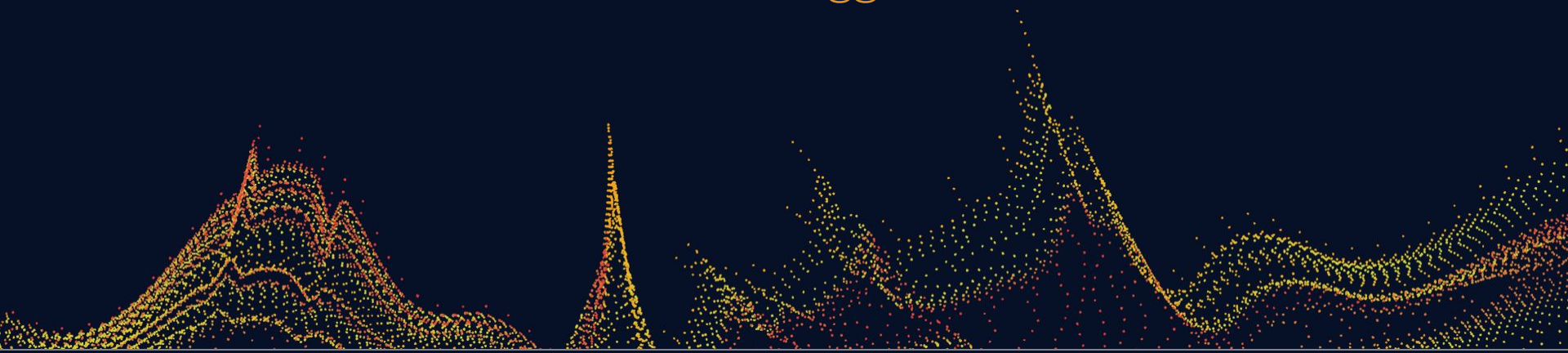
PQSHIELD

Weighing Post-Quantum Authentication

Thom Wiggers



The public key crypto in the TLS handshake

- ClientHello
  - 1 public key
- ServerHello
  - 1 ~~public key~~ ciphertext
- Server Certificates
  - Leaf certificate: 1 public key, 1 signature
  - Intermediate Certificate: 1 public key, 1 signature
  - Bonus content: 3x Certificate Transparency
- Server CertificateVerify
  - 1 signature

- Not pictured:
  - OCSP (Stapling)

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Classic EC	X25519	ECDSA P-256	ECDSA P-256	ECDSA P-256	ECDSA P-256	ECDSA P-256	3 ECDSA P-256	**626**	ECDSA P-256
	64	72	65	72	65	72	216		
Current deployment	X25519MLKEM768	ECDSA P-256	ECDSA P-256	ECDSA P-256	ECDSA P-256	ECDSA P-256	3 ECDSA P-256	**2194**	ECDSA P-256
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ML-DSA Level II	X25519MLKEM768	ML-DSA-44	ML-DSA-44	ML-DSA-44	ML-DSA-44	ML-DSA-44	3	ML-DSA-44	**18776**	ML-DSA-44
	1632	2420	1312	2420	1312	2420		7260		

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Falcon	X25519MLKEM768	Falcon-512	Falcon-512	Falcon-512	Falcon-512	Falcon-512	3	Falcon-512	**7422**	Falcon-512
	1632	666	897	666	897	666		1998		

* Falcon is difficult to implement correctly!

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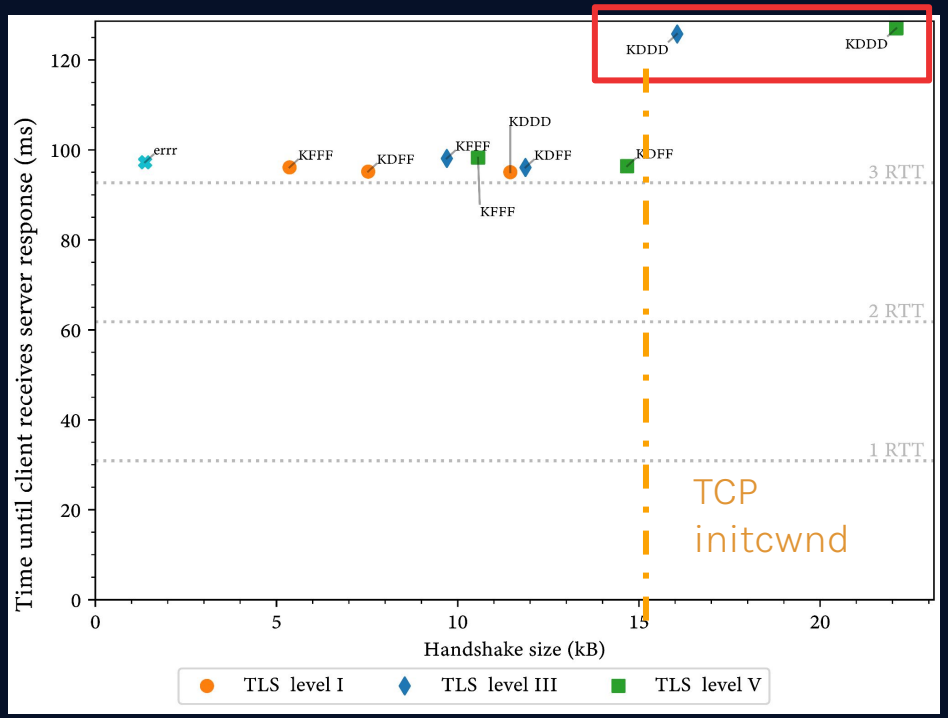
Optimized MAYO	X25519MLKEM768	MAYO-1	MAYO-1	MAYO-1	MAYO-1	MAYO-2	3	MAYO-2	**6124**	MAYO-2
	1632	454	1420	454	1420	186		558		

Preface

- All lattice-based PQC algorithms are **stupid fast** on smartphones, computers
- All effects in benchmarks can be attributed to **sizes**

Synthetic Benches

- 1000mbps, 31ms RTT latency
- First RTT: TCP SYN/ACK
- Second RTT: TLS Handshake
- Third RTT: tiny HTTP Request / Response



Label XABC:
X: Key exchange
A: Handshake auth
B: Intermediate Certificate
C: Root CA certificate

errr: X25519+RSA2048
K: Kyber
D: Dilithium
F: Falcon

No SCTs!

Source: "Post-Quantum TLS", Thom Wiggers, PhD thesis. 2024

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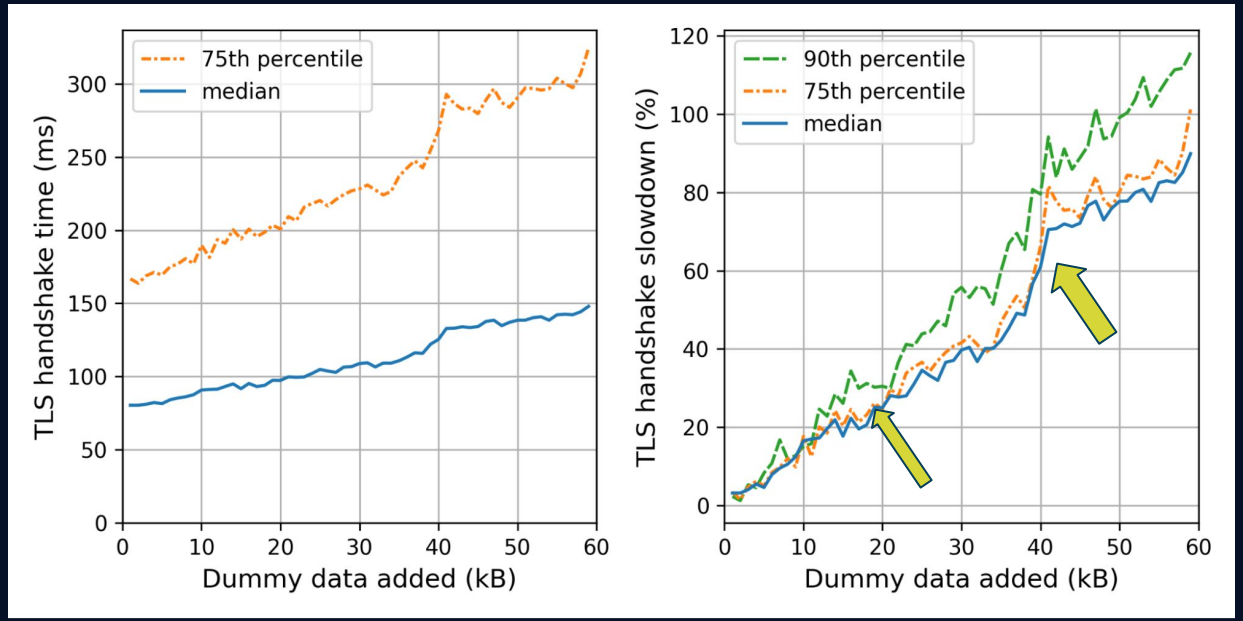
Practical benchmarks

Slowdown more gradual than synthetic benchmark

25% slowdown predicted for ML-DSA-44 (~18k).

Note: Cloudflare has initcwnd of 30 MSS, “cliff” may need to be moved to the left!

(someone please inform the protocol police of this violation of RFC 6928)



Src: Sizing Up Post-Quantum Signatures by Bas Westerbaan

Some random server operator

“So I need to add 15kB to the handshake, potentially slowing down my website by 20%, for something that doesn’t exist today?”

But we do want this guy to deploy PQC!

Google Chrome's take

"Transmitting Kyber keys is quite slow. The extra size from Kyber causes the TLS ClientHello to be split into two packets, resulting in a 4% median latency increase to all TLS handshakes in Chrome on desktop."

Chromium Blog: Advancing Our Amazing Bet on Asymmetric Cryptography

"Adding ~7KB is implausible unless a cryptographically relevant quantum computer (CRQC) is tangibly imminent."

Google Chrome Security Building a Deployable Post-quantum Web PKI

Are things this dire?

- Panos Kampanakis & Will Childs-Klein. The impact of data-heavy, post-quantum TLS 1.3 on the Time-To-Last-Byte of real-world connections
  - "The time-to-**last**-byte increase stays below 5% for high-bandwidth, stable networks. It goes from 32% increase of the handshake time to under 15% increase of the time-to-last-byte when transferring 50KiB of data or more under low-bandwidth, stable network conditions.

- Cloudflare: "The median number of bytes transferred from server-to-client over a resumed QUIC connection is 4.4kB, while the average is 395kB. For non-resumptions the median is 7.8kB and average is 551kB.