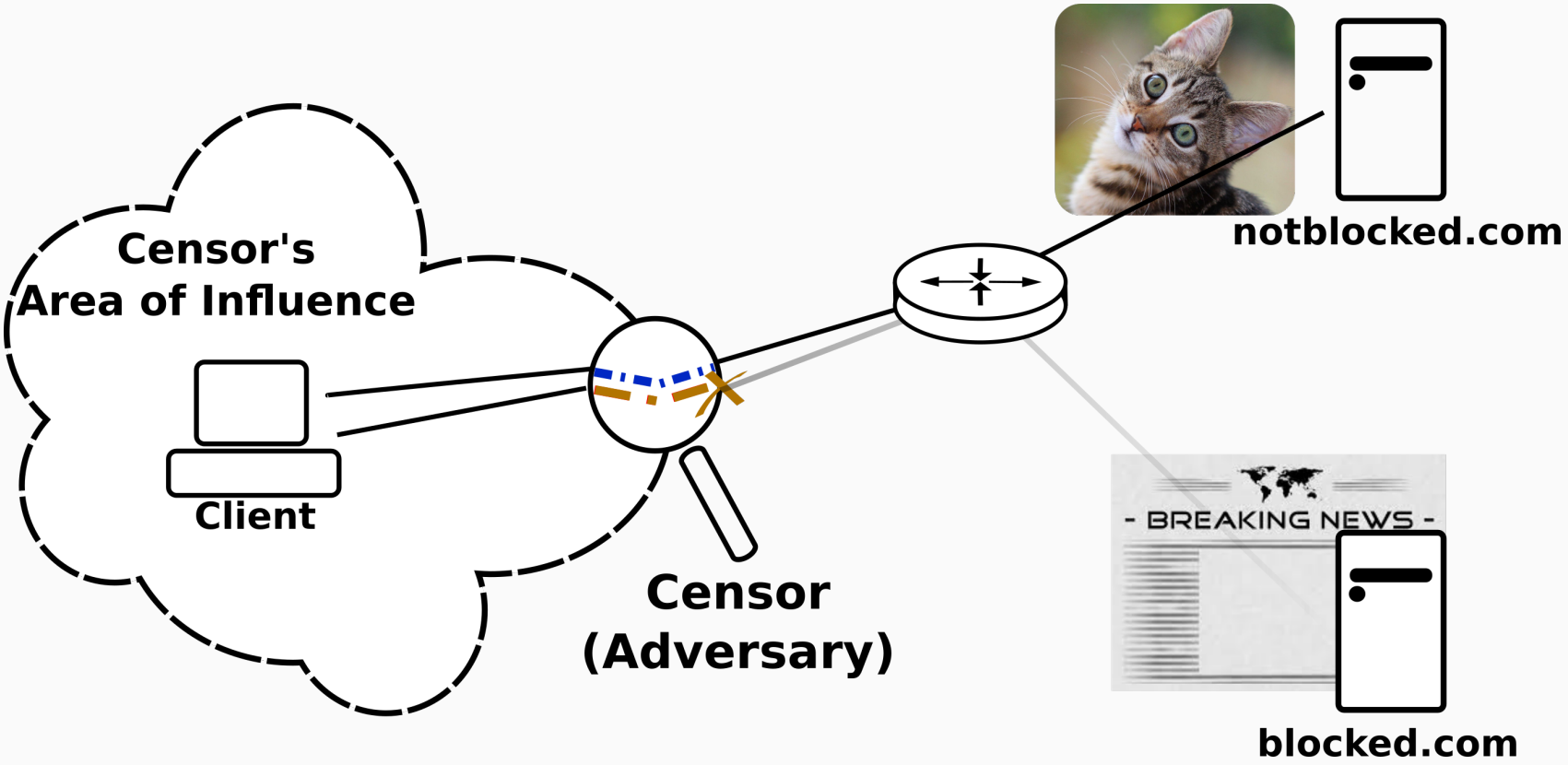
Perfect Imitation and Secure Asymmetry for Decoy Routing Systems with Slitheen

Cecylia Bocovich **Ian Goldberg**

20 June 2017
EPFL Summer Research Institute

Censorship



Censors may monitor, alter or block traffic that enters or leaves their area of influence.

Censorship Strategies

Censorship measurement studies in Iran [Aryan et al.], Pakistan [Nabi et al.], and China [Winter and Lindskog] show the following techniques:

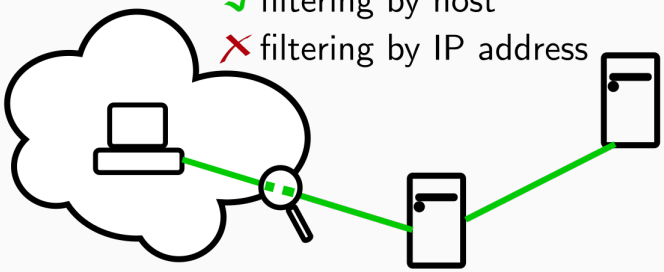
- Filtering by IP address
- Filtering by hostname
- Protocol-specific throttling
- URL keyword filtering
- Active probing
- Application-layer DPI

Censorship Circumvention

Simple Proxies

✓ filtering by host

✗ filtering by IP address



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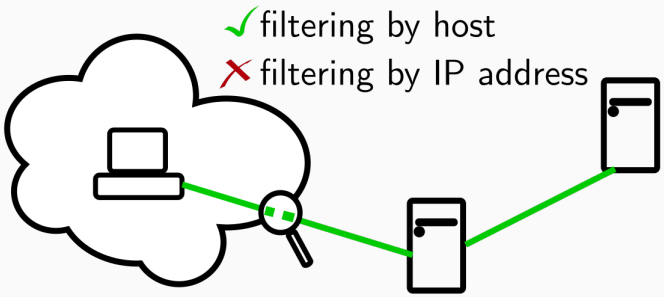
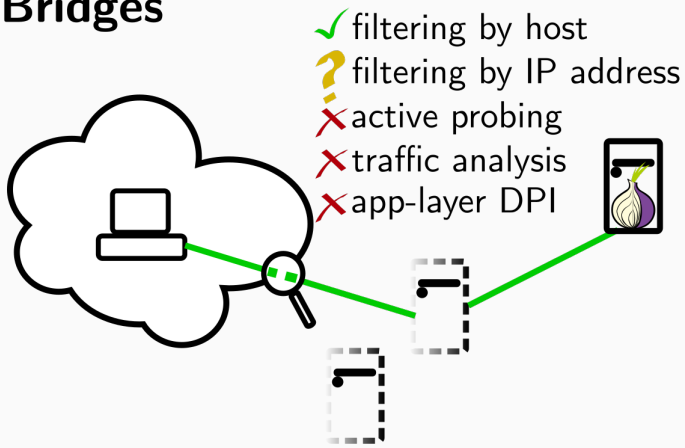


Tor Bridges



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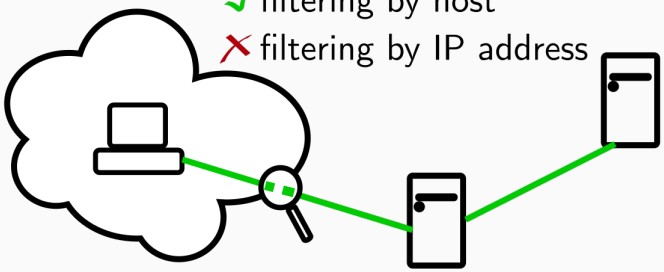

Tor Bridges

✓ filtering by host
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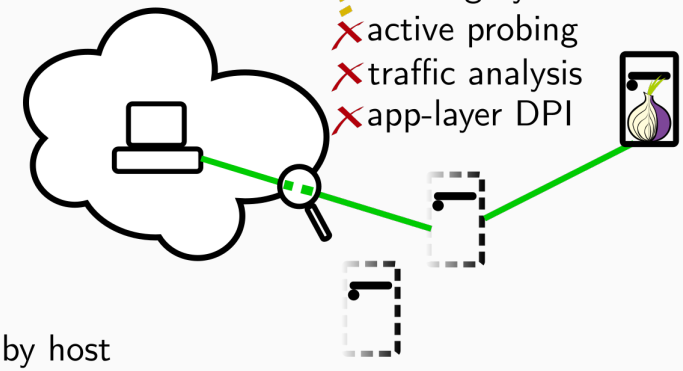
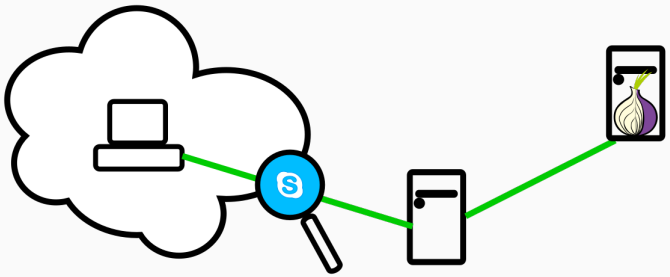


Pluggable Transports



SkypeMorph (Mohajeri Moghaddam et al., 2012)
StegoTorus (Weinberg et al., 2012)
Marionette (Dyer et al., 2015)

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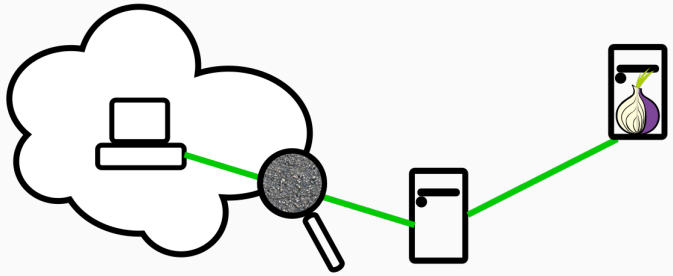
ScrambleSuit (Winter et al., 2012)
Obfsproxy (Dingledine, 2012)



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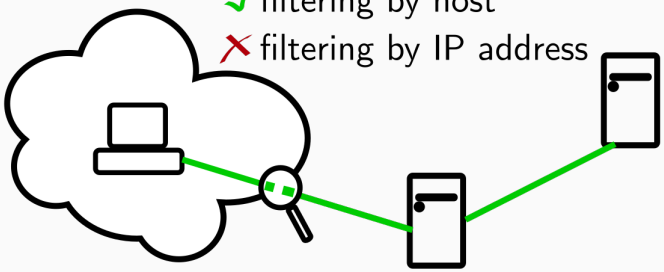

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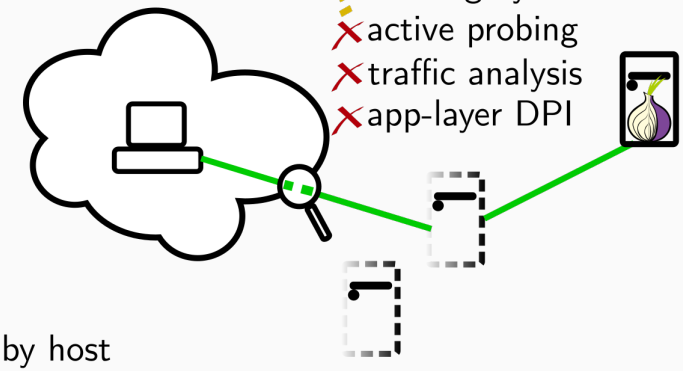

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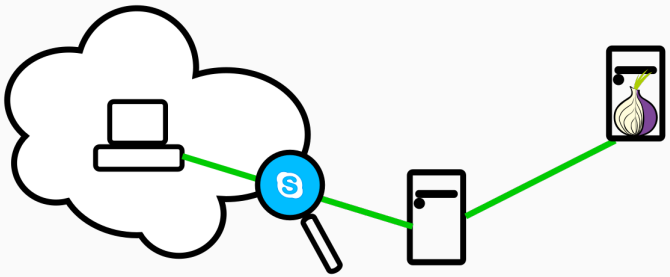

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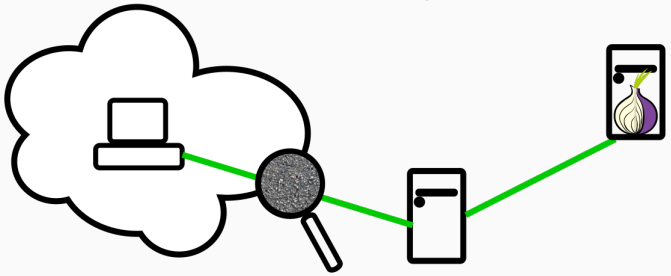
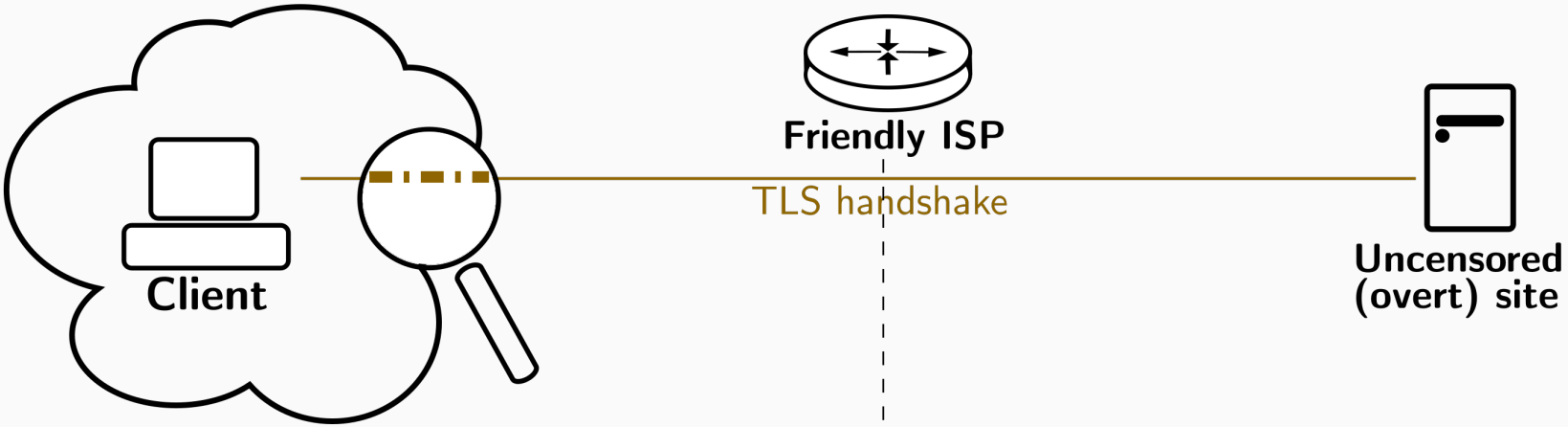


(Houmansadr et al., 2013)

Decoy Routing



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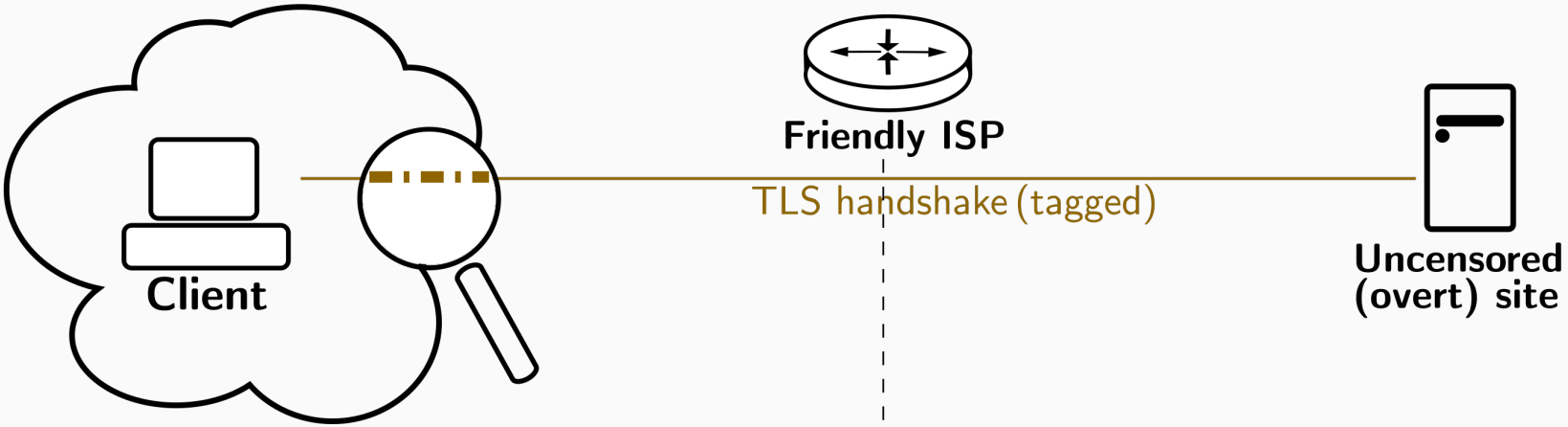
Decoy Routing



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2. Steganographically share TLS master secret with friendly ISP
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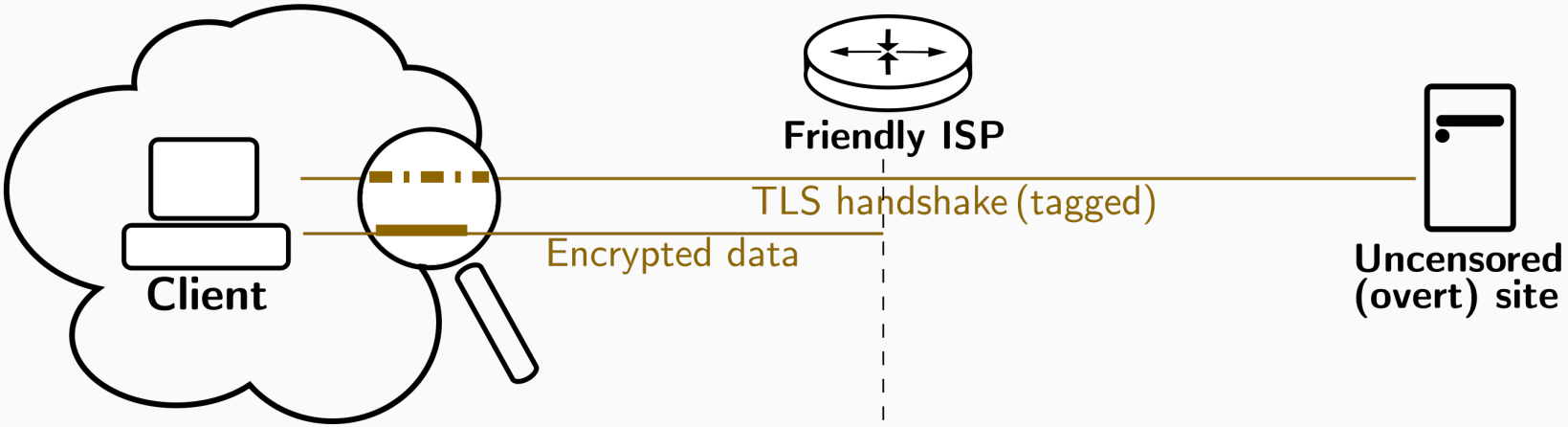

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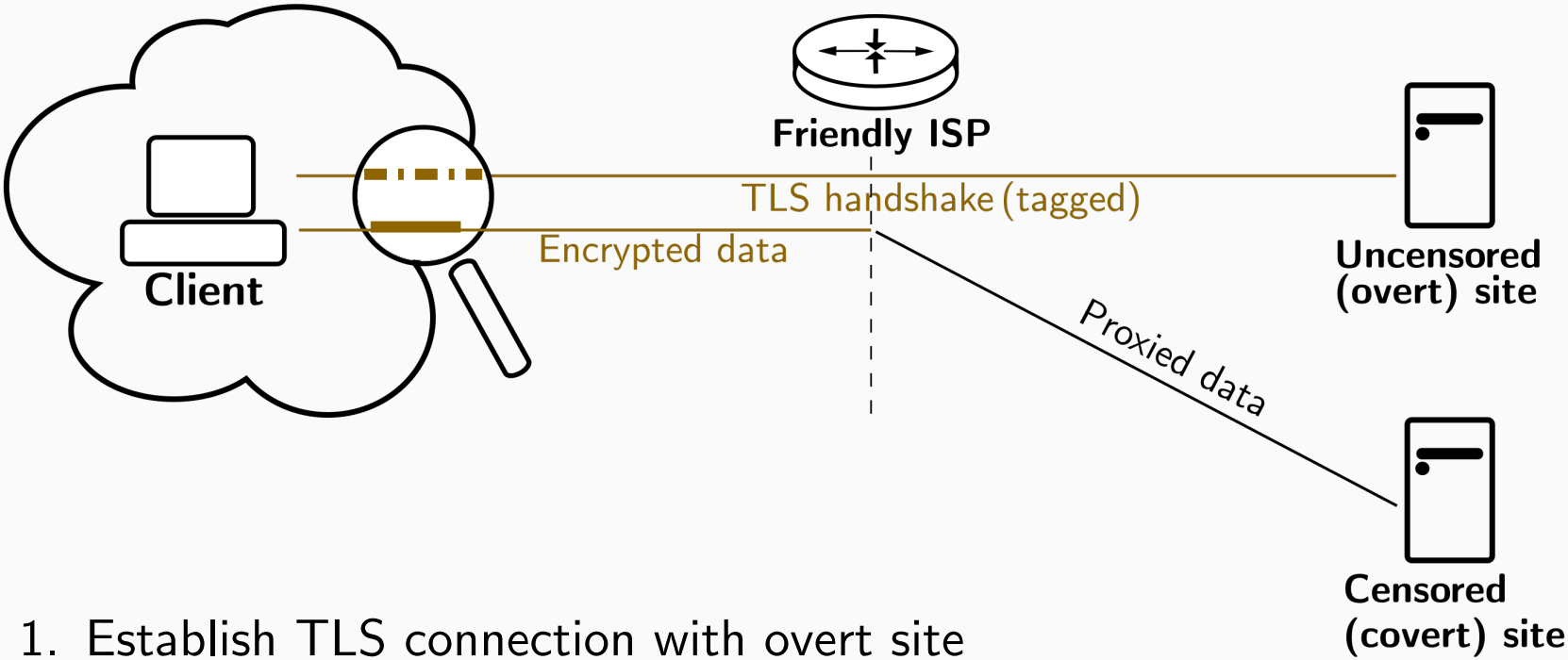

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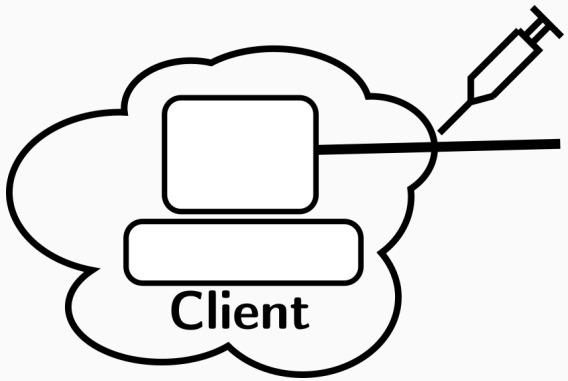
4. Proxy information between client and covert site

Attacks on Decoy Routing

(Wustrow et al., 2011)
(Schuchard et al., 2012)



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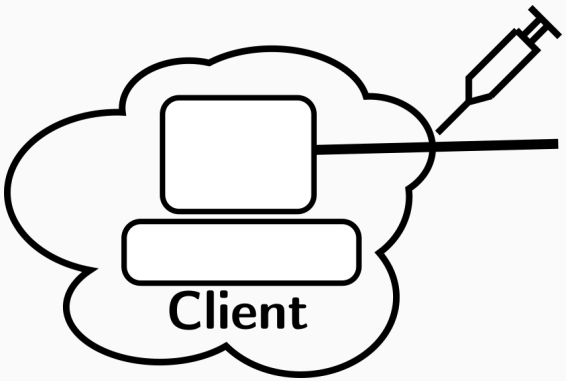

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Routing-Based (RAD) Attacks

- TCP replay
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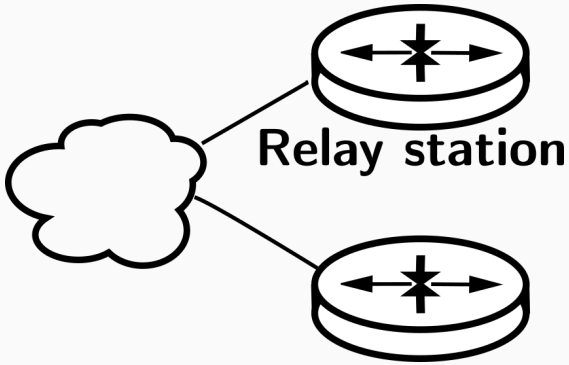

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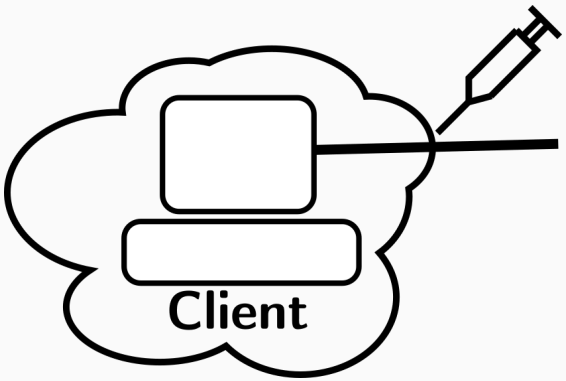

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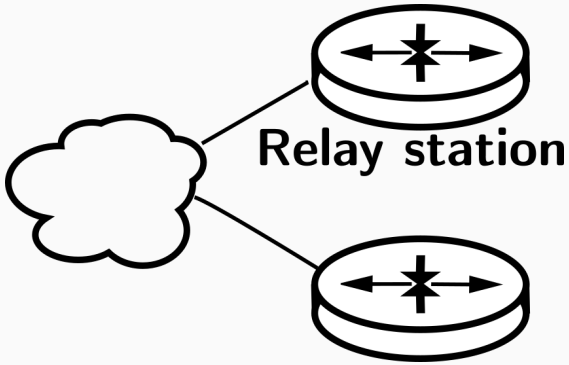

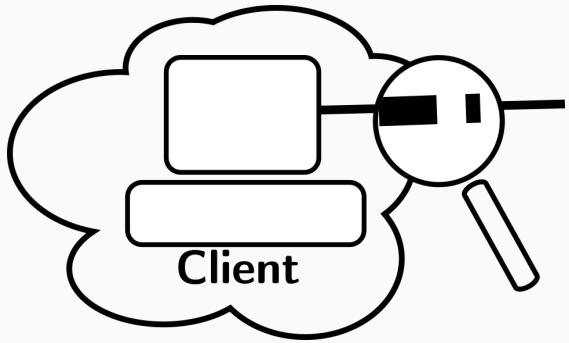

Passive Attacks

- Traffic analysis
- Latency analysis

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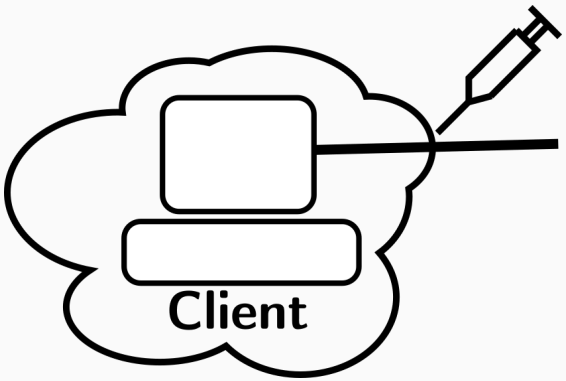

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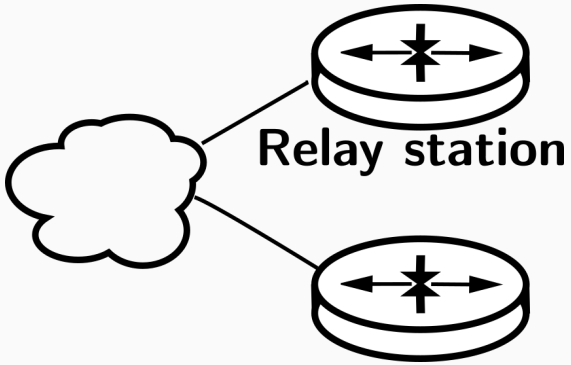

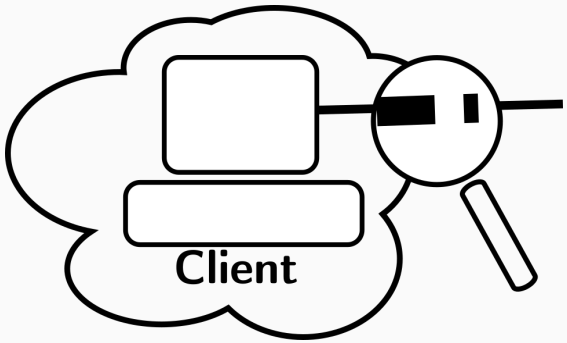

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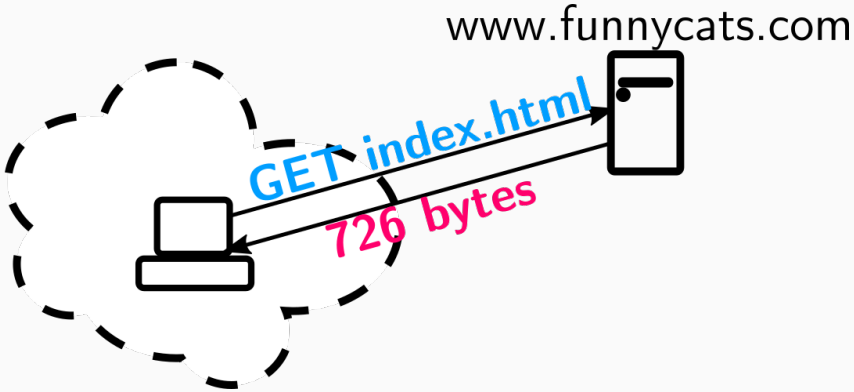

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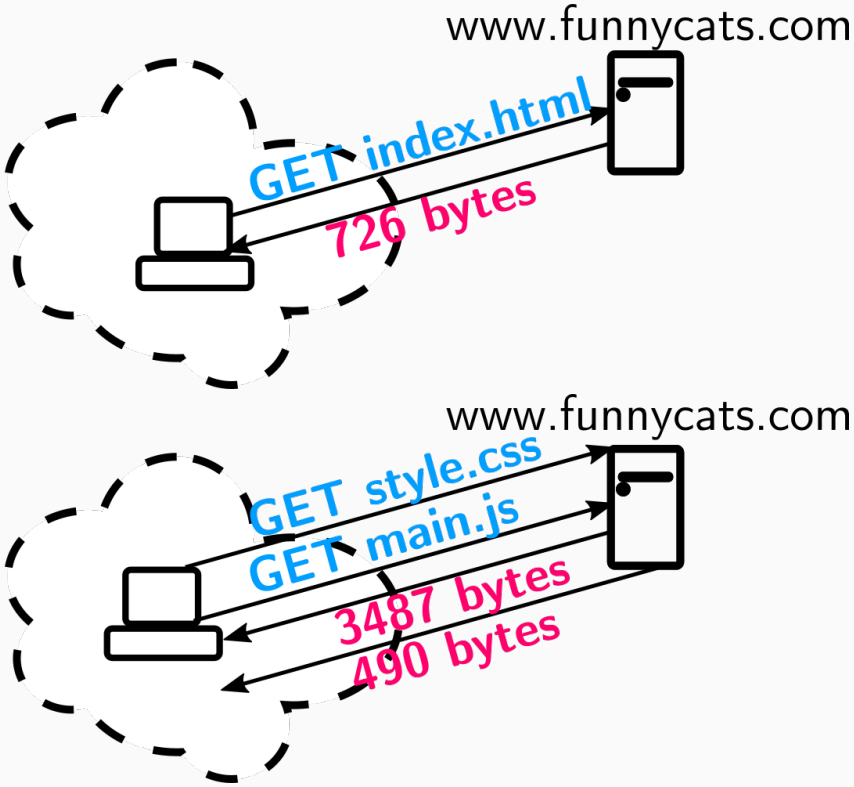

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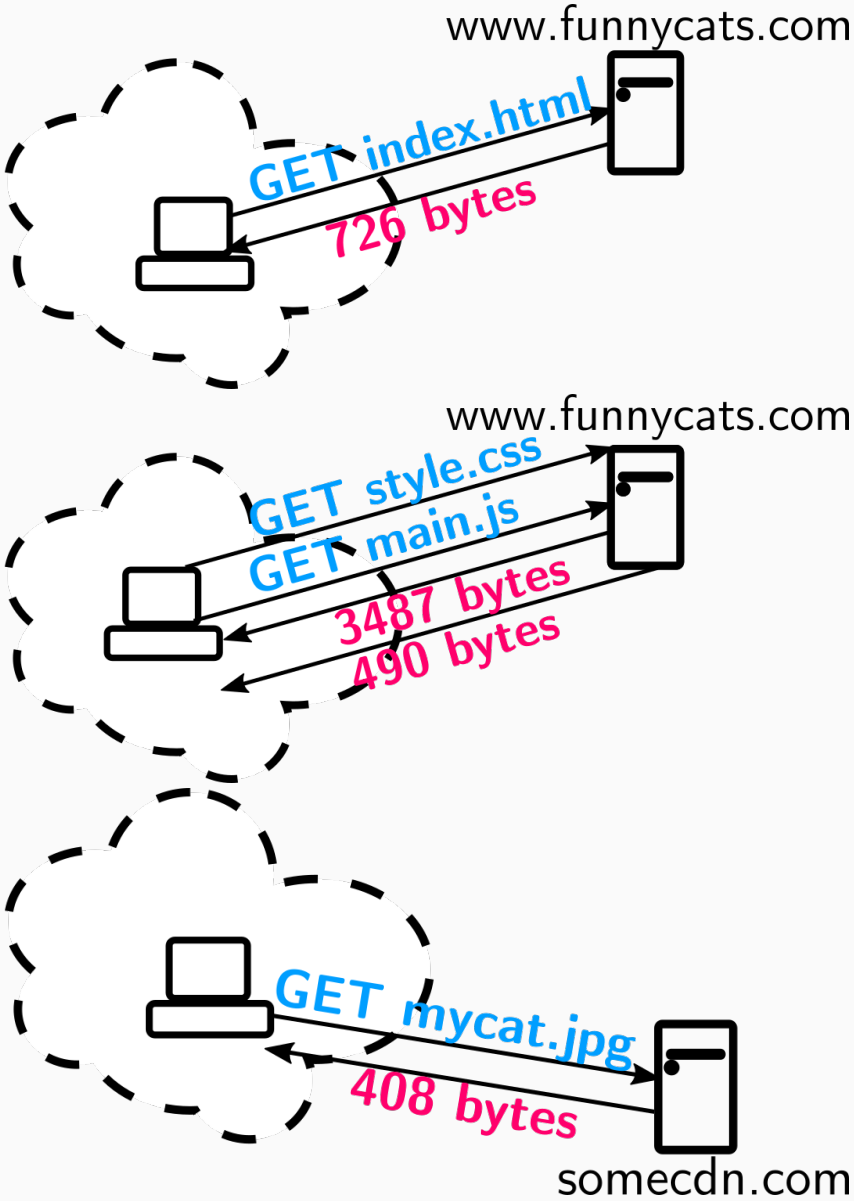

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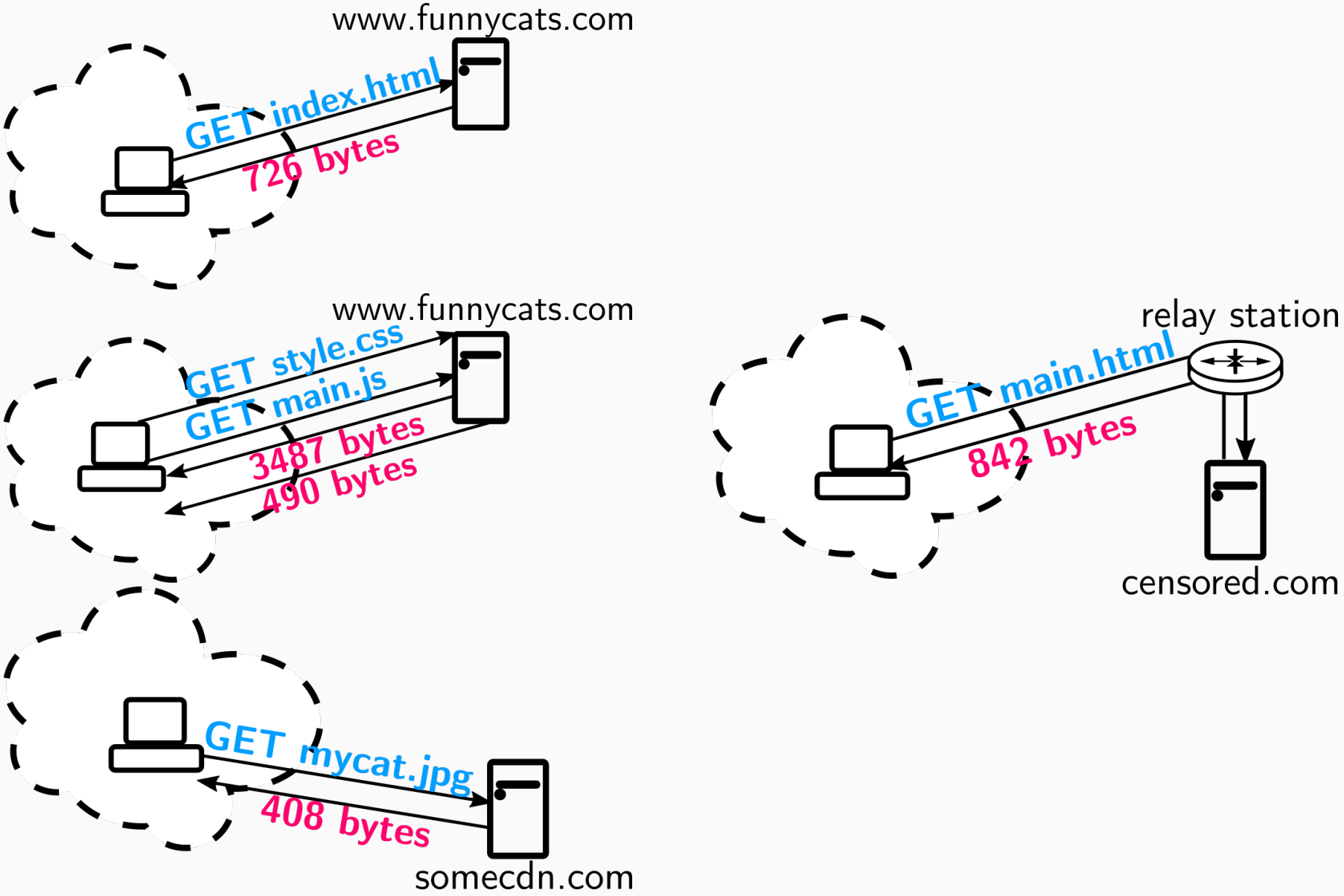

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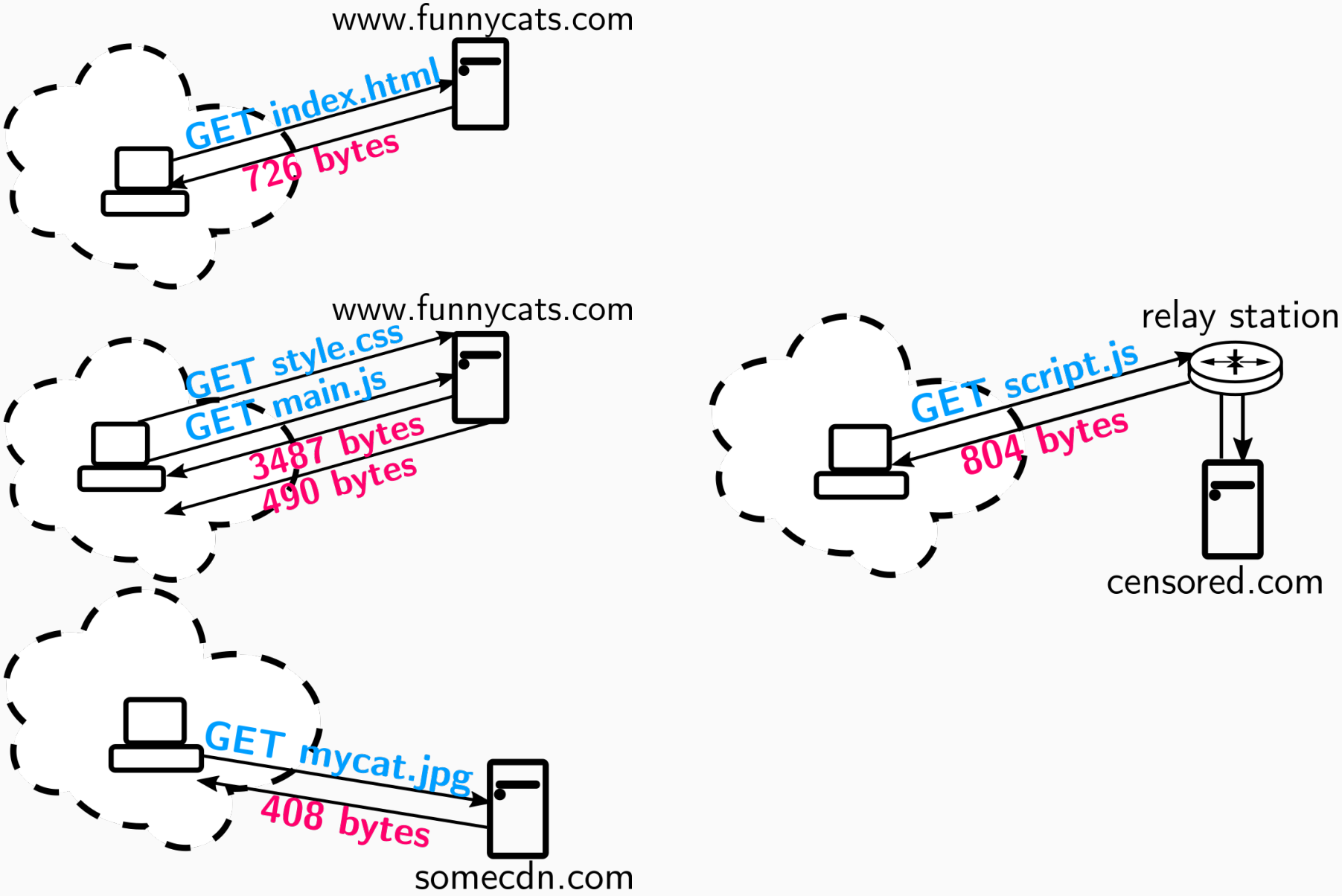

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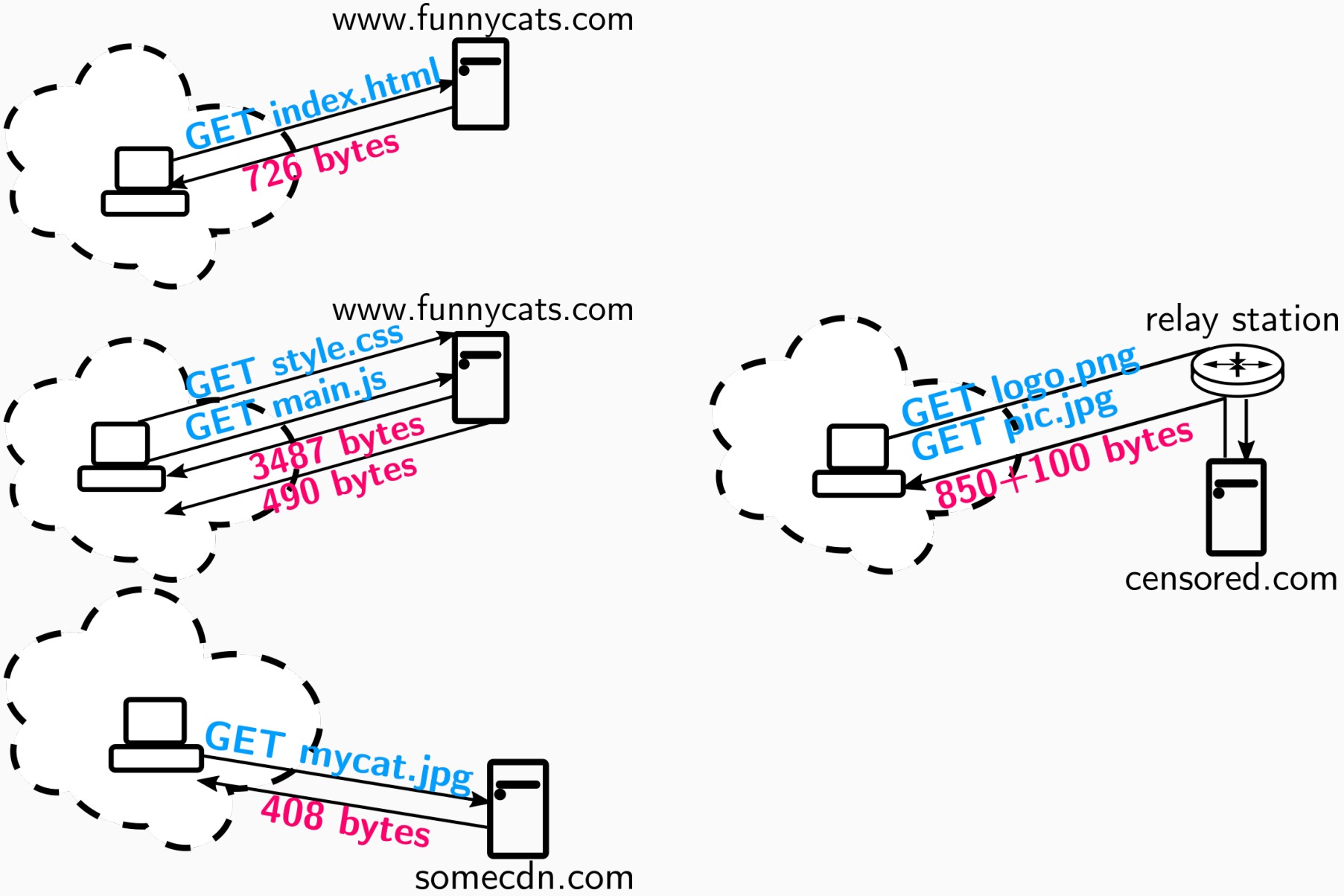

Latency Analysis

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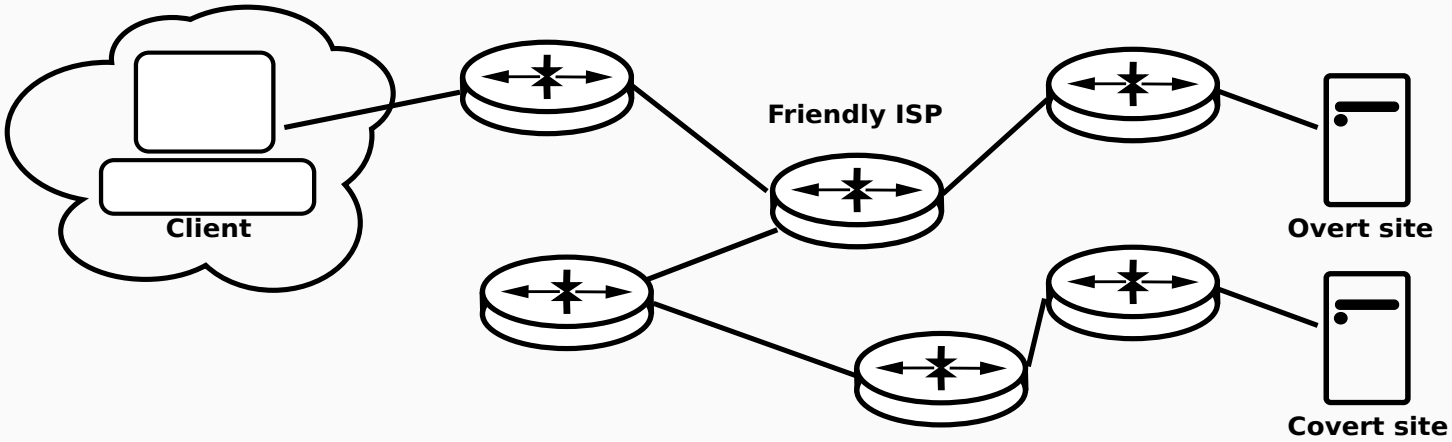
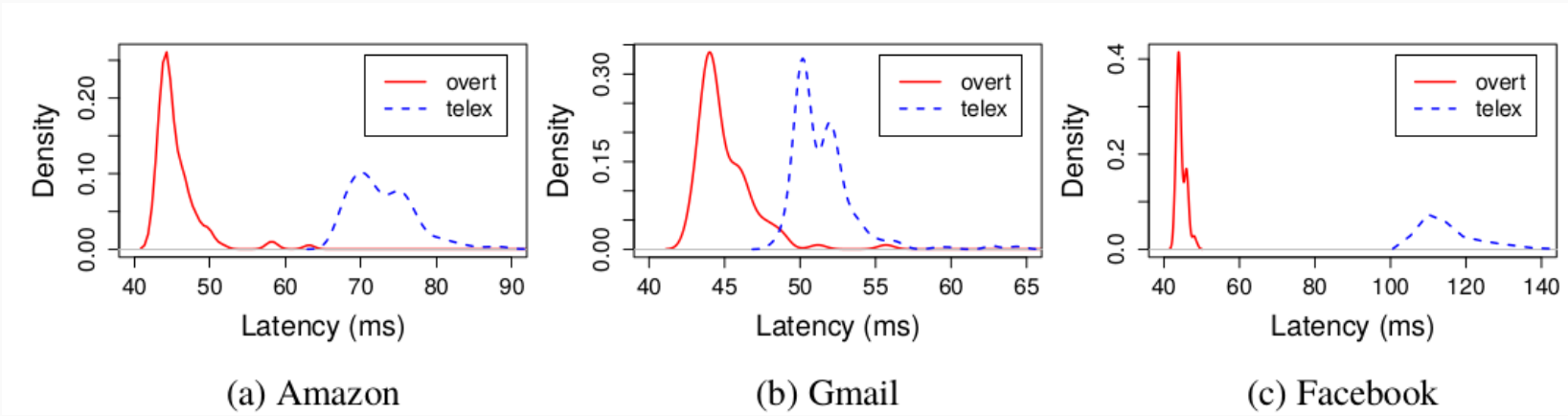


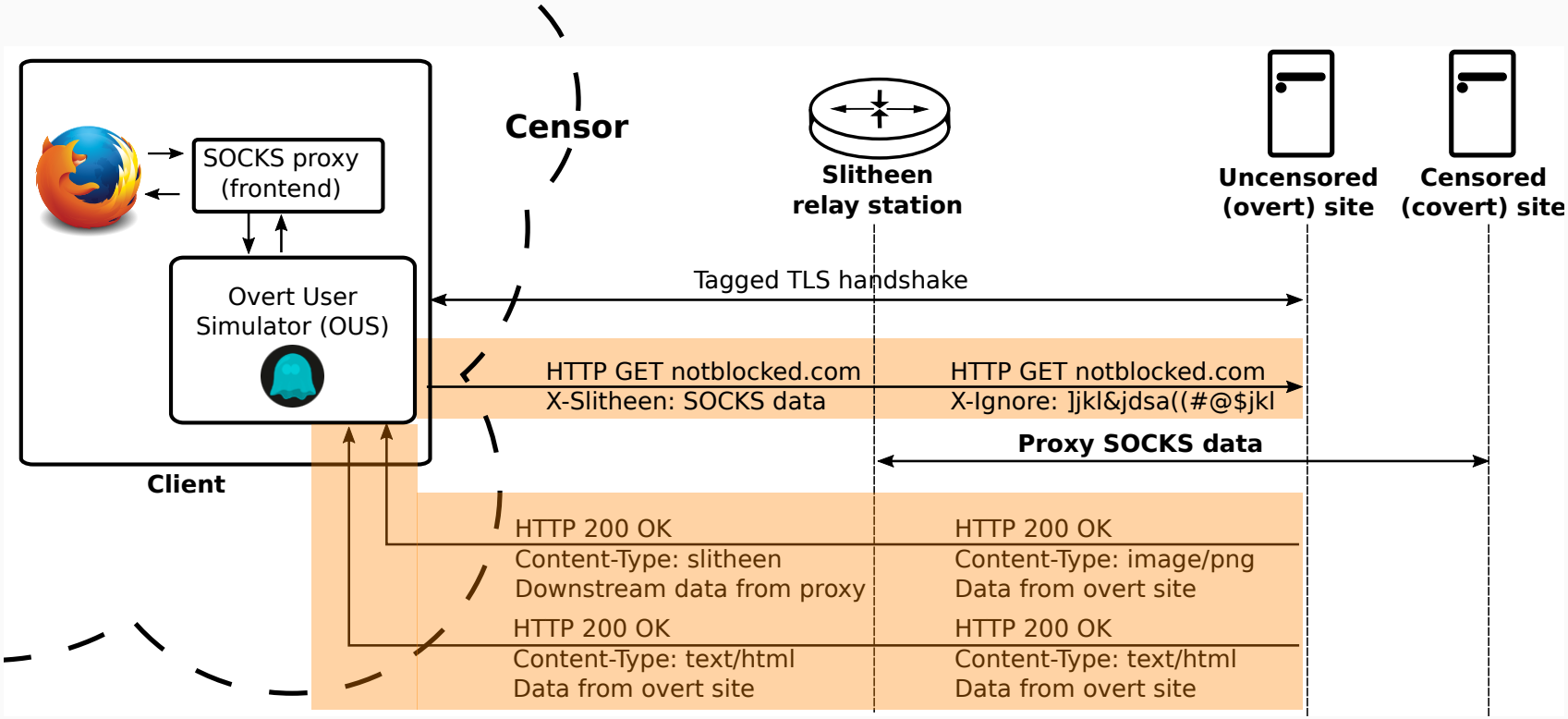


Slitheen

Slitheen traffic patterns to overt destinations **are identical to** a regular access to the overt site.

Covert content is squeezed into “leaf” resources (images, videos, etc.) that do not affect future connections for additional overt resources.

Architecture Overview



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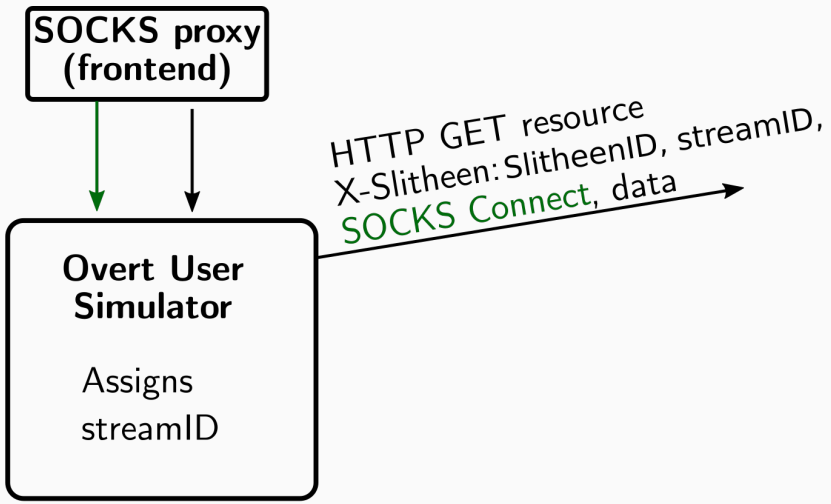
- Relay station modifies the server's Finished message to alert the client that Slitheen is active

Data Replacement



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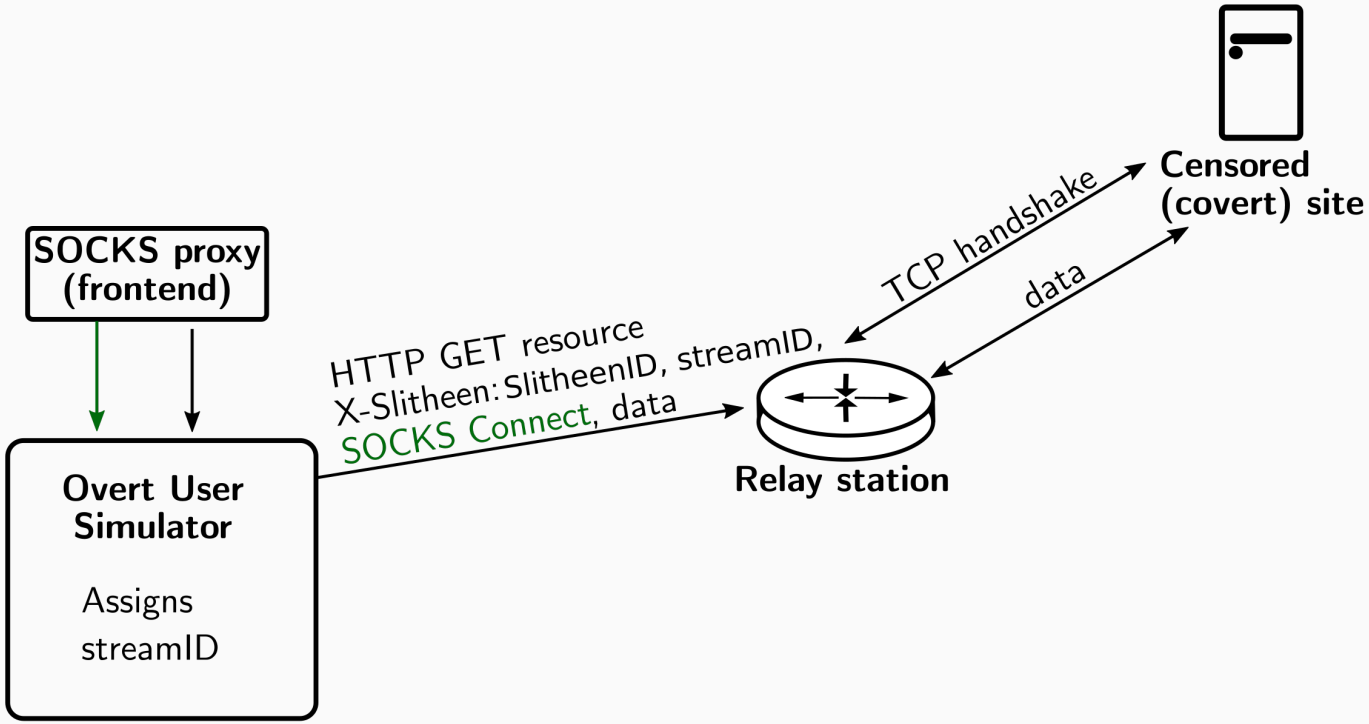

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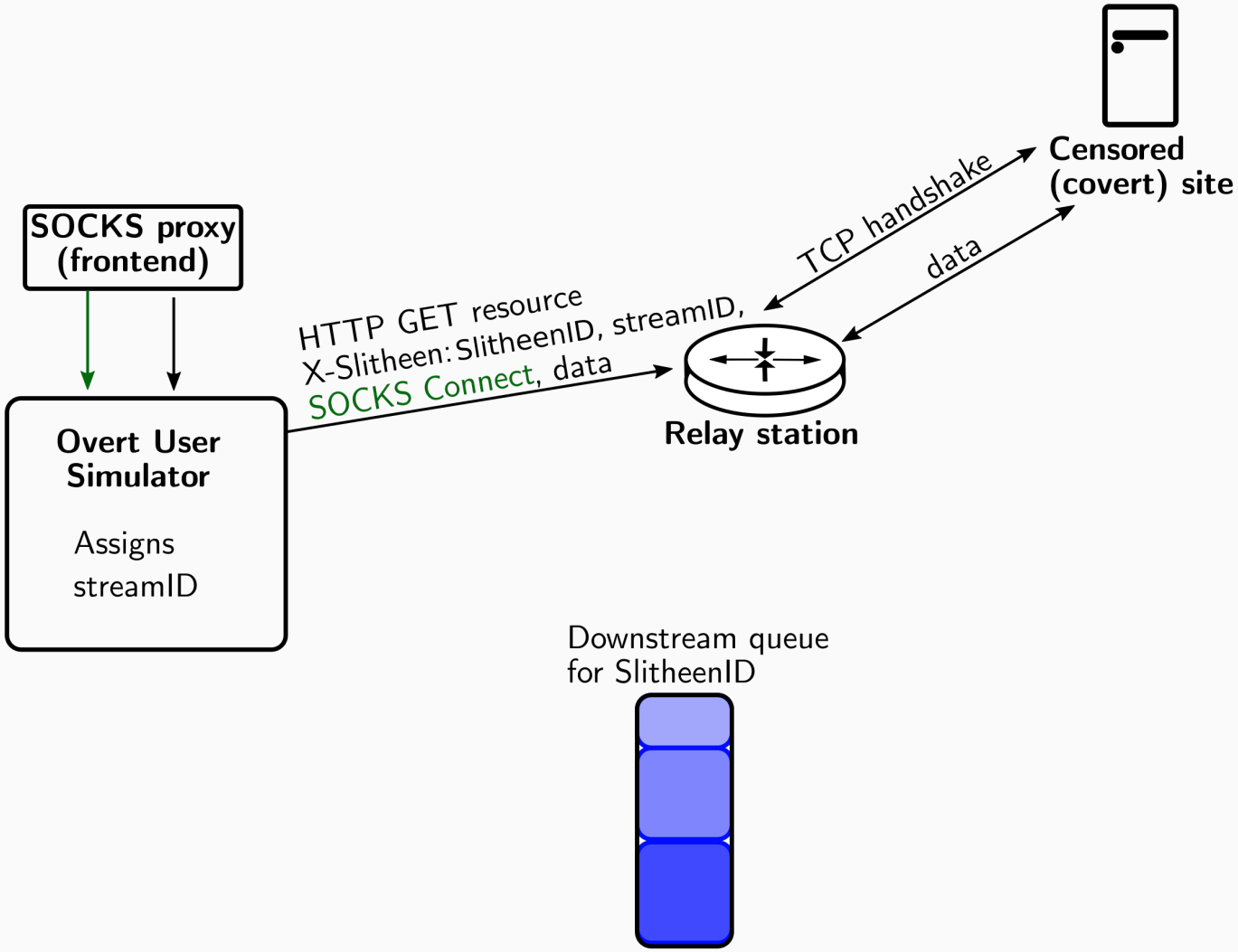

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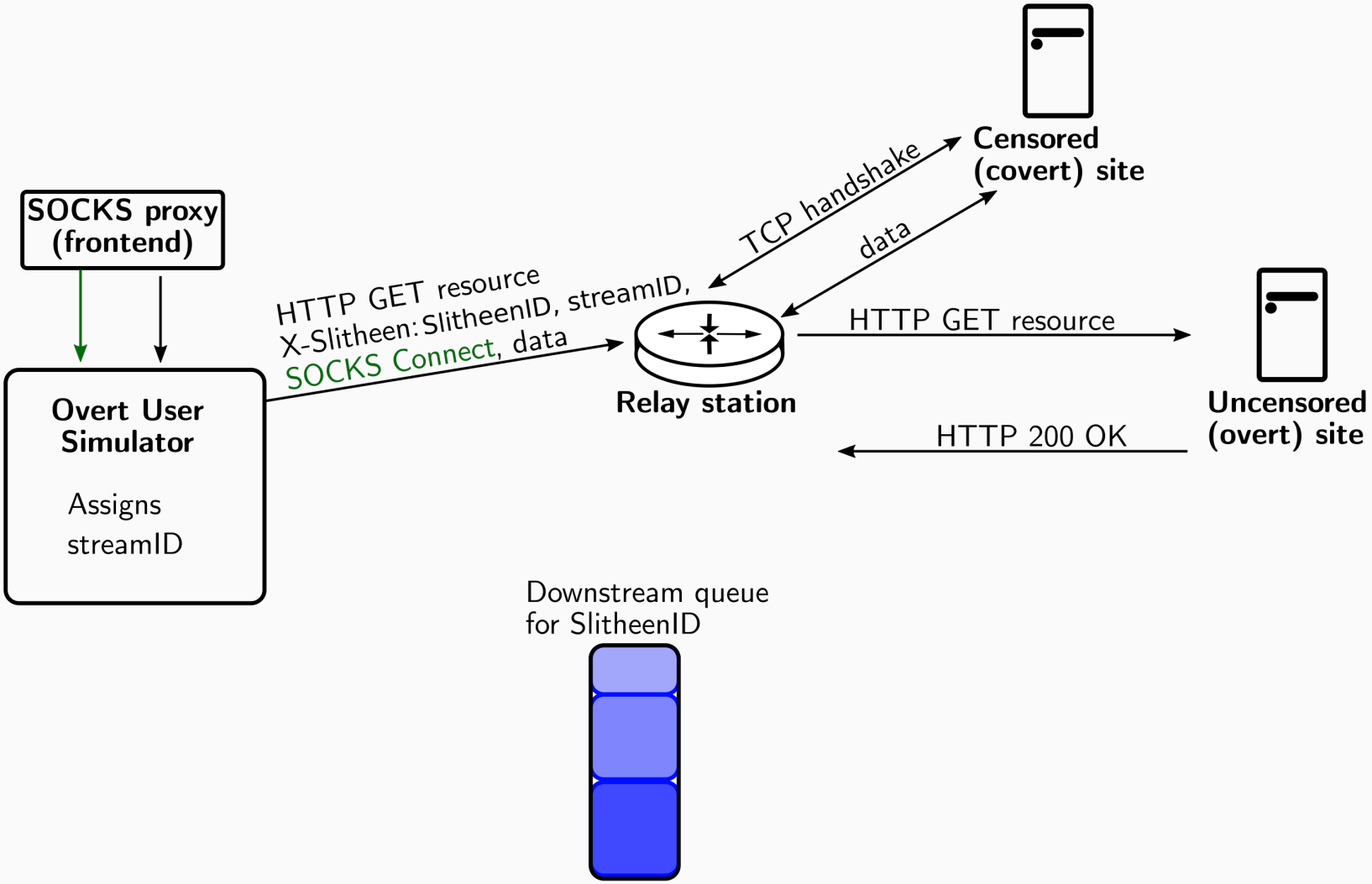

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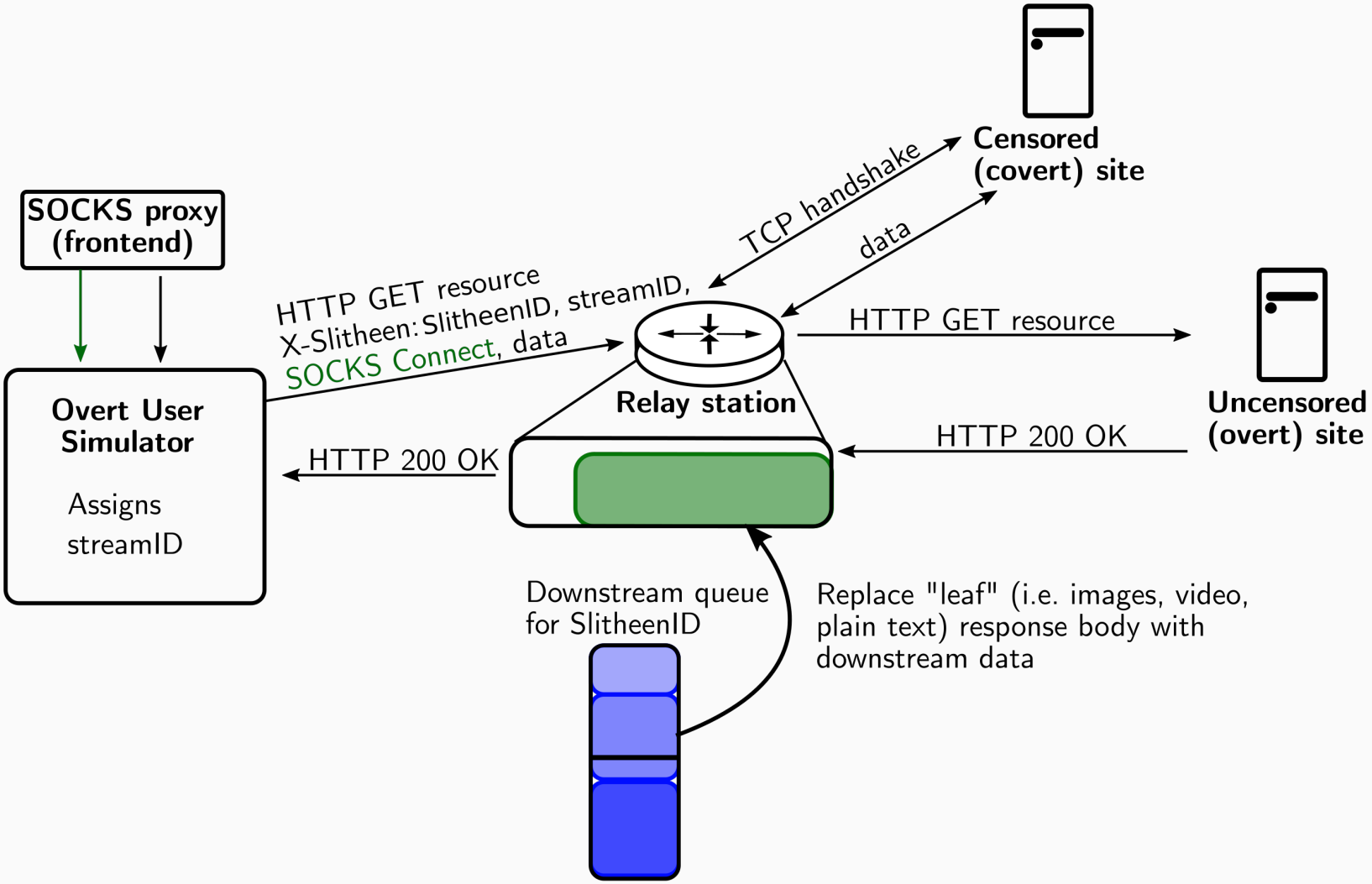

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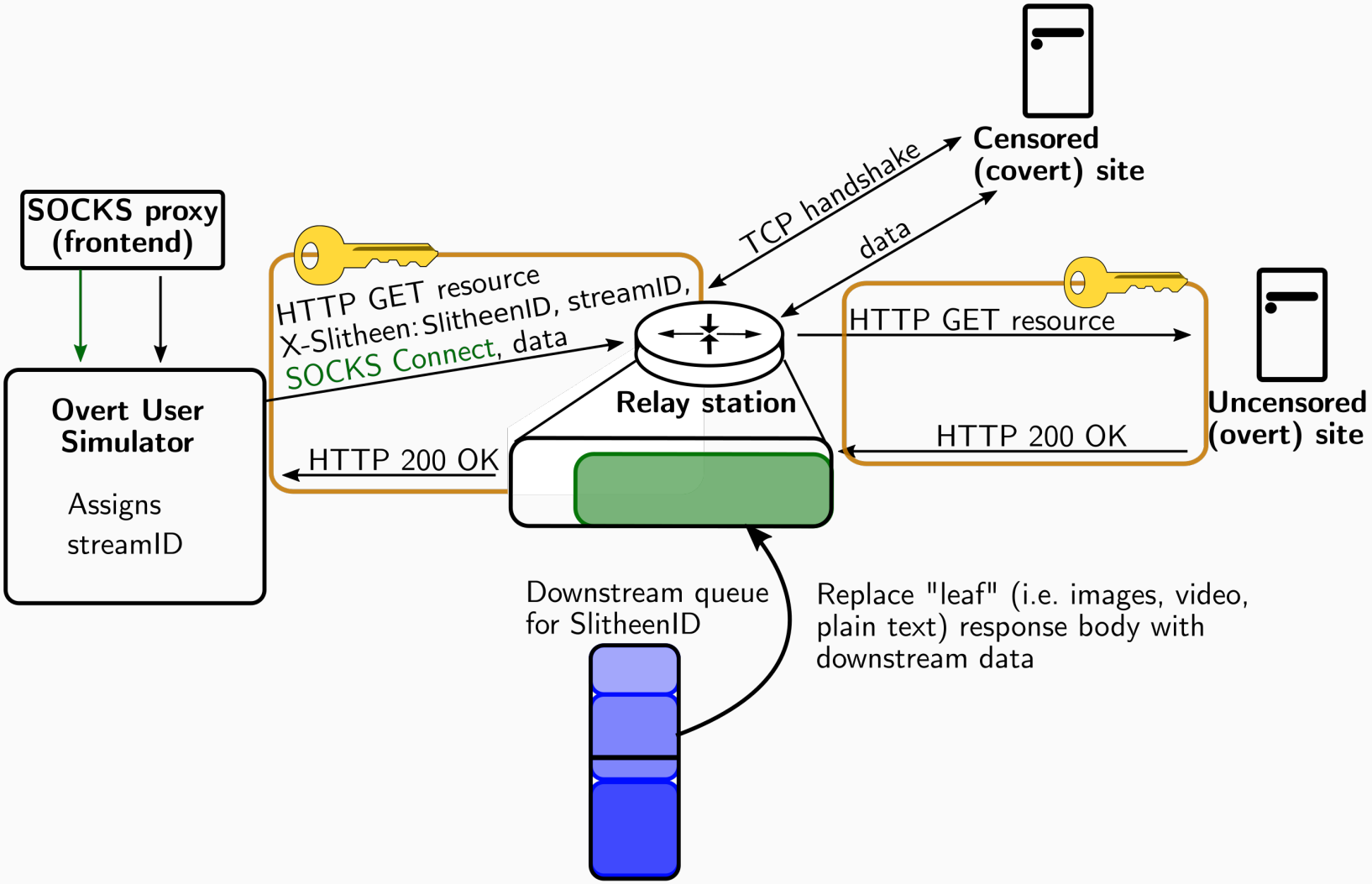
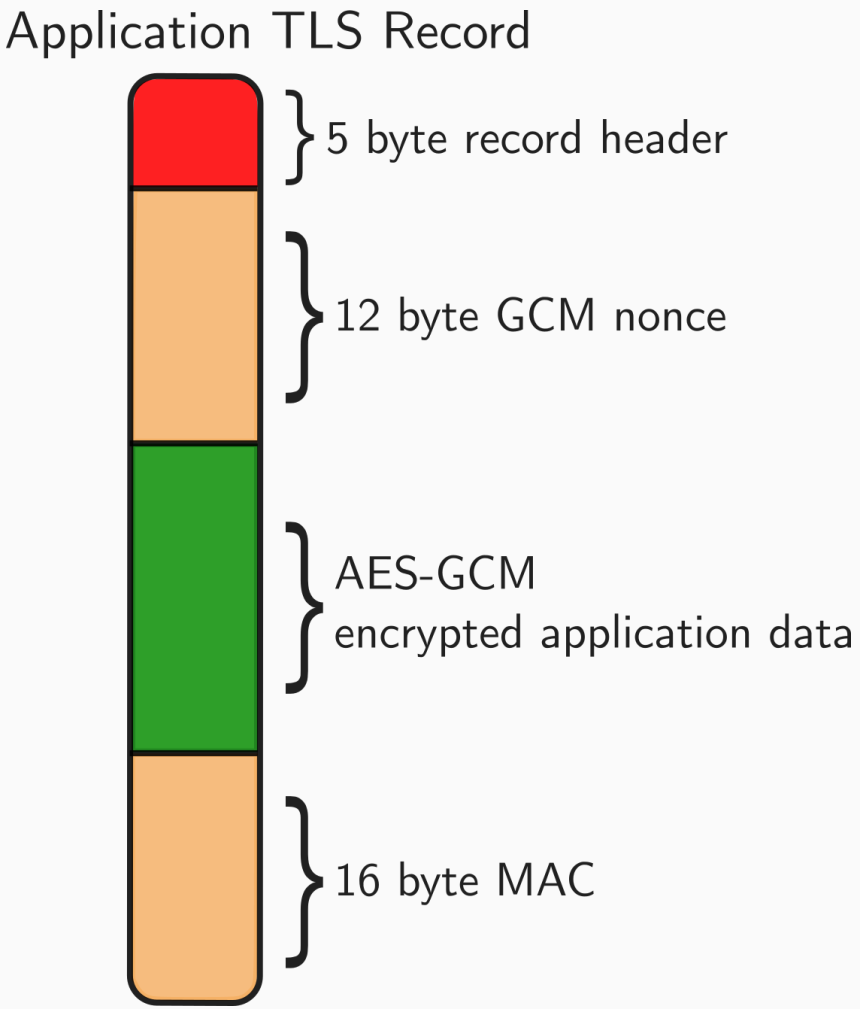
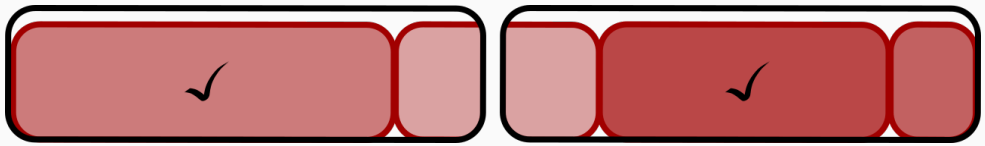


TLS Record Format



- Encrypted HTTP responses are sent from the overt site in a series of TLS records
- TLS records can be (and often are) fragmented across packets
- We do not delay packets at the relay station to reconstruct records

Finding Leaves



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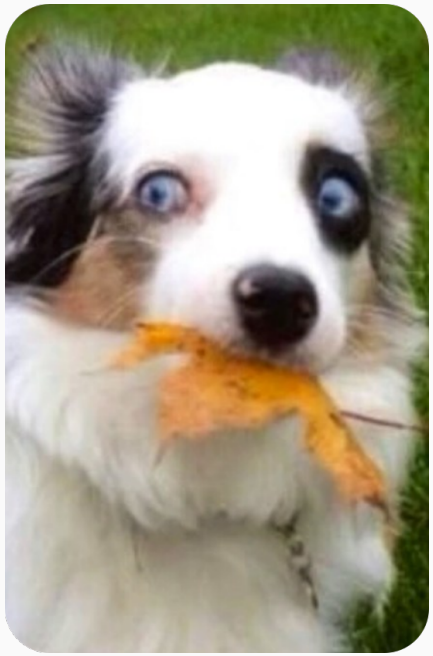

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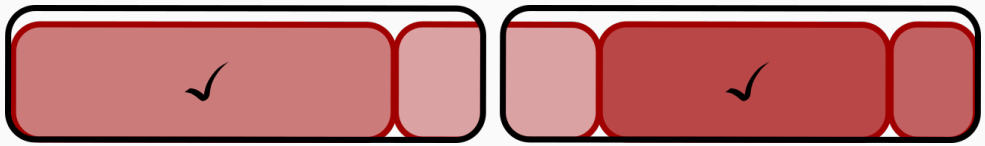

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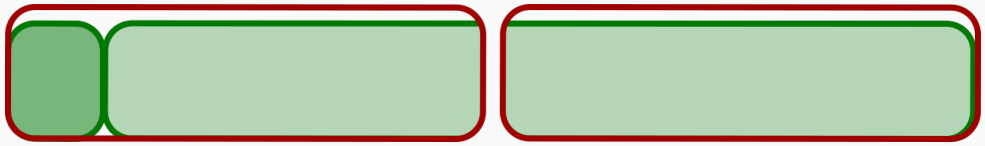

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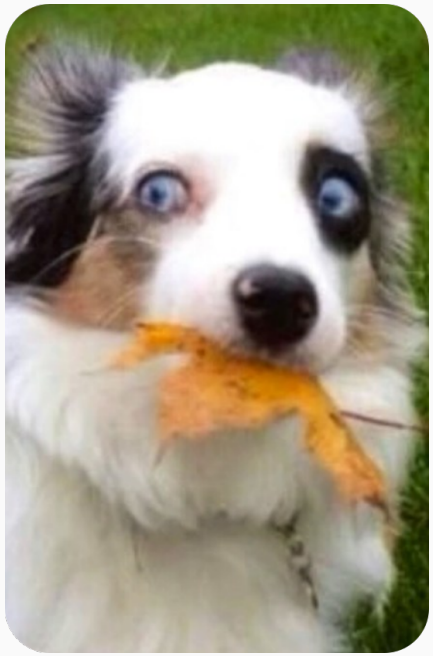

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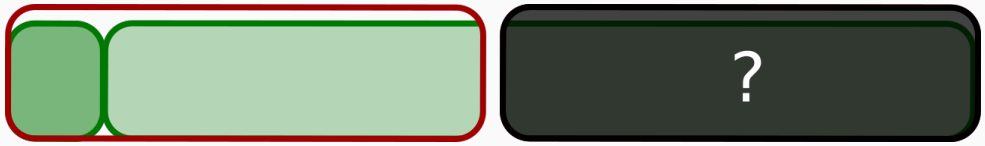

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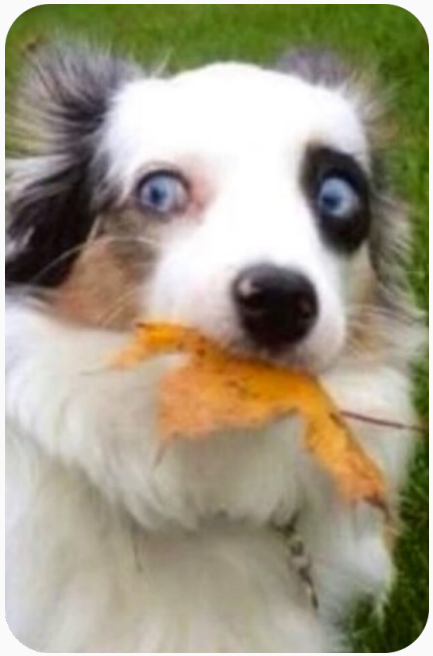
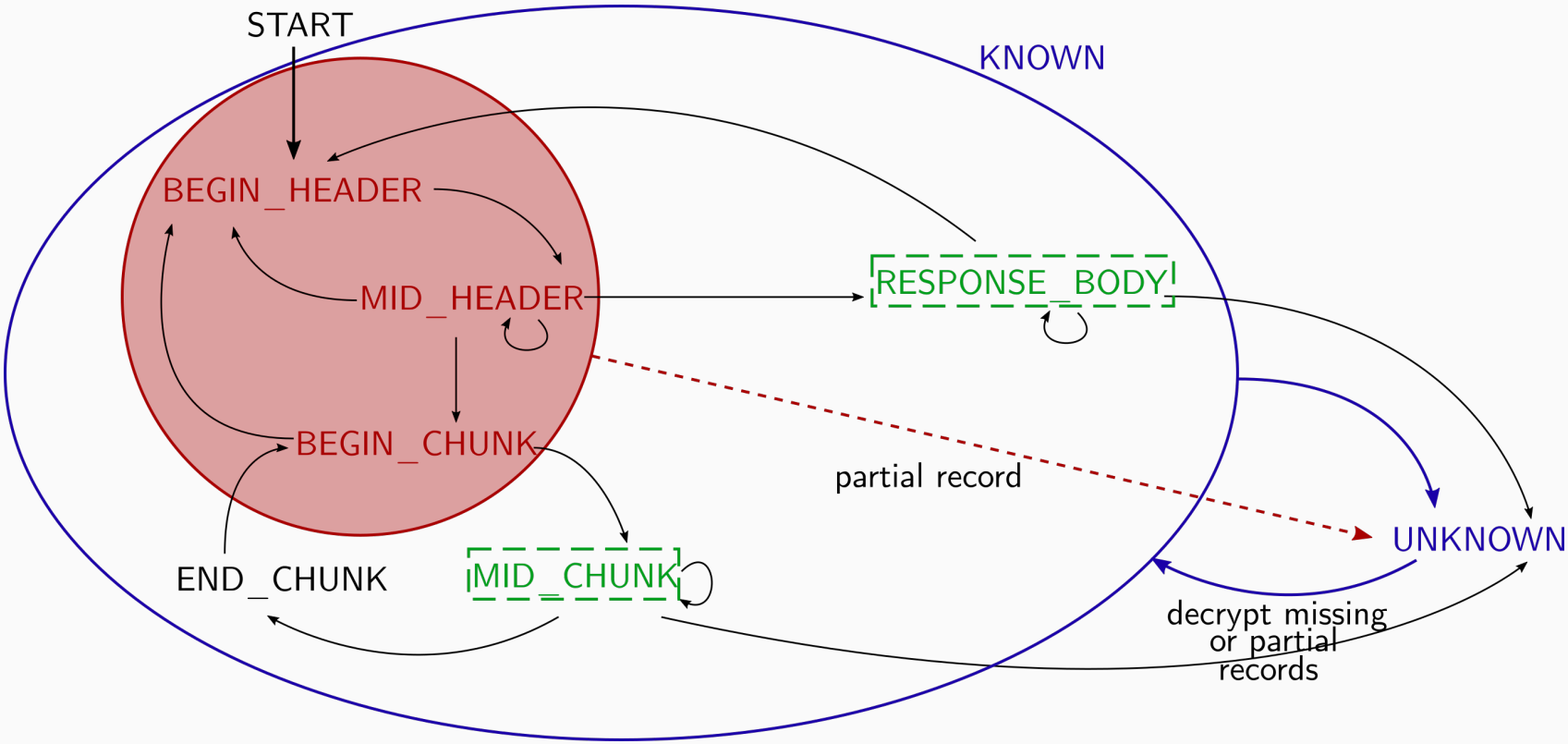
Misordered packets further complicate our decisions.

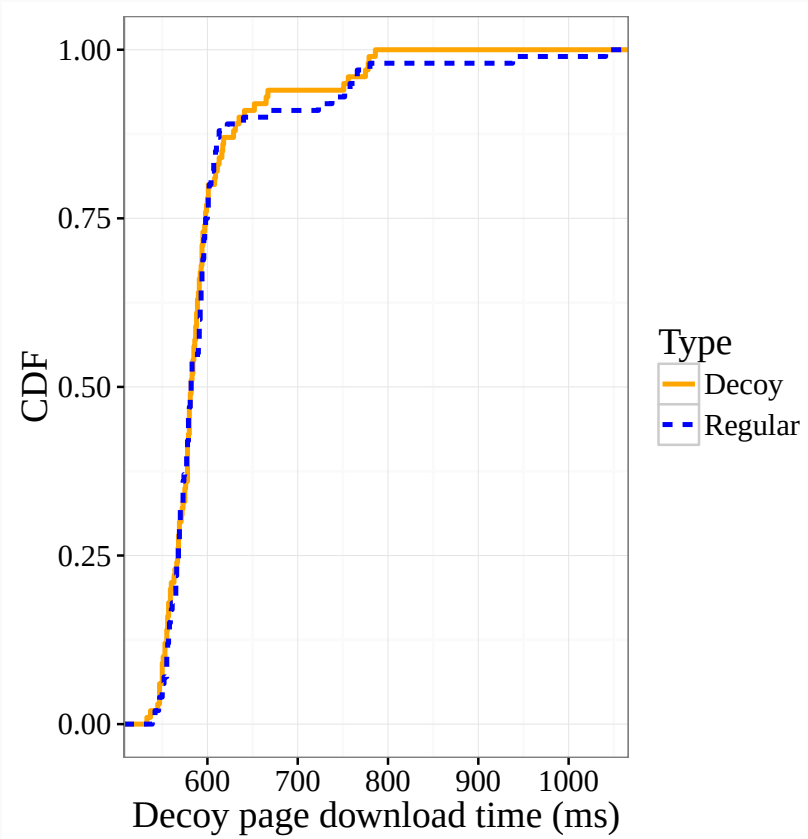


HTTP States

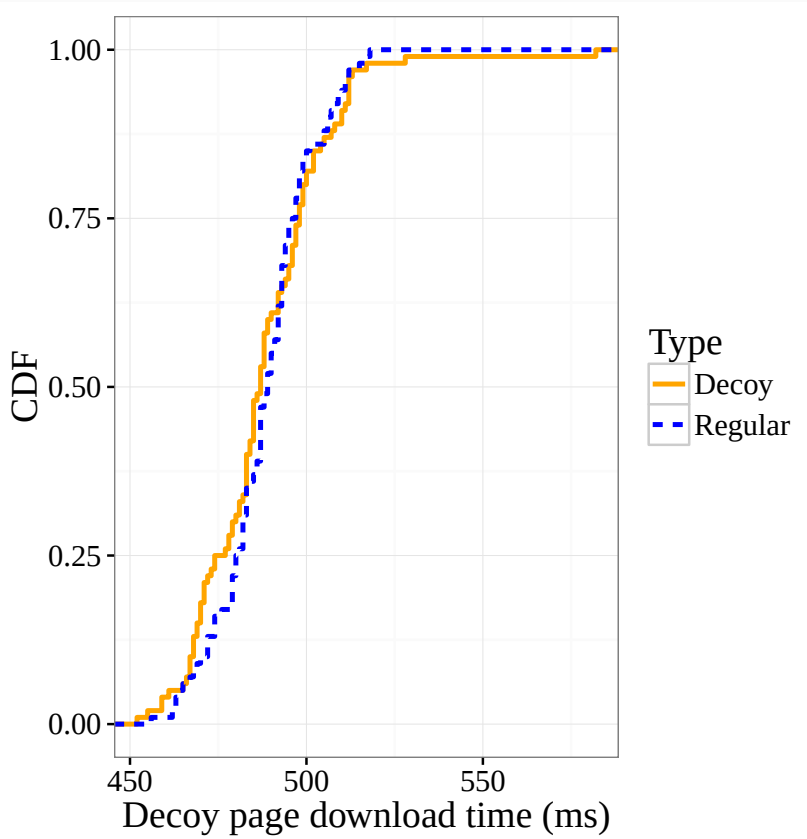

START
KNOWN
BEGIN_HEADER
MID_HEADER
RESPONSE_BODY
BEGIN_CHUNK
partial record
UNKNOWN
END_CHUNK
MID_CHUNK
decrypt missing
or partial
records

Latency Results

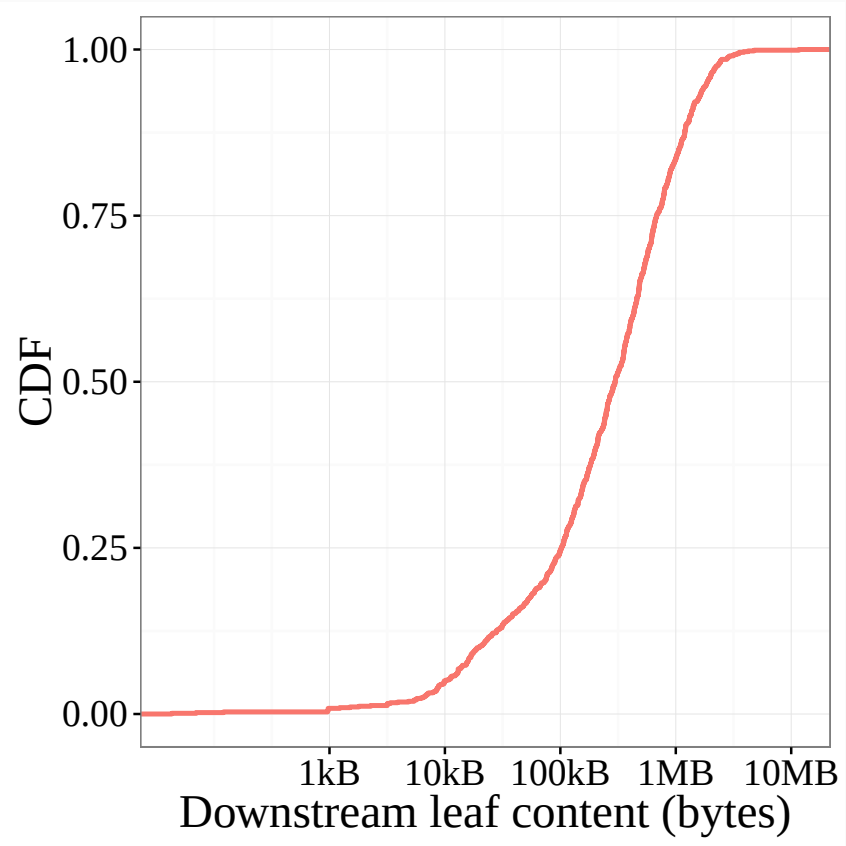
Gmail



Wikipedia



Bandwidth

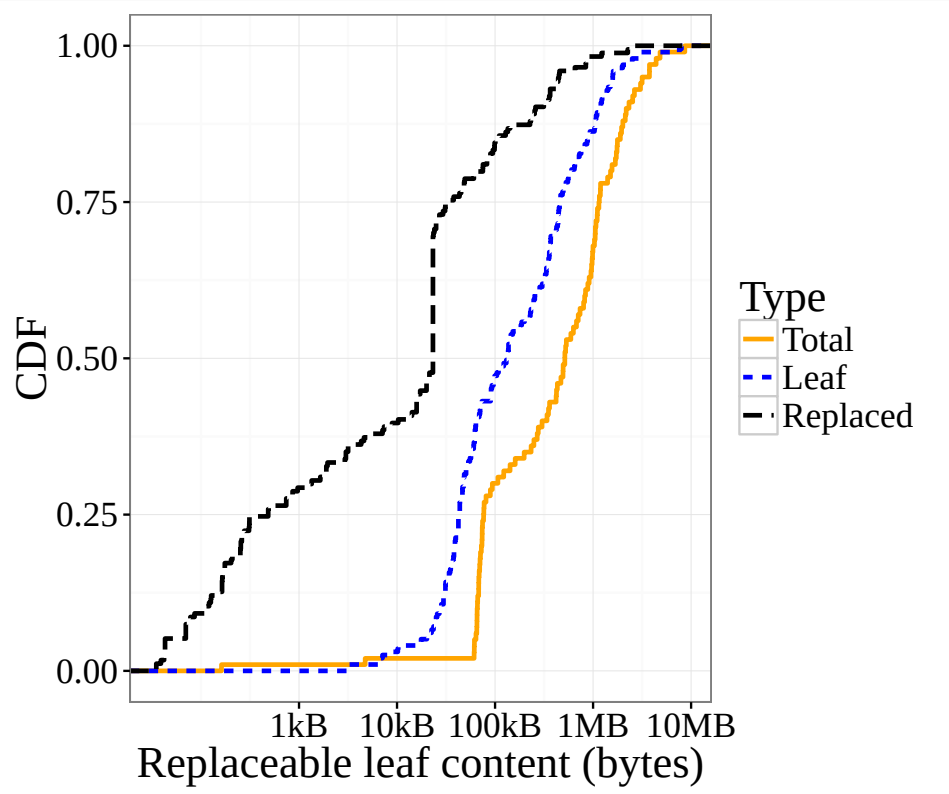


Downstream leaf content from the Alexa top 10,000 TLS sites

- Roughly 25% of all sites offer 500 kB or more of potentially replaceable content
- About 40% of traffic across all sites was leaf content

Realistic Bandwidth

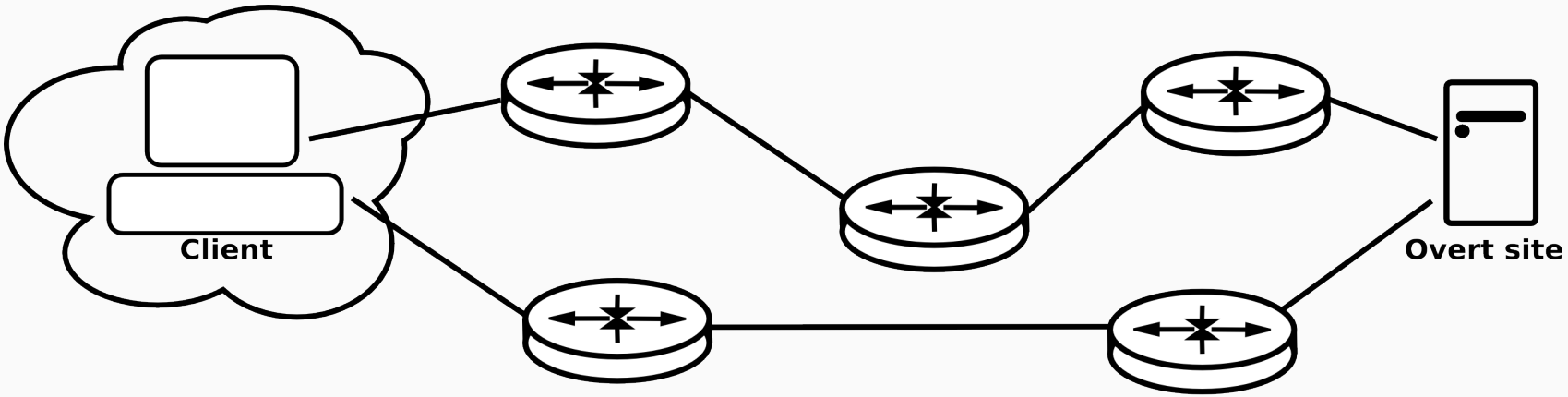
Site name	Leaf content (bytes)	% leaf content replaced	% total replaced
Gmail	8800 ± 100	87.7 ± 0.2	23 ± 9
Wikipedia	24000 ± 2000	100 ± 0	33 ± 4
Yahoo	400000 ± 100000	100.0 ± 0.2	40 ± 20
Facebook	40000 ± 10000	0 ± 0	0 ± 0



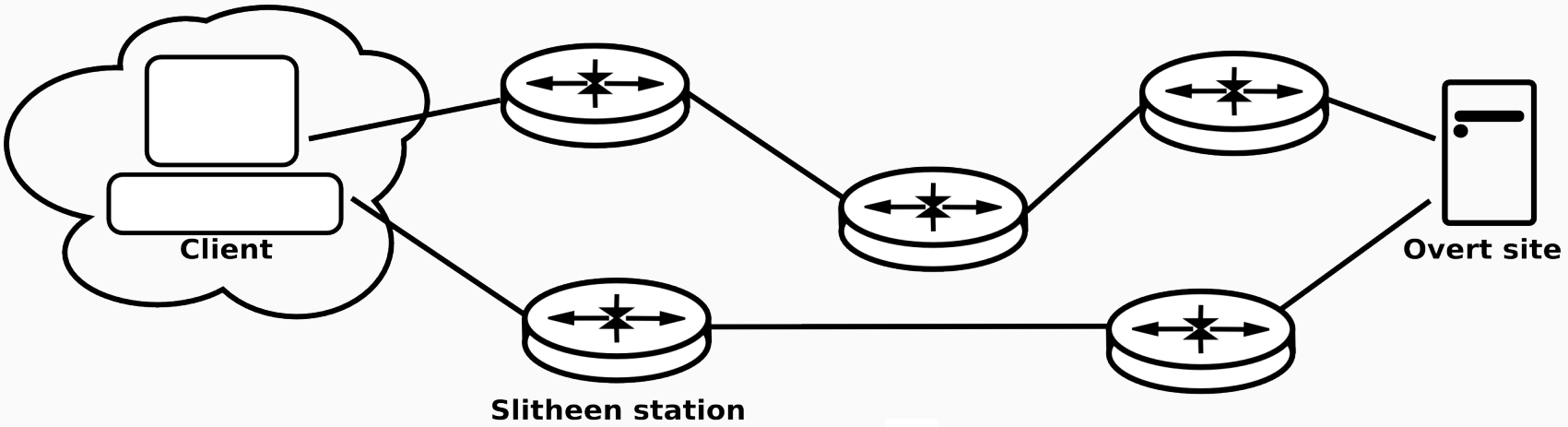
Comparison

	Telex	Cirripede	Curveball	TapDance	Rebound	Slitheen
No in-line blocking	○	○	○	●	○	○
Supports asymmetric routes	○	●	○	●	●	○
Defends against TCP replay attacks	●	●	●	○	●	●
Defends against latency analysis	○	○	○	○	●	●
Defends against website fingerprinting	○	○	○	○	○	●
RAD-resistant	○	○	○	○	○	○

Supporting Asymmetry and RAD-Resistance

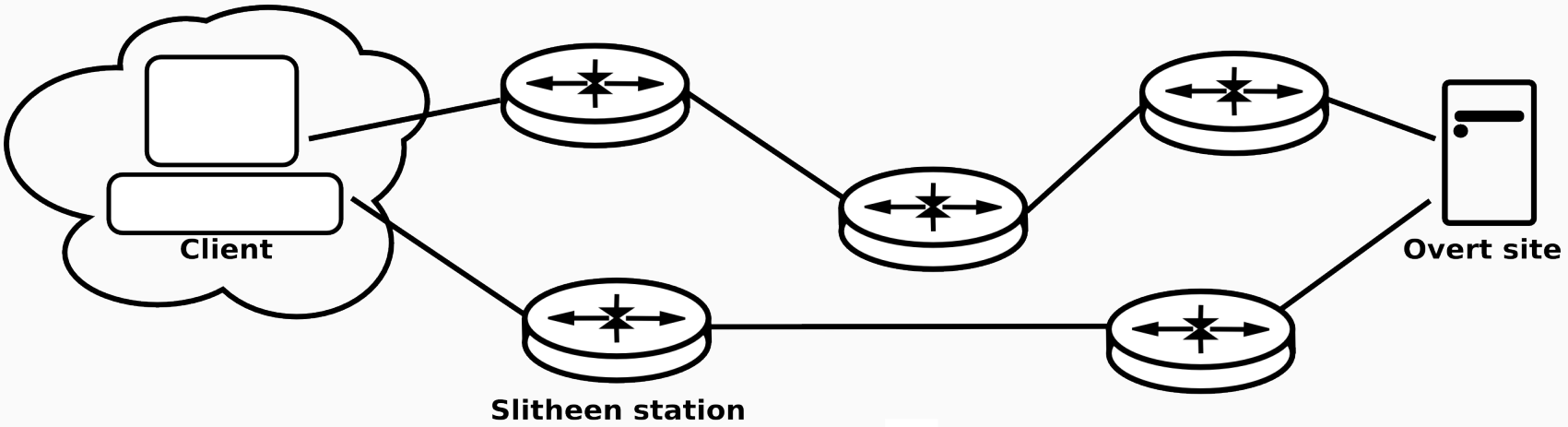


Supporting Asymmetry and RAD-Resistance



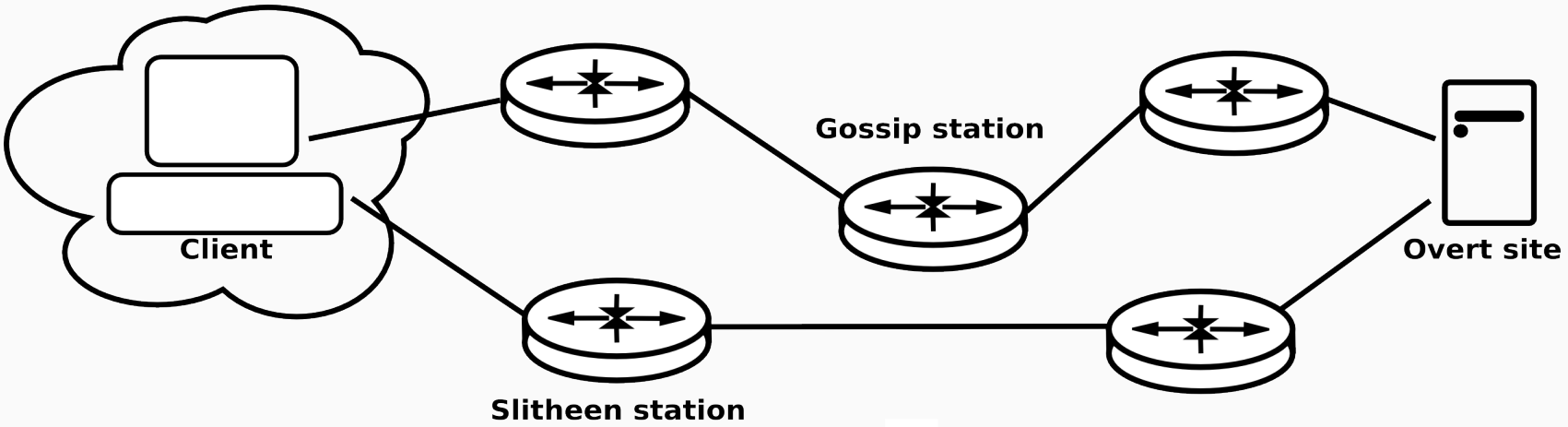
- Slitheen station is on downstream path
  - Opposite to TapDance, Rebound

Supporting Asymmetry and RAD-Resistance



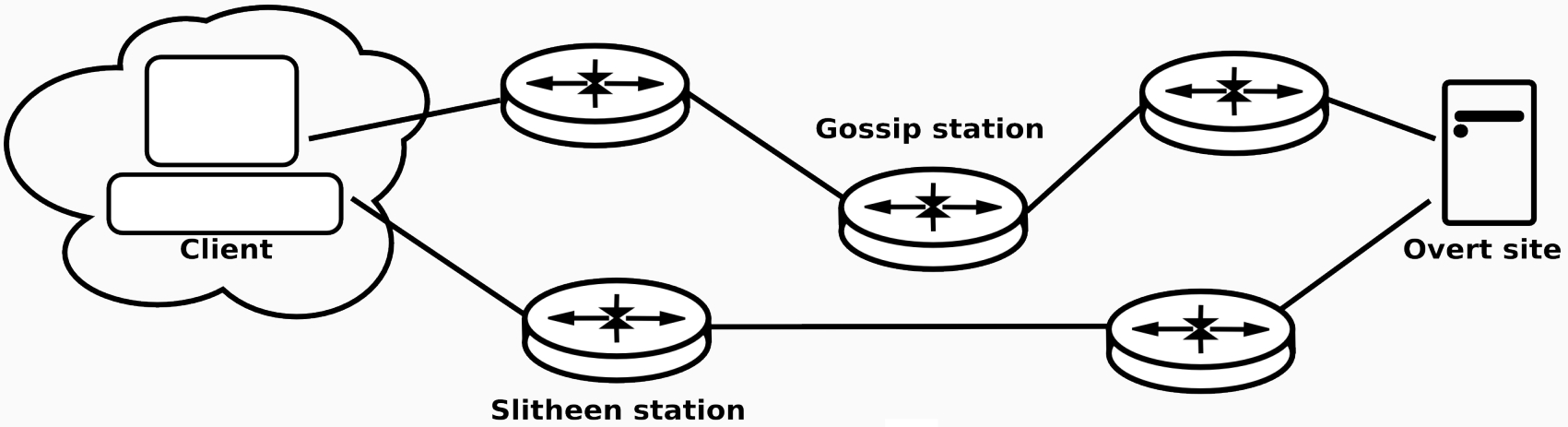
- Slitheen station is on downstream path
  - Opposite to TapDance, Rebound
- How does it identify tagged flows and learn the TLS master secret?

Supporting Asymmetry and RAD-Resistance



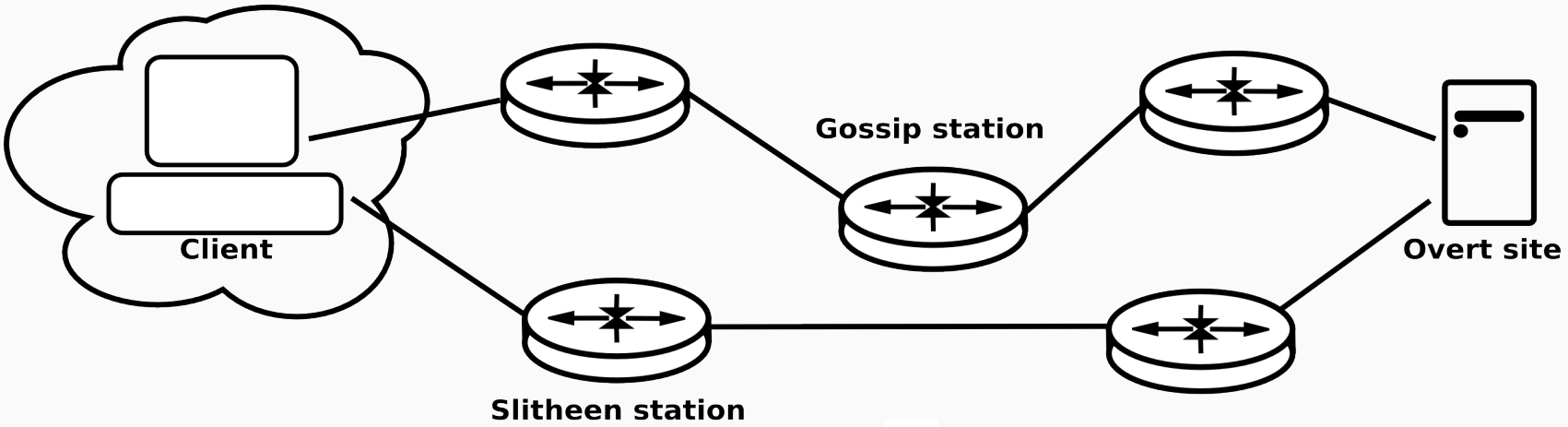
- Lightweight gossip station on upstream path
  - No flow blocking; just gets a copy of TLS flows
  - When it sees a TLS ClientHello (without having seen a TCP SYN ACK), broadcast it to Slitheen stations
  - If a Slitheen station claims the tag, send upstream TLS data to it

Supporting Asymmetry and RAD-Resistance



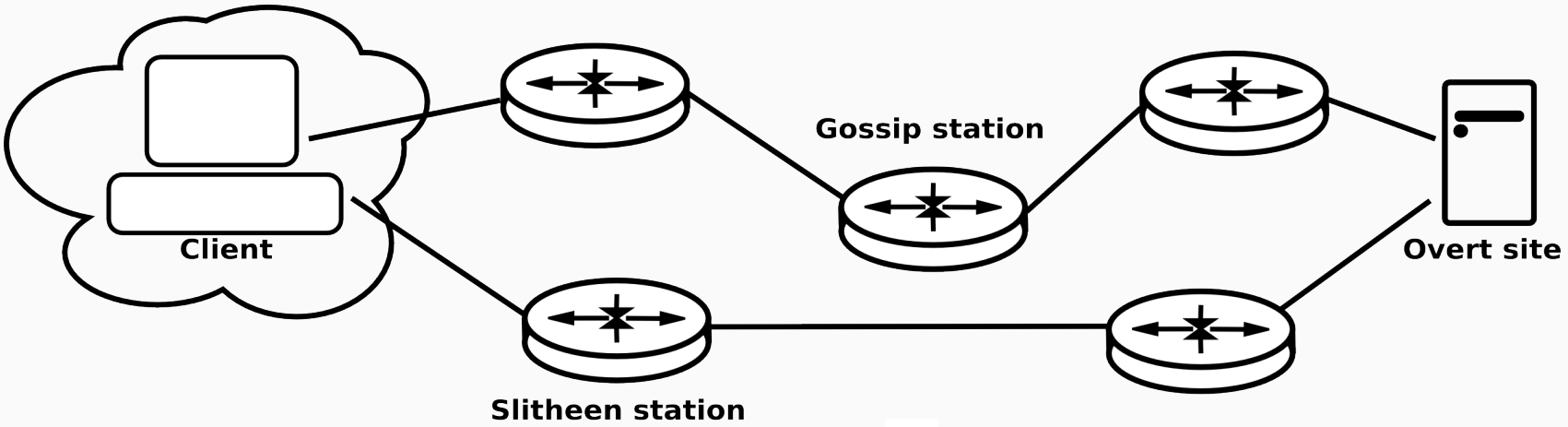
- But surely that upstream ClientHello won't get from the gossip station to the Slitheen station in time?
  - The Slitheen station needs it before the TLS handshake completes so that it can read and modify the Finished message

Supporting Asymmetry and RAD-Resistance



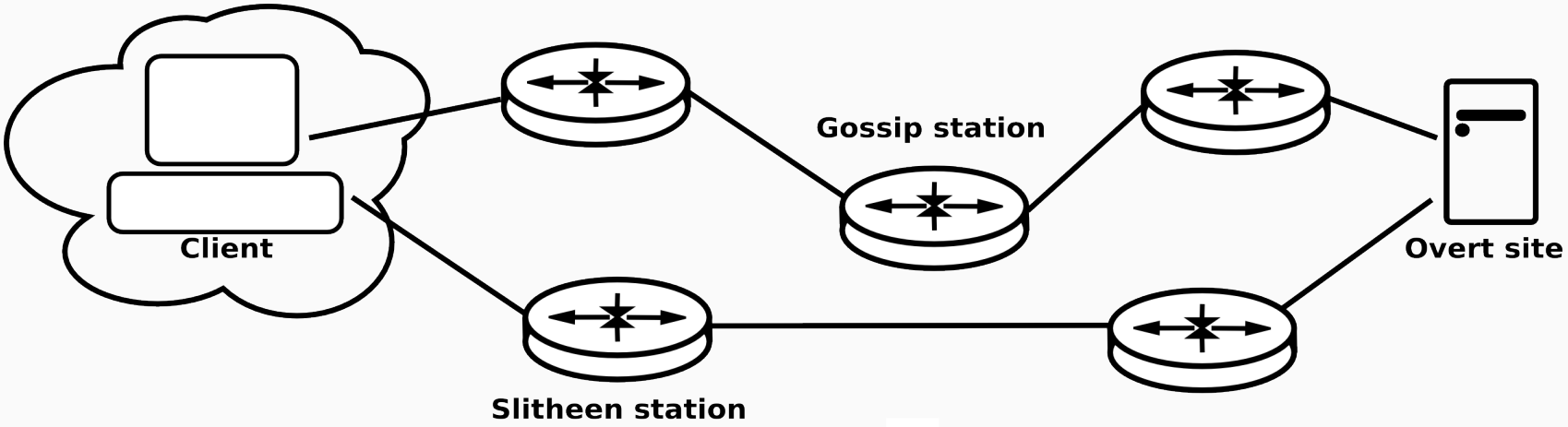
- Key idea: the client's Slitheen secret *s* on its *next* connection to that overt site will be selected as a function of the *previous* client-relay shared secret
  - The first connection acts as a Cirripede-esque registration
  - The Slitheen station can then predict that client's future ClientHello messages!

Supporting Asymmetry and RAD-Resistance



- Gossip stations offer a *two-tiered deployment* strategy
- No need for flow-blocking or traffic replacement routers
  - So easier to deploy

Supporting Asymmetry and RAD-Resistance



- Easier for censor to perform RAD attack on upstream data (change routing for *that one flow*) than downstream (advertise new BGP route to *everyone*)
  - Put lots of cheap gossip stations on possible upstream paths
  - More heavyweight Slitheen stations on more stable downstream paths

Comparison

	Telex	Telex+gossip	Cirripede	Curveball	Curveball+gossip	TapDance	Rebound	Slitheen	Slitheen+gossip
No in-line blocking	○	○	○	○	○	●	○	○	○
Supports asymmetric routes	○	●	●	○	●	●	●	○	●
Defends against TCP replay attacks	●	●	●	●	●	○	●	●	●
Defends against latency analysis	○	○	○	○	○	○	●	●	●
Defends against website fingerprinting	○	○	○	○	○	○	○	●	●
RAD-resistant	○	●	○	○	●	○	○	○	●

Summary

- Slitheen is a new proposal for a decoy routing system
- Slitheen addresses previously undefended passive attacks
- Our results show no discernible difference in latency between a "decoy access" to an overt destination and a regular access
- By design, Slitheen defends against website fingerprinting attacks by maintaining packet sizes, timings, and directionality
- The gossip protocol addresses the major challenges to deployability: RAD attacks, asymmetric flows, and concerns over inline blocking
- Implementation and source code of Slitheen (but not yet the gossip protocol) available:
  `https://crysp.uwaterloo.ca/software/slitheen/`