Towards new security standards

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Les communautés d'experts

Outline

1 Overview of the main security aspects

2 Quantum computers and their impact over current security

3 Counter-measures and work in progress

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Security goals

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- Confidentiality
- Authentication
- Integrity
- Non-repudiation / Traceability / Accountability

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(Modern) encryption (see below)

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Digital signature (see below)

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Cryptographic mecanisms involved

(Collision-resistant) hash functions

Modern cryptographic schemes

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1976	**D**iffie-**H**elmann (DH) key exchange protocol
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1992	**E**lliptic **C**urve **D**igital **S**ignature **A**lgorithm (ECDSA)
1993	Blowfish
1999	Triple-DES

Legend :
- symmetric scheme
- asymmetric scheme

Current security

Current security vs. computing power (2019)

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1 standard machine : 64 bits architecture

2^6

Current security vs. computing power (2019)

1 standard machine : 8 cores

$2^6 \times 2^4$

Current security vs. computing power (2019)

1 standard machine : 4 GHz

$2^6 \times 2^4 \times 2^2 \times 10^9$

Current security vs. computing power (2019)

1 standard machine : running 1 month

$2^6 \times 2^4 \times 2^2 \times 10^9 \times 60 \times 60 \times 24 \times 30$

Current security vs. computing power (2019)

NSA $\geq$ 10 000 standard machines ?

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A concrete example

During 2018, there were 2^{89} SHA-256 hashes computed on the blockchain BitCoin...

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Security in 2019

Setting parameters so that best known attacks have complexity (at least) 2^{128}.

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Classical best known attacks :

- Symmetric primitives : brute-force
- Asymmetric primitives : GNFS, sub-exponential complexity

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1994	**Shor's algorithm** [Sho97]
1996	**Grover's algorithm** [Gro96]

Shor's algorithm

SIAM J. COMPUT.
Vol. 26, No. 5, pp. 1484–1509, October 1997

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POLYNOMIAL-TIME ALGORITHMS FOR PRIME FACTORIZATION AND DISCRETE LOGARITHMS ON A QUANTUM COMPUTER*

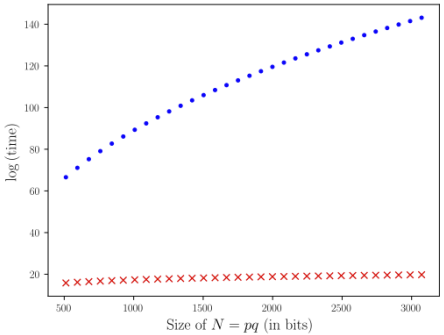
PETER W. SHOR†

Abstract. A digital computer is generally believed to be an efficient universal computing device; that is, it is believed able to simulate any physical computing device with an increase in computation time by at most a polynomial factor. This may not be true when quantum mechanics is taken into consideration. This paper considers factoring integers and finding discrete logarithms, two problems which are generally thought to be hard on a classical computer and which have been used as the basis of several proposed cryptosystems. Efficient randomized algorithms are given for these two problems on a hypothetical quantum computer. These algorithms take a number of steps polynomial in the input size, e.g., the number of digits of the integer to be factored.

Consequences of Shor's algorithm on PKC

- Factoring becomes polynomial-time
- Discrete logarithm becomes almost polynomial-time

In other words, **security as we know it becomes down**...



Grover's algorithm

A fast quantum mechanical algorithm for database search

Lov K. Grover
3C-404A, Bell Labs
600 Mountain Avenue
Murray Hill NJ 07974
lkgrover@bell-labs.com

Summary

Imagine a phone directory containing N names arranged in completely random order. In order to find someone's phone number with a probability of $\frac{1}{2}$, any classical algorithm (whether deterministic or probabilistic) will need to look at a minimum of $\frac{N}{2}$ names. Quantum mechanical systems can be in a superposition of states and simultaneously examine multiple names. By properly adjusting the phases of various operations, successful computations reinforce each other while others interfere randomly. As a result, the desired phone number can be obtained in only $O(\sqrt{N})$ steps. The algorithm is within a small constant factor of the fastest possible quantum mechanical algorithm.

Consequences of Grover's algorithm

(n-entries) Database search takes $\mathcal{O}(\sqrt{n})$ queries instead of $\mathcal{O}(n)$.

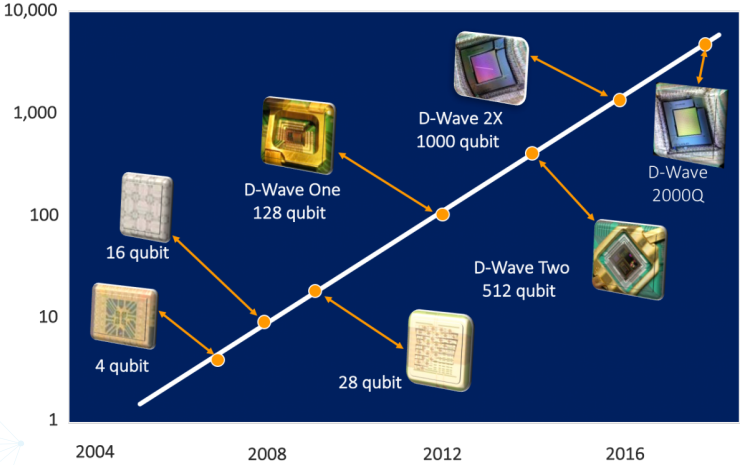
Consequence over symmetric crypto :

→ The length of the secret key must be **doubled** to preserve the same level of security

Consequence over hash functions :

→ More tricky (depending on the model, the size of the quantum computer, ...), at least +33% to preserve the security level

How far are we from a large-scale quantum computer ?



Analog to Moore's law for quantum computing : the number of qubits (y-axe, logarithmic scale) approximately doubles every year (x-axe). (Source : D-Wave)

Large-scale quantum computing : a caveat

This analog to Moore's law has several drawbacks :

- essentially corresponds to multiple 32 qubits architectures mounted in parallel
- fault-tolerance remains an open problem
- still far from what is required to factor 2048 bits moduli

In 2019, the largest quantum computer features 72 qubits (Google).

Open challenges towards quantum computing

More work in required to embrace a large scale quantum computer :

- the developing error-correcting codes for error-free quantum computing
- building architectures and interfaces between quantum computers and communication systems
- developing reliable quantum memories
- developing quantum programming languages, compilers and middle-ware stack

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Still, a Sword of Damocles hanging over our heads, and **now** is the time for designing **quantum-safe** alternatives.

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- 1978 — **R**ivest **S**hamir **A**dleman (RSA) [RSA78]
- 1978 — McEliece cryptosystem (error-correcting codes) [McE78]
- 1979 — Lamport (one-time) signature scheme (hash based) [Lam79]
- 1988 — C^* cryptosystem (multivariate) [MI88]
- 1991 — **I**nternational **D**ata **E**ncryption **A**lgorithm (IDEA)
- 1996 — NTRU cryptosystem (lattices) [HPS98]
- 2006 — Isogeny based encryption [RS06]

Using different primitives

The aforementioned schemes are based upon :

- euclidean lattices,
- error-correcting codes,
- security of hash functions,
- multivariate polynomials,
- supersingular isogenies.

Until now, **none** of these primitives are known to allow **quantum speedups**.

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IAD will initiate a transition to quantum resistant algorithms in the not too distant future. Based on experience in deploying Suite B, we have determined to start planning and communicating early about the upcoming transition to quantum resistant algorithms. Our ultimate goal is to provide cost effective security against a potential quantum computer. We are working with partners across the USG, vendors, and standards bodies to ensure there is a clear plan for getting a new suite of algorithms that are developed in an open and transparent manner that will form the foundation of our next Suite of cryptographic algorithms.

`https://apps.nsa.gov/iaarchive/programs/iad-initiatives/cnsa-suite.cfm`

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→ Expect smaller moduli ⇒ room for faster algorithms

A team of experts next to you

Carlos Aguilar Melchor (ISAE-Supaéro) and myself (ÉNAC) are involved (together with a lot of people) in NIST's standardization process :

- 4 submissions still in race for standardization (2^{nd} round)
- Provide either encryption or key-exchange
- Some of our candidates feature best properties among all candidates

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Together with Jérôme Lacan (ISAE-Supaéro), we are announcing the creation of a **workgroup around post-quantum cryptography**.

Stay tuned, or reach out directly to us if interested :
pqcrypto@recherche.enac.fr

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Thanks !

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