NIST First Call for Multi-Party Threshold Schemes

Notes presented* at the TPMPC 2023 Workshop:

Theory and **P**ractice of **M**ulti-**P**arty **C**omputation

June 09, 2023 | Aarhus (Denmark)

Suggested reading: NISTIR 8214C ipd

NIST First Call for Multi-Party Threshold Schemes

(Initial Public Draft) [2023-Jan-25]

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Expressed opinions are from the speaker and should not be construed as official NIST views. Joint work with René Peralta.

Outline

NIST = National Institute of Standards and Technology.

NIST: Laboratories → Divisions → Groups

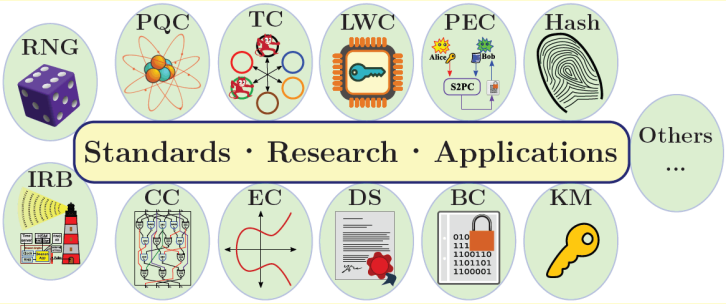
- **Non-regulatory** federal agency (@ U.S. Dept. Commerce)
- **Mission:** ... innovation ... industrial competitiveness ... measurement science, standards, and technology ... economic security ... quality of life.

NIST name and address plate (source: nist.gov)

INFORMATION TECHNOLOGY LABORATORY → **Computer Security Division (CSD):**

→ **Cryptographic Technology Group (CTG):** *research, develop, engineer, and produce guidelines, recommendations and best practices for cryptographic algorithms, methods, and protocols.*

Activities in the "Crypto" Group



- Public documentation: FIPS; Special Publications (SP 800); NIST Reports (IR).
- International cooperation: government, industry, academia, standardization bodies.

Legend: **BC** = **B**lock **C**iphers. **CC** = **C**ircuit **C**omplexity. **Crypto** = **Crypto**graphy. **DS** = **D**igital **S**ignatures. **EC** = **E**lliptic **C**urves. **FIPS** = **F**ederal **I**nformation **P**rocessing **S**tandards. **IR** = **I**nternal or **I**nteragency (denoting that the public NIST report was developed internally at NIST or in an interagency collaboration, respectively. **IRB** = **I**nteroperable **R**andomness **B**eacons. **KM** = **K**ey **M**anagement. **LWC** = **L**ightweight **C**rypto. **PEC** = **P**rivacy-**E**nhancing **C**rypto. **PQC** = **P**ost-**Q**uantum **C**rypto. **RNG** = **R**andom-**N**umber **G**eneration. **SP 800** = **S**pecial **P**ublications in Computer Security. **TC** = [Multi-Party] **T**hreshold **C**rypto).

More details at https://www.nist.gov/itl/csd/cryptographic-technology

Intro: NIST has various Crypto Projects

- **PQC:** [standardization] "**post-quantum**" signatures and key-encapsulation
- **LWC:** [standardization] "**lightweight**" **A**uth. **E**nc. w/ **A**ssoc. **D**ata, and hashing
- **PEC:** [exploratory] "**privacy-enhancing**" (advanced) features/functionalities
- **MPTC:** [exploratory] "**multi-party threshold**" schemes for crypto primitives
- **...** (various other projects in the NIST "Crypto group" [CTG])

The "Threshold Call" (from MPTC+PEC): to gather **reference material** for public analysis ... aiming for **recommendations** (in a 1st phase), including about PEC.

Legend: AEAD = **A**uth[enticated] **E**nc[ryption] w[ith] **A**ssoc[iated] **D**ata. **CTG** = **C**ryptographic **T**echnology **G**roup. **LWC** = **L**ightweight **C**ryptography. **MPTC** = **M**ulti-**P**arty **T**hreshold **C**ryptography. **NIST** = **N**ational **I**nstitute of **S**tandards and **T**echnology. **PEC** = **P**rivacy-**E**nhancing **C**ryptography. **PQC** = **P**ost-**Q**uantum **C**ryptography.

On the PEC and MPTC projects

Exploratory work to assess potential for recommendations, and standardization processes.

Main approach: promote development of **reference material**.

PEC: Privacy-Enhancing Cryptography

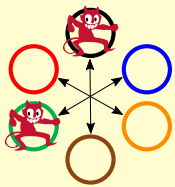
- Crypto (that can be) used to enhance privacy [emphasis on non-standardized tools].

ZKP	MPC	FHE	PSI	GRS	FnE	PIR	StE
Zero- **K**nowledge **P**roofs	(**S**ecure) **M**ulti**p**arty **C**omputation	**F**ully **H**omomorphic **E**ncryption	**P**rivate **S**et **I**ntersection	**G**roup and **R**ing **S**ignatures	**Fn**ctional **E**ncryption (Inc. ABE & IBE)	**P**rivate **I**nformation **R**etrieval	**St**ructured **E**ncryption (Symm./Pub.)

Legend: ABE: attribute-based encryption. IBE: identity-based encryption. Symm./pub.: symmetric-key or public-key based.

MPTC: Multi-Party Threshold Cryptography

- *Threshold Schemes* for diverse Cryptographic Primitives
  1. Split (**secret-share**) the secret/private-key across multiple parties.
  2. Use **MPC** to perform needed operation (with split key), e.g., decrypt.



Outline

1. **NIST Introduction**
2. **The “Threshold” Call**
3. **The Process**

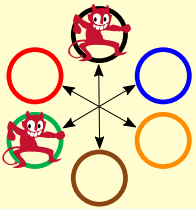
NIST = National Institute of Standards and Technology.

NIST Call for Multi-Party Threshold Schemes

- NISTIR 8214C ipd: initial public **draft** (Jan. 2023).
- Final version (by ≈ Nov. 2023) will specify submission deadline (≈ mid 2024))

Calling for submissions of threshold schemes for diverse primitives:

- **Cat1: Selected NIST-standardized primitives**
  - EdDSA, ECDSA, RSA, AES, ECC-KE, ...
- **Cat2: Primitives not specified by NIST**
  - Interest in **threshold friendliness** and **quantum resistance**
  - Interest in "advanced" primitives from PEC: FHE, IBE, ZKP, ...



AES = Advanced Encryption Standard. EC = Elliptic curve. ECC-KE = EC cryptography (based) key-exchange. EdDSA = Edwards-Curve digital signature algorithm. ECDSA = EC digital signature algorithm. FHE = Fully-homomorphic encryption. IBE = Identity-based encryption. NIST = National Institute of Standards and Technology. PEC = Privacy-enhancing cryptography. RSA = Rivest–Shamir–Adleman. ZKP = Zero-knowledge proof.

Category Cat1 of NIST Call for Multi-Party Threshold Schemes

Too many acronyms, we know. (Legend further below)

Subcategory: Type	Families of specifications	NIST references
C1.1: **Signing**	EdDSA sign, ECDSA sign, RSADSA sign	FIPS 186-5 (see also NISTIR 8214B)
C1.2: **PKE**	RSA decrypt, RSA encrypt (a secret value)	SP 800-56B Rev2
C1.3: **2KA**	EC-CDH, EC-MQV	SP 800-56A Rev3
C1.4: **Symmetric**	AES encipher/decipher, KDM/KC (for 2KE)	FIPS 197, SP 800-56C Rev2, ...
C1.5: **Keygen**	EC keygen, RSA keygen, bitstring keygen	(corresponding references above)

Legend: 2KA: **pair**-wise **k**ey-agreement. **2KE**: **pair**-wise **k**ey-establisment. **AES**: **A**dvanced **E**ncryption **S**tandard. **CDH**: cofactor **D**iffie–**H**ellman. **ECC**: **E**lliptic-**c**urve **c**ryptography (or, if used as an adjective, **EC**-based). **ECDSA**: **E**lliptic-**c**urve **D**igital **S**ignature **A**lgorithm. **EdDSA**: **Ed**wards-curve **D**igital **S**ignature **A**lgorithm. **E**lliptic-curve based **K**ey-**E**stablishment. **FIPS**: **F**ederal **I**nformation **P**rocessing **S**tandard. **KC**: **K**ey-**c**onfirmtion. **KDM**: **K**ey-**d**erivation **m**echanism. **Keygen**: **K**ey-**gen**eration. **MQV**: Menezes-Qu-Vanstone. **PKE**: **p**ublic-**k**ey **e**ncryption. **RSA**: **R**ivest–**S**hamir–**A**dleman (signature and encryption schemes). **RSADSA**: **RSA** digital signature algorithm. **SP 800**: **S**pecial **P**ublication (in Computer Security). **Note:** In the 2nd column, each item within a subcategory is itself called a family of specifications, since it may include diverse primitives or modes/variants.

Category Cat2 of the NIST "Threshold" Call

TF = **t**hreshold **f**riendly. QR = **q**uantum **r**esistant.

Subcategory: Type	Example types of schemes	Example primitives
C2.1: **Signing**	TF succinct & verifiably-deterministic signatures	Sign
|	TF-QR signatures	Sign
C2.2: **PKE**	TF-QR **p**ublic-**k**ey **e**ncryption (PKE)	Decrypt/Encrypt (a secret value)
C2.3: **Key agreem.**	TF Low-round multi-party **k**ey-**a**greement (KA)	Single-party primitives
C2.4: **Symmetric**	TF blockcipher/PRP	Encipher/decipher
|	TF key-derivation / key-confirmation	PRF and hash function
C2.5: **Keygen**	Any of the above	Keygen
C2.6: **Advanced**	TF-QR fully-homomorphic encryption	Decryption; Keygen
|	TF identity-based and attribute-based encryption	Decryption; Keygens
C2.7: **ZKPoK**	**Z**ero-**k**nowledge **p**roof **o**f **k**nowledge of private key	ZKPoK.Generate
C2.8: **Gadgets**	Garbled circuit (GC), broadcast, ...	GC.generate; GC.evaluate, ...

Note: While TF-QR is a desired combination for any type of scheme, some examples show just TF to highlight that it is welcome even if not QR.

Legend: agreem. = **agreem**ent. **Keygen** = **key-gen**eration. **PKE** = **p**ublic-**k**ey **e**ncryption. **PRF** = **p**seudorandom **f**unction [family]. **PRP** = **p**seudorandom **p**ermutation [family]. **QR** = **q**uantum **r**esistant. **TF** = **t**hreshold-**f**riendly. **ZKPoK** = **z**ero **k**nowledge **p**roof **o**f **k**nowledge.

Main components of a submission package

Check	#	Item
☐	M1	Written specification (S1–S16)
☐	M2	Reference implementation (Src1–Src4)
☐	M3	Execution instructions (X1–X7)
☐	M4	Experimental evaluation (Perf1–Perf5)
☐	M5	Additional statements

- (Optional) early public abstract: $\approx$ 3 months after final call.
- (Optional) preliminary submission to check completeness: $\approx$ 45 days before deadline.
- Package-submission: by the submission deadline.

Tentative timeframes (subject to change)

Some technical notes

1. **Submission focuses:** can specify a family of schemes (in various subcategories).
2. **Threshold profile:** open to choice: number of parties; dishonest proportion; ...
3. **Active security:** it is required, though open to diverse security formulations.
4. **Adaptive security:** at least "argued for" for major safety properties,
5. **Modularity:** modularize gadgets; encouraged proactive resharing module; ...
6. **Post-vs-Pre quantum crypto:** both in scope; pre-QC requires justification.
7. **Concrete implementation:** e.g., including communication (e.g., broadcast? P2P?).

Expected revisions in the call

1. In Cat1, add subcategories for the NIST-selected PQC primitives
2. In Cat2, differentiate better some subcategories (e.g., FHE; what can be thresholdized)
3. Clarify scope of “gadgets” subcategory (and how to motivate them)
4. Detail better some logistic requirements (e.g., code licensing)
5. Include LaTeX template for submission

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Tentative timeline

- **2023-Jul: Revised** version of the Call
- **2023-Sep:** Virtual **workshop** for feedback & awareness (TBA, likely Sep 26–28)
- **2023-Nov: Final** version of the call
- $\approx$ **Mid 2024:** Deadline for **submissions**
- **2024/2025: Workshop(s)** for characterization / analysis of submitted schemes
- $\geq$ **2025:** Initial recommendations (and new processes?)

Community participation

Various areas / possible synergies:

- Scope of the call is of interest to various crypto communities: MPC, ZKP, FHE, ...
- Work developed with other SDOs and in community efforts is also welcome.

(SDO = Standards Development Organization)

Some variables:

- How will the community compose teams? (How to avoid effort duplication?)
- How will the scope of the call be covered? (primitives / models / approaches)

Upcoming soon: Threshold Workshop ($\approx$ Sep 26–28) [about revised call ($\approx$ July)]

Welcome/needed interaction

1. **Feedback after the revised call ($\geq$ July):**
   - Suggested improvements to the Call
   - What schemes should be submitted
   - Your possible intention to submit (what?)

2. **Concrete submissions ($\approx$ Mid 2024):**
   – Structured specification, open source implementation, evaluation, ...

3. **Public scrutiny of submitted schemes ($\geq$ 2024/2025):**
   – Evaluation comments (can impact subsequent recommendations)

Concluding remarks

- **Setup:** A gathering of reference material (not a competition for a selection).
- **Expected:** The process will clarify relevant system models, best practices, ...
- **Aim:** Devise recommendations about advanced cryptography (PEC + MPTC)
  (Will support future standardization processes.)
- **Ample room for participation:** Give feedback $\rightarrow$ Submit $\rightarrow$ Analyze
- **It's time:** Consider starting to organize a future submission (team, scope, ...)

Thank you for your attention! Questions?

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Notes presented at the TPMPC 2023 Workshop

June 09, 2023 @ Aarhus (Denmark) — luis.brandao@nist.gov

- **NISTIR 8214C ipd:** https://csrc.nist.gov/publications/detail/nistir/8214c/draft
- **Send comments about the call to:** nistir-8214C-comments@nist.gov
- **MPTC Website:** https://csrc.nist.gov/projects/threshold-cryptography
- **Subscribe to the MPTC-Forum:** https://list.nist.gov/MPTC-forum
- **PEC Website:** https://csrc.nist.gov/projects/pec
- **Subscribe to the PEC-Forum:** https://list.nist.gov/PEC-forum