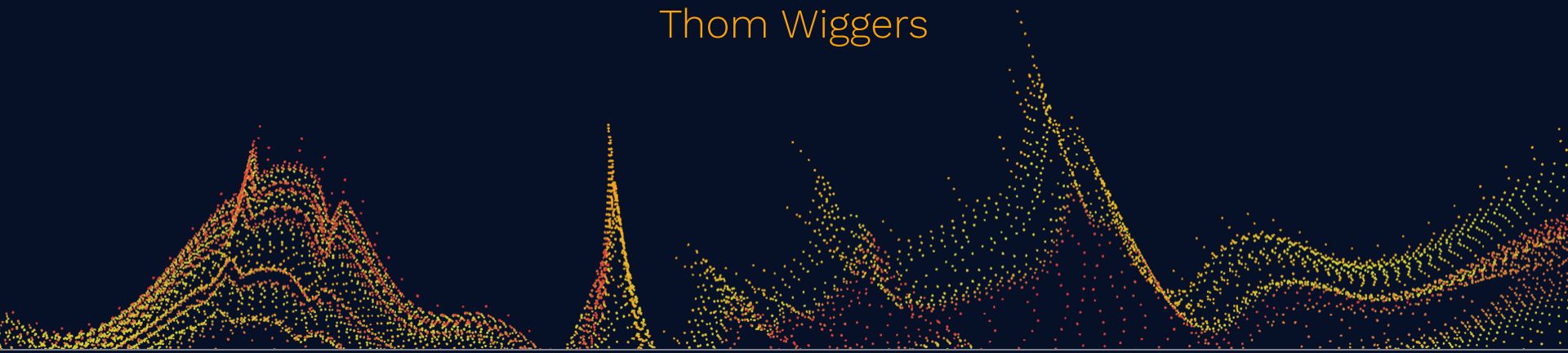
Fully PQ TLS in the WWW

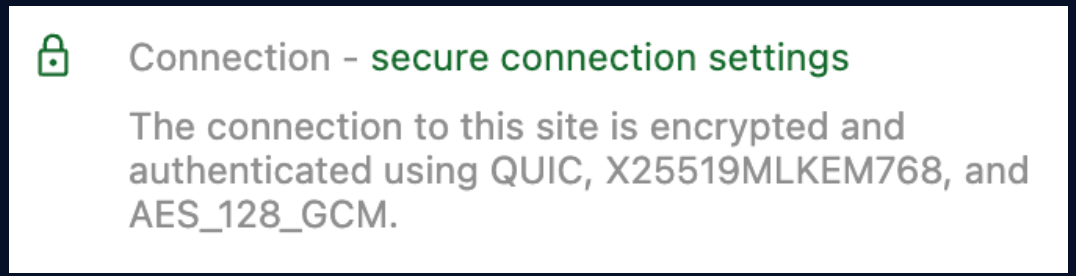
Where we're at and where we're going

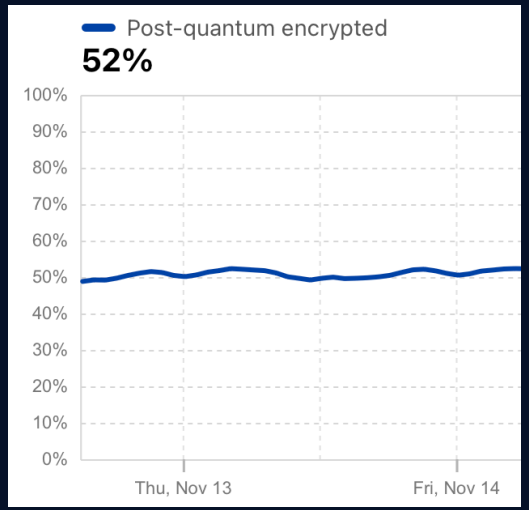
Thom Wiggers



PQ is going great

Cloudflare, Google Chrome, Microsoft Edge, and Firefox deployed PQ key exchange in web browsing.





radar.cloudflare.com

To Do: Where we're at

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☑ Get post-quantum key exchange

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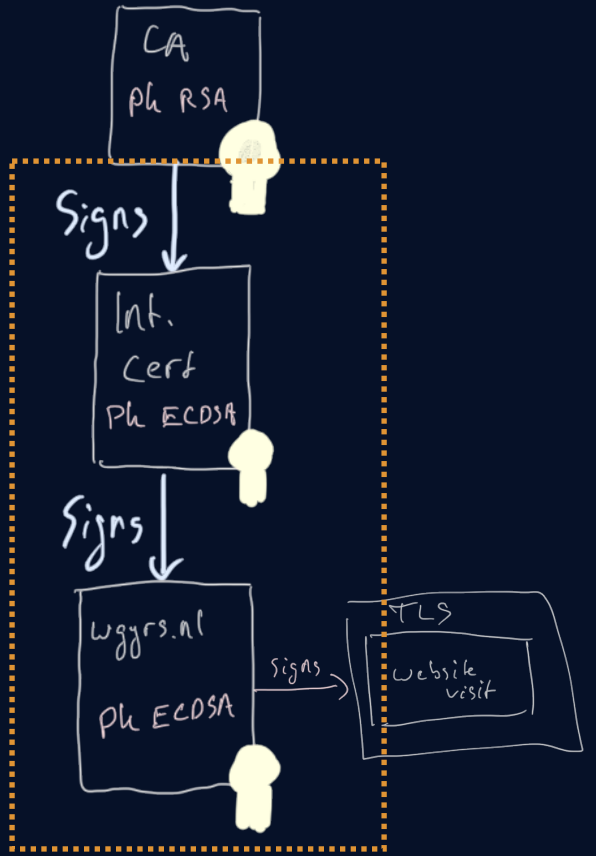
- ☑ Get post-quantum key exchange
- ☐ Get post-quantum authentication

Authentication in TLS



Authentication in TLS

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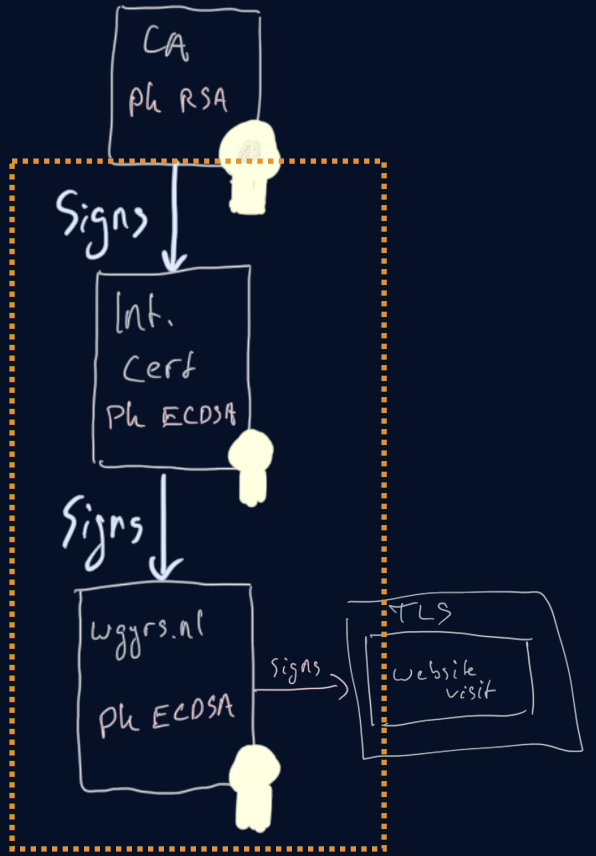

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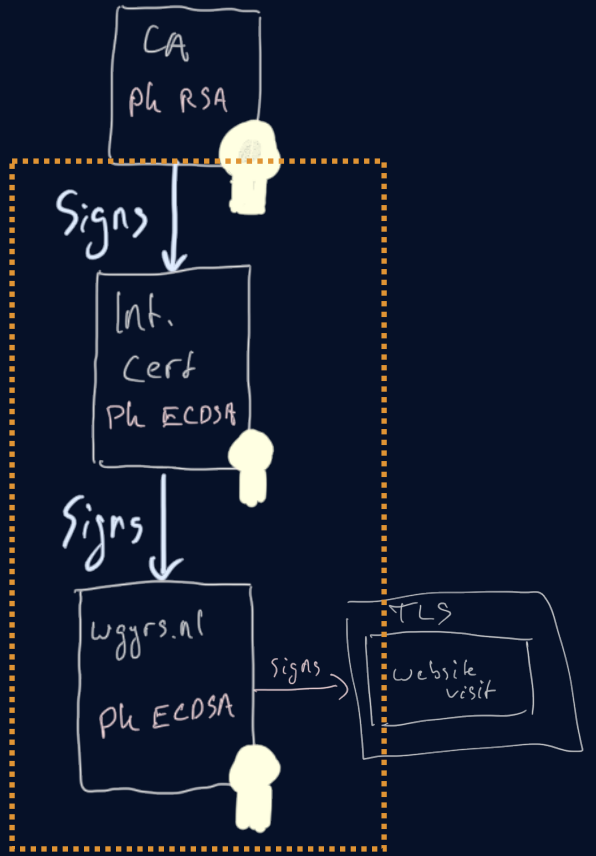
- Server certificate:
  - 1x public key, 1x signature
  - Bonus: 3x Certificate Transparency SCTs
  - 1x Signature on handshake



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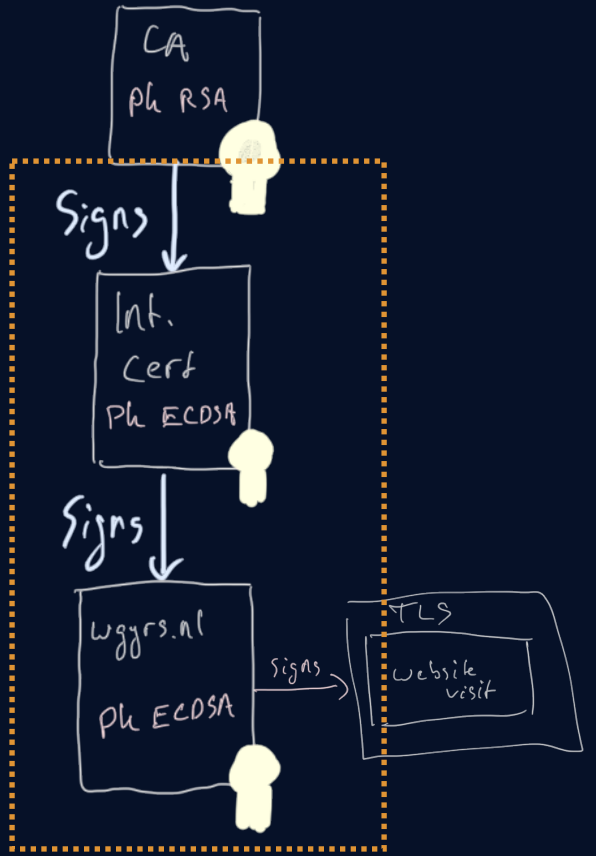

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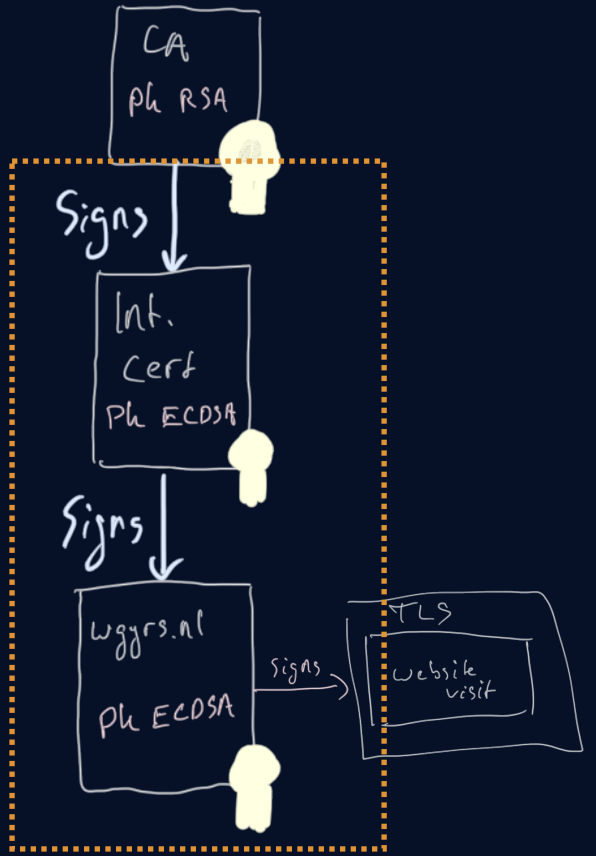
Replacing all of this by ML-DSA adds 18–36 kB!



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(See also last year's talk)

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PQ key exchange:

- Solves Harvest-Now-Decrypt-Later
- Only need to update in 1 spot
- Well-tested now
- Adds ~2kB of data to handshake
- ~4% slowdown for most clients is costly but acceptable (src: Google)

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"I'll wait"

(See also last year's talk)

Certificate Transparency

- Certificate transparency is a public log of all issued certificates
  - In particular, a Merkle Tree
- Aim: detect “DigiNotar” incidents
  - Hacked CA issued certificates for gmail.com
- Chrome, Firefox, Safari require Certificate Transparency

Certificate Transparency is fragile

Source: Let's Encrypt presentation in PLANTS meeting at IETF 124

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- Running a log is expensive
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  - Before PQC

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Certificate Transparency uses Trees

- CT logs only accept submissions from trusted CAs
  - The list only contains validated certificates
- Merkle Trees can produce a proof of inclusion in the tree
- So a proof of inclusion could prove validity of the certificate!
  - Inclusion proof is just a bunch of hashes

MTC: Merkle Tree Certificates

Src: https://datatracker.ietf.org/meeting/124/materials/slides-124-plants-solution-space-and-dispatched-work-00

MTC: Merkle Tree Certificates

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  - Independent mirrors and witnesses co-sign log state

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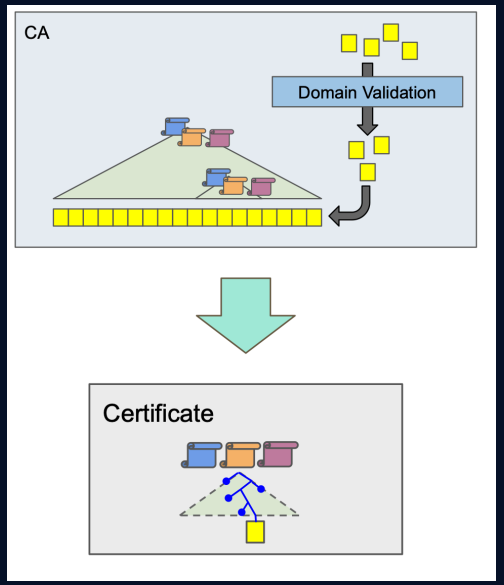
MTC: Issuance and Verification

- CA creates certificates and builds Merkle Tree
- Tree state gets checked and tree head is signed by co-signers
- Certificate is now:
  - Public key
  - Path in Merkle Tree
  - The (co)signatures on the tree head

- Note that these signed tree heads are shared with many log entries, and can be distributed out-of-band!



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- Log errors/downtime only means issuance failure, no log disqualification

MTC: Optimised certificates

- 3 ML-DSA signatures: 7,260 bytes (1 CA sig, 2 SCTs)
- 1 inclusion proof: 736 bytes
  - Tree size depends on issuance rate
  - (estimated from Web PKI / Let's Encrypt volumes)
- No longer a need for intermediate certificates

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MTC: How to deploy this?

- TLS Clients (browsers) must be updated with support
  - Ability to fetch tree heads out-of-band
- TLS Servers must be updated with support
  - Clients will indicate which tree-heads they have
  - Server selects “full” or “signature-less” MTC certificate
    - “Full” will include the signatures on the tree head
    - “Signature-less” omits signatures if client is up-to-date with tree heads
  - Server must update its inclusion proof periodically
    - Likely via ACME (aka Let’s Encrypt’s “certbot”)

What about “old-fashioned” certificates

- MTC will (likely) only work in WebPKI and similar settings
- “Old-fashioned” certificates with chains of signatures will probably continue to exist
  - Fall-back in the WebPKI
  - Private PKIs
  - Non-Web use cases

How real is this?

- Proposal is being pushed by Google Chrome and Cloudflare
- Standards are being developed in the PLANTS (PKI, Logs, And Tree Signatures) working group in IETF
  - Disclaimer: I was asked to be co-chair of this working group
  - Please review and comment
  - Join the mailing list plants@ietf.org

- Cloudflare and Google announced they will start experimenting on the web in 2026

More lessons from real people, on our podcast

- **Shielded - the Last Line of Cyber Defense Podcast** launched March 2025 - now with nearly 160,000 subscribers on YouTube!
- Purpose - to share PQC migration stories from global organisations
- 21 episodes so far, including:
  - Cloudflare, CISA, Linux Foundation, NIST, Signal Messenger, Thales, Entrust, Lattice Semiconductor, UK NCSC, Schneider Electric, Bill Buchanan, AMD, Yolanda Reid, Digicert, OpenSLL Foundation, Capgemini, HSBC, HP and many more

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