Analyzing the Costs (and Benefits) of DNS, DoT, and DoH for the Modern Web

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DNS Privacy Has Become a Significant Concern

- On-path network observers can spy on and tamper with DNS traffic (Do53)
- Two protocols have been proposed to encrypt DNS traffic
  - DNS-over-TLS (DoT): RFC 7858
  - DNS-over-HTTPS (DoH): RFC 8484
Contributions

- Extensive performance study of Do53, DoT, and DoH
- Insights to optimize DNS performance
Experiment Overview

● Goal: Understand how Do53, DoT, and DoH affect user experience
  ○ Query response times
  ○ Page load times
  ○ Effect of changing network conditions
1. Client with traffic shaping
   (Princeton, 4G, Lossy 4G, 3G)

2. Recursive Resolvers
   (Princeton, Cloudflare, Google, Quad9)

3. Websites
   (Tranco top list)
Response Times from Cloudflare on Princeton’s Network

https://arxiv.org/abs/1907.08089
Response Times from Google on Princeton’s Network

https://arxiv.org/abs/1907.08089
Response Times from Quad9 on Princeton’s Network

https://arxiv.org/abs/1907.08089
Takeaway: DoH Can Outperform Do53

- DoH outperforms Do53 in the tail of response times
  - Caching of DNS wire format?
- This result supports Mozilla’s findings
Measuring Page Load Time

● We measured page load times to understand user experience
● For this talk, we’re only focusing on Cloudflare
  ○ Fastest response times

https://arxiv.org/abs/1907.08089
Measuring Page Load Time

- We also performed traffic shaping
  - Princeton’s network was the baseline
  - 4G: 53.3ms additional latency, 1ms jitter, 0.5% loss
  - Lossy 4G: 53.3ms additional latency, 1ms jitter, 1.5% loss
  - 3G: 150ms additional latency, 8ms jitter, 2.5% loss
Page Loads with Cloudflare on Princeton’s Network

https://arxiv.org/abs/1907.08089
Page Loads with Cloudflare on Emulated 4G Network

https://arxiv.org/abs/1907.08089
Page Loads with Cloudflare on Emulated, Lossy 4G Network

https://arxiv.org/abs/1907.08089
Page Loads with Cloudflare on Emulated 3G Network

https://arxiv.org/abs/1907.08089
Takeaway: DNS-over-TCP Can Help Page Load Times

- TCP packets can be retransmitted as soon as two round-trips
- This helps DoT/DoH perform well on lossy networks
- Timeout for Do53 implementations might be higher
Potential Improvements for Do53, DoT, and DoH

● Opportunistic partial responses
● Wire format caching
● HTTP/2 push for DoH
Conclusion

- DoT performs better than DoH, and sometimes better than Do53
- DoH has potential!
- Choice of recursor & network matter
- Transport characteristics of TCP should be explored

Check out the full pre-print: https://arxiv.org/abs/1907.08089