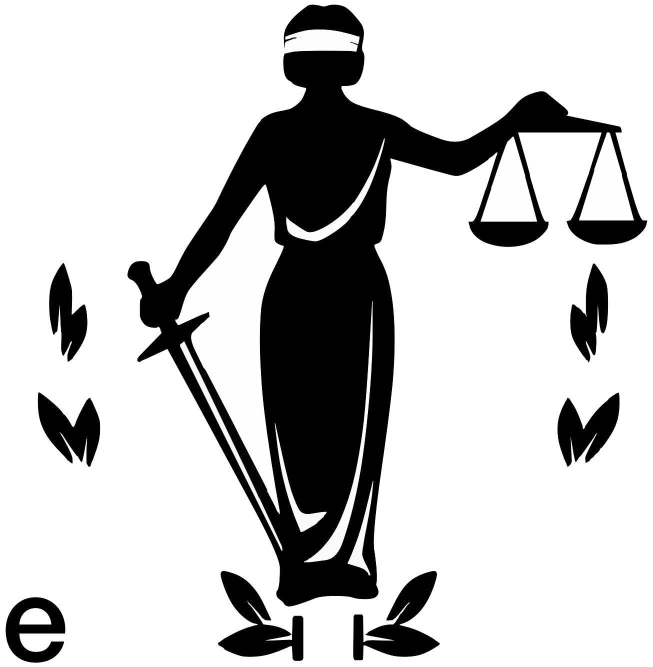

Quantum secure message authentication via blind-unforgeability

Christian Majenz

Joint work with Gorjan Alagic, Alexander Russell and Fang Song

QCrypt 2018, Shanghai, China

QuSoft Research Center for Quantum Software

UCONN

Portland State University

Joint Center for Quantum Information and Computer Science

Message authentication

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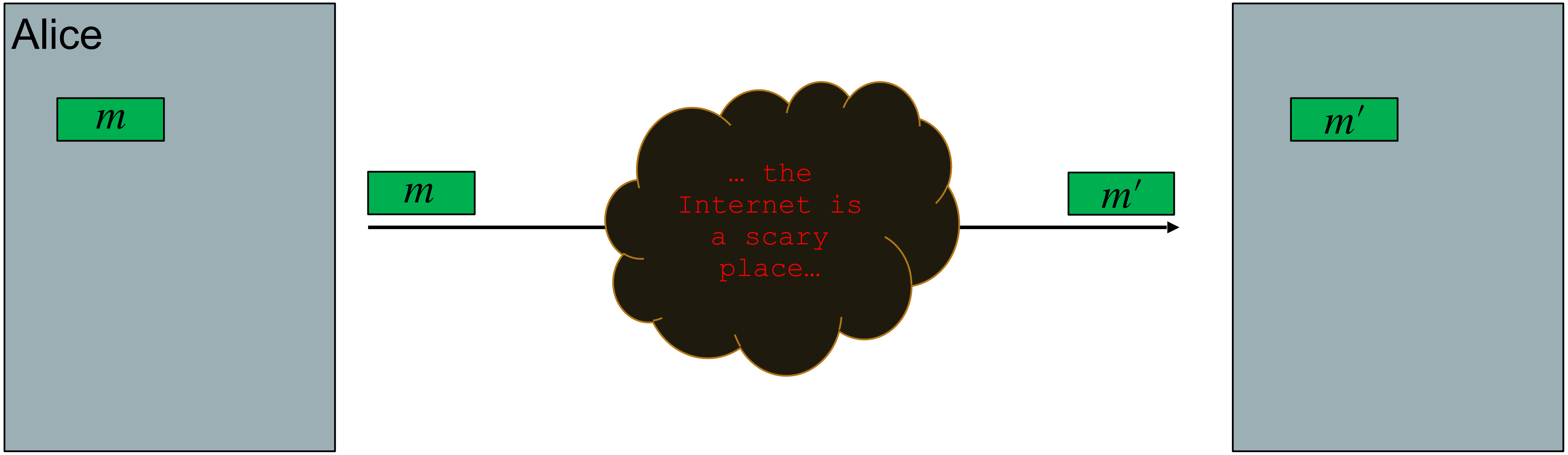

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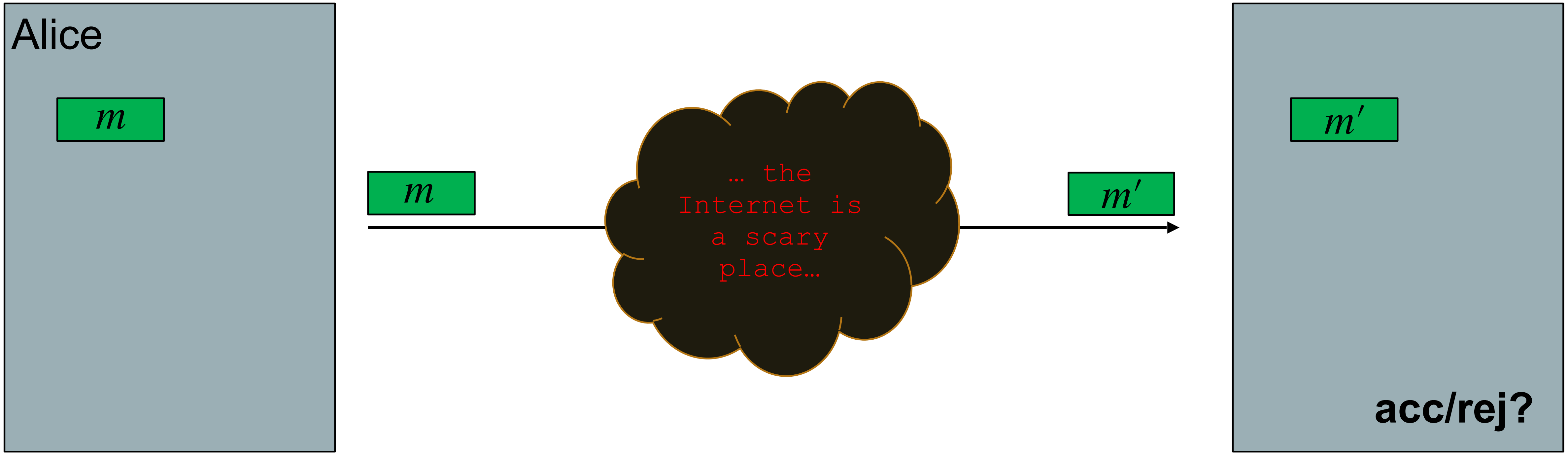

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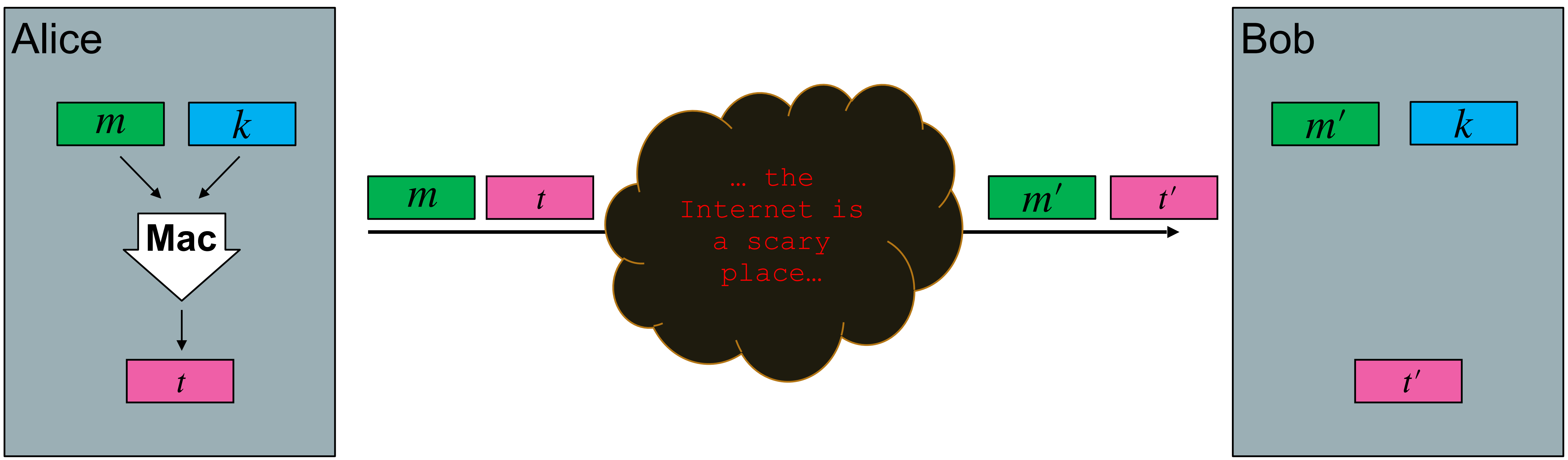

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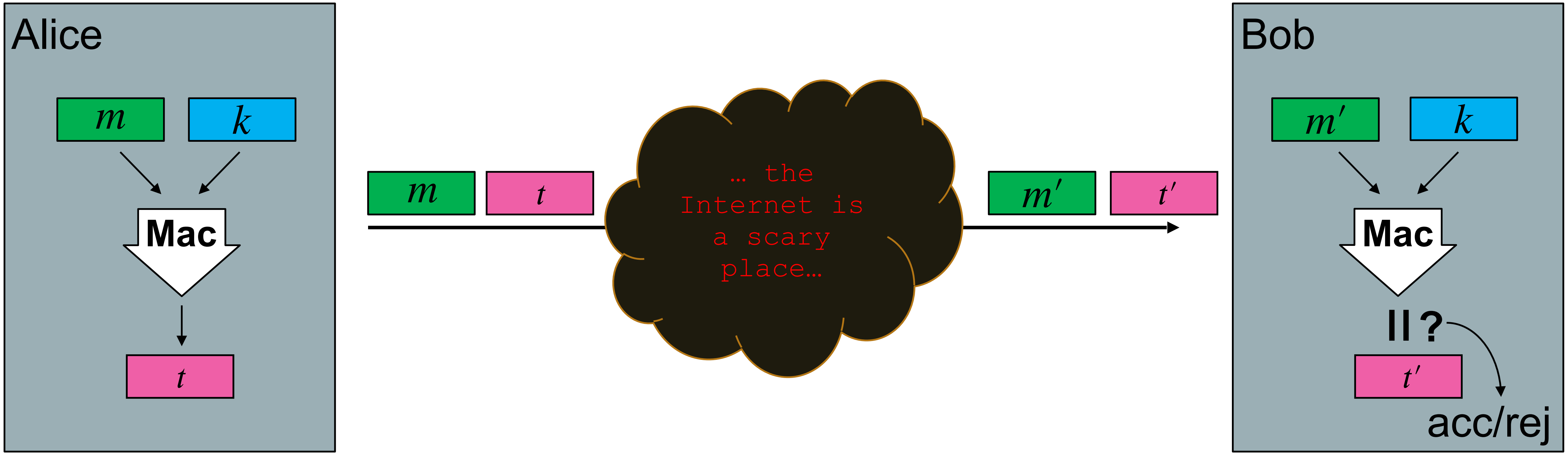

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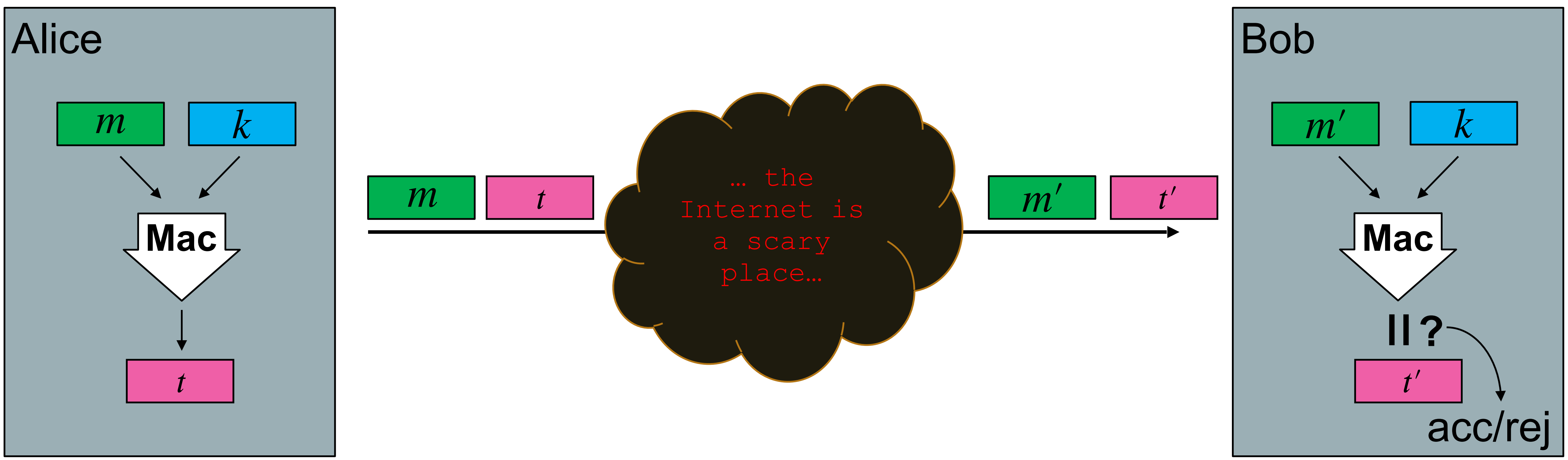

Note: Bob is only checking *consistency with the function .*

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Key property: ***unpredictability*** of $\mathbf{Mac}_k$.

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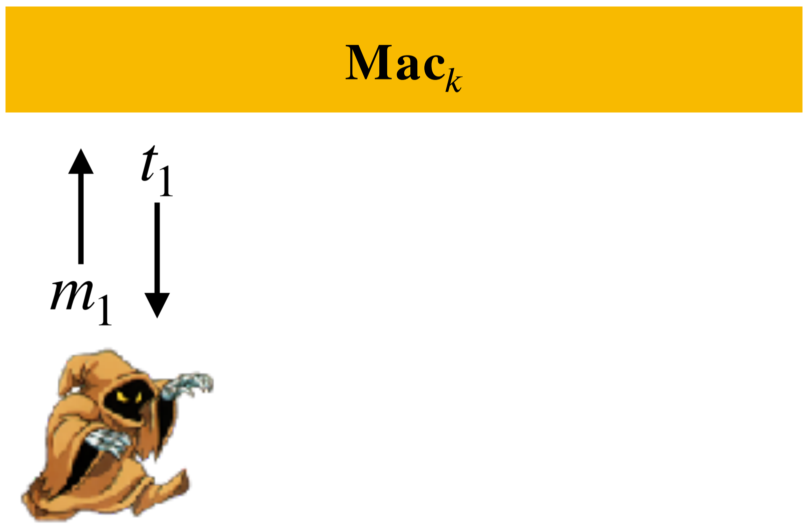

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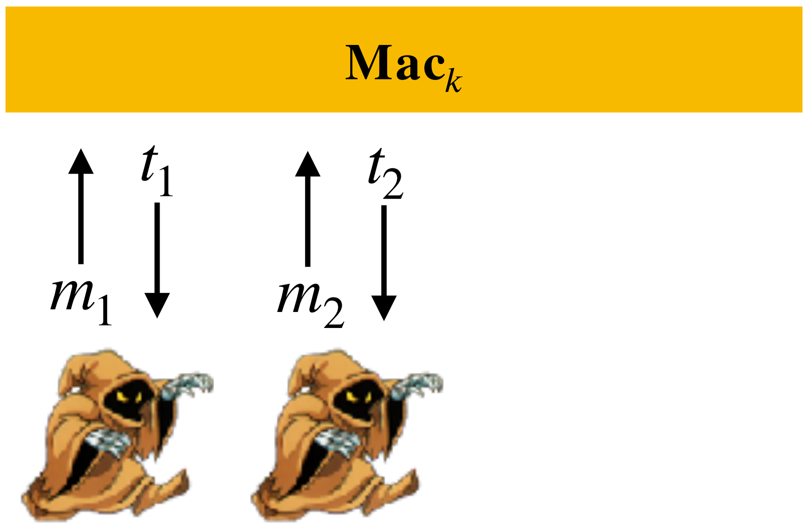

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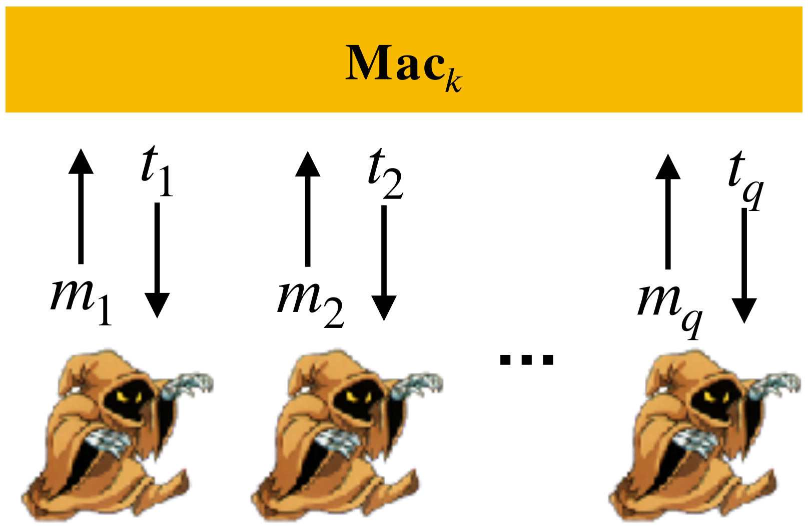

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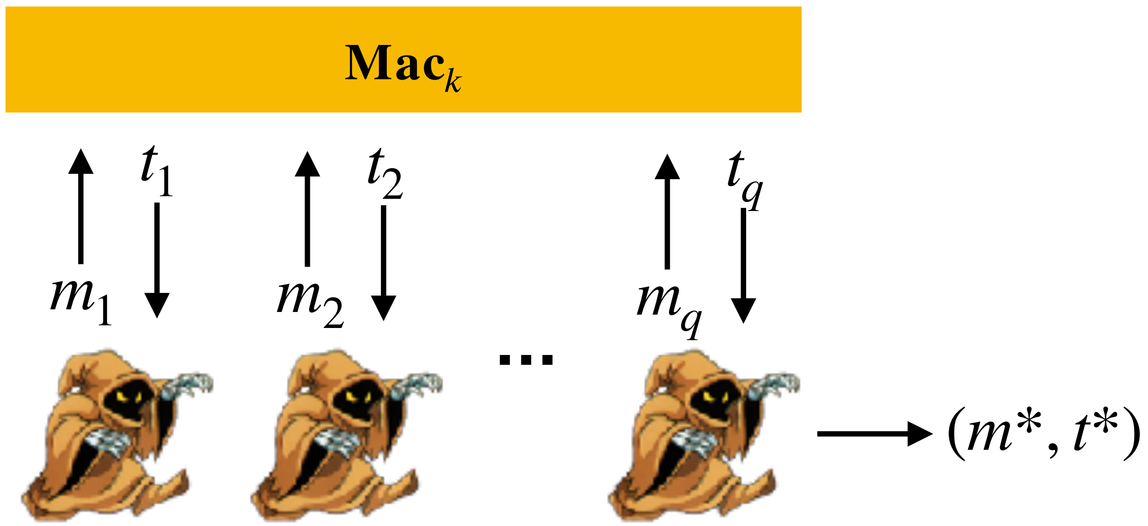

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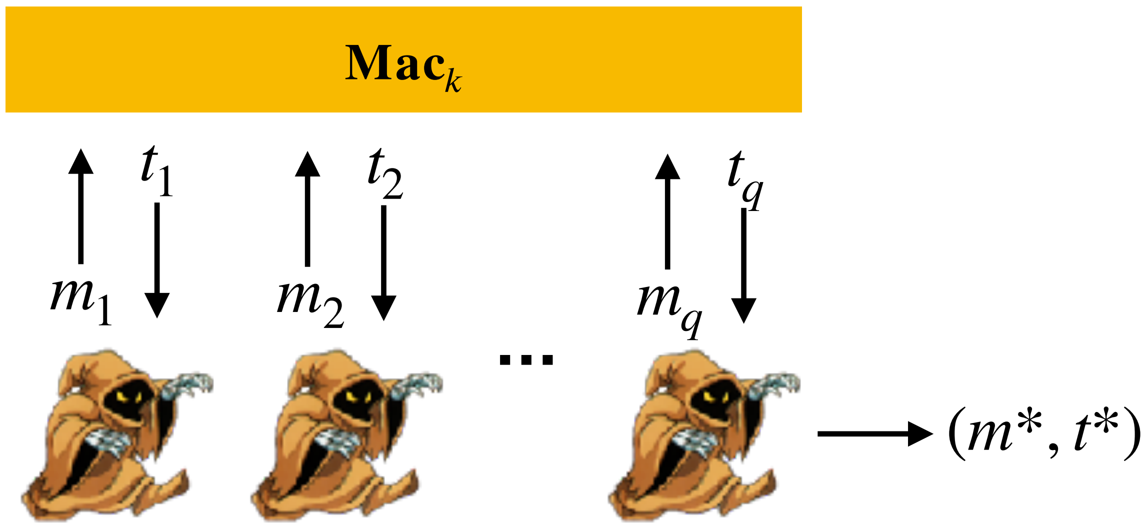

Success:

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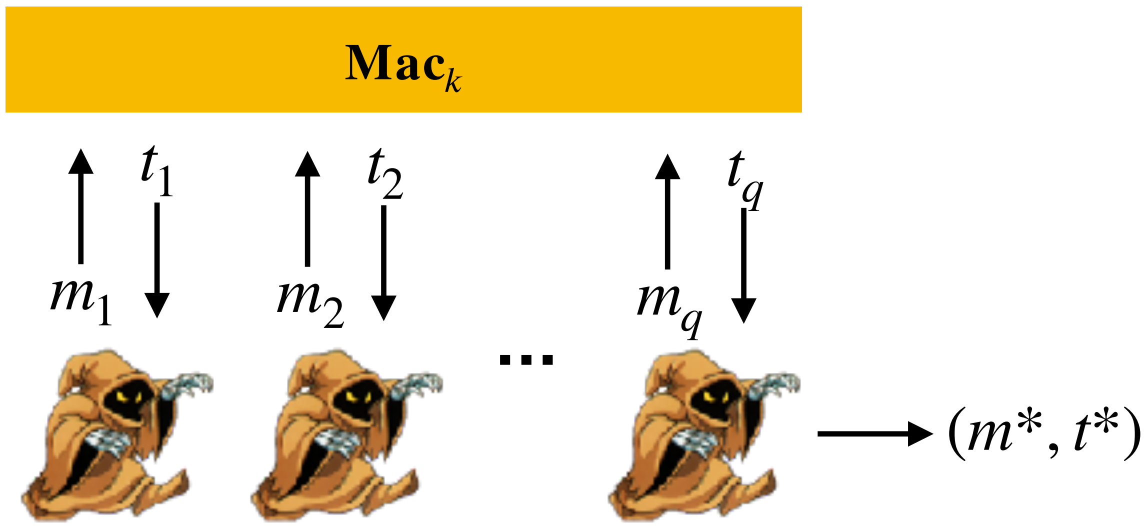

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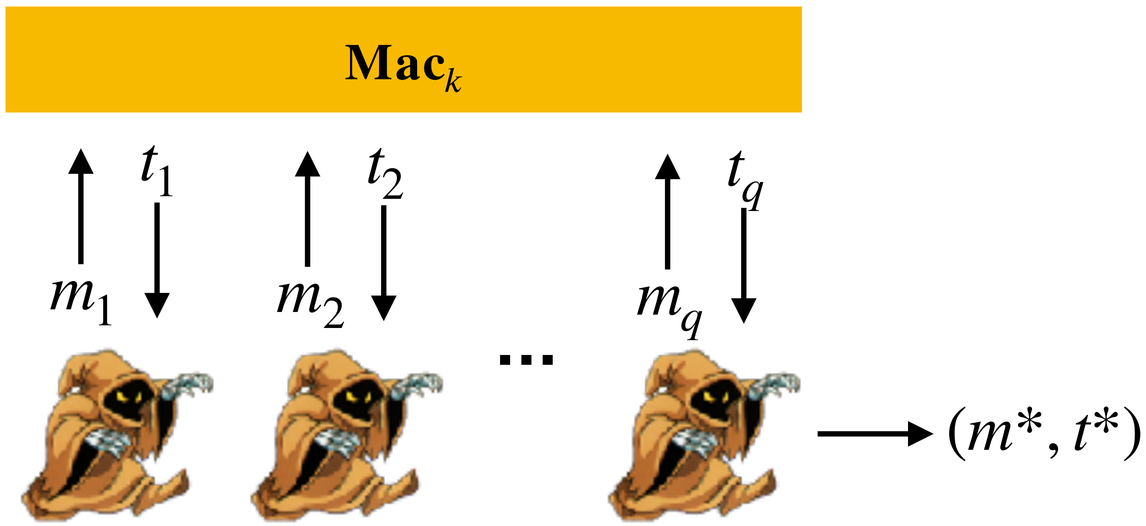

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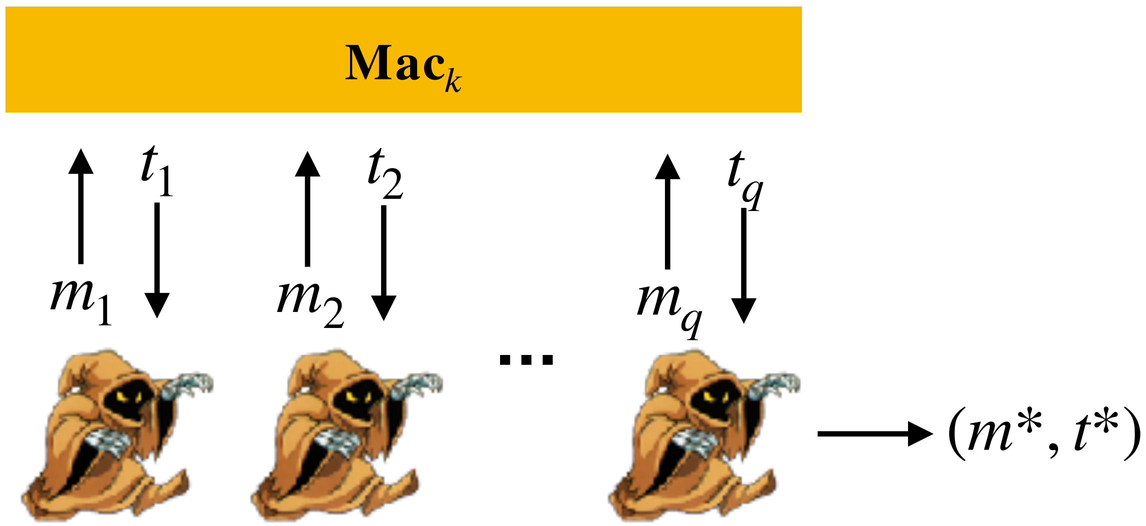

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i) Query $m_1 = \sum_{m\in\{0,1\}^n} |m\rangle|0\rangle$ to obtain $\sum_{m\in\{0,1\}^n} |m\rangle|\mathrm{Mac}_k(m)\rangle$

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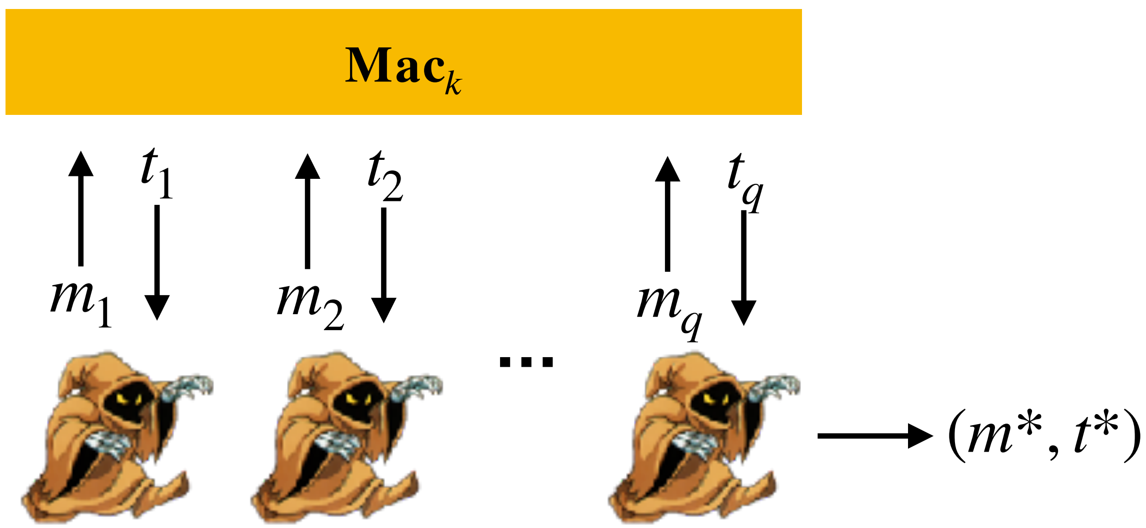

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EUF-CMA doesn't make sense anymore…

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A good predictor:

key k specifies a random periodic function f_k with period p_k

$\mathbf{Mac}_k(p_k) = 0$, and $\mathbf{Mac}_k(x) = f_k(x)\ \forall x \neq p_k$

i) run period finding to find p_k

ii) output $(p_k, 0)$

Boneh Zhandry unforgeability

A proposal: (Boneh and Zhandry, EUROCRYPT 2013):

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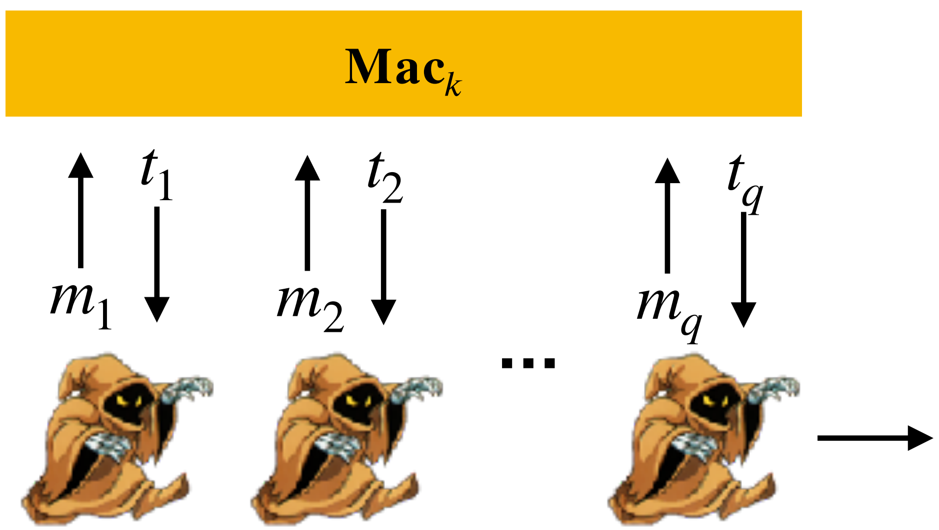

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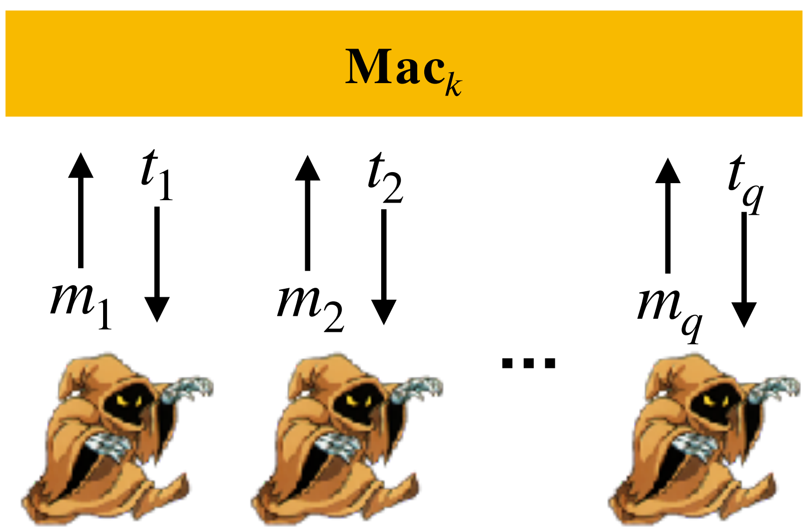

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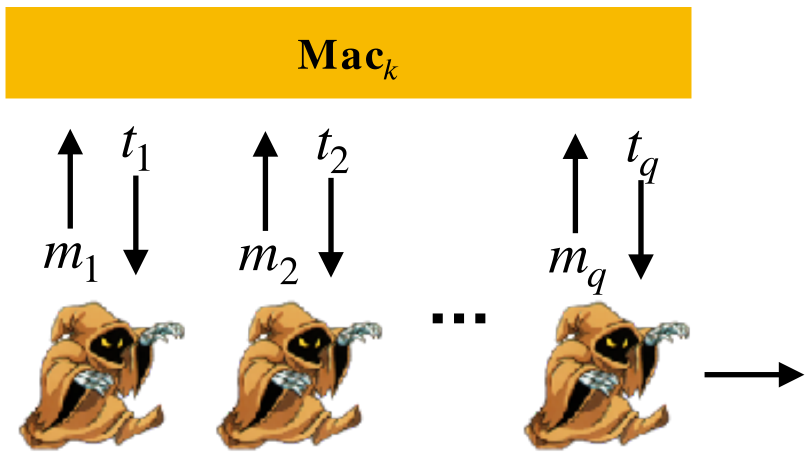
Has some nice properties:

- Equivalent to **EUF-CMA** for classical oracle
- A random function is BZ-unforgeable (BZ '13)

The right definition?



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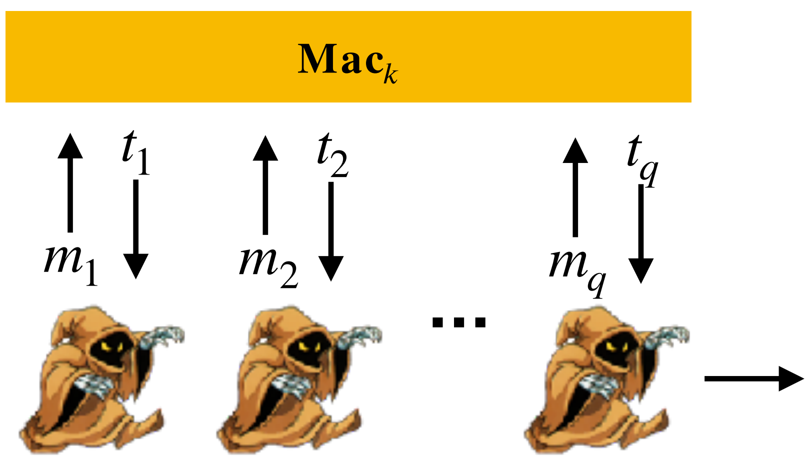

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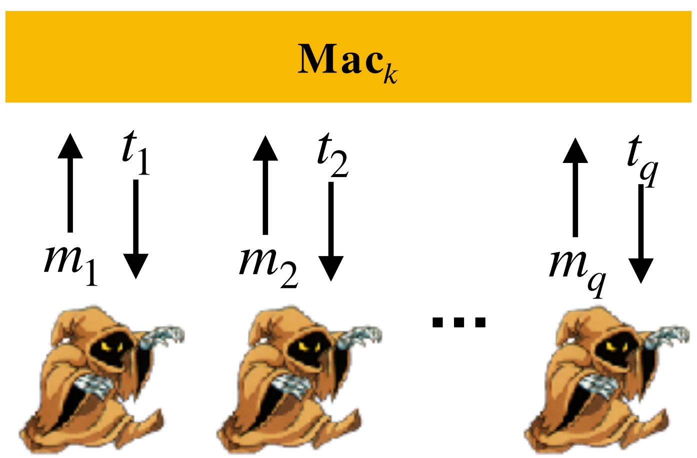

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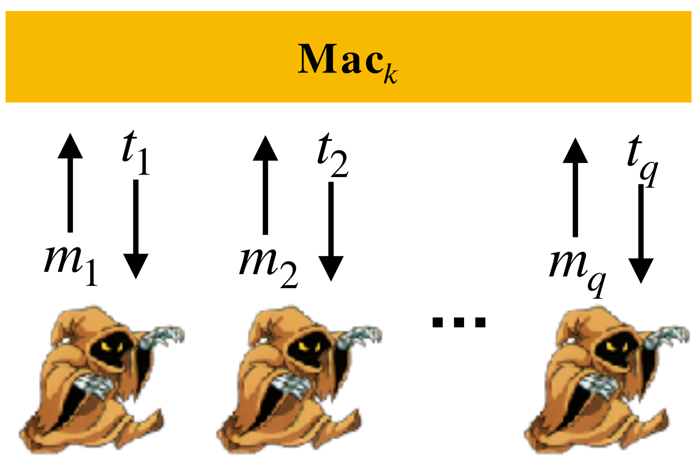

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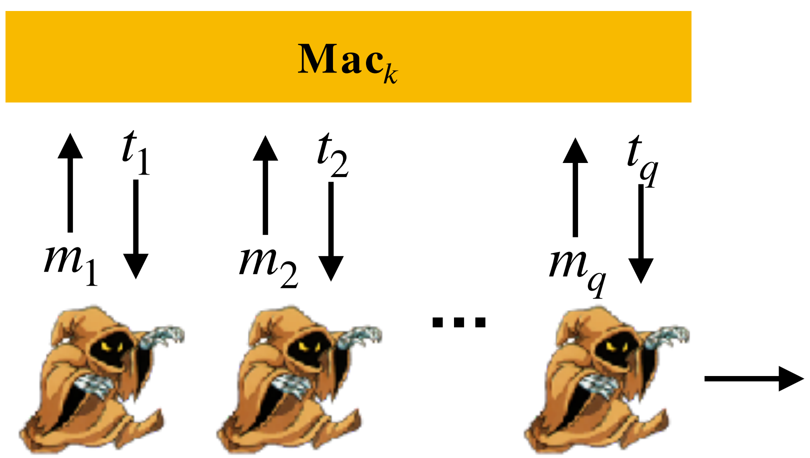

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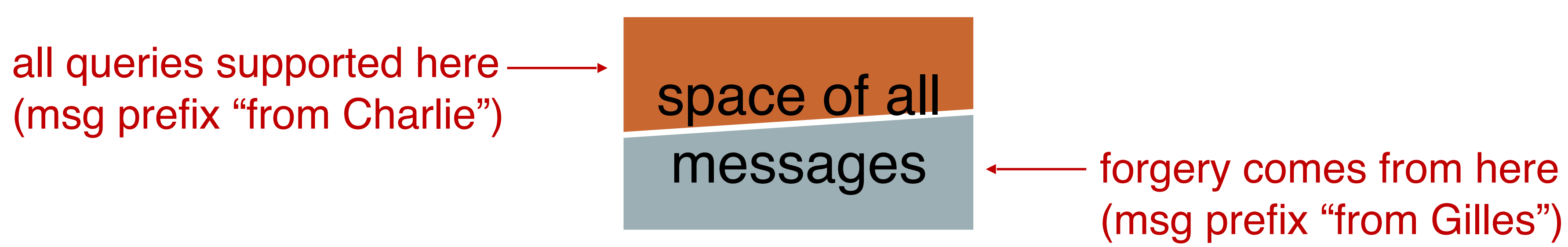

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Is our intuition right? One obstacle: "property finding" cannot be used.

Not the right definition!

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- Let f_0, f_1 be random functions; let A be a large random subgroup of $\mathbb{Z}_2^n$;
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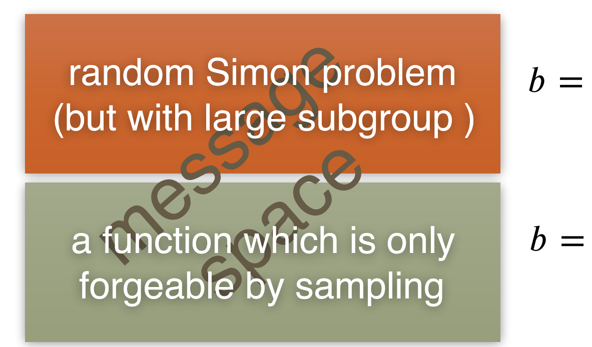

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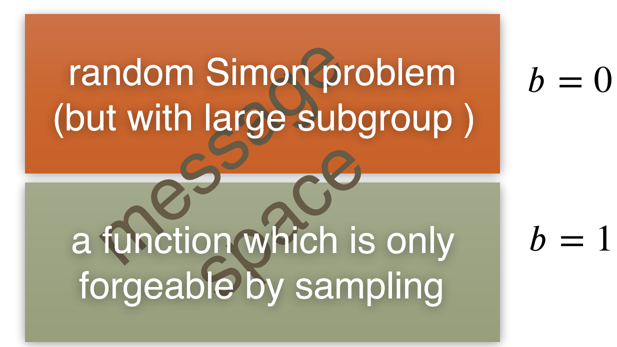

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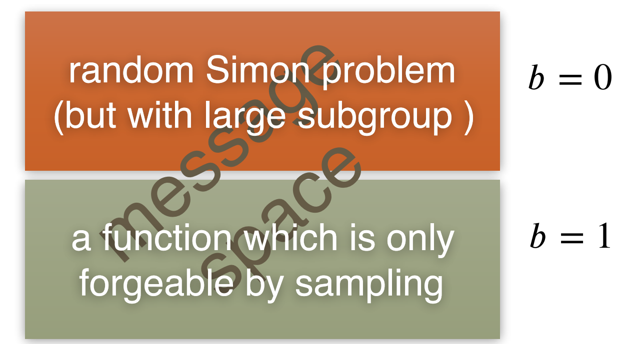

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Theorem (AMRS17). There are no efficient quantum algorithms which query $\mathbf{Mac}_k$ once but output two distinct input-output pairs of $\mathbf{Mac}_k$.

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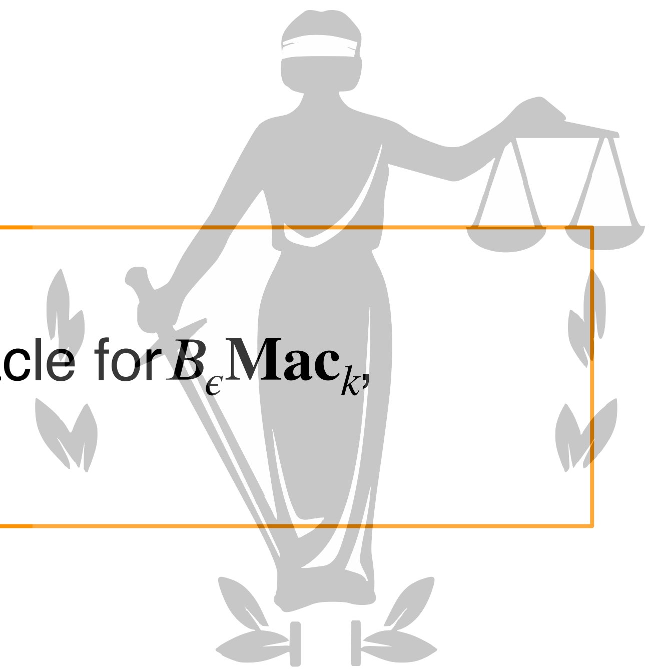

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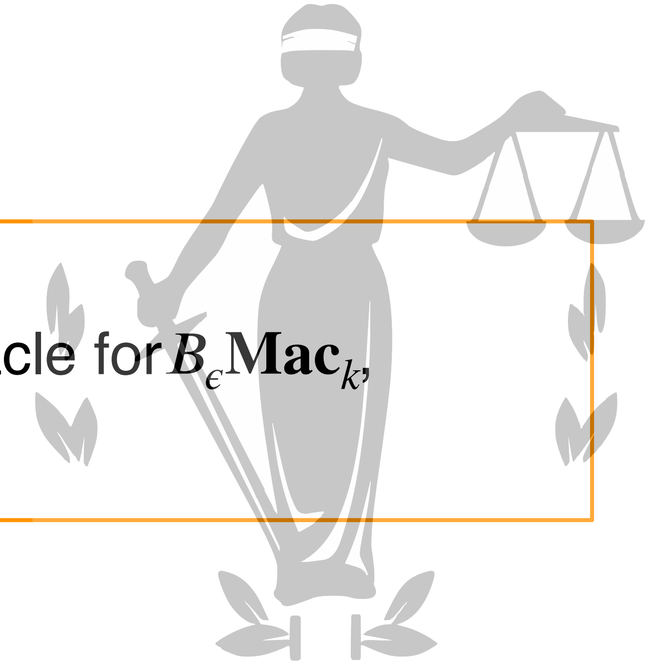

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Does this work?

- equivalent to **EUF-CMA** in classical setting;
- random functions satisfy it;
- classifies the examples we have seen thus far correctly.

1.

1. prepare: $m_1 = \sum_{m \in \{0,1\}^n} |m\rangle|0\rangle$;
2. query
3. measure

Output: $(m, B_\varepsilon\mathbf{Mac}_k(m))$ for random m.

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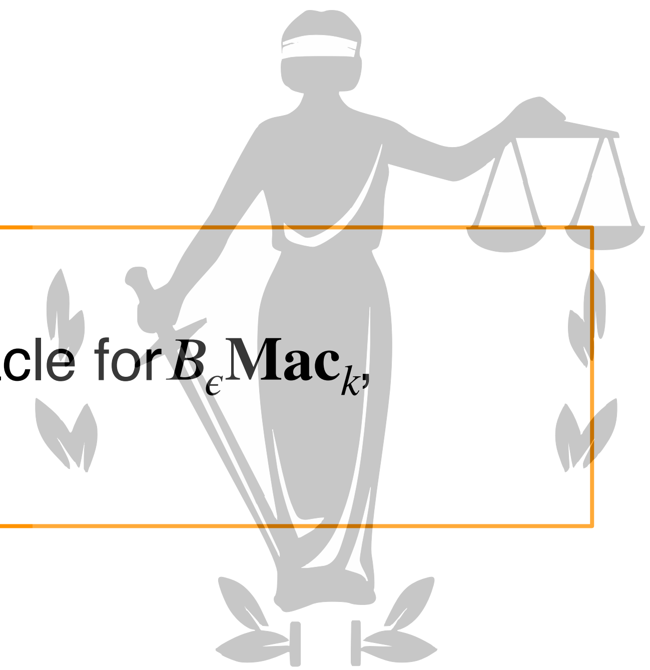

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Does this work?

- equivalent to **EUF-CMA** in classical setting;
- random functions satisfy it;
- classifies the examples we have seen thus far correctly.

1.

1. prepare: $m_1 = \sum_{m \in \{0,1\}^n} |m\rangle |0\rangle$;
2. query
3. measure

Output: $(m, B_\varepsilon \mathbf{Mac}_k(m))$ for random m.

Check, e.g., for random functions:

- if oracle is blinded…
- …$\mathbf{Mac}_k(m)$ for blinded m is *independent* of post-query state,
- this adversary fails.

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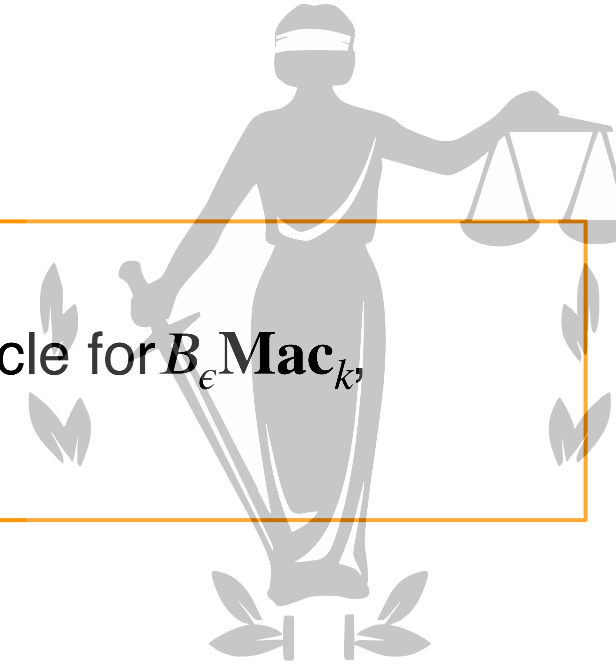

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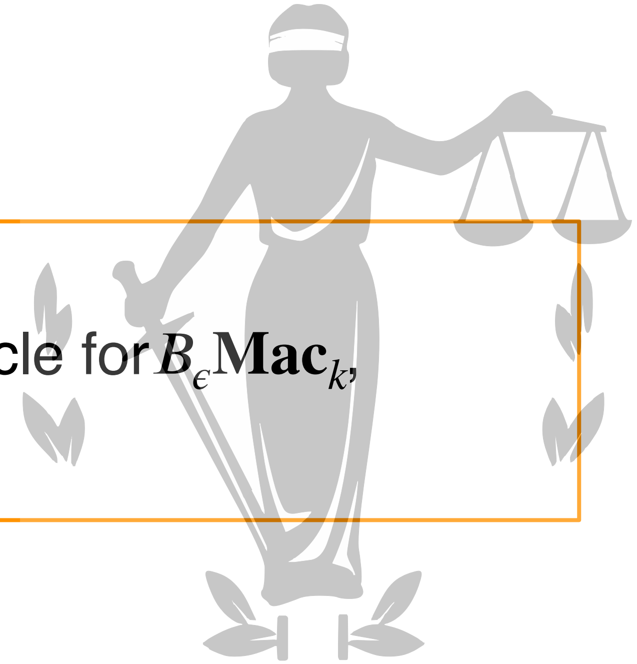

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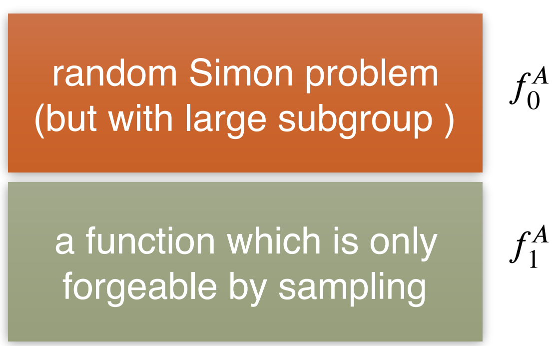

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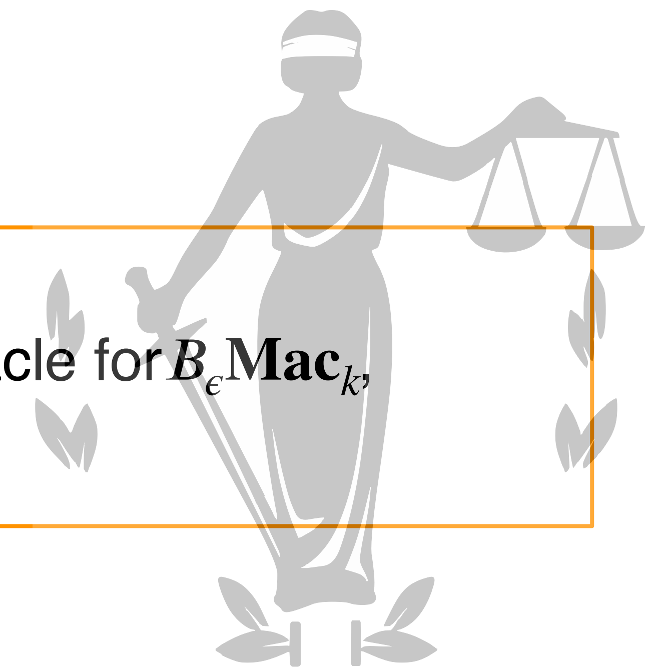

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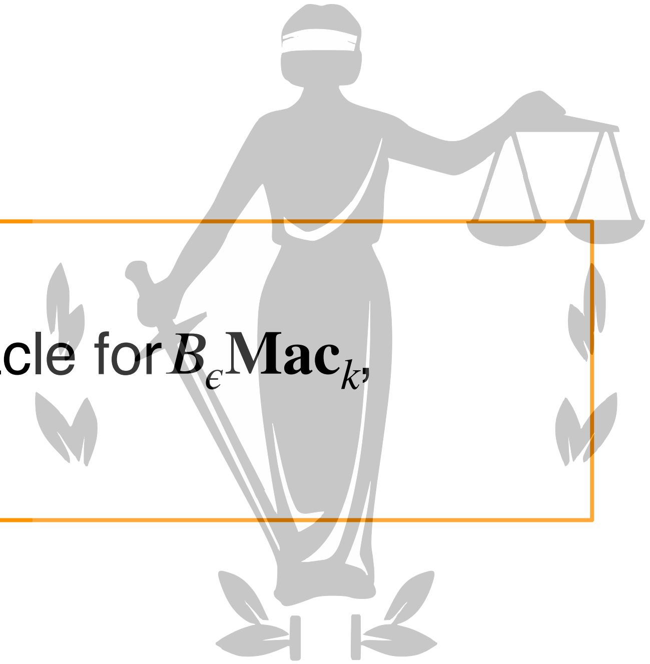

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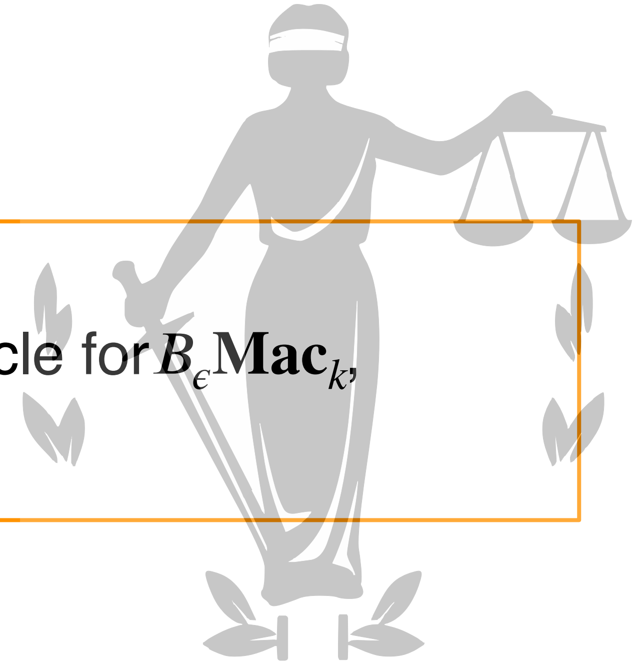

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- *…post-query state won't change too much;*
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- so this adversary succeeds!

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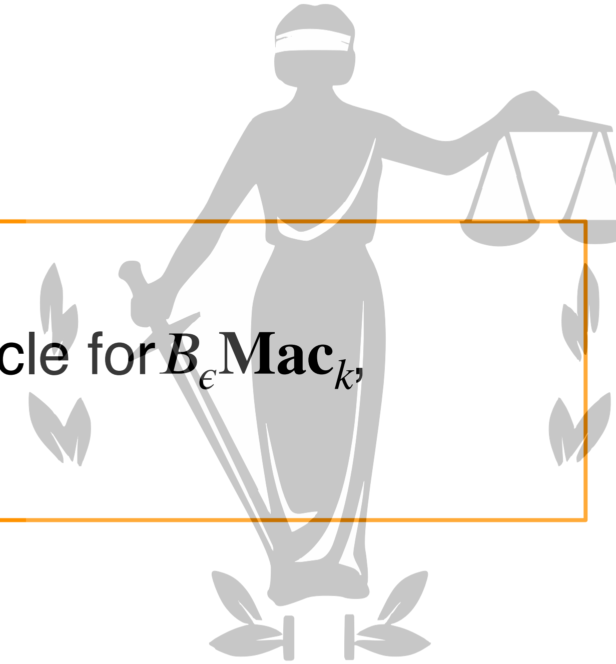

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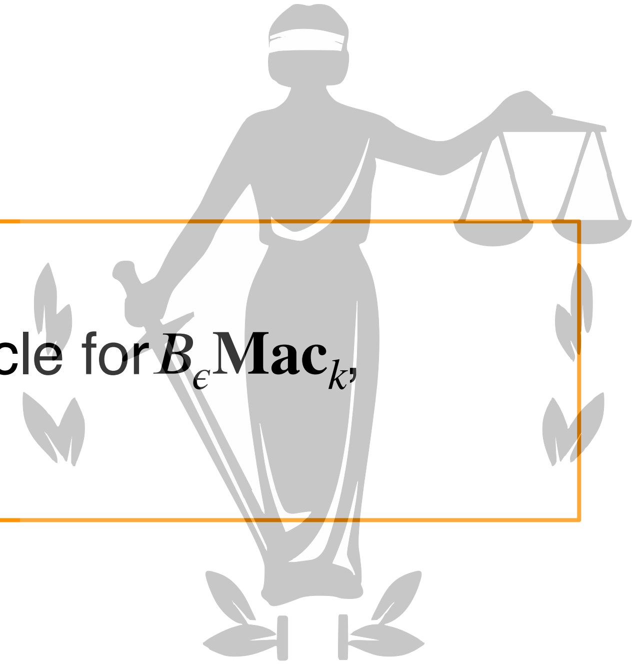

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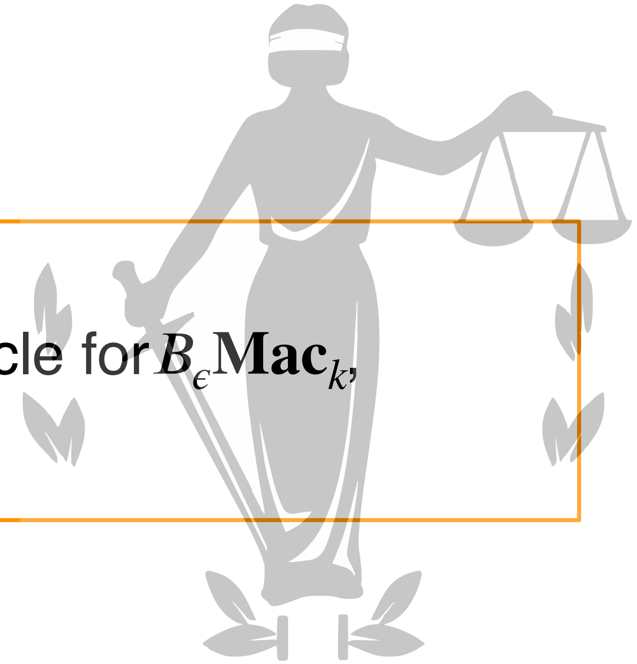

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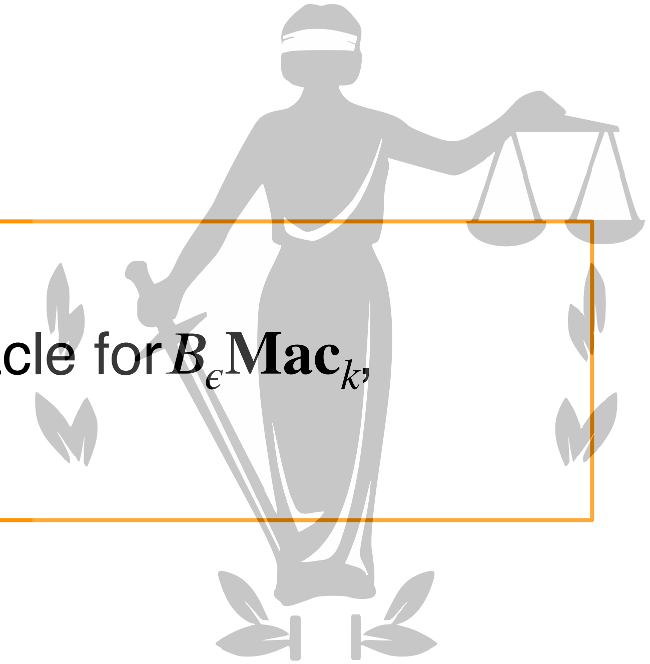

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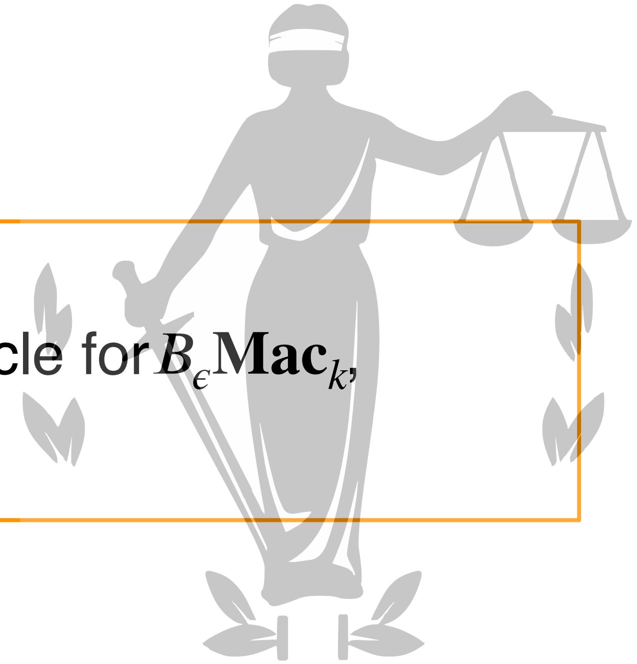

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- Zhandry's superposition representation of quantum random oracles

Outlook

What's next?

- did we solve the problem?
- is blind-unforgeability the "right" notion of unforgeability against quantum adversaries?
- maybe: it does the right thing on all the examples we could think of;
- maybe not: it seems hard to prove that it implies **BZ** (does that matter?); we can come up with lots of seemingly inequivalent variants of **BU.**

In general: we need to develop and refine new techniques for quantum query complexity to suit "crypto needs", e.g. to analyze

1. algorithms which only succeed on a small space of inputs;
2. algorithms which succeed with vanishing (but non-negligible) probability;
3. non-asymptotics: problems with an "easy/impossible" thresholds of one (or few) queries.