Securing the Tor Network

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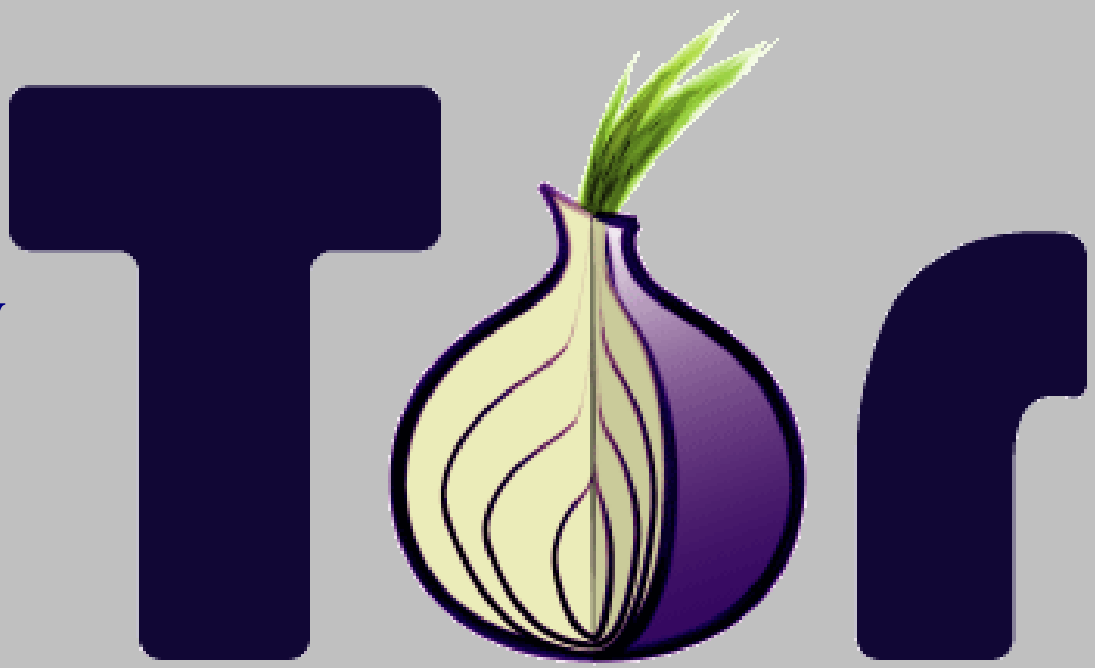
Black Hat USA 2007
Defcon 2007



Who am I?

- Volunteer Tor developer
- Forward+Reverse engineer
- Employed by Riverbed (shameless plug)
  - Leading manufacturer of WAN accelerators
  - 20-200X (not percent. X) improvement of CIFS
  - 5-50X improvement of MAPI/Exchange
  - Protocol independent data reduction
  - > 90% head to head win rate
  - Outselling Cisco accelerators 2:1

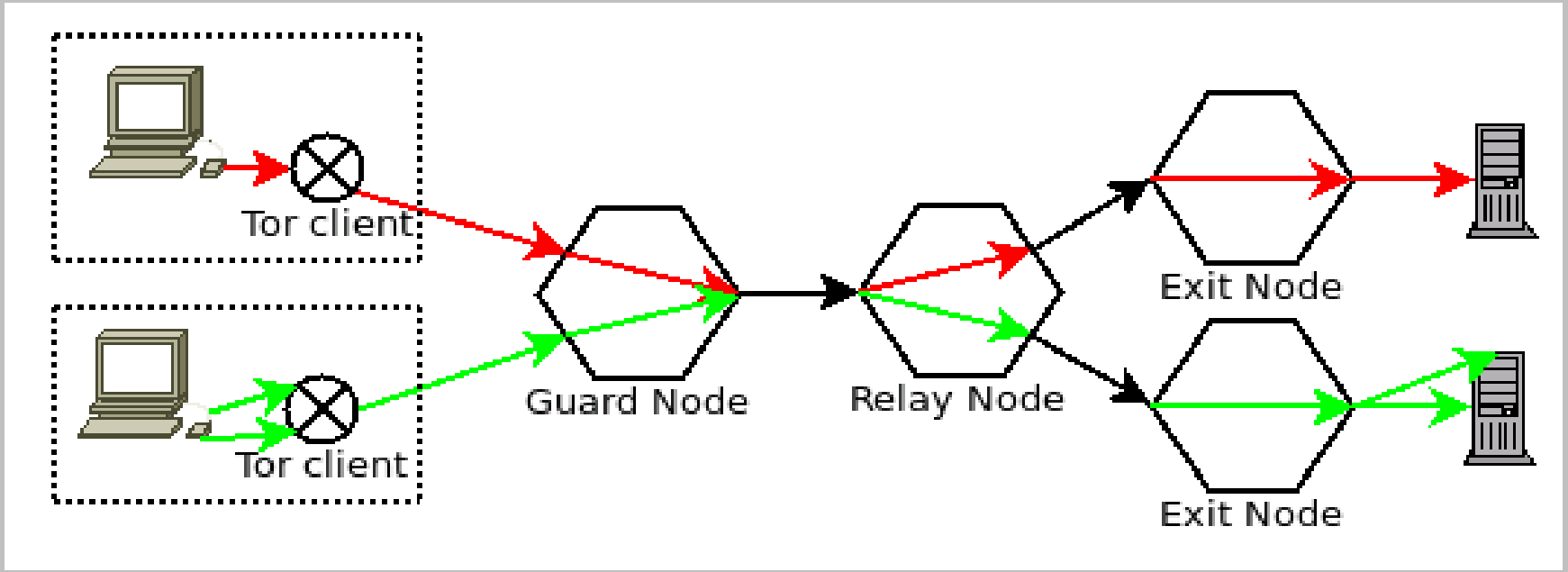
Preaching to the Choir

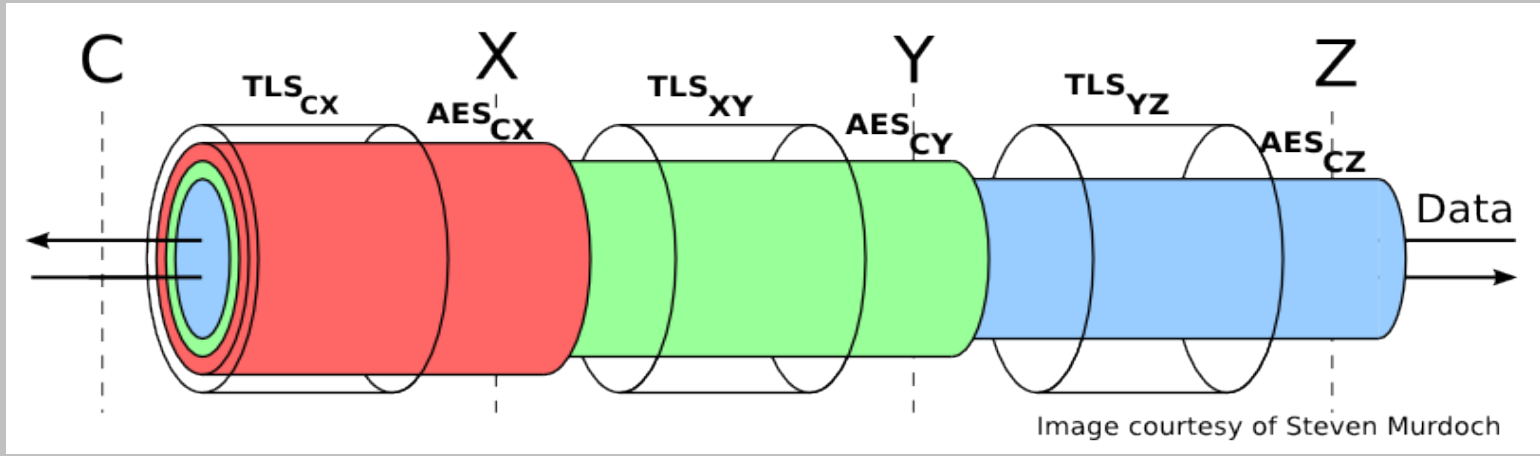
- Don't yet understand consequences of having lives+thoughts archived by IP, bought and sold
- Google may not be (that) evil, but what about ISPs, other search engines?
- Information can come back to bite in unexpected ways
  - Divorce cases
  - Lawsuits
  - Catalogs/Spam

What is Tor?

- Volunteer run relay network designed for privacy, anonymity, and censorship resistance.
- Client acts as SOCKS proxy
- Relays TCP connections (“streams”)
  - Multiplexed on encrypted paths (“circuits”)
- Circuits multiplexed over node-to-node TLS/SSL
- Circuits route through 3 nodes
  - “Guard”, “relay”, “exit”

Tor Routing


Tor client
Tor client
Guard Node
Relay Node
Exit Node
Exit Node


C
X
Y
Z
TLS CX
AES CX
TLS XY
AES CY
TLS YZ
AES CZ
Data
Image courtesy of Steven Murdoch

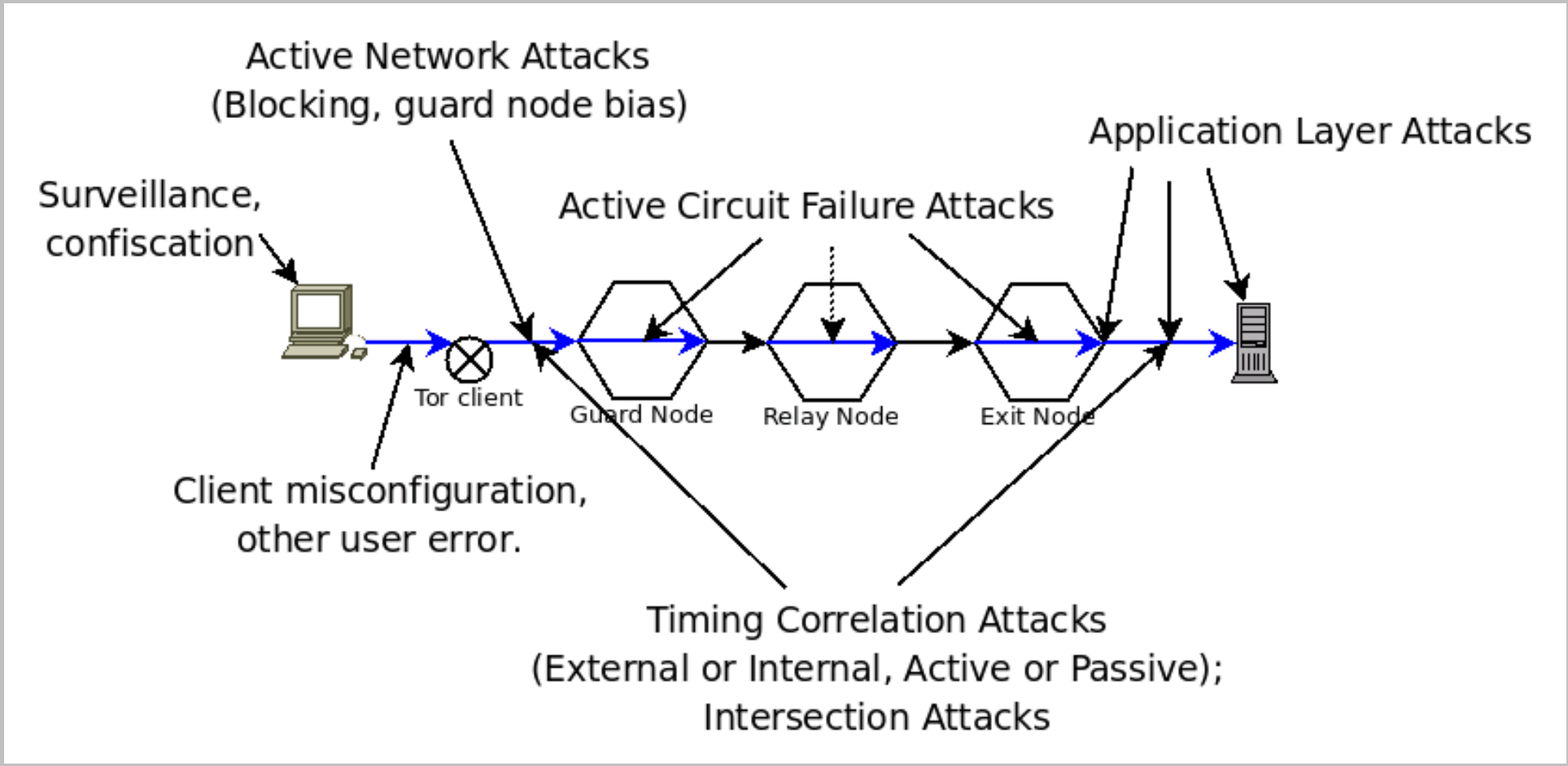
Classes of Attack

- Passive attacks
  - Packet and connection timing correlation
  - Fingerprinting of traffic/usage patterns
  - “Intersection Attacks” of multiple attributes of users
- Active attacks
  - Lying about bandwidth to get more traffic
  - Failing circuits to bias node selection
  - Modifying application layer traffic at exit

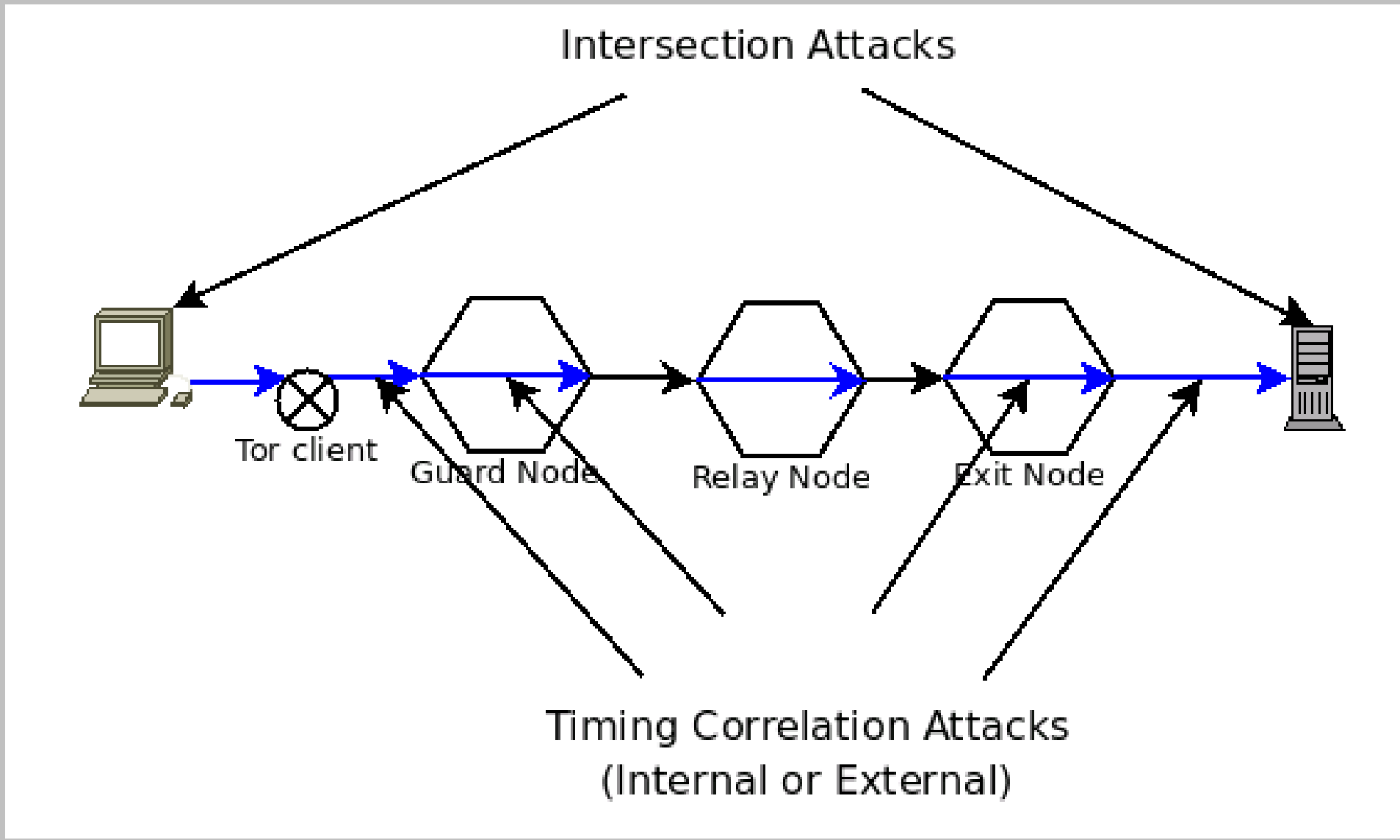
Position of Attack

- Internal
  - Node operator
  - Can differentiate circuits at guard and relay.
  - Able to differentiate streams per circuit at exit
- External
  - ISP or Echelon-style adversary
  - Assumed to be unable to see inside TLS streams
  - Likely frustrated to a large degree by running Tor as both node and client

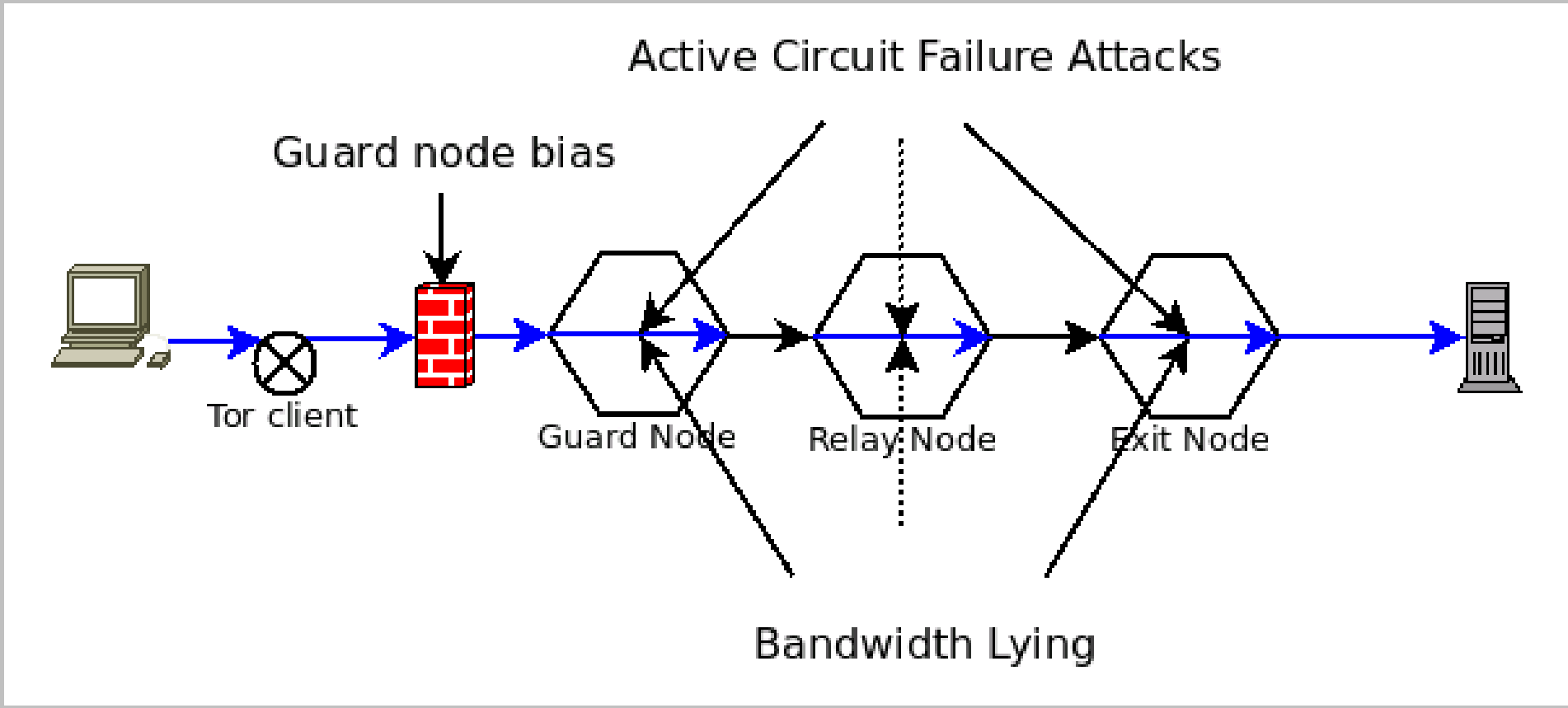
Attack Points



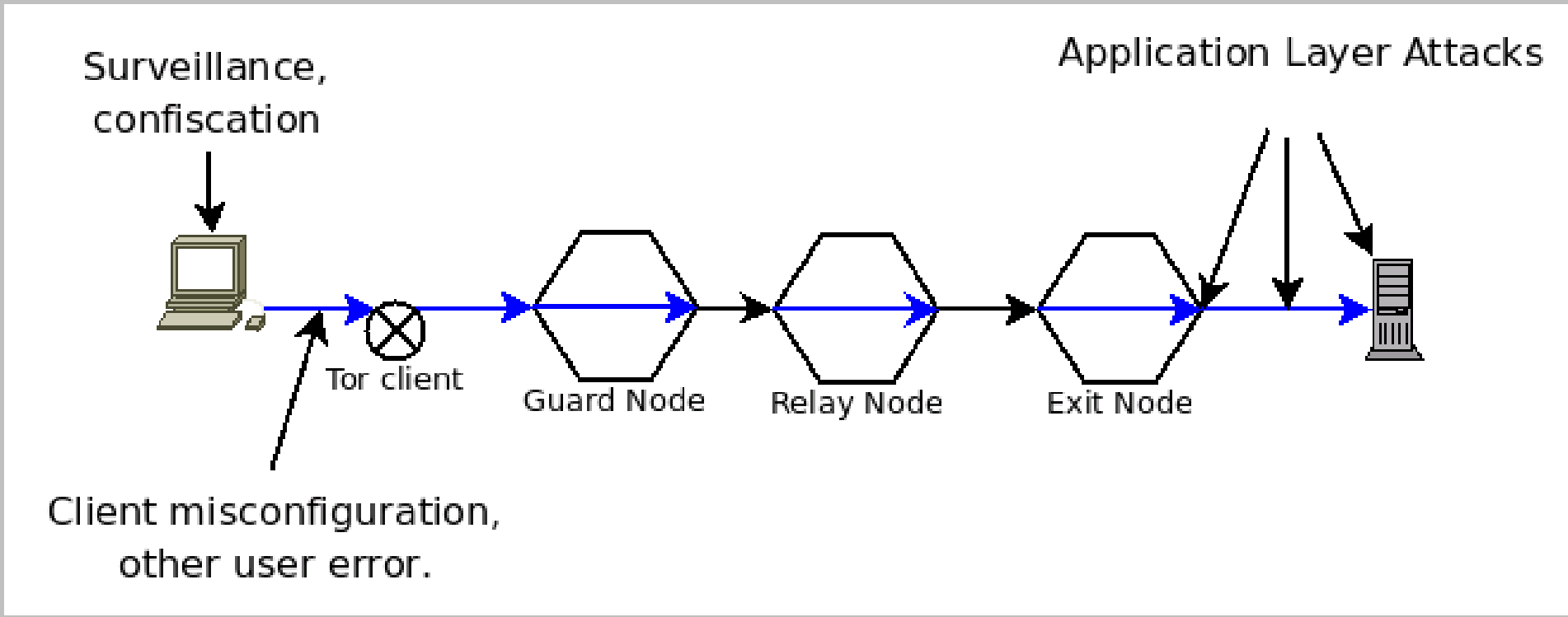
Passive Attacks



Active Attacks



Application Attacks



Questions/Intermission 1

Questions so far?

Approaches to Security

- Verify node operators (Ha!)
- Path selection hacks
- “Tor up from the floor up”
- Improve network speed and usability
- Scan nodes for modification/reliability
- Secure the applications (different threat model)

Path Selection Hacks

- /16 hack: No two nodes from same /16 netmask
  - Many ISPs have disjoint IP ranges..
- Guard nodes
  - Chosen from top 50% uptime, top 50% bandwidth
  - Foil “repetitive fetch” application layer attacks
  - Reduces long-term fingerprinting potential
  - Without rotation, can deter intimidation attacks
  - Difficult to do right. Typically still rotate
    - Essentially a time-tradeoff of risk

Tor Routers and LiveCDs

- JanusVM, Anonym.OS, xBVM
  - “Tor up from the floor up”
  - Address application-level attacks to bypass Tor
  - Block UDP
- Major flaw: Circuit reuse -> app correlation
  - AV software update, other ID-based software updates
  - AIM, ssh, email usage of different “nyms”
  - Media players checking recommended music, etc etc

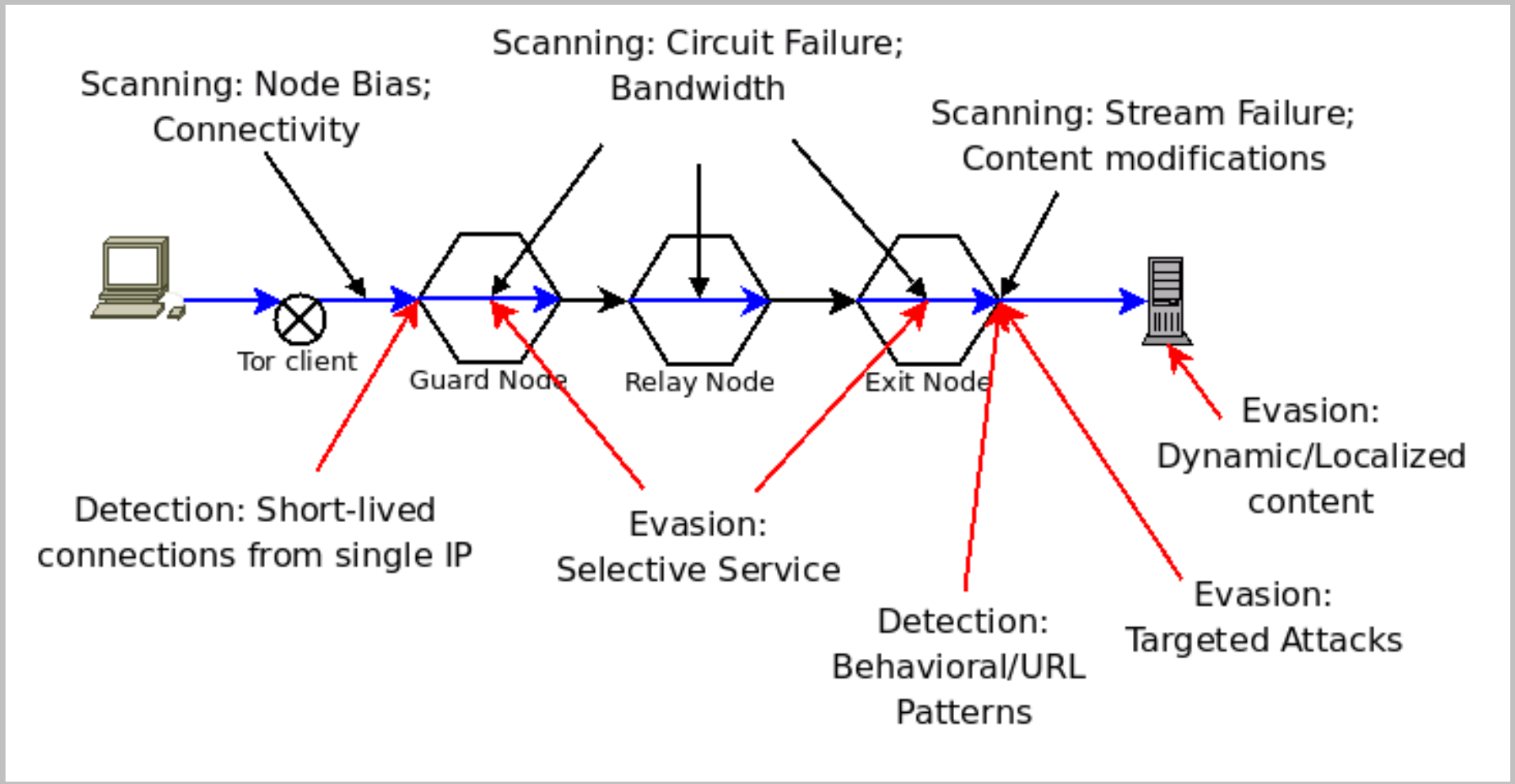
Improving Speed and Usability

- Key component of Tor security: Large userbase
  - Users have been harassed because of small anonymity sets! Whistleblower/Blogger scenario can be unsafe!
- Users want speed and ease of use
  - Many do not need as much anonymity
  - Two hop proposal (semi-controversial)
  - Intelligent path selection
  - Ensure network is evenly balanced and reliable

Centralized Network Scanning

- Tor control port is fun stuff
- Snakes on a Tor and TorFlow
  - Verifies md5 sums of googled URLs
  - Also verifies node reliability+bandwidth
- Works against incompetent+blanket adversaries
  - Actually found some broken+malicious nodes
- Does not work against selective adversaries
- Vulnerable to detection

Scanning Methods and Weaknesses



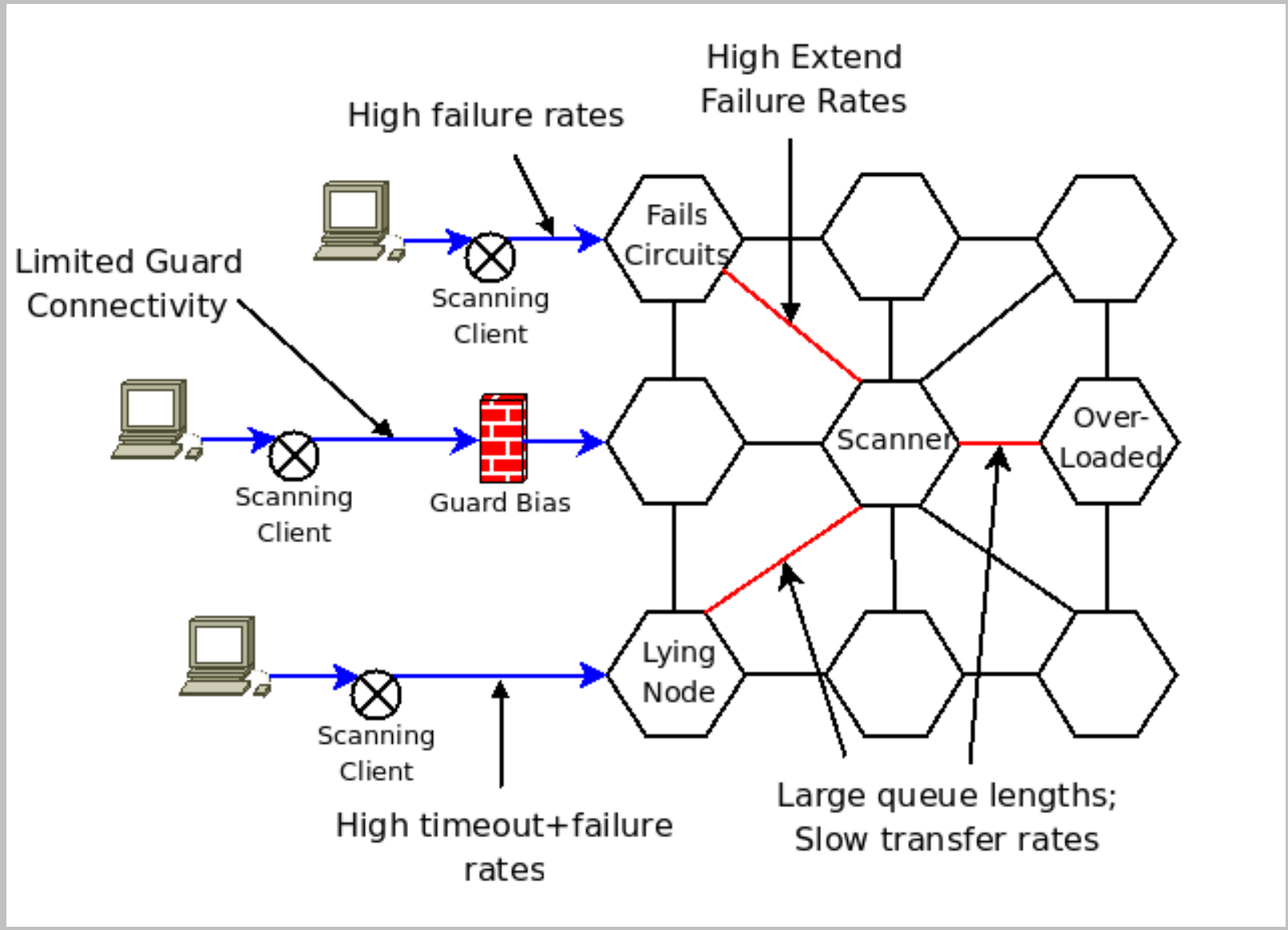
Stuff We Found Anyway

1. Chinese ISP doing SSL MITM
2. Popup blocking! :)
3. Google Analytics Blocking! <3
4. DNS Spoofing
5. SSH+SSL MITM
6. Overloaded nodes
7. Balancing issues :(

Decentralized Network Scanning

- Client-based:
  - Use reliability averages from TorFlow
  - Alert user if guard node fails more than X% circuits
  - Measure observed bandwidth/latency of nodes
- Node-based:
  - Gather statistics on average capacity and queue lengths to peers, compare to node rankings
  - Report major deviations or use as balancing feedback loop.

Passive Client+Node Based Scanning



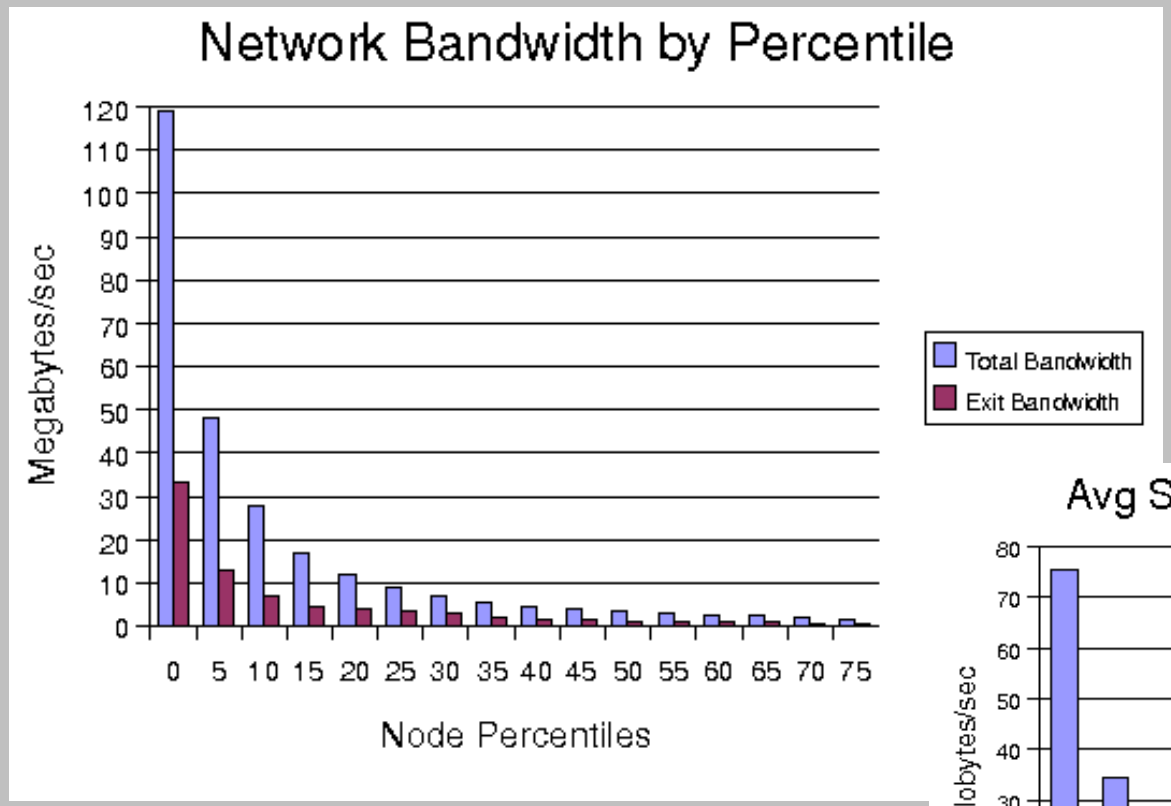
Balancing Issues

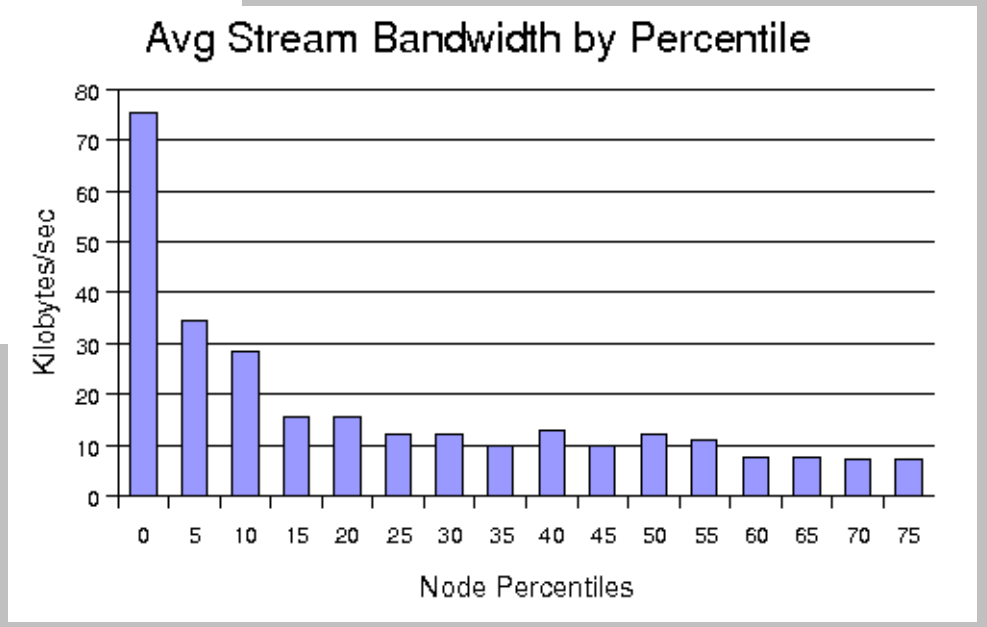
- Tor network is unbalanced
  - Guard node issues (bug #440)
  - Bandwidth clipping
- Detectable during scans
  - Top 5% of nodes have room for 7X more capacity
  - Next 10% of nodes have room for 3X more capacity
  - High circuit failure rates that drop off at 50% mark
  - High extend times that drop off at 50% mark

Scanning Methodology

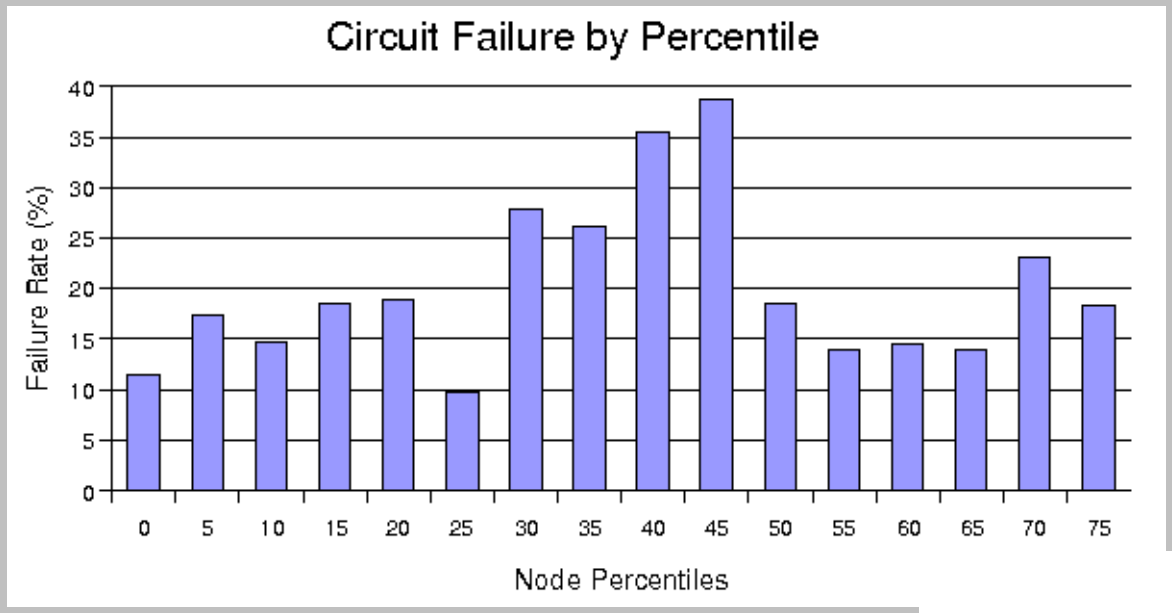
- Divide Tor network into 5-percentile segments
  - About 80 nodes each
- Circuit Scanning
  - Build 500 three hop paths for each range
  - Fetch ~20k file on each path
  - Count failures, track extend times
- Bandwidth Scanning
  - Fetch 512k file 200 times over two hop paths
  - Average the observed bandwidth for each range

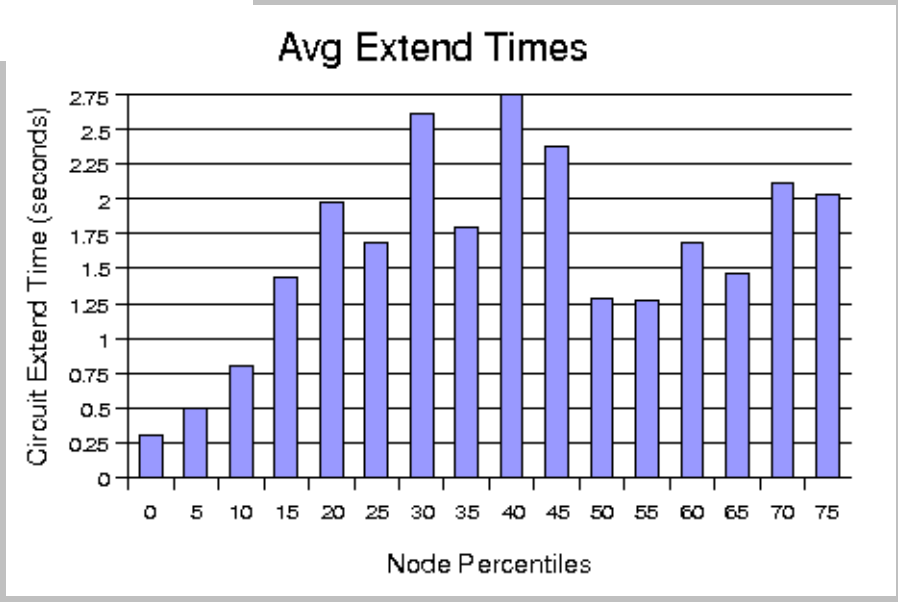
Bandwidth (Mis)Balancing





Side Effects of Unbalancing





Probability of Existing Tor Usability

- 70% Chance of choosing one unbalanced guard
  - Tor goal: 3 guards
- .7x.7x.7 = 34% chance of 3 unbalanced guards
  - Tor is likely unbearable for 34% of users
- C(3,2)x.7x.7x.3 = 44% chance of 2/3 bad guards
- C(3,1)x.7x.3x.3 = 19% chance of 1/3 bad guards
- .3x.3x.3 = 3% chance of 3/3 usable guards

Other Load Balancing Factors

- Insane exit policies
  - Allowing bittorrent, p2p, smtp..
- High uptime vs low uptime
- Scarce guard bandwidth
  - Avoid guards for relay choice
- Directory vs Node traffic
- Time of day
- Location

Questions/Intermission 2

Questions so far?

Securing the Application Layer

- Tor has a superset of the threat model most applications are written for.
  - No UDP!
  - Unique identifiers are bad
  - Proxy settings must be sacrosanct
  - Location information must not be transmitted
  - Updates are dangerous. Hostile network.

Tor's Web Attack Profile

1. Bypassing proxy settings
2. Correlation of Tor vs Non-Tor
3. History disclosure
4. Location information
5. Misc Anonymity set reduction
6. History records

Plugin Wall of Shame

- Flash v9
- Quicktime v7.2
  - RTSP proxy (does not apply to web streams)
- Windows Media Player v10.000000.4040
  - Has proxy settings. Even has a “No Bypass” option.
    - Still Ignores them
- Adobe Acrobat Reader Plugin v8.1
  - Leaks DNS
- mplayerplug-in

Solution: Improved TorButton

- Disable plugins while Tor is enabled
- Isolate dynamic content per Tor load state
- Cookie jars/cookie clearing
- Cache management
- History management
- User agent spoofing during Tor
- Timezone+Locale spoofing

TorButton Demo

- http://gemal.dk/browserspy/basic.html
- http://gemal.dk/browserspy/css.html
- http://gemal.dk/browserspy/date.html
- http://gemal.dk/browserspy/plugins.html
- http://metasploit.com/research/misc/decloak/index
- http://ha.ckers.org/weird/CSS-history.cgi
- http://www.tjkdesign.com/articles/css%20pop%2(

Interesting Technical Details

- Context issues
- Tab tagging
- XPCOM hooking and XPCOM policies
- Javascript hooking

Final Thoughts

- Tor security != Internet security
  - Superset, actually
  - Adversary has different goals
  - Many apps do not consider privacy vulnerabilities as real vulnerabilities

Credits+Contributions

Scott Squires (Original TorButton Author)

Collin Jackson (History blocking+Cookie jars)

Johannes Renner (TorFlow contributions+research)

Nick & Roger (Advice, Tor in general)

Nitin, Dave, Thom (Advice, Moral Support)

“What can I do to help Tor?”

- Extra bandwidth? Run a node!
  - See conference CD for Linux 'tc' prioritization script
  - No need to impact your own traffic flows
- Post patches/plugins to your favorite apps to protect against info disclosure.
  - Work to raise awareness that privacy issues should be considered as part of security measures