NIST Post-Quantum Cryptography Standardization

Lily Chen
Computer Security Division, Information Technology Lab
National Institute of Standards and Technology (NIST)

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U.S. Department of Commerce

NIST Cryptographic Standards

- Crypto standards
  - Public key based
    - Signature (FIPS 186)
    - Key establishment (800-56A/B/C)
  - Tools
    - RNG (800-90A/B/C)
    - KDF (800-108, 800-135)
  - Symmetric key based
    - AES (FIPS 197) TDEA (800-67)
    - Modes of operations (800 38A-38G)
    - SHA-1/2 (FIPS 180) and SHA-3 (FIPS 202)
    - Randomized hash (800-106)
    - HMAC (FIPS 198)
    - SHA3 derived functions (parallel hashing, KMAC, etc. (800-185)
  - Guidelines
    - Hash usage/security (800-107)
    - Transition (800-131A)
    - Key generation (800-133)
    - Key management (800-57)

Quantum Impact

Quantum computing changed what we have believed about the hardness of discrete log and factorization problems

- Using quantum computers, an integer *n* can be factored in polynomial time using Shor's algorithm
- The discrete logarithm problem can also be solved by Shor's algorithm in polynomial time

As a result, the public key cryptosystems deployed since the 1980s will need to be replaced

- RSA signatures, DSA and ECDSA (FIPS 186-4)
- Diffie-Hellman Key Agreement over finite fields and elliptic curves(NIST SP 800-56A)
- RSA encryption (NIST SP 800-56B)

We have to look for quantum-resistant counterparts for these cryptosystems

Quantum computing also impacted security strength of symmetric key based cryptography algorithms

- Grover's algorithm can find AES key with approximately $\sqrt{2^n}$ operations where n is the key length
- Intuitively, we should double the key length, if 2^{64} quantum operations cost about the same as 2^{64} classical operations

Quantum Impact to NIST Standards

Post-Quantum Cryptography

- **Crypto standards**
  - **Public key based**
    - Signature (FIPS 186)
    - Key establishment (800-56A/B/C)
  - **Tools**
    - RNG (800-90A/B/C)
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  - **Symmetric key based**
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NIST Team has been in action

2012 – NIST begin PQC project

- Research and build NIST team

April 2015 – 1st NIST PQC workshop

Feb 2016 – NIST Report on PQC (NISTIR 8105)

Feb 2016 – NIST preliminary announcement of standardization plan

Aug 2016 – Draft submission requirements and evaluation criteria released for public comments

Sep 2016 – Comment period ends

Dec 2016 – Announcement of finalized requirements and criteria(Federal Register Notice)

Nov. 30, 2017 – Submission deadline, received 82 submissions

Dec. 24, 2017 – Announced the first round 69 algorithms, as “complete and proper”

PQC Families - Actively Researched as Examples

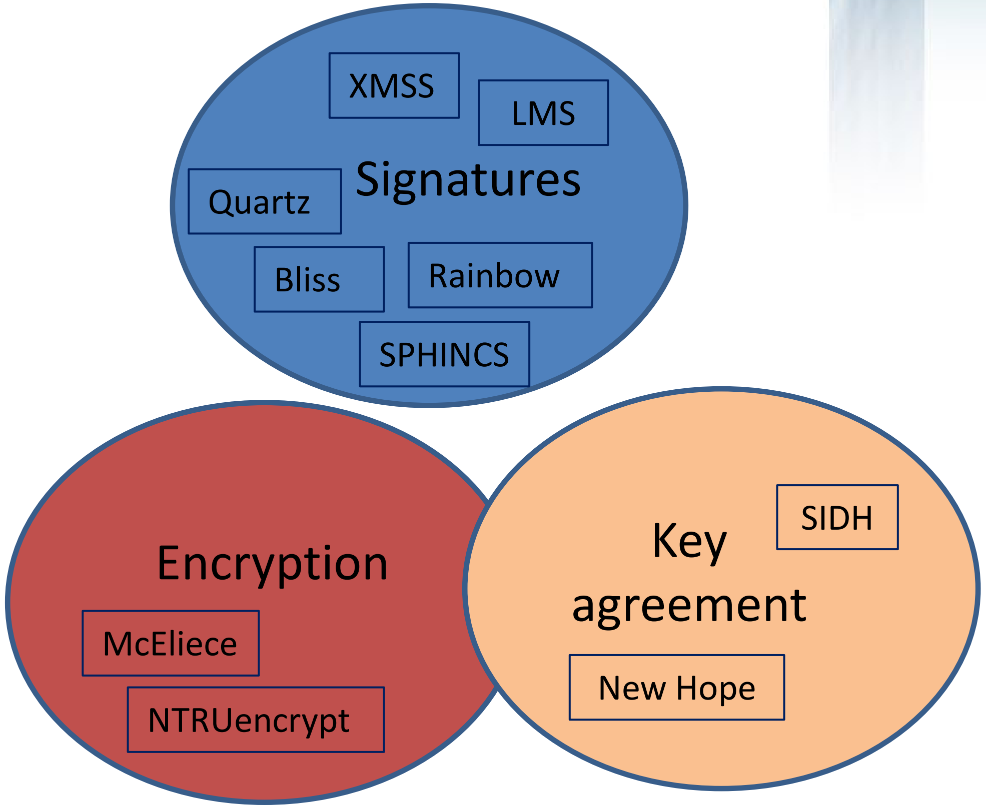
Lattice-based
- NTRUencrypt
- Signature, e.g. Bliss
- (Ring-based) Learning with Errors (e.g. Key Agreement - New Hope)

Code-based
- McEliece encryption and the variants

Multivariate
- Rainbow (signature), Quartz (signature), etc.

Hash-based signatures
- LMS, XMSS, SPHINCS

Isogeny-based schemes
- Supersingular isogeny Diffie–Hellman key exchange (SIDH)



NIST Timeline

NIST will hold the first PQC Standardization Workshop in April 12-13, 2018

Initial analysis phase 12-18 months

Narrow the pool and hold the second workshop in late 2019

Second analysis phase 12-18 month

May take third analysis phase if needed

Expect draft standards in 2022-2023

Submissions to NIST Call for Proposals

Upon the submission deadline (Nov. 30, 2017), NIST received 82 submissions from 26 countries and 6 continents

After an initial review, 69 submissions are considered as complete and proper

At the time of this presentation, 3 of them have been confirmed as “broken” and 66 remains as the first round submissions

46 Key Establishment schemes

- 24 lattice-based
- 17 code-based
- 5 other (2 multi-variate, 1 RSA, 1 random walk, 1 isogeny-based)

20 Signature schemes

- 7 multi-variate
- 5 lattice
- 3 code-based
- 3 hash-based (or symmetric based)
- 2 other (1 RSA, 1 braids)

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Tough Jobs Ahead

Secure analysis against both classical and quantum attacks

Secure against side-channel attacks

Performance evaluation, including

- Computational efficiency
- Key size, signature size, ciphertext expansion
- Handling decryption failure, auxiliary functions, padding, etc.

Drop-in exercise to existing applications, check whether an algorithm can drop in

- a protocol like Internet Key Exchange (IKE) and Transport Layer Security (TLS)
- an application like software authentication (code signing)
- etc.

Join Us for PQC Standardization

For NIST PQC project, please follow us at
https://csrc.nist.gov/Projects/Post-Quantum-Cryptography

Join discussion mailing list pqc-forum@nist.gov