SYNACKTIV

# Beyond post-quantum stereotypes

Antoine Gicquel & Benjamin Sepe

Hack.lu 2025

# About us

SYNACKTIV

**Antoine Gicquel**

Pentester / Security auditor

@bluesheeet.bsky.social

**Benjamin Sepe**

Pentester / Security auditor

@butanol.bsky.social

# Table of Contents

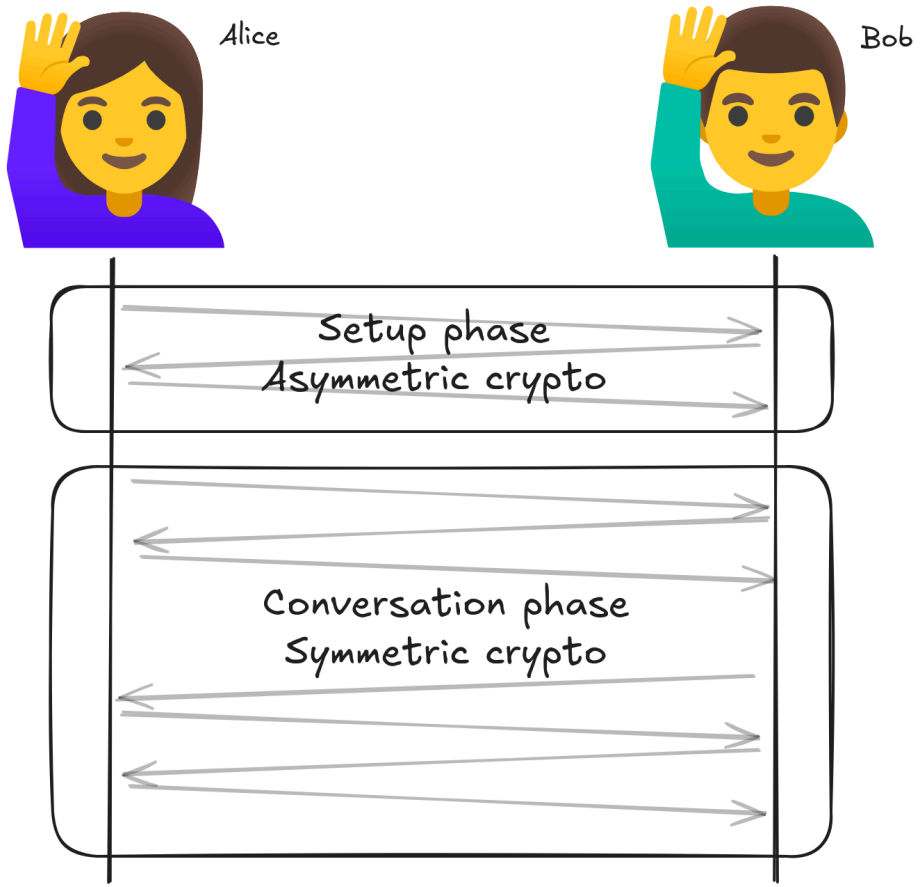
SYNACKTIV

# Refreshers

# Modern crypto 101

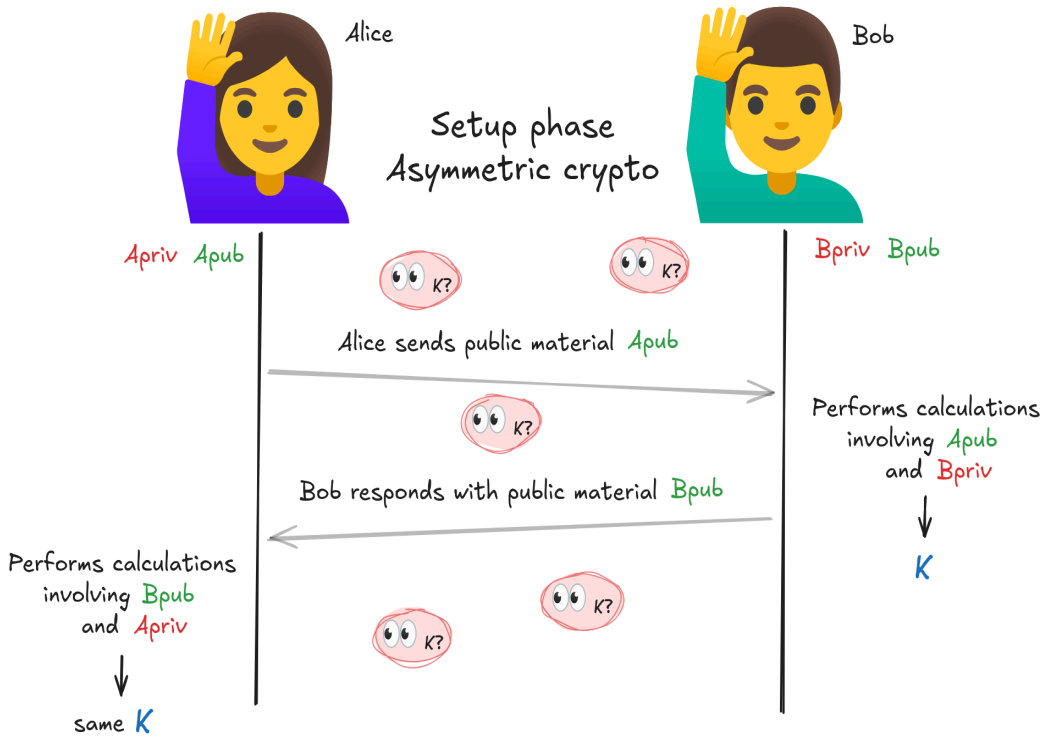
SYNACKTIV

- **A simple goal**: to enable *Alice* 🙋‍♀️ and *Bob* 🙋‍♂️ to have a secure conversation
- **A smart combination of two paradigms**
  - **Asymmetric (Public-Key) Cryptography**: For the initial setup
  - **Symmetric Cryptography**: For the actual conversation



# Modern crypto 101

## Key Exchange



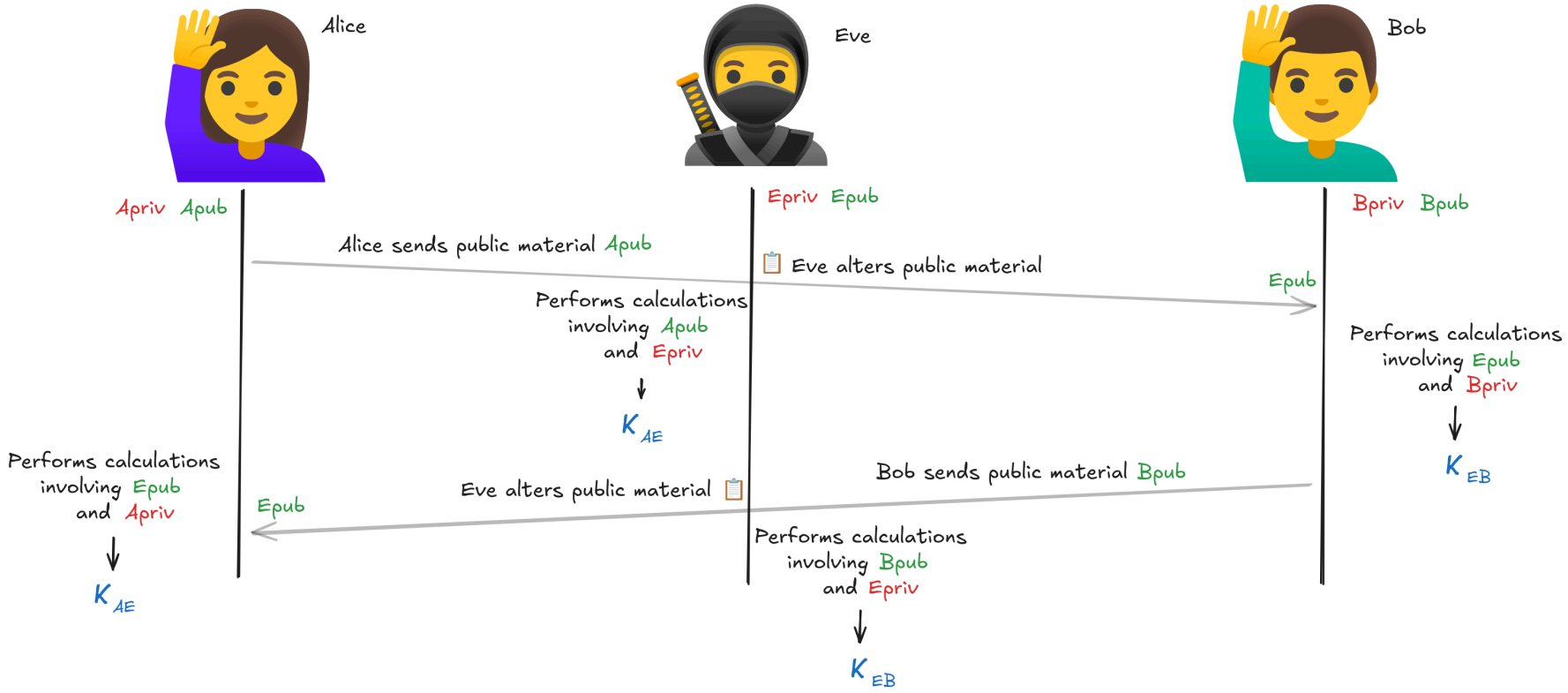

- **Securely agree on a shared secret key** thanks to asymmetric crypto
- **Over the untrusted internet**
- **Follow-up messages can be encrypted with $K$**

# Modern crypto 101

Trust

SYNACKTIV

## How can Alice trust Bob's public key?

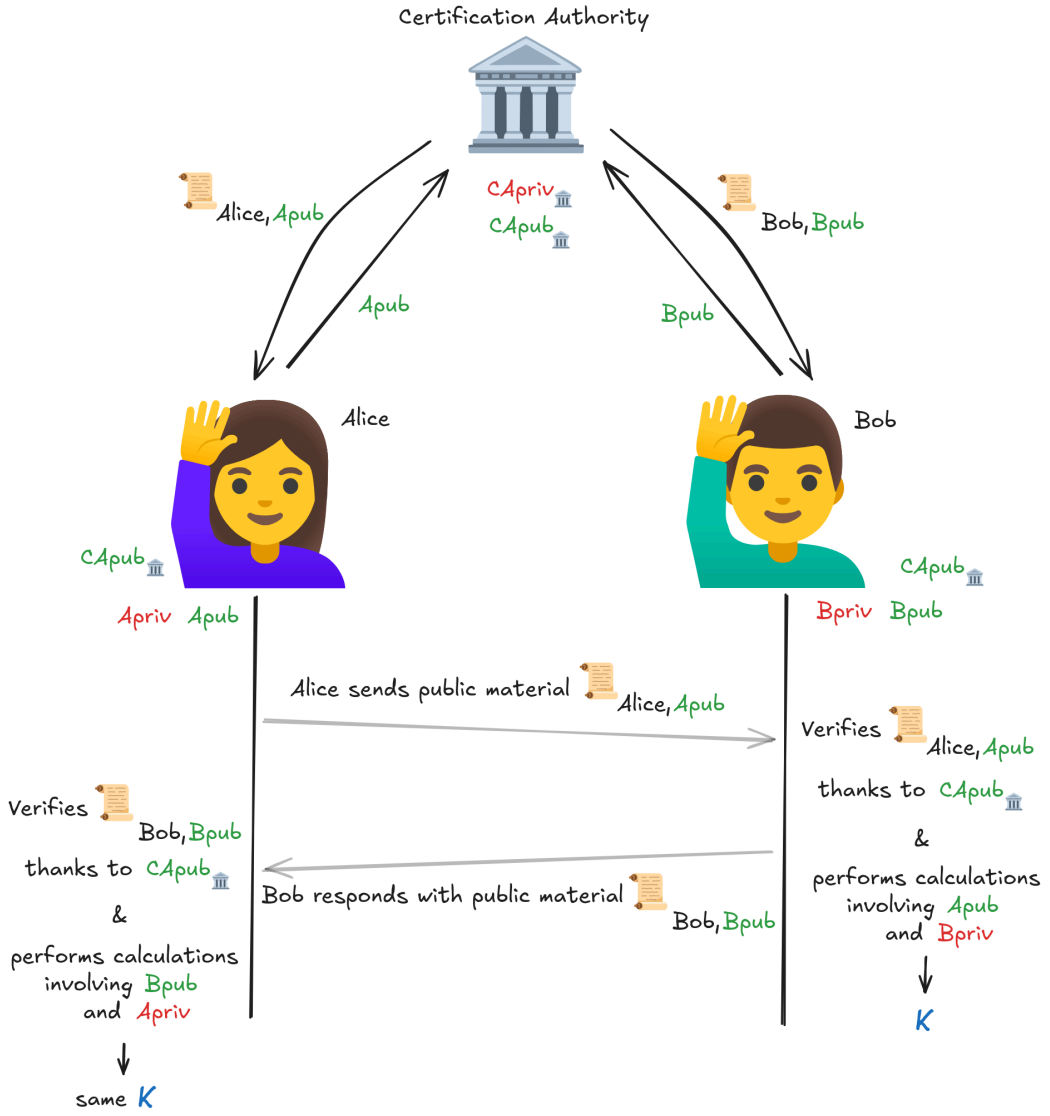


# Modern crypto 101

📜 Certificates and signatures

SYNACKTIV

- **Signature from a trusted Certificate Authority (CA)**
- It links a public key to an identity (Bob)
- Alice verifies the CA's signature thanks to a pre-trusted CA public key




**That's basically TLS!**

# Modern crypto 101

Security

SYNACKTIV

- **Communications mainly rely on 3 primitives**
  - Signing data
  - Establishing a shared secret
  - Encrypting with symmetric algorithms
- **Security = difficulty for an attacker to falsify or decrypt information**
- **Difficulty = number of computational operations**
- **Good security: >$2^{100}$ operations**, impractical even in the next few decades
- **Example: AES-128**, symmetric scheme, best attack is bruteforcing the key, $2^{128}$ op.

# A quantum threat to security

# Quantum Computing vs. Crypto

SYNACKTIV

- **Based on new principles**: Uses **qubits** instead of *classical* bits
- **Superposition**: Wave function, probability to read $0$ / $1$ for each bit
- **Entanglement**: Qubits can be linked, their states correlated
- Quantum computers can solve certain problems exponentially faster

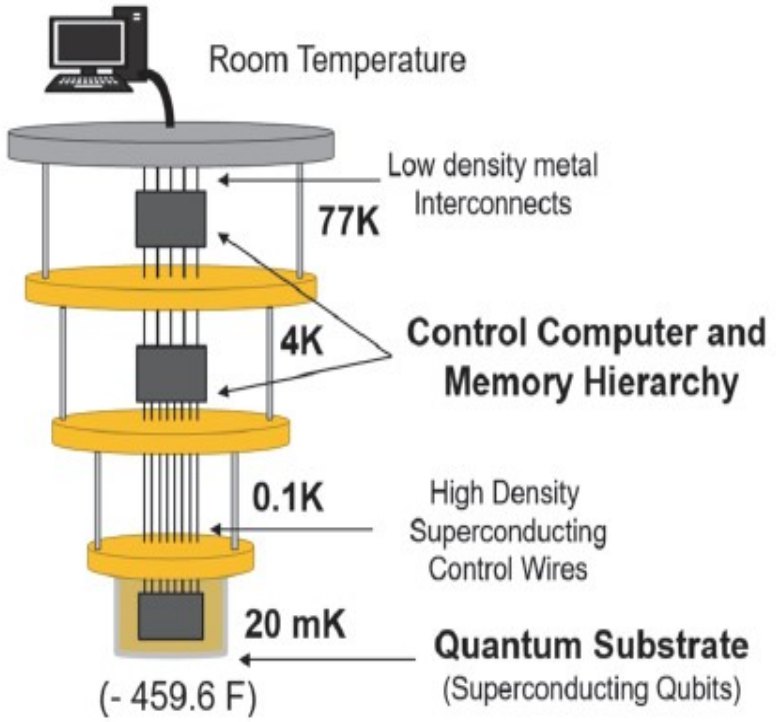



Image source: https://attend.ieee.org/qc-dcep/purpose/

# Quantum Computing vs. Crypto

SYNACKTIV

- **Shor's Algorithm:** finding periods in any function ( $n^3$ )
  - **Breaks integer factorisation & discrete log**
  - **Asymmetric crypto in danger**
  - **Example:** factoring a 2048-bit integer
    - **Classical:** $2^{112}$ operations → **secure** ✅
    - **Quantum:** $2048^3$ ($\sim 2^{33}$) operations → **insecure** ❌
- **Grover's algorithm**: enhancing bruteforce, quadratic speedup ( $2^n \rightarrow 2^{n/2}$ ) [1]
  - **Symmetric crypto in danger**
  - **Example:** AES-128
    - **Quantum: ~$2^{64}$** operations → **insecure** ❌
    - **AES-256 stays secure vs. quantum computer**, **~$2^{128}$** operations → **secure** ✅

1: https://davidbkemp.github.io/animated-qubits/grover.html

# The impacts on our secure channel

SYNACKTIV

So, what breaks in our Alice and Bob setup?

- **Key exchange (DH, ECC)**: **broken!** ❌
  - Shor's algorithm solves their underlying math problems
- **Digital signatures (RSA, ECDSA)**: **broken!** ❌
  - Also vulnerable to Shor. Certificates can be forged
- **Symmetric encryption (AES)**: **weakened!** ⚠️
  - Grover's algorithm halves the effective key length
  - *Use AES-256 instead of AES-128*

# Upgrading to post-quantum...

# Upgrading to post-quantum

SYNACKTIV

- **Need to find new math problems** that are hard for both classical and quantum computers
  - **Lattice-based problems**: ML-KEM, ML-DSA, Falcon, …
  - **Code-based problems**: BIKE, HQC
  - **Hash-based problems**: SLH-DSA, XMSS
  - **Multivariate Quadratic polynomial equations**: UOV
  - **…**
- **These algorithms run on classical computers**
  - Post-quantum is **not** quantum

# Upgrading to post-quantum

## Hybridization

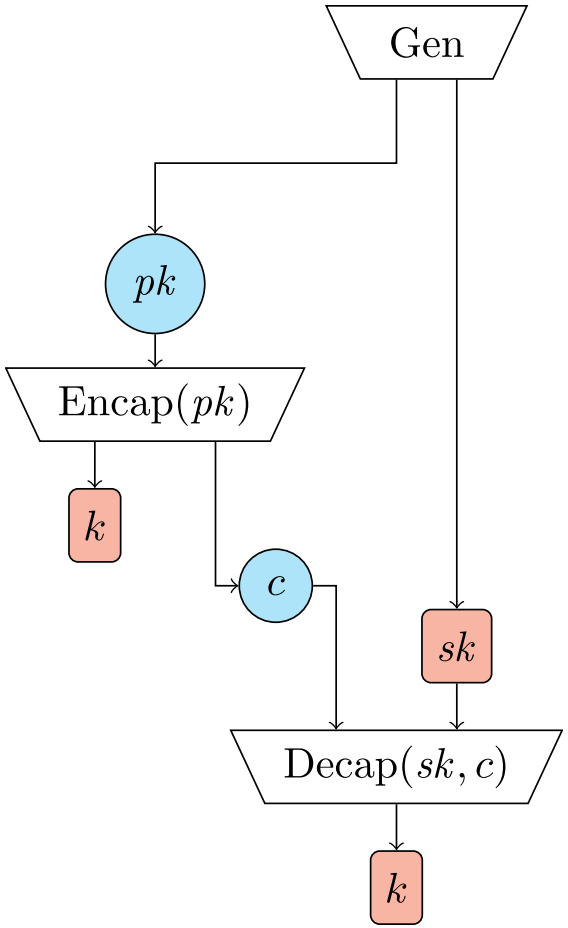
SYNACKTIV

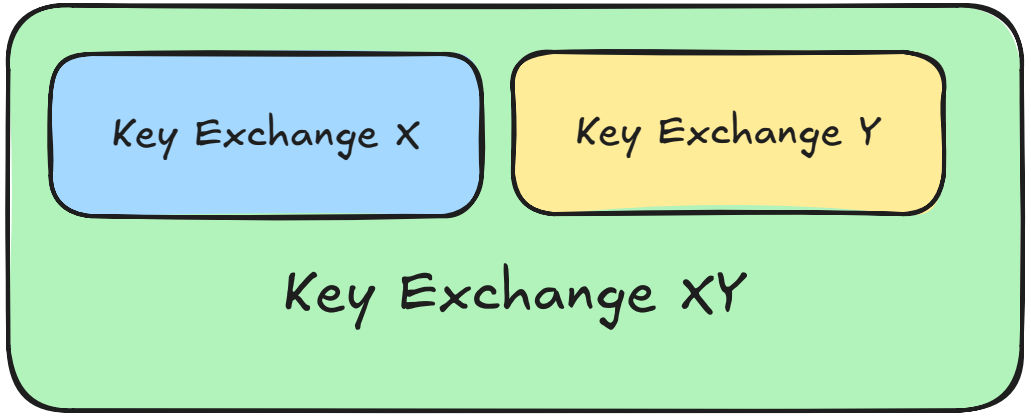
- **New algorithms are not "battle-tested"** 🪖
  - e.g., SIDH, a former candidate, was broken in 2022
- **→ Hybridization**
  - Combine a classical algorithm (e.g., ECDH) with a PQC one (e.g., ML-KEM)
  - Security is at least as good as the strongest of the two
  - A crucial safety net if the PQC algorithm fails
  - See the recently-published articles on the Synacktiv blog [1] [2]

1: https://www.synacktiv.com/en/publications/quantum-readiness-hybridizing-key-exchanges
2: https://www.synacktiv.com/en/publications/quantum-readiness-hybridizing-signatures

# Upgrading to post-quantum

## Hybridization



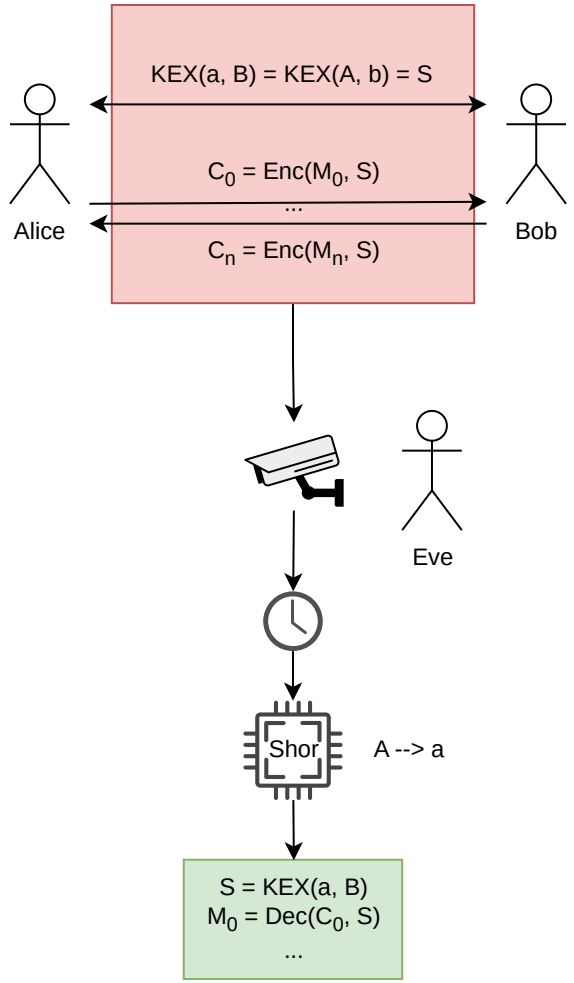

Left: https://en.wikipedia.org/wiki/Key_encapsulation_mechanism

# Upgrading to post-quantum

Issues to tackle

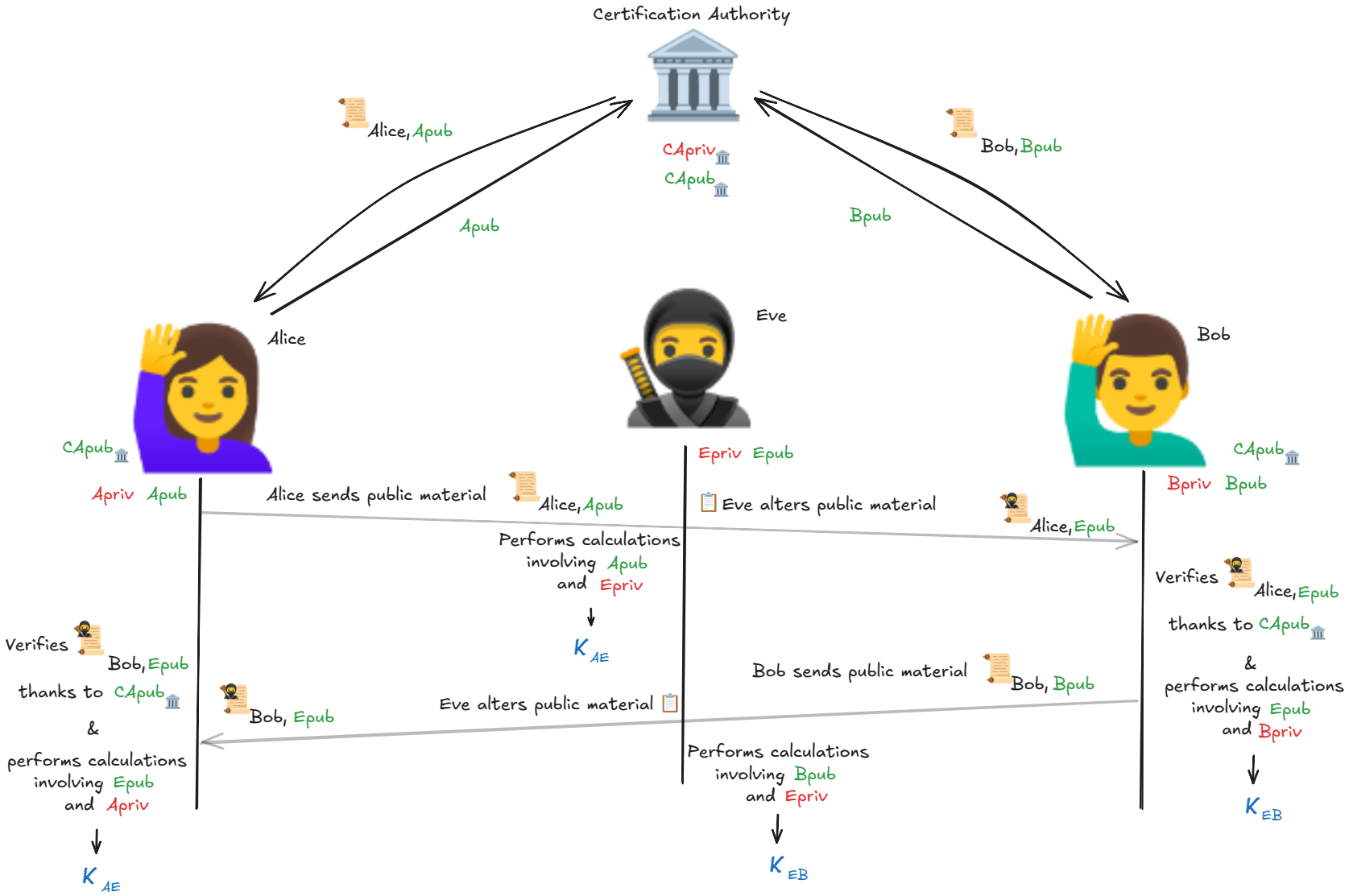
SYNACKTIV

- **Today's issue**: Store now / Decrypt later
  - Upgrade key exchanges ASAP!
- **Tomorrow's issue**: Authenticating
  - Signature forgery with quantum computing
  - Update your keys / certificates to use PQ signature schemes
  - Needs regeneration of all secrets



# Upgrading to post-quantum

## Signature forgery



# Upgrading to post-quantum

For organizations

SYNACKTIV

- **Pre-requisite**: *What crypto do I use? Where do I use it in my organization?*
- **PQ transition may already have started in your organization**
  - Chrome >131 sends ClientHello with Hybrid ML-KEM / X25519 by default [1]
  - CloudFlare / Google / Azure support Hybrid ML-KEM / X25519
  - All major web reverse proxies support Hybrid ML-KEM / X25519 in their latest version
  - Recent OpenSSH (client & server) uses hybrid key exchange by default

1: https://developers.cloudflare.com/ssl/post-quantum-cryptography/pqc-support/

# Upgrading to post-quantum

For organizations

SYNACKTIV

- **So it's *that* easy?**
  - You may use other stuff (MACSec? Exotic VPN?) with no automatic update process
  - Microsoft is *actively working to get PQC support to [their] Windows customers via the Windows TLS stack (Schannel)* [1]
  - All of the previous is for key exchanges, don't forget signatures !!
- **Check your infra and contact vendors!**

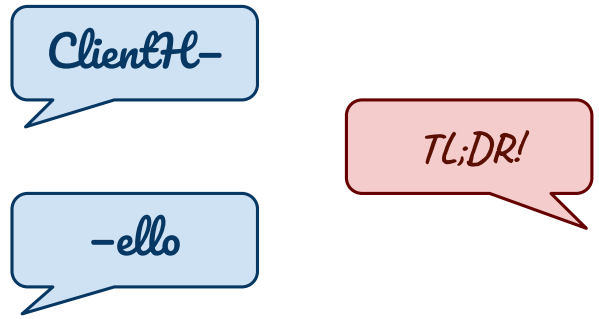
1: https://techcommunity.microsoft.com/blog/microsoft-security-blog/post-quantum-cryptography-comes-to-windows-insiders-and-linux/4413803

# Upgrading to post-quantum

Some bugs along the way

SYNACKTIV

- ⚠️ **PQC algorithms have much larger keys and signatures**
- **Sometimes broke existing protocols and systems**[1]
  - Large PQC keys may not fit in a single TCP packet
  - → fragmented ClientHello / ServerHello
  - Packet fragmentation can cause network gear to fail




1: See https://tldr.fail/ & https://blog.cloudflare.com/post-quantum-to-origins/#when-things-break-and-how-to-move-forward

# … and auditing it!

# … and auditing it!

SYNACKTIV

The math is new, but the audit process is not.

**Auditing PQC implementations is like auditing classical crypto.**

- **Verify standards compliance**
  - Uses standard parameters (e.g., NIST FIPS 204)?
  - Passes all official **test vectors**?
- **Hunt for implementation bugs and leaks**
  - Random number generation
  - Key management
  - Look for common **side-channel vulnerabilities**
    - **Timing attacks**: Is execution time constant?
    - **Cache attacks**: Do memory access patterns leak secrets?
    - **Physical attacks**: Power analysis, EM emissions, …

**If you can audit classical crypto implementations now, you can audit PQ crypto implementations now.**

# Questions ?

SYNACKTIV

https://www.linkedin.com/company/synacktiv

https://x.com/synacktiv

https://bsky.app/profile/synacktiv.com

https://synacktiv.com