Overview of
Quantum computing and quantum-safe cryptography

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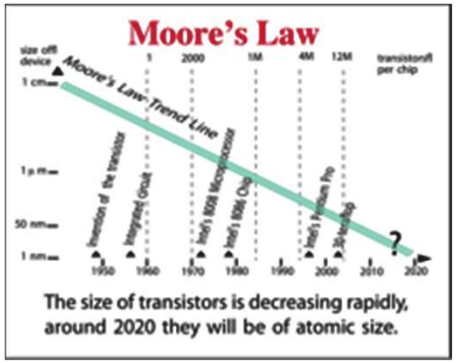
14 juillet, 2018

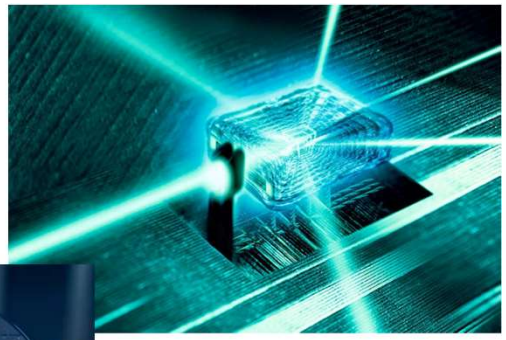
Agenda

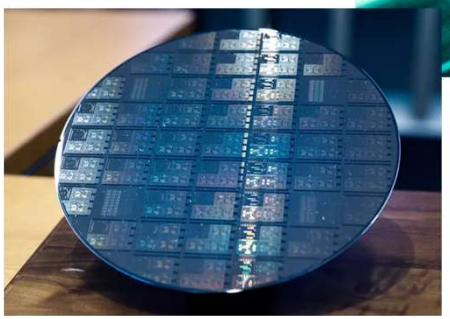
1. About quantum computing
2. The impact of quantum computing on security
3. Industry response to quantum-based security threats
4. Landscape of quantum-safe security mechanisms
5. Standardization activities

Quantum computing is the marriage of…

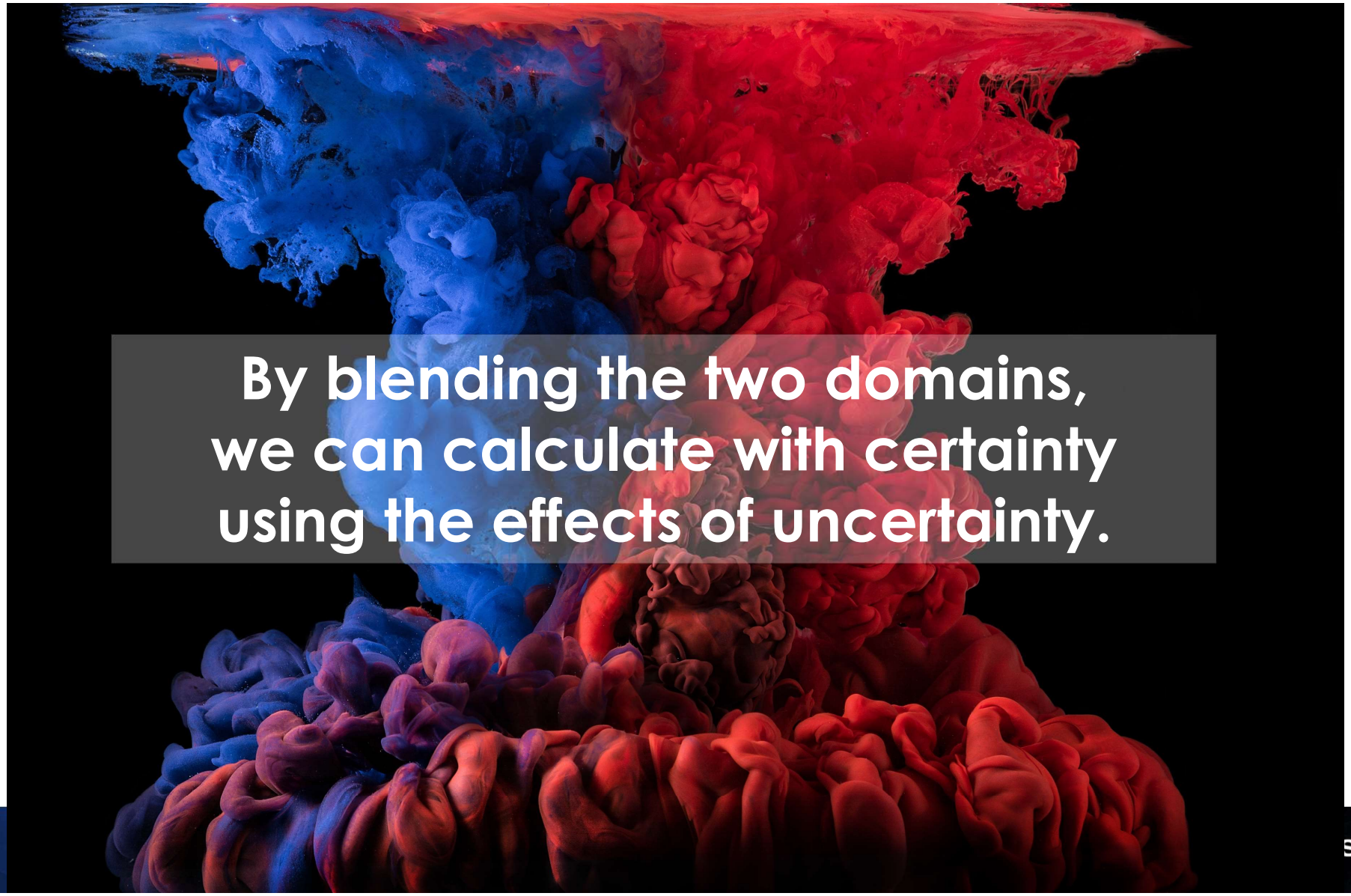


INFORMATION THEORY





QUANTUM MECHANICS


By blending the two domains,
we can calculate with certainty
using the effects of uncertainty.

A classical bit is either 1 or 0

- A classical bit is like a light bulb that's either on or off
- In a standard Von Neumann processor, we get one set of states per clock tick

0

"Off"

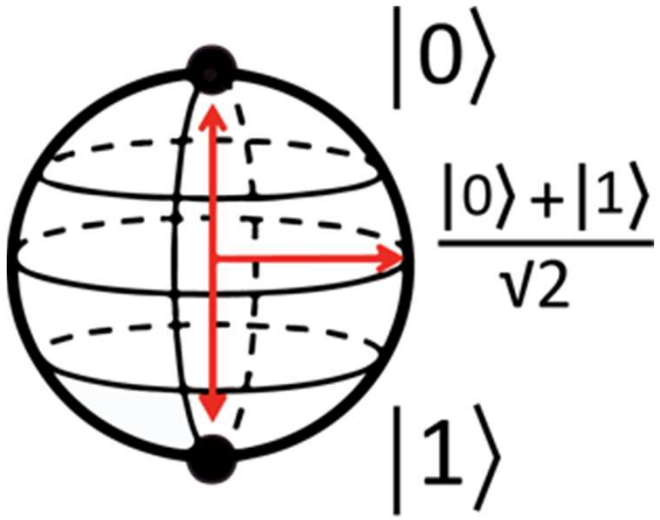
or

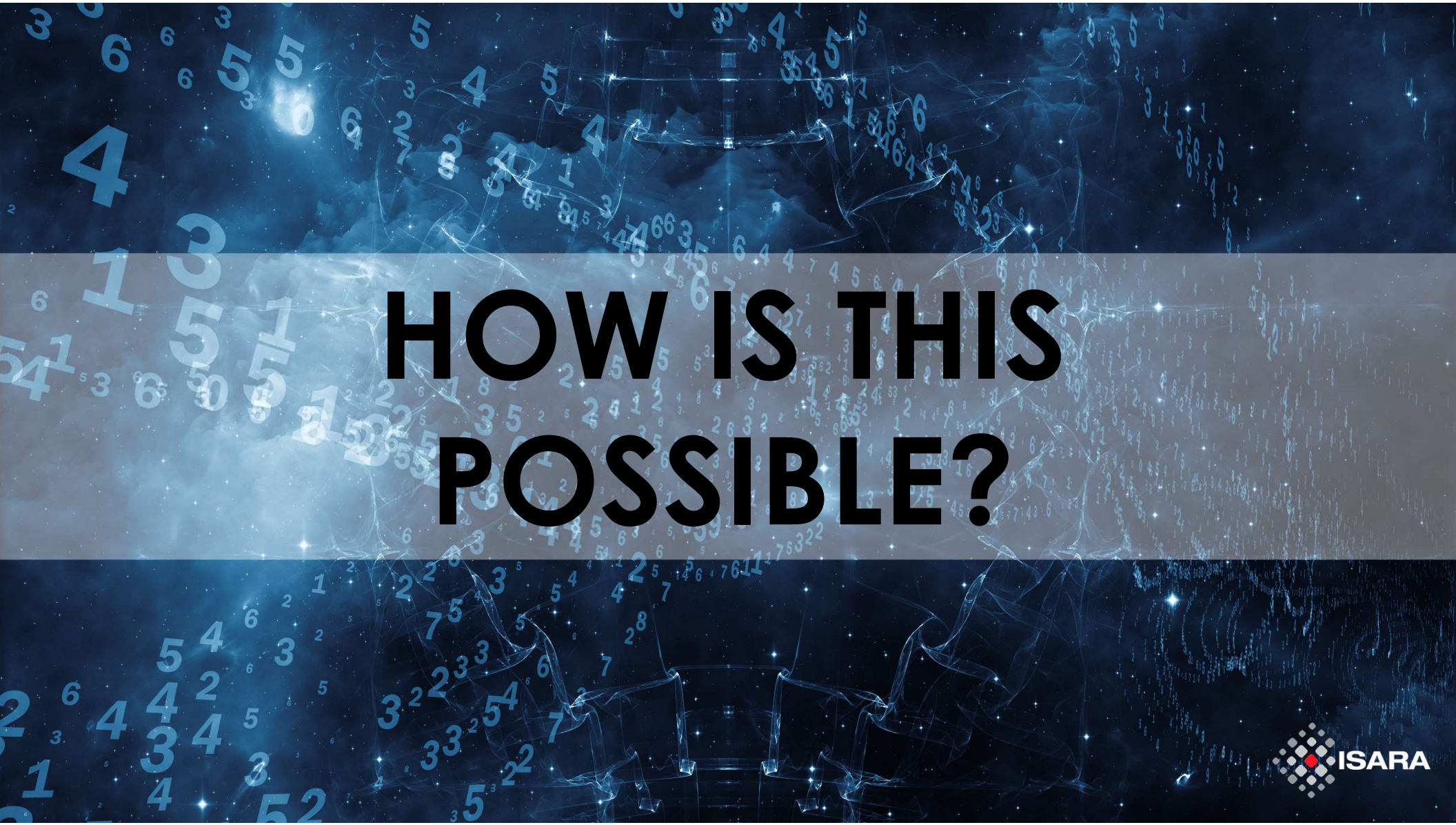
1

"On"

A quantum bit (qubit) is different

- A quantum bit can exist in **multiple states simultaneously**, like a light bulb that's on and off at the same time
- Number of states = 2^N, where N = number of qubits
- Example: A system with 16 qubits can be in 2^{16} = **65,536** states at once!




HOW IS THIS POSSIBLE?
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There's a better question…

How can we use this interesting property of being in many states at once to solve important problems ?

Because the quantum computer lends itself to solving certain types of problems extremely easily.


IS QUANTUM COMPUTING FASTER?
It depends on the problem
(…like the so-called travelling salesman problem.)
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THE QUANTUM
RACE IS ON
Microsoft
Google
rigetti
D:wave
The Quantum Computing Company™
IBM
intel
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Quantum computing will solve today's unsolvable problems, opening up
A NEW REALM OF POSSIBILITIES.
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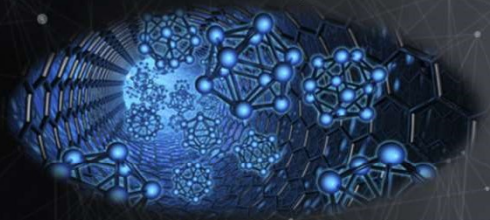
QUANTUM COMPUTING
WILL REVOLUTIONIZE MANY INDUSTRIES



MATERIAL DESIGN

CRYPTOGRAPHY

BIG DATA

WEATHER SERVICES

CHEMISTRY

MACHINE LEARNING

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THE CHALLENGE
Quantum computing will break today's public key encryption standards.
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EFFECT ON TODAY'S CRYPTOGRAPHY

Type	Algorithm	Key Strength Classic (bits)	Key Strength Quantum (bits)	Quantum Attack
Asymmetric	RSA 2048	112	0	Shor's Algorithm
	RSA 3072	128		
	ECC 256	128		
	ECC 521	256		
Symmetric	AES 128	128	64	Grover's Algorithm
	AES 256	256	128	

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IMPACT ON SECURE COMMINICATIONS

Secure Communication Protocol

Handshake | **Data Exchange**

Shor's algorithm **breaks** current public-key algorithms

Authentication
Key Establishment

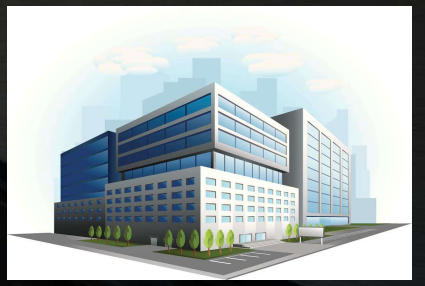
Symmetric Encryption

AES 256 → AES 128

Grover's algorithm **reduces** the effective symmetric key size to half

IMPACT ON SOFTWARE UPDATES

Embed a Root of Trust at Manufacture



- Create software update
- Digitally sign the update

Digital Signature | **Software Update**

- Receive software update
- Verify ECDSA or RSA digital signature → **broken using Shor's algorithm**
- Apply software update

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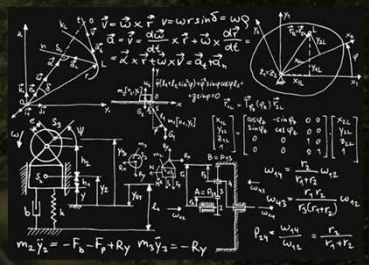
PATHWAYS TO QUANTUM SAFETY

Quantum Key Distribution



Quantum-Safe Cryptography

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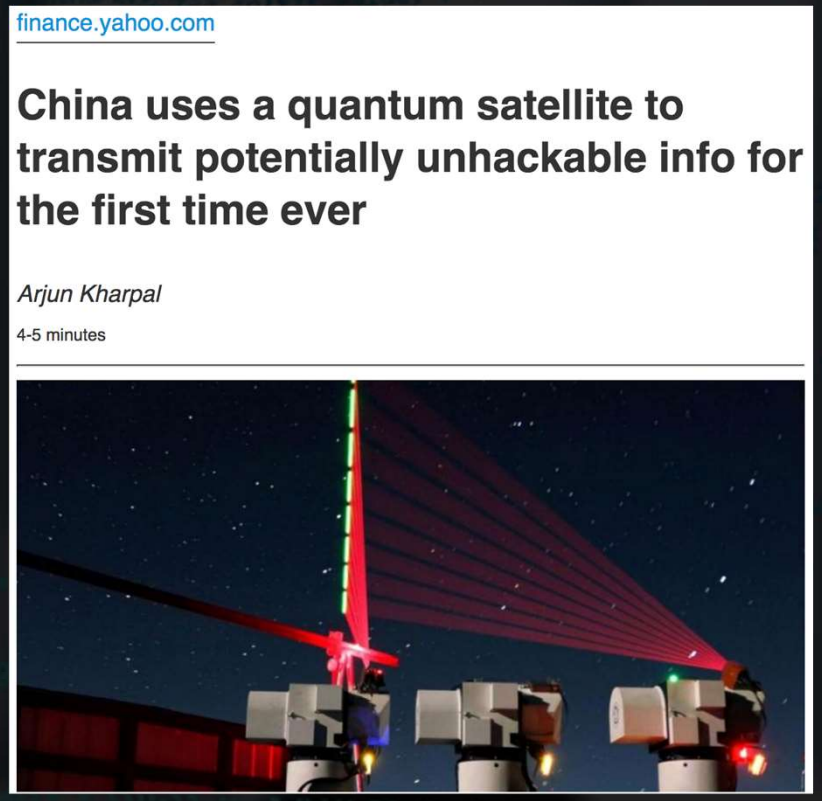
Quantum Key Distribution

- Utilize basic physical properties to protect information
- Requires a fibre optic connection or line of sight
- Serious distance restrictions
- Side channel risks
- Still requires an authentic channel protected by quantum-resistant cryptography



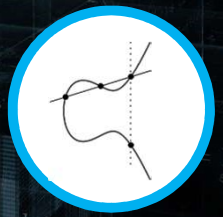
QSC: THE "NEW" MATH

Hash-based

Code-based

Lattice-based

Multivariate-based



Isogeny-based

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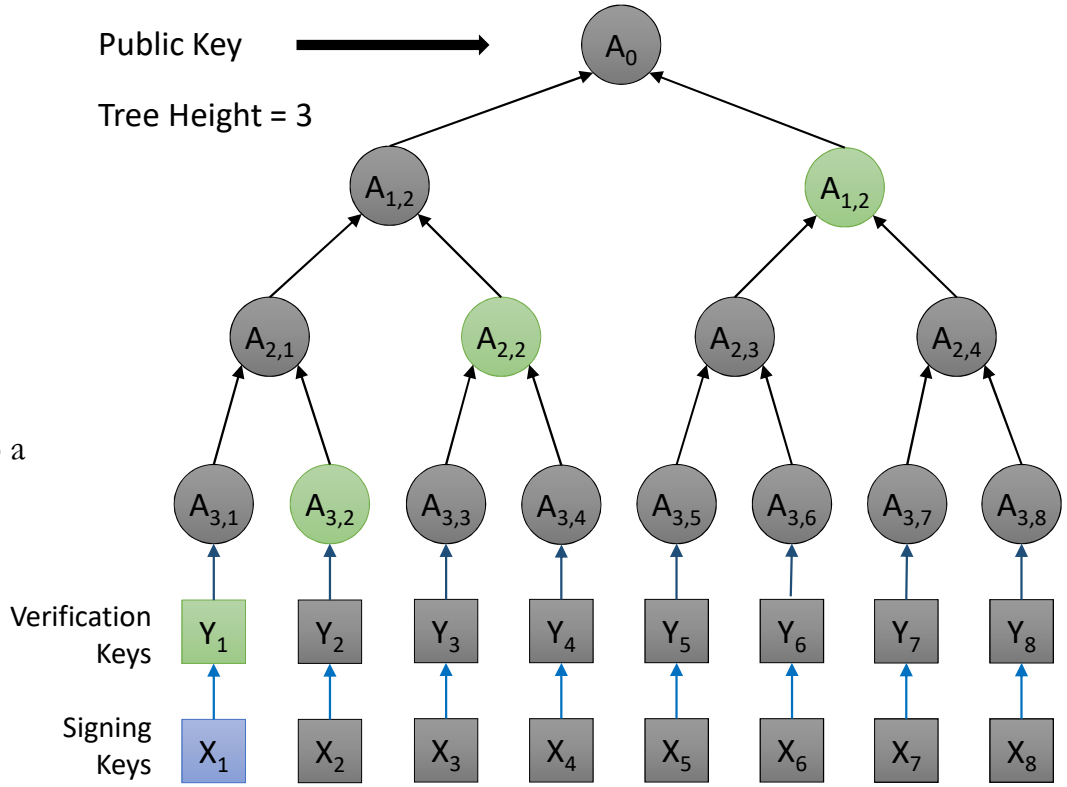
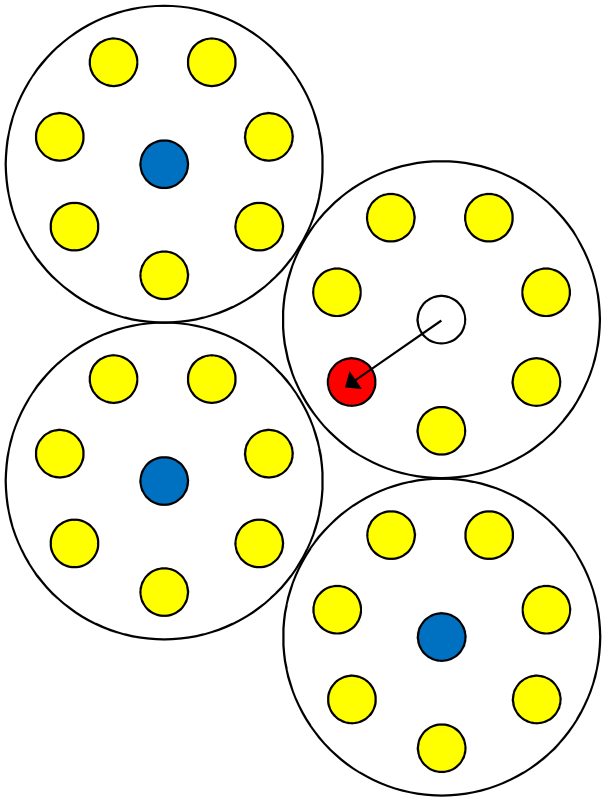
Hash-Based Cryptography

- Introduced by Merkle in 1979
- "One-Time Signatures"
- Small public key but very large private key
- Fast signing & verifying
- Stateful
- Became practical by combining all verification keys into a single Public Key
- And it happens to be Quantum-Safe
- Candidates:
  - Leighton-Micali Signatures (LMS)
  - eXtended Merkle Signature Scheme (XMSS)
  - SPHINCS



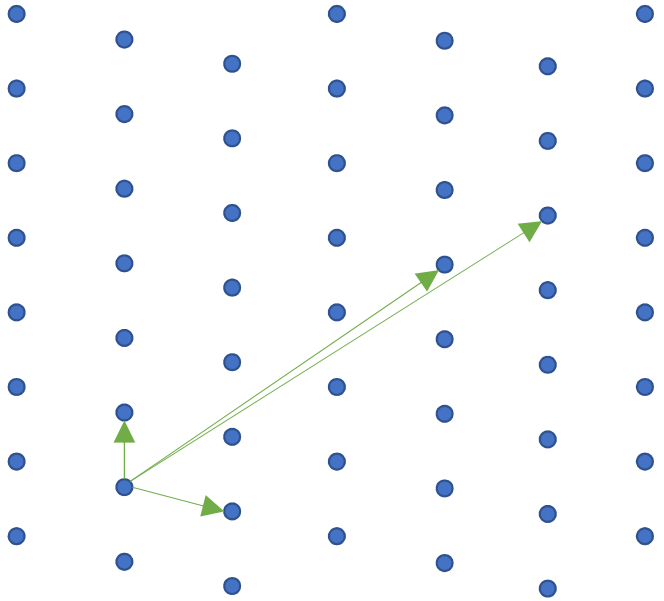
Code-Based Cryptography

- Introduced by McEliece in 1978
- Relies on hardness of decoding unknown codes
- Very large public keys
- Fast encryption and decryption
- Smaller variants – QC-MDPC, McBits, others
- Recent attacks mitigated through ephemeral use



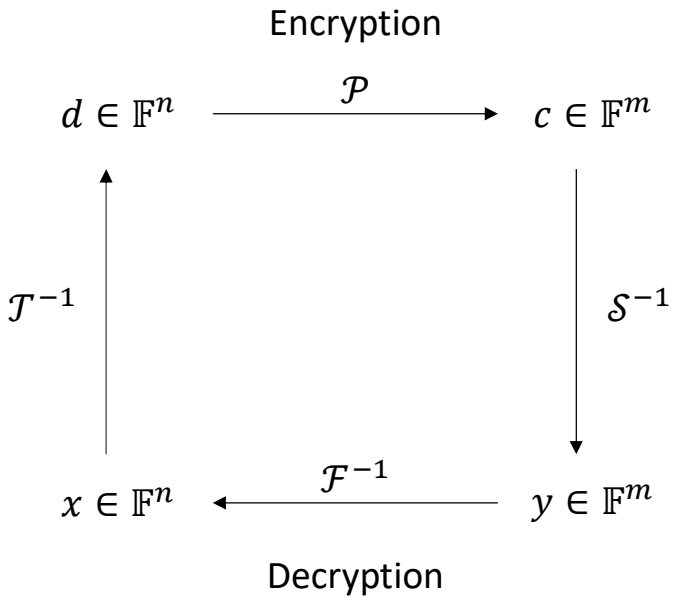
Lattice-Based Cryptography

- First commercial version was NTRU (1996)
- Hard Problems
  - Shortest Integer Solution (SIS)
  - Learning With Errors (LWE)
- Competitive key sizes and fast operations
- Open questions around tightness of reductions
- Risks when used in a static or static/ephemeral environment
- Google public experiments with NewHope in Chrome Canary



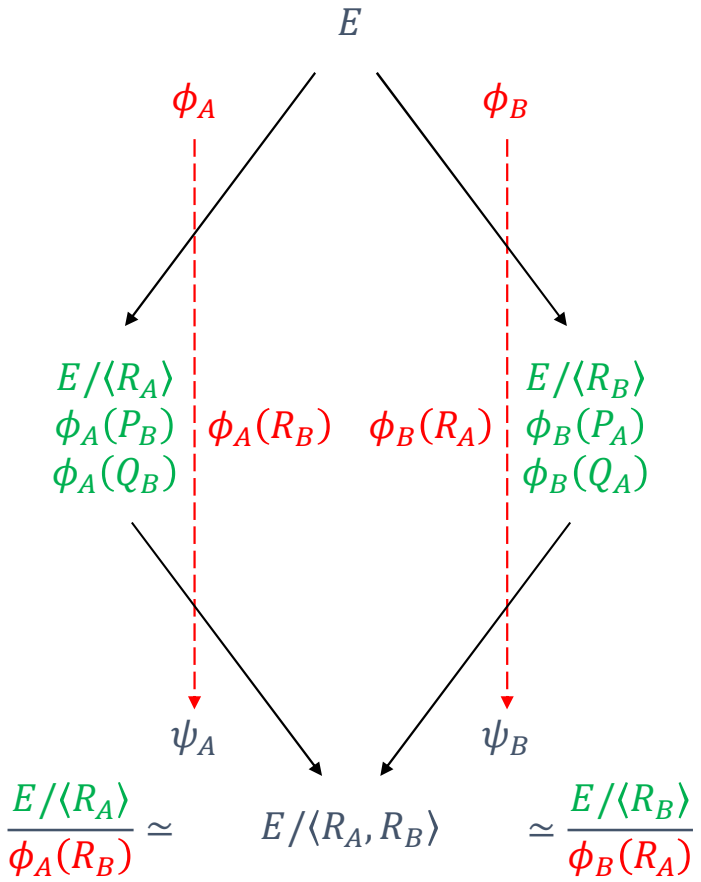
Multivariate-Based Cryptography

- Introduced by Matsumoto and Imai in 1988
- Based on the fact that solving n randomly chosen (non-linear) equations in n variables is NP-complete
- Can be formulated into signatures, key exchange and key transport
- Often trade offs between key size and public/private key operation speeds



Isogeny-Based Cryptography

- Introduced by Jao in 2009
- Relies on difficulty of finding isogenies (mappings) between Elliptic Curves
- Competitive key sizes
- Slower operations
- Risks when used in a static or static/ephemeral way



SUCCESS REQUIRES

STANDARDS

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USING STATEFUL HASH-BASED SIGNATURES

- The math is mature to be used
- ETSI Working Group QSC was first to characterize these signatures
- IETF is in the final stages of specification
- NIST will standardize stateful hashes for code signing
- ISARA successfully implemented LMS and XMSS on an HSM
- The implementation uses tree reduction and state management
- Trees of height 20 provide million+ signatures

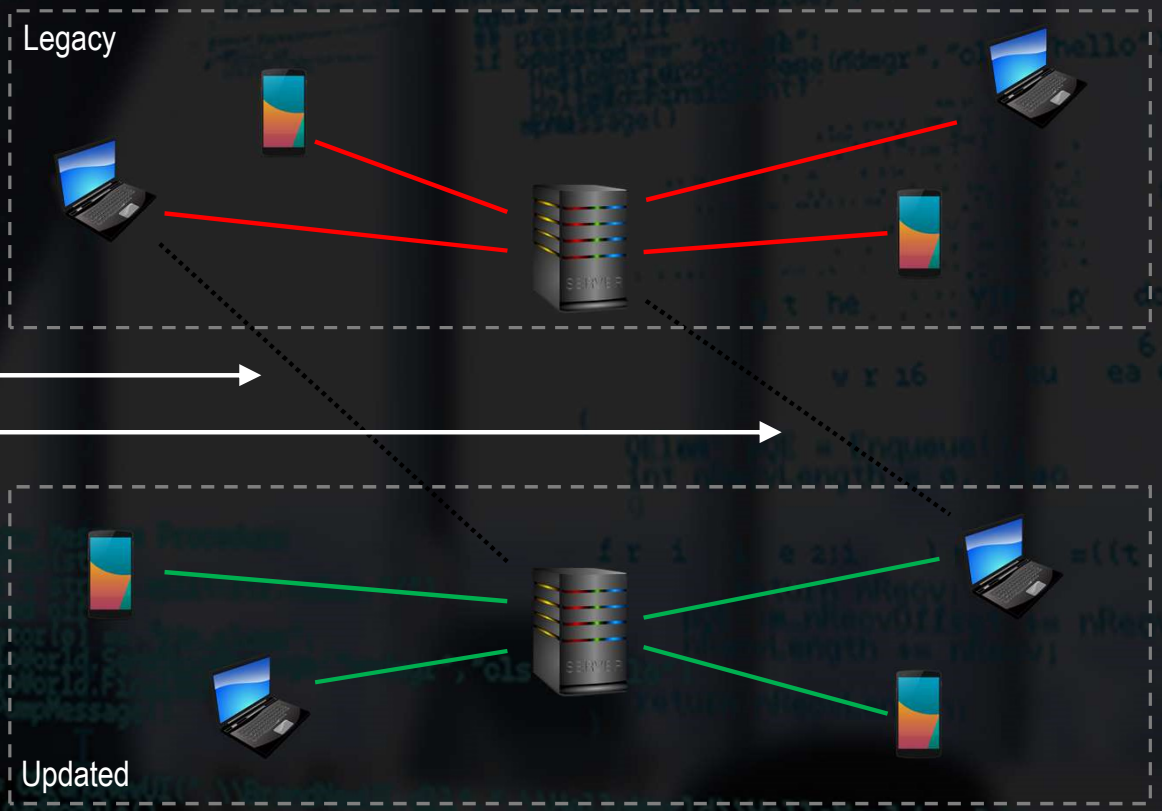
Migration could take years…

Classic Connection

Quantum-Safe Connection

Peers typically can negotiate **key establishment** algorithms

Authentication uses a single algorithm that is used by the PKI-issued certificates



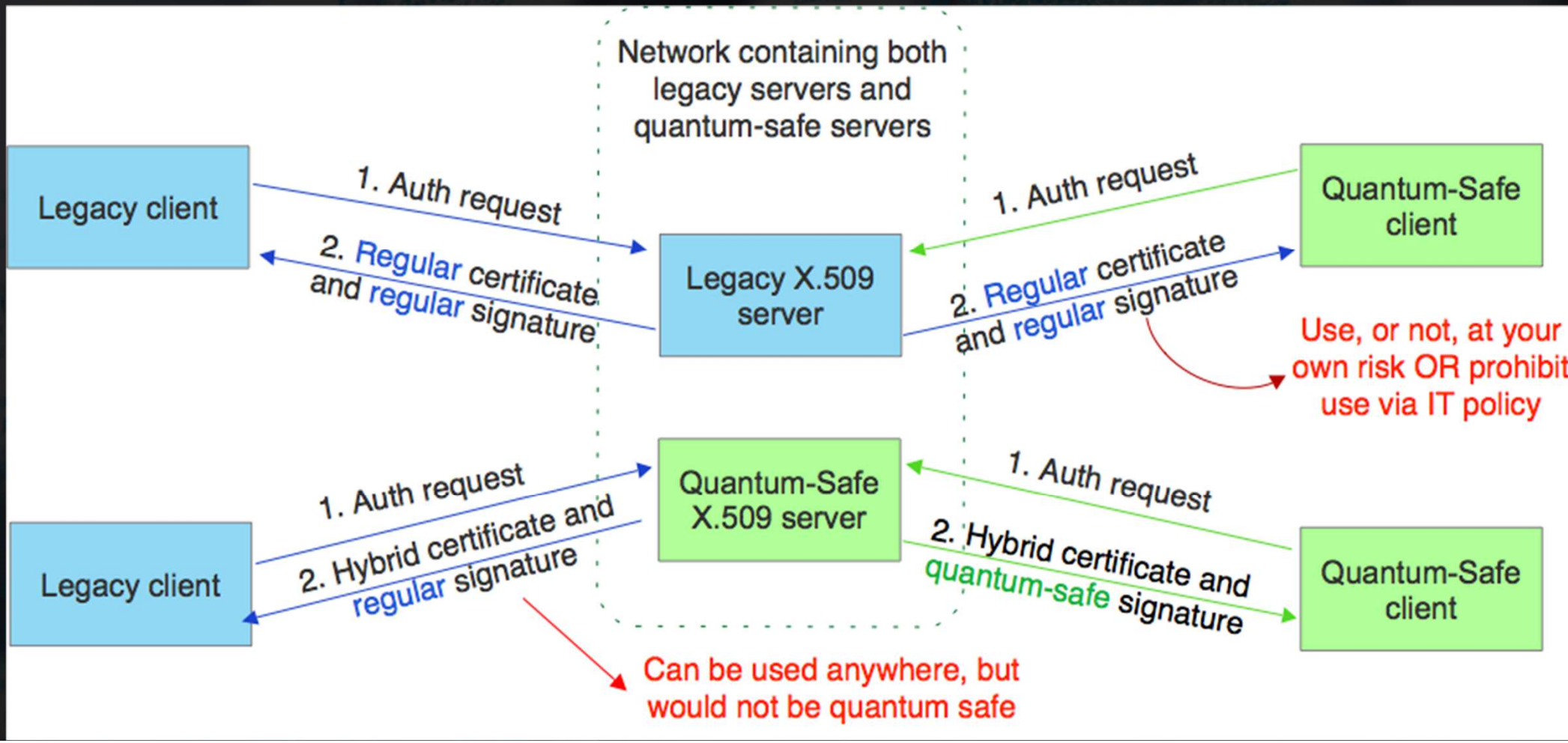
What's needed is crypto-agility

- The concept of crypto-agility is the notion that a given system or subsystem is specified and implemented in such a manner that different cryptographic techniques may be added or removed based on security requirements

X.509 certificate standard made crypto-agile

- The X.509 certificate standard is the most widely-used cryptographic standard in the world
- Recently, the ITU-T SG17 accepted a proposal to update the next version of the ITU Rec. X.509 certificate to be crypto-agile
- The certificate is now able to support multiple signing algorithms, some of which may be quantum-safe

How does a crypto-agile certificate work?

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Mark Pecen

- **Mark Pecen, Chief Operating Officer of ISARA Corporation, which develops security libraries for next-generation networks and computing platforms.**
- **Chairman of the European Telecommunication Standards Institute (ETSI) TC Cyber Working Group for Quantum Safe Cryptography (QSC), in Sophia Antipolis, FRANCE**
- Former senior executive for BlackBerry, Ltd. where he founded the Advanced Technology Research Centre and developed a significant portion of BlackBerry's wireless and networking patent portfolio

- Awarded the title of Motorola Distinguished Innovator and Science Advisory Board member for developing valuable intellectual property for cellular wireless communication – managed professional services for clients in Europe and North America
- Inventor on over 100 patents of technologies adopted globally and used in everyday wireless services, including for the Global System for Mobile Telecommunication (GSM), Universal Mobile Telecommunication System (UMTS), High-Speed Packet Access (HSPA+), Long-Term Evolution (LTE) for 4G wireless and others
- Serves on boards of Mobiquity, Safeguard Scientifics, Rocket Wagon, Swift Labs, Ontario Centres of Excellence, University of Waterloo Institute for Quantum Computing, Wilfred Laurier University School of Business
- Graduate of the University of Pennsylvania, Wharton School of Business and School of Engineering and Applied Sciences