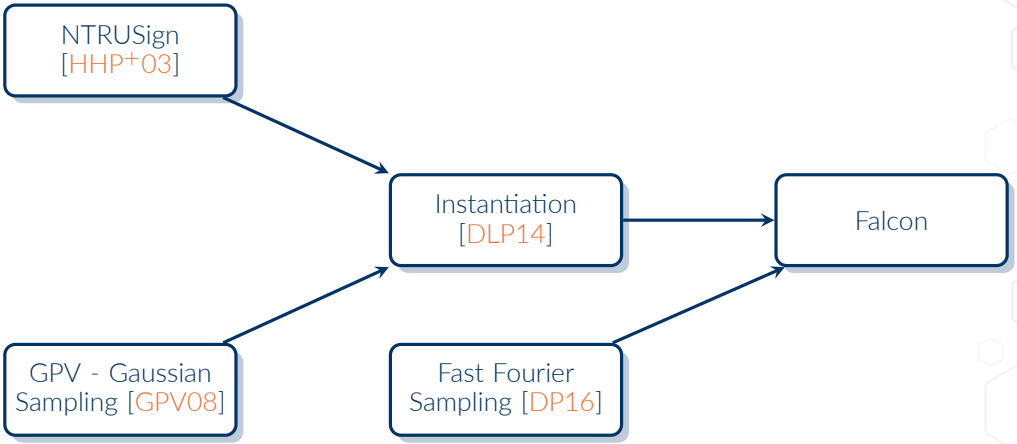
Falcon

Pierre-Alain Fouque[1] Jeffrey Hoffstein[2] Paul Kirchner[1] Vadim Lyubashevsky[3] Thomas Pornin[4] Thomas Prest[5] Thomas Ricosset[6] Gregor Seiler[3] William Whyte[7] Zhenfei Zhang[8]

A Long Lineage



Keygen(1^λ)

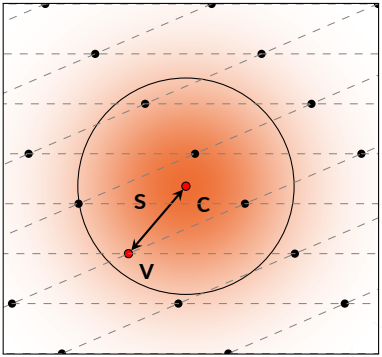
1. Gen. matrices $\mathbf{A}, \mathbf{B}$ s.t.:
   - $\mathbf{B} \cdot \mathbf{A} = 0$
   - $\mathbf{B}$ has small coefficients
2. $\mathsf{pk} := \mathbf{A}, \mathsf{sk} := \mathbf{B}$

Sign$(\mathtt{M}, \mathbf{sk} = \mathbf{B})$

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

Verify$(\mathtt{M}, \mathbf{pk} = \mathbf{A}, \mathtt{sig} = \mathbf{s})$

Check ($\mathbf{s}$ short) & ($\mathbf{s} \cdot \mathbf{A} = H(\mathtt{M})$)



Advantages & Drawbacks

PQ SHIELD

Advantages:

- The most bandwidth-efficient finalist
- Verification (in particular) is fast and RAM efficient
- Extensive research on the security of lattices (and NTRU)
- Side-channel resistance is now better understood [Por19, HPRR20, FKT+20]

What can be improved:

- Key generation and signing remain complex
- Key generation and signing rely on floating-point arithmetic
- More work on side-channel resistance is always welcome

Falcon is the Most Compact Finalist

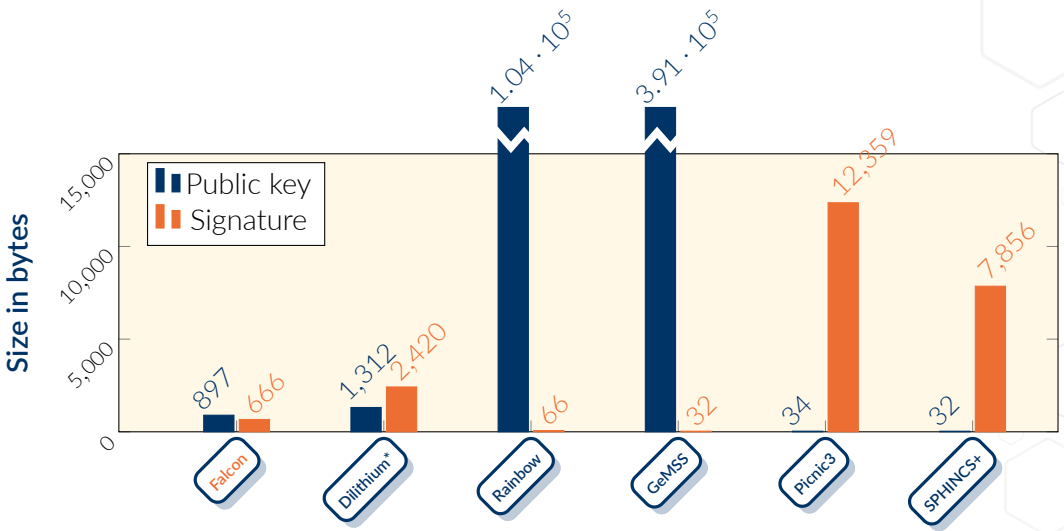


Figure 1: Bandwidth cost at NIST Level ≥ 1

Recent Improvements

PQ SHIELD

Changes in Round 3:

- Gaussian sampler over the integers:
  - Now formally specified, complete with test vectors
  - Secure and isochronous, see [HPRR20]
- We propose a unique encoding of signatures that avoids benign malleability[1]
- The security analysis is now more detailed and reproducible (Python script)

What's next:

- Adding beyond unforgeability features (BUFF) [CDF+20]
- More simplification where possible (see also later slide)

[1] We are thankful to Quan Nguyen to pointing this out.

Birds of a Feather - Advanced Primitives

Raptor: *A Practical Lattice-Based (Linkable) Ring Signature* [LAZ19]

→ A linear-size ring signature, very efficient for small rings

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Quantum-safe HIBE: *does it cost a* ***Latte****?* [ZMS+21]

→ A HIBE, under consideration for standardisation by NCSC and ETSI

Birds of a Feather - Alternative Designs

ModFalcon: *Compact signatures based on module-NTRU lattices* [CPS+20]

→ Provides more modularity in parameter selection

Mitaka: *A Simpler, Parallelizable, Maskable Variant of Falcon* [TETW21]

→ A simpler, masking-friendly variant of Falcon

Zalcon: *an alternative FPA-free NTRU sampler for Falcon* [FGRY21]

→ A simpler, FPA-free variant of Falcon

Deployment in TLS and V2V

Suitability of 3rd Round Signature Candidates for Vehicle-to-Vehicle Communication [BMTR21]

> " For example it might turn out that only Falcon can be used in high density situations, such as congested intersections, if our implementations follows the V2V standard specifications. "

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

> " Our results show that the PQ algorithms with the best performance for time-sensitive applications are Dilithium and Falcon. "

Deployment on Embedded Devices

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

> " On the Cortex-M3, the implementation submitted to NIST uses around 500 bytes of stack space, public keys of circa 900 bytes, signatures of around 800 bytes, and a 4 kB scratch buffer. The overall memory footprint is about 6.5 kB. Hence, streaming in the data in small packets is not necessary. "

Using streaming, we can probably get the RAM usage to < 2 kB.

Falcon is:

- Based on a strong theory and well-studied assumptions
- Compact and fast
- Naturally connected to more sophisticated primitives
- Amenable to several usecases

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Thank you

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