Post-Quantum Blockchain

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- Understand the basis of the signature scheme we modified and implemented
- Ensure compatibility between GO and C programs
- Modular integration : Ease the change of the algorithm used
- Evaluate the impact of these algorithms on the performances

Hyperledger : an open-source Blockchain manipulation tool

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Hyperledger : an open-source Blockchain manipulation tool

- Open source framework for developing Blockchain-based applications
- Source code is written in GO
- Signature algorithm implemented is Schnorr [**C. P. Schnorr.** ***Efficient Identification and Signatures for Smart Cards***] combined with Elliptic curves [**Neal Koblitz, Alfred Menezes, and Scott Vanstone.** ***The State of Elliptic Curve Cryptography***]

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    - Size of keys has to be doubled to keep the same level of security
  - Shor's algorithms **[Peter W. Shor. *Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer*]**
    - Huge impact on the signature process
    - Polynomial algorithm to solve the discrete logarithm problem

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Post-quantum signature solutions

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National Institute of Standards and Technology

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- GeMSS **[Jean-Charles Faugère, Ludovic Perret and all. *GeMSS: A Great Multivariate Short Signature*]**
  - Security is based on multivariate polynomials equations over the finite field $\mathbb{F}_2$
  - Three security levels : 128, 192 or 256
  - Short signature length but longer keys
  - For GeMSS128 : 417,408 bytes and 14,208 bytes for public/secret keys, 48 bytes for signature

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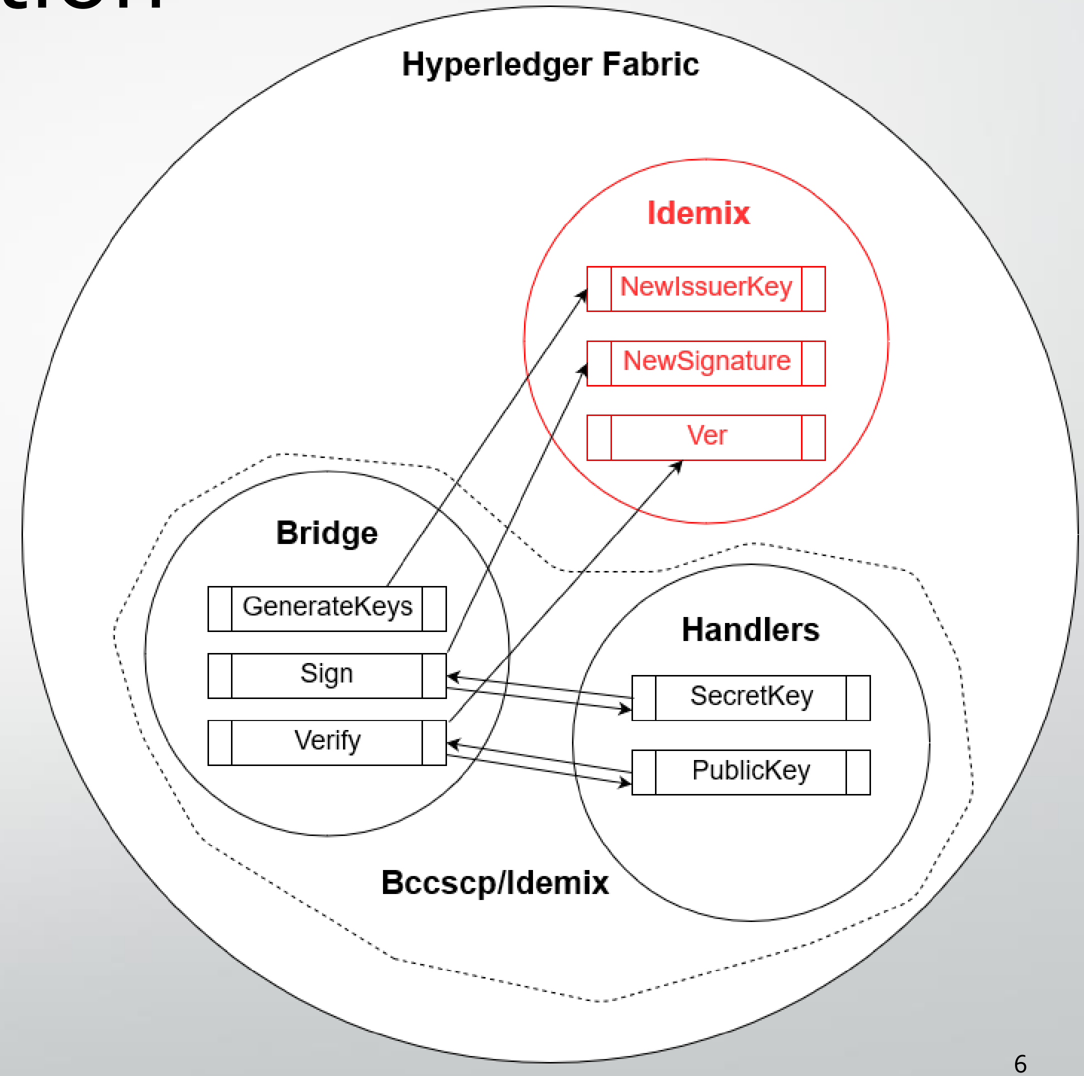
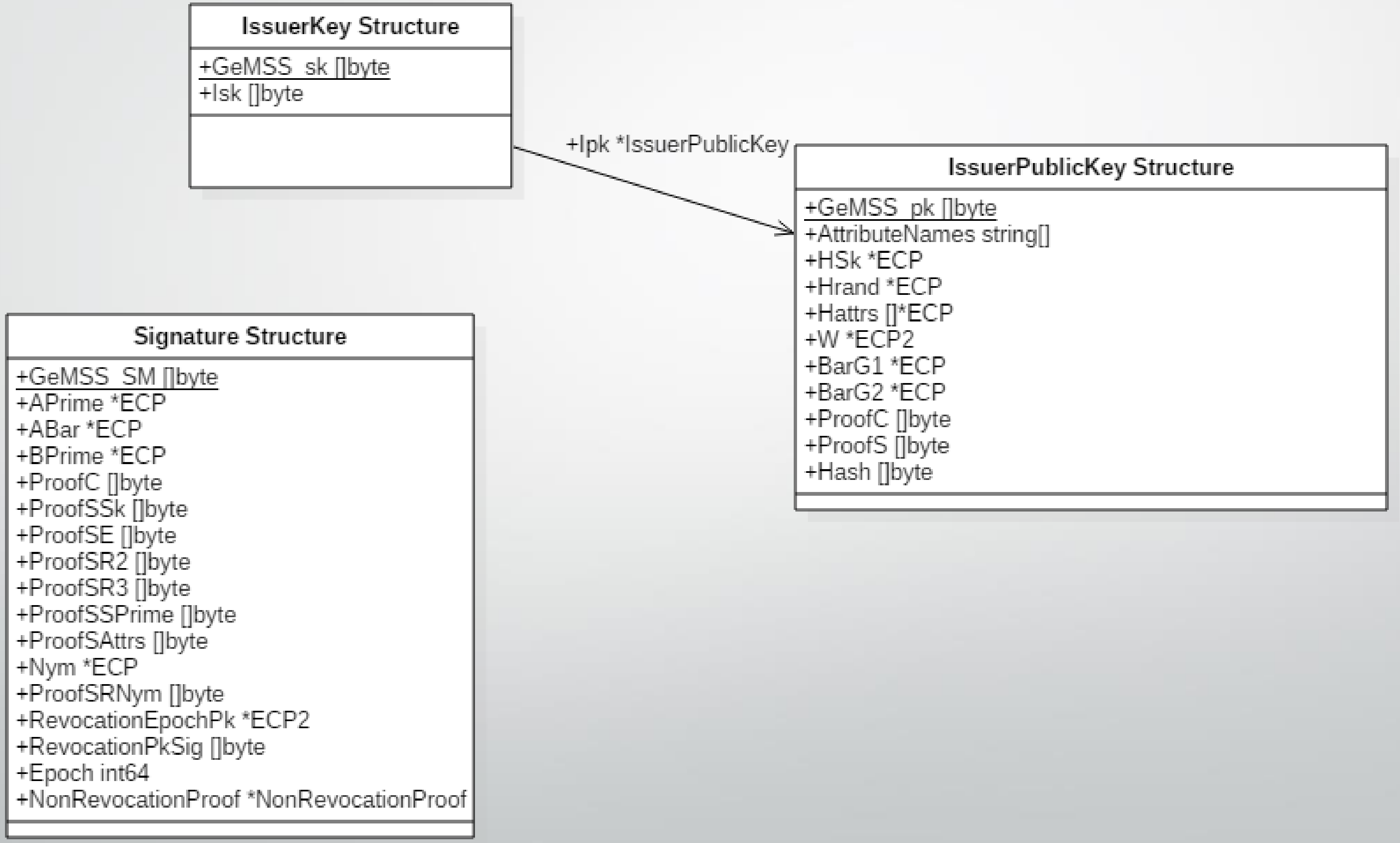
- MQDSS **[Ming-Shing Chen, Andreas Hulsing and all. *From 5-pass MQ-based identification to MQ-based signatures*]**
  - MQ problem **[Christopher Wolf and Bart Preneel. *Taxonomy of Public Key Schemes Based on the Problem of Multivariate Quadratic Equations*]** : multivariate polynomial equations over a finite field $\mathbb{F}_q$ with q a prime
  - Short keys but longer signature
  - 62 bytes and 32 bytes for public/secret keys, 32,882 bytes for signature

Hyperledger organisation

- *Idemix* : Implementation of the cryptographic functions
- *Handlers* : functions used to make the conversion between types
- *Bridge :* Converts parameters before a cryptographic function call



Integration : Structures



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- Wrapper functions to perform correct-sized malloc and appropriate function calls
- Swap between post-quantum signature algorithms by changing one macro

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Hybrid-cryptography model

$$s = S_1(H(m), sk_1) \,||\, S_2(H(m), sk_2)$$

- S_1 and S_2 : Signature algorithms
- sk_1, sk_2 : Secret keys
- $||$: Concatenation operator
- m : message to sign
- H : Hash function

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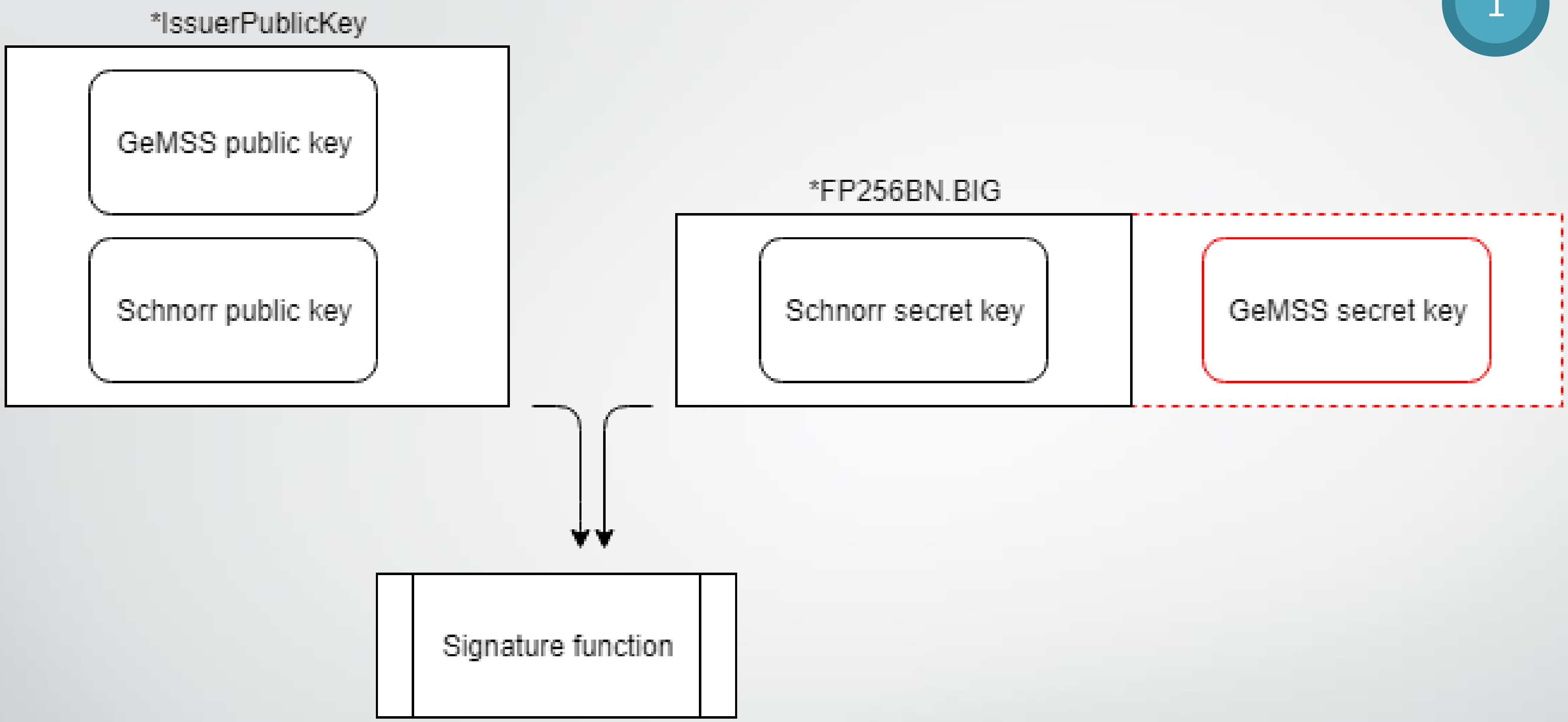
- Improve the security without changing Hyperledger's prototypes



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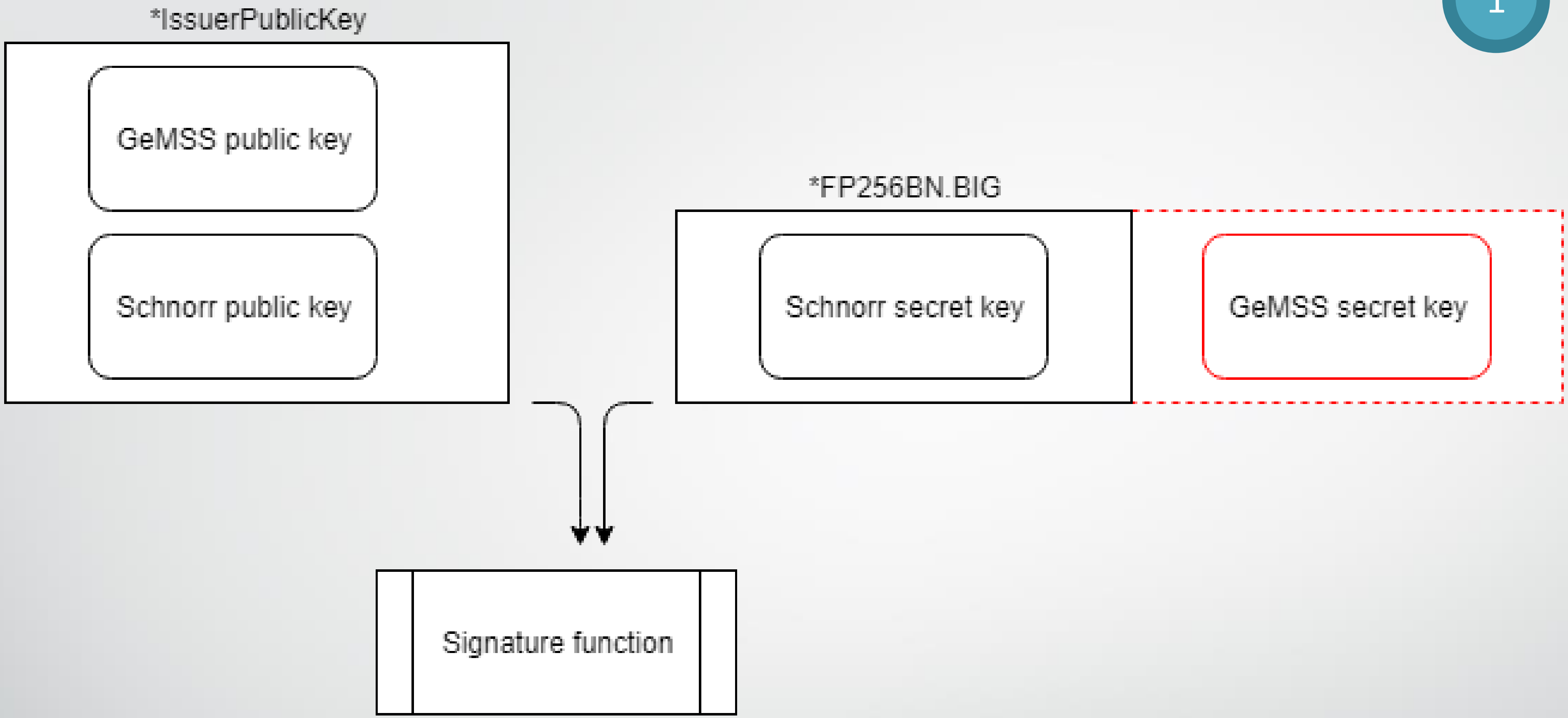

- Signature uses a big integer *FP256BN.BIG* instead of the secret key
- Format memory to add GeMSS's secret key after the *FP256BN.BIG*

Performances tests

	Hyperledger	GeMSS (128)	MQDSS (120)	GeMSS (192)	GeMSS (256)
Keys generation	0.002 ms	13 ms	1 ms	60 ms	191 ms
Signature	31 ms	220 ms	33 ms*	560 ms	905 ms
Signature verification	60 ms	0.05 ms	22 ms	0.2 ms	0.5 ms

	Hyperledger + GeMSS 128	Hyperledger + MQDSS	Hyperledger + GeMSS 192	Hyperledger + GeMSS 256
Keys generation	14 ms	1.1 ms	66 ms	207 ms
Signature	227 ms	61 ms*	619 ms	1180 ms
Signature verification	60 ms	85 ms	62 ms	62 ms

Measures on *Intel(R) Core(TM) i5-7600K CPU @ 3.80GHz*

** Time taken over a few runs*

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	GeMSS 128	MQDSS	GeMSS 192	GeMSS 256
Keys generation	434 KB	0.288 KB	1351 KB	3137 KB
Signature	0.232 KB	49.288 KB	0.264 KB	0.288 KB
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Memory consumption for one function call with a 40 bytes message

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- Signatures are stored in blocks so their sizes have to be taken into account
- GeMSS adapted for Blockchains : Large quantity of verifications
- Memory allocation for the verification is the same and depends on the message's size

Remaining tasks

- Finalize the implementation
  - Adapt the hybrid-cryptography model to the application
- Test a real use case
  - Test over a broad network
  - Perform multiple transactions
- Incorporate other post-quantum signature algorithms

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- Modify structures to take into account those new functions and fields
- The drawbacks on performances are small
- Changing to post-quantum signature algorithm is already possible and usable even in current applications

References

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