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PeerFlow: Secure Load Balancing in Tor

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Privacy Enhancing Technologies Symposiu

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Overview

- Problem: Secure load-balancing in Tor
- Existing Solutions
  - TorFlow
  - EigenSpeed

  } Demonstrate attacks
- New Solution: PeerFlow
  - Prove security against bandwidth-limited adversary
  - Experiments show similar performance to TorFlow

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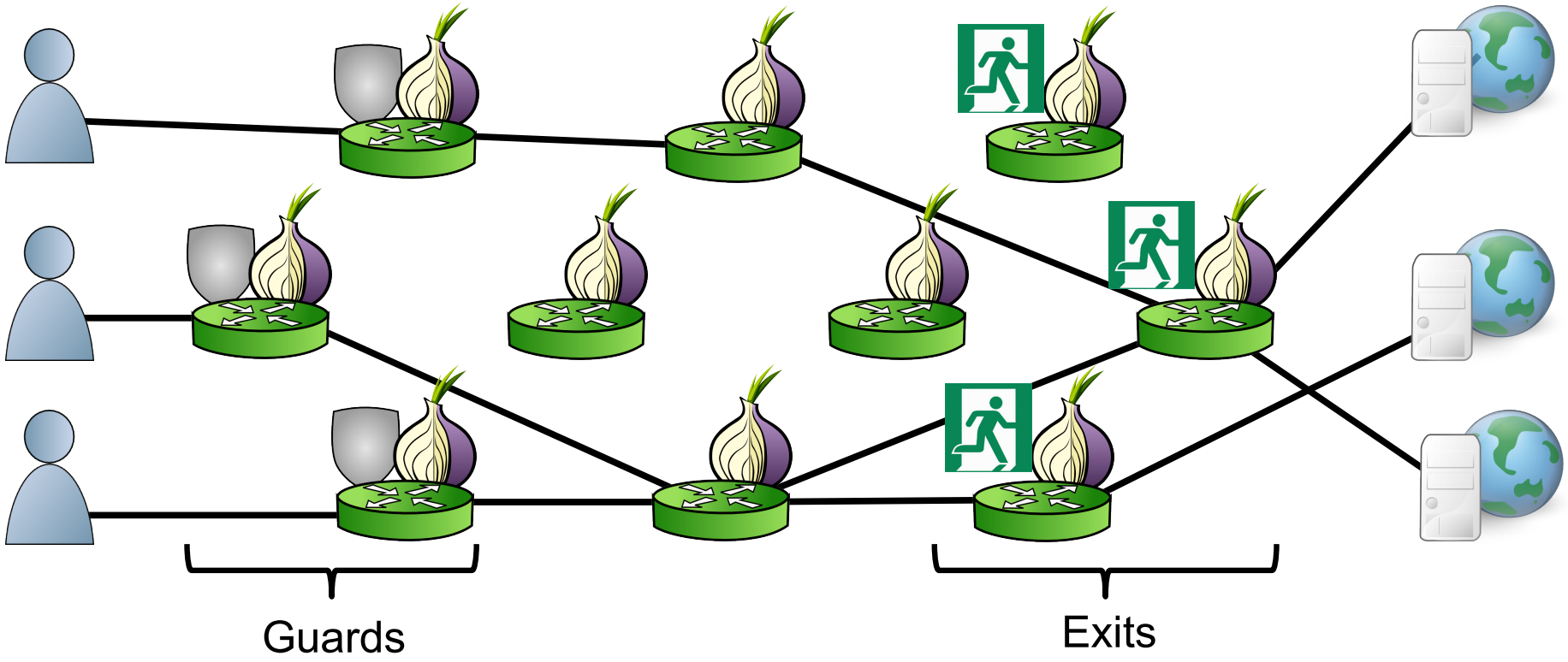

Clients Relays Destinations

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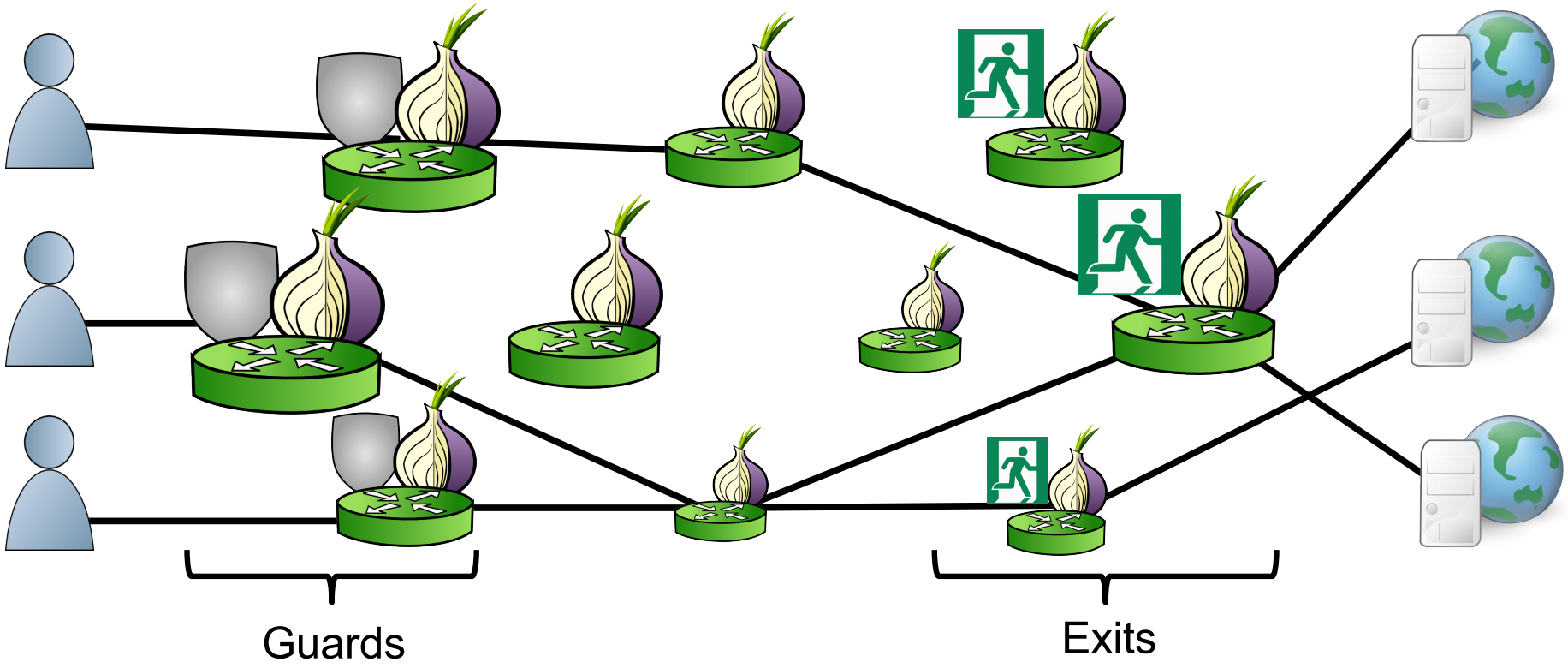

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- Tor relays have varying unknown *capacities*

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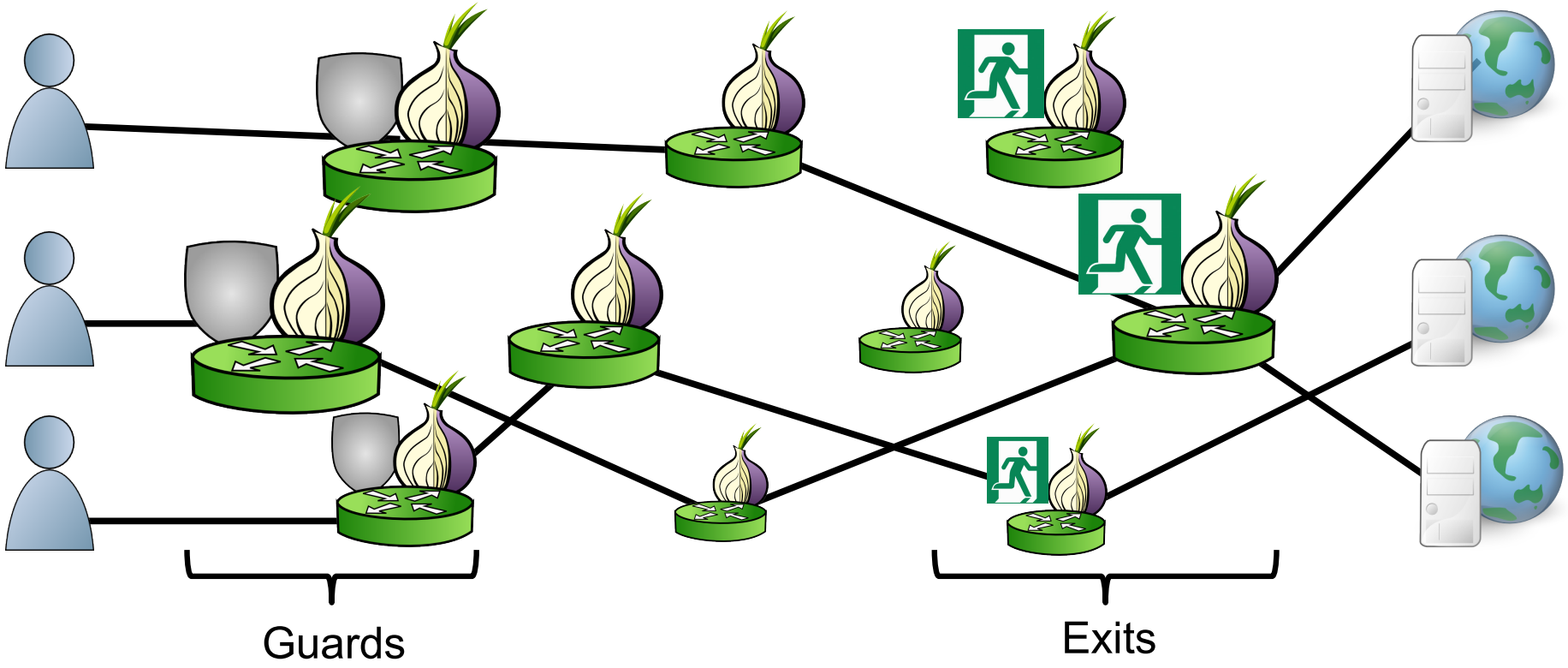

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- Clients must balance load

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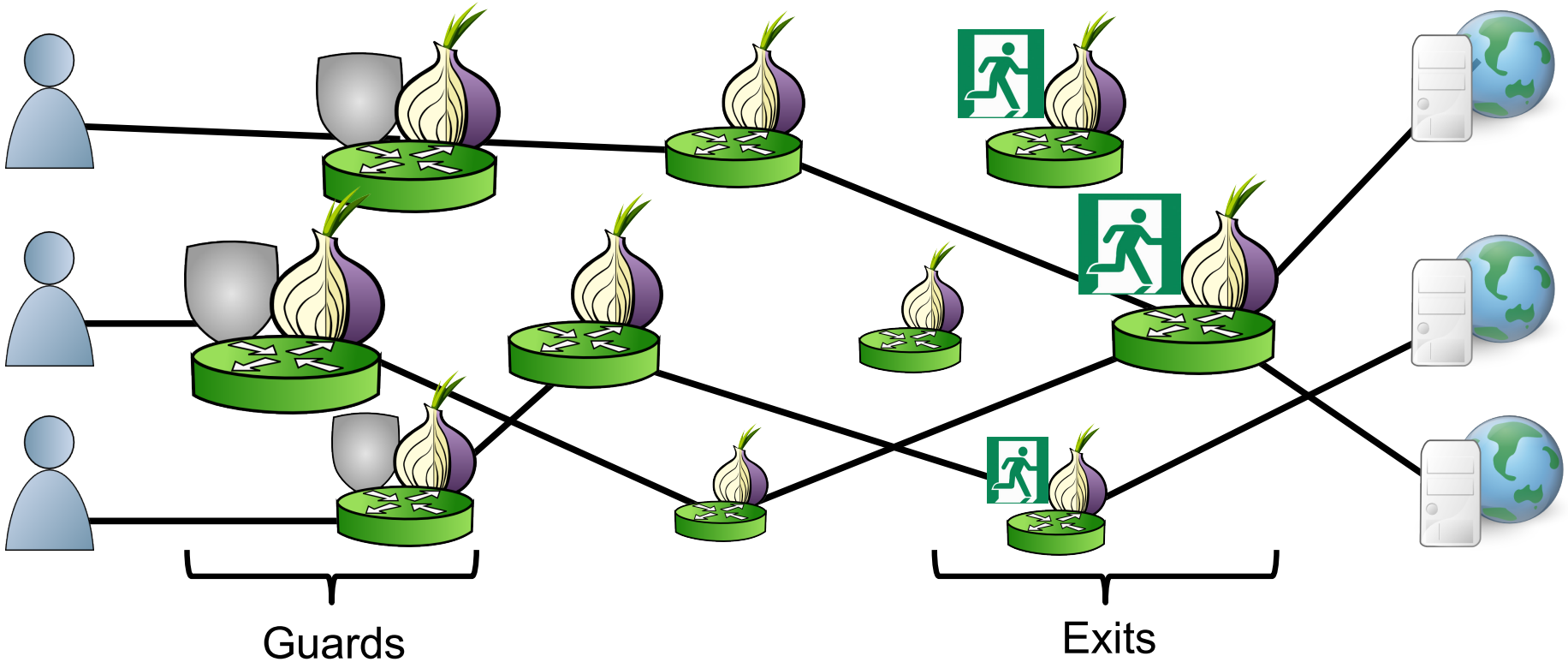

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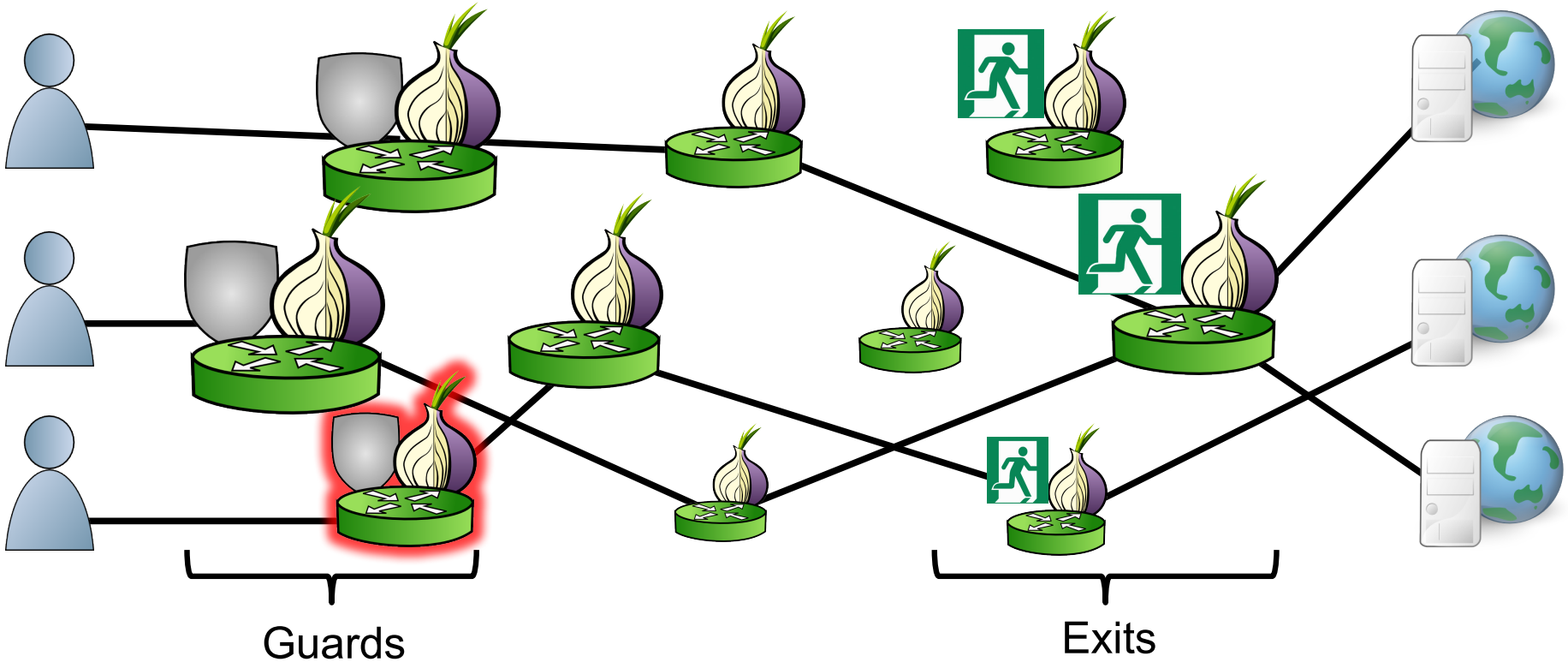

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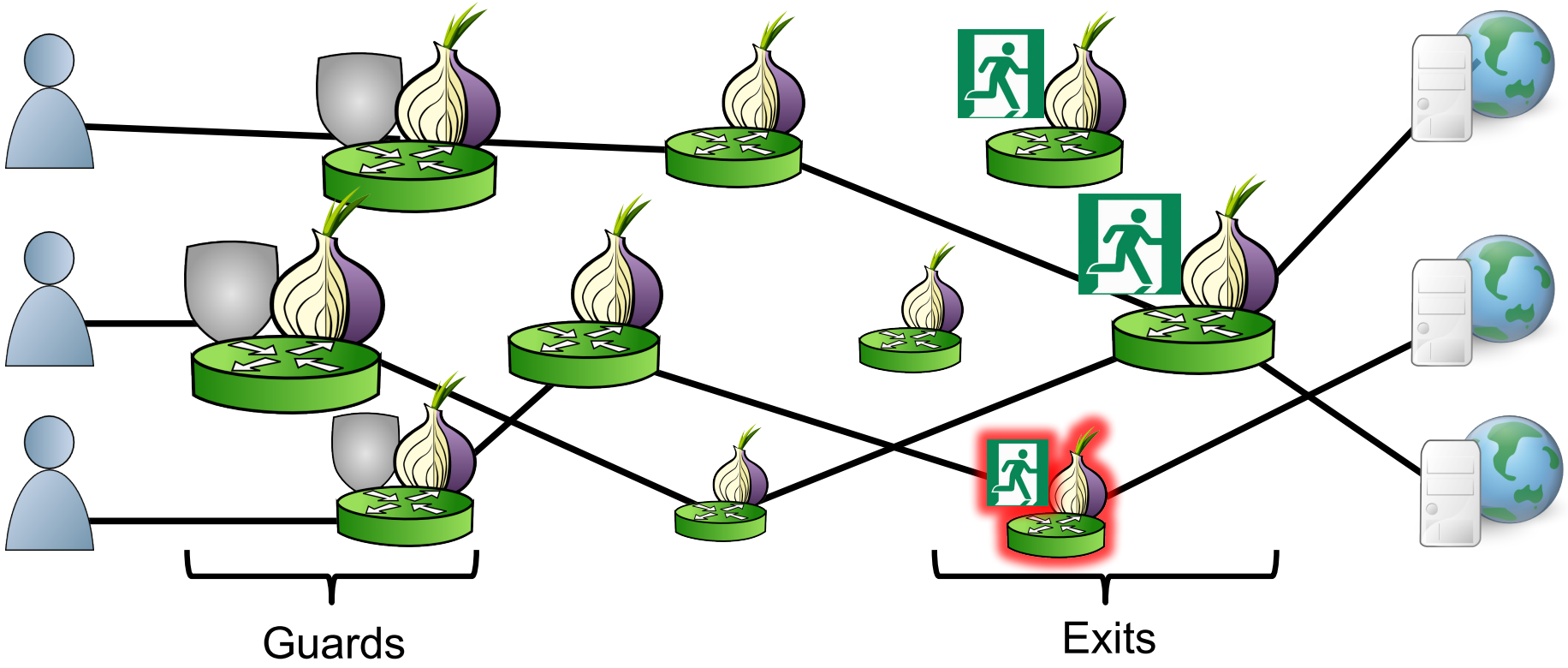

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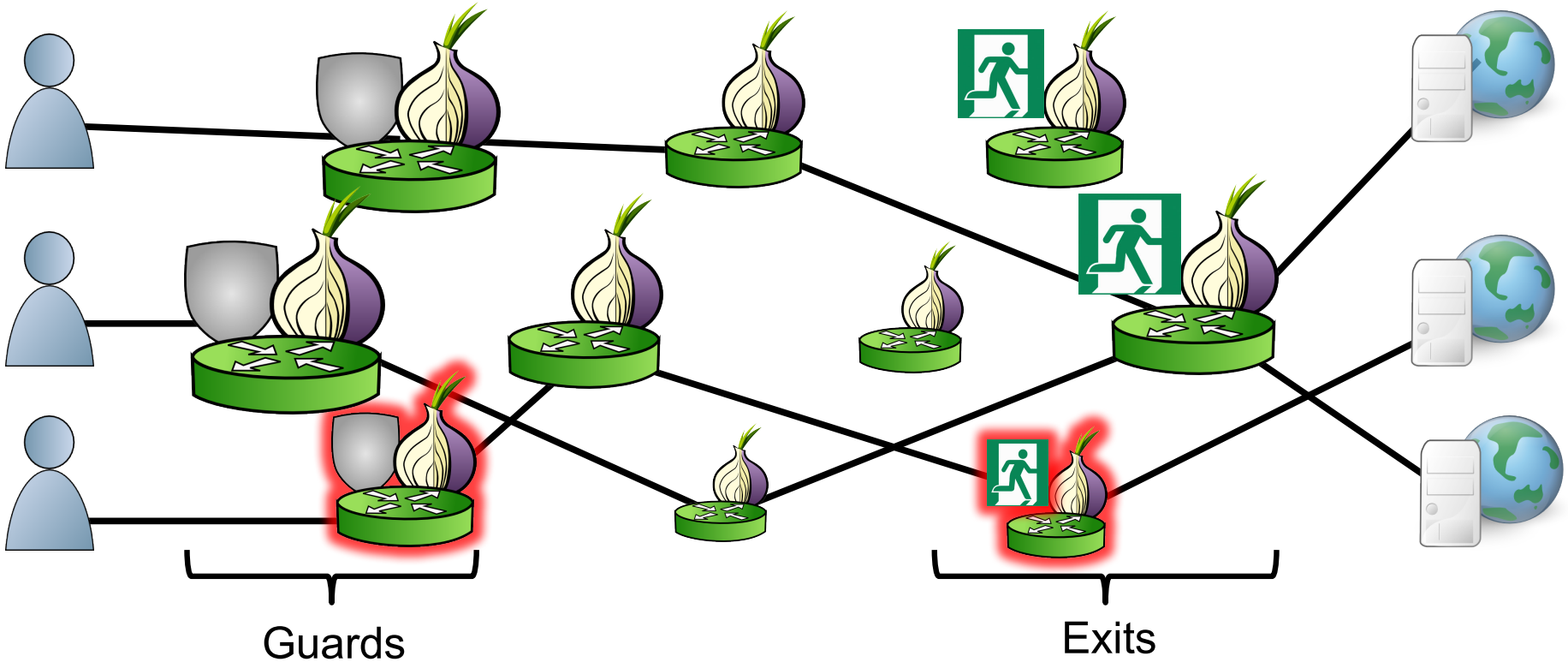

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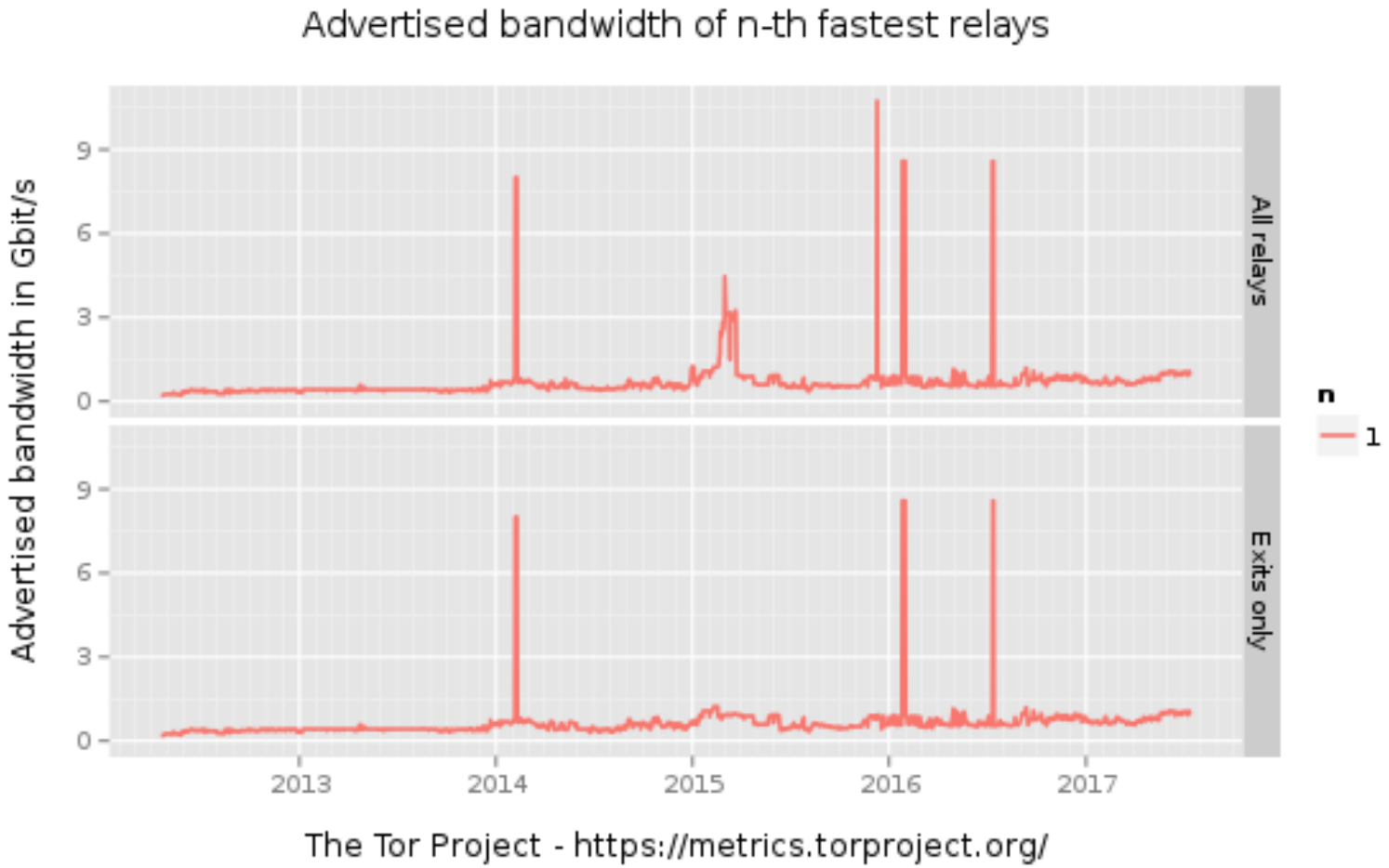
Problem

The threat is real: relay falsely advertise bandwidth.



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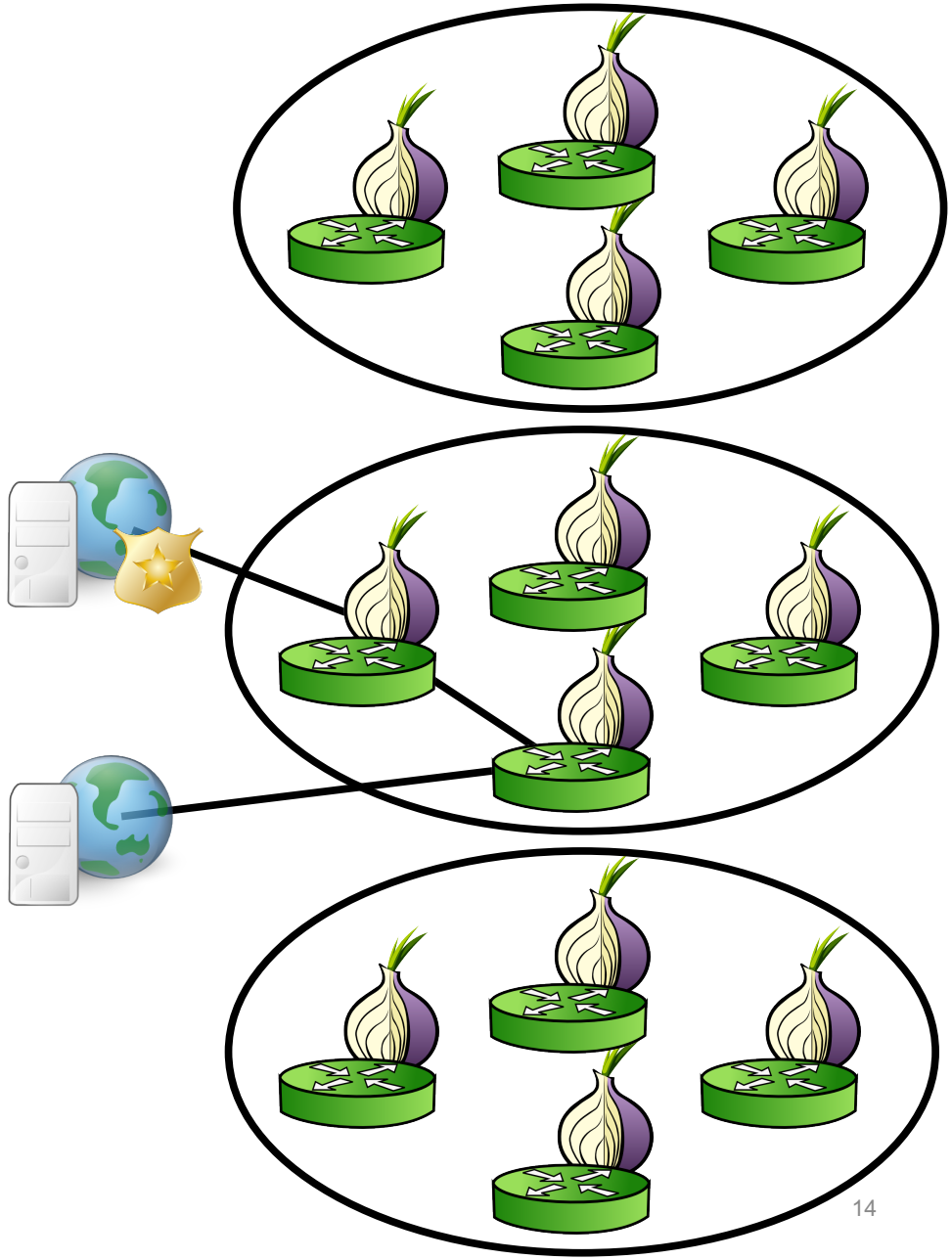
TorFlow

Design

1. Relays are divided into 50-relay slices by estimated capacity.
2. Bandwidth Authorities (BWAuths) time fetching test files through pairs of relay in each slice.
3. Relays given capacities by multiplying self-reported bandwidth by test speed divided by average speed.



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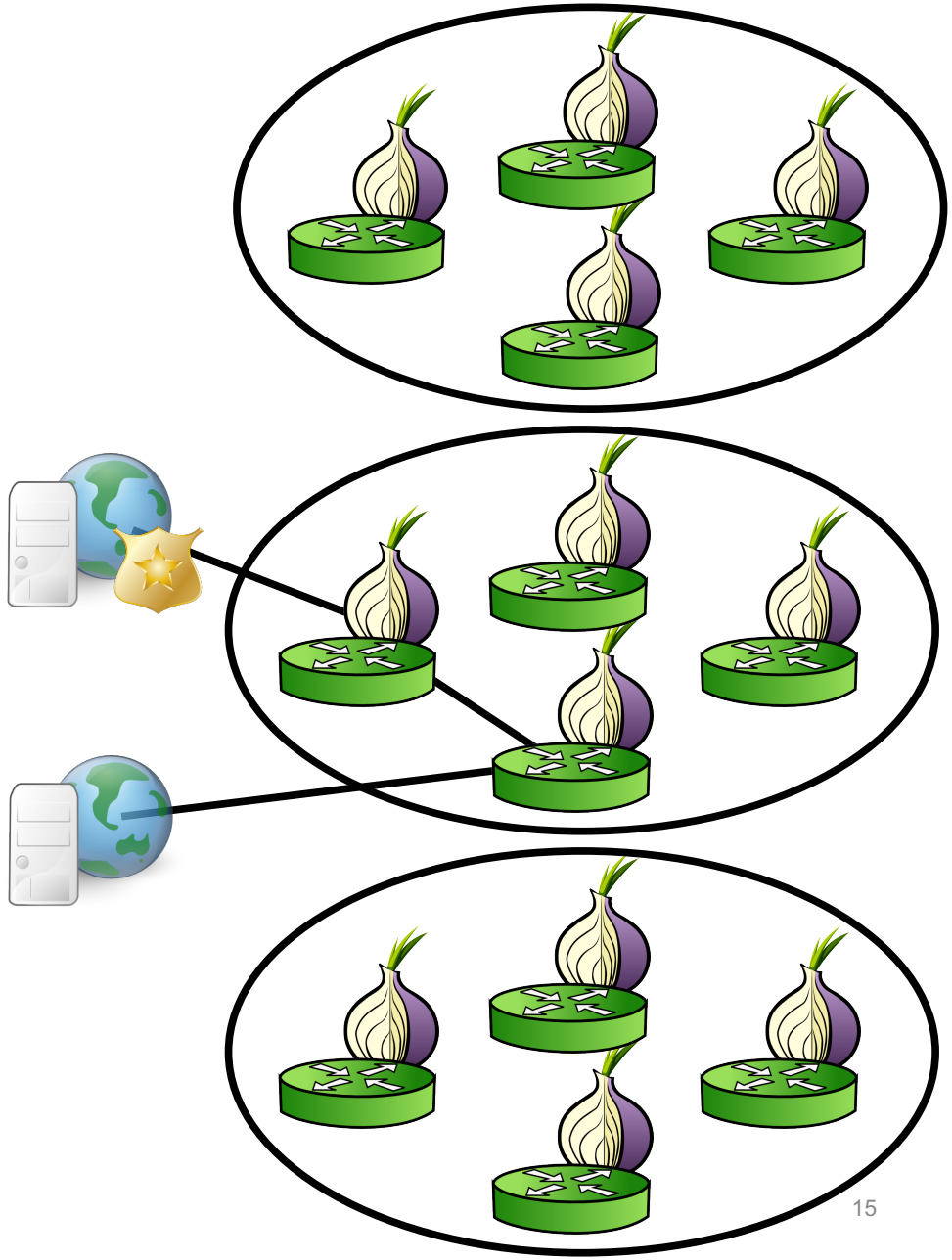
3. Malicious pairs need not actually download the file (no validation).



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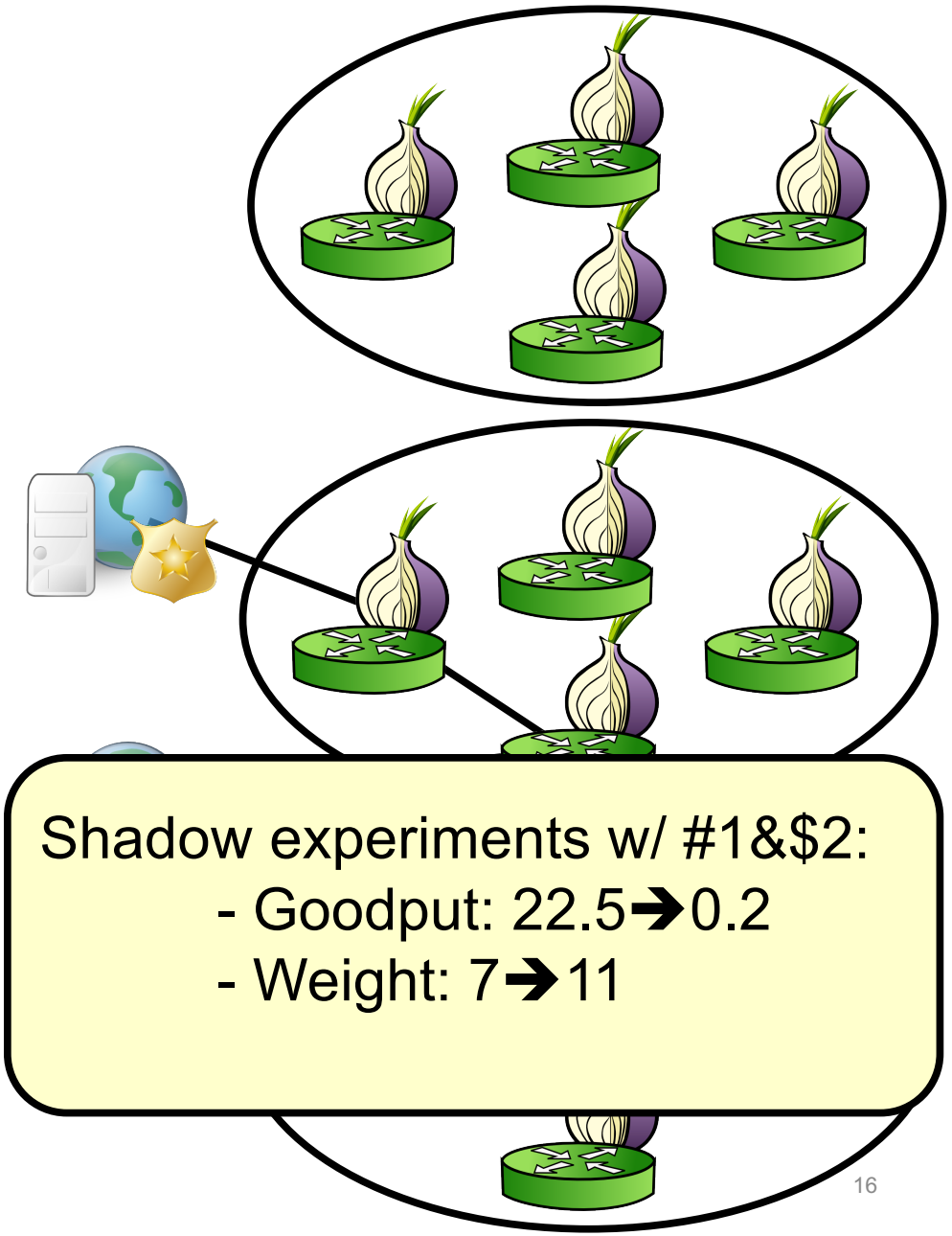

Shadow experiments w/ #1&$2:
- Goodput: 22.5➔0.2
- Weight: 7➔11

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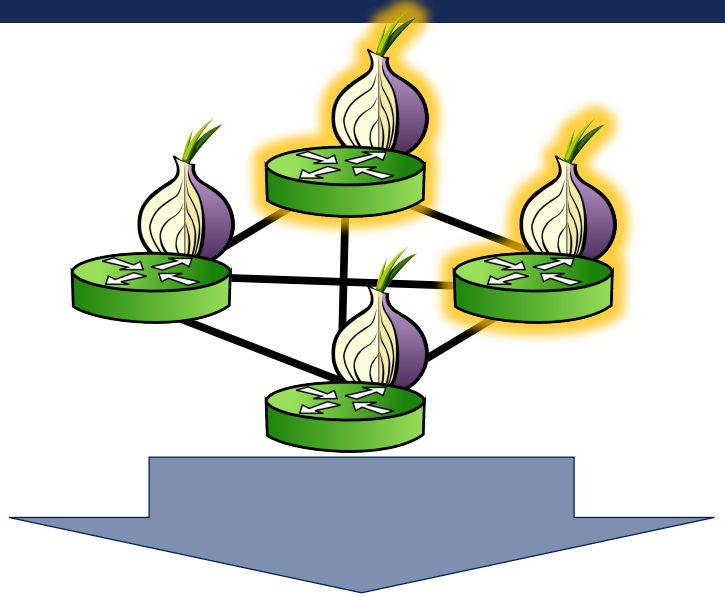
EigenSpeed (Snader and Borisov, IPTPS 2009)

Design

1. Relays periodically send max speed of other relays to a BWAuth.
2. Aggregator calculates capacities as eigenvector of largest connected component with *trusted* relays.
3. Exclude as "liars" relays w/ reports
   1. Changing too quickly during computation, or
   2. Too different from eigenvector



$$T = \begin{bmatrix} 0 & s_{12} & s_{13} & s_{14} \\ s_{21} & 0 & s_{23} & s_{24} \\ s_{31} & s_{32} & 0 & s_{34} \\ s_{41} & s_{42} & s_{43} & 0 \end{bmatrix}$$

Normalize T: T'

Output v^*: $v^*T=\lambda T$, $\lambda \geq 1$

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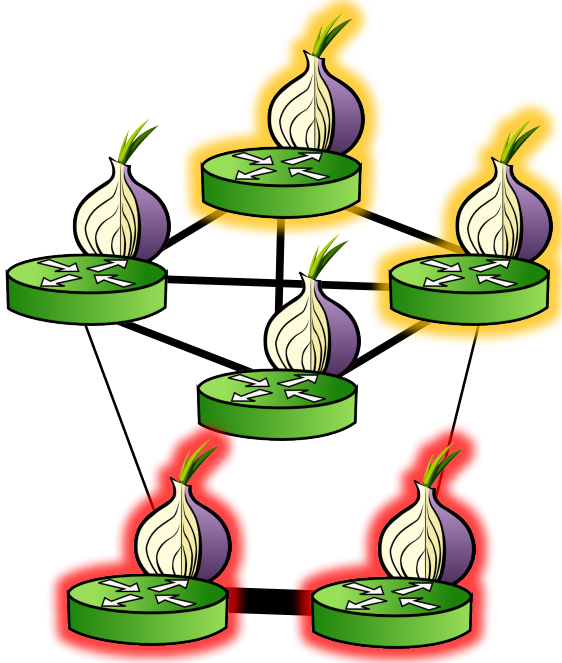

Fat-pipe attack: Large false speeds among malicious relays, small elsewhere. EigenSpeed's liar detection is designed to prevent this.

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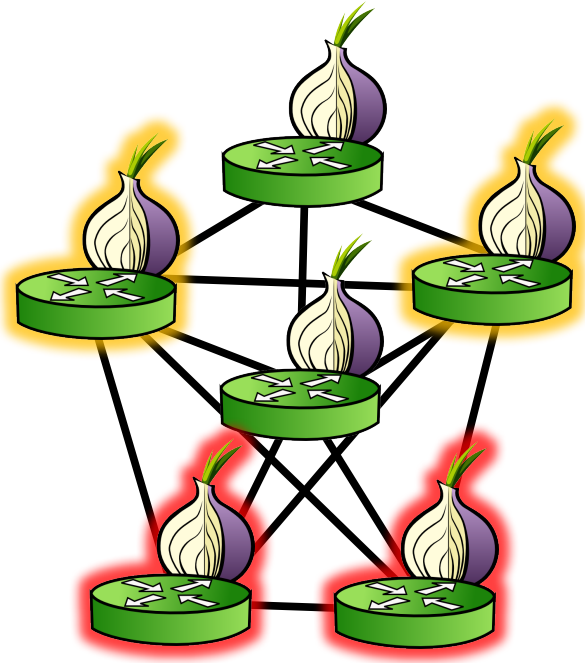
Attack

1. "Frame" some honest non-trusted relays under liar metric #1 with avg speeds with all but framed relays.



Framing attack: With 1118 trusted relays and 2.83% malicious BW, and 558 malicious relays, 559 of 5000 honest relays are framed.

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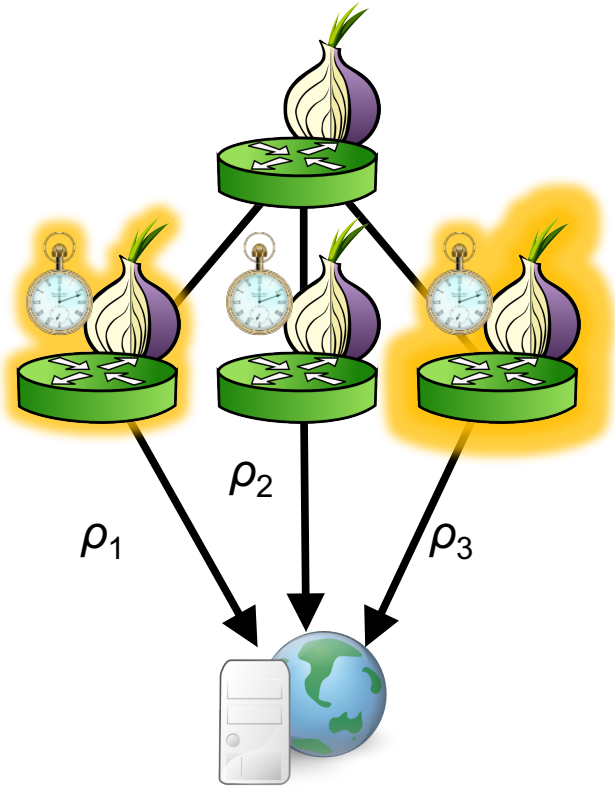

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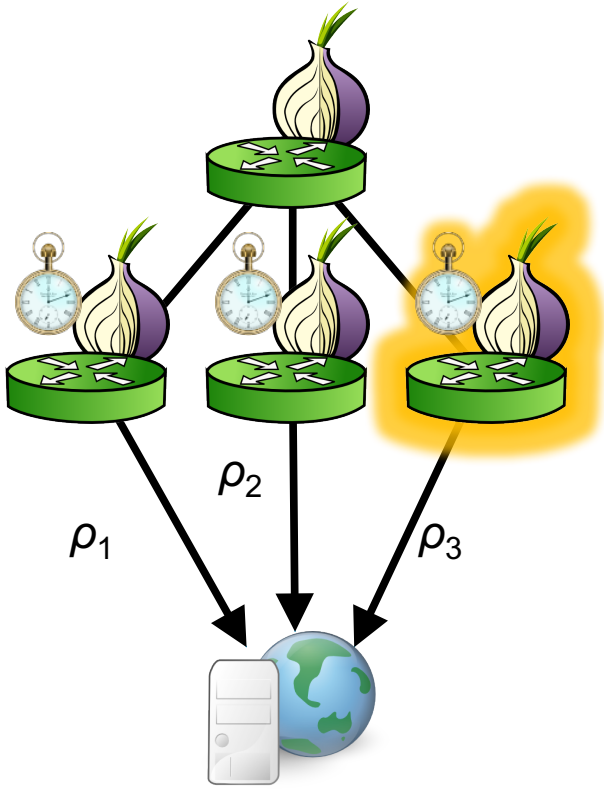

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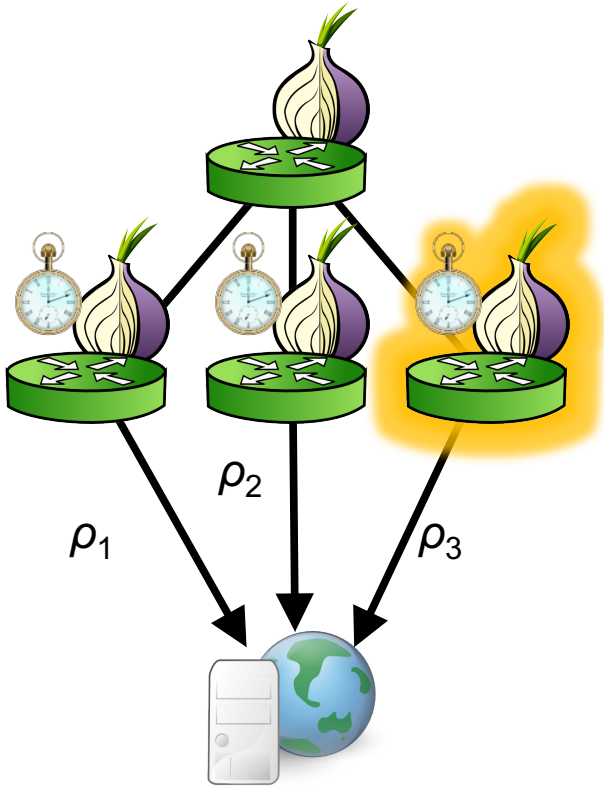

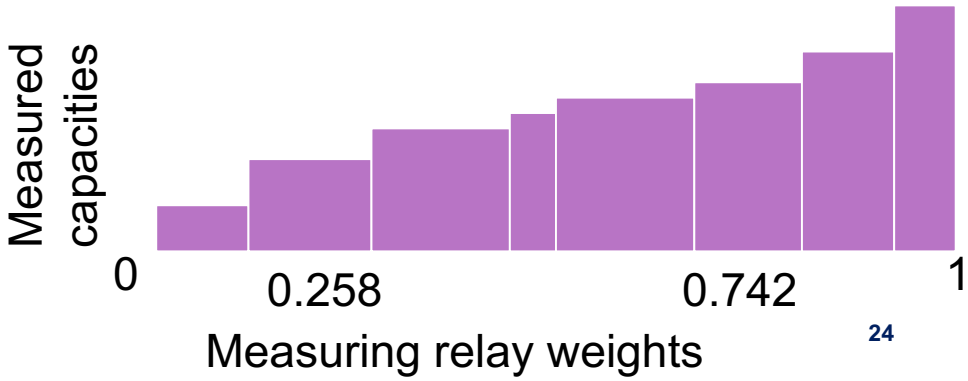

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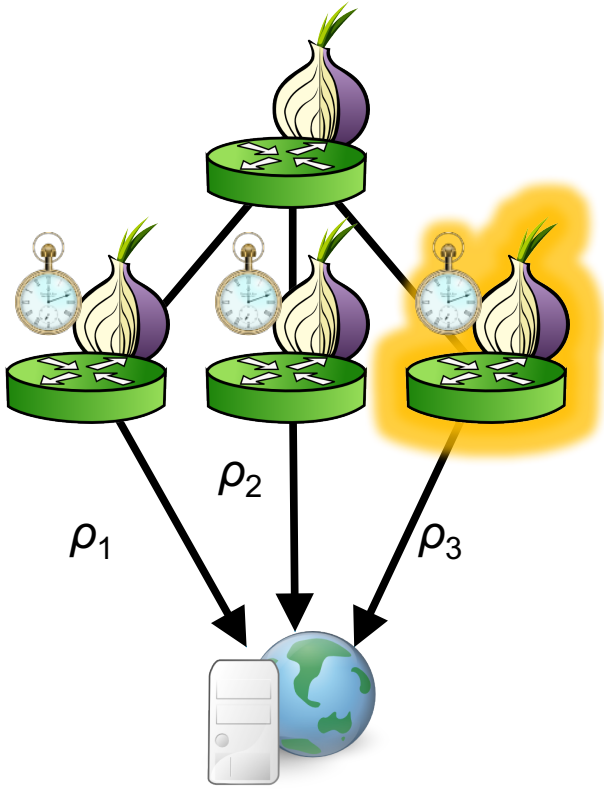

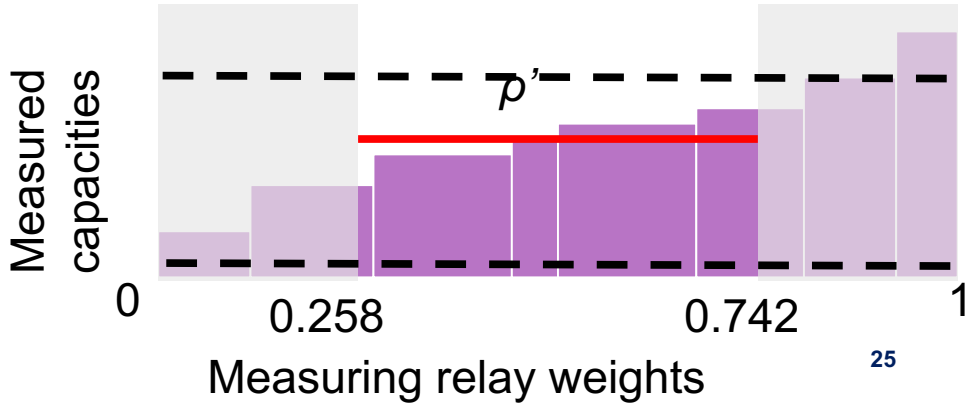

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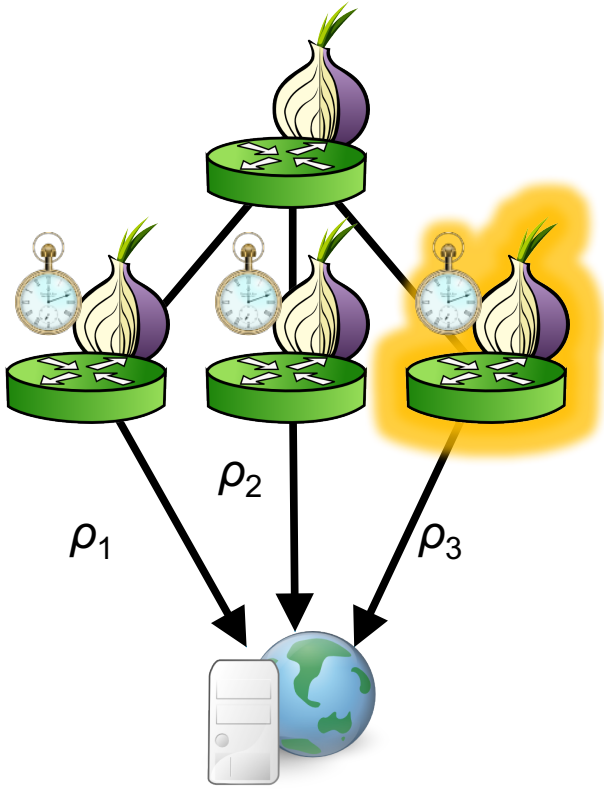

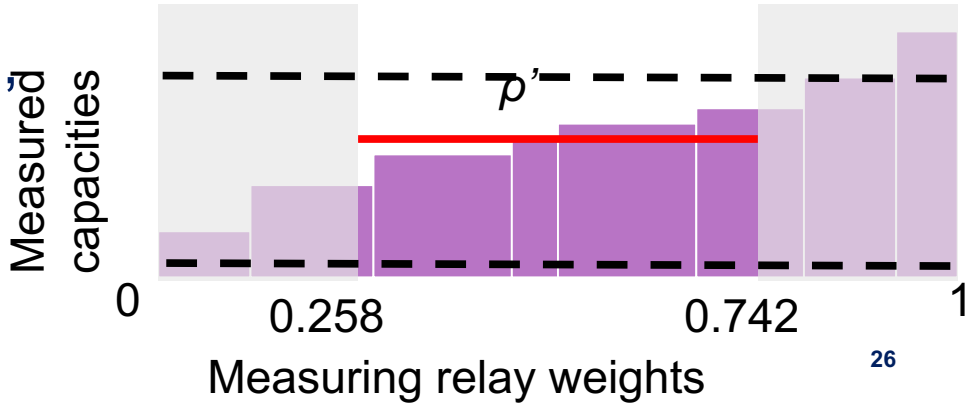

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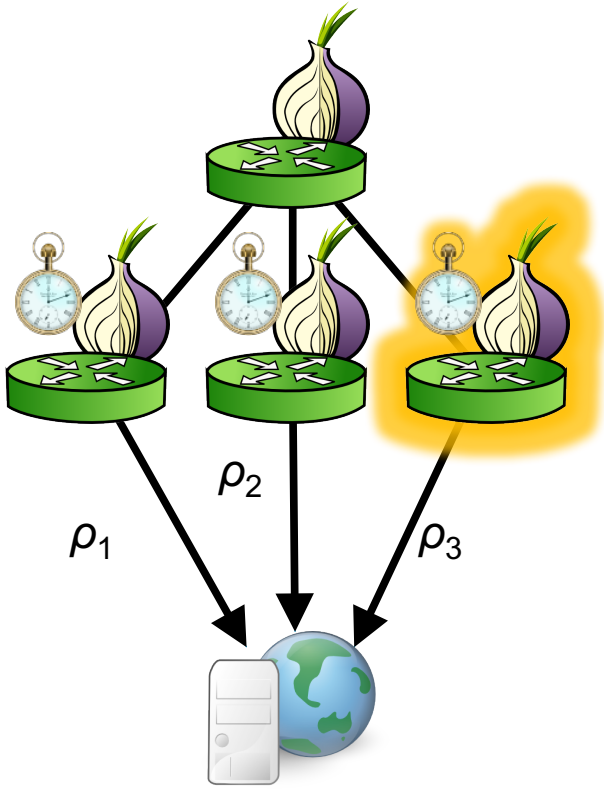
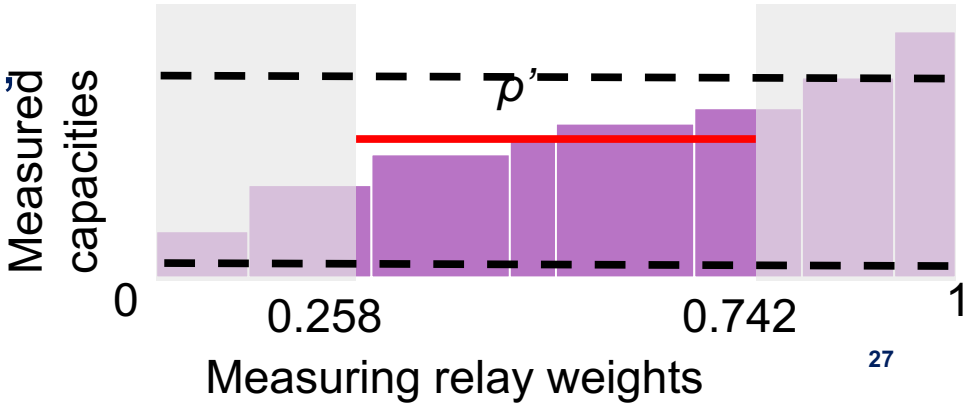
5. New relays only selected for middle position





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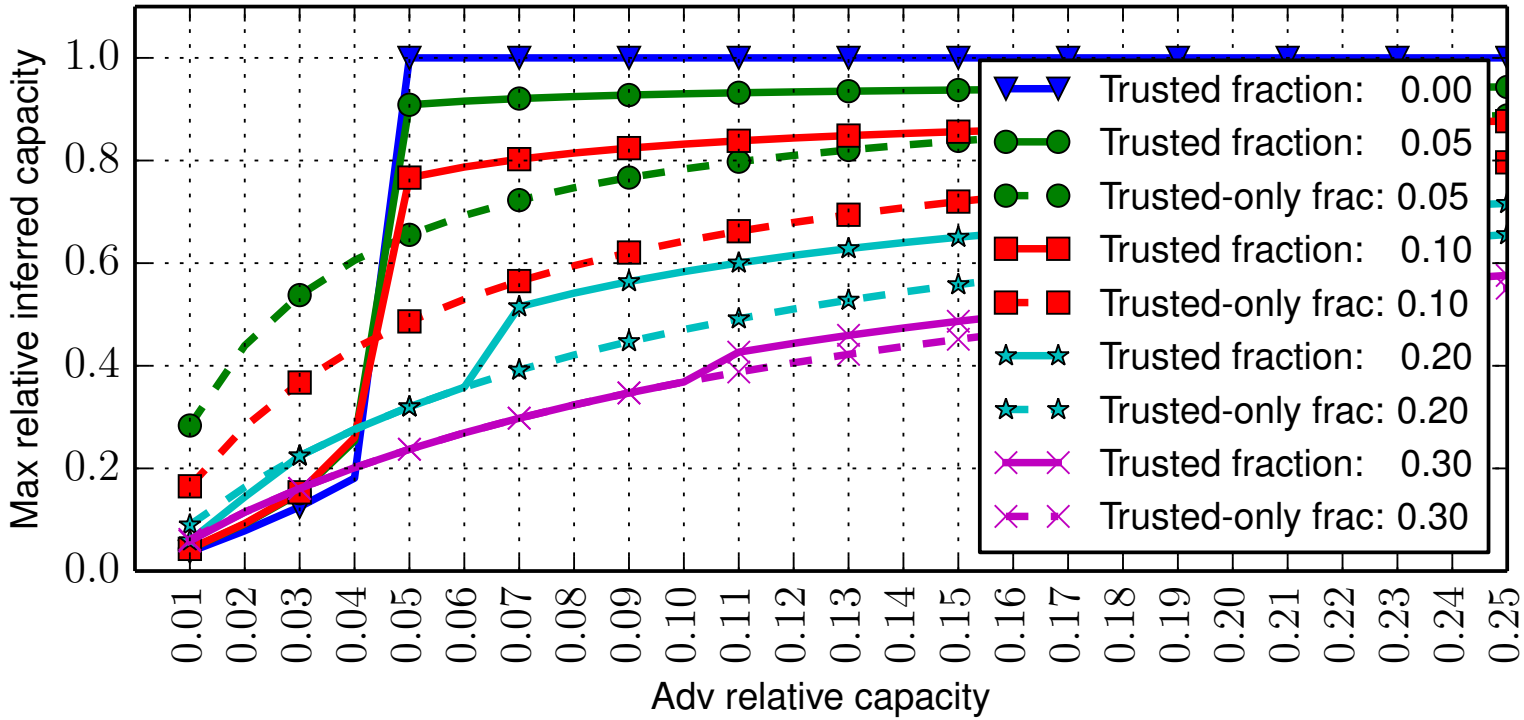
PeerFlow: Security

Attack	Weight multiple
Only carry traffic in one direction	2
Only exchange traffic with measuring relays	1.33
Do not exchange traffic with the lower trimmed fraction of relays	1.34

Single-round capacity inflation



Multiple-round capacity inflation

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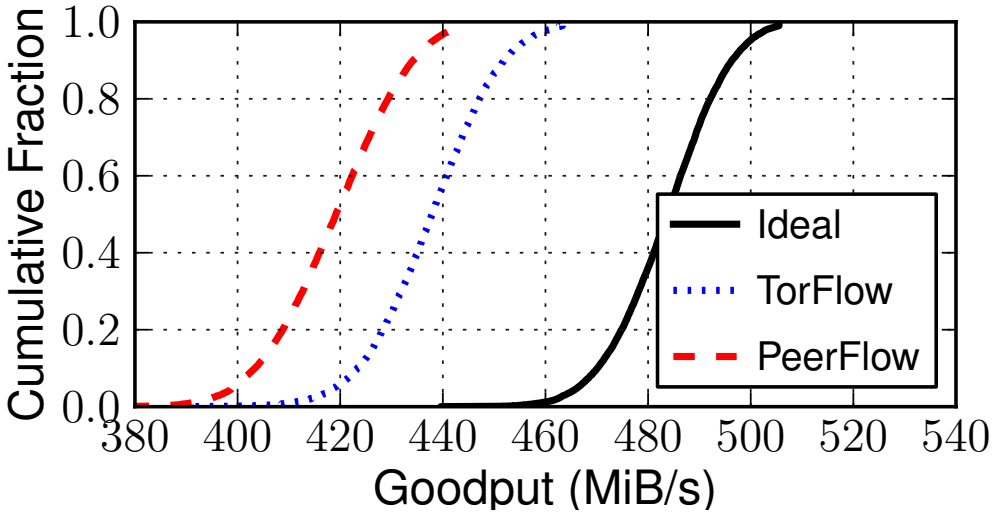
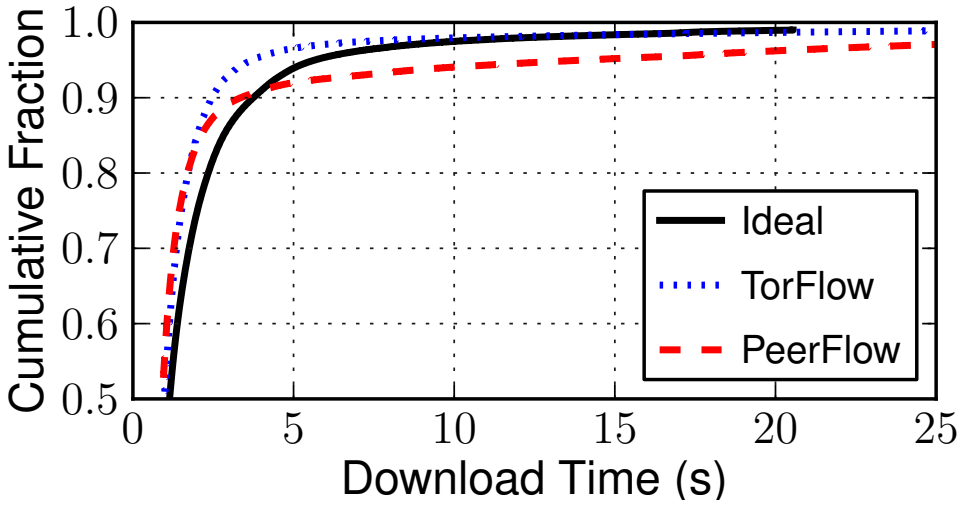
PeerFlow: Performance

Shadow experiments comparing PeerFlow, TorFlow, and Ideal

- 4 Tor directory authorities
- 498 Tor relays
- 7,500 Tor clients
- 1,000 servers



Aggregate relay goodput per second



Time to last byte of 320KiB file

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Conclusion

1. Tor needs secure load balancing
2. Demonstrated attacks on existing solutions
   - TorFlow
   - EigenSpeed
3. Presented PeerFlow
   - Demonstrated secure against bandwidth-limited adversary
   - Experimentally showed performance is similar to current Tor performance