THE FIRST NIST PQC STANDARDS

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U.S. Department of Commerce

NIST CRYPTOGRAPHIC STANDARDS

- NIST DEVELOPED THE FIRST ENCRYPTION STANDARDS IN 1970S
  - DATA ENCRYPTION STANDARD (DES), PUBLISHED 1977 AS FEDERAL INFORMATION PROCESSING STANDARD (FIPS) 46

Nearly all commercial laptops, cellphones, Internet routes, VPN servers, and ATMs use NIST Cryptography

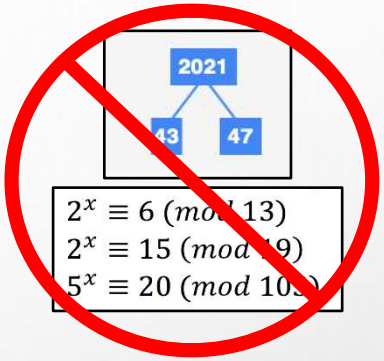
- OVER 40 YEARS, NIST CONTINUES TO EVOLVE ITS CRYPTOGRAPHIC STANDARDS
  - ENABLE TO RESPOND THE GROWING APPLICATION DEMAND
  - ENHANCE SECURITY STRENGTH TO AGAINST MORE SOPHISTICATED ATTACKS

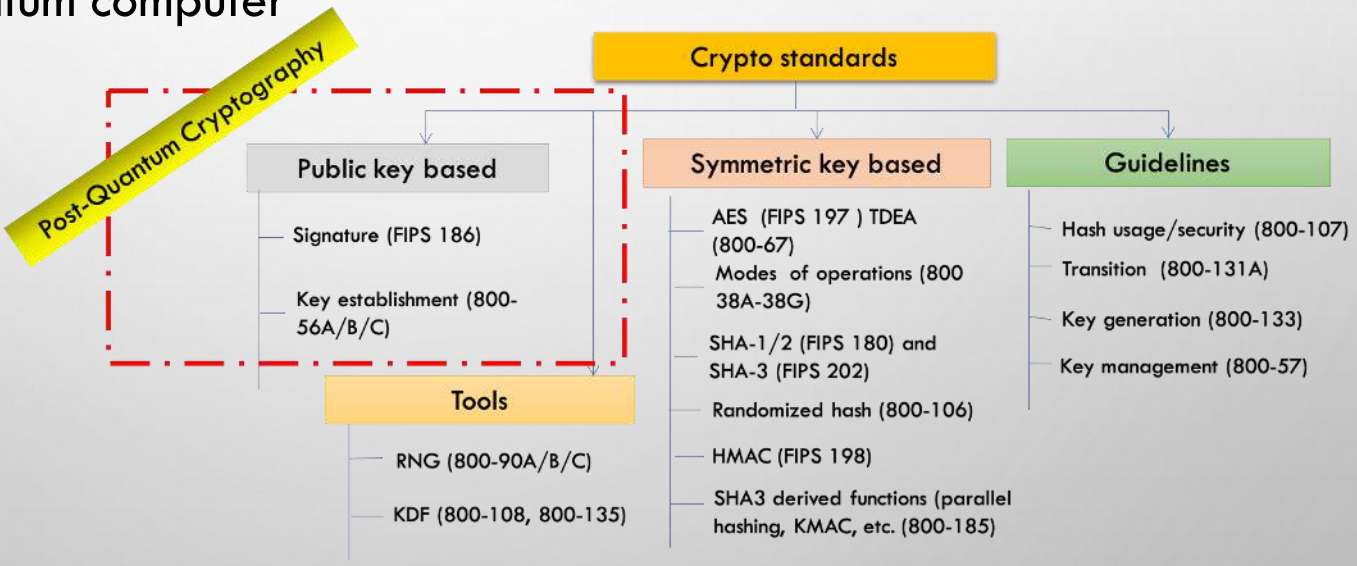
THE QUANTUM THREAT

- NIST public-key crypto standards
  - **SP 800-56A**: Diffie-Hellman, ECDH
  - **SP 800-56B**: RSA encryption
  - **FIPS 186**: RSA, DSA, and ECDSA signatures

all vulnerable to attacks from

a (large-scale) quantum computer





- Symmetric-key crypto (AES, SHA) would also be affected (by Grover's algorithm), but less dramatically

HOW SOON DO WE NEED TO WORRY?

HOW SOON SHOULD WE WORRY?

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

THE DIRECTOR

November 18, 2022

M-23-02

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Shalanda D. Young
Director

SUBJECT: Migrating to Post-Quantum Cryptography

This memorandum provides direction for agencies to comply with
Memorandum 10 (NSM-10), *on Promoting United States Leadership in Q*
While Mitigating Risk to Vulnerable Cryptographic Systems (May 4, 2022

One Hundred Seventeenth Congress
of the
United States of America

AT THE SECOND SESSION
Begun and held at the City of Washington on Monday, the third day of January, two thousand and twenty-two

An Act

Administration

BRIEFING ROOM

National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems

MAY 04, 2022 • STATEMENTS AND RELEASES

NATIONAL SECURITY MEMORANDUM/NSM-10

”The United States must prioritize the transition of cryptographic systems to *quantum-resistant cryptography*, with the goal of mitigating as much of the quantum risk as is feasible by 2035.”

THE OMB 'MIGRATING TO PQC' MEMO

- PRIORITIZE INVENTORY OF CRYPTOGRAPHIC SYSTEMS
  - FOCUS ON HIGH VALUE ASSETS AND HIGH IMPACT SYSTEMS
  - ANNUALLY SUBMIT RESULTS TO ONCD AND CISA UNTIL 2035
    - ONCD/CISA WILL RELEASE TOOLS AND PROCEDURES FOR INVENTORY
  - MORE SPECIFICS PROVIDED…..
- ANNUAL ASSESSMENT OF FUNDING REQUIRED FOR MIGRATION
- AGENCIES SHOULD HAVE ALREADY DESIGNATED A MIGRATION LEAD
  - OMB WILL COORDINATE GOVERNMENT-WIDE RESPONSE
- TESTING PRE-STANDARDIZED PQC ALGORITHMS ENCOURAGED
- NIST WILL CREATE A WORKING GROUP TO DEVELOP BEST PRACTICES

"THE UNITED STATES MUST PRIORITIZE THE TRANSITION OF CRYPTOGRAPHIC SYSTEMS TO *QUANTUM-RESISTANT CRYPTOGRAPHY*, WITH THE GOAL OF MITIGATING AS MUCH OF THE QUANTUM RISK AS IS FEASIBLE BY 2035."

CNSA - COMMERCIAL NATIONAL SECURITY ALGORITHM SUITE 2.0

- IN SEPT 2022, NSA ANNOUNCED CNSA 2.0 ADVISORY TO PREPARE NATIONAL SECURITY SYSTEMS FOR THE TRANSITION TO PQC

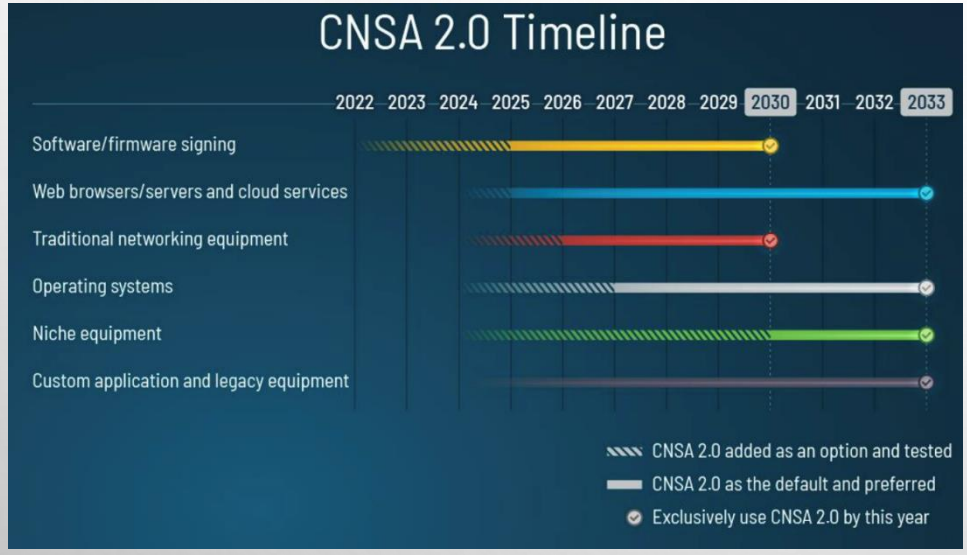


Table IV: CNSA 2.0 algorithms

Algorithm	Function	Specification	Parameters
Advanced Encryption Standard (AES)	Symmetric block cipher for information protection	FIPS PUB 197	Use 256-bit keys for all classification levels.
CRYSTALS-Kyber	Asymmetric algorithm for key establishment	TBD	Use Level V parameters for all classification levels.
CRYSTALS-Dilithium	Asymmetric algorithm for digital signatures	TBD	Use Level V parameters for all classification levels.
Secure Hash Algorithm (SHA)	Algorithm for computing a condensed representation of information	FIPS PUB 180-4	Use SHA-384 or SHA-512 for all classification levels.
Leighton-Micali Signature (LMS)	Asymmetric algorithm for digitally signing firmware and software	NIST SP 800-208	All parameters approved for all classification levels. SHA256/192 recommended.
Xtended Merkle Signature Scheme (XMSS)	Asymmetric algorithm for digitally signing firmware and software	NIST SP 800-208	All parameters approved for all classification levels.

- NSA EXPECTS THE TRANSITION TO QR ALGORITHMS FOR NSS TO BE COMPLETE BY 2035 IN LINE WITH NSM-10.

THE NIST PQC "COMPETITION"

- IN 2016, NIST CALLED FOR QUANTUM-RESISTANT CRYPTOGRAPHIC ALGORITHMS FOR NEW PUBLIC-KEY CRYPTO STANDARDS
  - DIGITAL SIGNATURES
  - ENCRYPTION/KEY-ESTABLISHMENT
- OUR ROLE: MANAGING A PROCESS OF ACHIEVING COMMUNITY CONSENSUS IN A **TRANSPARENT** AND TIMELY MANNER
- DIFFERENT AND MORE COMPLICATED THAN PAST AES/SHA-3 COMPETITIONS
- THERE WOULD NOT BE A SINGLE "WINNER"
  - IDEALLY, SEVERAL ALGORITHMS WILL EMERGE AS 'GOOD CHOICES'

SELECTION CRITERIA

1. **SECURE** AGAINST BOTH CLASSICAL AND QUANTUM ATTACKS

Level	Security Description
I	At least as hard to break as AES128 (exhaustive key search)
II	At least as hard to break as SHA256 (collision search)
III	At least as hard to break as AES192 (exhaustive key search)
IV	At least as hard to break as SHA384 (collision search)
V	At least as hard to break as AES256 (exhaustive key search)

2. **PERFORMANCE** - MEASURED ON VARIOUS "CLASSICAL" PLATFORMS

3. **OTHER PROPERTIES**
   - DROP-IN REPLACEMENTS - COMPATIBILITY WITH EXISTING PROTOCOLS AND NETWORKS
   - PERFECT FORWARD SECRECY
   - RESISTANCE TO SIDE-CHANNEL ATTACKS
   - SIMPLICITY AND FLEXIBILITY
   - MISUSE RESISTANCE, ETC…

THE FIRST THREE ROUNDS

ROUND 1 (DEC '17 – JAN '18)

- 69 CANDIDATES AND 278 DISTINCT SUBMITTERS
- SUBMITTERS FROM >25 COUNTRIES, ALL 6 CONTINENTS
- APR 2018, 1ST NIST PQC CONFERENCE
- ALMOST 25 SCHEMES BROKEN/ATTACKED
- NISTIR 8240, NIST REPORT ON THE 1ST ROUND

	Signatures	KEM/Encryption	Overall
Lattice-based	5	21	26
Code-based	2	17	19
Multi-variate	7	2	9
Symmetric based	3		3
Other	2	5	7
Total	**19**	**45**	**64**

ROUND 2 (JAN '18 – JUL '20)

- 26 CANDIDATES
- AUG 2019 – 2ND NIST PQC CONFERENCE
- 7 SCHEMES BROKEN/ATTACKED
- NISTIR 8309, NIST REPORT ON THE 2ND ROUND

	Signatures	KEMs/Encryption	Total
Lattice-based	3	9	12
Code-based	0	7	7
Multi-variate	4	0	4
Symmetric-based	2		2
Other	0	1	1
Total	**9**	**17**	**26**

ROUND 3 (JUL '20 – JUL '22)

- 7 FINALISTS AND 8 ALTERNATES
- JUNE 2021 – 3RD NIST PQC CONFERENCE
- NISTIR 8413, NIST REPORT ON THE 3RD ROUND

	Signatures	KEMs/Encryption	Total
Lattice-based	2	5	7
Code-based	0	3	3
Multi-variate	2	0	2
Symmetric-based	2	0	2
Other	0	1	1
Total	**6**	**9**	**15**

ROUND 3 RESULTS

3rd round selection (KEM)	3rd round selection (Signatures)
CRYSTALS-Kyber	**CRYSTALS-Dilithium, Falcon, SPHINCS+**

See NISTIR 8413, *Status Report on the 3rd Round of the NIST PQC Standardization Process*, for the rationale on the selections

4th round candidates (all KEMs) evaluated for 18-24 months

- ClassicMcEliece
- BIKE
- HQC
- ~~SIKE~~

On-ramp signatures

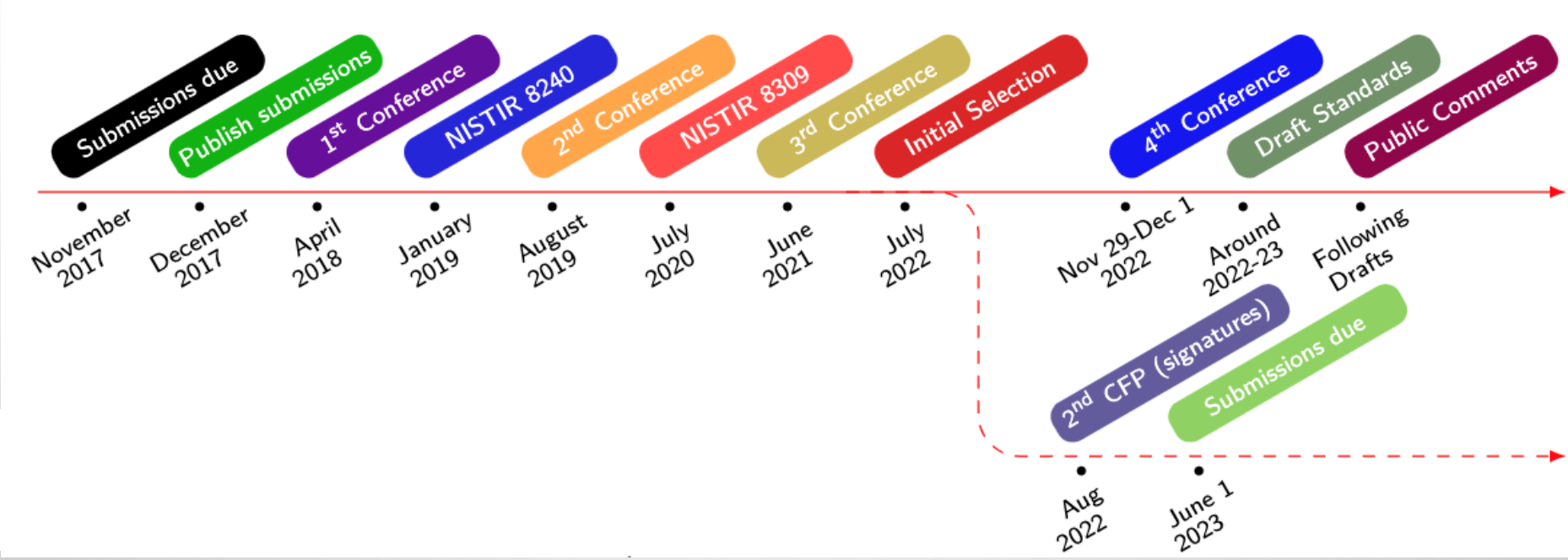
- NIST issued a new call for additional signatures – preferably for signatures based on non-lattice problems

THE SELECTED ALGORITHMS

- CRYSTALS-KYBER
  - KEM BASED ON STRUCTURED LATTICES
  - GOOD ALL-AROUND PERFORMANCE AND SECURITY

- CRYSTALS-DILITHIUM
  - DIGITAL SIGNATURE BASED ON STRUCTURED LATTICES
  - GOOD ALL-AROUND PERFORMANCE AND SECURITY, RELATIVELY SIMPLE IMPLEMENTATION
  - NIST RECOMMENDS IT BE THE PRIMARY SIGNATURE ALGORITHM USED
- FALCON
  - DIGITAL SIGNATURE BASED ON STRUCTURED LATTICES
  - SMALLER BANDWIDTH, BUT MUCH MORE COMPLICATED IMPLEMENTATION
  - THE FALCON STANDARD WILL COME OUT AFTER THE OTHERS
- SPHINCS+
  - DIGITAL SIGNATURE BASED ON STATELESS HASH-BASED CRYPTOGRAPHY
  - SOLID SECURITY, BUT PERFORMANCE NOT AS GOOD IN COMPARISON TO DILITHIUM/FALCON

TIMELINE



- The 5th NIST PQC Standardization Conference
  - April 10-12, 2024 in Rockville, Maryland
- Draft standards for public comment released Aug 2023
  - Deadline for comments: November 22, 2023
- **The first PQC standards should be published in 2024**

STANDARDIZATION

- THE 1ST PQC STANDARDS
  - FIPS 203: ML-KEM (KYBER)
  - FIPS 204: ML-DSA (DILITHIUM)
  - FIPS 205: SLH-DSA (SPHINCS+)
  - FN-DSA (FALCON) – UNDER DEVELOPMENT
- WILL HAVE OTHER DOCS WITH MORE GUIDANCE/DETAILS

- SOME CHOICES MADE
  - WHICH PARAMETER SETS, WHICH HASH FUNCTIONS, OTHER SYMMETRIC PRIMITIVES, ETC

- PLEASE PROVIDE FEEDBACK
  - PQC-FORUM, EMAIL ETC

THE KEMS IN THE 4TH ROUND

- Classic McEliece
  - NIST is confident in the security
  - Smallest ciphertexts, but largest public keys
  - We'd like feedback on specific use cases for Classic McEliece
- BIKE
  - Most competitive performance of 4th round candidates
  - We encourage vetting of IND-CCA security
- HQC
  - Offers strong security assurances and mature decryption failure rate analysis
  - Larger public keys and ciphertext sizes than BIKE
- SIKE
  - The SIKE team acknowledges that SIKE (and SIDH) are insecure and should not be used

AN ON-RAMP FOR SIGNATURES

- Scope:
  - NIST is primarily interested in additional general-purpose signature schemes that are not based on structured lattices.
  - NIST may also be interested in signature schemes that have short signatures and fast verification.
  - Any lattice signature would need to significantly outperform CRYSTALS-Dilithium and FALCON and/or ensure substantial additional security properties.

- The more mature the scheme, the better.
- NIST will decide which (if any) of the received schemes to focus attention on

No on-ramp for KEMs currently planned.

THE ONRAMP NUMBERS

- 50 submissions received by the final deadline
  - There were 23 signatures (and 59 KEMs) submitted in 2017
  - 262 distinct submitters

- 40 submissions accepted as 'complete and proper'
  - From 5 continents and 28 countries

- For complete specs (including code):

  see www.nist.gov/pqcrypto

Type	Number
Lattice	7
Code-based	6
Multivariate	11
MPC in the head	6
Symmetric	4
Isogeny	1
Other	5
Total	40

STATEFUL HASH BASED SIGNATURES FOR EARLY ADOPTION

Stateful hash-based signatures were proposed in 1970s

- Rely on assumptions on hash functions, that is, not on number theory complexity assumptions
- It is essentially limited-time signatures, which require state management

NIST specification on stateful hash-based signatures

- NIST SP 800-208 "*Recommendation for Stateful Hash-Based Signature Schemes*"

Internet Engineering Task Force (IETF) has released two RFCs on hash-based signatures

- RFC 8391 "XMSS: eXtended Merkle Signature Scheme" (By Internet Research Task Force (IRTF))
- RFC 8554 "Leighton-Micali Hash-Based Signatures" (By Internet Research Task Force (IRTF))

ISO/IEC JTC 1 SC27 WG2 Project on hash-based signatures

- Stateful hash-based signatures will be specified in ISO/IEC 14888 Part 4
- It is in the 1st Working Draft stage

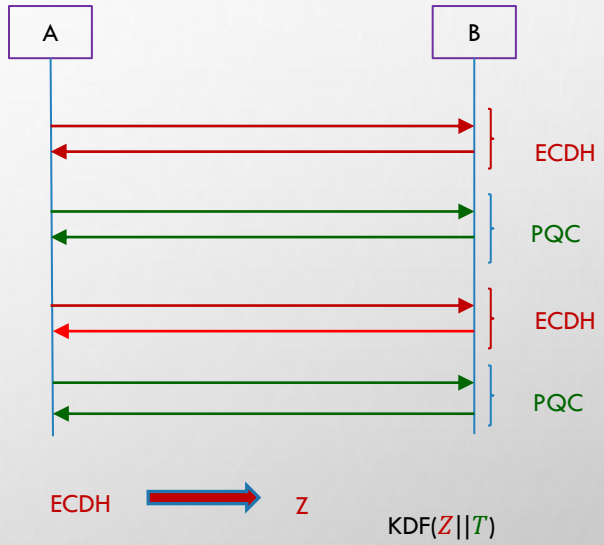
Stateful hash-based signatures from SP 800-208 are allowed for signing software/firmware updates in CNSA 2.0

OTHER STANDARDS ORGANIZATIONS

- WE ARE AWARE THAT MANY STANDARDS ORGANIZATIONS AND EXPERT GROUPS ARE WORKING ON PQC
  - ASC X9 HAS DONE STUDIES AND WRITTEN WHITE PAPERS
  - IEEE P1363.3 HAS STANDARDIZED SOME LATTICE-BASED SCHEMES
  - IETF HAS STANDARDIZED STATEFUL HASH-BASED SIGNATURES LMS/XMSS AND IS CURRENTLY DOING NEW WORK GEARED TO THE PQC MIGRATION
  - ETSI HAS RELEASED QUANTUM-SAFE CRYPTOGRAPHY REPORTS
  - EU EXPERT GROUPS PQCRYPTO AND SAFECRYPTO MADE RECOMMENDATIONS AND RELEASED REPORTS
  - ISO/IEC JTC 1 SC27 WG2 IS DEVELOPING A STANDARD TO SPECIFY PQC ALGORITHMS AS AN AMENDMENT TO ISO/IEC 18033-2
- NIST IS INTERACTING AND COLLABORATING WITH THESE ORGANIZATIONS AND GROUPS
- SOME COUNTRIES HAVE BEGUN STANDARDIZATION ACTIVITIES

TRANSITION AND MIGRATION

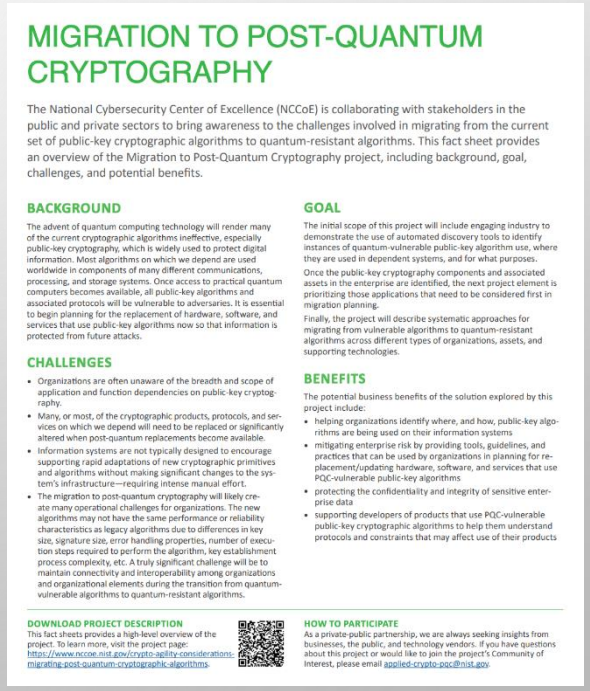
- THERE HAS BEEN MUCH DISCUSSION ON HYBRID/COMPOSITE MODES
  - NIST SP800-56C REV. 2 ALLOWS FOR A CERTAIN HYBRID MODE
  - WE WILL WORK WITH THE COMMUNITY IN DIFFERENT STAGES OF MIGRATION TO ASSURE SECURITY
- NIST WILL PROVIDE TRANSITION GUIDELINES TO PQC STANDARDS
  - NIST HAS PROVIDED SUCH GUIDANCE BEFORE
    - EXAMPLES: TRIPLE DES, SHA-1, KEYS < 112 BITS
  - TIMEFRAME WILL BE BASED ON RISK ASSESSMENT OF QUANTUM ATTACKS



THE NCCOE MIGRATION TO PQC PROJECT

- COMPLEMENT STANDARDIZATION AND TACKLE CHALLENGES WITH ADOPTION, IMPLEMENTATION AND DEPLOYMENT TO PQC
    - COORDINATE WITH SDO'S AND INDUSTRY COLLABORATORS
- PRODUCT DELIVERABLES
    - PRACTICE GUIDES, PLAYBOOKS, REFERENCE ARCHITECTURES, AUTOMATED TOOLS, PROOF OF CONCEPT CODE, ETC
    - DRAFT SP 1800-38 VOLUME A
- OUTREACH AND ENGAGEMENT
    - COMMUNITY OF INTEREST, WEBINARS, PUBLIC EVENTS
    - IN PERSON MEETING – AUG 15 AT NCCOE
    - APPLIED-CRYPTO-PQC@NIST.GOV

NCCoE NATIONAL CYBERSECURITY CENTER OF EXCELLENCE



MIGRATION TO POST-QUANTUM CRYPTOGRAPHY

The National Cybersecurity Center of Excellence (NCCoE) is collaborating with stakeholders in the public and private sectors to bring awareness to the challenges involved in migrating from the current set of public-key cryptographic algorithms to quantum-resistant algorithms. This fact sheet provides an overview of the Migration to Post-Quantum Cryptography project, including background, goal, challenges, and potential benefits.

BACKGROUND

The advent of quantum computing technology will render many of the current cryptographic algorithms ineffective, especially public-key cryptography, which is widely used to protect digital information. Most algorithms on which we depend are used worldwide in components of many different communications, processing, and storage systems. Once access to practical quantum computers becomes available, all public-key algorithms and associated protocols will be vulnerable to adversaries. It is essential to begin planning for the replacement of hardware, software, and services that use public-key algorithms now so that information is protected from future attacks.

CHALLENGES

- Organizations are often unaware of the breadth and scope of application and function dependencies on public-key cryptography.
- Many, or most, of the cryptographic products, protocols, and services on which we depend will need to be replaced or significantly altered when post-quantum replacements become available.
- Information systems are not typically designed to encourage supporting rapid adaptations of new cryptographic primitives and algorithms without making significant changes to the system's infrastructure—requiring intense manual effort.
- The migration to post-quantum cryptography will likely create many operational challenges for organizations. The new algorithms may not have the same performance or reliability characteristics as legacy algorithms due to differences in key size, signature size, error handling properties, number of execution steps required to perform the algorithm, key establishment process complexity, etc. A truly significant challenge will be to maintain connectivity and interoperability among organizations and organizational elements during the transition from quantum-vulnerable algorithms to quantum-resistant algorithms.

GOAL

The initial scope of this project will include engaging industry to demonstrate the use of automated discovery tools to identify instances of quantum-vulnerable public-key algorithm use, where they are used in dependent systems, and for what purposes.

Once the public-key cryptography components and associated assets in the enterprise are identified, the next project element is prioritizing those applications that need to be considered first in migration planning.

Finally, the project will describe systematic approaches for migrating from vulnerable algorithms to quantum-resistant algorithms across different types of organizations, assets, and supporting technologies.

BENEFITS

The potential business benefits of the solution explored by this project include:

- helping organizations identify where, and how, public-key algorithms are being used on their information systems
- mitigating enterprise risk by providing tools, guidelines, and practices that can be used by organizations in planning for replacement/updating hardware, software, and services that use PQC-vulnerable public-key algorithms
- protecting the confidentiality and integrity of sensitive enterprise data
- supporting developers of products that use PQC-vulnerable public-key cryptographic algorithms to help them understand protocols and constraints that may affect use of their products

DOWNLOAD PROJECT DESCRIPTION

This fact sheets provides a high-level overview of the project. To learn more, visit the project page: https://www.nccoe.nist.gov/crypto-agility-considerations-migrating-post-quantum-cryptographic-algorithms.

HOW TO PARTICIPATE

As a private-public partnership, we are always seeking insights from businesses, the public, and technology vendors. If you have questions about this project or would like to join the project's Community of Interest, please email applied-crypto-pqc@nist.gov.

MIGRATION TO POST QUANTUM CRYPTOGRAPHY

Consortium Members

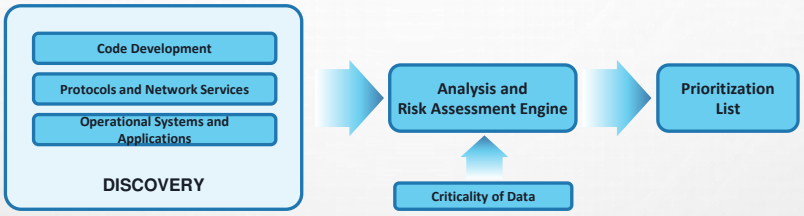
These companies are working together to develop actionable guidance for PQC migration:

Amazon Web Services, Inc. (AWS)
Cisco Systems, Inc.
Crypto4A Technologies, Inc.
CryptoNext Security
Dell Technologies
DigiCert
Entrust Corporation
IBM
Infosec Global
ISARA Corporation
JPMorgan Chase Bank, N.A.
Microsoft
Samsung SDS Co., Ltd.
SandboxAQ
Thales DIS CPL USA, Inc.
Thales Trusted Cyber Technologies
Vmware, Inc.
wolfSSL

Working to ease the migration from the current set of public-key cryptographic algorithms to quantum-resistant algorithms.

DISCOVERY WORKSTREAM

Bringing together discovery tools to detect and report the presence and use of quantum vulnerable cryptography with enough detail and context to inform risk analysis and remediation.



INTEROPERABILITY WORKSTREAM

Identifying the challenging problems and bottlenecks that one will face when implementing the first algorithms NIST will standardize as a result of the PQC Standardization Process.

PERFORMANCE WORKSTREAM

Measuring the performance of classical, PQC, and PQ-hybrid use cases across multiple protocols and test conditions.

PROJECT GOALS

- Align and complement the NIST PQC standardization activities.
- Develop practices to ease the migration from the current set of public-key cryptographic algorithms to replacement algorithms that are resistant to cryptanalytically relevant quantum computer (CRQC) attacks.
- Deliver white papers, playbooks, and demonstrable implementations for organizations that provide cryptographic standards and protocols and enterprises that develop, acquire, implement, and service cryptographic products.

Visit the project page:

Email the team: applied-crypto-pqc@nist.gov

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WHAT CAN ORGANIZATIONS DO NOW?

- (FOLLOW GUIDANCE IN THE OMB MEMO)
- NEW CISA/NSA/NIST FACTSHEET: *QUANTUM READINESS – MIGRATION TO POST-QUANTUM CRYPTOGRAPHY*
  - CRYPTOGRAPHIC INVENTORY
  - DISCUSS POST-QUANTUM ROADMAP W/ TECHNOLOGY VENDORS
  - SUPPLY CHAIN QUANTUM-READINESS
- DEVELOP A KNOWLEDGE BASE AND TRACK DEVELOPMENTS IN THE FIELD
  - TESTING THE ALGORITHMS ENCOURAGED
- ESTABLISH A ROADMAP TO QUANTUM READINESS FOR YOUR ORGANIZATION
- ACT NOW – IT WILL BE LESS EXPENSIVE, LESS DISRUPTIVE, AND LESS LIKELY TO HAVE MISTAKES CAUSED BY RUSHING AND SCRAMBLING

QUANTUM-READINESS: MIGRATION TO POST-QUANTUM CRYPTOGRAPHY

TLP:CLEAR

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

BACKGROUND

The Cybersecurity and Infrastructure Security Agency (CISA), the National Security Agency (NSA), and the National Institute of Standards and Technology (NIST) created this factsheet to inform organizations – especially those that support Critical Infrastructure – about the impacts of quantum capabilities, and to encourage the early planning for migration to post-quantum cryptographic standards by developing a Quantum-Readiness Roadmap. NIST is working to publish the first set of post-quantum cryptographic (PQC) standards, to be released in 2024, to protect against future, potentially adversarial, cryptanalytically-relevant quantum computer (CRQC) capabilities. A CRQC would have the potential to break public-key systems (sometimes referred to as asymmetric cryptography) that are used to protect information systems today.

WHY PREPARE NOW?

A successful post-quantum cryptography migration will take time to plan and conduct. CISA, NSA, and NIST urge organizations to begin preparing now by creating quantum-readiness roadmaps, conducting inventories, applying risk assessments and analysis, and engaging vendors. Early planning is necessary as cyber threat actors could be targeting data today that would still require protection in the future (or in other words, has a long secrecy lifetime), using a catch now, break later or harvest now, decrypt later operation. Many of the cryptographic products, protocols, and services used today that rely on public key algorithms (e.g., Rivest-Shamir-Adleman [RSA], Elliptic Curve Diffie-Hellman [ECDH], and Elliptic Curve Digital Signature Algorithm [ECDSA]) will need to be updated, replaced, or significantly altered to employ quantum-resistant PQC algorithms, to protect against this future threat. Organizations are encouraged to proactively prepare for future migration to products implementing the post-quantum cryptographic standards. This includes engaging with vendors around their quantum-readiness roadmap and actively implementing thoughtful, deliberate measures within their organizations to reduce the risks posed by a CRQC.

ESTABLISH A QUANTUM-READINESS ROADMAP

While the PQC standards are currently in development, the authoring agencies encourage organizations to create a quantum-readiness roadmap by first establishing a project management team to plan and scope the organization's migration to PQC. Quantum-readiness project teams should initiate proactive cryptographic discovery activities that identify the organization's current reliance on quantum-vulnerable cryptography. Systems and assets with quantum-vulnerable cryptography include those involved in creating and validating digital signatures, which also incorporates software and firmware updates. Having an inventory of quantum-vulnerable systems and assets enables an organization to begin the quantum risk assessment processes, demonstrating the prioritization of migration. Lead by an organization's Information Technology (IT) and Operational Technology (OT) procurement experts, the inventory should include engagements with supply chain vendors to identify technologies that need to migrate from quantum-vulnerable cryptography to PQC.

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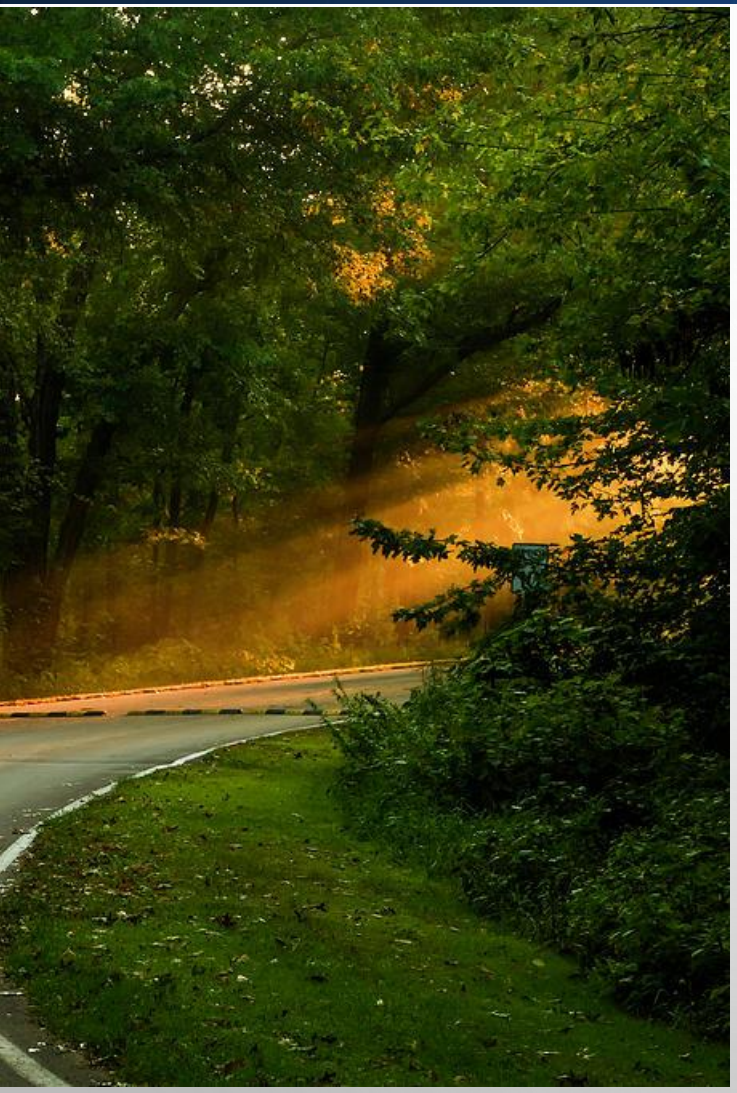
CONCLUSION



- THE BEGINNING OF THE END IS HERE!
- OR IS IT THE END OF THE BEGINNING?

- NIST IS GRATEFUL FOR EVERYBODY'S EFFORTS

- CHECK OUT WWW.NIST.GOV/PQCRYPTO
  - SIGN UP FOR THE PQC-FORUM FOR ANNOUNCEMENTS & DISCUSSION
  - SEND E-MAIL TO PQC-COMMENTS@NIST.GOV