CNT 4406, Spring 2024

Message Authentication Code

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The slides are loosely based on those of Prof. Mihir Bellare, UC San Diego.

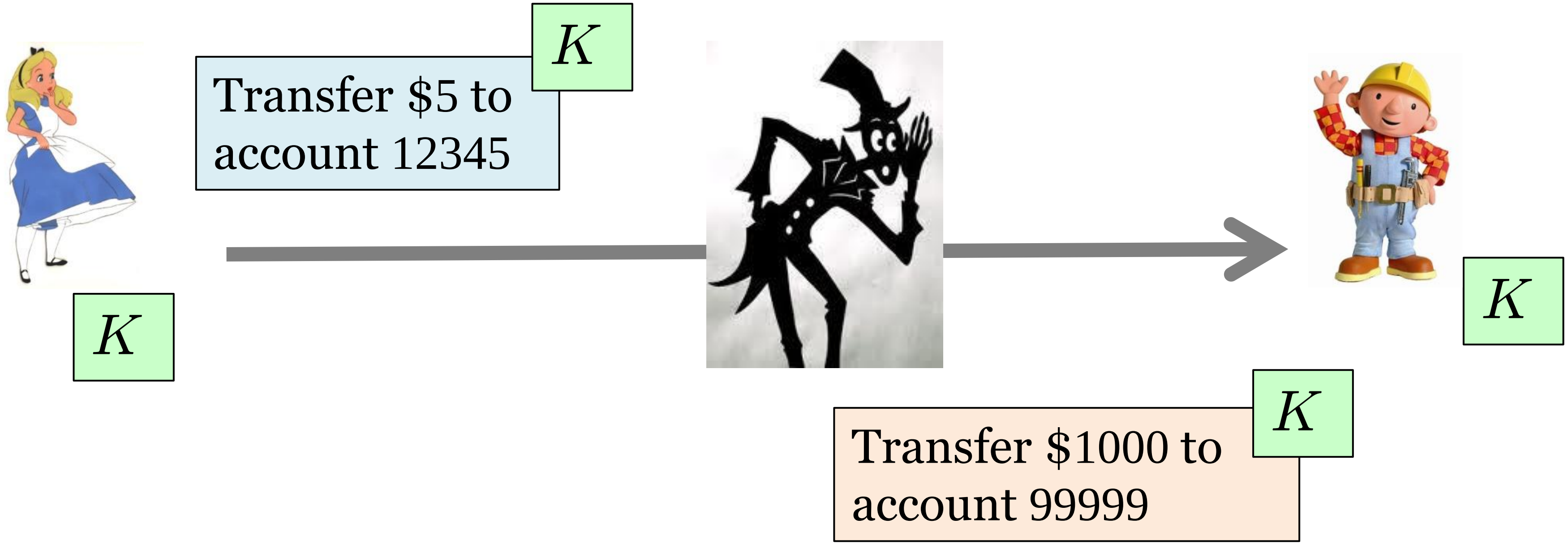
Agenda

1. MAC and Authenticity

2. MAC Constructions

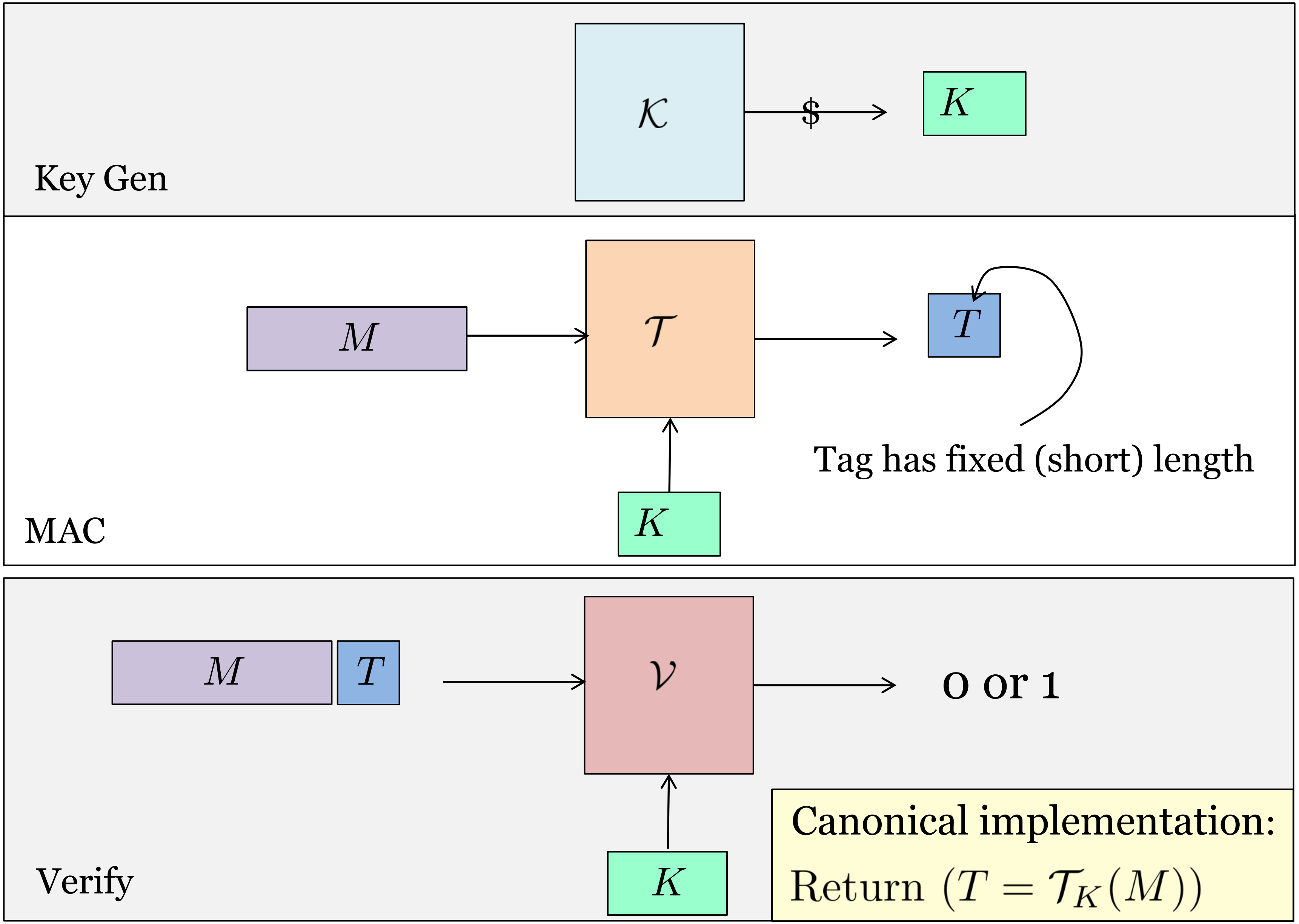
3. How to Construct Good MAC

The Need for Authenticity



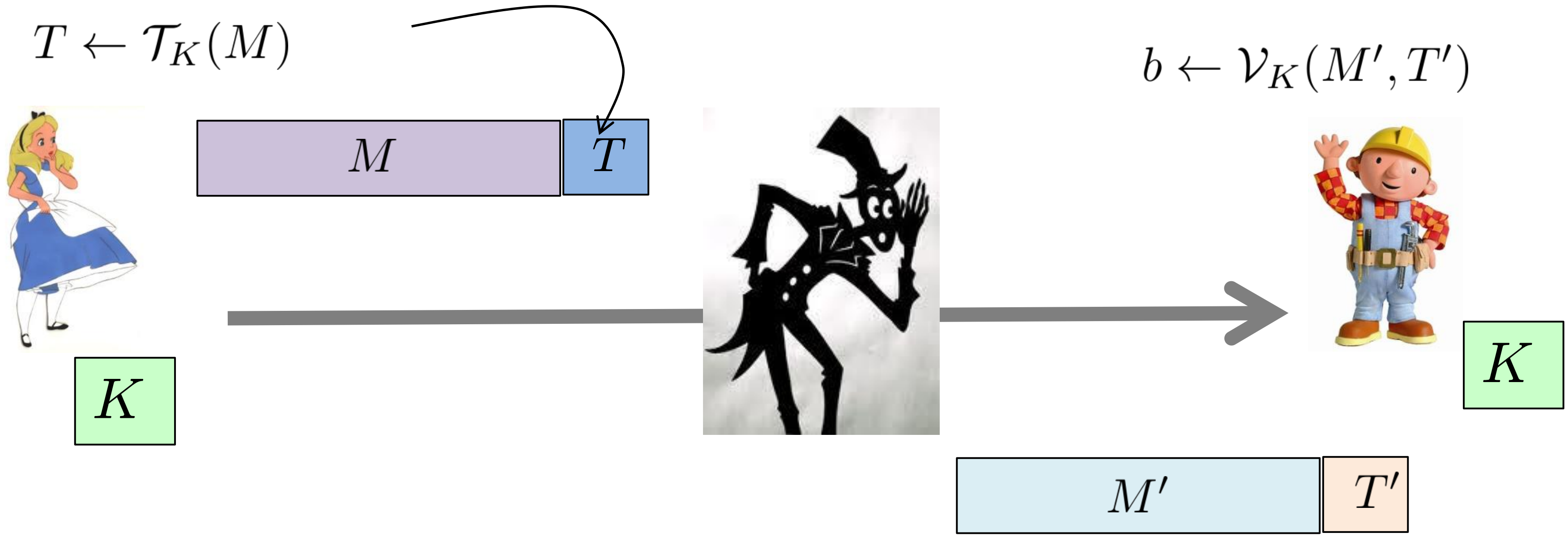
Classical encryptions (CTR, CBC) don't provide authenticity

MAC Syntax



Key Gen
$\mathcal{K}$
$
K
MAC
M
$\mathcal{T}$
T
K
Tag has fixed (short) length
Verify
M
T
$\mathcal{V}$
0 or 1
K
Canonical implementation:
Return $(T = \mathcal{T}_K(M))$

MAC Usage



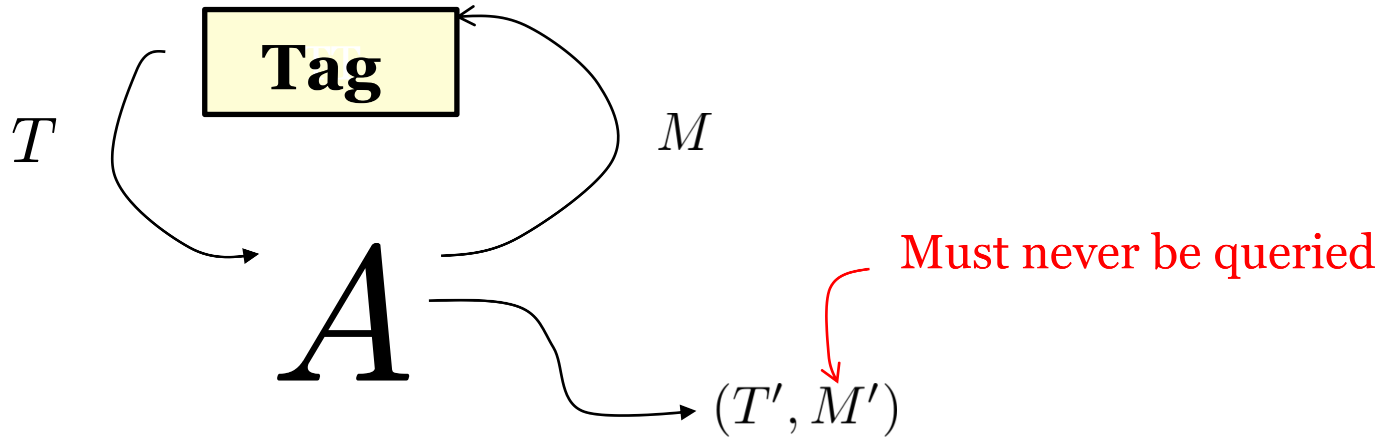
Formalizing Security

MAC$_{\mathcal{T}}$

procedure Initialize()
$K \xleftarrow{\$} \mathcal{K}$

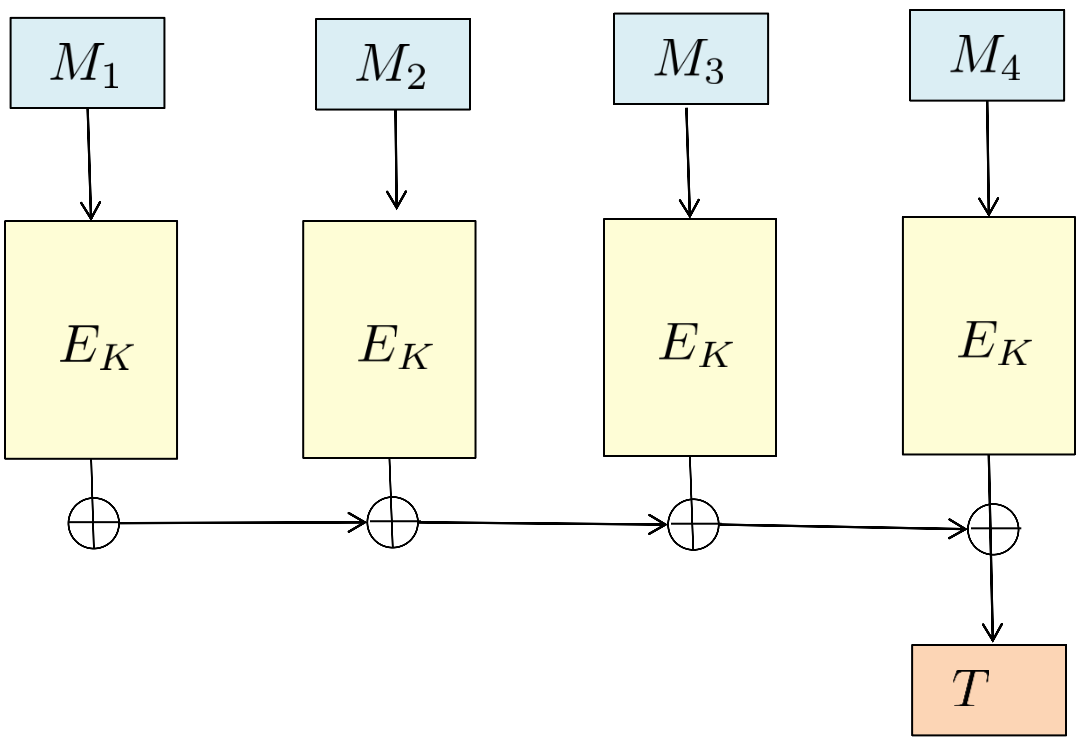
procedure Tag(M)
Return $\mathcal{T}_K(M)$

procedure Finalize(T', M')
Return $(T' = \mathcal{T}_K(M'))$

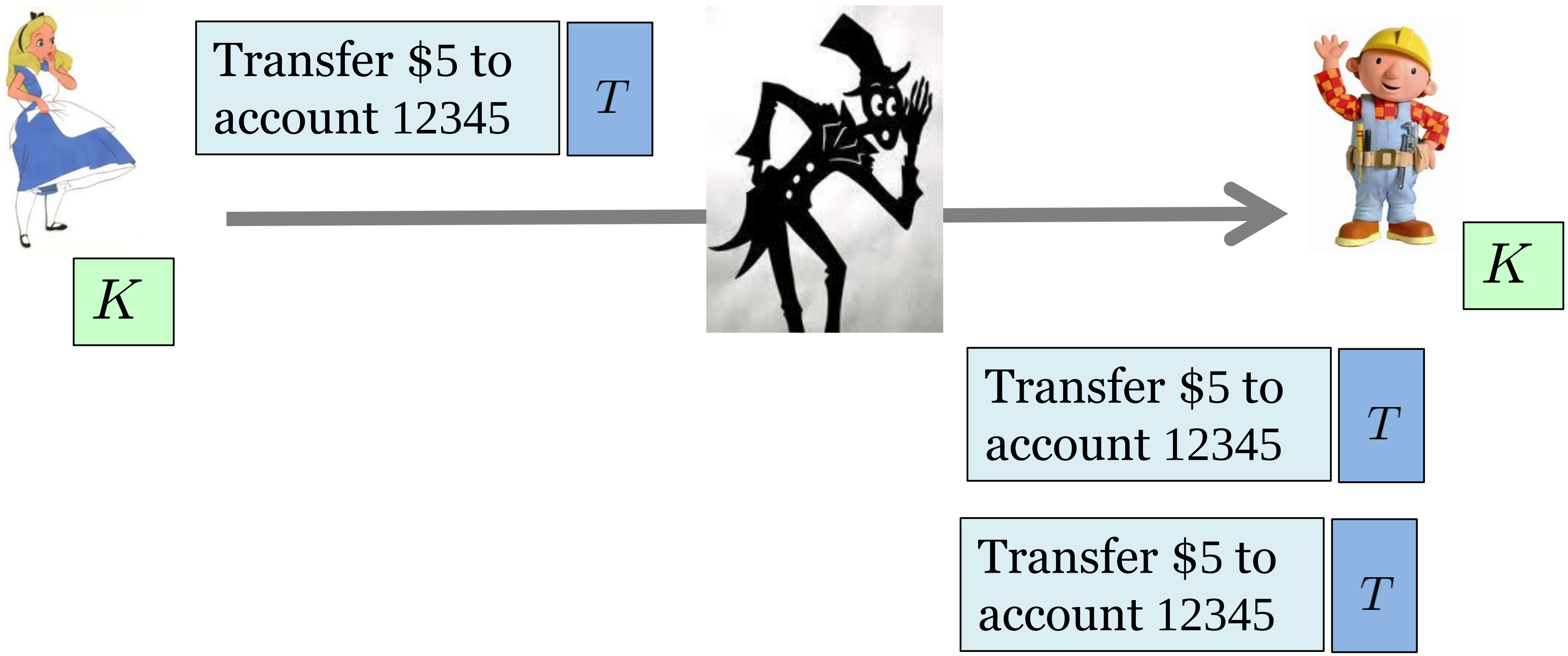


$$\mathbf{Adv}^{\mathrm{mac}}_{\mathcal{T}}(A) = \Pr[\mathrm{MAC}^{A}_{\mathcal{T}} \Rightarrow 1]$$

Exercise: Breaking MAC Security With No Query



Replay Attack

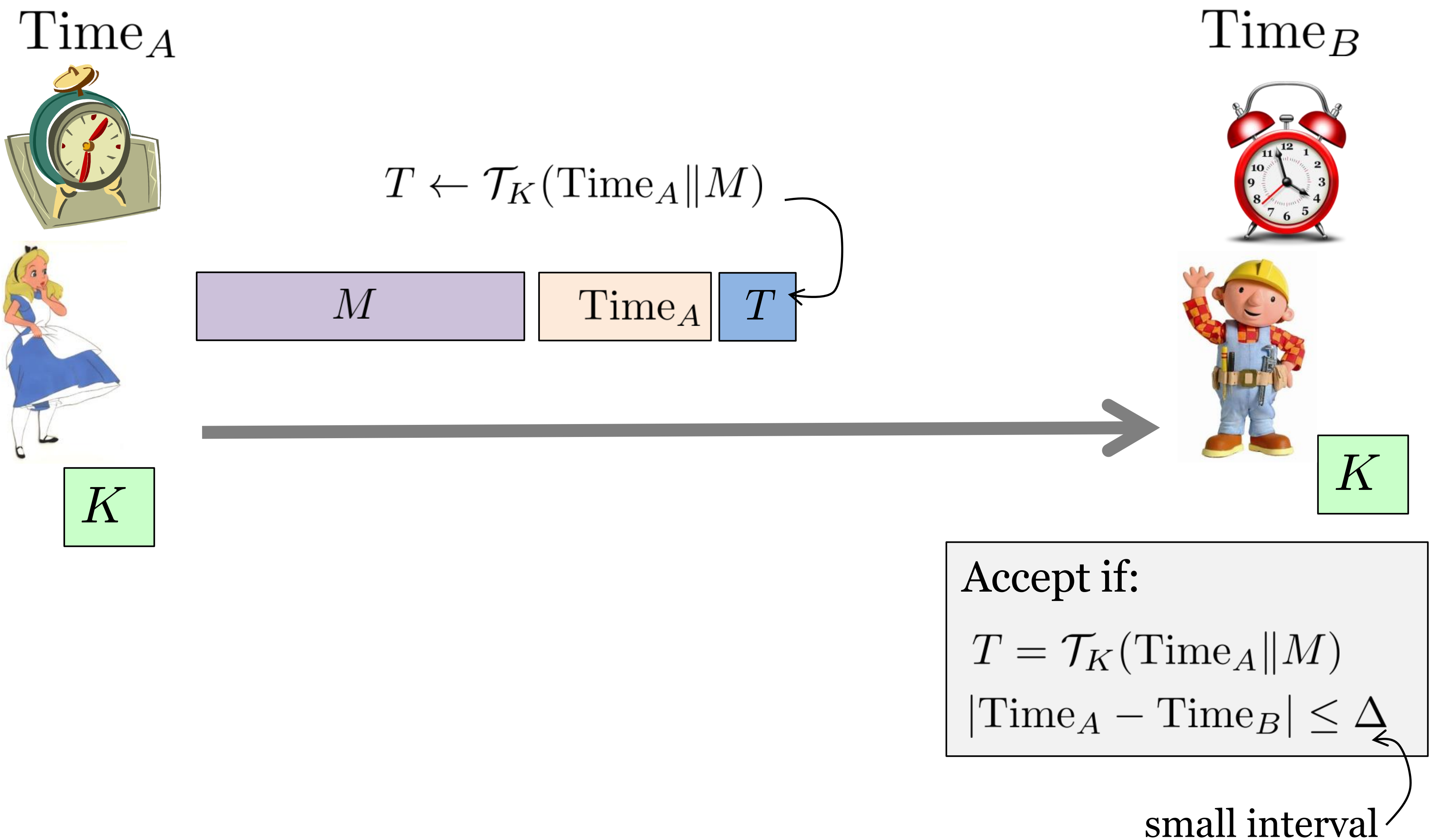


Bob transfers $10 instead of $5 !!

MAC wasn’t defined to handle replay attack.

Replay is best addressed as an add-on to standard msg authentication

Prevent Replay Attack Using Timestamp



Prevent Replay Attack Using Counter

counter_A

K

$T \leftarrow \mathcal{T}_K(\text{counter}_A \| M)$

$\text{counter}_A \leftarrow \text{counter}_A + 1$

M T

counter_B

K

If $T = \mathcal{T}_K(\text{counter}_B \| M)$

$\text{counter}_B \leftarrow \text{counter}_B + 1$

accept

Counters need to be synchronized

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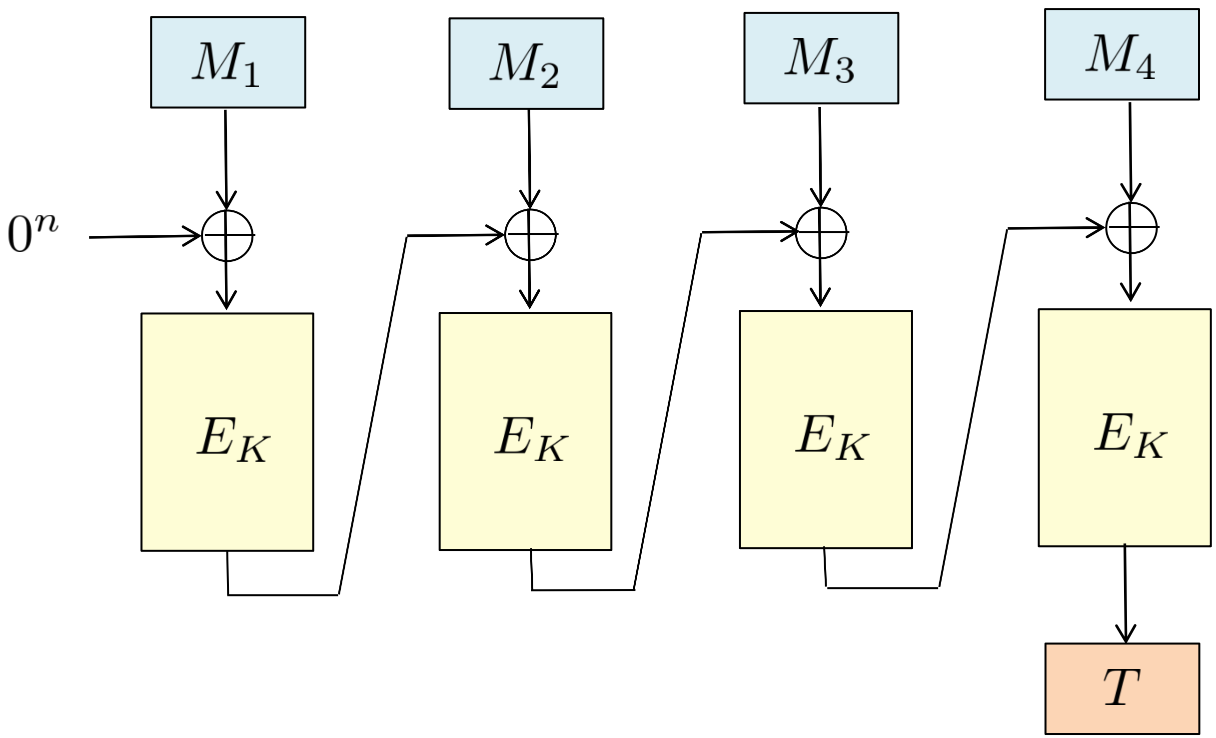
1. MAC and Authenticity

2. **MAC Constructions**

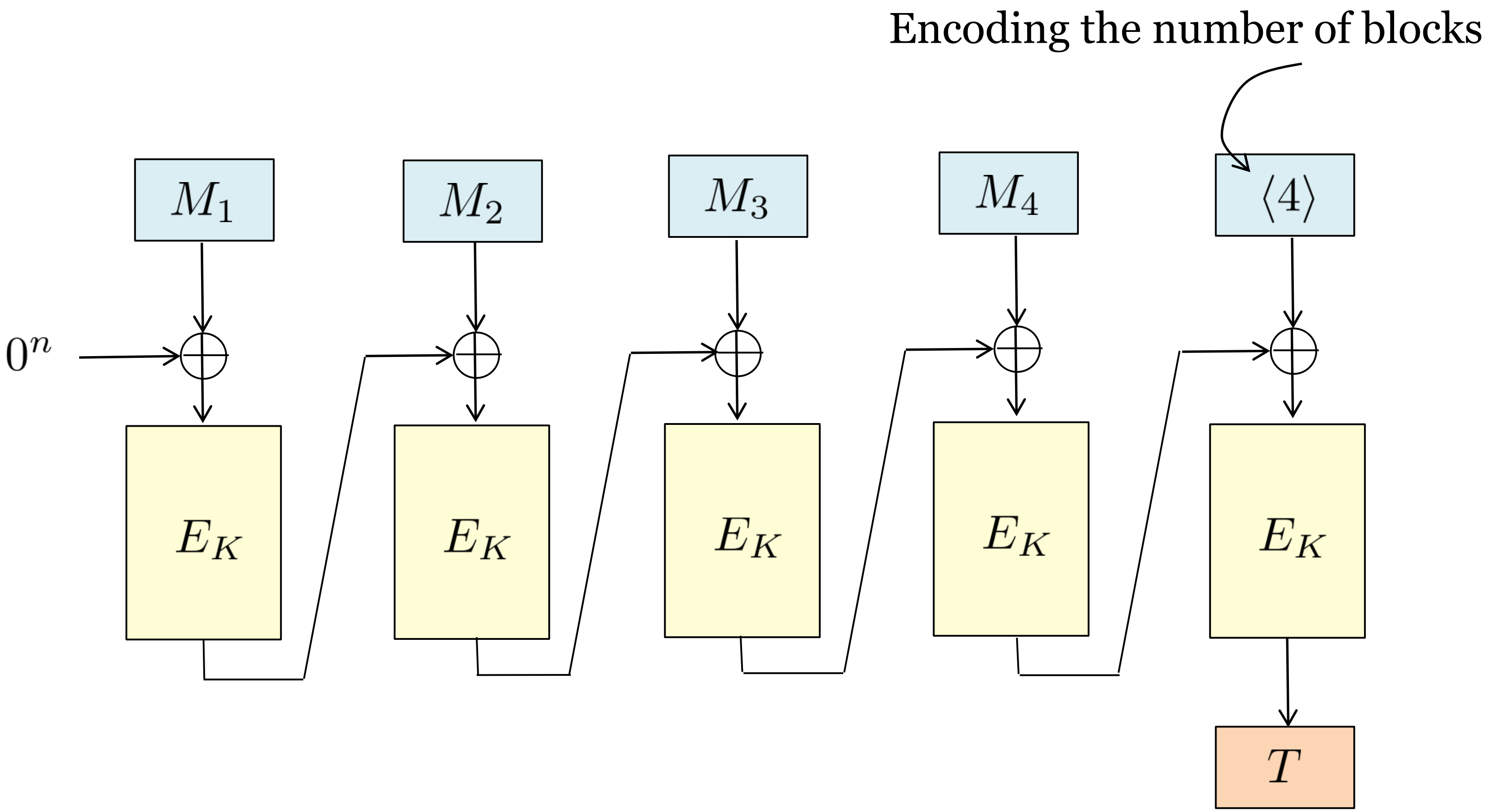
3. How to Construct Good MAC

An Insecure Construction: Plain CBC-MAC



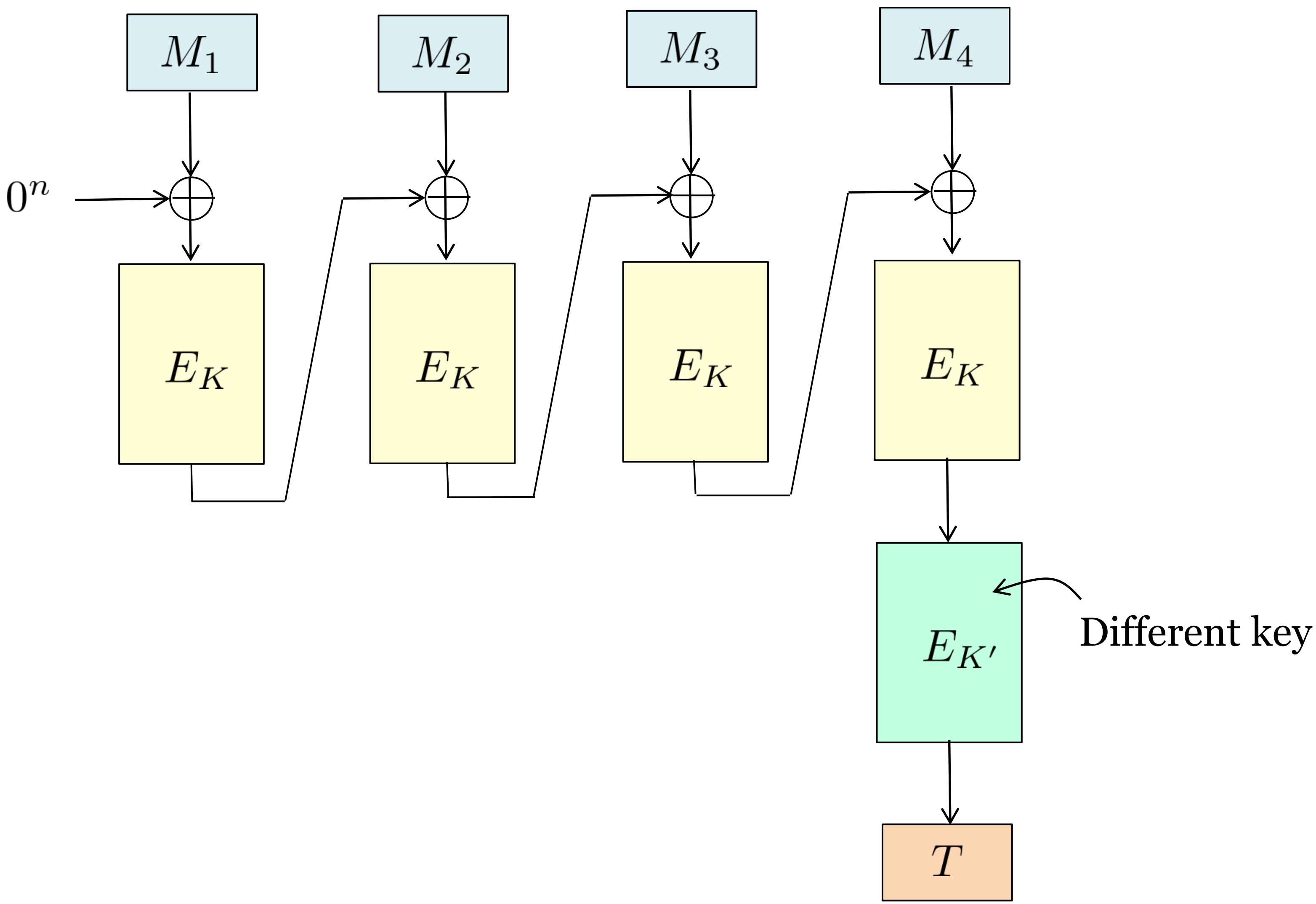
Question: Break CBC-MAC with a single Tag query

An Incorrect Fix of CBC-MAC



Exercise: Break this version using 3 Tag queries

A Good Construction: Encrypted CBC-MAC

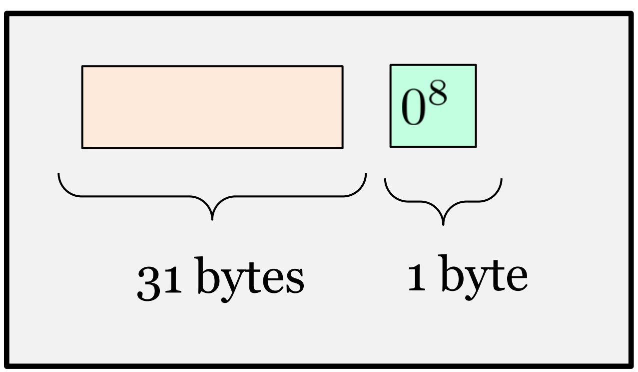


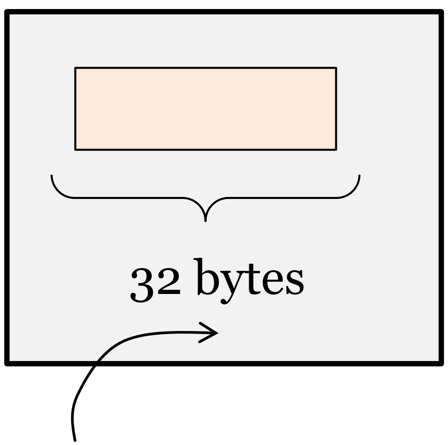
Dealing with Fragmentary Data

Solution: Padding with 10^*

Question: Can we instead use padding with 0^*?

Example: Suppose that the block length is 16 bytes.





No padding → save bandwidth

Answer: No, can break this with a single Tag query

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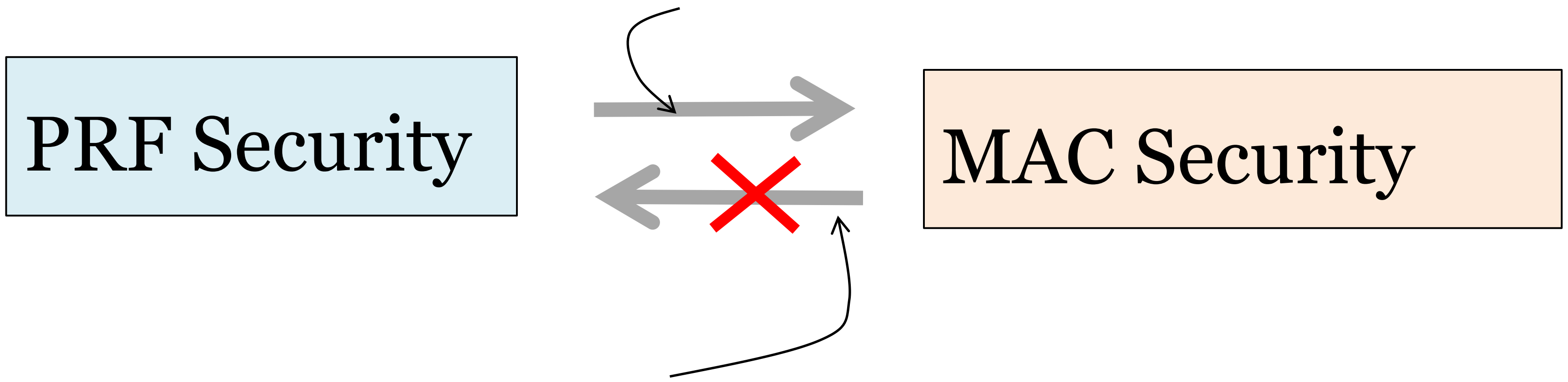
PRF Is a Good MAC

Intuition: - A good MAC means the output should be unpredictable

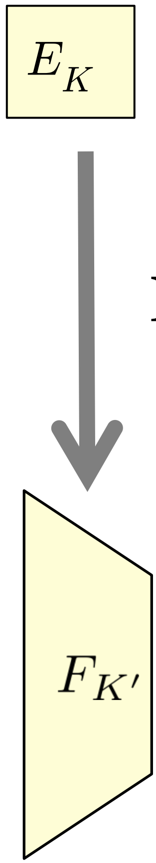
- Random strings are unpredictable



Question: Given a good MAC F, construct F' that is still a good MAC but has a trivial PRF attack.

PRF Extension

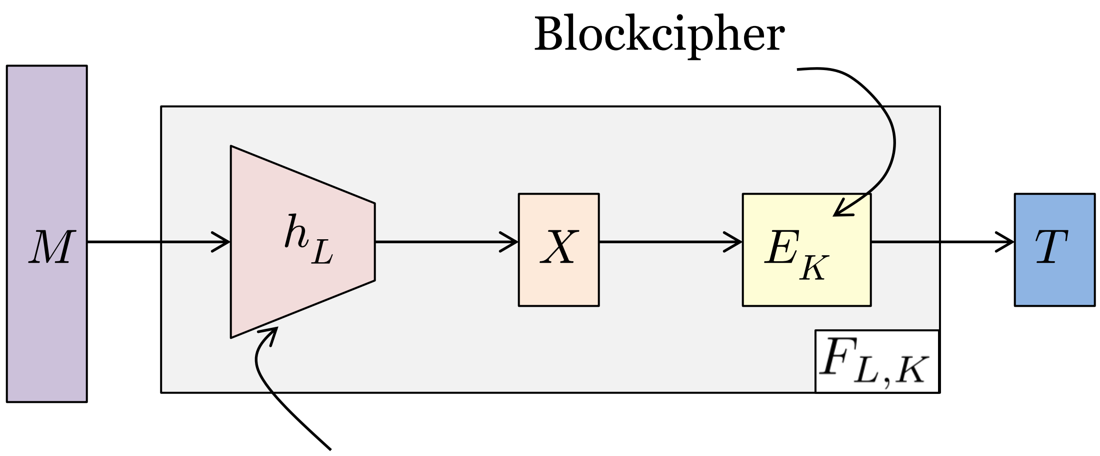
Blockcipher: Good PRF with small domain $\{0,1\}^n$



How to extend the domain of a PRF?

Want: Good PRF with large domain $\{0,1\}^*$

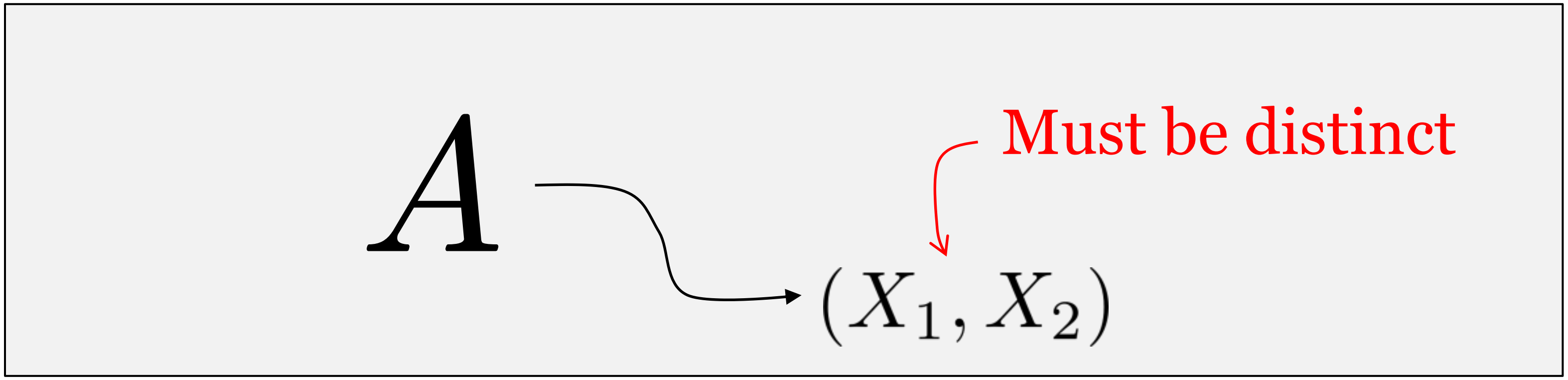
Extending Domain: Carter-Wegman Paradigm



Condensing msg using a (keyed) hash

What's the needed property for the hash?

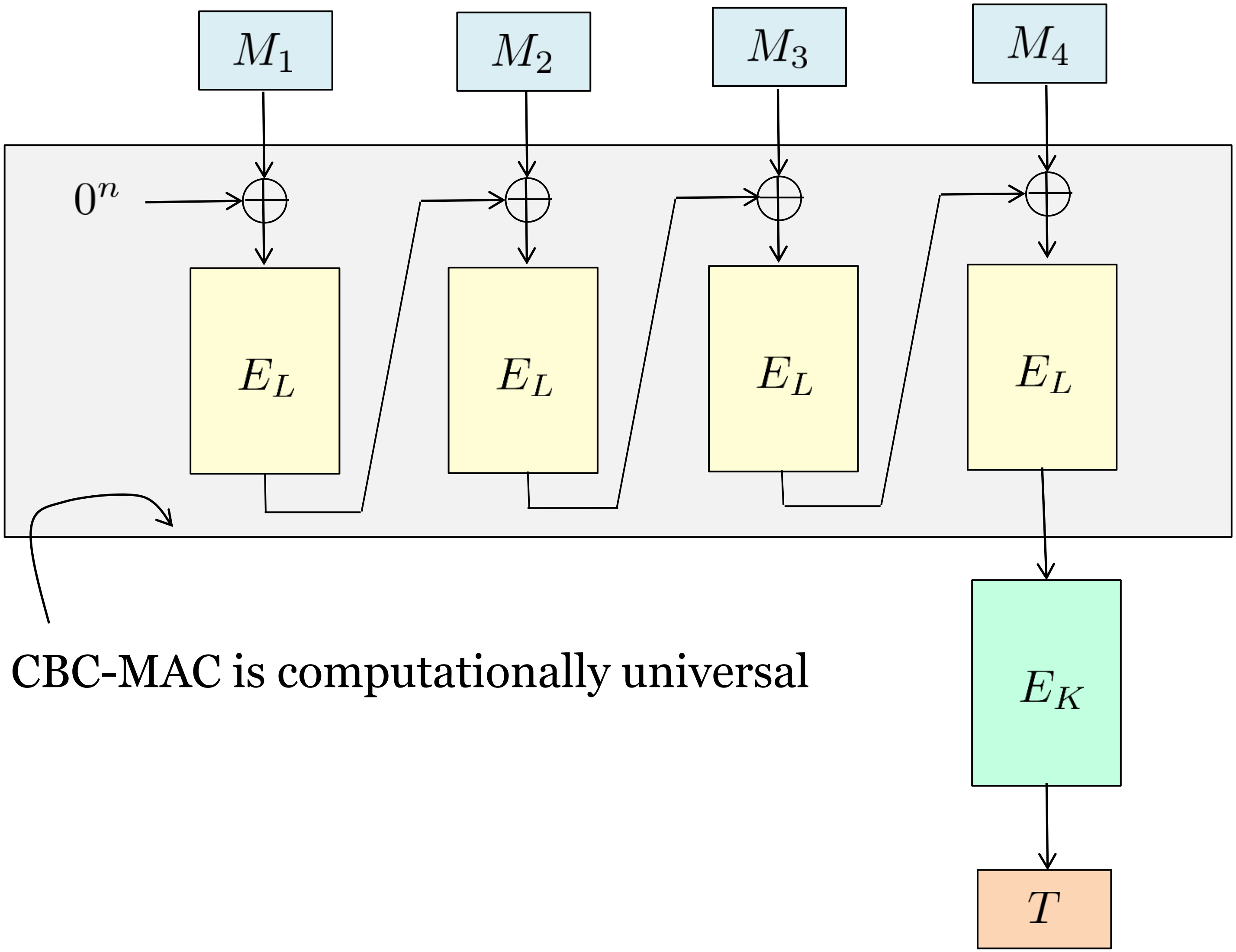
Computationally Almost Universal Hash



$$\mathbf{Adv}_h^{\mathrm{cau}}(A) = \Pr_{L \leftarrow_\$ \mathcal{L}}[h_L(X_1) = h_L(X_2)]$$

Building A PRF Via Carter-Wegman

Encrypted CBCMAC



CBC-MAC is computationally universal