HAWK: an update

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Joppe W. Bos[1], Olivier Bronchain[1], Léo Ducas[2,3], Serge Fehr[2,3], Yu-Hsuan Huang[2], Thomas Pornin[4], Eamonn W. Postlethwaite[5], Thomas Prest[6], **Ludo N. Pulles**[2], Wessel van Woerden[6]

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[1]NXP Semiconductors, [2]Cryptology Group, CWI, [3]Leiden University, [4]NCC Group, [5]King's College London, [6]PQShield

Eurasian sparrowhawk by Bart Hoekstra, CC-BY-NC-SA 4.0

HAWK: an intro

HAWK is the only lattice-based scheme in the 2nd round of NIST's additional standardisation process.

Why use HAWK?

Fast:	KeyGen: 3.5 ms[1]	Sign/Verify: < 0.1 ms
Compact:	$\lvert pk_{\text{pub}} \rvert = 1024$ bytes	$\lvert \text{sig} \rvert = 555$ bytes
Hardware friendly:	$\leq$ 12kiB RAM	no `float`/`double`

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The scheme, and its reference implementation are mature:

- isochronous implementation,
- BUFF-secure as is [ADM+24],
- simple samplers: centred binomial and discrete gaussian on two cosets of $\mathbb{Z}$.

Its security is based on relatively new problems...
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Update on LIP

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LIP

HAWK is *inspired* by the lattice isomorphism problem (LIP).

[DvW22] *On LIP, quadratic forms, remarkable lattices, and cryptography*
💡 Build cryptography from **non random lattices** with good geometry.

[BGPS23] *Just how hard are rotations of $\mathbb{Z}^n$?*
💡 LIP seems hard for $\mathbb{Z}^n$.

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💡 Use **module structure** over cyclotomic rings and **simplify** KeyGen and Sign.

Does module structure or the simplification weaken security?

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HAWK: private key recovery

Recover HAWK $\mathsf{sk}_{\mathsf{priv}}$ $\iff$ solve 'search module LIP' (smLIP) in rank 2

In particular,

setup: use the ring $R = \mathbb{Z}[\zeta]$, with $\zeta^n = -1 \qquad (n \in \{2^9, 2^{10}\})$,
sample $\mathbf{U} \in \mathrm{GL}_2(R)$, and compute $\mathbf{Q} = \mathbf{U}^*\mathbf{U}$,

problem: upon input $\mathbf{Q}$, output any $\mathbf{V} \in \mathrm{GL}_2(R)$ with $\mathbf{Q} = \mathbf{V}^*\mathbf{V}$.

HAWK was designed with [GS02, LS19] in mind: rank 1 'ideal' LIP is polynomial time.

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smLIP using any number field

More general: $R = \mathcal{O}_K$ where K is a number field.

Literature on smLIP$_K$:

[MPPW24] (heuristic) smLIP is polynomial time if K is totally real,

[APvW25] (heuristic*) smLIP is polynomial time if K has at least one real embedding,

[CME+25] smLIP reduces to solving a 'norm reduced principal ideal problem' (nrdPIP) in (for HAWK) a noncommutative quaternion algebra.

Cyclotomics are totally imaginary, hence the first two attacks do not apply.

The current understanding is: nrdPIP is fundamentally different to PIP, and there seems no easy way to generalise Gentry–Szydlo.

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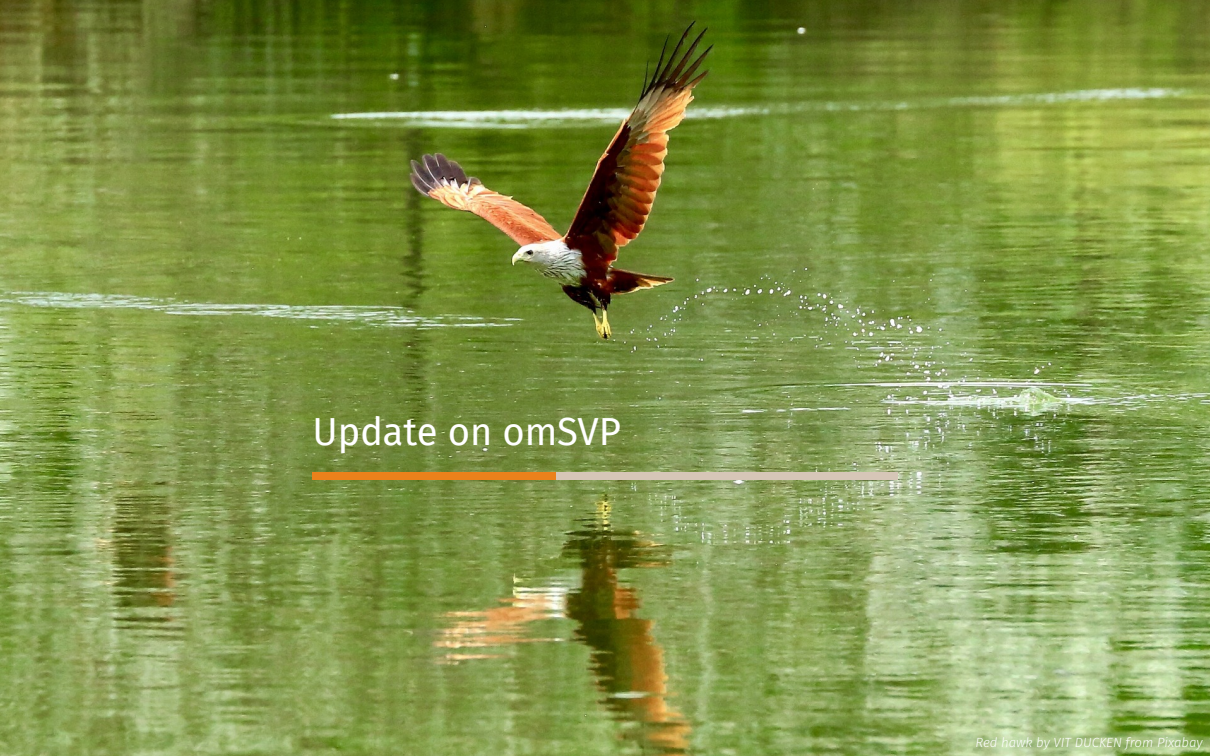

Update on omSVP

Red hawk by VIT DUCKEN from Pixabay

SUF-CMA security of HAWK

One more short vector problem (omSVP)
reduces to
SUF-CMA security of HAWK in qROM.

(if you forge a HAWK signature, you solve omSVP)

Solving omSVP leaves the *design* of HAWK unsupported

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omSVP in detail

omSVP captures the idea that,

> given an oracle providing short lattice vectors $\mathbf{v}_i$,
> returning a **'fresh'** and similarly short lattice vector is hard.

Here, 'fresh' accounts for structure.

HAWK v1.0: not 'fresh' is multiplying $\mathbf{v}_i$ with a root of unity, ζ^j.

[LJPW24] There is an efficiently computable *'symplectic automorphism'* ω.
💣 This solves omSVP: take $\mathbf{v}_1$ from the oracle, and output $\omega(\mathbf{v}_1)$.

HAWK v1.1: $\zeta^j \mathbf{v}_i$ and $\zeta^j \omega(\mathbf{v}_i)$ are not 'fresh'.

[vGP25] Any other automorphism makes smLIP easy to solve *(later today)*
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Update on Key Generation

Key Generation

- Given $f, g \in R$, HAWK key generation requires one to find $F, G \in R$ with

$$fG - gF = 1.$$

  (Similar to FALCON except we use 1 instead of prime q.)

- Solve recursively by passing to fields of half the degree until reaching $\mathbb{Z}$ then lift solutions [PP19]. Use size reduction to find a *small* lift F, G.

Improvements

By tuning this intermediate size reduction, the works [Por23] and [Por25] were able to reduce the cycle count and RAM usage.

Table 1: Performance of HAWK-512 key generation

	Prior	[Pornin25]	
x86 w/ AVX2	7.68 Mcyc	6.11 Mcyc	↓ 20%
ARM Cortex M4	47.92 Mcyc	38.56 Mcyc	↓ 20%
RAM usage	14 kiB	12 kiB	↓ 14%

Wrapping up

Northern harrier by Iulian Ursache from Pixabay

Cryptanalysis conclusion

- At present, key recovery requires either a single real embedding or solving nrdPIP in a noncommutative quaternion algebra. It is not known how to efficiently perform the latter.
- Finding any further automorphisms would practically recover the secret key, but this seems as hard as finding a short vector ([vGP25] *later today*).
- Solving omSVP does not imply signature forgeries against HAWK, only that its SUF-CMA security is unsupported by a reduction.

Open research directions

1. How hard is nrdPIP in the HAWK case?
2. How hard is omSVP concretely, assuming no further automorphisms?
3. Can the (relative) simplicity of discrete Gaussians over $\mathbb{Z}$ and $\mathbb{Z} + 1/2$ lead to plausibly efficient masking?
   ([GR24] provides an initial side-channel study with practical countermeasures.)

Thank you!

Questions?

https://hawk-sign.info

team@hawk-sign.info

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