr/local/etc/tor:$ su -
Password:

root@trout:~# cat >> /usr/local/etc/tor/torrc
HiddenServiceDir /home/btoll/hidden_service/
HiddenServicePort 80 127.0.0.1:1972

root@trout:~# exit
Logout

/usr/local/etc/tor:$ killall -HUP tor

# Tor adds new directory hidden_service/ to home directory.

~:$ ls -R hidden_service/
hidden_service/:
hostname  private_key

~:$ cat hidden_service/hostname
tiucrrm2slunknhb.onion
```

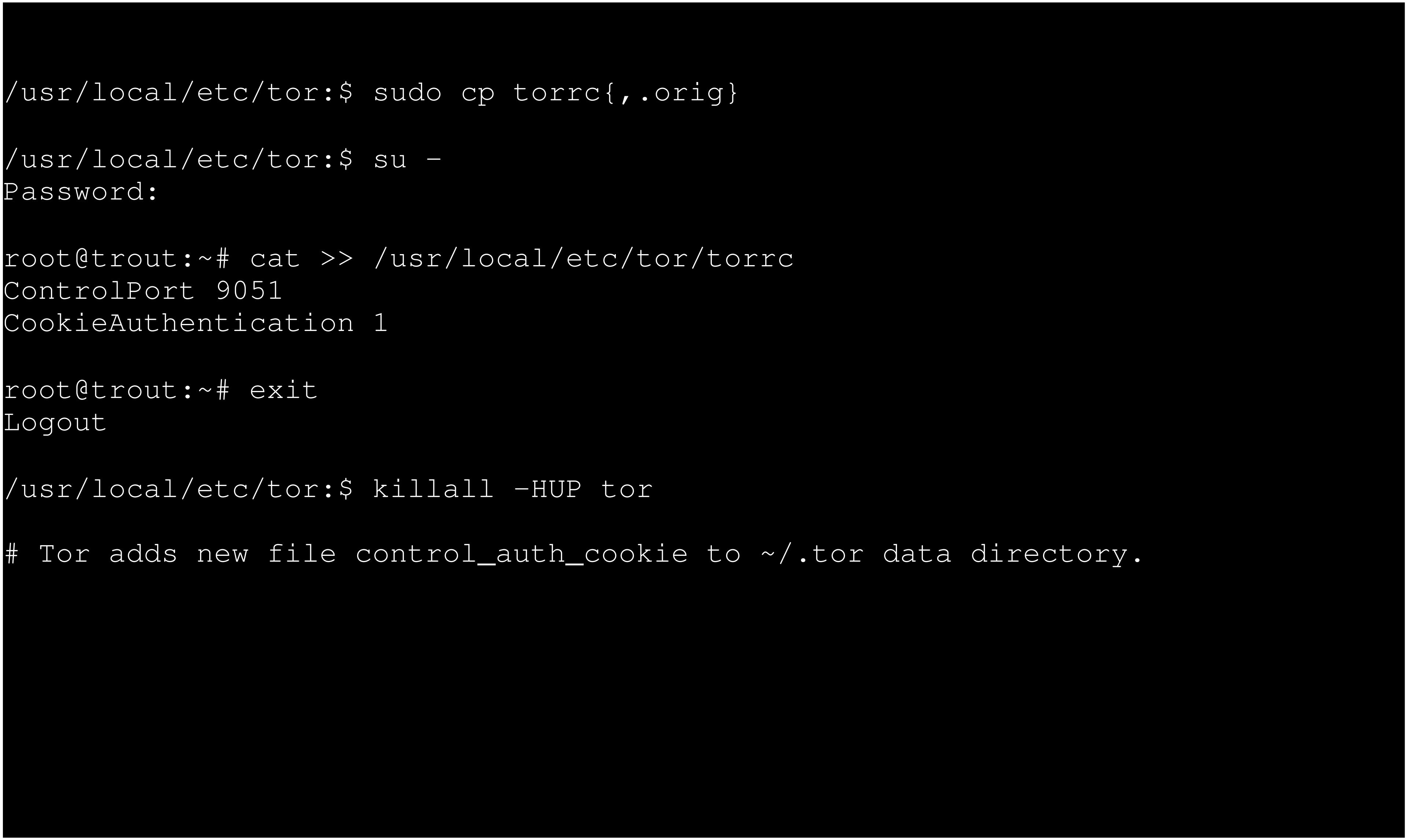
Add new `server` block to nginx

/etc/nginx/sites-available/default

```
server {
    listen 1972;
    listen [::]:1972;

    root /var/www/html;

    index index.html index.htm

    server_name tiucrrm2slunknhb.onion;

    location / {
        try_files $uri $uri/ =404;
    }
}
```

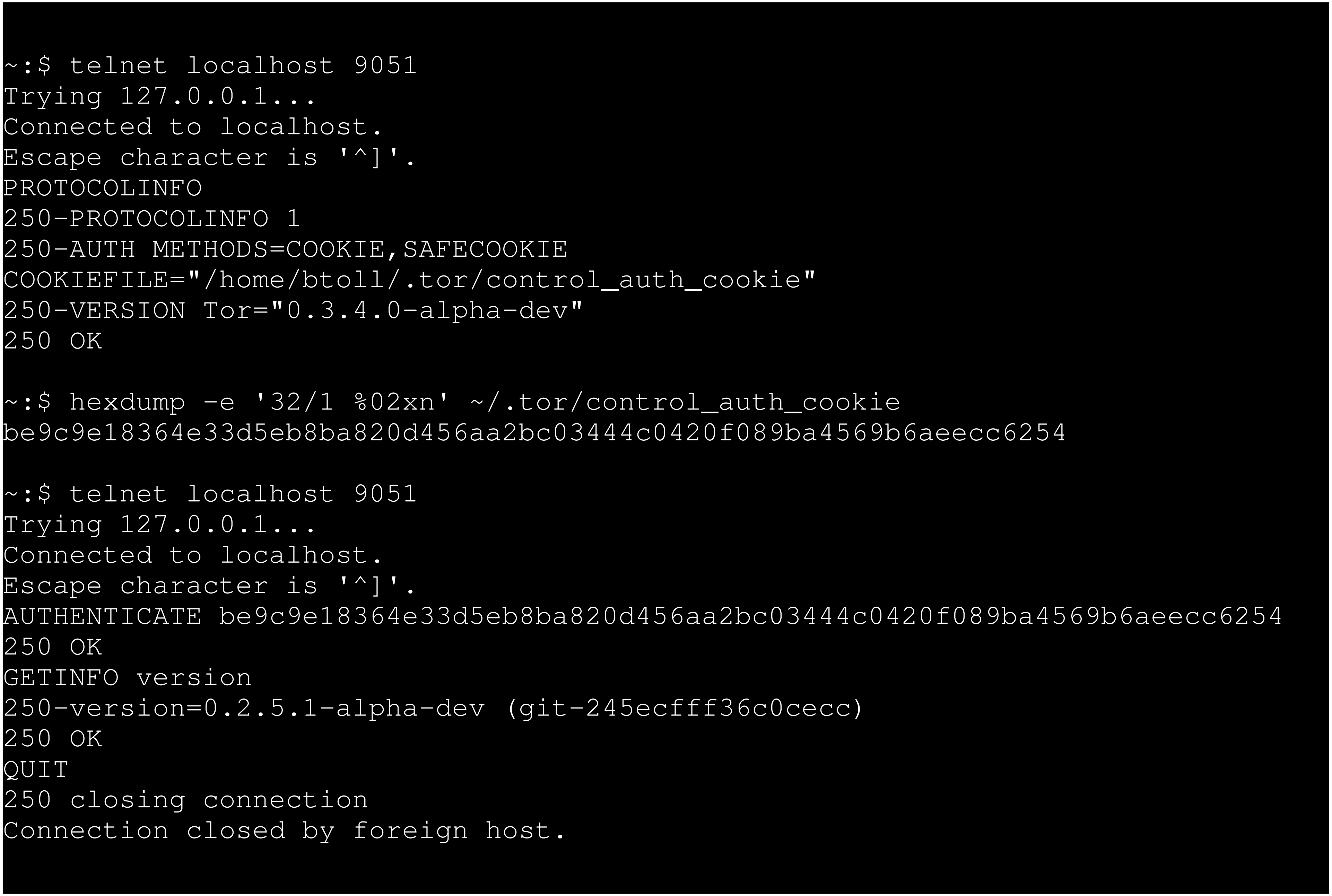
Talking to Tor

Add ControlPort and CookieAuth directives to torrc



```
/usr/local/etc/tor:$ sudo cp torrc{,.orig}

/usr/local/etc/tor:$ su –
Password:

root@trout:~# cat >> /usr/local/etc/tor/torrc
ControlPort 9051
CookieAuthentication 1

root@trout:~# exit
Logout

/usr/local/etc/tor:$ killall –HUP tor

# Tor adds new file control_auth_cookie to ~/.tor data directory.
```

Talk to Tor (telnet)

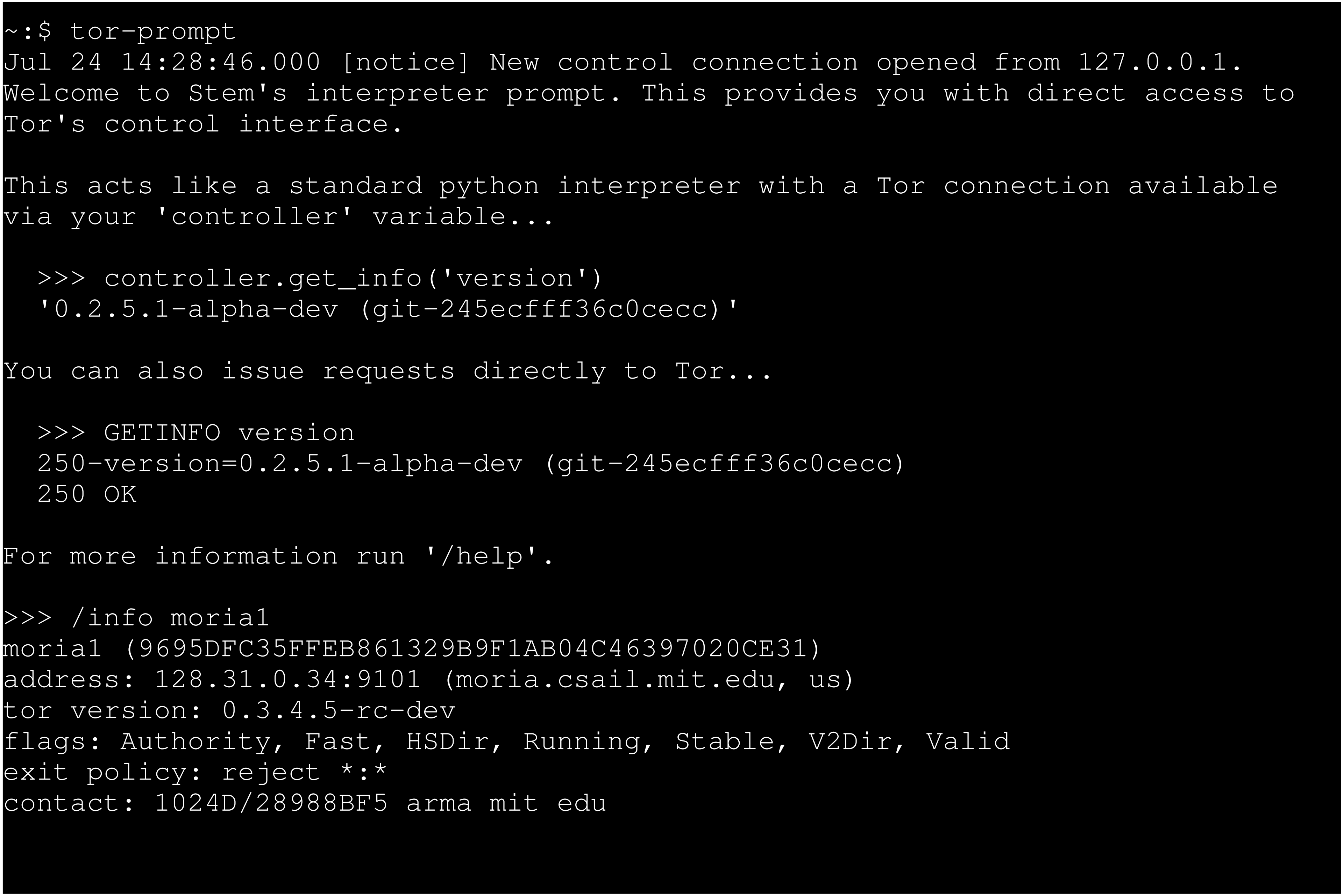


```
~:$ telnet localhost 9051
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
PROTOCOLINFO
250-PROTOCOLINFO 1
250-AUTH METHODS=COOKIE,SAFECOOKIE
COOKIEFILE="/home/btoll/.tor/control_auth_cookie"
250-VERSION Tor="0.3.4.0-alpha-dev"
250 OK

~:$ hexdump -e '32/1 %02xn' ~/.tor/control_auth_cookie
be9c9e18364e33d5eb8ba820d456aa2bc03444c0420f089ba4569b6aeecc6254

~:$ telnet localhost 9051
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
AUTHENTICATE be9c9e18364e33d5eb8ba820d456aa2bc03444c0420f089ba4569b6aeecc6254
250 OK
GETINFO version
250-version=0.2.5.1-alpha-dev (git-245ecfff36c0cecc)
250 OK
QUIT
250 closing connection
Connection closed by foreign host.
```

Stem python library

- Part of the Tor Project
- Script against the Tor process
- Useful for:
  - Creating onion services
  - Inspecting metadata about a Tor circuit and nodes
  - Subscribe to Tor events
  - Many others!
- Available for download with most (all?) Unix package managers
  - `sudo apt-get install python-stem python3-stem`

Talk to Tor (python)



```
~:$ tor-prompt
Jul 24 14:28:46.000 [notice] New control connection opened from 127.0.0.1.
Welcome to Stem's interpreter prompt. This provides you with direct access to
Tor's control interface.

This acts like a standard python interpreter with a Tor connection available
via your 'controller' variable...

  >>> controller.get_info('version')
  '0.2.5.1-alpha-dev (git-245ecfff36c0cecc)'

You can also issue requests directly to Tor...

  >>> GETINFO version
  250-version=0.2.5.1-alpha-dev (git-245ecfff36c0cecc)
  250 OK

For more information run '/help'.

>>> /info moria1
moria1 (9695DFC35FFEB861329B9F1AB04C46397020CE31)
address: 128.31.0.34:9101 (moria.csail.mit.edu, us)
tor version: 0.3.4.5-rc-dev
flags: Authority, Fast, HSDir, Running, Stable, V2Dir, Valid
exit policy: reject *:*
contact: 1024D/28988BF5 arma mit edu
```

Example: Query Consensus for Relay Descriptors

1) Create the python script:

```
~:$ cat > get_consensus.py
import stem.descriptor.remote

try:
  for desc in stem.descriptor.remote.get_consensus().run():
    print("found relay %s %s %s" % (desc.nickname, desc.address, desc.fingerprint))
except Exception as err:
  print("Unable to retrieve the consensus: %s" % err)
```

2) Write consensus to file and query for a specific relay node:

```
~:$ python get_consensus.py | tee consensus | ag loki
found relay lokid 212.19.17.213 4EC47AB2DB37C8EDB7068A04B36DA25BD6BC178F
found relay loki 51.15.145.150 5A6451D4E4B4FFDE0B2682D8D8DAA0D10A500066
found relay Loki 104.244.75.194 C8850DE0EBC07481808F32F2BAA76CA65CB659FB
```

3) Subsequent searches don’t need to burden the network:

```
~:$ cat consensus | ag moria1
found relay moria1 128.31.0.34 9695DFC35FFEB861329B9F1AB04C46397020CE31
```

Example: Query Tor Process for Relay Descriptors

1) Add to .torrc. As root:

```
root@trout:~# cat >> /usr/local/etc/tor/torrc
FetchDirInfoEarly 1
FetchDirInfoExtraEarly 1
FetchUselessDescriptors 1
DownloadExtraInfo 1
```

2) SIGHUP so it reloads its config (if started Tor as a daemon):

```
~:$ killall -HUP tor
```

3) List the .tor data directory, there will be new entries (triggered by the 3rd directive above). If anything listed below is missing, it will be there after restarting the Tor process:

```
cached-consensus
cached-descriptors
cached-descriptors.new
cached-extrainfo
Cached-extrainfo.new
```

4) Create the python script:

```
~:$ cat > get_descriptors.py
from stem.descriptor import parse_file

for desc in parse_file('/home/btoll/.tor/cached-consensus'):
    print('found relay %s %s %s' % (desc.nickname, desc.address, desc.fingerprint))
```

Other privacy tools

- Tails
- tor-resolve
- torsocks
- GNU Privacy Guard (GPG)
- Signal
- OTR
- DuckDuckGo

References

- Onion Routing https://www.onion-router.net
- Tor Project https://www.torproject.org/
- Tor design paper https://svn.torproject.org/svn/projects/design-paper/tor-design.html
- Tor browser design paper https://www.torproject.org/projects/torbrowser/design/
- Tor overview https://www.torproject.org/about/overview.html.en
- Tor onion service protocol https://www.torproject.org/docs/onion-services.html.en

FIN

Benjamin Toll
benjamintoll.com
benjam72@yahoo.com