PROMETHEUS

PRivacy preserving pOst-quantuM systEms from
advanced crypTograpHic mEchanisms Using latticeS

Industrial Workshop
Technical overview

Sébastien Canard – Tuesday 28th June 2022

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Context: quantum computing & cryptography

Quantum technologies

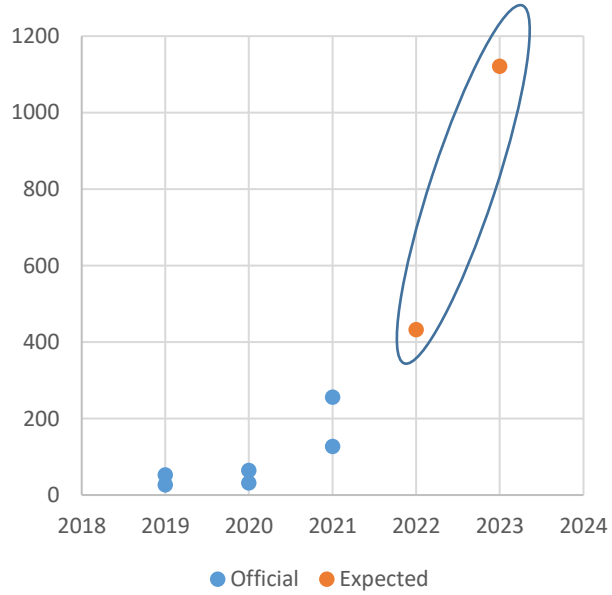
- Quantum superposition
  ⇒ more states are treated
  ⇒ qubits: 0, 1 or uncertain

- Quantum entanglement
  ⇒ linking distant objects

Quantum computing

- quantum computers think differently
- Quantum algorithms (Grover, Shor)

Evolution of quantum processors (in physical qubits) by year



Secret key cryptography

- Grover ⇒ better brute-force attack on the key
- 864 logical qubits to break AES-128

⇒ key lengths should be doubled

- Additional specific quantum attacks

Public key cryptography

- Shor's algorithm on factorization and discrete logarithm ⇒ full break
- 9217 logical qubits to break RSA-3072
- 2330 logical qubits to break ECC-256

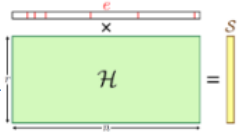
Quantum computers are not a threat now, but we need to be prepared as they could take off quickly

Long term confidentiality

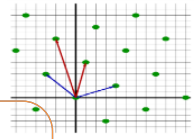
ANSSI BSI ENISA NCSC NSA

Post-Quantum Cryptography

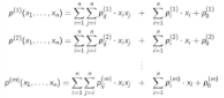
- Post-Quantum Cryptography is related to new mathematical problems for which quantum computers are not better than classical ones
- Several practical solutions are known exist since mid 70s



Codes

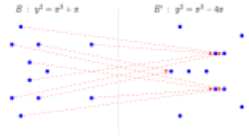


Euclidean lattices



Multivariate polynomials

Hash trees



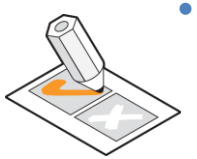
Isogenies

PROMETHEUS' identity card

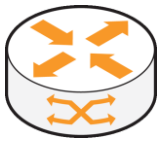
- PROMETHEUS: PRivacy preserving pOst-quantuM systEms from advanced crypTograpHic mEchanisms Using latticeS
- H2020 project financed by the European Commission
- When?
  - Starting date: January 2018, duration: 4 years (1/2)
- Who?
  - Coordinator: ENS Lyon
  - Scientific leader: Orange
  - Academic partners: CWI, IDC, Royal Holloway, RUB, UPC, Université Rennes 1, Weizmann Institute
  - Industrial partners: SCYTL, Thales, TNO
- How much?
  - Grant amount: 5.5 M€, manpower: 790 p.m.

PROMETHEUS outline

- KEM and Encryption
  - Data confidentiality
  - Using additional secret key cryptography or not



- Digital signatures
  - Person/message authentication
  - Integrity and non-repudiation



- Advanced cryptography
  - Privacy-preserving techniques
  - Sensitive data protection

TLS, IPSEC, …

EMV, PKI, …

e-consumer, e-vote, anonymous authentication, end-to-end encryption, cloud outsourcing, …

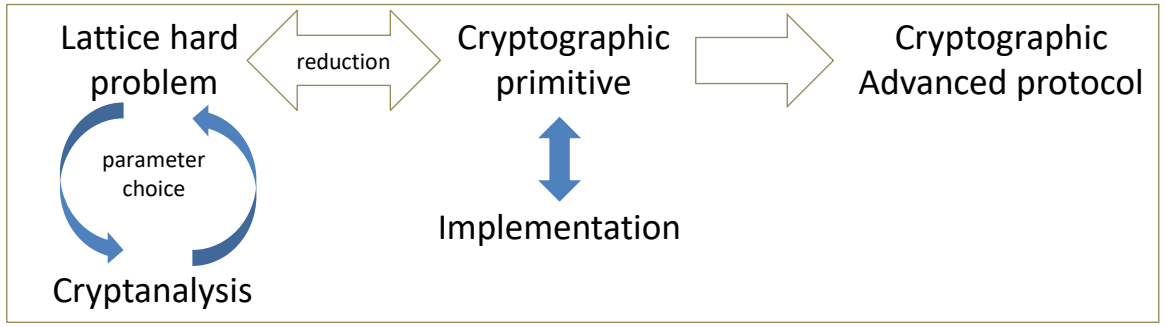
PROMETHEUS

Propose post-quantum solutions using lattices

- Objective 1: Build a complete study of the foundations of lattice-based cryptography
- Objective 2: Provide innovative lattice-based cryptographic primitives
- Objective 3: Protect the privacy of individuals in a post-quantum era

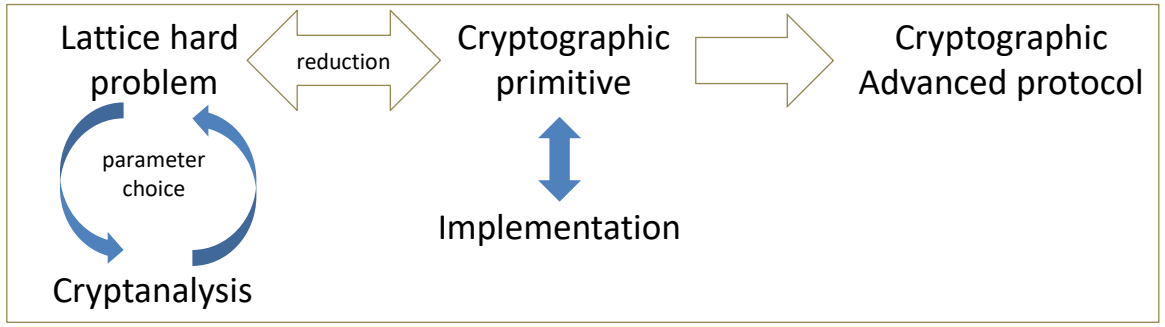
PROMETHEUS' result

Research (118 published papers)



PROMETHEUS' result

Research (118 published papers)

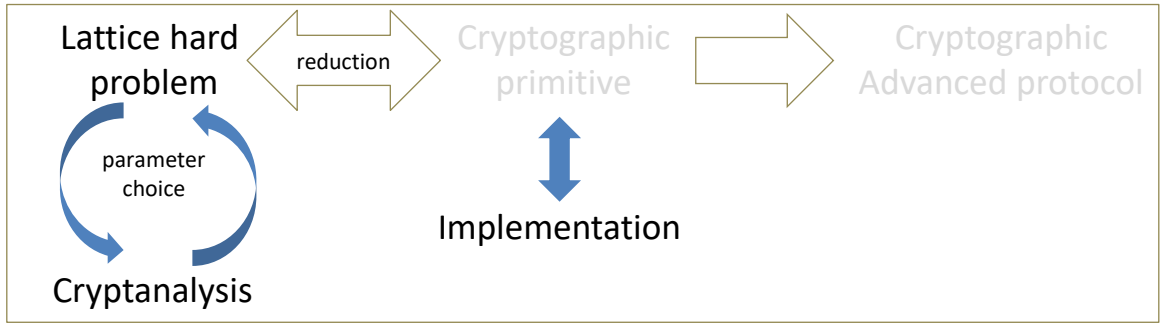


- Foundations ⇒ Objective 1
- Primitives ⇒ Objective 2
- Advanced protocols ⇒ Objective 3

PROMETHEUS' result

See Eamonn's presentation

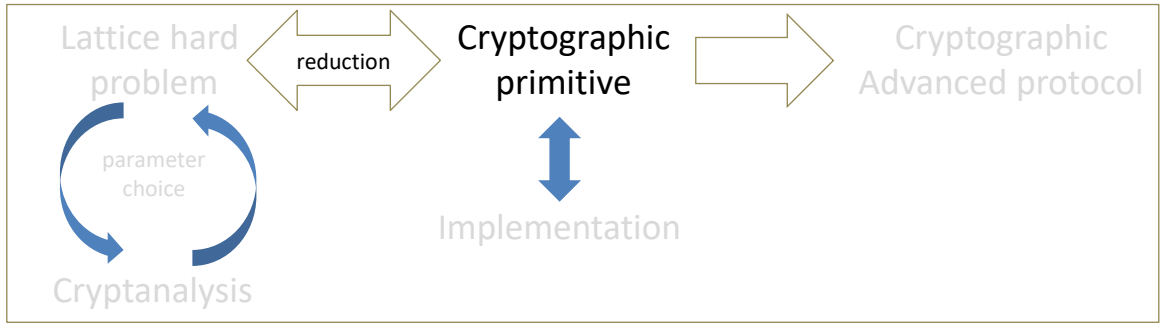
Research (118 published papers)



- Foundations ⇒ Objective 1
  - Better understanding of (structured) lattice-related hard problems and security proofs/reductions in the quantum setting
  - Better control of concrete security
  - More efficient and secure lattice basic algorithms
  - Better comprehension of side-channel attacks on implementations and countermeasure techniques
- Primitives ⇒ Objective 2
- Advanced protocols ⇒ Objective 3

PROMETHEUS' result

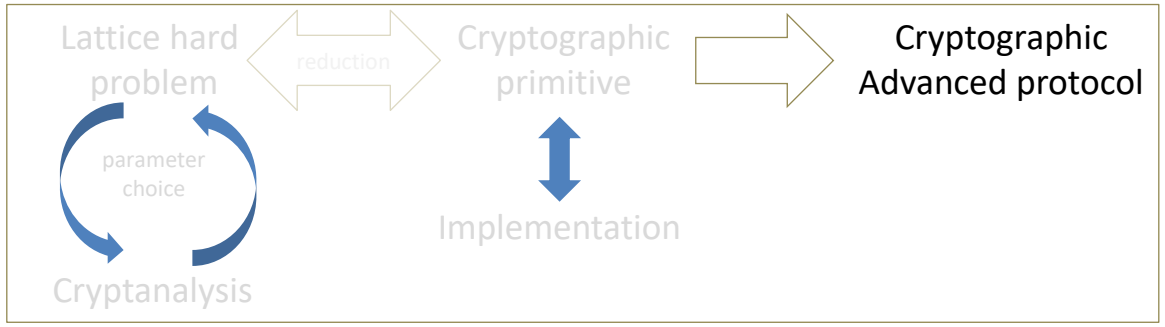
Research (118 published papers)



- Foundations ⇒ Objective 1
- Primitives ⇒ Objective 2
  - Evaluation and defense of NIST competitors on lattice-based signatures and Key Encapsulation Mechanisms
  - Building blocks for use cases: better design of signature schemes with efficient protocols, full redesign of lattice-based blind signatures, many zero-knowledge proofs of knowledge, several improvements on homomorphic encryption
- Advanced protocols ⇒ Objective 3

PROMETHEUS' result

Research (118 published papers)



- Foundations ⇒ Objective 1
- Primitives ⇒ Objective 2
- Advanced protocols ⇒ Objective 3
  - First secure lattice-based e-cash system
  - Several frameworks for lattice-based e-voting
  - First implementation of lattice-based anonymous credentials

PROMETHEUS' result

Research

Standardization

See Damien's presentation

NIST

- PROMETHEUS' members are implied in several finalists
- Strong participation to NIST discussions

ISO/IEC

- Strong involvement in WG2 - Cryptography and security mechanisms
- See ISO/IEC standards on blind and group signatures
- Participation in the vote for a new ISO/IEC standard on FHE

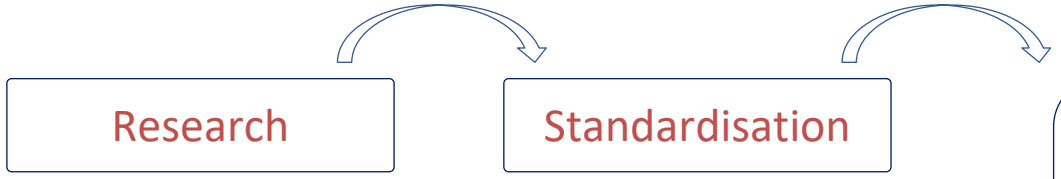
ETSI

- Strong involvement in TC Cyber
- Contribution to a report on PQ signatures

IETF

- Follow-up of internal studies

PROMETHEUS' result



See Georg's presentation

Implementation

- Lattice foundations
  - (Leaky)-LWE Estimator: open-source software for estimating the security of lattice-based cryptography (in presence of side channels for the "Leaky" version)
- Basic primitives
  - Several implementations of NIST competitors
  - Taking into account side-channel attacks
  - Crysalid: quantum resistant hybrid cryptographic library for signature and key-exchange functions
  - Other primitives: blind signatures, ZKPK, homomorphic encryption
- Advanced protocols
  - Implementation related to our use cases

PROMETHEUS' result

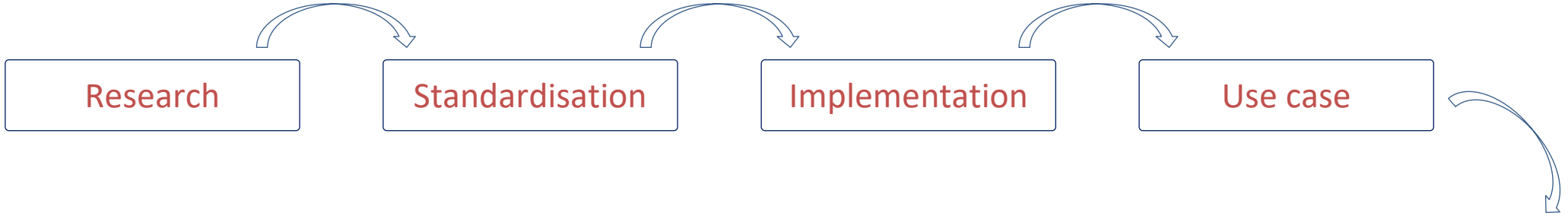
See Aleix's presentation

See Gabriele's presentation

Use cases

- Individual as a consumer
  - Quantum resistant e-payment
- Individual as a citizen
  - Quantum resistant e-voting
- Personal data minimization in proximity services
  - Quantum resistant Identity wallet
- Cyber threat intelligence to protect companies' data

PROMETHEUS' result



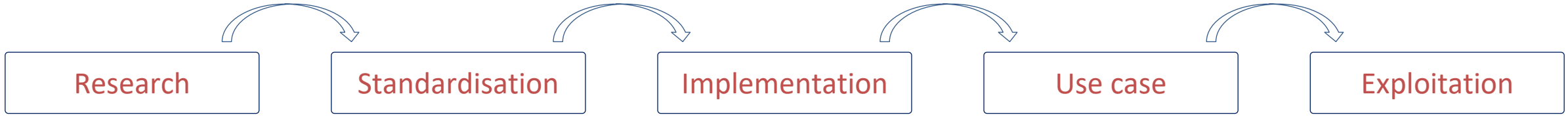
See Jean-Michel's presentation

See Thomas's presentation

Exploitation

- Short-term exploitation of lattice-based signatures and encryption (see security agencies' positions)
  - Transition to post-quantum cryptography should be thought today ⇒ efficiency is there!
  - Hybrid systems
  - Crypto agility
- Middle to long-term exploitation of advanced use cases
  - Maturity is sometimes very far from what can be done using classical cryptography

Key results and takeaways



Quantum computers are not a threat now, but we need to be prepared as they could take off quickly

Importance to design alternatives to historical cryptography

PROMETHEUS' outcomes

- Give to the community a large number of improvements related to lattice-based cryptography, from foundations to advanced protocols
- Thoroughly assess the exact maturity level of lattice-based cryptography
- Share our conclusions to academic, industry and authorities (https://www.h2020prometheus.eu/ and https://twitter.com/h2020prometheus)

Today’s agenda

Tuesday, 28 June 2022			
From	**To**	Topic	Speakers
10:00	10:15	Welcome and introduction	Jean Bolot - Orange
10:15	10:45	PROMETHEUS project technical overview	Sébastien Canard - Orange
10:45	**11:00**	Status of NIST standardization process on post-quantum	Damien Stehlé - ENS de Lyon
11:00	**11:45**	PQ implementation on hardware and side-channels attacks	Georg Land - University of Bochum
11:45	**12:30**	Overview of the impacts of post-quantum cryptography for an operator's IP network	Jean Michel Combes - Orange
12:30	**14:00**	**Buffet**	
14:00	**14:30**	Quantum-safe cryptography for Cyber-Threat Intelligence sharing	Gabriele Spini - TNO
14:30	**15:00**	Presentation of the different tools for parameters selection and their usage	Eamonn Postlethwaite - CWI
15:00	**15:45**	Impact of the transition to post-quantum cryptography on space and defence systems	Thomas Ricosset - Thales
15:45	**16:30**	Quantum-resistant mixnet prototype for e-voting systems	Aleix Amill - Scytl
16:30	**17:00**	**Informal discussions**	

Thank you