NIST Call for Multi-Party Threshold Schemes
Brief Notes at ICMC 2023

Presented by Lily Chen[*] at **ICMC 2023**

International Cryptographic Module Conference

September 22nd @ Ottawa, Canada

Expressed opinions are from the speakers/authors and should not be construed as official NIST views.

Slides authored by Luís Brandão[†], based on "*NISTIR 8214C ipd*" (L. Brandão and R. Peralta. January 2023.)

[*] Lily Chen is at NIST. [†] Luís Brandão is at NIST as a Foreign Guest Researcher (non-employee), contractor from Strativia.

Outline

1. NIST Crypto Standardization/Exploratory Projects
2. The "Threshold Call" (at a high level)
3. Subcategories and Submissions

(Slides will be publicly available)

Legend: Crypto = Cryptography. NIST = National Institute of Standards and Technology.

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NIST Crypto Standardization/Exploratory Projects

- **PQC:** [standardization] "**Post-Quantum**" signatures and key-encapsulation
- **LWC:** [standardization] "**LightWeight**" **a**uth. **e**nc. w/ **a**ssoc. **d**ata, and hashing

Legend: **AEAD** = **A**uth[enticated] **E**nc[ryption] w[ith] **A**ssoc[iated] **D**ata. **CTG** = **C**ryptographic **T**echnology **G**roup. **LWC** = **L**ight**w**eight **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.

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- **...** (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.

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Privacy-Enhancing Cryptography (PEC): NIST Project

Cryptography (that can be) used to **enhance privacy**.

(emphasis on non-standardized tools)

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Goals:

1. Accompany the progress of **emerging *PEC 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	**Fun**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. Inc.: including. PEC: privacy-enhancing cryptography. Symm./pub.: symmetric-key or public-key based.

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Cryptography (that can be) used to **enhance privacy**.
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Goals:

1. Accompany the progress of **emerging *PEC tools***.
2. Promote development of PEC **reference material**.

- **PEC tools**
- **STPPA (series of talks)**
- **PEC use-case suite**
- **Threshold schemes**
- **ZKProof collaboration**
- **Encounter metrics**
- **Email list (PEC Forum)**

https://csrc.nist.gov/projects/pec

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1. Accompany the progress of **emerging *PEC tools***.
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3. **Exploratory work** to assess potential for recommendations, standardization; ...

- **PEC tools**
- **STPPA (series of talks)**
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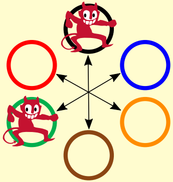
Multi-Party Threshold Cryptography: NIST project

Cryptographic primitives: Signing Encryption KeyGen Hashing etc.

Threshold schemes (for cryptographic primitives):



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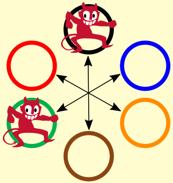

1. Split (**secret-share**) the secret/private-key across multiple parties.
2. Use **MPC** to perform needed operation (with split key), e.g., sign.
   (MPC = secure multiparty computation ... or call it “Threshold Cryptography”)

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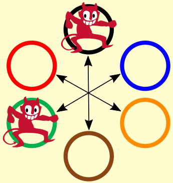

- **"Threshold" (f):** Operation is secure if number of corrupted parties is $\leq f$.
- **Decentralized** trust about key **(not reconstructed)**: avoids single-point of failure.

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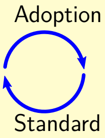

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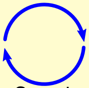
Next section: A public **Call** for reference material ... toward **recommendations**

Adoption



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- NISTIR 8214C: Initial public **draft** (**Jan 2023**) ⇒ Revised version (**late 2023**).
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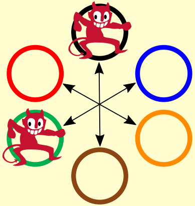

Calling for submissions of threshold schemes

(And gadgets for modular use)

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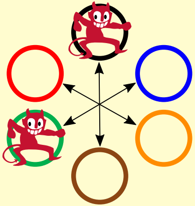

Calling for submissions of threshold schemes for:

- **[Cat1] Selected NIST-standardized primitives**
- **[Cat2] Other primitives (including FHE, IBE/ABE, ZKP)**

  (And gadgets for modular use)

FHE = Fully-homomorphic encryption.
IBE/ABE = Identity/Attribute-based encryption.
ZKP = Zero-knowledge proof.

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Notes about the process

- **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.)

  PEC = Privacy-Enhancing Crypto
  MPTC = Multi-Party Threshold Crypto
- **Ample room for participation:** Give feedback → Submit → Analyze
- **It's time:** Consider starting to organize a future submission (team, scope, ...)

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The call is not aimed at directly selecting a standard, but is part of a longer process toward possible standardization.

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)

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- How will the community compose teams? (How to avoid effort duplication?)
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MPTS 2023: (Sep 26–28) NIST Workshop on **M**ulti-**P**arty **T**hreshold **S**chemes

http://csrc.nist.gov/events/2023/mpts2023

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Category Cat1 of NIST Call for Multi-Party Threshold Schemes

Subcategory: Type
C1.1: **Signing**
C1.2: **PKE**
C1.3: **2KA**
C1.4: **Symmetric**
C1.5: **Keygen**

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)

Legend: **2KA**: pair-wise key-agreement. **2KE**: pair-wise key-establishment. **AES**: Advanced Encryption Standard. **CDH**: cofactor Diffie–Hellman. **ECC**: Elliptic-curve cryptography (or, if used as an adjective, EC-based). **ECDSA**: Elliptic-curve Digital Signature Algorithm. **EdDSA**: Edwards-curve Digital Signature Algorithm. Elliptic-curve based Key-Establishment. **FIPS**: Federal Information Processing Standard. **KC**: Key-confirmtion. **KDM**: Key-derivation mechanism. **Keygen**: Key-generation. **MQV**: Menezes-Qu-Vanstone. **PKE**: public-key encryption. **RSA**: Rivest–Shamir–Adleman (signature and encryption schemes). **RSADSA**: **RSA** digital signature algorithm. **SP 800**: Special Publication (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.

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Subcategory: Type	Families of specifications	NIST references
C1.2: **PKE**	RSA decrypt, RSA encrypt (a secret value)	SP 800-56B Rev2

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Subcategory: Type	Families of specifications	NIST references
C1.4: **Symmetric**	AES encipher/decipher, KDM/KC (for 2KE)	FIPS 197, SP 800-56C Rev2, ...

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C1.2: **PKE**	RSA decrypt, RSA encrypt (a secret value)	SP 800-56B Rev2
C1.3: **2KA**	ECC-CDH, ECC-MQV	SP 800-56A Rev3
C1.4: **Symmetric**	AES encipher/decipher, KDM/KC (for 2KE)	FIPS 197, SP 800-56C Rev2, ...
C1.5: **Keygen**	ECC keygen, RSA keygen, bitstring keygen	(corresponding references above)

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Also to be added to Category Cat1

Primitives from NIST draft standards emerging from the PQC and LWC projects:

- **ML-KEM** (based on KYBER) Draft FIPS 203: ***M**odule-**L**attice-Based KEM Standard*
- **ML-DSA** (based on DILITHIUM) Draft FIPS 204: ***M**odule-**L**attice-Based DSA*
- **SLH-DSA** (based on SPHINCS) Draft FIPS 205: ***S**tate**l**ess **H**ash-Based DSA*
- **FN-DSA** (based on Falcon): Upcoming Draft FIPS
- **AEAD and XOF standards** (based on ASCON): Upcoming Special Publication(s)

Legend: AEAD = **A**uthenticated **E**ncryption with **A**ssociated **D**ata. DSA = **D**igital **S**ignature **A**lgorithm. FIPS = **F**ederal **I**nformation **P**rocessing **S**tandard [Publication]. KEM = **K**ey-**E**ncapsulation **M**echanism. ML = **M**odule **L**attice. SLH = **S**tate**L**ess **h**ash. XOF = e**x**tendable **O**utput **F**unction.

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Category Cat2 of the NIST “Threshold” Call

Subcategory: Type
C2.1: **Signing**
C2.2: **PKE**
C2.3: **Key-agreem.**
C2.4: **Symmetric**
C2.5: **Keygen**

Note: While TF-QR is desired 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**seudo**r**andom **f**unction [family]. **PRP** = **p**seudo**r**andom **p**ermutation [family]. **QR** = **q**uantum **r**esistant. **TF** = **t**hreshold-**f**riendly. **ZKPoK** = **z**ero **k**nowledge **p**roof **o**f **k**nowledge.

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

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Subcategory: Type
C2.6: **Advanced**
C2.7: **ZKPoK**
C2.8: **Gadgets**

Note: While TF-QR is desired 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**seudo**r**andom **f**unction [family]. **PRP** = **p**seudo**r**andom **p**ermutation [family]. **QR** = **q**uantum **r**esistant. **TF** = **t**hreshold-**f**riendly. **ZKPoK** = **z**ero **k**nowledge **p**roof **o**f **k**nowledge.

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**
C2.6: **Advanced**	TF-QR fully-homomorphic encryption	Decryption; Keygen
	TF identity-based and attribute-based encryption	Decryption; Keygens

Note: While TF-QR is desired 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**seudo**r**andom **f**unction [family]. **PRP** = **p**seudo**r**andom **p**ermutation [family]. **QR** = **q**uantum **r**esistant. **TF** = **t**hreshold-**f**riendly. **ZKPoK** = **z**ero **k**nowledge **p**roof **o**f **k**nowledge.

Category Cat2 of the NIST "Threshold" Call

Subcategory: Type	**Example types of schemes**	**Example primitives**
C2.7: **ZKPoK**	**Z**ero-**k**nowledge **p**roof **o**f **k**nowledge of private key	ZKPoK.Generate

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Category Cat2 of the NIST "Threshold" Call

Subcategory: Type	Example types of schemes	Example primitives
C2.8: **Gadgets**	Garbled circuit (GC)	GC.generate; GC.evaluate

Note: While TF-QR is desired 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**seudo**r**andom **f**unction [family]. **PRP** = **p**seudo**r**andom **p**ermutation [family]. **QR** = **q**uantum **r**esistant. **TF** = **t**hreshold-**f**riendly. **ZKPoK** = **z**ero **k**nowledge **p**roof **o**f **k**nowledge.

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 key-agreement	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)	GC.generate; GC.evaluate

Note: While TF-QR is desired 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**seudo**r**andom **f**unction [family]. **PRP** = **p**seudo**r**andom **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

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□	M5	Additional statements

The revised version of the call will detail better each **component**.

A submission package can propose various **objects** (schemes/gadgets).

Each **component** will then map all such **objects**.

Some technical notes

1. **Submission focuses**
2. **Threshold profile**
3. **Active security**
4. **Adaptive security**
5. **Modularity**
6. **Post-vs-Pre quantum crypto**

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:** 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-quantum needs justification.

Concluding remarks

Selected takeaways

- The “Threshold Call” has a **wide scope** of subcategories for submission
- Enables an **exploration** of advanced cryptography, before promising standards
- The initial process will devise **recommendations** for subsequent processes
- Community **participation** is essential (feedback; submissions; analyses)

Thank you for your attention! Questions?

NIST Call for Multi-Party Threshold Schemes Brief Notes at ICMC 2023

Presented at ICMC 2023 | September 22nd @ Ottawa, Canada

We appreociate followup comments: luis.brandao@nist.gov

Threshold Call (Draft)

MPTS 2023 (Sept. 26–28)

MPTC-Forum (email list)

PEC-Forum (email list)