Efficient Length Doubling From Tweakable Block Ciphers

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Modes of operation

- block cipher: fixed-input-length (FIL)

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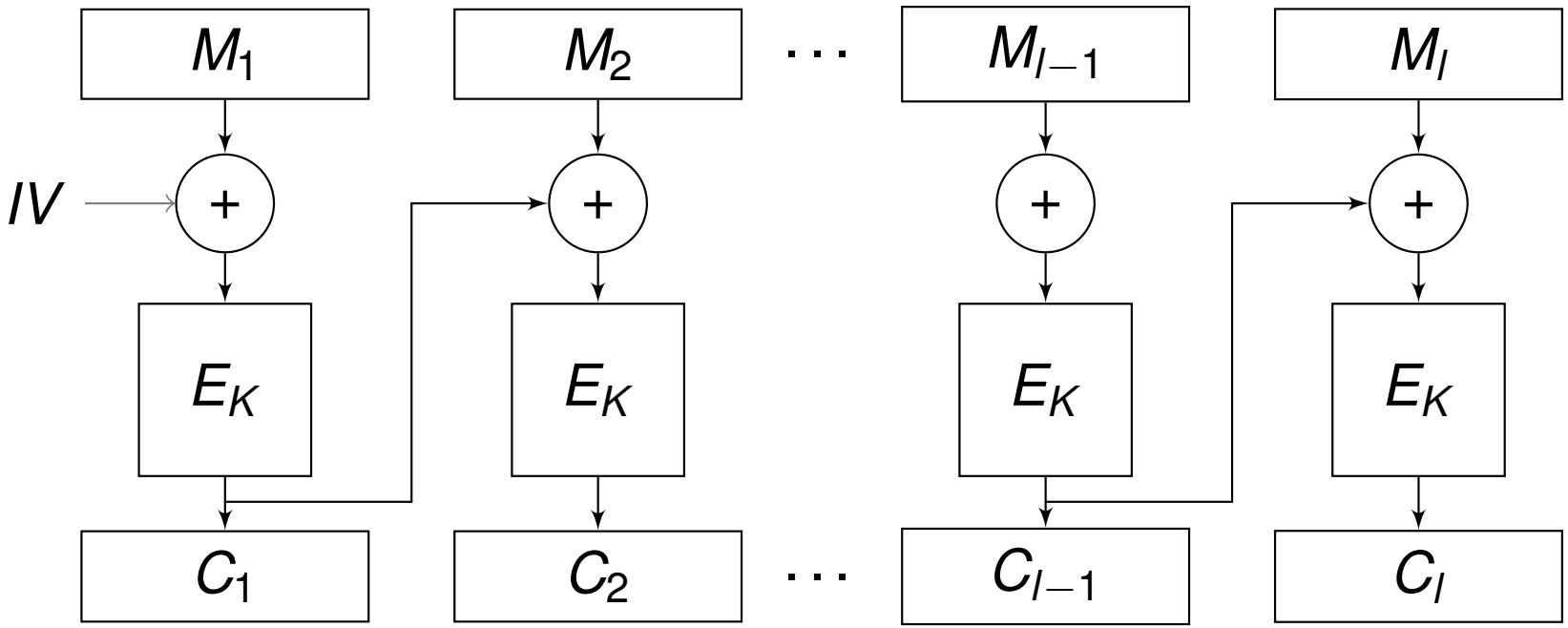
- block cipher: fixed-input-length (FIL)
- apply block cipher iteratively

CBC mode



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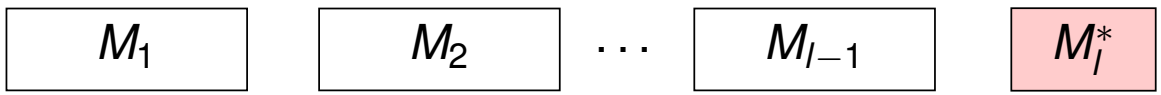
fractional data $\Longrightarrow$ padding

CBC+padding



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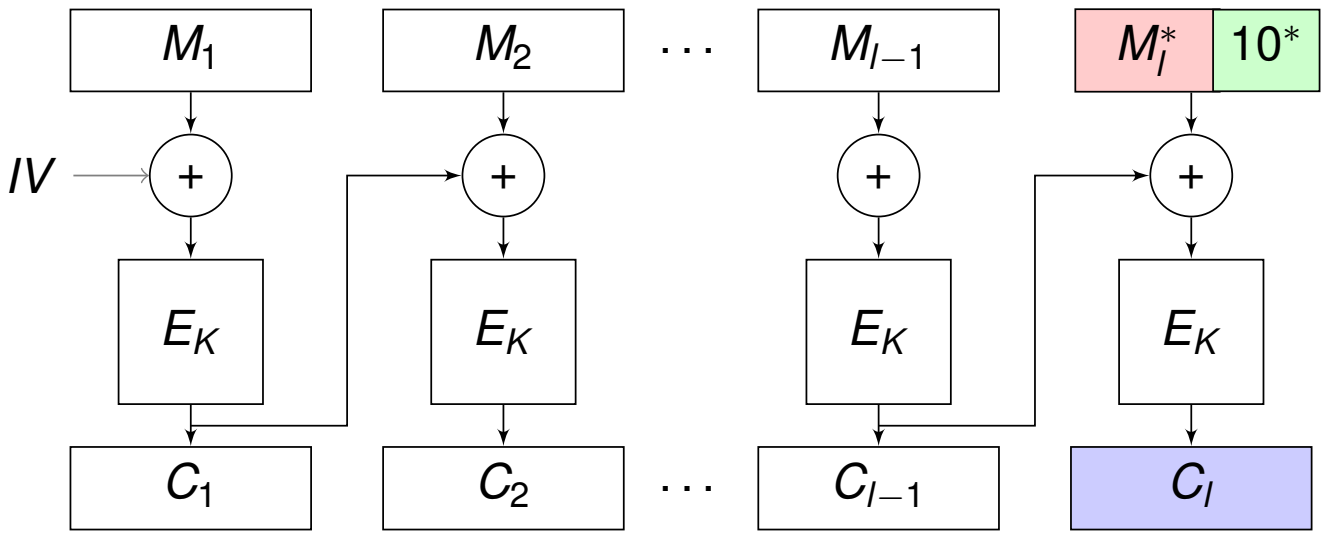

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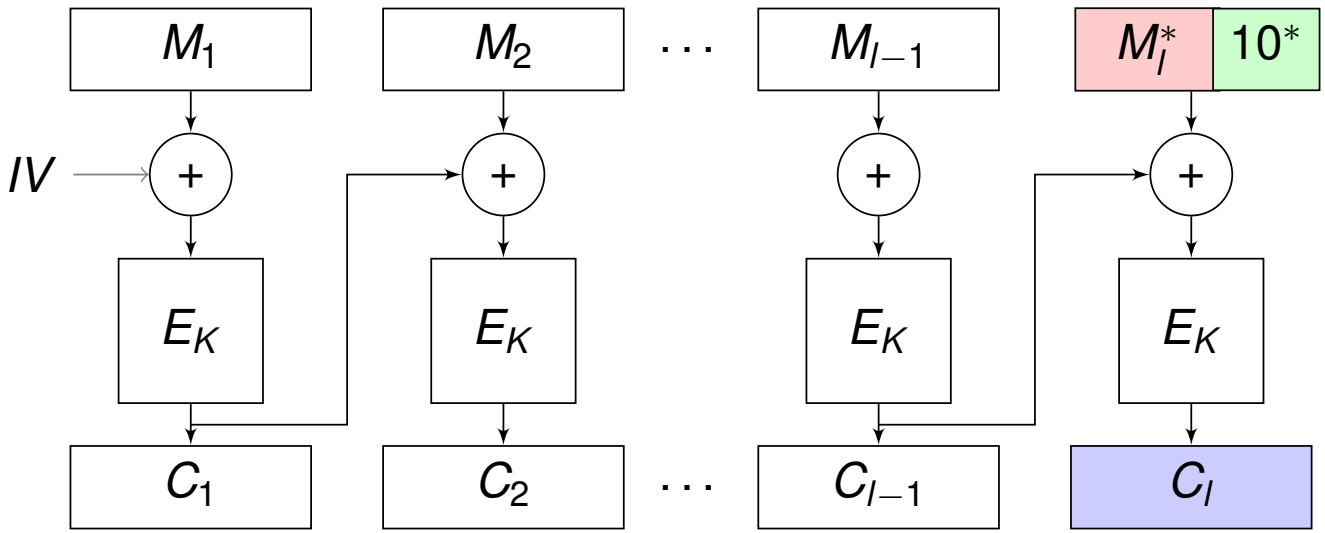

ciphertext expansion: $|C| > |M|$

Avoiding ciphertext expansion

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   $\Longrightarrow$ not suitable for some applications

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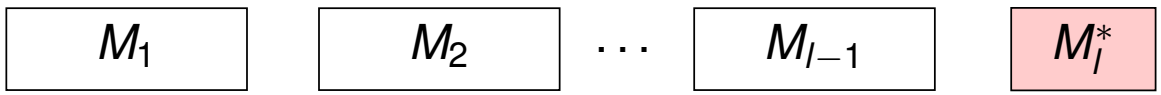

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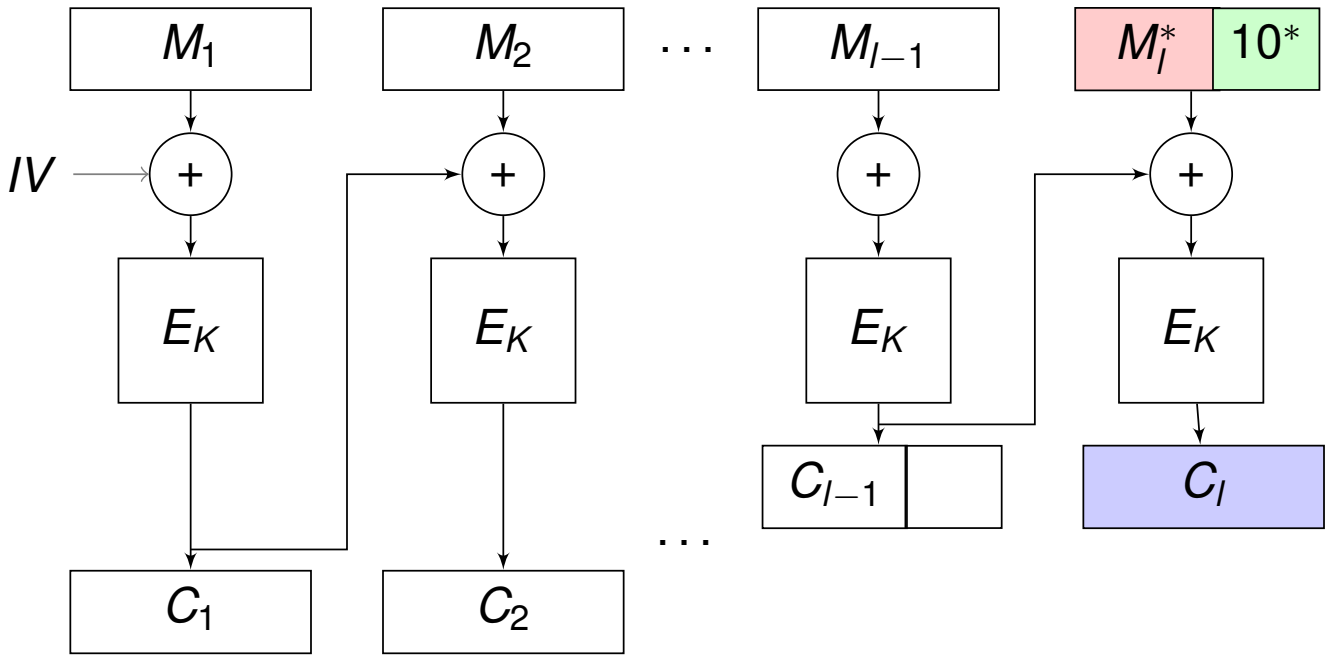

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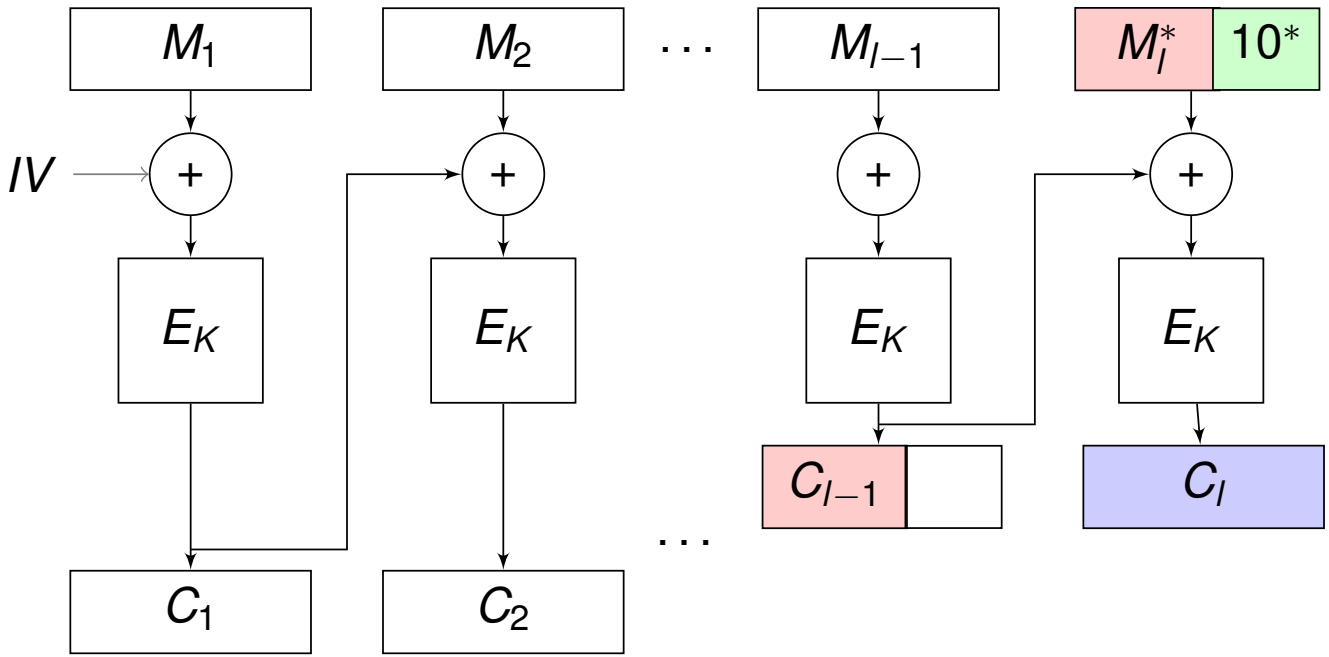

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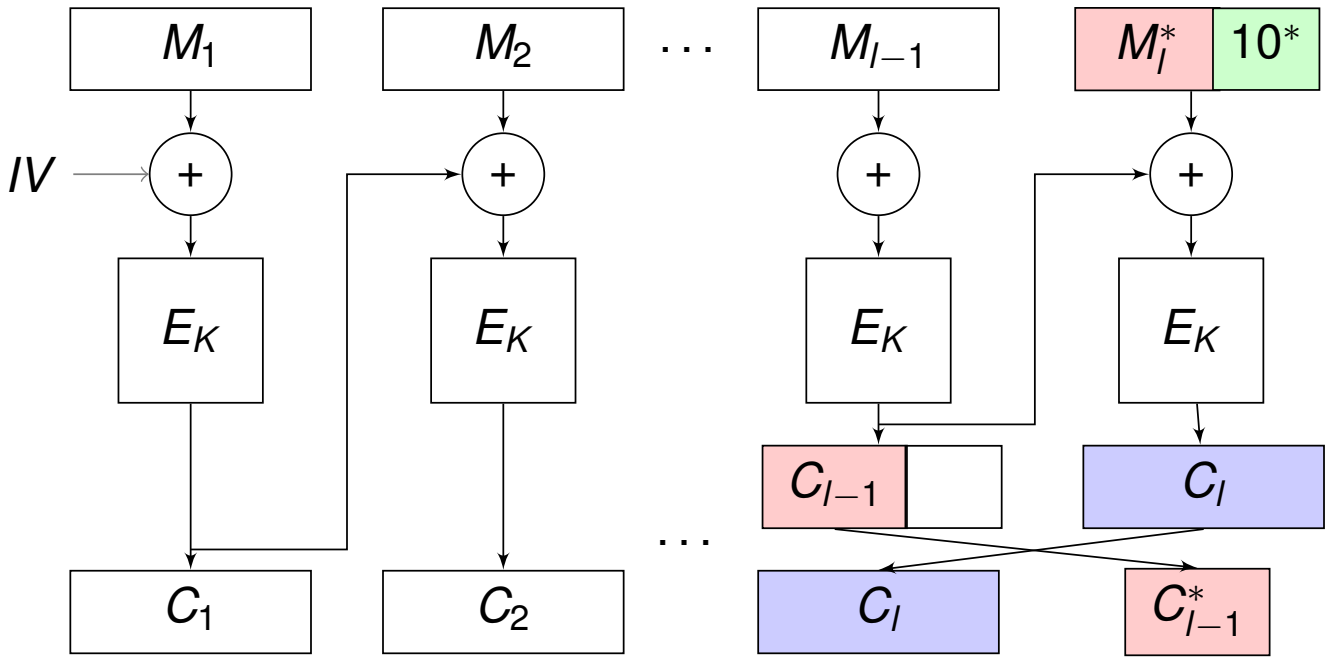

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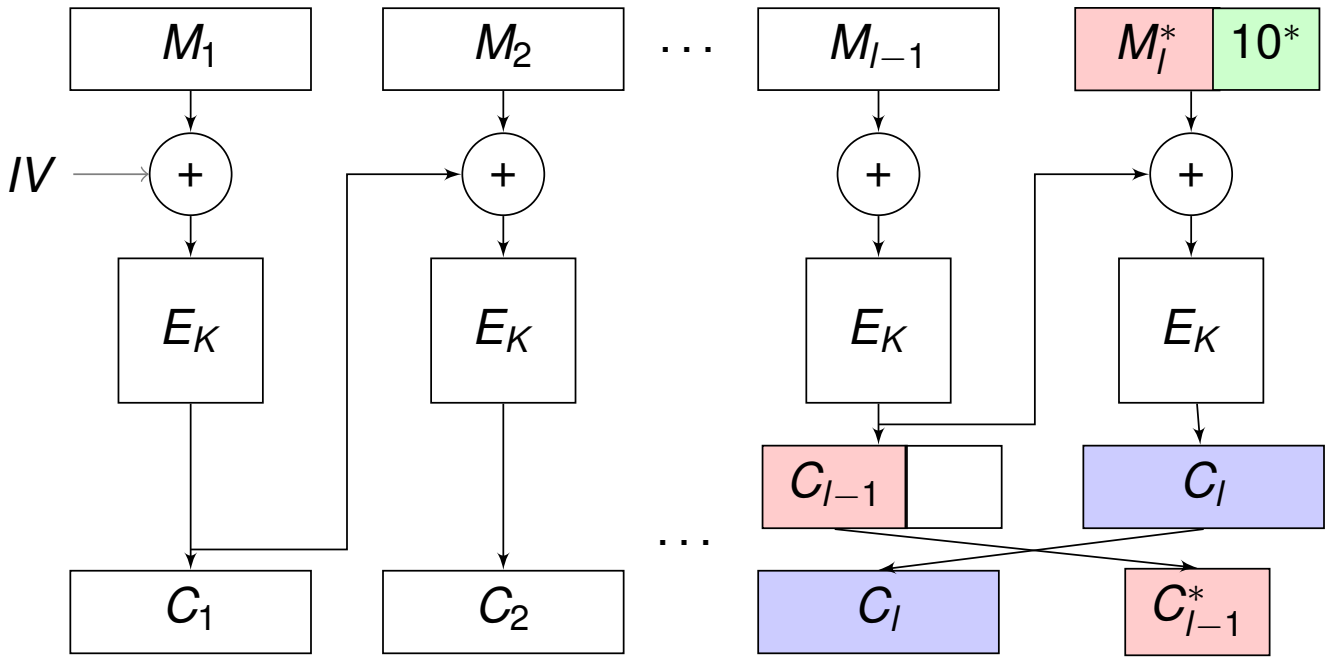
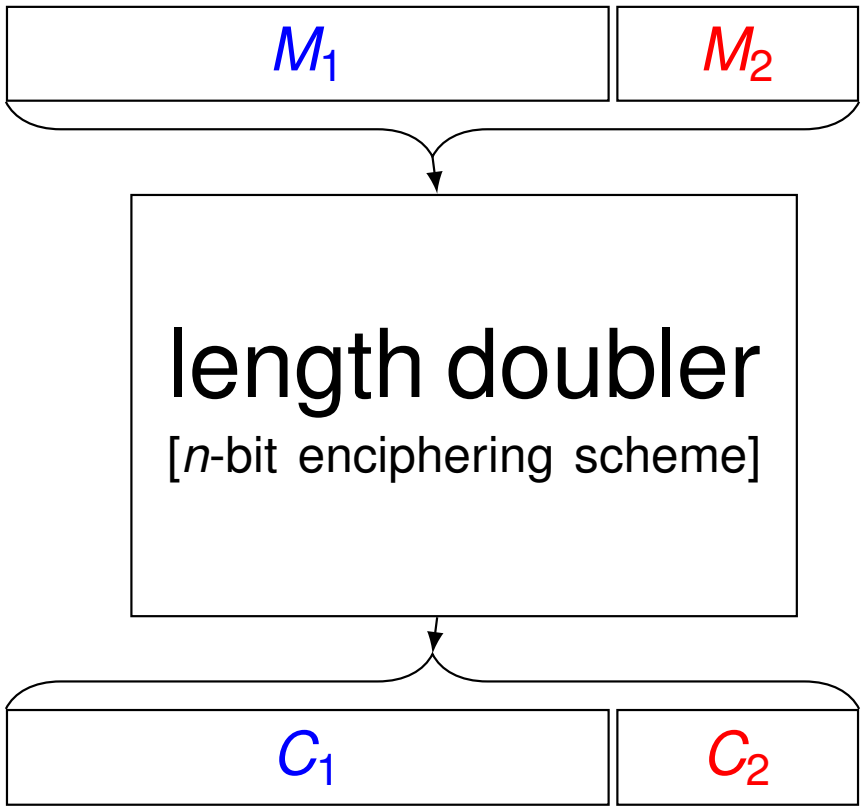


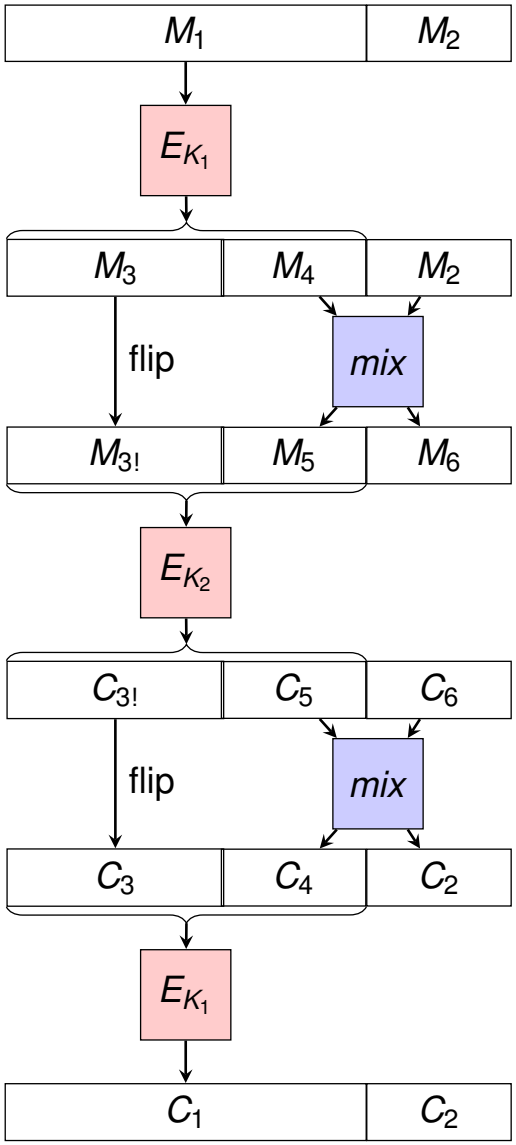
- condition: C_i's need to be decrypted independently

Length doublers



- $|M_1| = |C_1| = n =$ block size
- $|M_2| = |C_2| \in [0, n-1]$

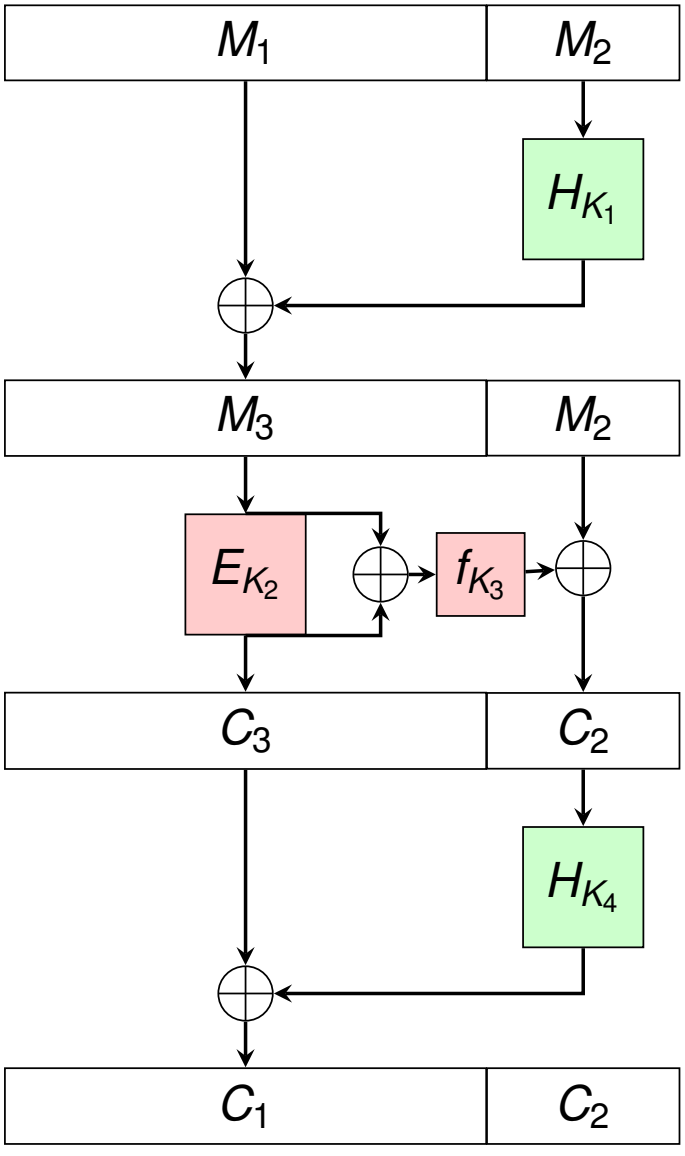
XLS



Ristenpart and Rogaway (2007)

- ϵ-good mixing function
- broken by Nandi in 2014

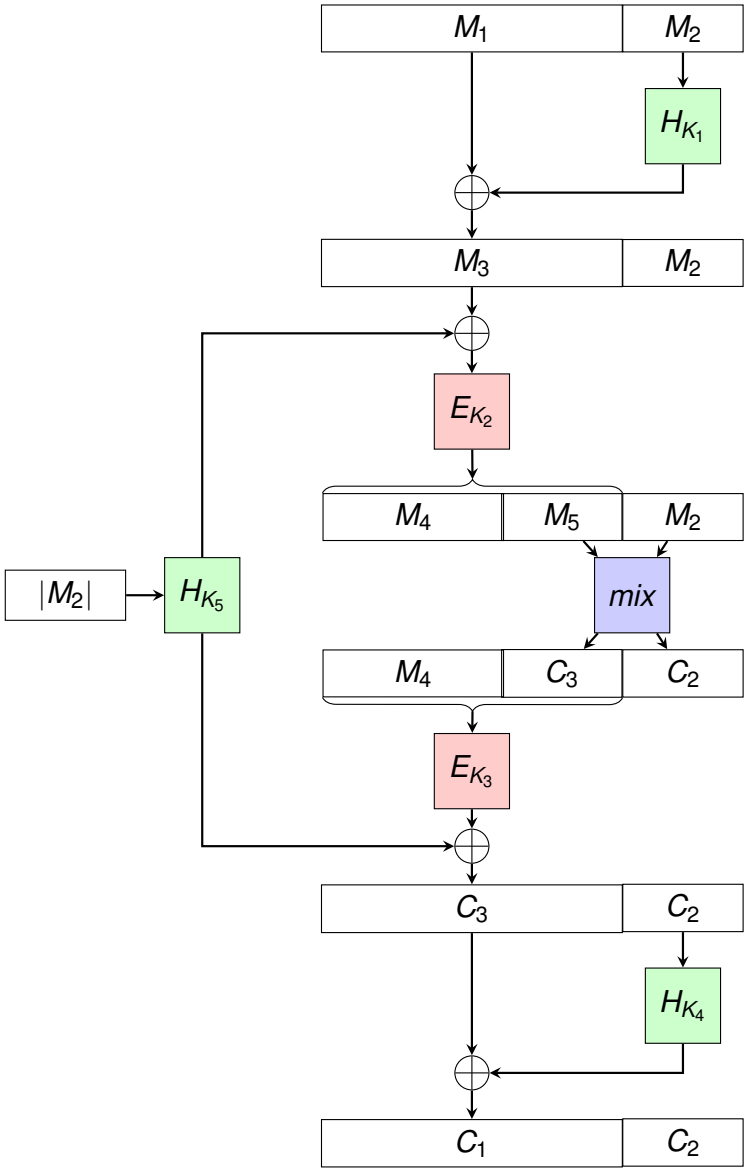
DE



Nandi (2009)

- four cryptographic primitive calls

HEM



Zhang (2012)

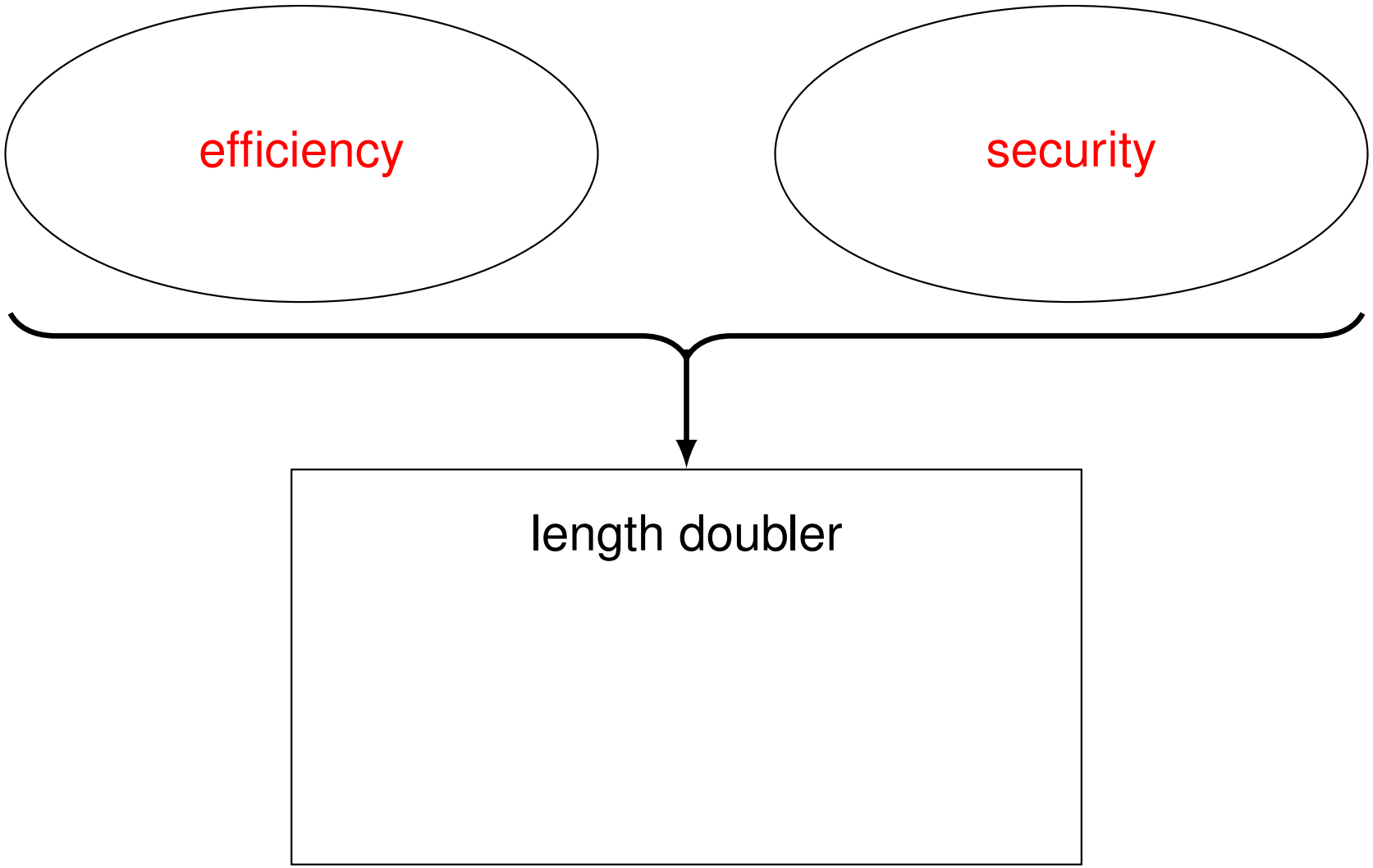
- five cryptographic primitive calls
- ϵ-good mixing function

State of the art

length doubler	security ($\log_2$)	key length	cryptographic primitive calls	mixing function
XLS	$n/2$	$2n$	3 BC	ϵ-good
DE	$n/2$	$5n$	4 hash+BC	-
HEM	$n/2$	$3n$	4 hash+BC	ϵ-good

- at least 4 cryptographic primitive calls needed?
- beyond $2^{n/2}$ security?

Our contribution



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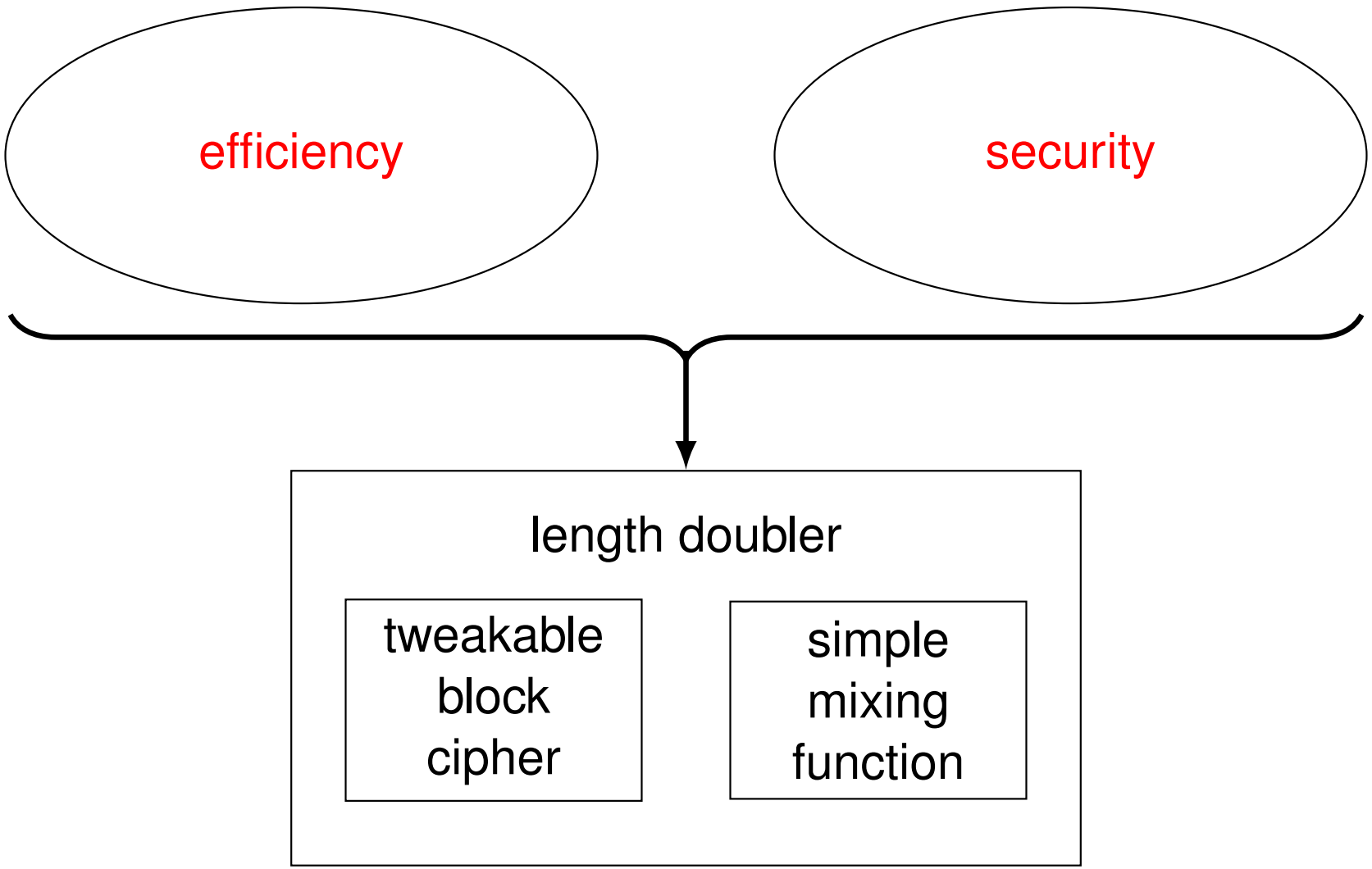

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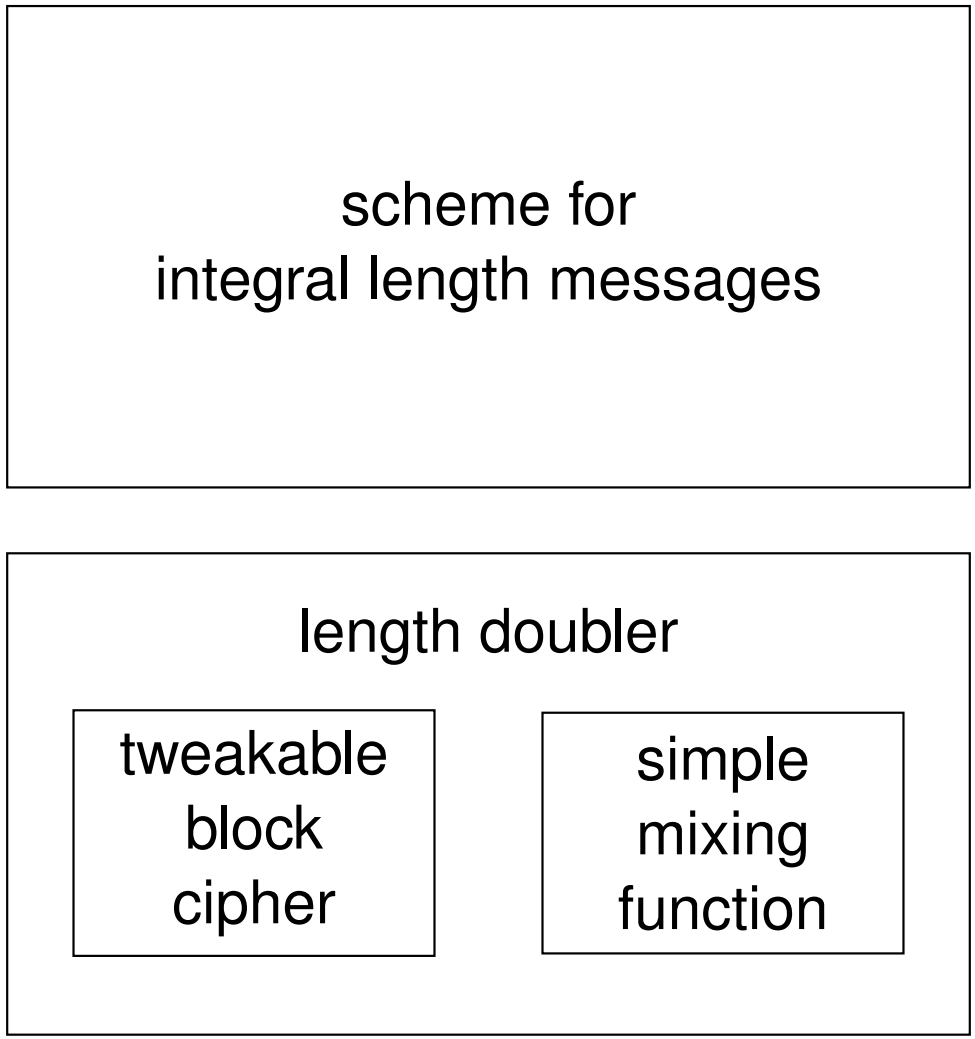

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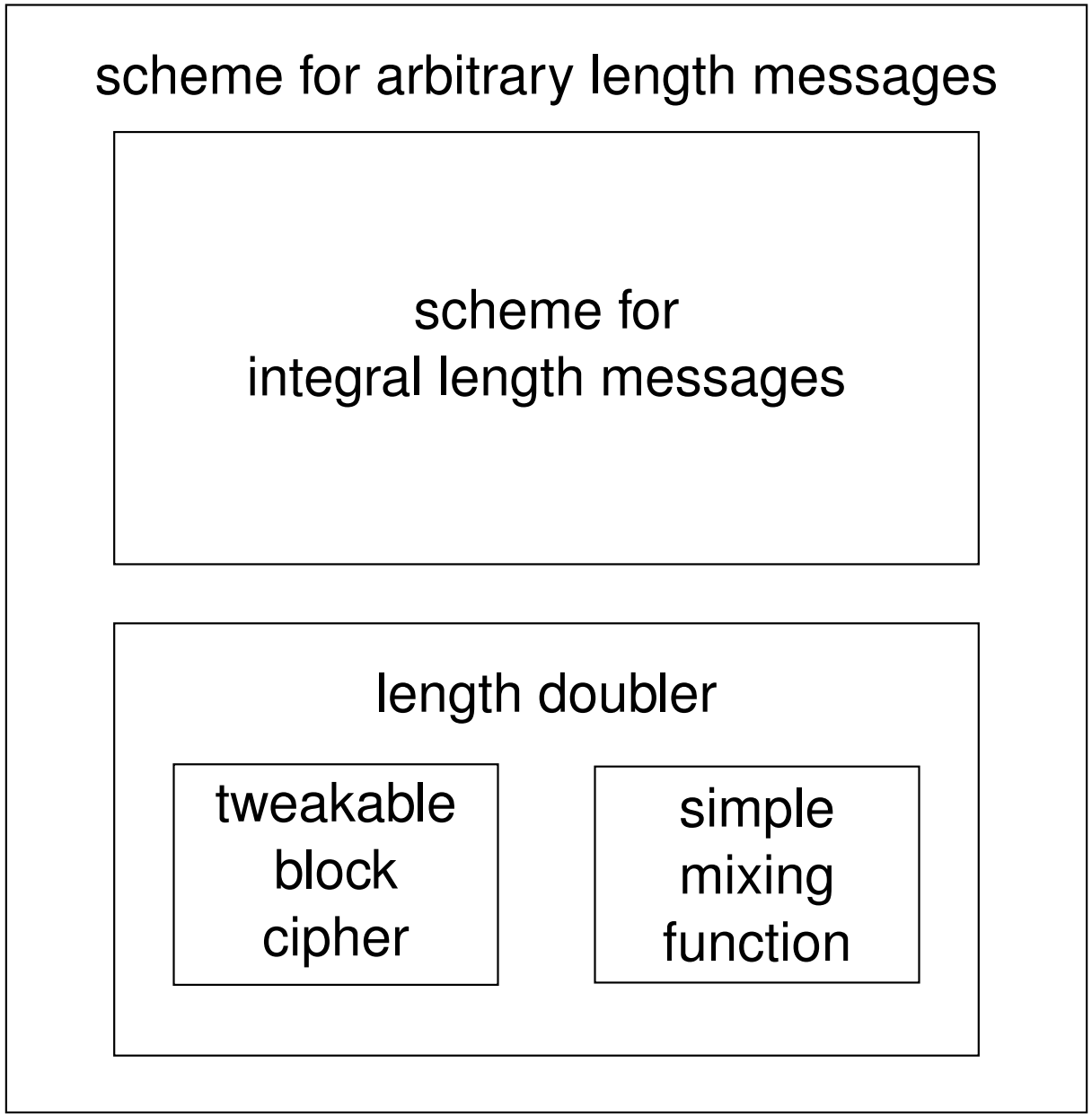
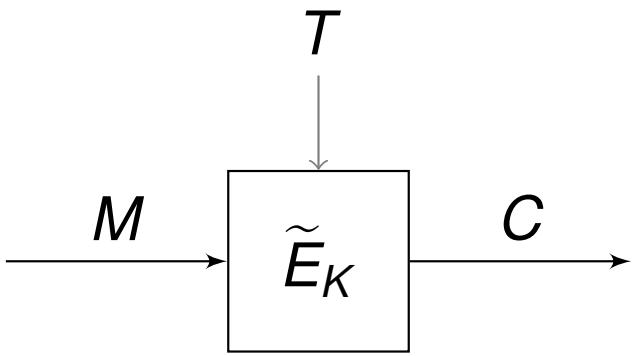


Tweakable block ciphers

- extension of conventional block cipher
- different tweak $T \longrightarrow$ independent permutation



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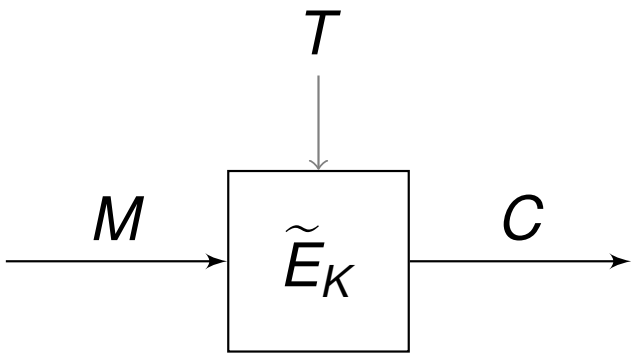

examples

- LRW, CRYPTO 2002
- XEX, ASIACRYPT 2004
- TWEAKEY, ASIACRYPT 2014
- SKINNY, CRYPTO 2016

Pure mixing functions

- ϵ-good mixing functions: smaller ϵ is better
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- easier to construct than ϵ-good mixing functions

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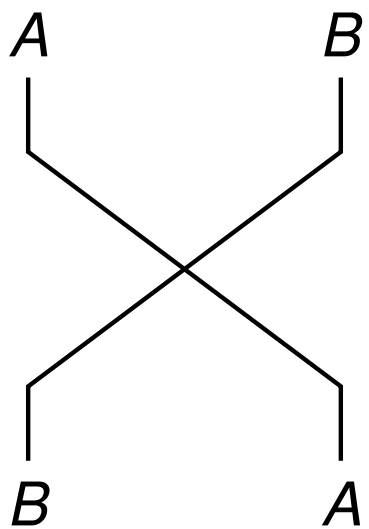
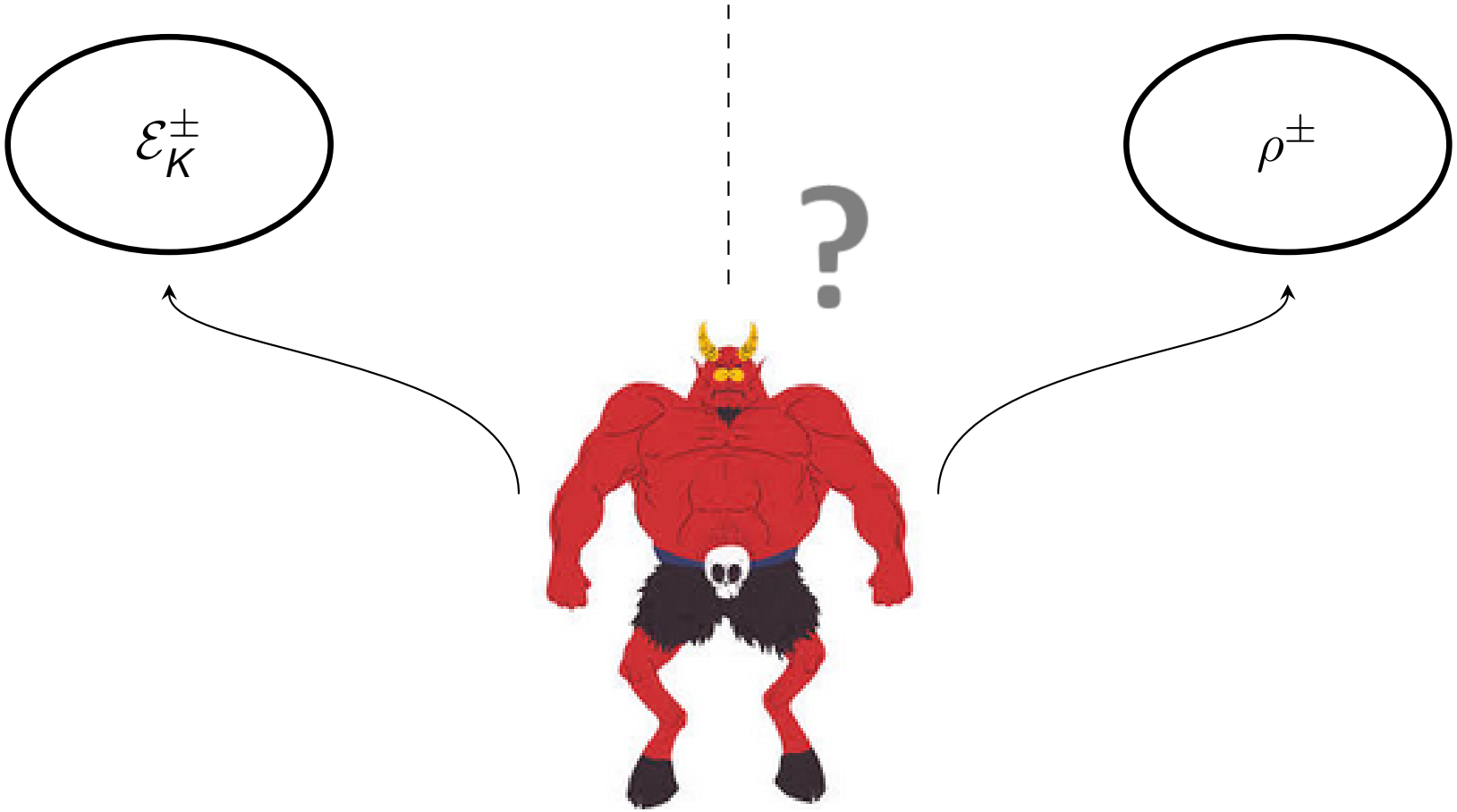
simplest example (not ϵ-good)



Security definition



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- adversary $\mathcal{A}$ makes q queries to oracle ($\mathcal{E}_K$ or ρ)

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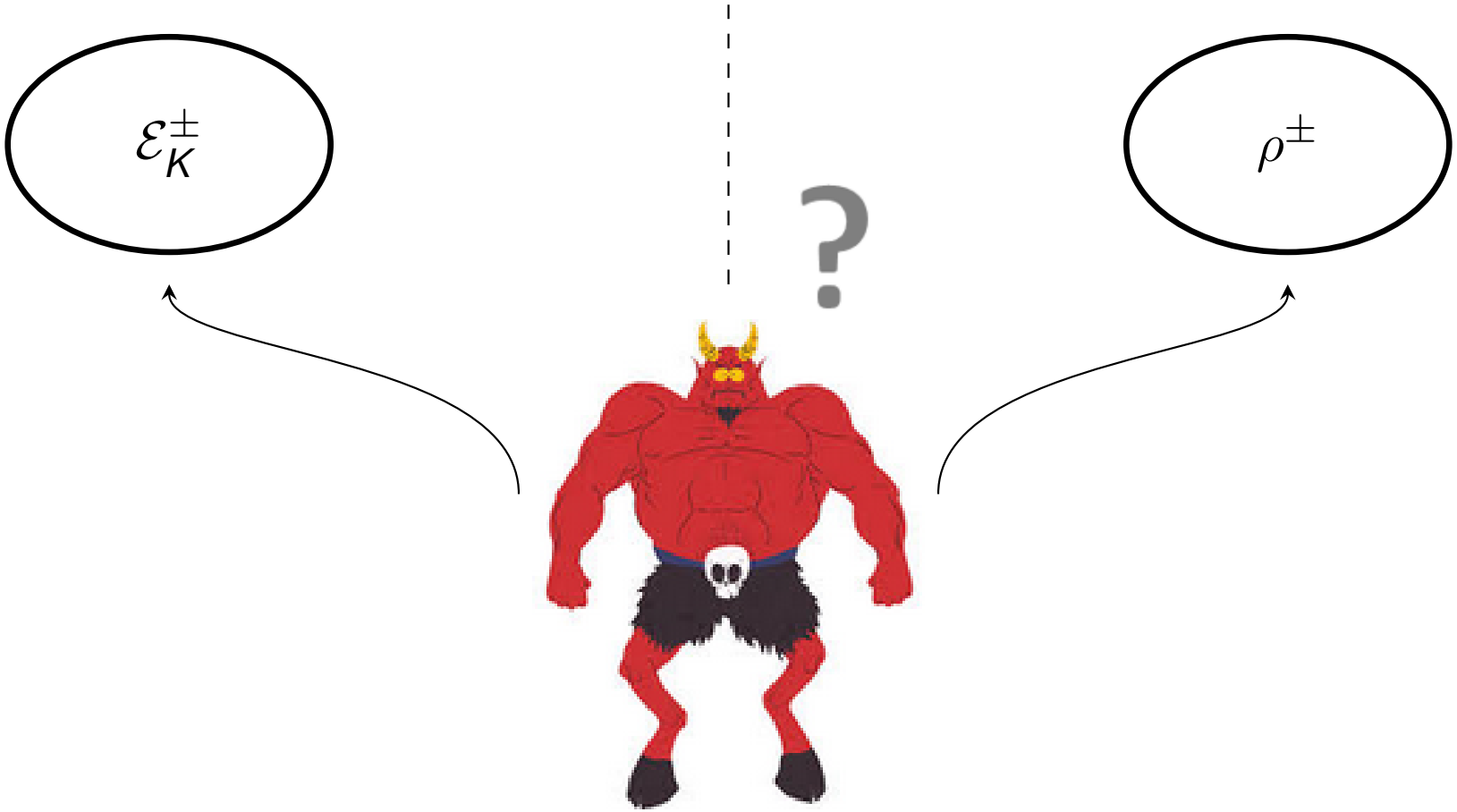

adversary $\mathcal{A}$

- adversary $\mathcal{A}$ makes q queries to oracle ($\mathcal{E}_K$ or ρ)
- strong length-preserving pseudorandom permutation
  $\iff$ $\mathcal{A}$ cannot determine which world it is interacting with

Our length doubler **LDT**

- 2 tweakable block cipher calls
- pure mixing function
- decryption function similar to encryption function

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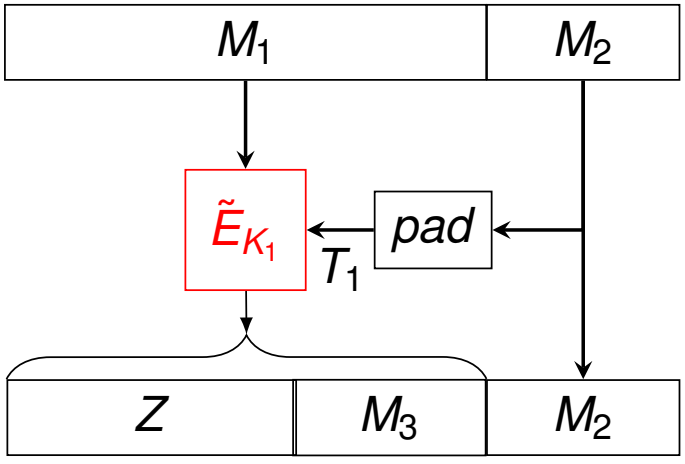

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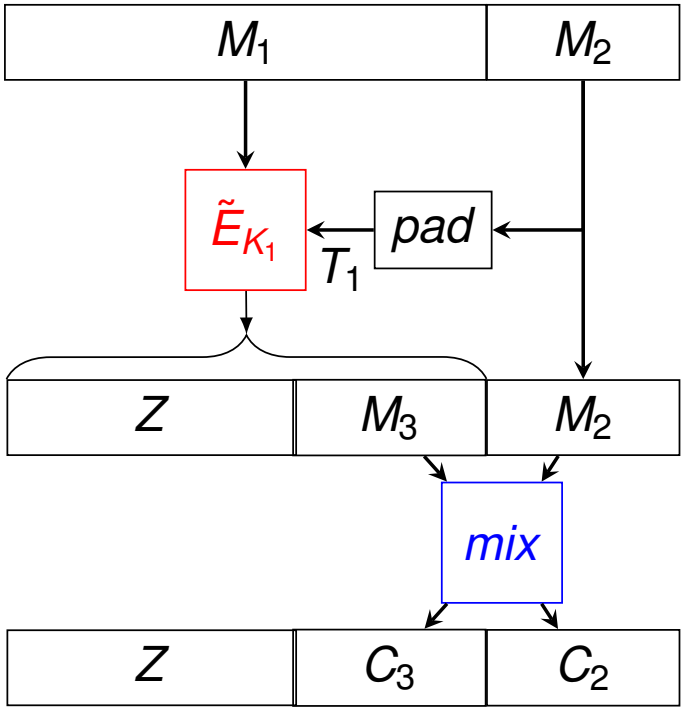

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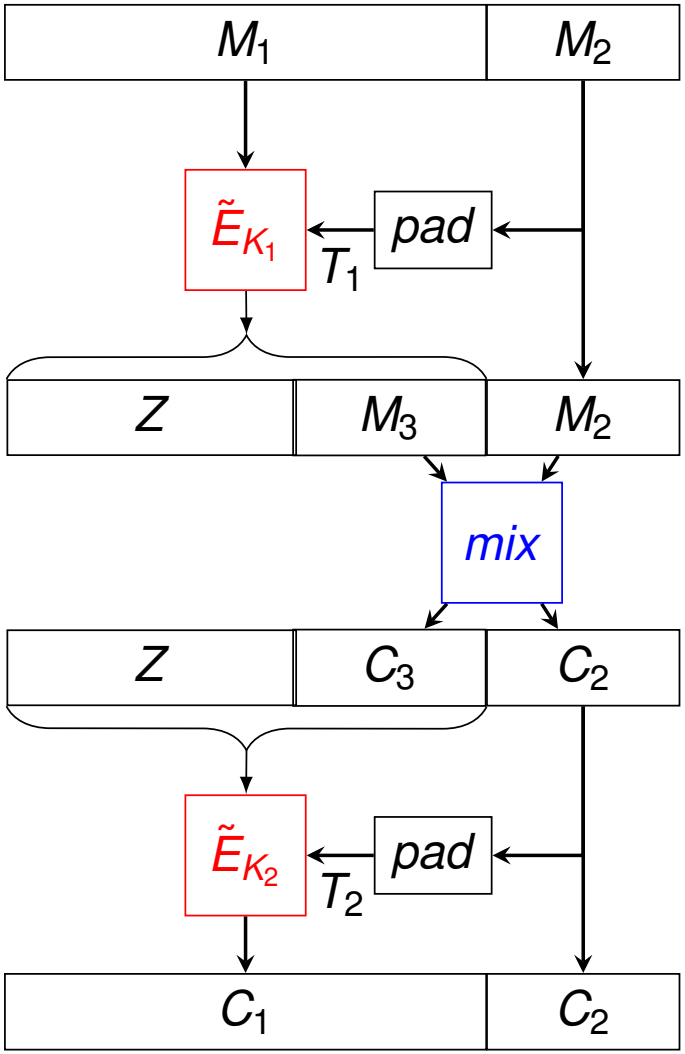

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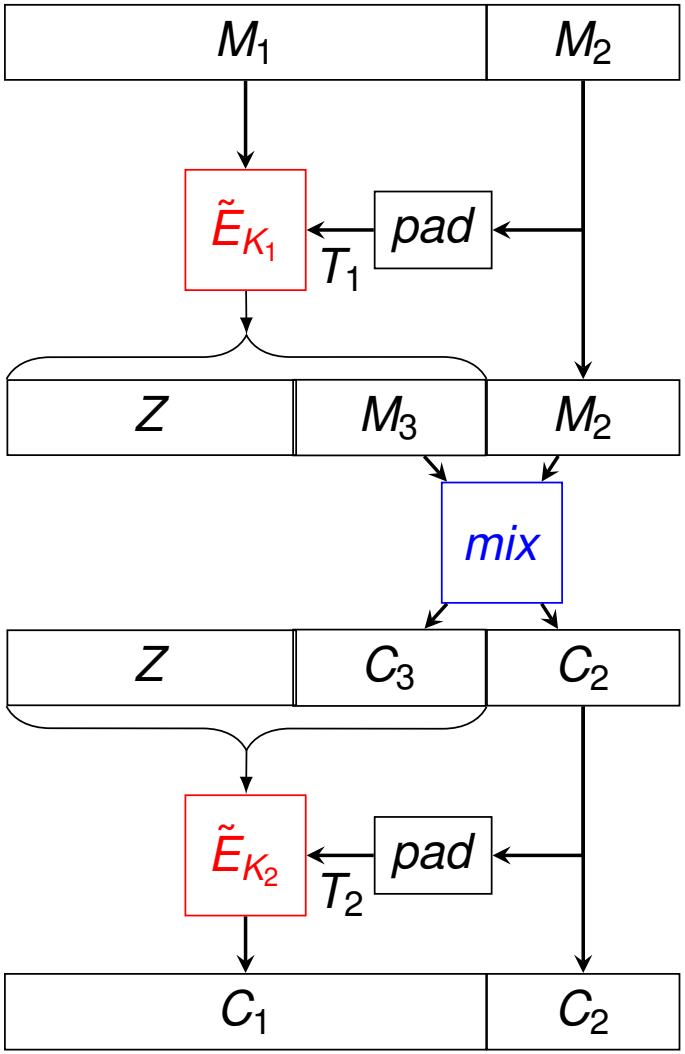

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security lower bound: $2^{n/2}$

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- our case: $Pr(X_{\mathcal{P}} \in \mathcal{T}_{\text{bad}}) = 0$ and $\epsilon = q^2/2^n$

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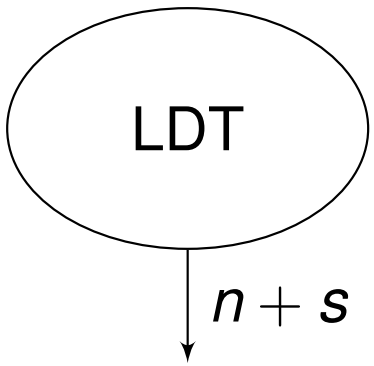

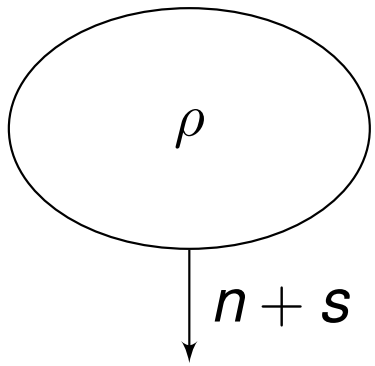

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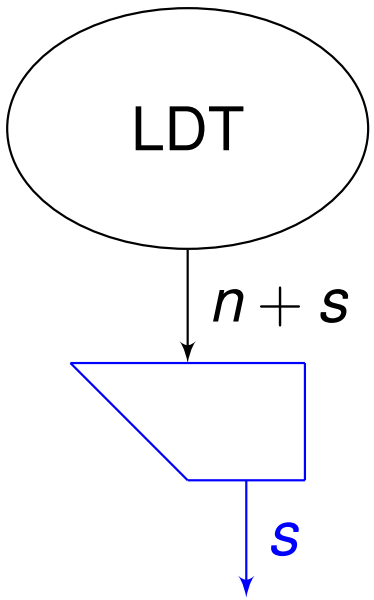

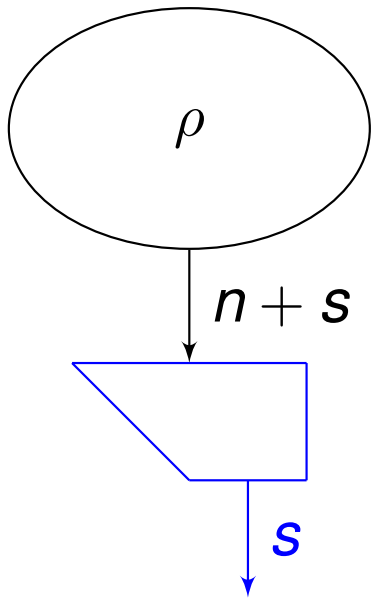

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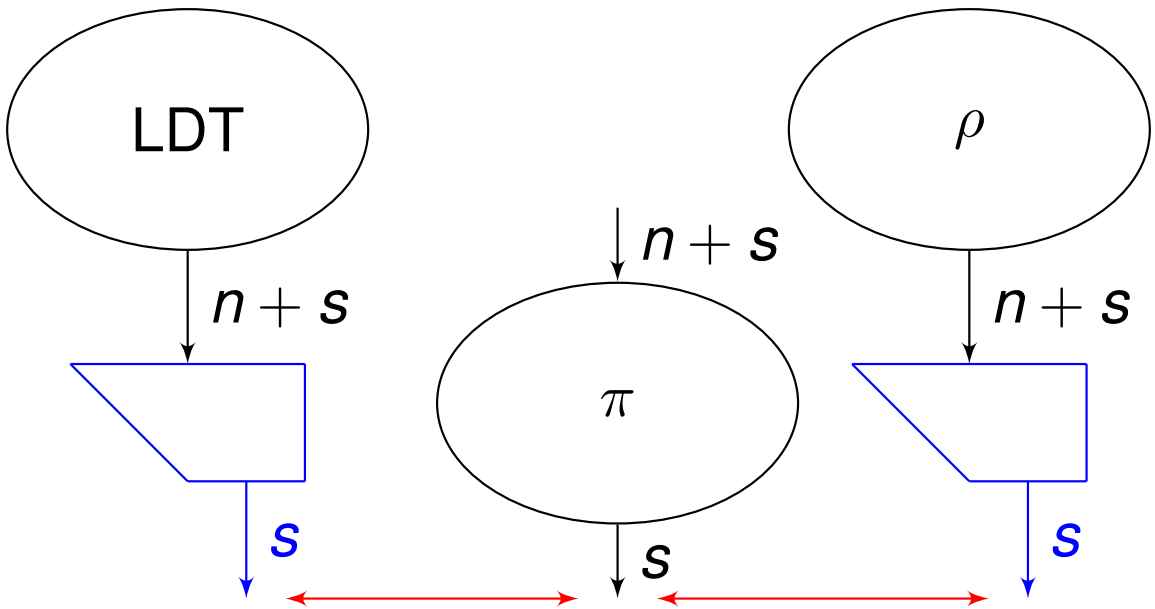

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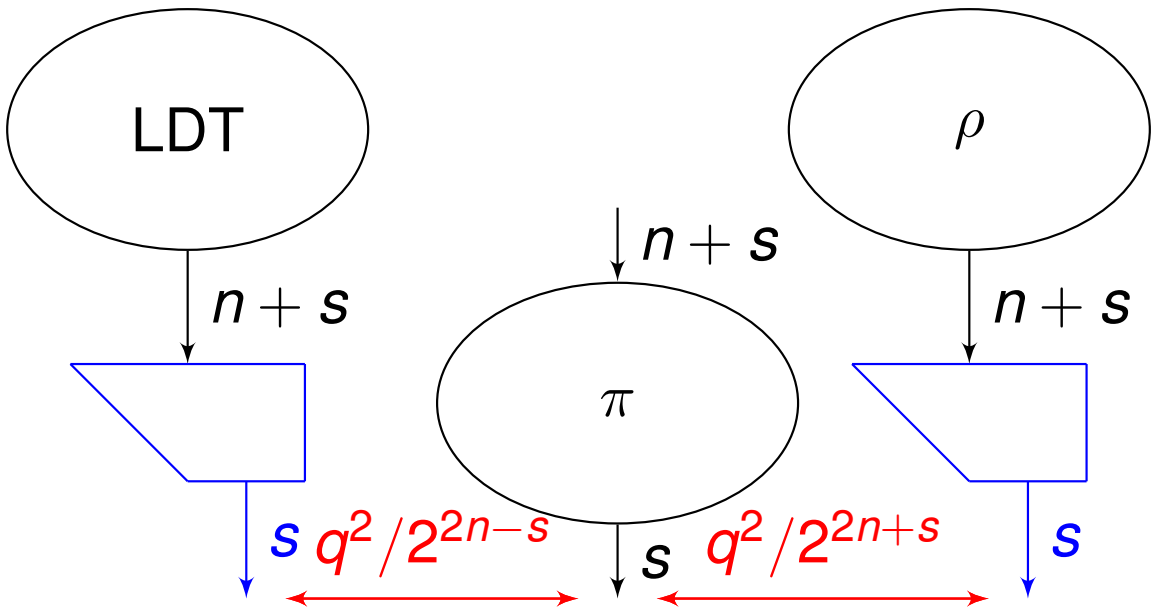

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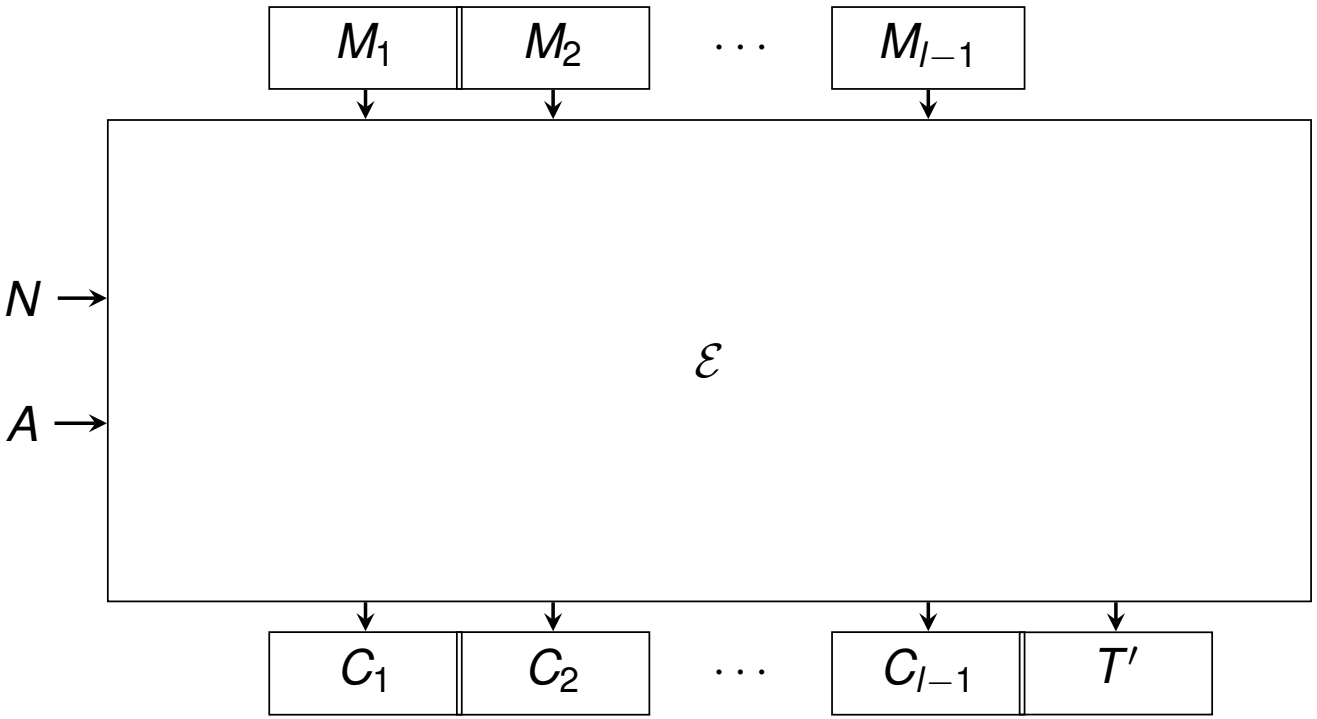

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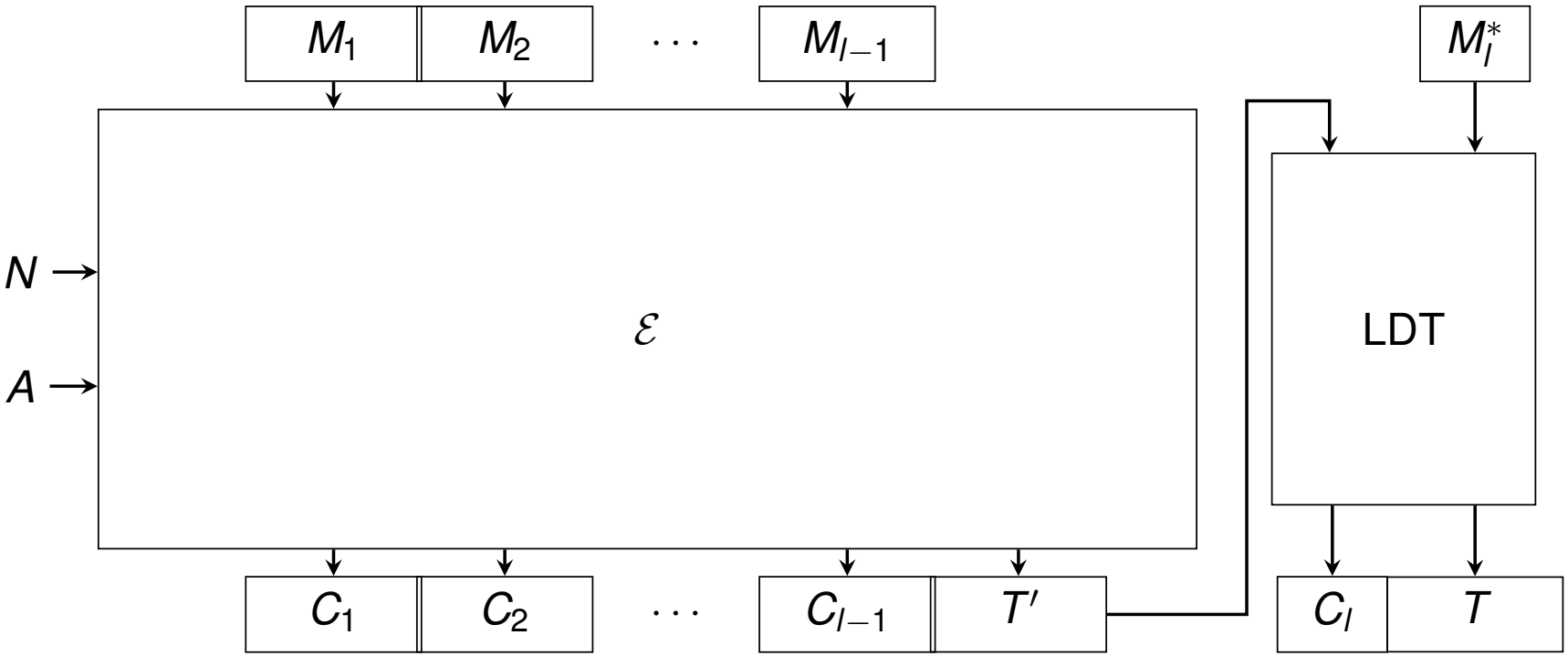

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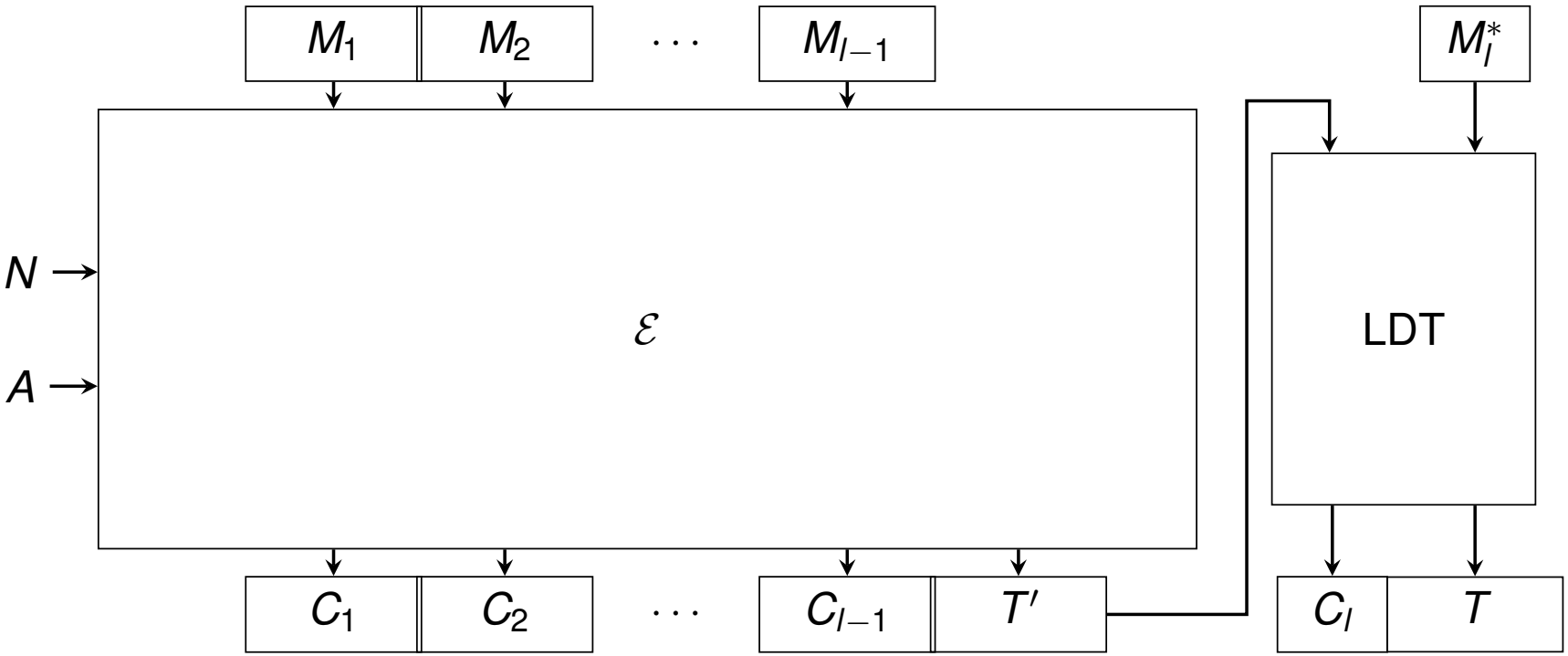

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