The H2020 PQCRYPTO project, an update

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5th ETSI/IQC Workshop on Quantum-Safe Cryptography
Post-Quantum Cryptography for Long-term Security

- Project funded by EU in Horizon 2020.
- Starting date 1 March 2015, runs for 3 years.
- 11 partners from academia and industry, TU/e is coordinator
What does PQCRYPTO mean for you?

- Expert recommendations for post-quantum secure cryptosystems.
- Recommended systems will get faster/smaller as result of PQCRYPTO research.
- More benchmarking to compare cryptosystems.
- Cryptographic libraries will be made freely available for several computer architectures.
- Find more information online at http://pqcrypto.eu.org/.
- Final reports next summer.
- Follow us on twitter https://twitter.com/pqc_eu.
Initial recommendations (September 2015)

- **Symmetric encryption** Thoroughly analyzed, 256-bit keys:
  - AES-256
  - Salsa20 with a 256-bit key

Evaluating: Serpent-256, ...

- **Symmetric authentication** Information-theoretic MACs:
  - GCM using a 96-bit nonce and a 128-bit authenticator
  - Poly1305

- **Public-key encryption** McEliece with binary Goppa codes:
  - length \( n = 6960 \), dimension \( k = 5413 \), \( t = 119 \) errors

Evaluating: QC-MDPC, Stehlé-Steinfeld NTRU, ...

- **Public-key signatures** Hash-based (minimal assumptions):
  - XMSS with any of the parameters specified in CFRG draft
  - SPHINCS-256

Evaluating: HFEv-, ...
The last year

- ECRYPT-CSA executive school in Eindhoven, ~ 40 people.
- PQCRYPTO school in Eindhoven (at TU/e)
  120 Participants, 21 lectures, videos & slides online:
  https://2017.pqcrypto.org/school/schedule.html
- PQCrypto 2017, Utrecht
  67 submissions, 23 papers accepted;
  226 participants; videos to come.
  https://2017.pqcrypto.org/conf
Selected research results

(only minimally subjective)
Post-quantum signatures with formal security arguments

The quantum accessible ROM

- ROM: every party gets access to *ideal* hash function.
- Hash-function has public description.
- Assuming quantum adversaries we need to give quantum access!

Results

- Picnic: Signatures from symmetric key primitives.\(^1\)
- SOFIA: Signatures based on MQ-based identification.\(^2\)

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\(^1\)Chase, Derler, Goldfeder, Orlandi, Ramacher, Rechberger, Slamanig, Zaverucha. Post-Quantum Zero-Knowledge and Signatures from Symmetric-Key Primitives. [ia.cr/2017/279](https://ia.cr/2017/279)

Hash function security

Common belief
- Grover is provably optimal $\Rightarrow$ Attacks gain at most a square-root factor.
- Only in the worst case if function is random!

Constructive results
- Also only square-root speed-up in average case (for random function).\(^3\)
- Sponges are collapsing, CR, SPR, OW, if block function is random function or OW-permutation.\(^4\)

Destructive result
- Can parallelize Grover search for 1 out of $t$ images on $p$ small cores to achieve $\sqrt{\frac{N}{pt^{1/2}}}$ runtime.\(^5\)

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\(^3\) Hülsing, Rijneveld, Song. Mitigating Multi-Target Attacks in Hash-based Signatures. PKC’16. (OW / SPR, CR was shown by Zhandry)

\(^4\) Czajkowski, Groot Bruinderink, Hülsing, Schaffner, Unruh. Post-quantum security of the sponge construction. QCRYPT’17.

\(^5\) Banegas, Bernstein. Low-communication parallel quantum multi-target preimage search SAC’17
## Lattice-based KEMs

<table>
<thead>
<tr>
<th>Scheme</th>
<th>PQ sec.</th>
<th>ct?</th>
<th>Cycles</th>
<th>Bytes</th>
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<td>Streamlined NTRU Prime</td>
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**Table:** Source: Hülsing, Rijneveld, Schanck, Schwabe. High-speed key encapsulation from NTRU. CHES 2017. (See source for references and more details)
Finding short vectors

Not enough study in literature

- SVP: find shortest nonzero vector in a lattice.
- Big improvements in attack speed in last several years.
- Breaking SVP breaks lattice-based crypto.
- Lattice-based crypto uses additional structure: ideal lattices, approximation vectors, FHE.
- Fast quantum attack recently developed against Gentry’s original FHE system.\(^6\)

Destructive results

- Fast non-quantum attack against a reasonable FHE system.\(^7\)

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\(^6\) Eisenträger, Kitaev, Hallgren, Song, STOC’14; Campbell, Groves, Shepherd, 2014; Biasse, Song, SODA’16.

\(^7\) Bauch, Bernstein, de Valence, Lange, van Vredendaal, Short generators without quantum computers: the case of multiquadratics. Eurocrypt’17.
Discrete Gaussian sampling

- Important building block in lattice-based crypto.
- Used to “hide” secrets.
- Hard to do fast, constant-time implementation.

Destructive results

- Many existing samplers vulnerable to side-channel attacks.\(^8\)

Constructive results

- Can switch to rounded Gaussians for signatures.
- Sample continuous Gaussian and round to nearest Integer.
- *Rounded Gaussians* can be sampled efficiently in constant-time.

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\(^8\)Pessl, Groot Bruinderink, Yarom. To BLISS-B or not to be – Attacking strongSwan’s Implementation of Post-Quantum Signatures. CCS’17
Coming soon

- **NIST (Not-)Competition**
  - Several submissions in progress.
  - Signatures, KEX and KEM.
  - Not just plain published schemes but optimized variants.

- **Nature article on post-quantum crypto**
  - Really soon: today’s issue

- **XMSS RFC**
Thank you

- All papers can be found online at http://pqcrypto.eu.org/papers.html.
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