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

Austin Hounsel* Kevin Borgolte* Paul Schmitt*
Jordan Holland* Nick Feamster†
Princeton University* University of Chicago†

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

https://arxiv.org/abs/1907.08089

Contributions

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

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Experiment Overview

- Goal: Understand how Do53, DoT, and DoH affect user experience
  - Query response times
  - Page load times
  - Effect of changing network conditions

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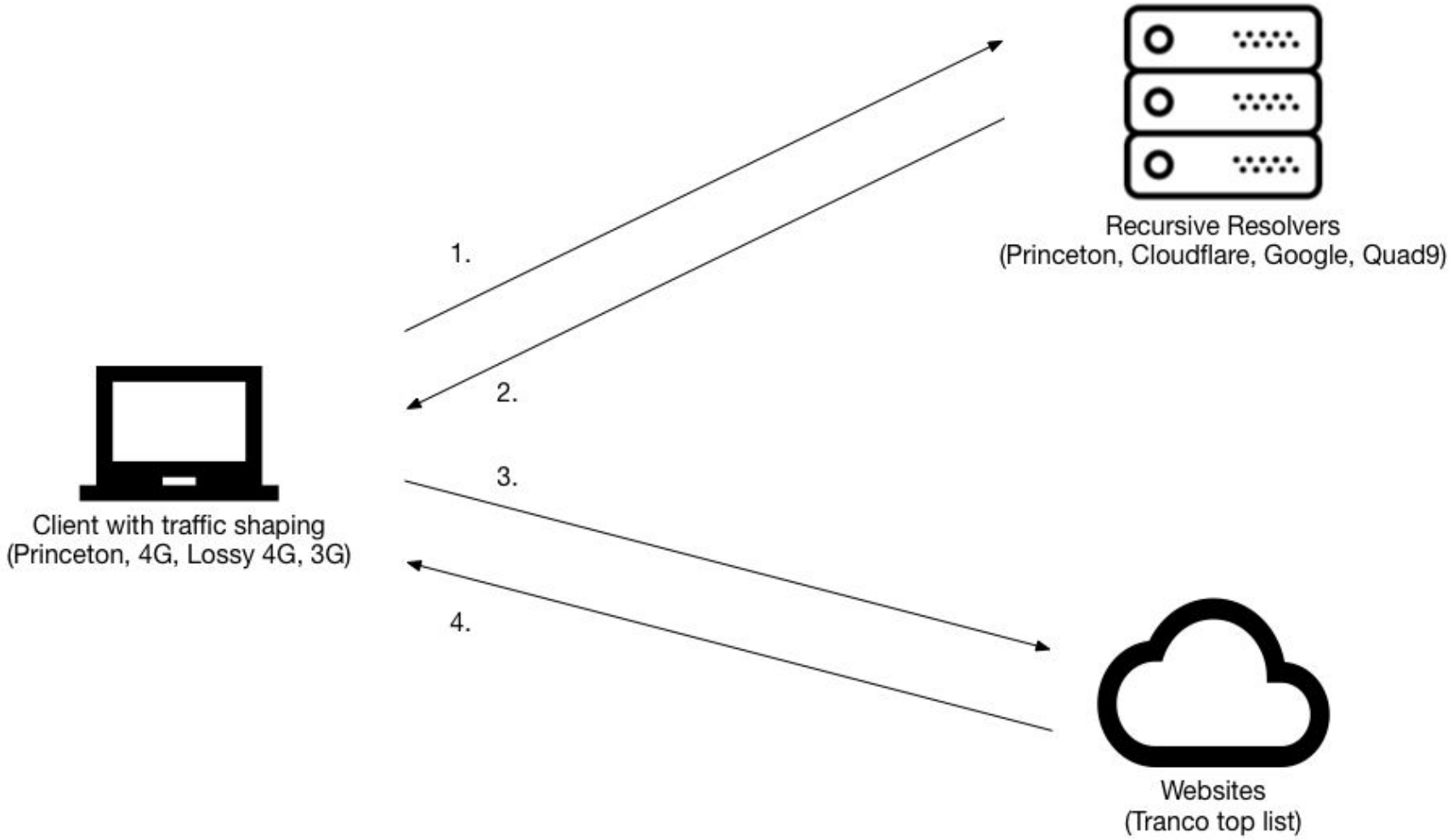
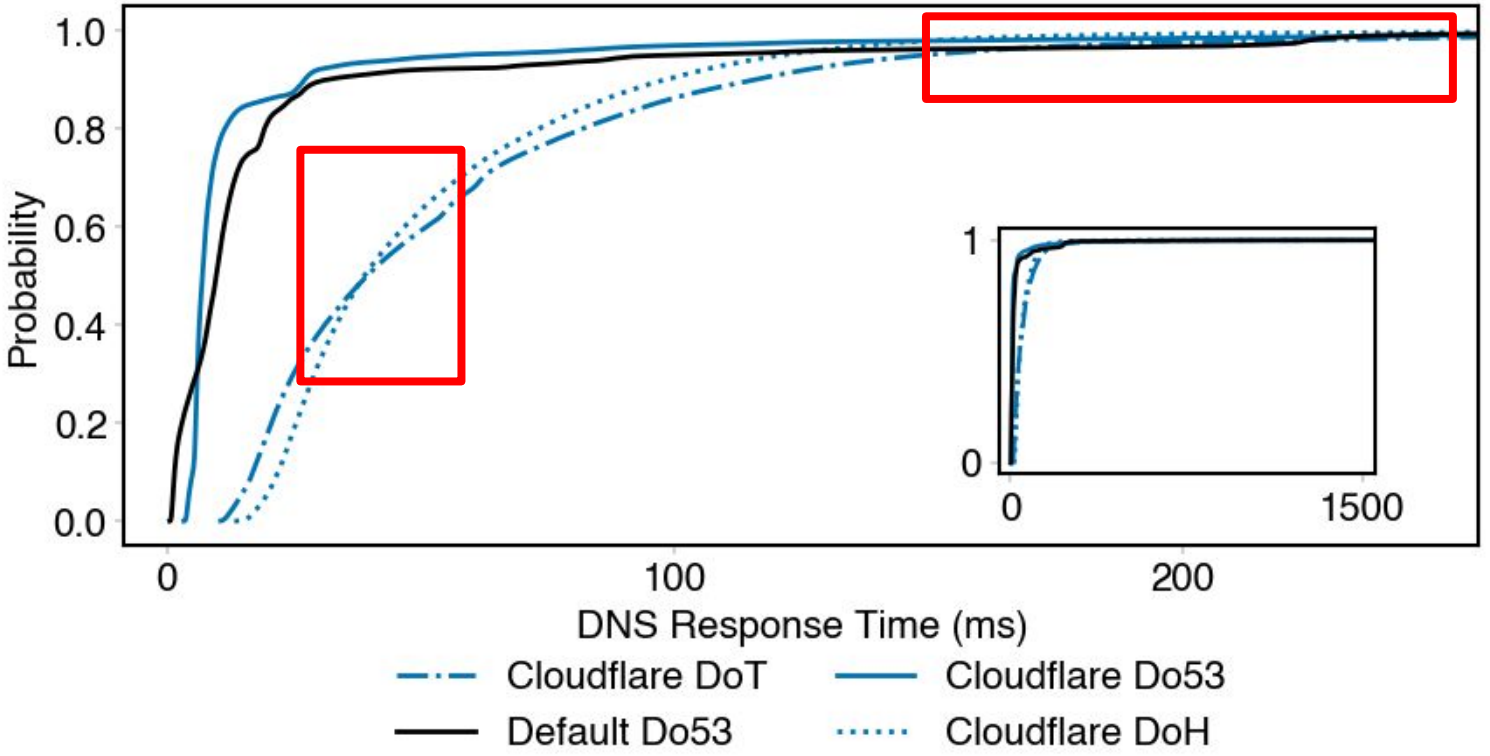

Recursive Resolvers
(Princeton, Cloudflare, Google, Quad9)
1.
2.
3.
4.
Client with traffic shaping
(Princeton, 4G, Lossy 4G, 3G)
Websites
(Tranco top list)

Response Times from Cloudflare on Princeton's Network



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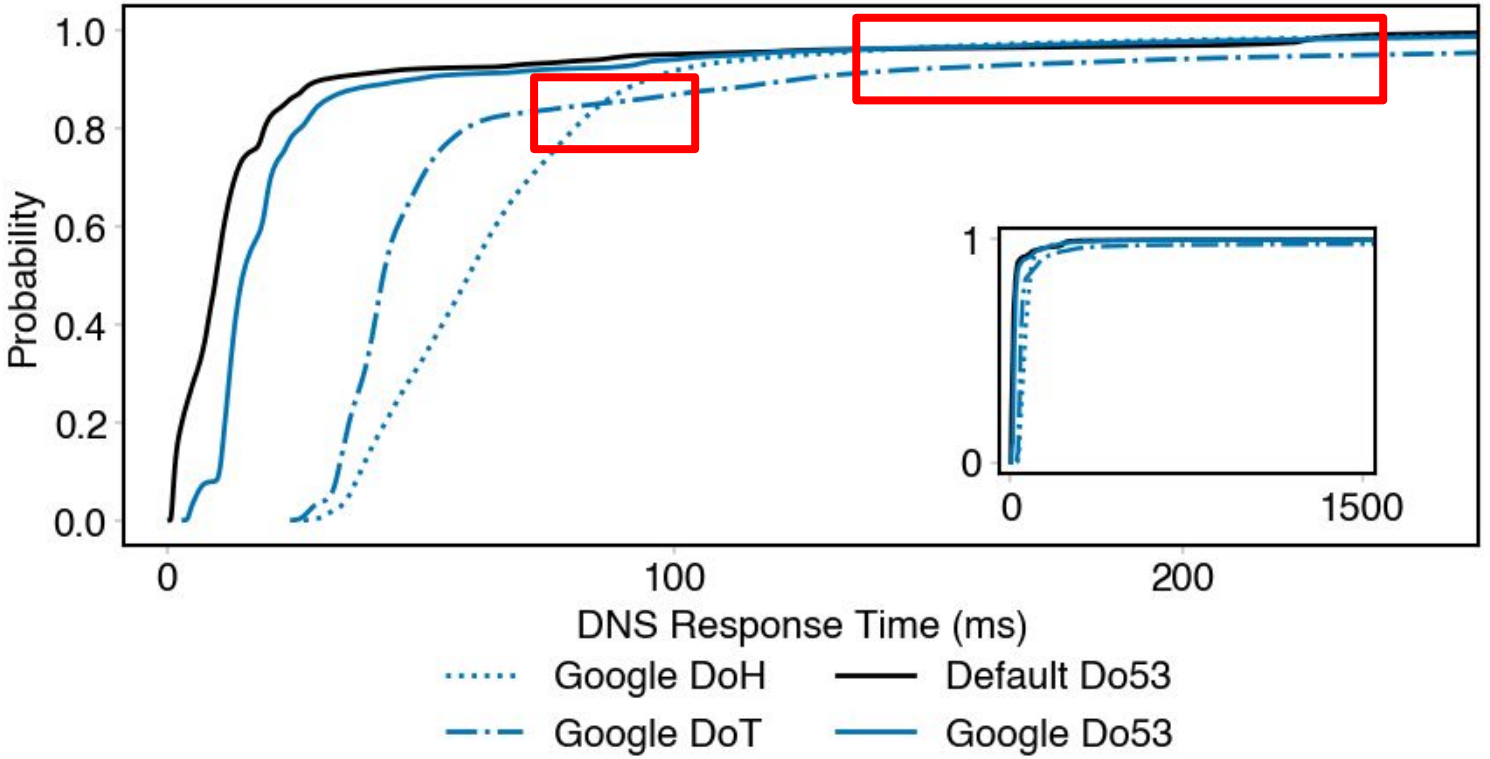
Response Times from Google on Princeton's Network



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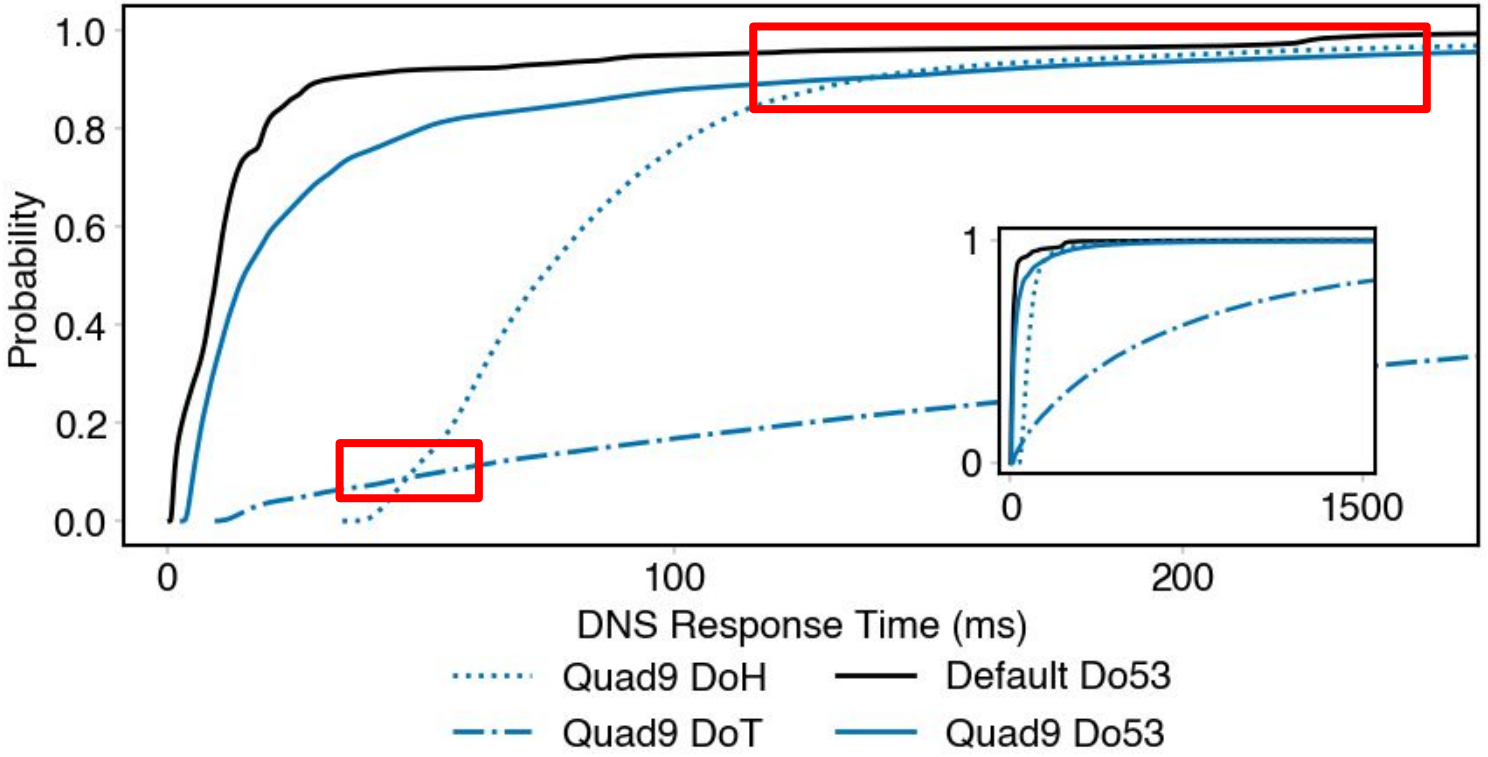
Response Times from Quad9 on Princeton's Network



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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

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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

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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

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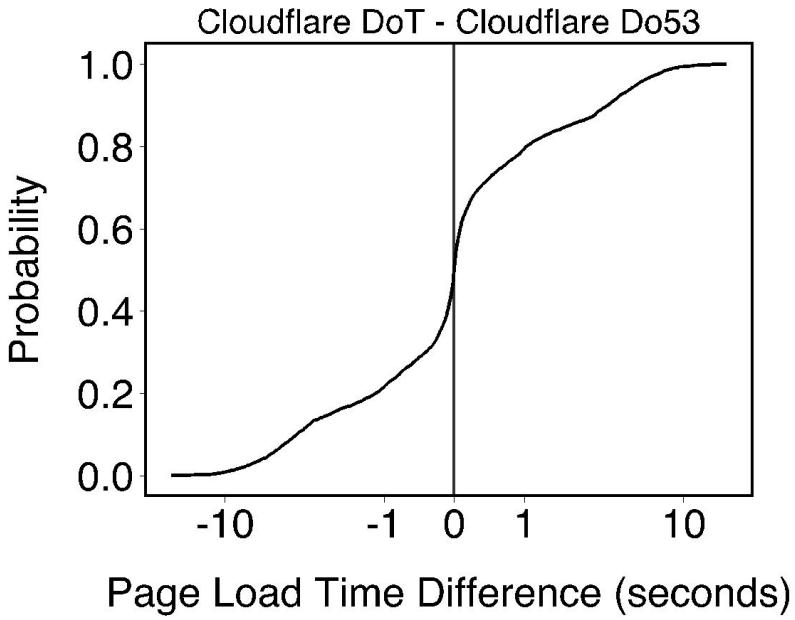
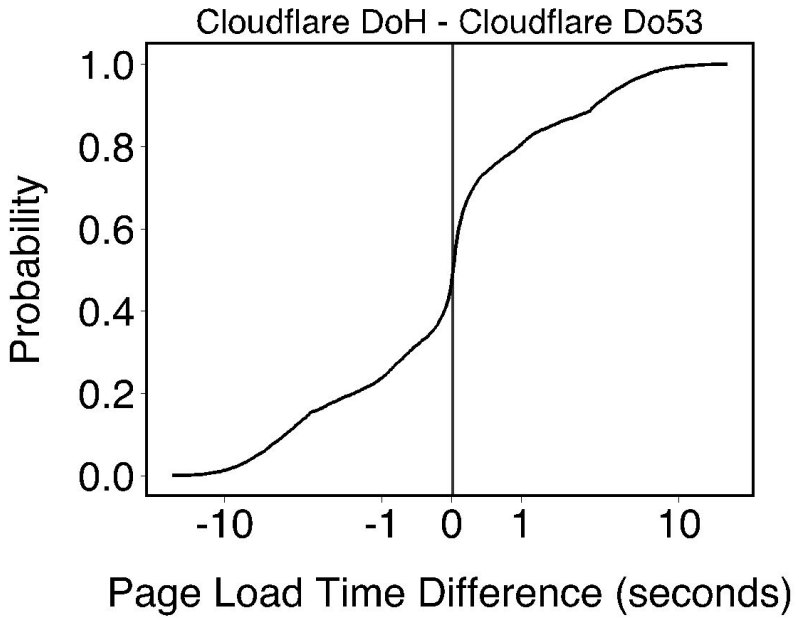
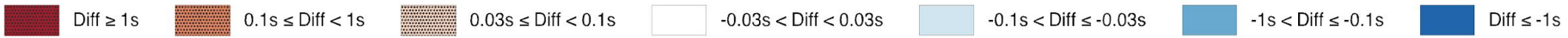
Page Loads with Cloudflare on Princeton's Network







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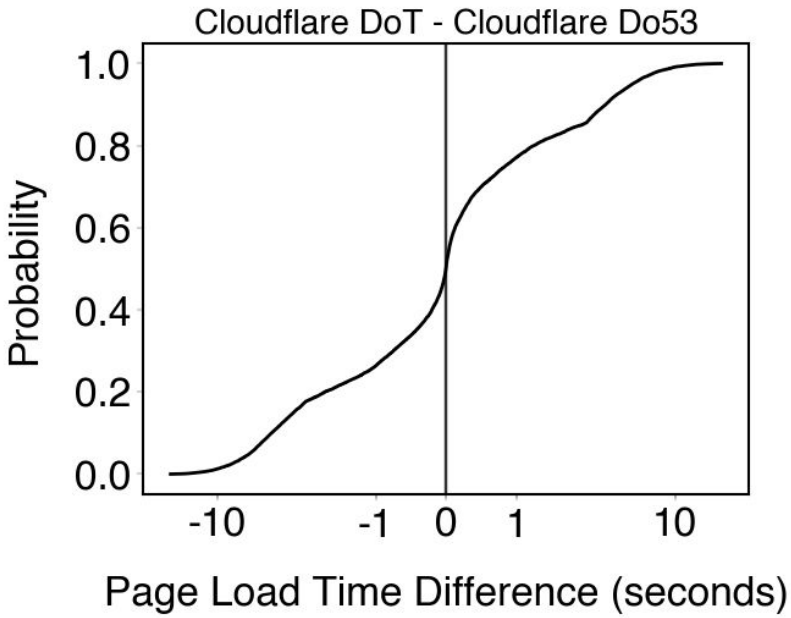
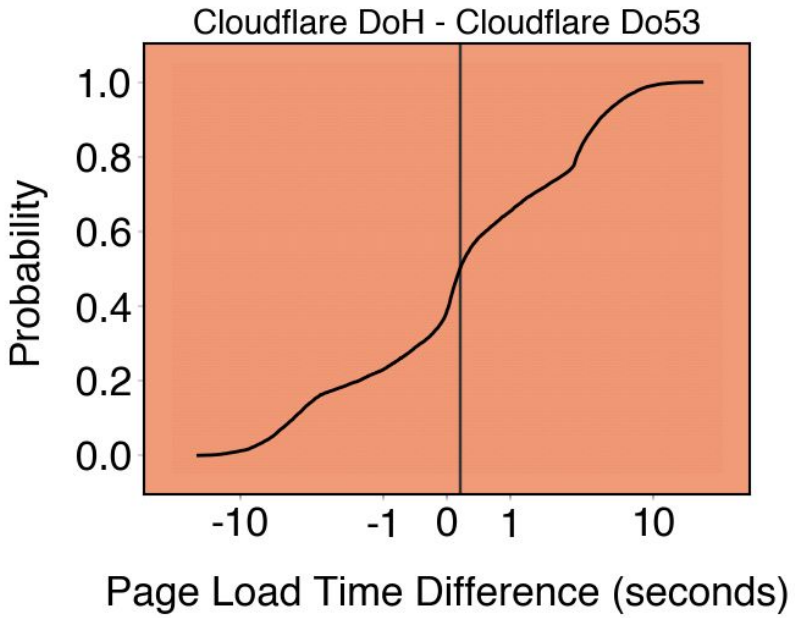
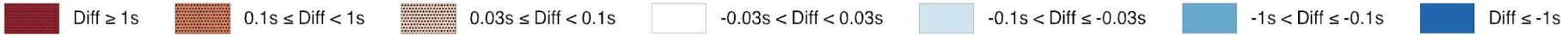
Page Loads with Cloudflare on Emulated 4G Network







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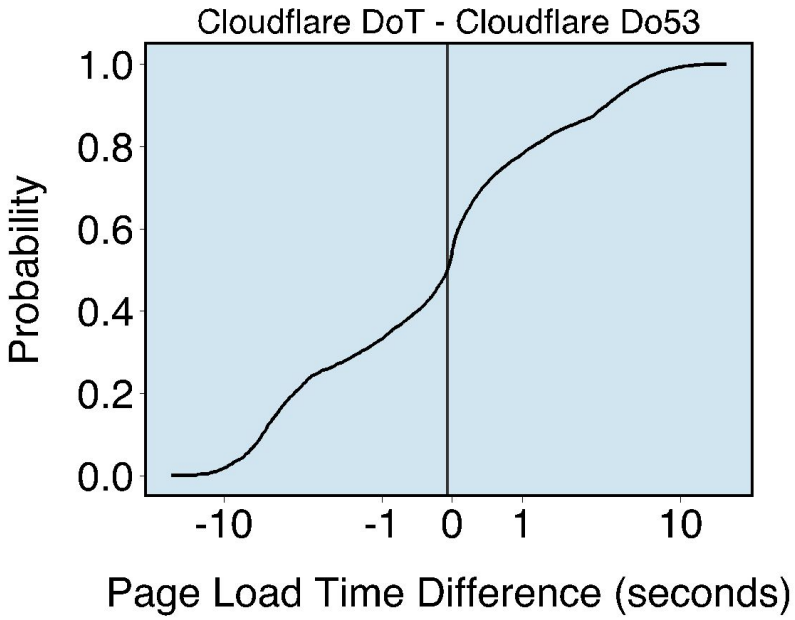
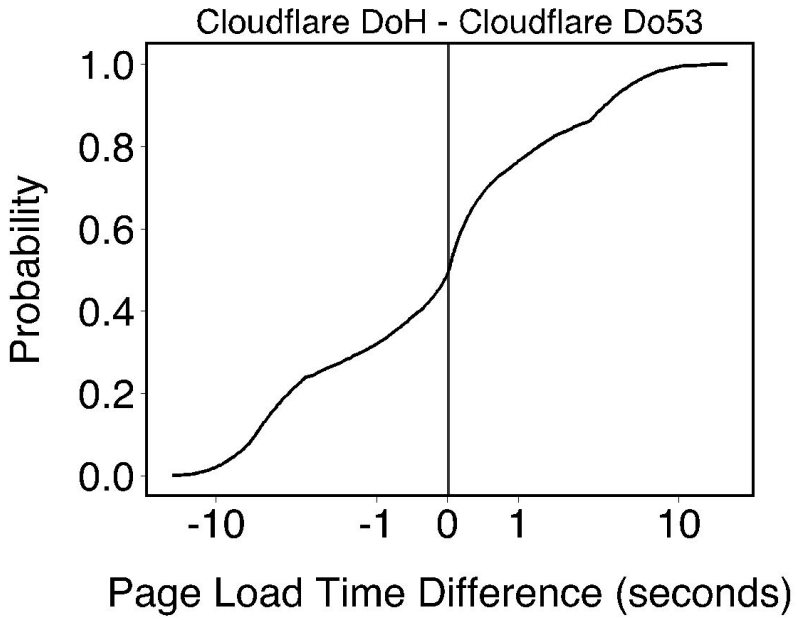
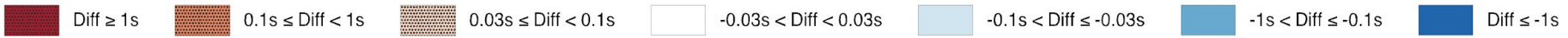
Page Loads with Cloudflare on Emulated, Lossy 4G Network







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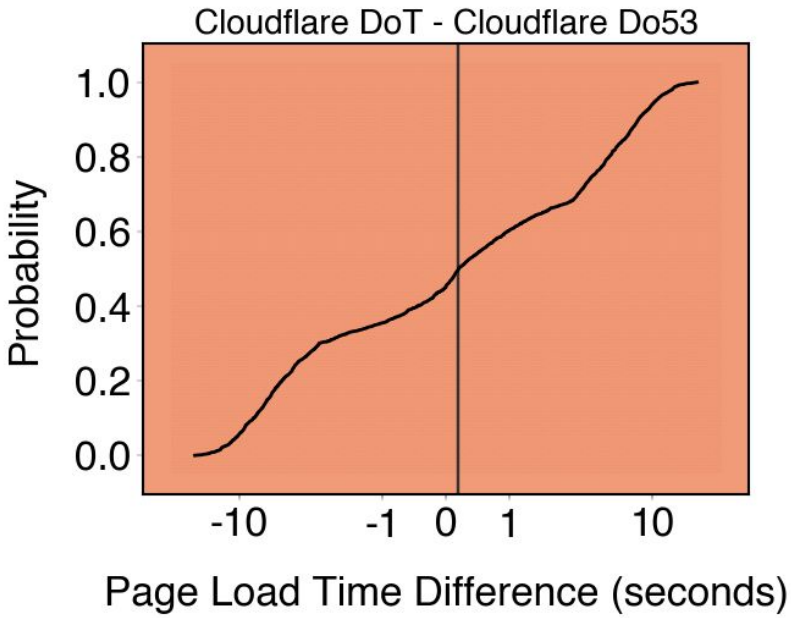
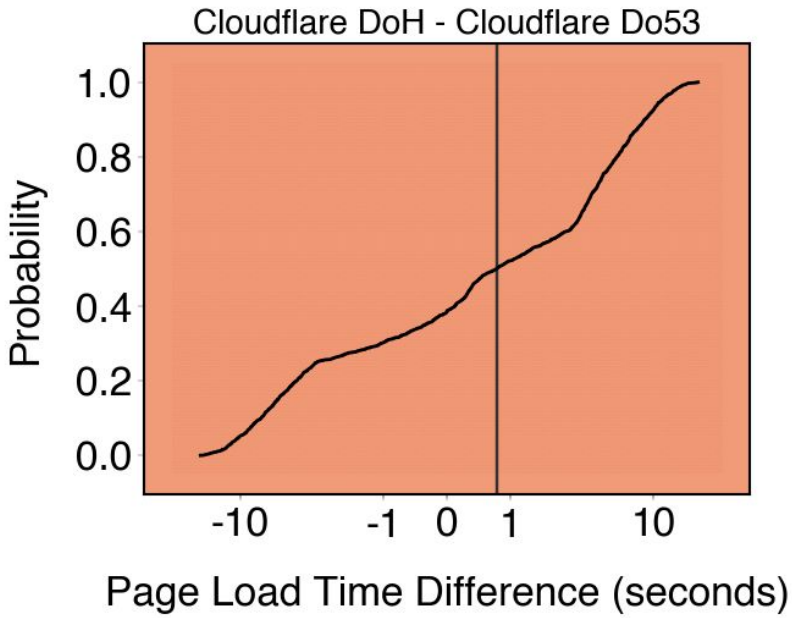
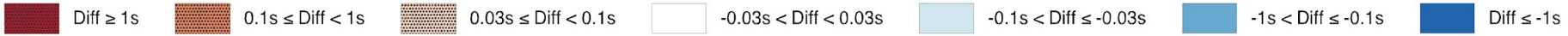
Page Loads with Cloudflare on Emulated 3G Network







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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

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Potential Improvements for Do53, DoT, and DoH

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

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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