Trufflehunter: Cache Snooping Rare Domains at Large Public DNS Resolvers

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Categories of harmful Internet behavior

**Common Internet abuse (well studied)**
- Spam Emails
- Botnets
- Malware

**Rare Internet abuse (sparsely studied)**
- Typo Squatting
- Hack for Hire
- Stalkerware

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If you can observe the DNS, you can observe these behaviors.
New Era in DNS: Public Resolvers

• Public resolvers are gaining popularity
• Many users now use these resolvers by default
  • Google home routers go to 8.8.8.8
  • Cloudflare DNS is default on Firefox
  • NYC Public WiFi uses Quad9
• Can a third-party observer use these services to observe rare behavior?
Observing requests on public resolvers

Well-known technique: **DNS cache snooping**.

Previous work: Find resolvers by scanning Internet
• Open resolvers usually **misconfigured home routers** – privacy threat

On public DNS resolvers, it’s **privacy-preserving**!
• Too many users to de-anonymize
Background: How Cache Snooping Works

DNS Resolver

User

example.com?

response

Cache

example.com present?

Yes

No

Authoritative Nameserver

example.com 1.2.3.4 TTL=60

Snooper

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Background: How Cache Snooping Works

User

DNS Resolver

Cache

example.com
1.2.3.4 TTL=30

Snooper

example.com?

RD = False

Response

example.com 1.2.3.4 TTL=30

Authoritative Nameserver

example.com 1.2.3.4 TTL=60
Cache snooping provides a lower bound on the number of users accessing a domain.

It can only observe one user at a time.
Simplified Public Resolver Cache Architecture

User

IP Anycast

Frontend Caches

Cache
Cache
Cache

Backend Resolvers

Cache
Cache

Public DNS Point of Presence (PoP)

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And it gets more complicated…

A snooper’s ability to estimate depends on their understanding of the cache architecture.

- Snooper only sees TTL and timestamp of DNS query!

We reverse engineer a model of each resolver to make snooping possible.
How We Modeled Cache Architectures

Experiment:
- Repeatedly query a resolver
  - Fill as many caches as possible
- Observe how our queries were cached: examine TTLs.
  - Some queries will hit the same cache, others will not

“TTL Line:” Model of how a TTL decreases in a cache.
- Rate: one second per second.
OpenDNS and Quad9

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Cloudflare

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And then there’s Google Public DNS…
And then there’s Google Public DNS…

No measurements!
And then there’s Google Public DNS…
Google Public DNS: Dynamic Caching

User

Empty frontend cache (miss!)

Full backend cache: TTL < maximum

550
Google Public DNS: Dynamic Caching

User receives backend TTL (550)

User receives max TTL (600)
Google Public DNS: Dynamic Caching

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Trufflehunter

• Distributed measurement tool
  • Deployed on CAIDA’s Ark project

• Sends DNS queries for domains of interest across the U.S.

• Interprets the responses according to our models to estimate counts of users

• Three months of data: March 6 – May 29 2020
How accurate is Trufflehunter at estimating filled caches?

Experiment:
- Place domain controlled by us into cache using ~900 RIPE Atlas probes
- Attempt to observe this domain with Trufflehunter
- Number of requests to our authoritative nameserver is true number of filled caches

Error in estimating the number of filled caches:
Case Studies

Three case studies:

- Stalkerware
- Contract Cheating
- Typo Squatting

Previously, all were hard to measure – little data available about prevalence.
Case Study #1: Stalkerware

Stalkerware: spyware used in IPV situations (Intimate Partner Violence)

- Monitors location
- Records all communication
- Can hide its presence

24 apps

- 6 dual use: Usually marketed for parental control or employee surveillance.
- 16 overt: “Undetectable,” can be marketed explicitly for spying on intimate partner.

Prior work has found little to no evidence of overt apps in clinical settings. So are they being used at all?
From Counting Caches to Counting Devices

- Apps often make DNS requests automatically, at regular intervals.
- Operating systems cache DNS responses – we assume devices make queries only once per TTL epoch.

Devices with stalkerware installed = \( \frac{\text{Filled Caches}}{\text{App Request Rate}} \)
At least 5,700 people are targeted by overt stalkerware in the U.S. today.
Case Study #2: Contract Cheating

- Contract cheating is the new plagiarism!
- Students hire services to complete homework, projects, even entire classes for them
- Hard to detect – original content, can’t be found with plagiarism checkers
Observed Contract Cheating

Some services decrease over time:
schools letting out for summer break?
Conclusion

• Public DNS resolvers enable privacy-preserving cache snooping
• We model the cache architecture of four public resolvers
• We present Trufflehunter, an open-source tool for measuring domain popularity
• We find non-trivial lower bounds of the popularity of previously under-studied Internet phenomena like stalkerware.

https://github.com/ucsdsysnet/trufflehunter