Post-Quantum Digital Signatures

QuData Project Kick-Off

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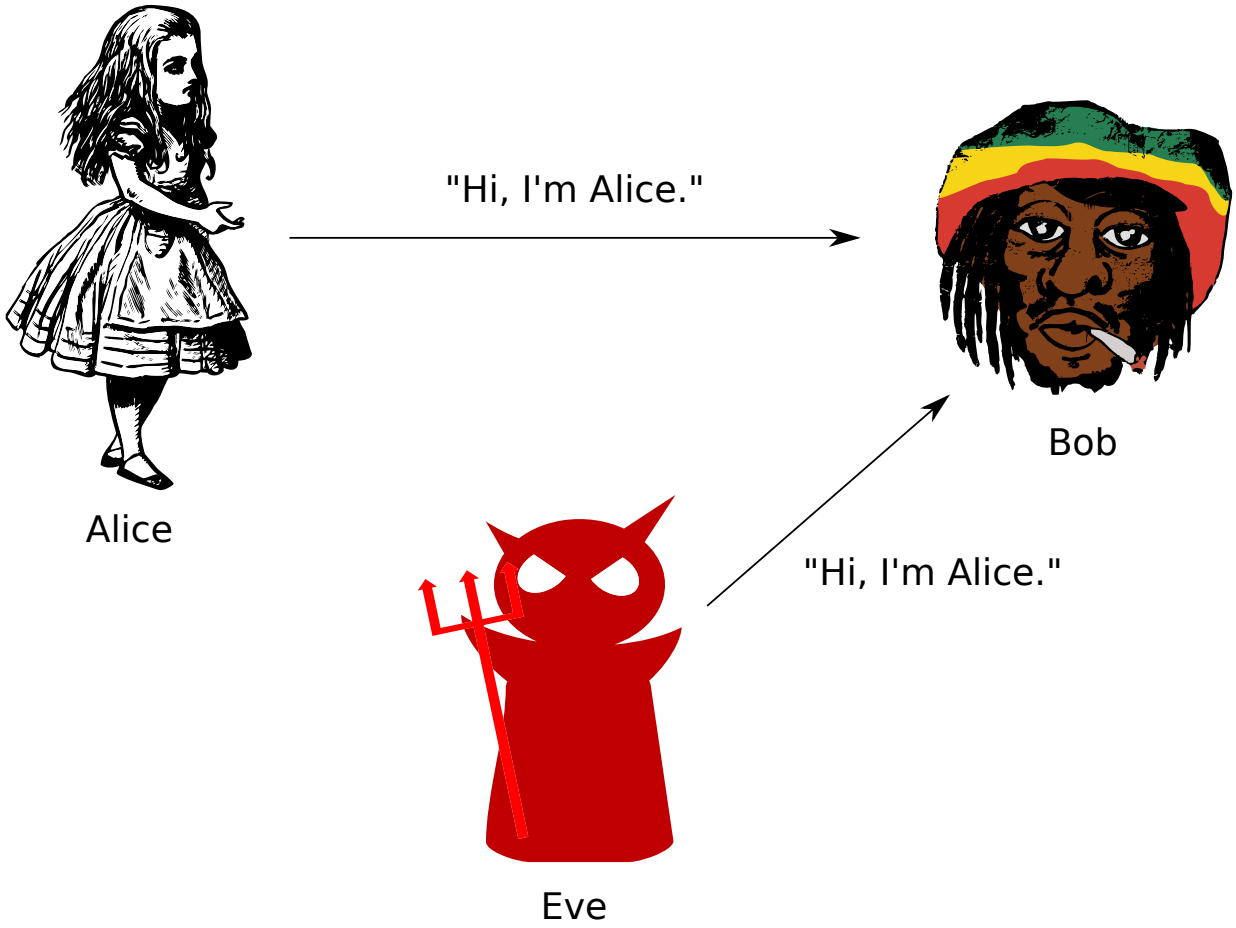
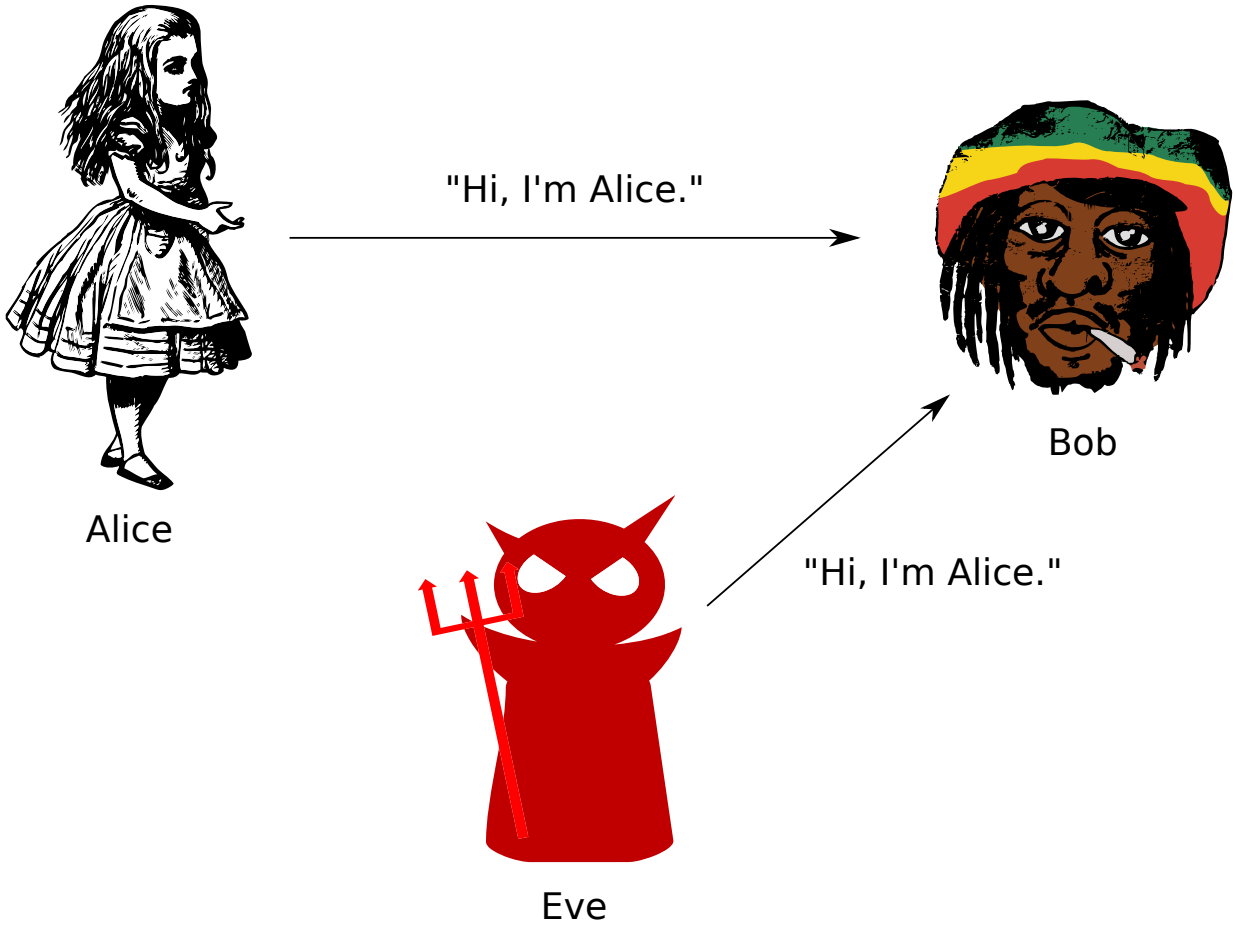
Alice

"Hi, I'm Alice."

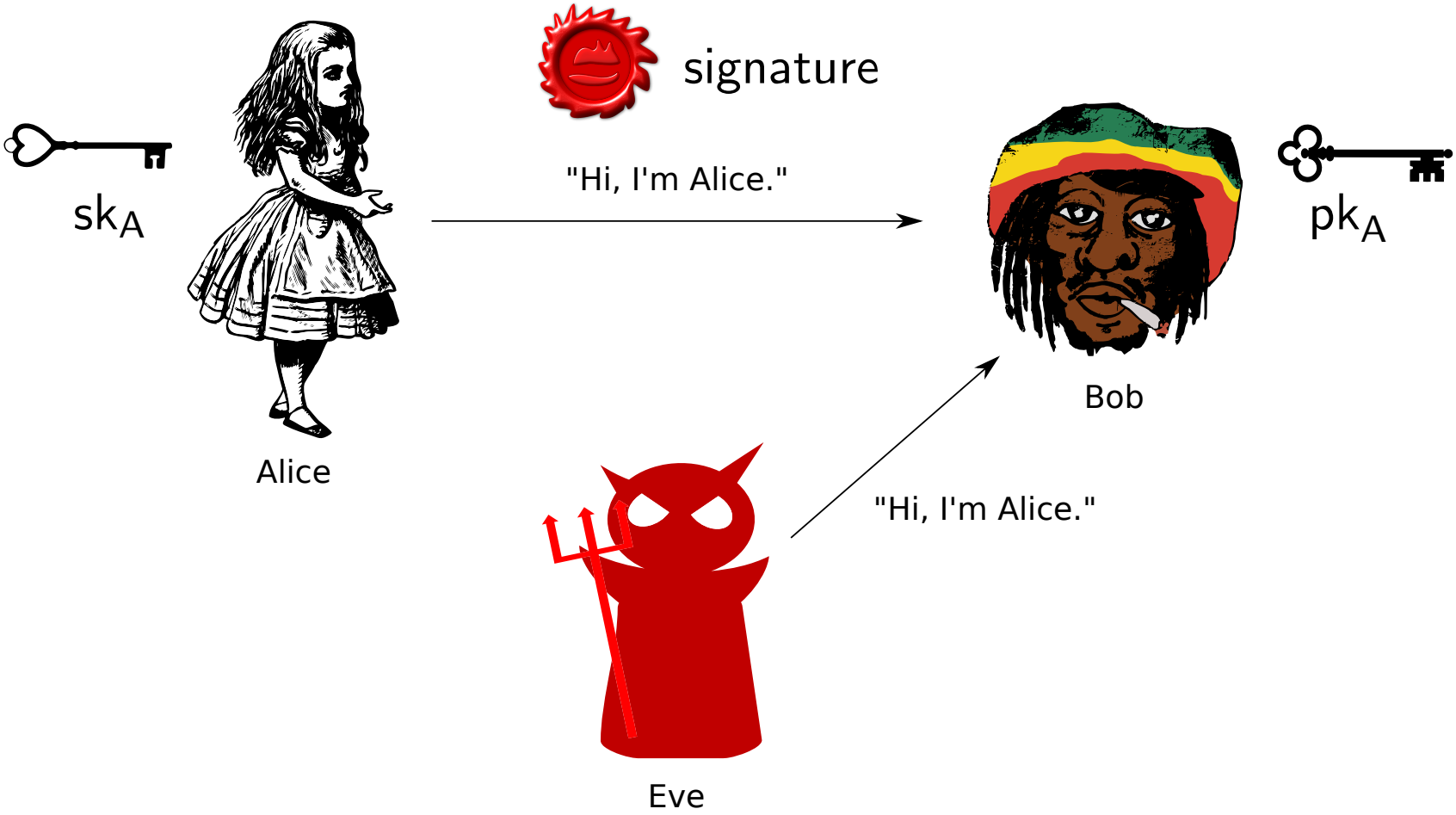
Bob


"Hi, I'm Alice."
Alice
Bob
"Hi, I'm Alice."
Eve

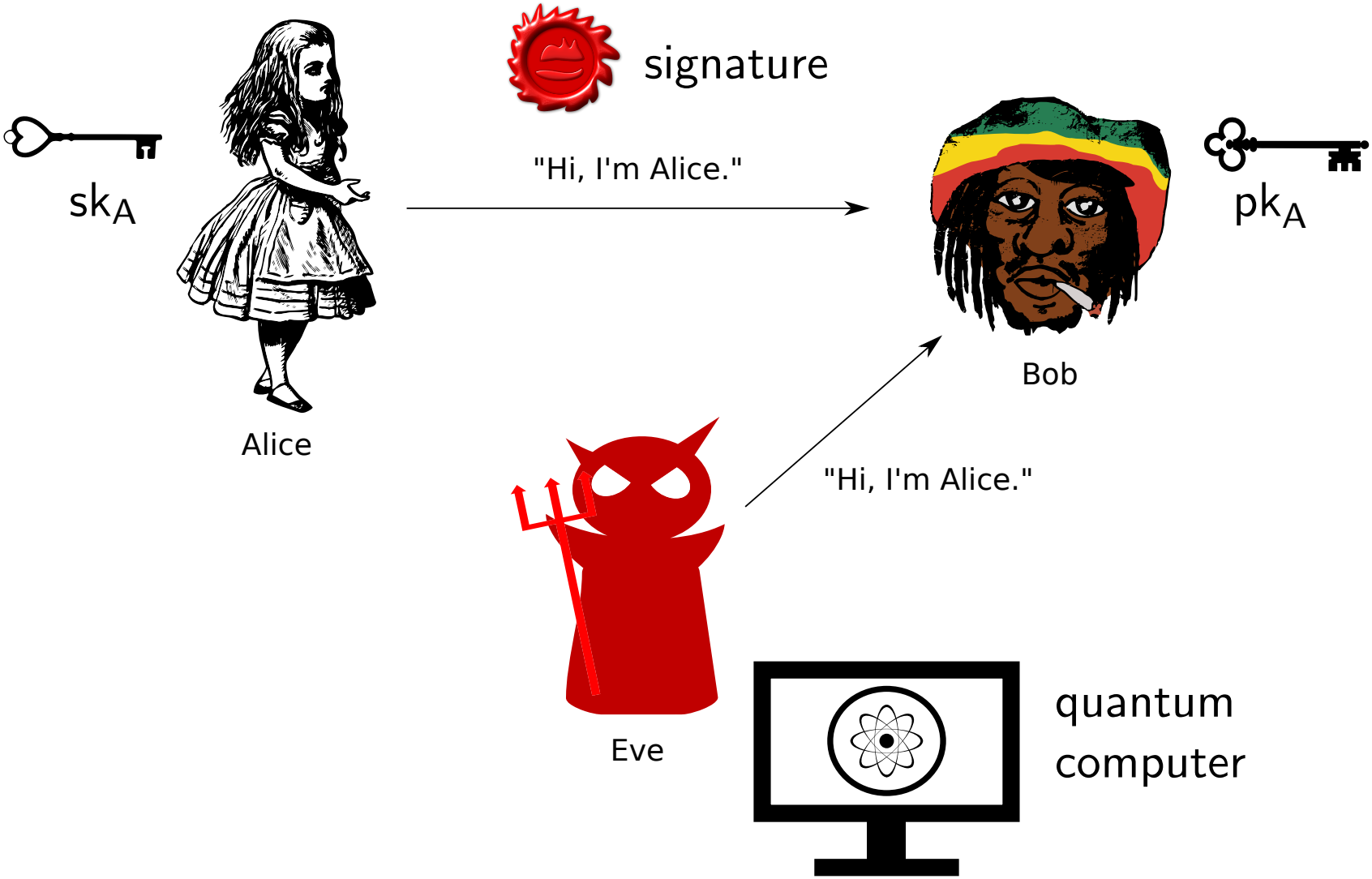
Authenticity and Integrity



Authenticity and Integrity



Authenticity and Integrity



Hard number-theoretic problems

Easy for quantum computers:

- Factoring
- Discrete logarithms

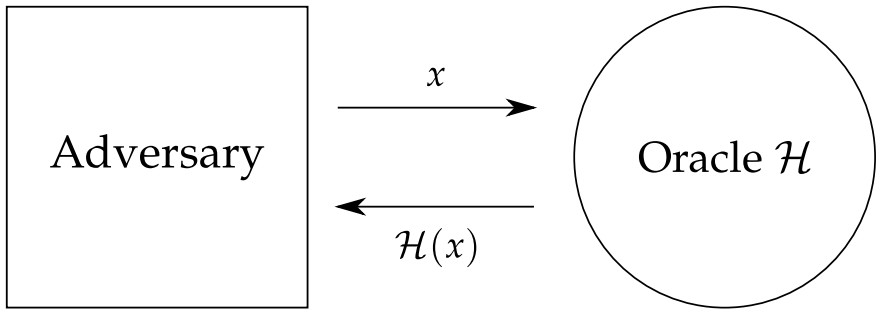
Problems assumed to be hard even for quantum computers based on:

- Coding theory
- Lattices
- Multivariate equations
- Isogenies between supersingular elliptic curves
- Mersenne primes
- ...

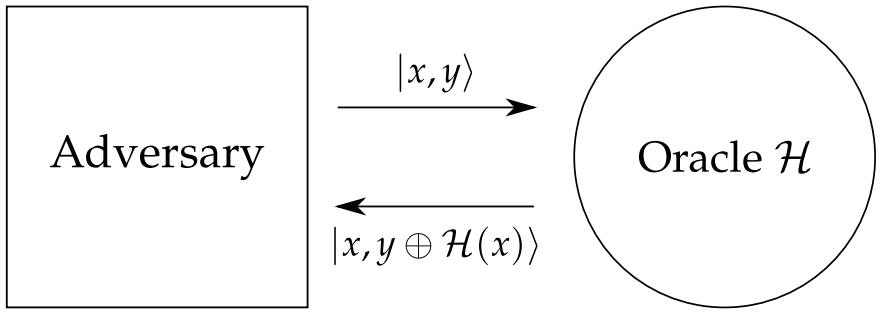
(Quantum) random oracle model

Hash functions have public descriptions: everybody can locally implement them

Classical ROM:



Quantum ROM:



(Quantum) random oracle model

How do quantum computers make the life of cryptographers harder?

- Quantum computers allow for faster attacks on symmetric cryptography, e.g.
  - Grover search for pre-image finding
  - Quantum collision search
- Some classical proof strategies in security reductions do not directly translate to the QROM, e.g.
  - Rewinding the adversary
  - Storing the state of an adversary

3-pass identification schemes

sk_A

Prover(sk) **Verifier**(pk)

$\mathsf{com} \leftarrow \mathcal{P}_0^{\mathsf{sk}}()$

com $\longrightarrow$

$\mathsf{ch} \leftarrow\!\!\$\ \mathit{ChSet}$

ch $\longleftarrow$

$\mathsf{resp} \leftarrow \mathcal{P}_1^{\mathsf{sk}}(\mathsf{ch})$

resp $\longrightarrow$

$\mathcal{V}^{\mathsf{pk}}(\mathsf{com}, \mathsf{ch}, \mathsf{resp})$?

pk_A

From ID to signature schemes

- 1987: Fiat-Shamir transform [FS87]
  - Security proof (only) in the Classical ROM
- 2014: Unruh transform [Unr14]
  - Security proof in the Quantum ROM
  - Large signatures
- 2017: Lossy Fiat-Shamir transform [KLS17]
  - Security proof in the Quantum ROM
  - Smaller signatures (than Unruh transform)
  - Additional requirement: lossy key generator

State of the art

128-bit post-quantum security level (all sizes in bytes)

Signature scheme	based on	sig size	sk size	pk size
Lossy-Stern-FS	**codes**	**218,485**	**32**	**218**
SOFIA-4-128	multivariate	126,176	32	64
Picnic-10-38	purely symmetric	195,458	32	64
SPHINCS$^+$-256f	hash-based	16,976	64	32
Elliptic Curve DSA	*pre-quantum*	*64*	*32*	*64*

Future work

Design shorter and more efficient signatures!
(without losing security)

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