Falcon

Towards FN-DSA

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Technical Overview

A bird's eye view

PQ SHIELD

Keygen(1^λ)

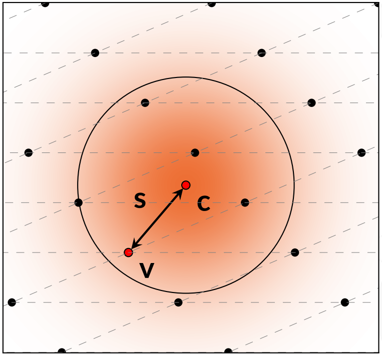
1. Gen. matrices $\mathbf{A}, \mathbf{B}$ s.t.:
   - $\mathbf{A}$ is pseudorandom
   - $\mathbf{B} \cdot \mathbf{A} = 0$
   - $\mathbf{B}$ has small coefficients
2. $\mathrm{pk} := \mathbf{A}, \mathrm{sk} := \mathbf{B}$

Verify(msg, pk $\quad \mathbf{A}$, sig $\quad \mathbf{s}$)

Check ($\mathbf{s}$ short) & ($\mathbf{s} \cdot \mathbf{A} = H(\mathrm{msg})$)

Sign(msg, sk $\quad \mathbf{B}$)

1. Compute $\mathbf{c}$ such that $\mathbf{c} \cdot \mathbf{A} = H(\mathrm{msg})$
2. $\mathbf{v} \leftarrow$ vector in $\mathcal{L}(\mathbf{B})$, close to $\mathbf{c}$
3. $\mathrm{sig} := \mathbf{s} = (\mathbf{c} - \mathbf{v})$



Details omitted: salt the hash as $H(\mathrm{salt}\|\mathrm{msg})$, restart if $\mathbf{s}$ not short enough, etc.

When to Deploy

Pros and cons

Pros

+ Compact sizes
+ Very fast verification
+ Signing is also fast, but less than Dilithium

Cons

− Keygen and signing require floating-point arithmetic
− Keygen and signing are complex to implement

Mapping criteria to applications

Compact sizes

Verification speed

Worst-case running time

Verification memory

Vehicle-to-vehicle (V2V) communications

Compact sizes

Verification speed

Worst-case running time

Verification memory

V2V

Drive (Quantum) Safe! – Towards Post-Quantum Security for V2V Communications [BMTR22]

> “ Only signature schemes whose explicit certificate can be sent in five or less fragments can be used in the *True Hybrid* design. [...] Falcon is the only viable scheme. ”

TLS certificates

TLS

Compact sizes	Verification speed
Worst-case running time	Verification memory

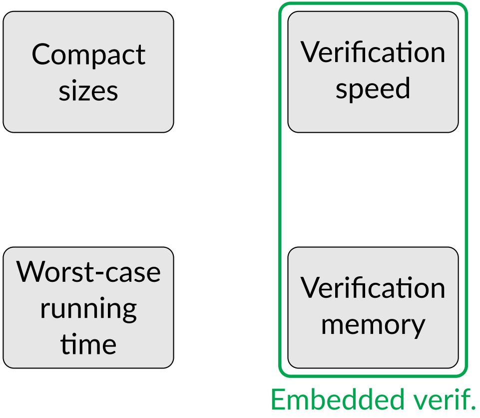
Post-Quantum Authentication in TLS 1.3: A Performance Study [SKD20]

> " The PQ algorithms with the best performance for time-sensitive applications are Dilithium and Falcon. "

NIST's pleasant post-quantum surprise [Wes22] recommends:

- → Falcon for offline signature
- → Dilithium for handshake

Verification on embedded devices



FPGA Energy Consumption of Post-Quantum Cryptography [BKG22]

> " For signature verification, Falcon provides the lowest energy consumption, highest throughput, and lowest transmission size [compared to Dilithium and SPHINCS+]. "

Verifying Post-Quantum Signatures in 8 kB of RAM [GHK+21]

> " On Cortex-M3, [Falcon's] overall memory footprint is about 6.5 kB. "

DNSSEC

DNSSEC

Compact sizes

Verification speed

Worst-case running time

Verification memory

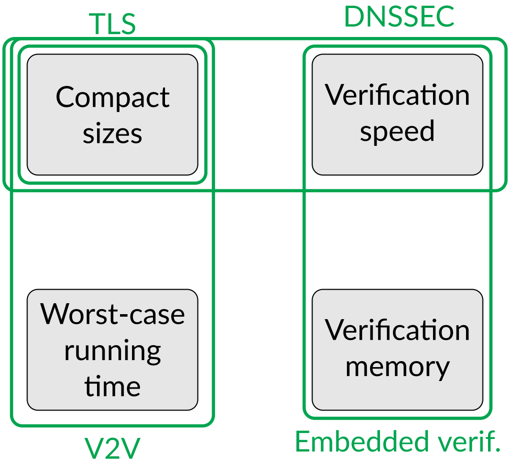
Retrofitting Post-Quantum Cryptography in Internet Protocols: A Case Study of DNSSEC [MdJvH+20]

> “ [...] the performance of Falcon-512 is closest to the current algorithms and meets the requirements of DNSSEC. ”

Post-Quantum Signatures in DNSSEC via Request-Based Fragmentation [GS22]

> “ [...] Falcon-512 may be the most suitable option currently available to be standardized for DNSSEC. ”

Summary



Suitable applications:

- → V2V
- → TLS certificates
- → Verification on embedded devices
- → DNSSEC
- → …

Towards FN-DSA

Floating-point arithmetic

Keygen and signing require **floating-point arithmetic (FPA)**

- Makes validation (i.e. KATs) difficult
- Be mindful on devices with non-existent or variable-time floating-point units
- Say goodbye to masking

How do we mitigate that?

→ **Key generation:** use fixed-point arithmetic as in Hawk

→ **Signing:** *potential* solution is to use Antrag

Antrag?

Antrag is a modified key generation algorithm proposed by Espitau et al., *Antrag: Annular NTRU Trapdoor Generation*, ASIACRYPT 2023 [ENS+23].

Pros

+ Gives "better quality" trapdoors
+ Make signing simpler (fast Fourier sampler $\rightarrow$ hybrid sampler)
+ FPA becomes easier to analyze and possibly remove

Cons

− Very recent, too early for standardisation
− Full security implications to be determined

See Quyen's talk tomorrow!

Smaller suggested tweaks for FN-DSA

- BUFF transform [CDF$^+$21]
  - Instead of $h = H(\mathrm{salt}\|\mathrm{msg})$, compute $h = H(H(\mathrm{pk})\|\mathrm{salt}\|\mathrm{msg})$ and include h in sig
  - Possibly better solution: use the lighter PS-3 transform [PS05] like HAWK
  - Provides additional security properties
- Add the condition $\|\mathbf{s}\|_\infty \leq B_\infty$, with $B_\infty \approx 840$ (suggested by Yang Yu)
  - Forgery remains at least as hard
- Make the signing restart rate very small
  - Desirable for applications where worst-case running time matters.

Negligible impact on performance.

Thank You!

https://falcon-sign.info/

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