A Threshold Signature Protocol Implementation via JavaCard API

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CHESS

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CROCS
Centre for Research on Cryptography and Security

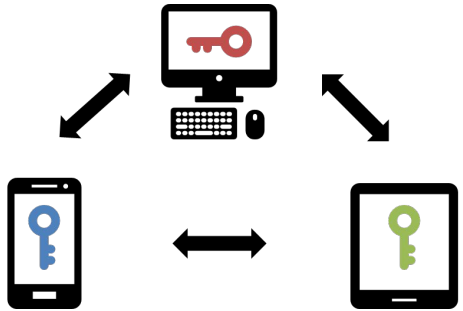
Outline

- Introduction
- Threshold signatures
  - Secure secret sharing
  - Threshold protocols
- Problems in use of threshold signatures
- JCFROST implementation
  - FROST protocol
  - JavaCard smartcards
  - Performance measurements
  - Demonstration
- Conclusion

Threshold signatures

- A concept mainly developed 90’s is now starting to be used in modern applications
  - Cryptocurrencies (multi-signature wallets)
  - Authentication (eIDAS-compliant – SplitKey/SmartID)

Single party computation



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- A concept mainly developed 90's is now starting to be used in modern applications
  - Cryptocurrencies (multi-signature wallets)
  - Authentication (eIDAS-compliant – SplitKey/SmartID)
- A convenient private key protection method
  - Decentralization of storage
  - Elimination of single point of failure
  - Easy integration with existing systems (backward compatibility)

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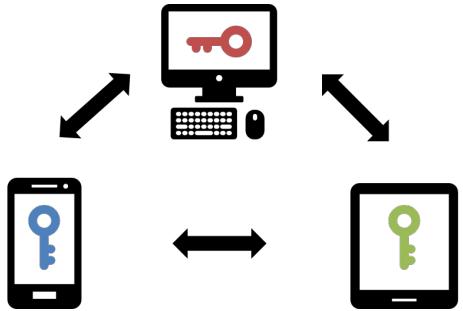

Threshold computation

Secure secret sharing

- Splitting a secret into **n** shares
  - At least **t** shares are needed to reconstruct the secret
  - Less than **t** shares gives *no information* about the secret
  - Can be created “bottom-up” using distributed key generation

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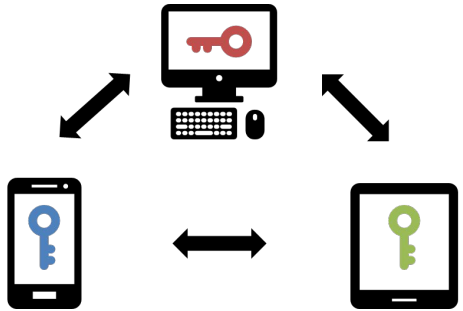

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  - More efficient to use with protocols
  - Supports non-interactive key generation

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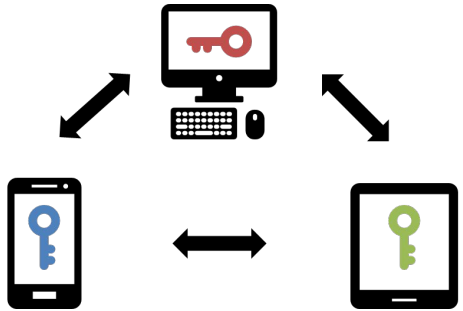

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- Shamir’s secret sharing (**t**-of-**n**)
  - Only **t** shares are needed to reconstruct the secret

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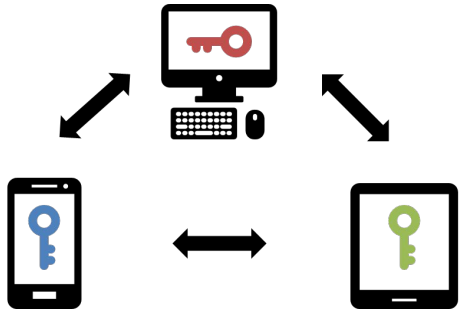

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- Devices operate with secret shares directly
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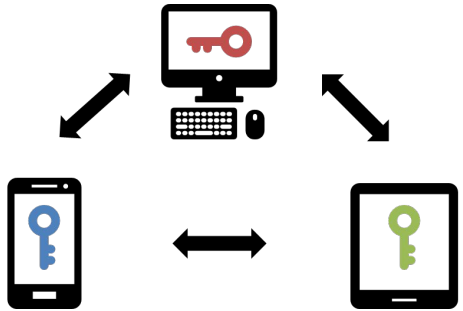

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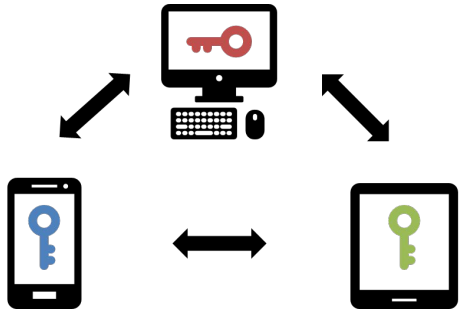

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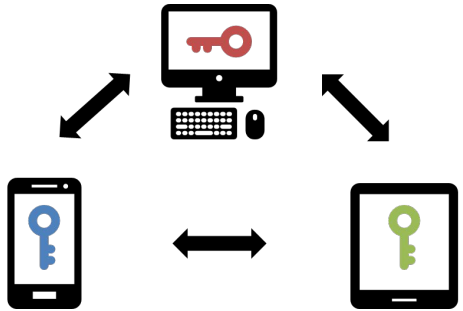

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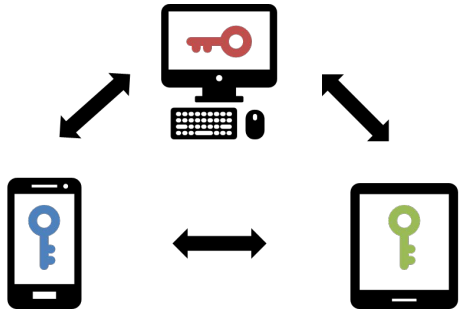
- Typically require
  - Multiple communication rounds
  - More complex computation compared to the base operation



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Practical problems of threshold protocols

- Protocol selection
  - Several protocols exist for each signature signature type
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  - Security assumptions (standard vs less conventional)

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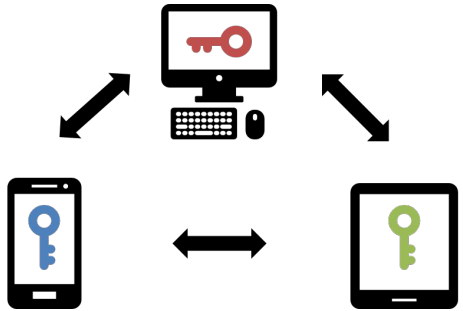

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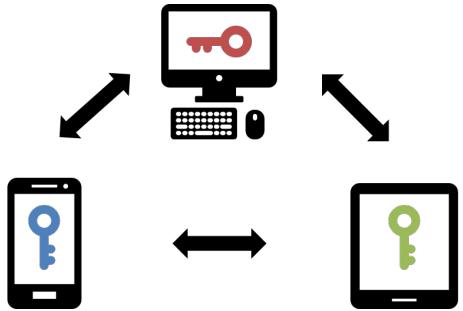

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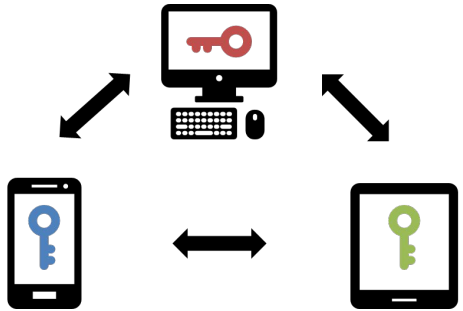

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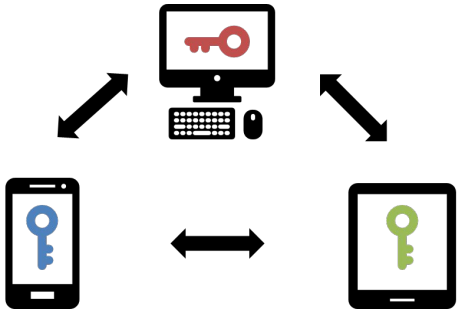

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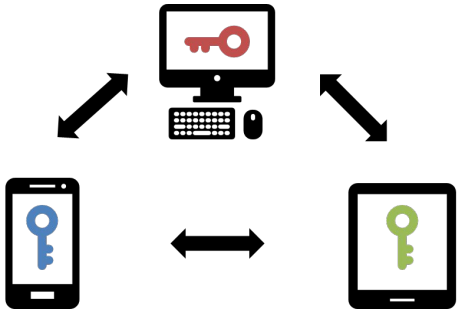

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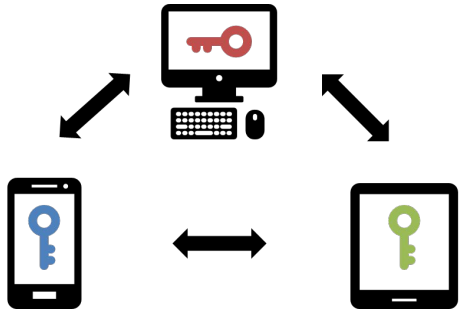

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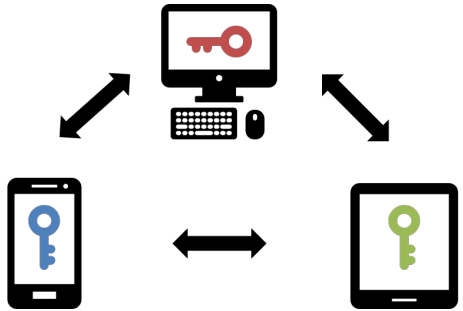

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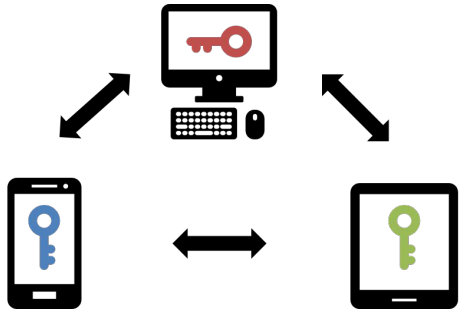

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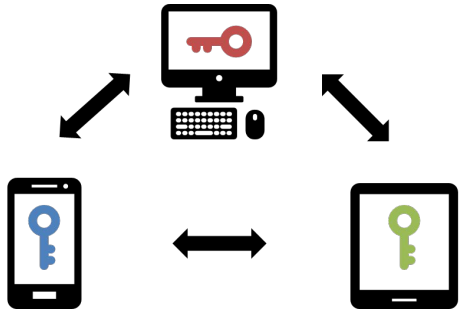
- Threshold protocols are not standardized
- Secure hardware may not be able to run the protocols
  - Hardware constraints
  - Limited interface and programmability



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Research question

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- The computation requires
  - Modular arithmetic (addition, subtraction, multiplication, inversion)
  - Elliptic curves (point addition, scalar multiplication)
  - Hash function

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  - Programmable with Java-like code that gets executed in JCVM
  - Insufficient performance for current public-key cryptography
- Hardware accelerators
  - Accessible only via high-level JC API algorithms (RSA, DH, ECDH, …)
  - Lack of low-level operation access (addition, multiplication, EC addition)
  - Repurposing algorithms to perform low-level operations

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- We extended the library
  - Support for new cards
  - Faster operations on new cards
    - Modular multiplication (4.5x speedup)
    - Accelerated point addition (7x speedup)
    - Fully accelerated scalar multiplication (4x speedup)
  - Added new operations
    - Combined point addition and multiplication (useful for FROST)
    - Point encoding and decoding

FROST on JavaCards

JCFROST

- Open-source FROST protocol implementation for JavaCards
  - Implements `FROST(secp256k1, SHA-256)`
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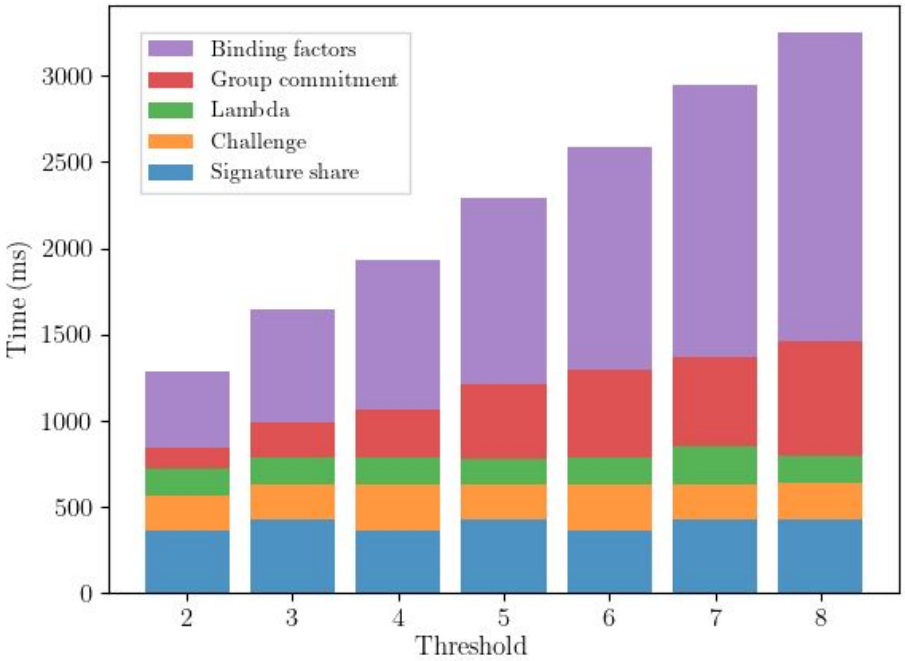
  - Constrained lambda computation ($n \leq 12$ or $n \leq 7$)
    - Intermediate computations can fit in int or short (depending on the constraint)
    - Allows for significant performance improvement over BigInteger-based version

Performance results



NXP J3R200 (2020)

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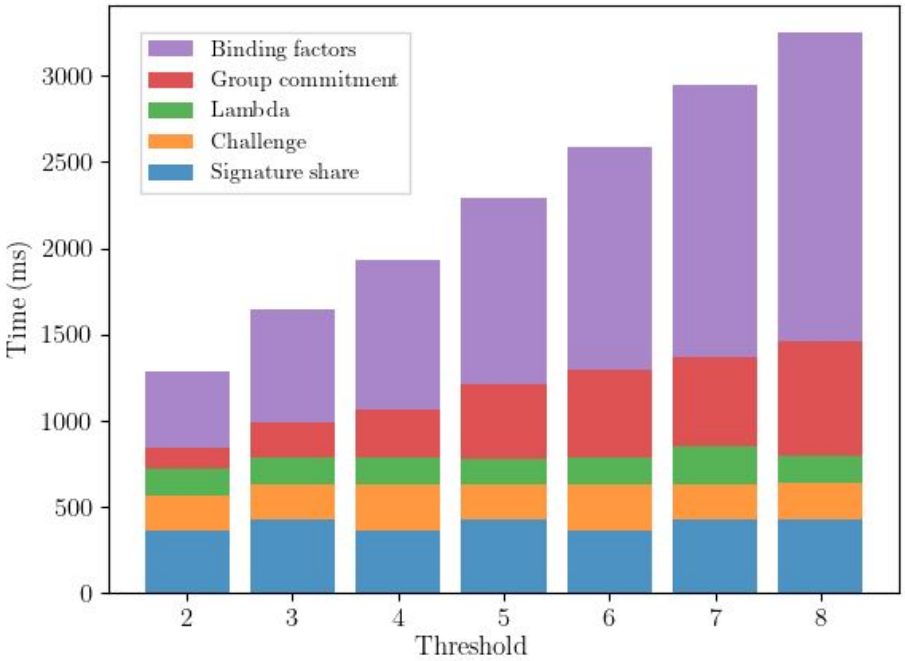

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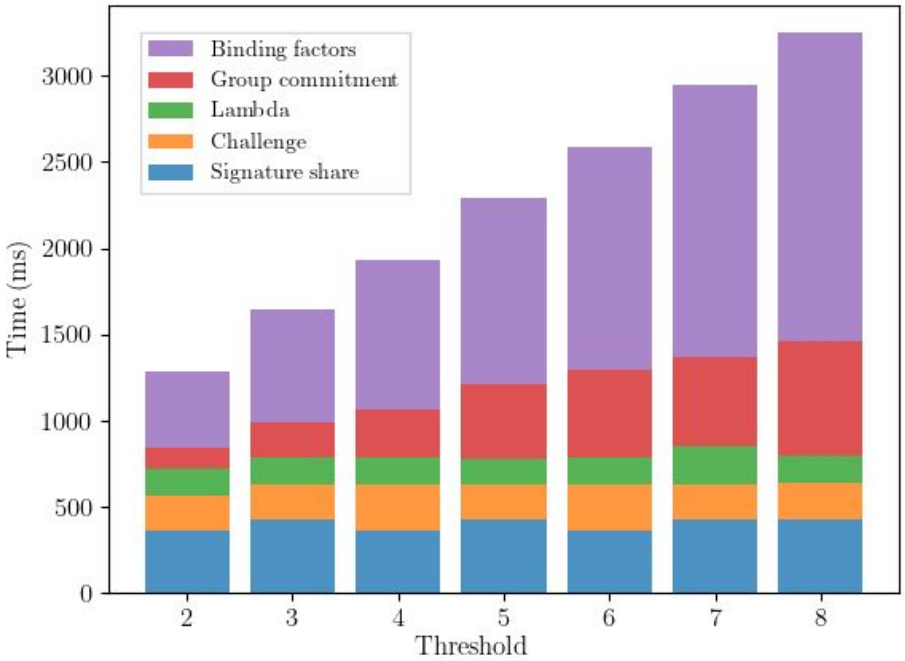

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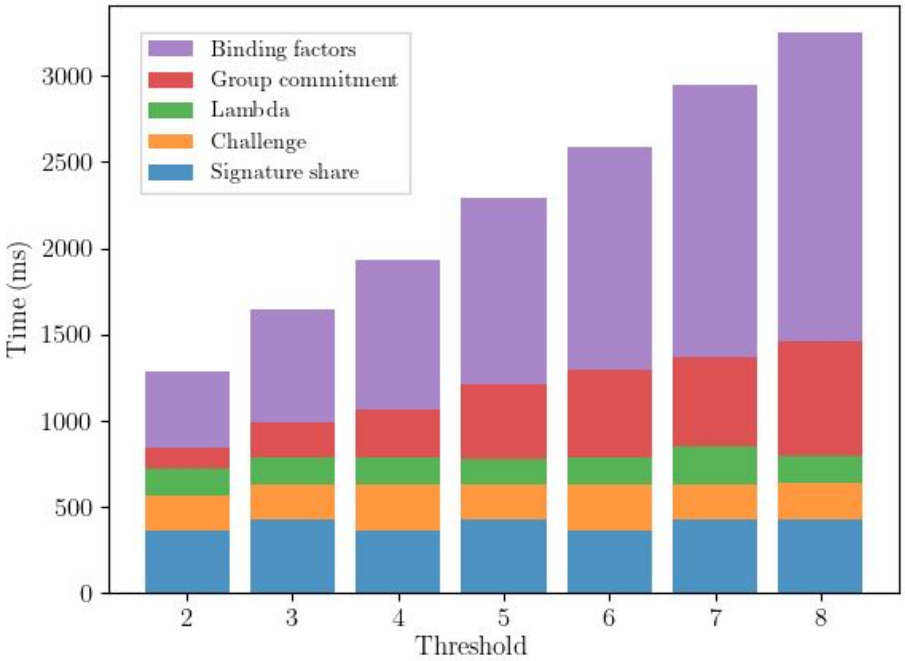

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- Group commitment performs on the platform's limits
- Other operations could be notably faster with low-level access to the platform

Demonstration

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- The positive result can generalize to similar EC-based schemes
  - CoSi [Syt+17], MuSig2 [JRS21], SimpleTSig [CKM22], Lindell22 [Lin22]
- On the contrary
  - ECDSA-based protocols currently seem too complex for this approach
  - Post-quantum signatures are mostly too demanding even in the single-party case

Thank you for your attention

JCFROST implementation

https://github.com/crocs-muni/JCFROST

JCMathLib library

https://github.com/OpenCryptoProject/JCMathLib

References

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