cybersecurity in the quantum era

radu ionicioiu

roqnet

QTSTRAT

plan

i. the quantum threat

ii. two solutions

iii. state-of-the-art

digitalisation: the next frontier

- digital Europe

- government cloud

digitalisation: the next frontier

- digital Europe

- government cloud

cybersecurity is paramount

crypto: we use it every day

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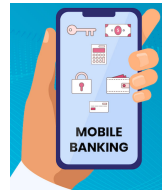
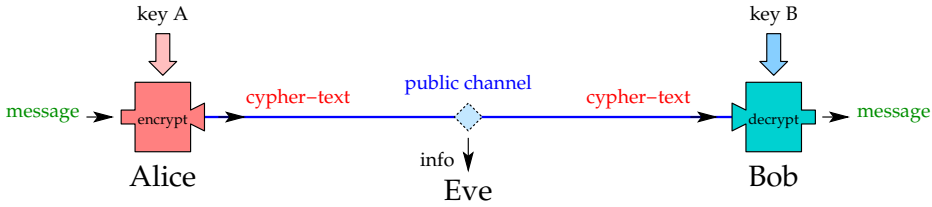


https://

classical crypto



- symmetric: *key A* = *key B* — one-time pad (OTP), AES-256/512
- asymmetric: *key A* ≠ *key B* — public-key, RSA, DH
- authentication, digital signatures, privacy, security

the problem

quantum computers will break internet security

- secure communications
- digital signatures
- mobile networks/5G
- financial transactions
  mobile banking, POS, e-commerce
- authentication
- critical infrastructure
- secure voting
- software updating
  cars, computers

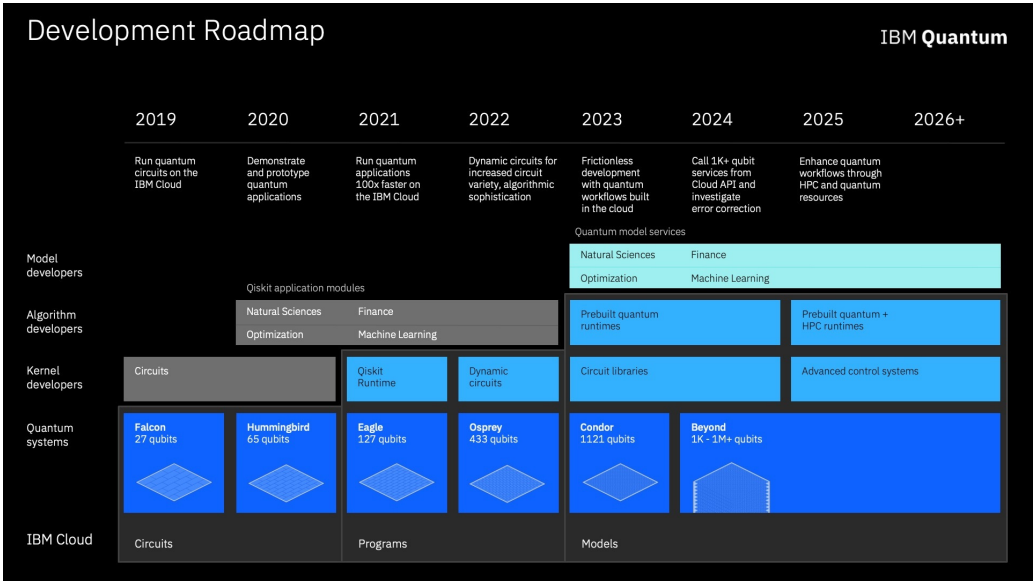
$\Rightarrow$ *need to avoid the Q-Day (quantum apocalypse)*

how serious is the threat?

quantum computing

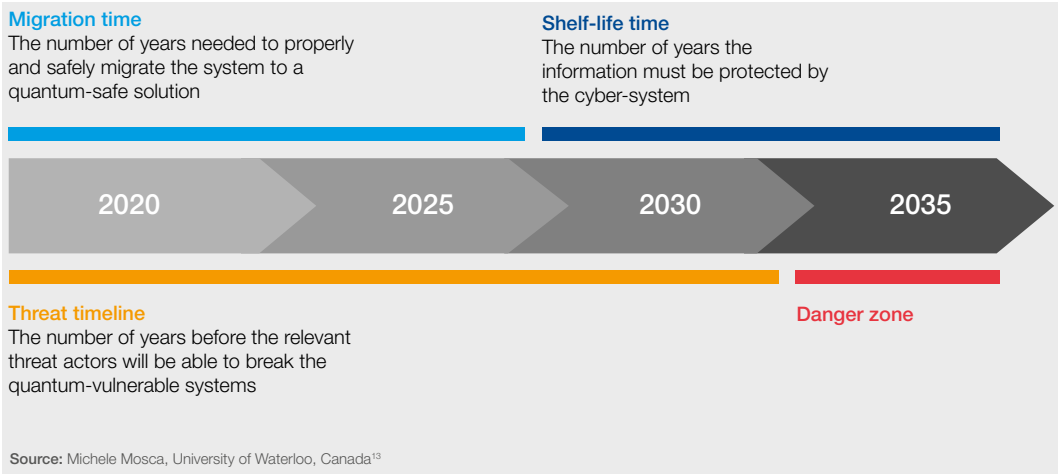
a $65 billion industry by 2030

IBM roadmap



Mosca equation

"store now, decrypt later" (SNDL) attack



Source: Michele Mosca, University of Waterloo, Canada[13]

... any solutions?

Q-Day

two ways out

1. the classical way: post-quantum crypto (PQC)

   find quantum-resistant, public-key classical algorithms $\Rightarrow$ *NIST PQC*

2. the quantum way: quantum key distribution (QKD)

   use the power of quantum + symmetric crypto (AES, OTP)

PKC: status

NOT QUANTUM SAFE

RSA encryption

The hard problem:
Factoring large integers into prime numbers

Diffie-Hellman key exchange

Solving $g^a \bmod p = c$ for a, given g, p and c

Elliptic curve cryptography

Finding the relation between two points on an elliptic curve

QUANTUM SAFE

Lattice-based crypto

Finding the nearest point in a high-dimensional lattice

Code-based crypto

Decoding a certain kind of error-correcting code

Hash-based crypto

Inverting a function that maps an input of arbitrary length to a fixed-length sequence

QUANTUM SAFE?

Multivariate crypto

One scheme broken
February 2022
Solving systems of nonlinear equations in many variables

Isogeny-based cryptography

One scheme broken
July 2022
Finding a map that relates two elliptic curves

https://www.quantamagazine.org

NIST PQC

the finalists

- NIST: PQC selection 2017-2022

type	PKE/KEM	signature
lattice	CRYSTALS-Kyber	CRYSTALS-Dilithium FALCON
hash-based		SPHINCS+

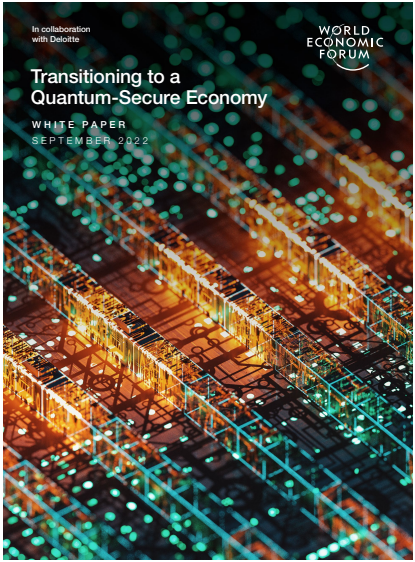
- round 4 launched

World Economic Forum

White Paper, September 2022

”20 billion digital devices will need to be upgraded or replaced with post-quantum crypto in the next 20 years”

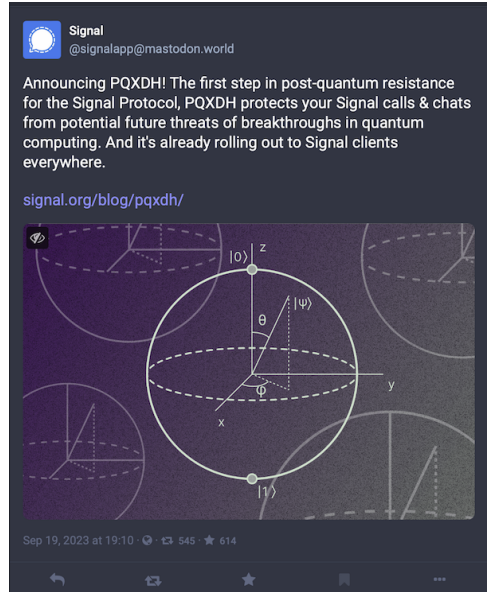
organizations should start planning for the transition now



PQC

deployed now

- signal protocol: enhanced by PQC
- protects from future threats of quantum computers
- chrome: Kyber KEM



the quantum way: QKD

1. use quantum resources to securely distribute keys
2. use keys in symmetric crypto (OTP, AES etc)

quantum solves 2 problems:

- true (quantum) randomness
- secure key distribution
  eavesdropper detected

the quantum way: QKD

why does it work?

- no-cloning theorem $\Rightarrow$ Eve cannot clone an unknown quantum state
- measurement changes a quantum state $\Rightarrow$ higher QBER, detectable

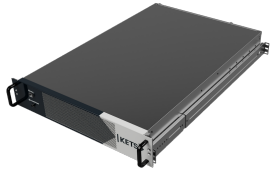
Eve will be detected !

classically impossible

QKD

commercial

- providers: IDQ, ThinkQuantum, Toshiba, QTI, KeeQuant, Kets Quantum, QO Jena, LuxQuanta . . .
- € 150-300 k/pair

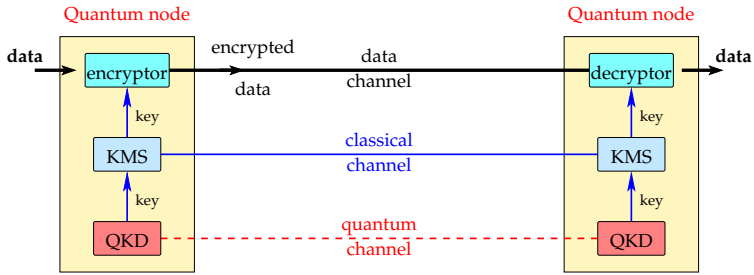


quantum networks

QKD systems: point-to-point $\Rightarrow$ need quantum communication networks

- 1st generation: trusted nodes
  - available now
  - low functionality: key distribution
- 2nd generation: quantum repeaters
  - challenging
  - advanced functionality: entanglement distribution, quantum internet, blind QC

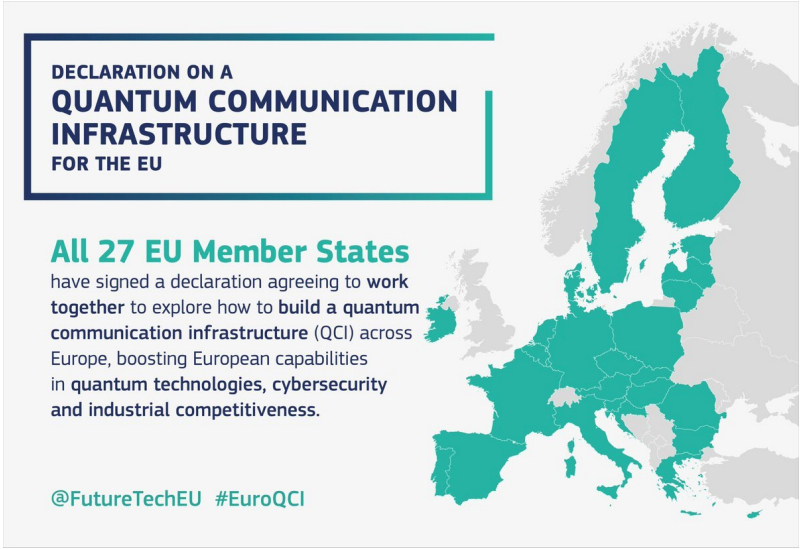
trusted quantum node



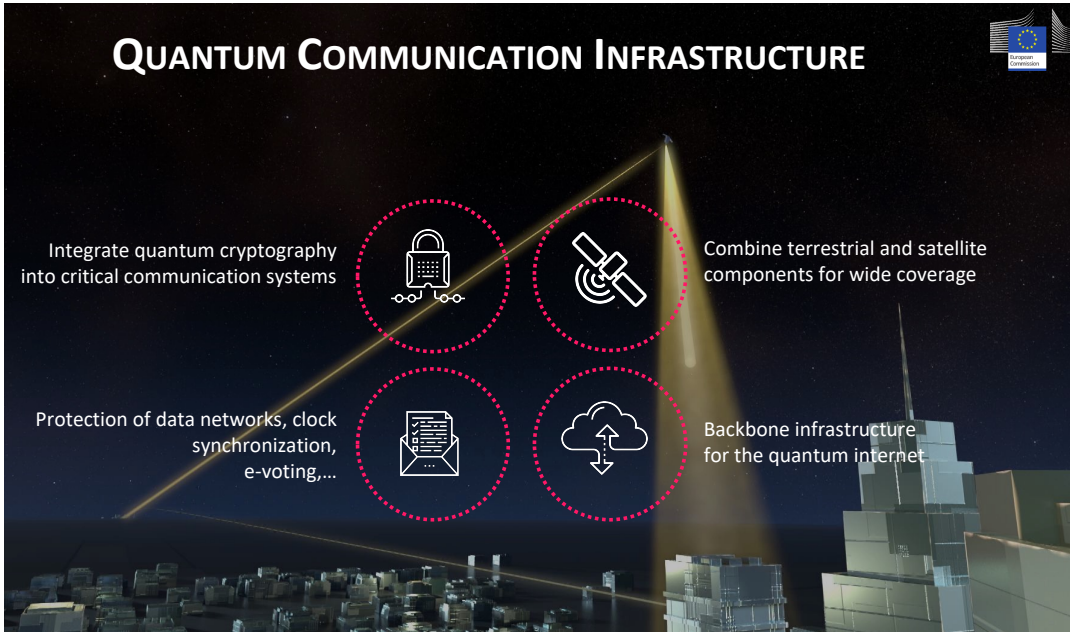
- QKD: establishes secure keys between neighbouring nodes
- KMS: shares keys between distant nodes
- encryptor: symmetric encryption (AES-256/512, OTP)

what's going on worldwide?

EuroQCI



Quantum Communication Infrastructure

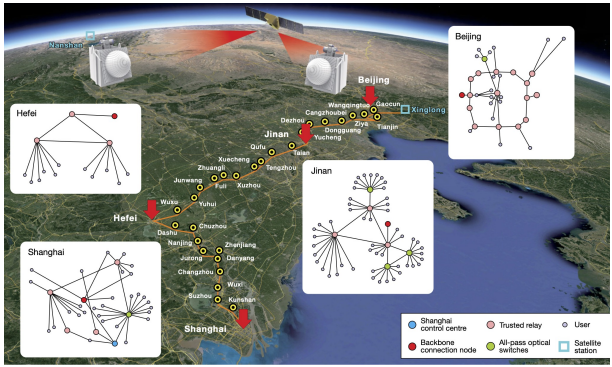


EU + ESA: EuroQCI

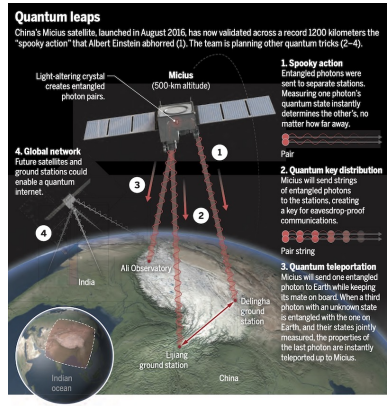
SAGA, Eagle1, Eagle2

China

Beijing-Shanghai quantum backbone, 2000 km (≃ Bucharest-Brussels)



Nature **589**, 214 (2021)



Science **356**, 1110 (2017)

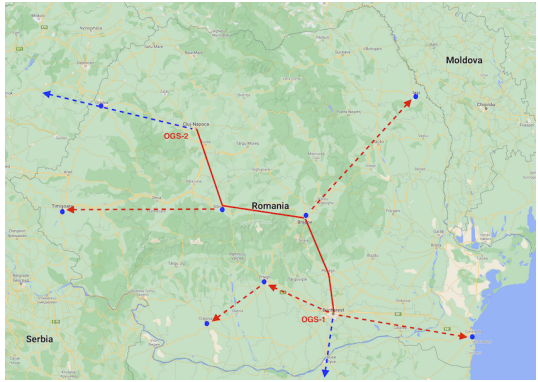
Hefei: 46 nodes intra-city quantum network

RoQCI

2021–

goal: develop the Romanian Quantum Communication Infrastructure

- Phase 1: two intra-city q. networks: Bucharest, Cluj
- Phase 2: National Quantum Backbone (RoQBone): Bucharest–Cluj
- Phase 3: optical ground stations (OGS)
- Phase 4: cross-border links: HU, BG

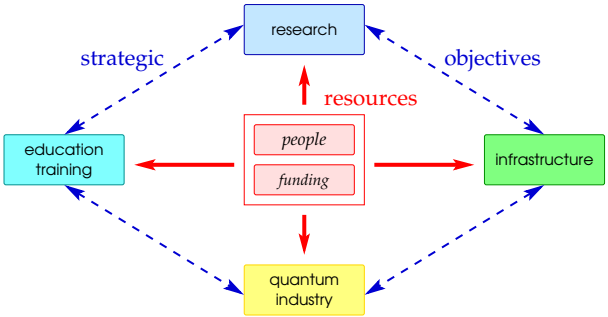


Phase 1,2: Digital Europe Programme (RoNaQCI)

QTSTRAT

RO national strategy in quantum communications

- **Q1. research**
  quantum research hubs
- **Q2. education and training**
  quantum specialists
- **Q3. infrastructure**
  intra-city q. networks, national quantum backbone, cross-border links
- **Q4. quantum industry**
  components, applications, services

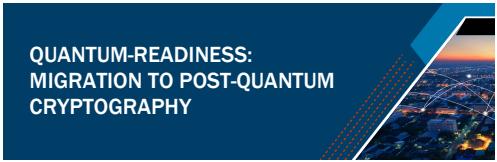


https://qtstrat.granturi.ubbcluj.ro

what to do next?

transition to quantum-resistant crypto

- create a quantum-readiness roadmap
- inventory of quantum-vulnerable systems
- start quantum risk assessment processes
- replace HW, SW that use public-key algorithms with quantum-resistant ones



www.nccoe.nist.gov/crypto-agility-considerations-migrating-post-quantum-cryptographic-algorithms

take home message

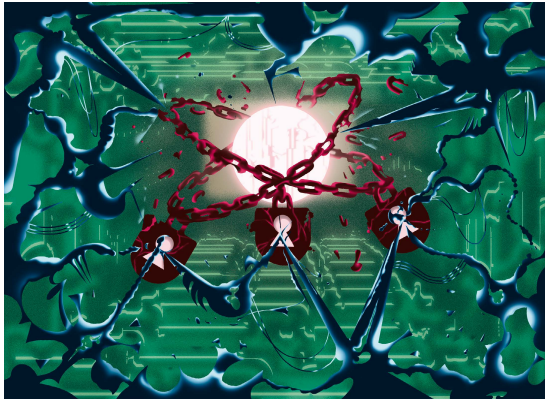
Q-Day is coming

not if, but when

- short term: PQC — deployed now: signal, chrome, ...
- medium term: QKD — safer, but expensive
- long term: quantum internet — full quantum power & functionality

prepare now, be safe later

are you ready?



PREPARING FOR Q-DAY

thank you!

Nature **602**, 198 (2022)