COBRA: A Parallelizable Authenticated Online Cipher without Block Cipher Inverse[1]

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COSIC
KU Leuven and iMinds

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[1] Joint work with E. Andreeva, B. Mennink, and K. Yasuda.

Overview

COBRA

1. Misuse resistance
2. Online
3. GCM-like efficiency
4. No block cipher inverse
5. Security reduction to block cipher

Background: Misuse Resistance

Nonces cannot always be guaranteed unique:

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2. Reset during backup
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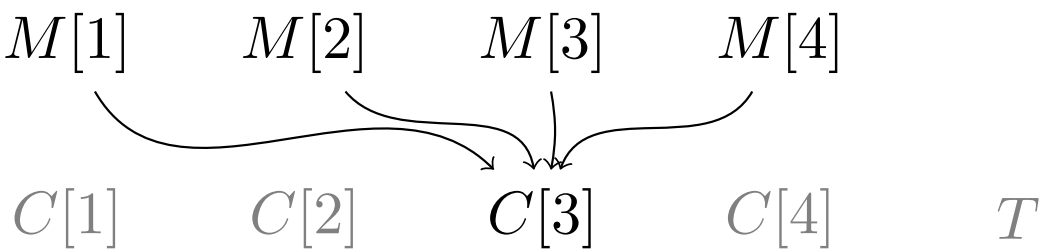
$\Rightarrow$ We want *online* schemes

Background: *Online* Scheme



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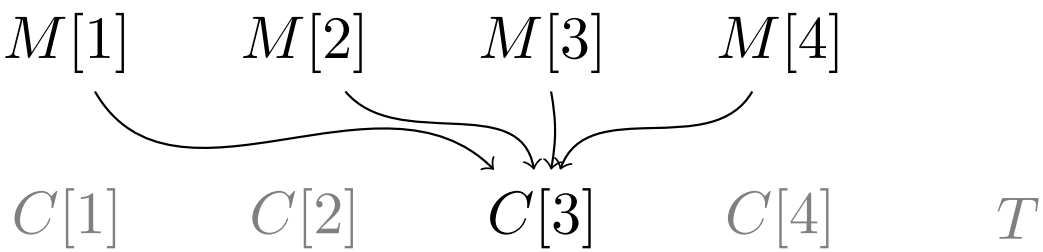

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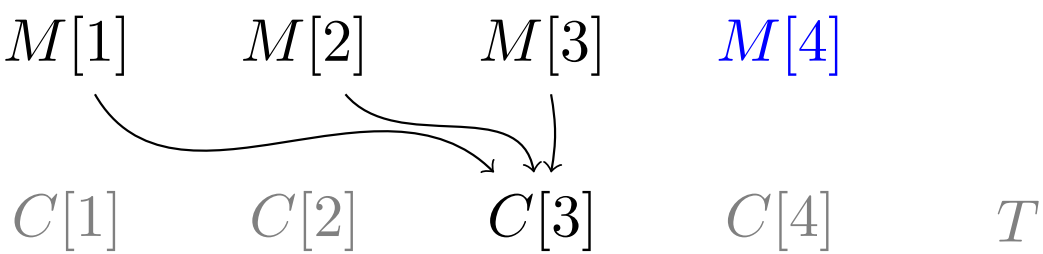
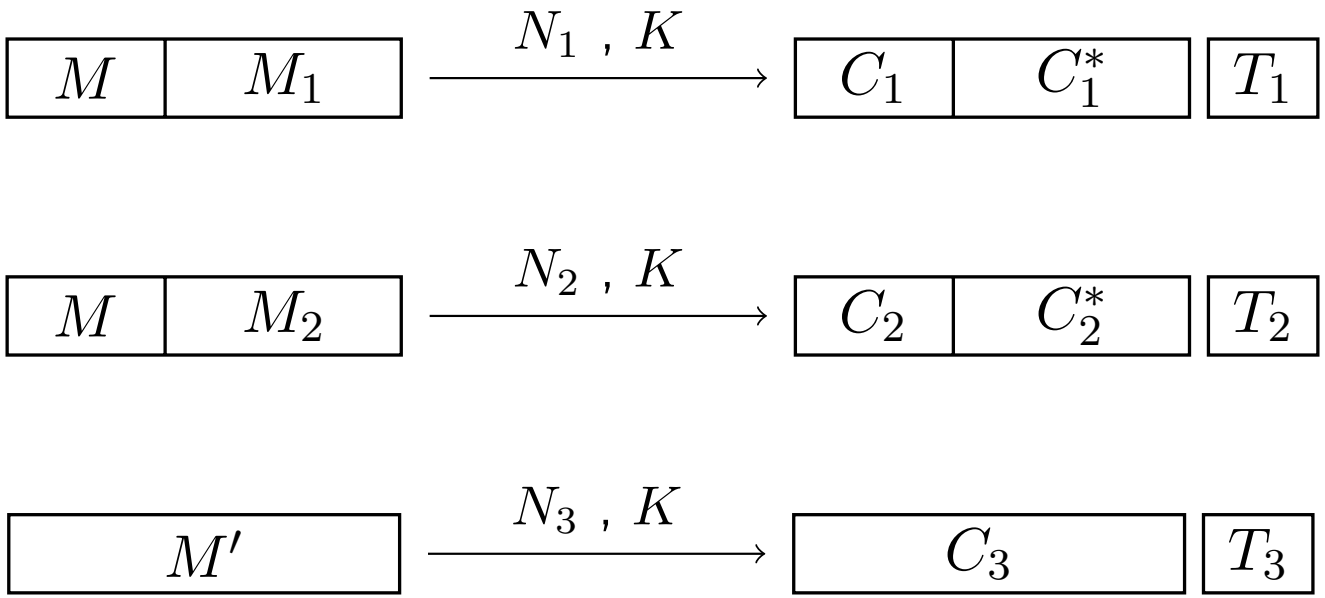


Dependency in an *online* AE scheme.

Background: *Online* Nonce Misuse



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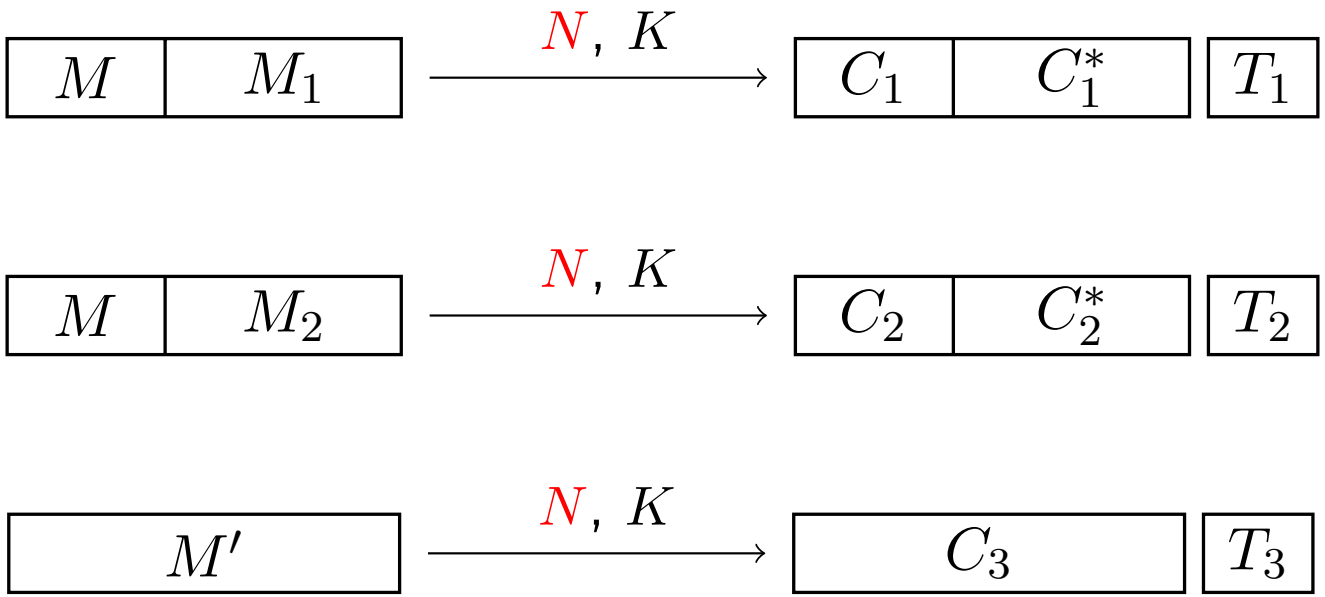

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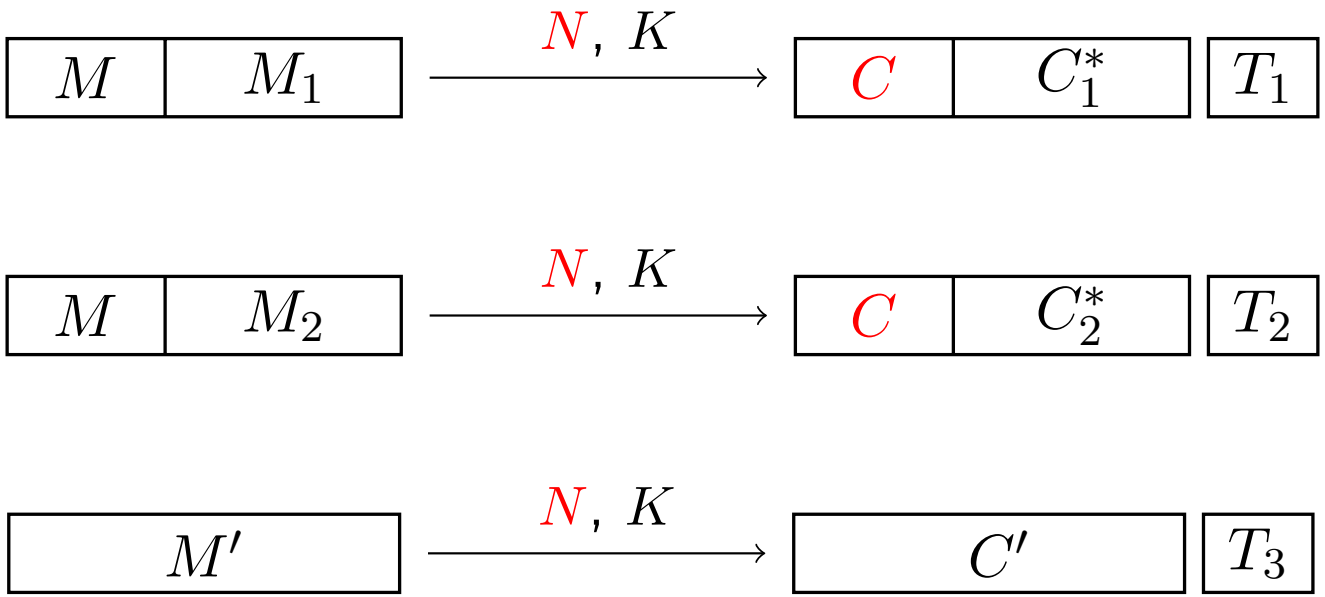

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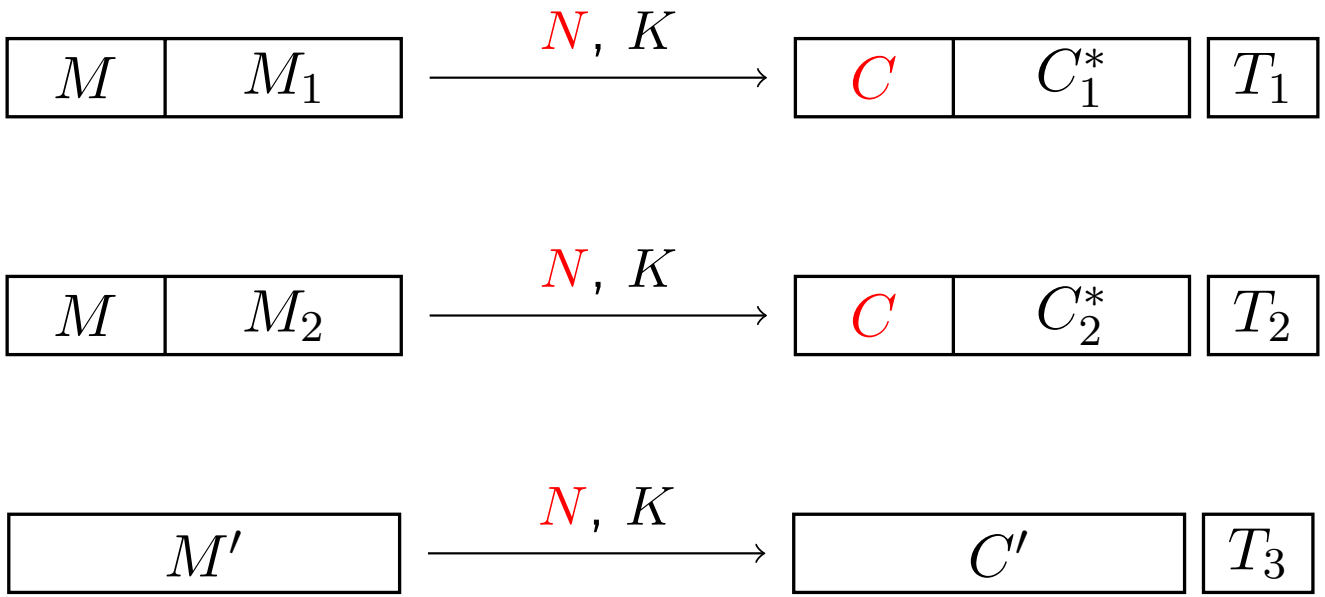

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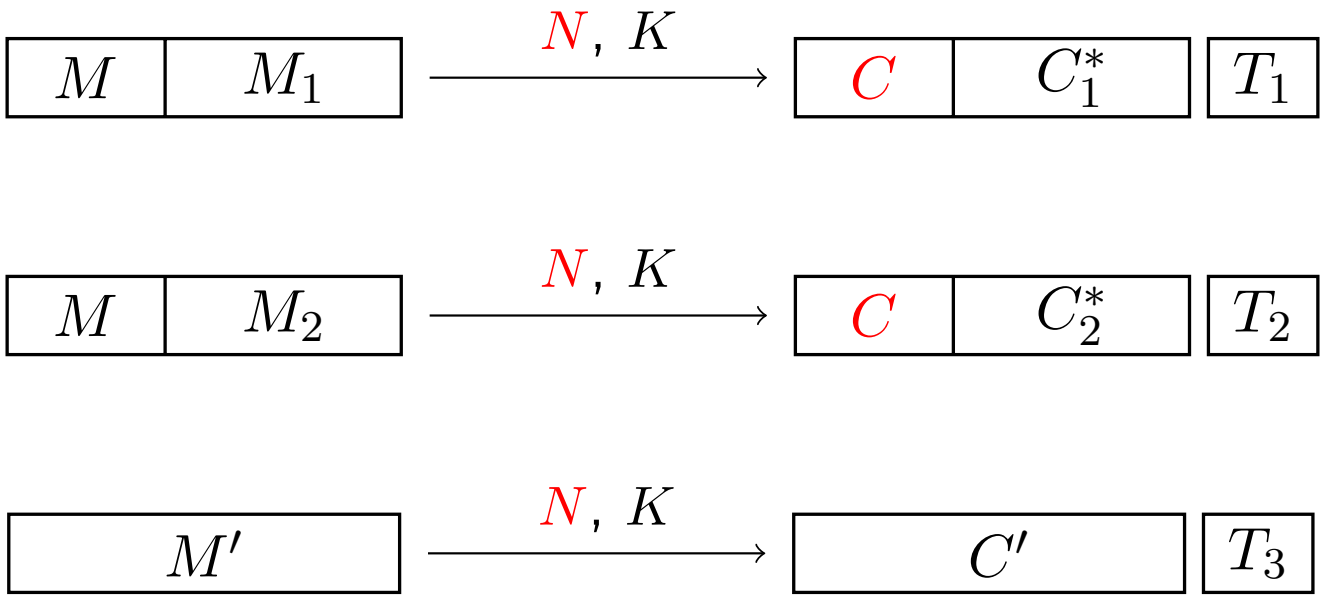
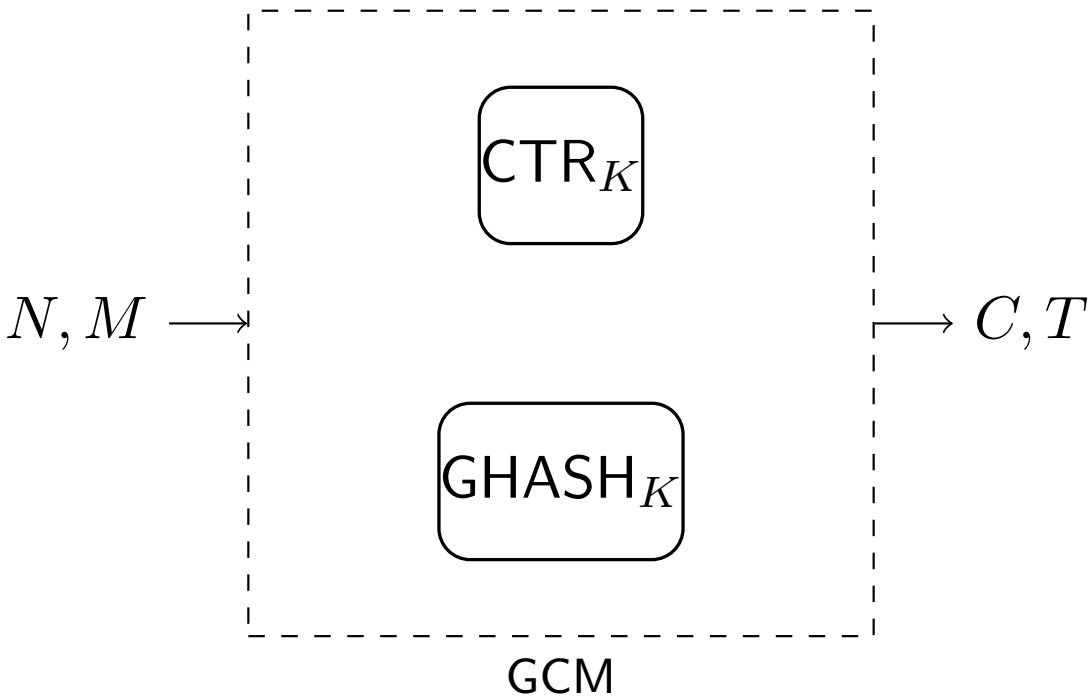


1. Equality of prefixes of messages determined
2. No relationship past common prefix

Background: GCM not Misuse Resistant



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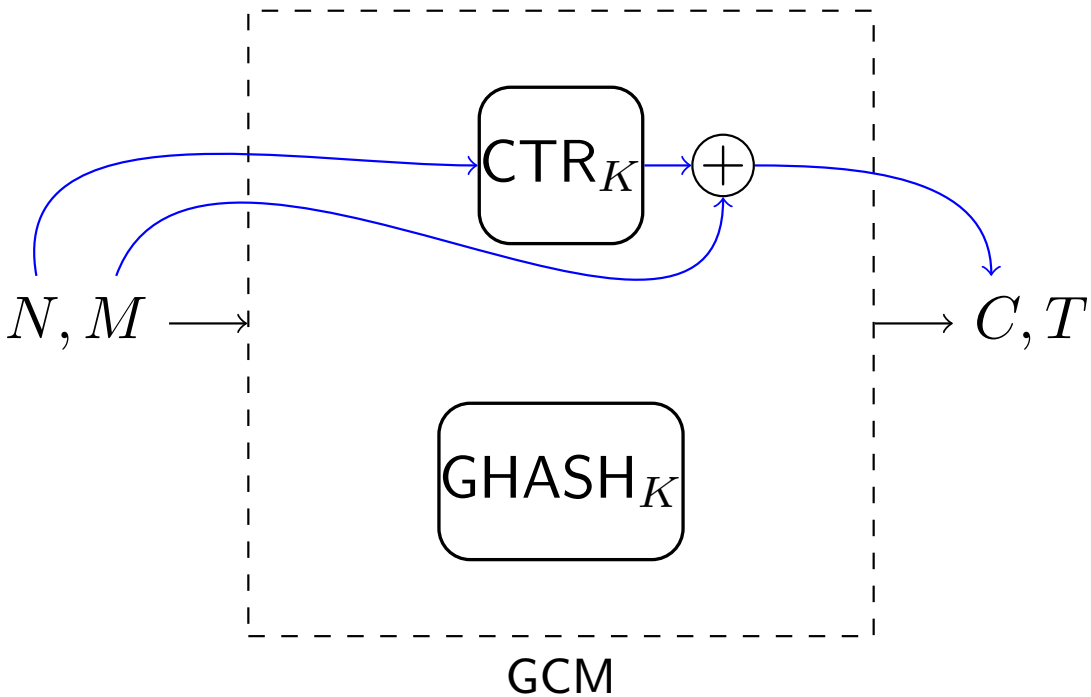

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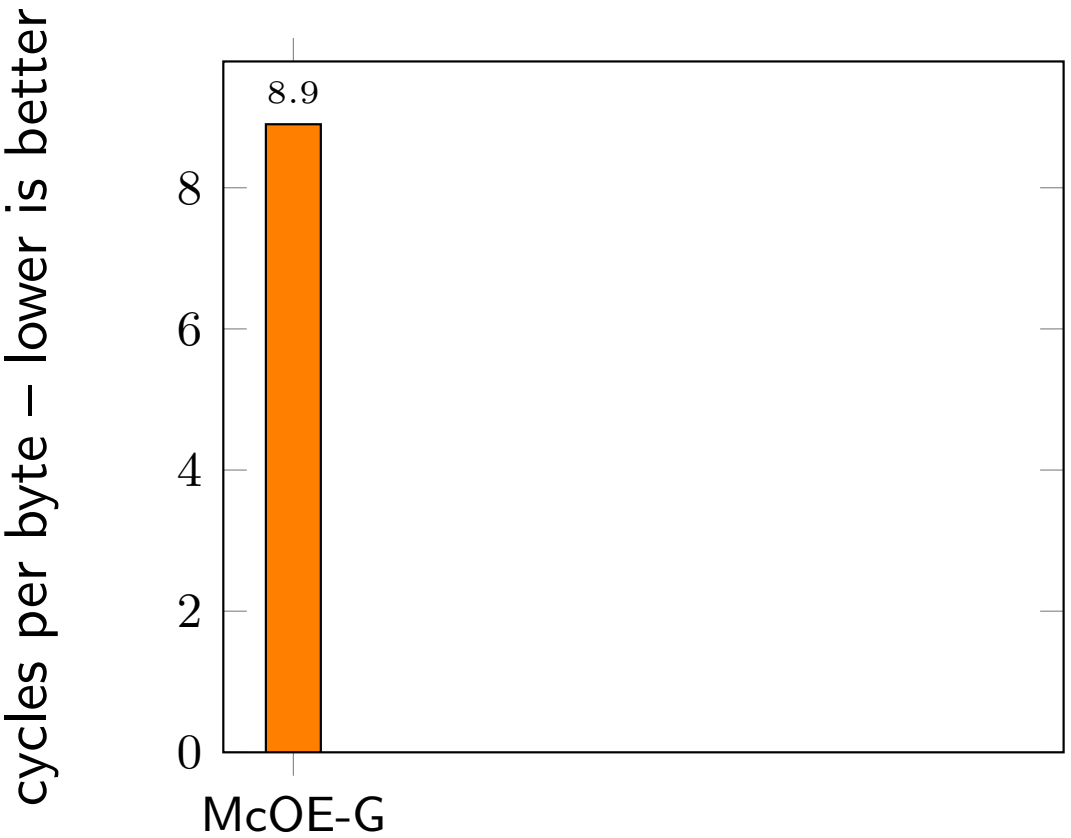

Figure : Sandy Bridge with AES-NI[2]

[2]References: Gueron DIAC 2013 and Andreeva et al. Asiacrypt 2013.

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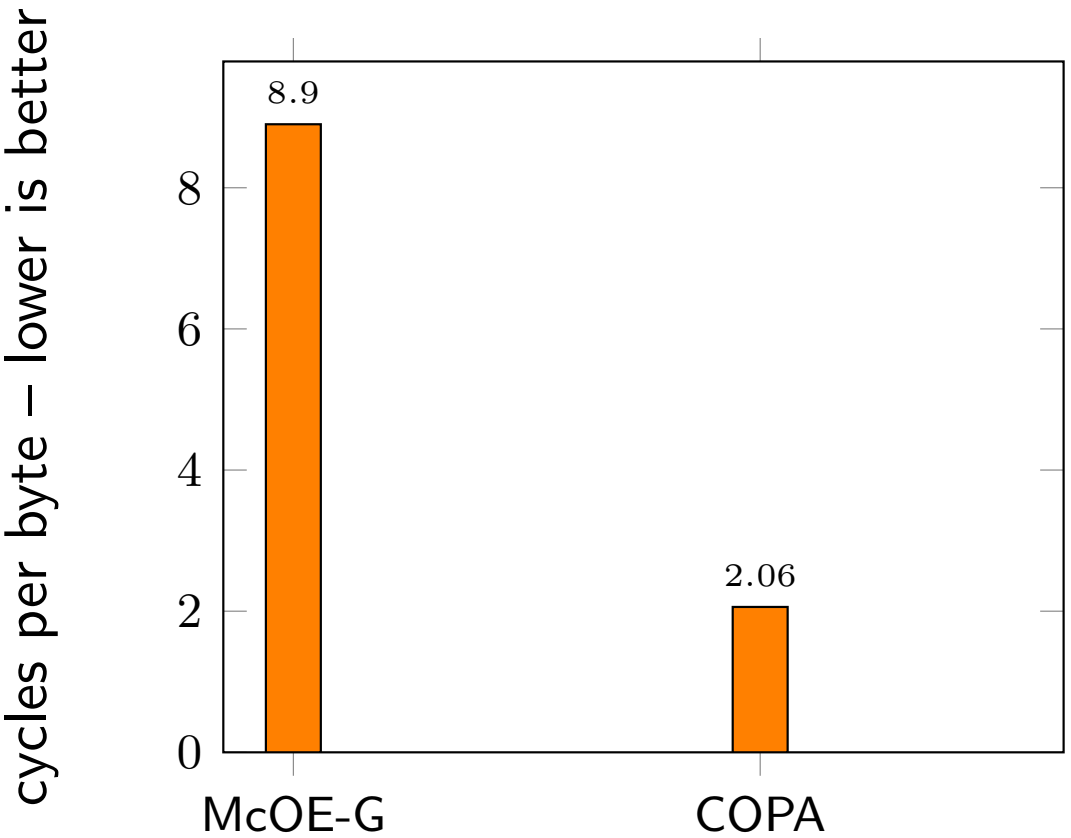

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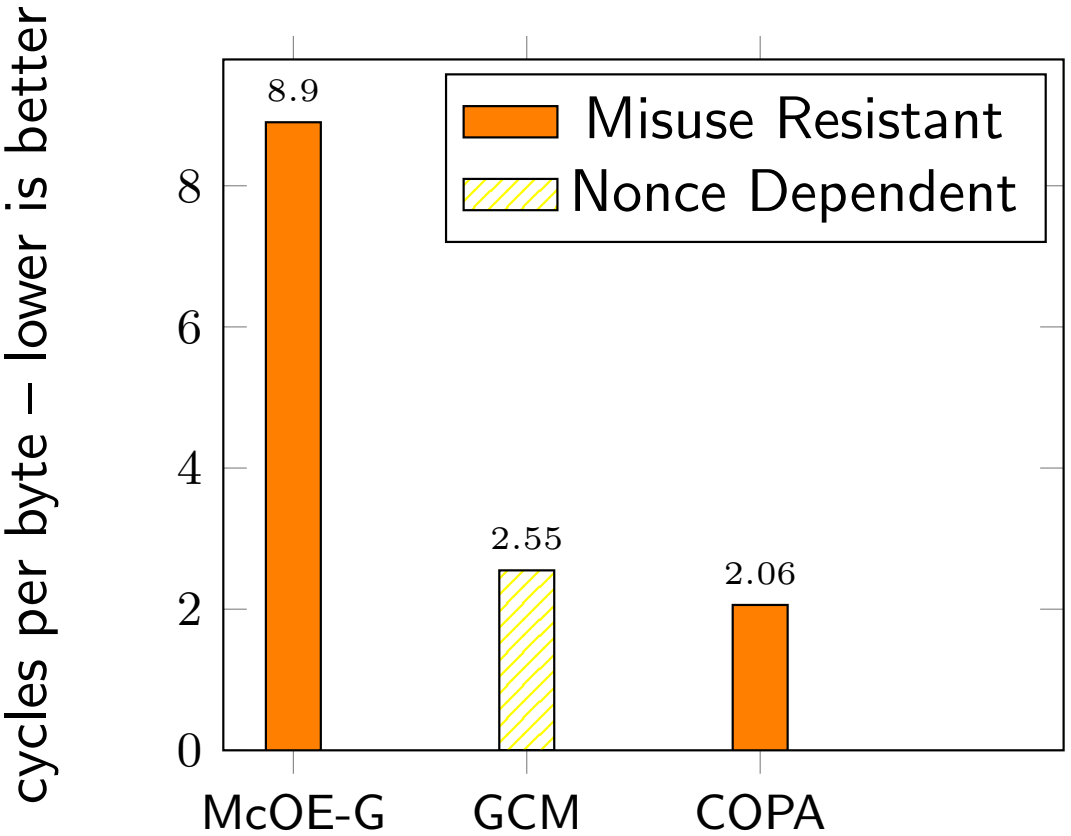

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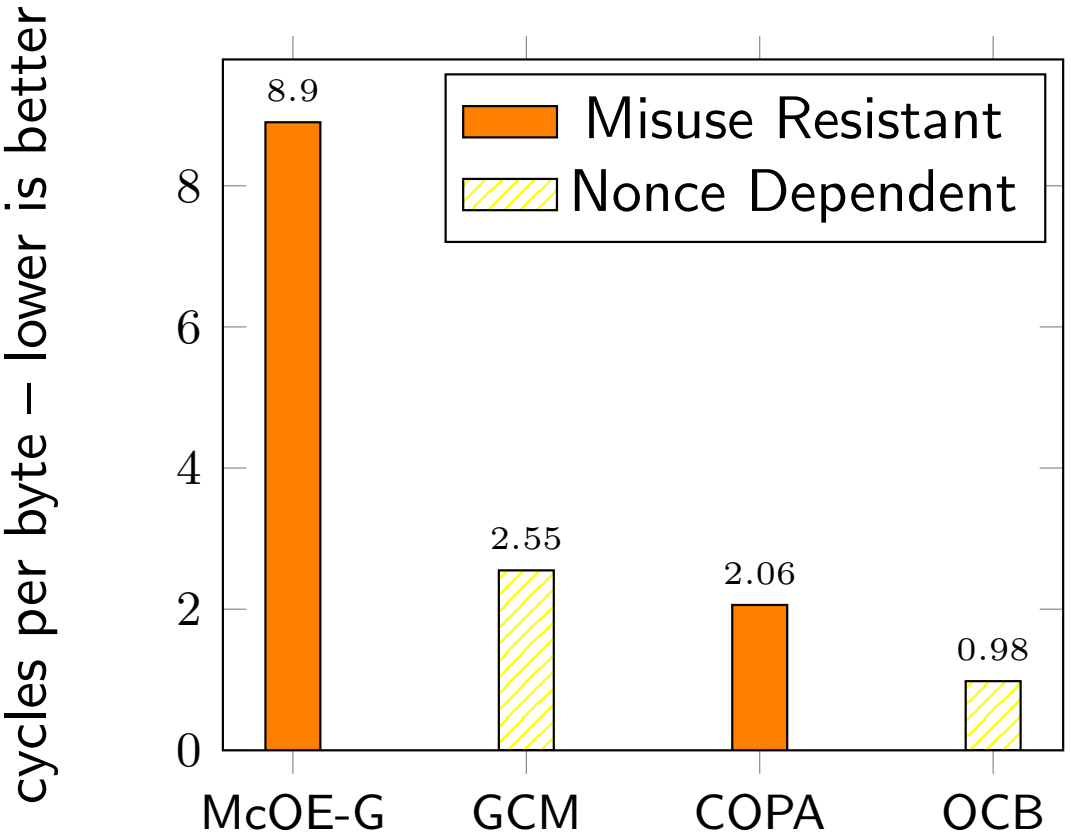

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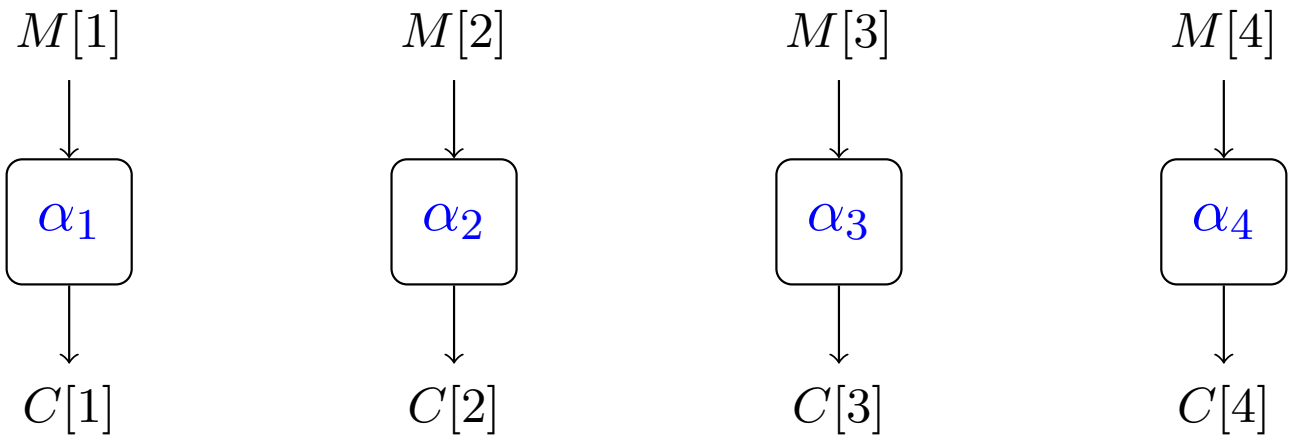
Motivation

Can we close the gap in efficiency between nonce dependent and misuse resistant schemes?

Motivation: Misuse Resistance From OCB?



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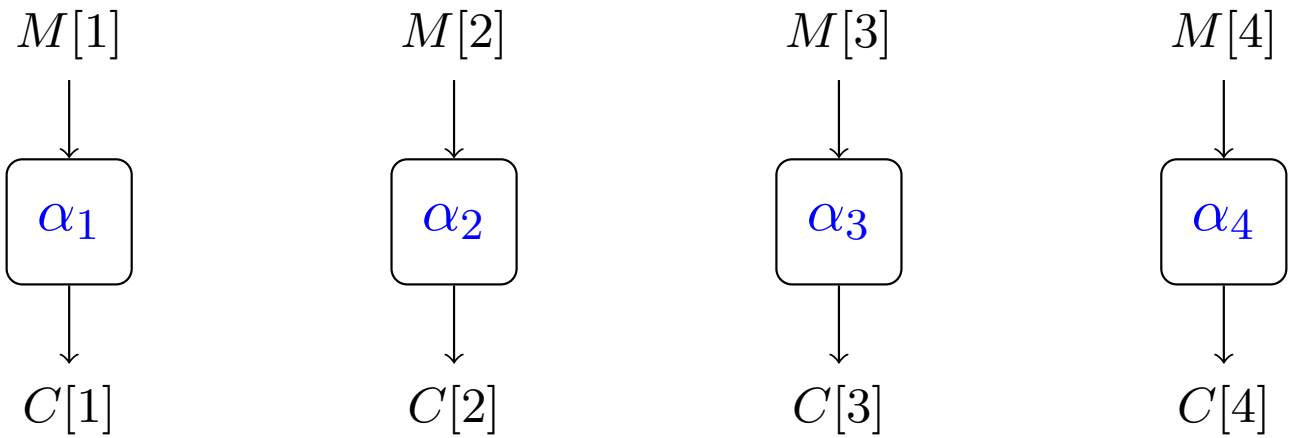

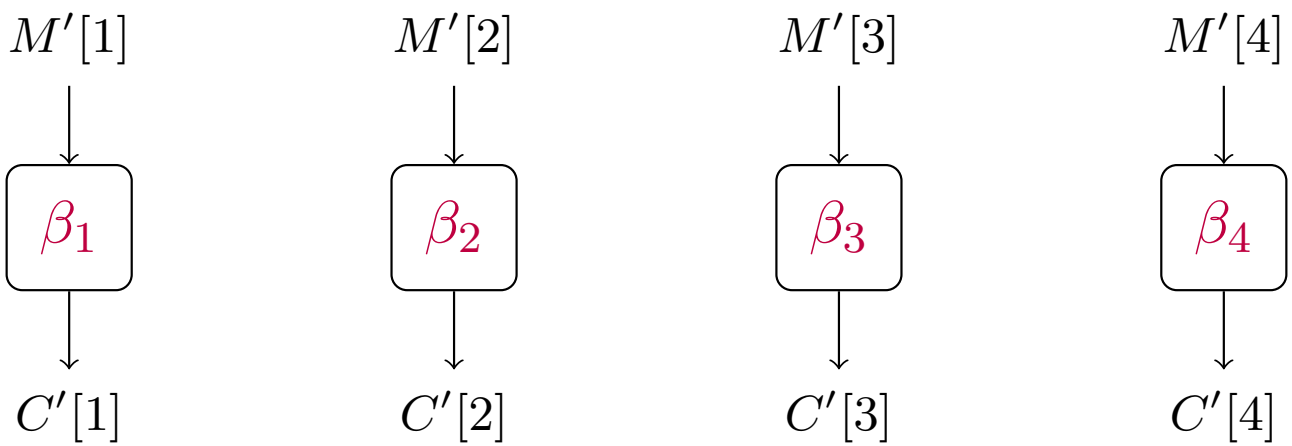

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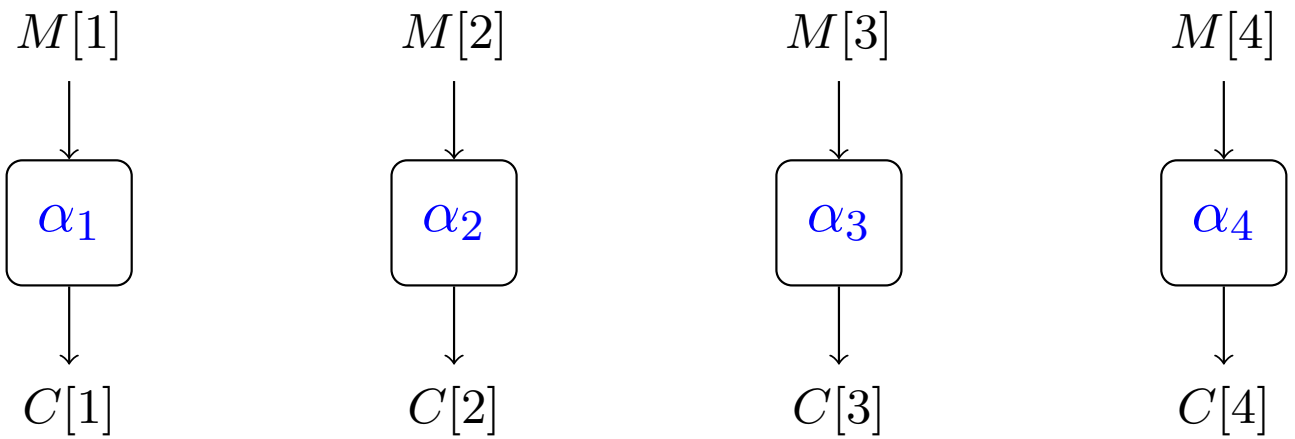

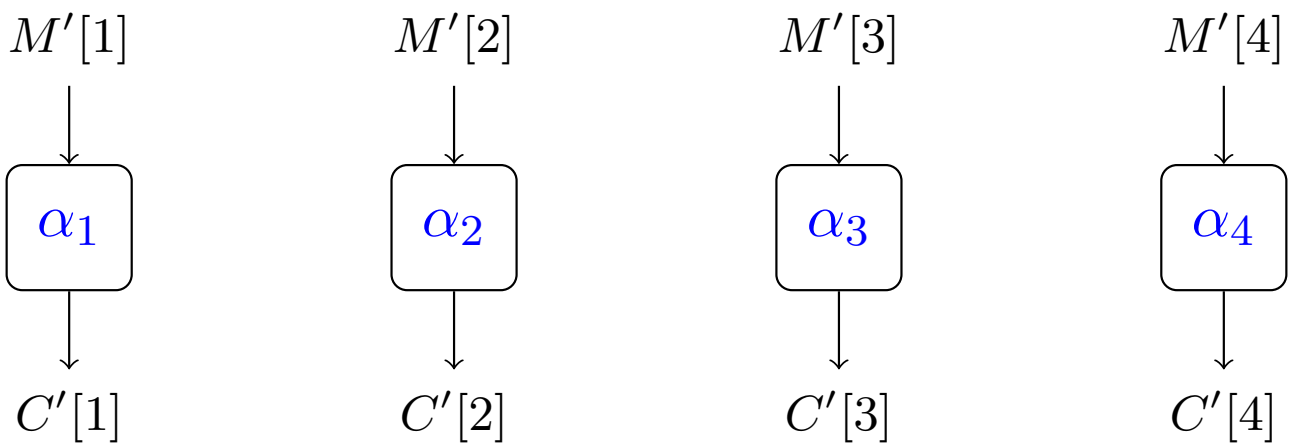

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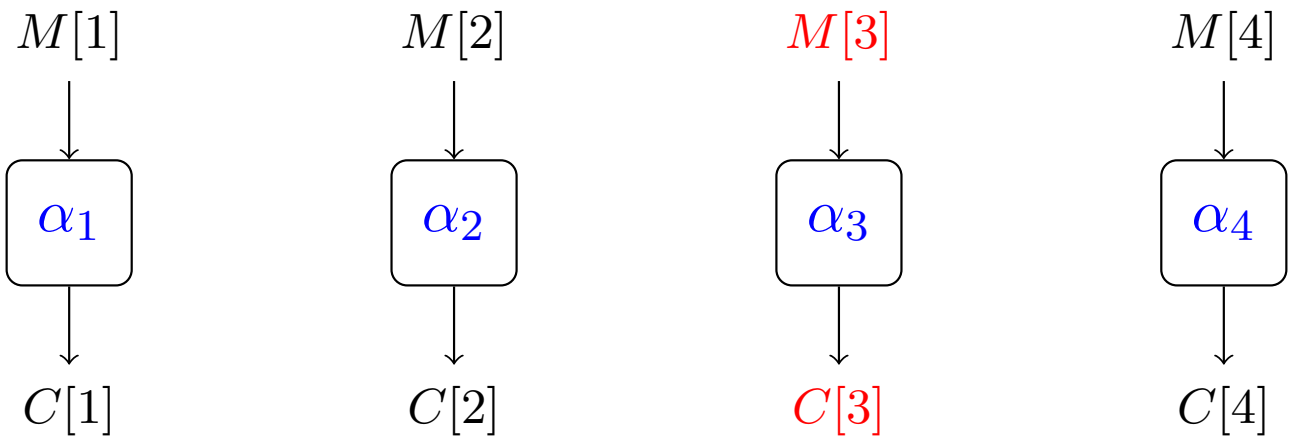

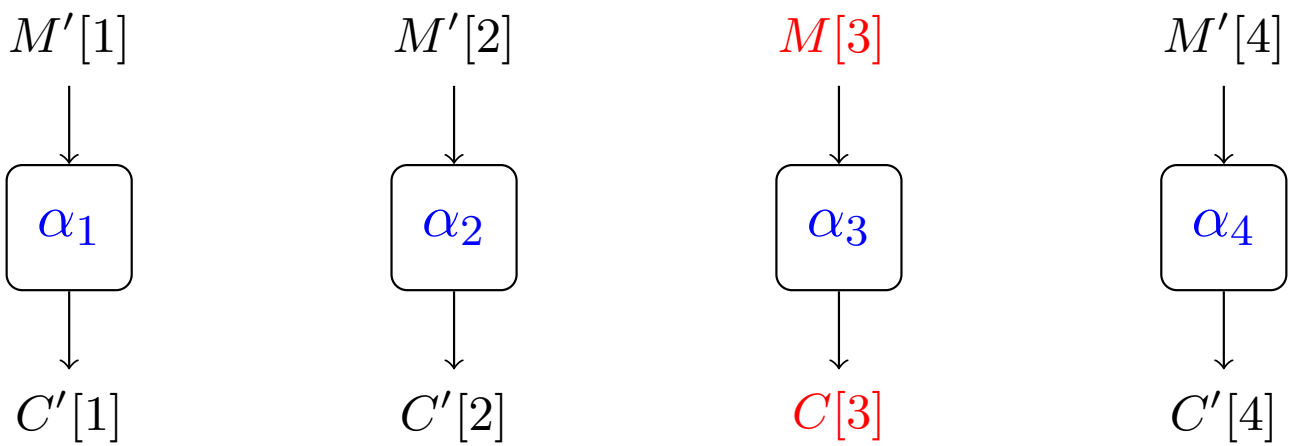

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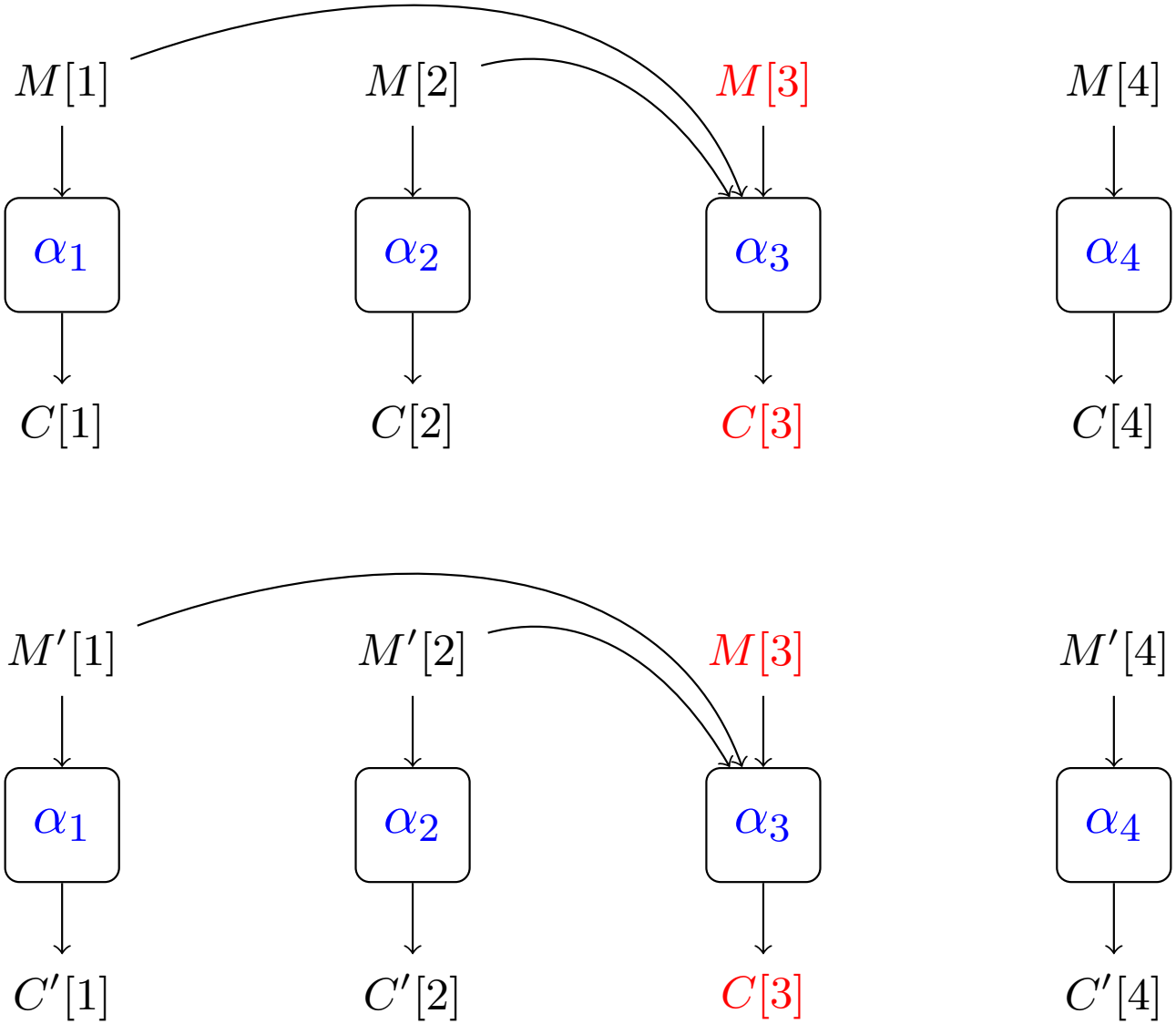

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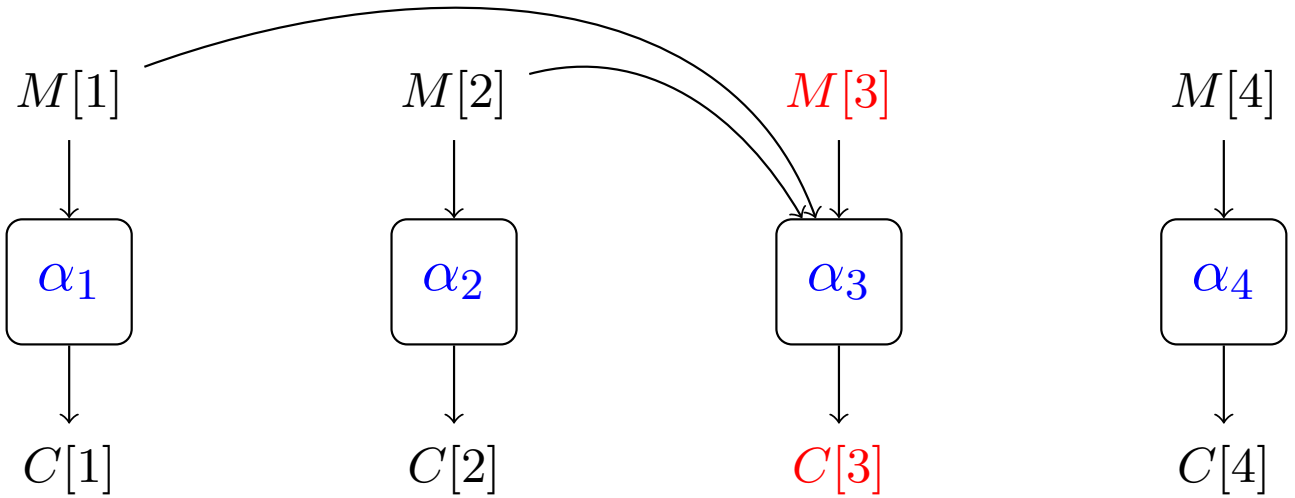

1. Dependency upon previous message blocks
2. Function using only key
3. No collisions between different messages

$\Rightarrow$ Universal hash

Motivation: Nonce Dependent Versus Misuse Resistant

Difference in efficiency:
at least efficiency of universal hash

Motivation: Universal Hash in AE

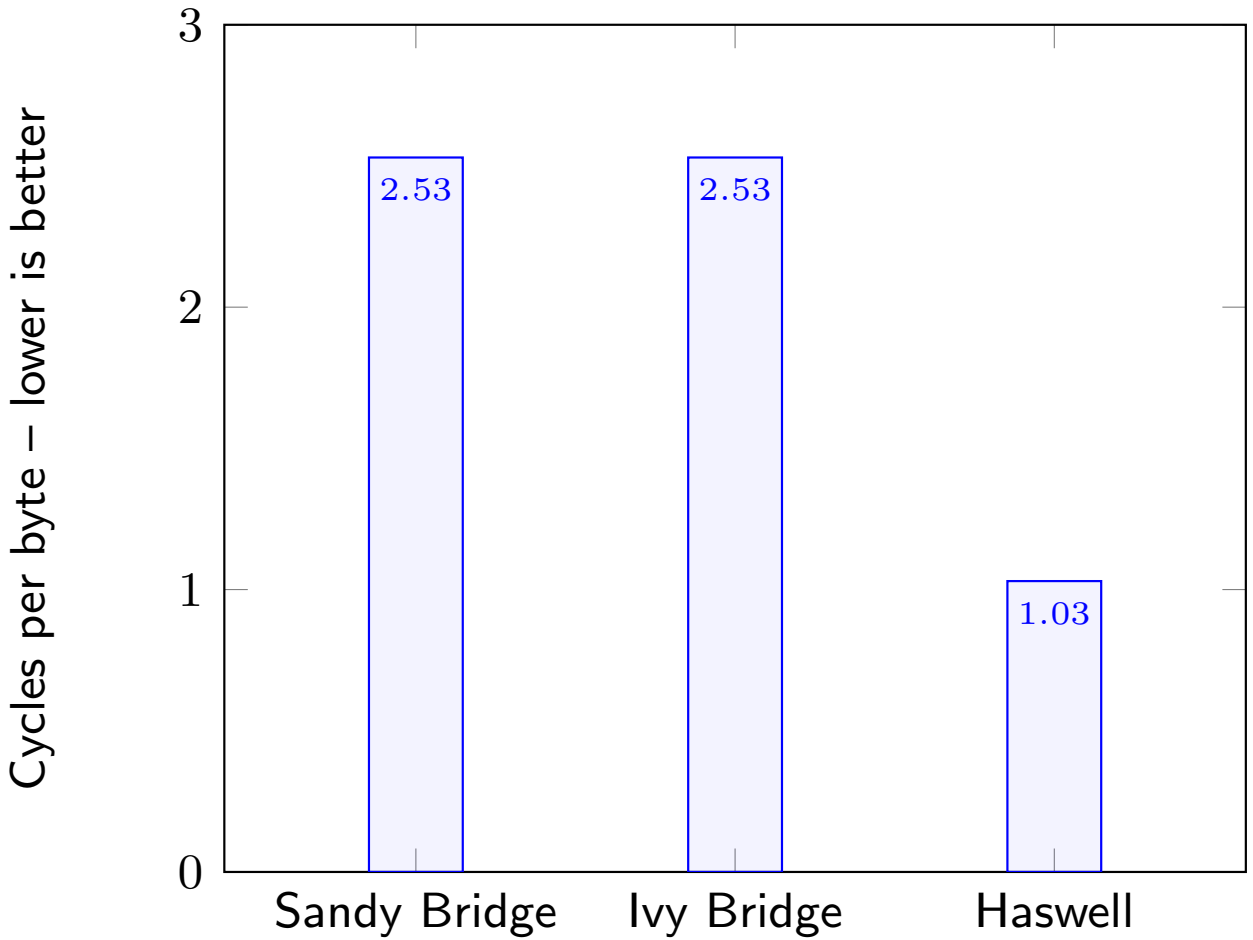

Figure : GCM with AES-NI. Results Gueron DIAC 2013.

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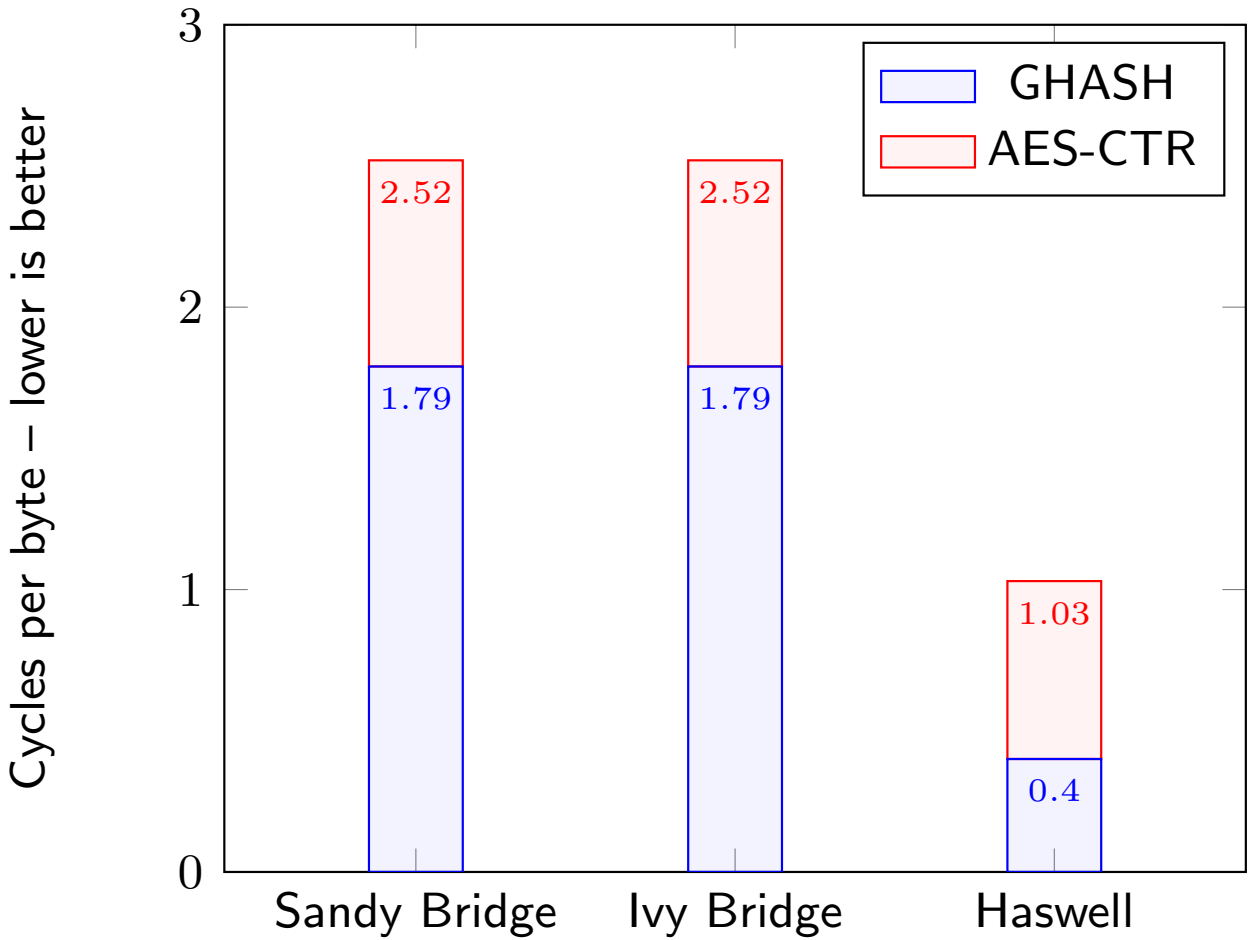

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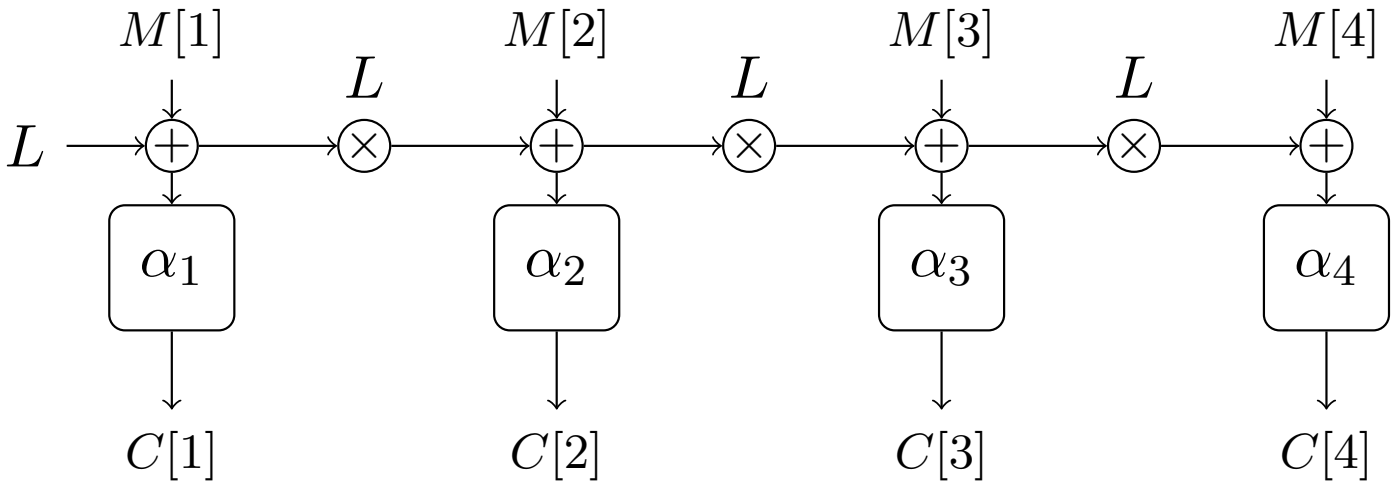
Motivation: How To Add Authenticity?



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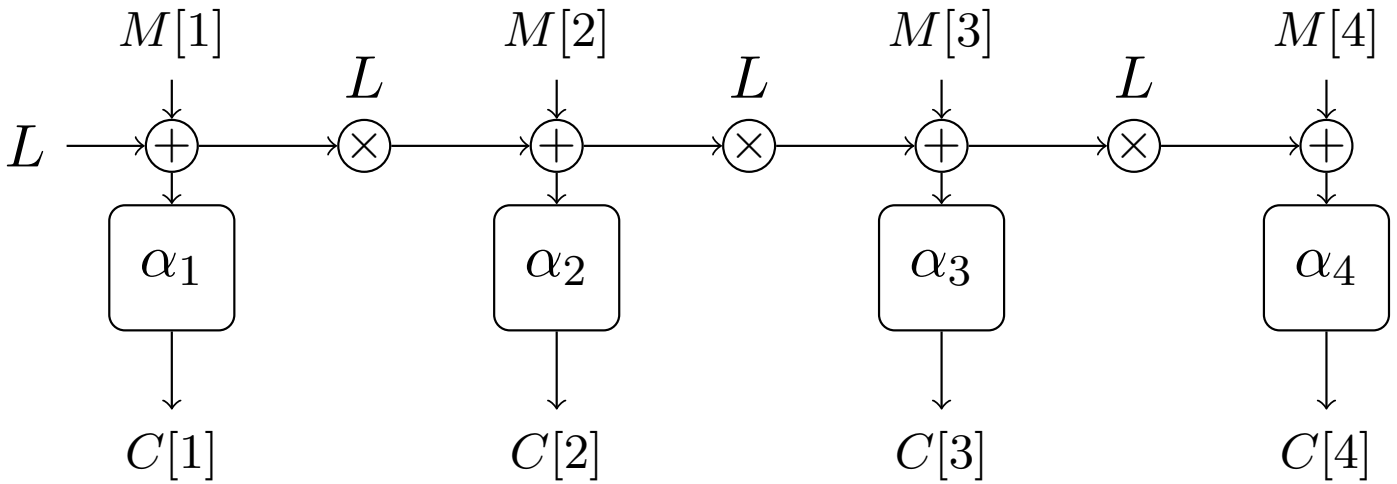

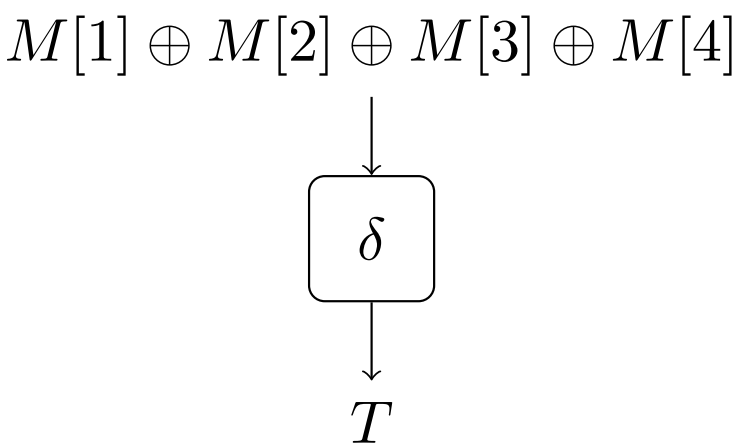

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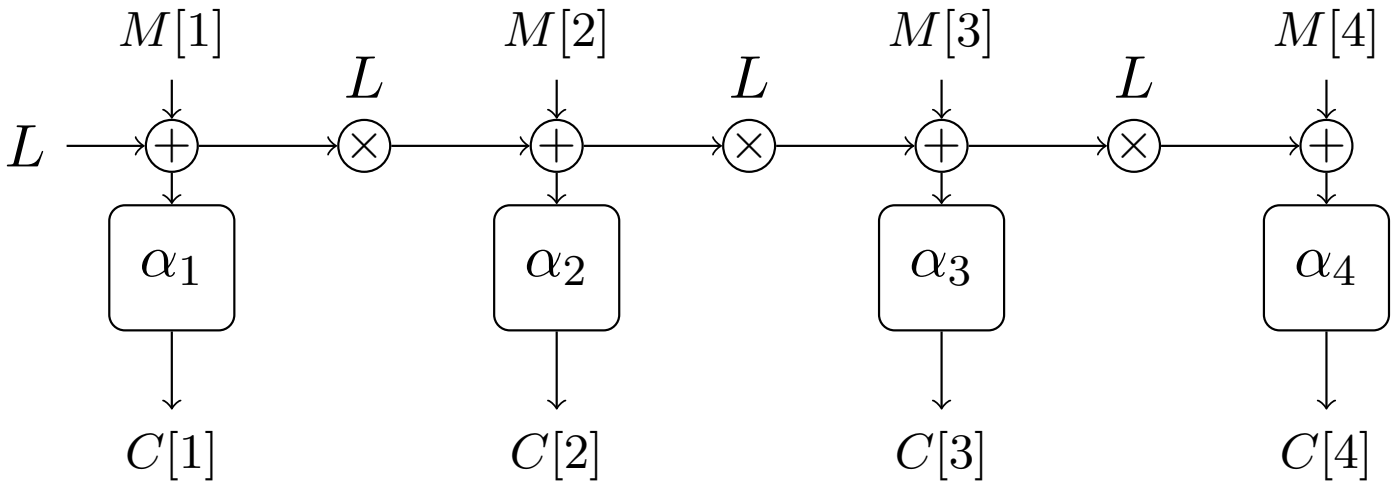

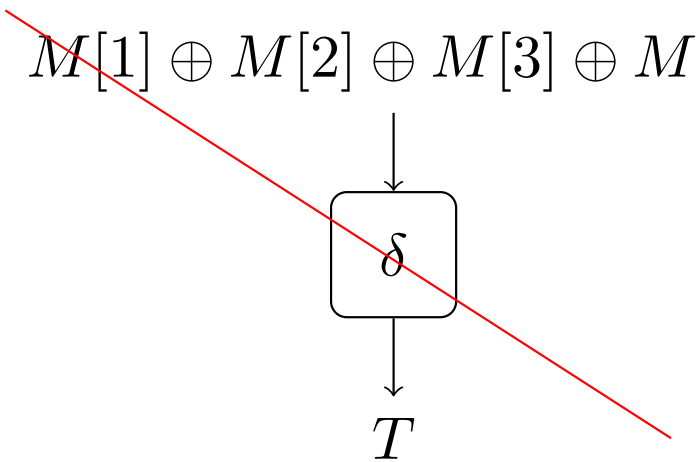

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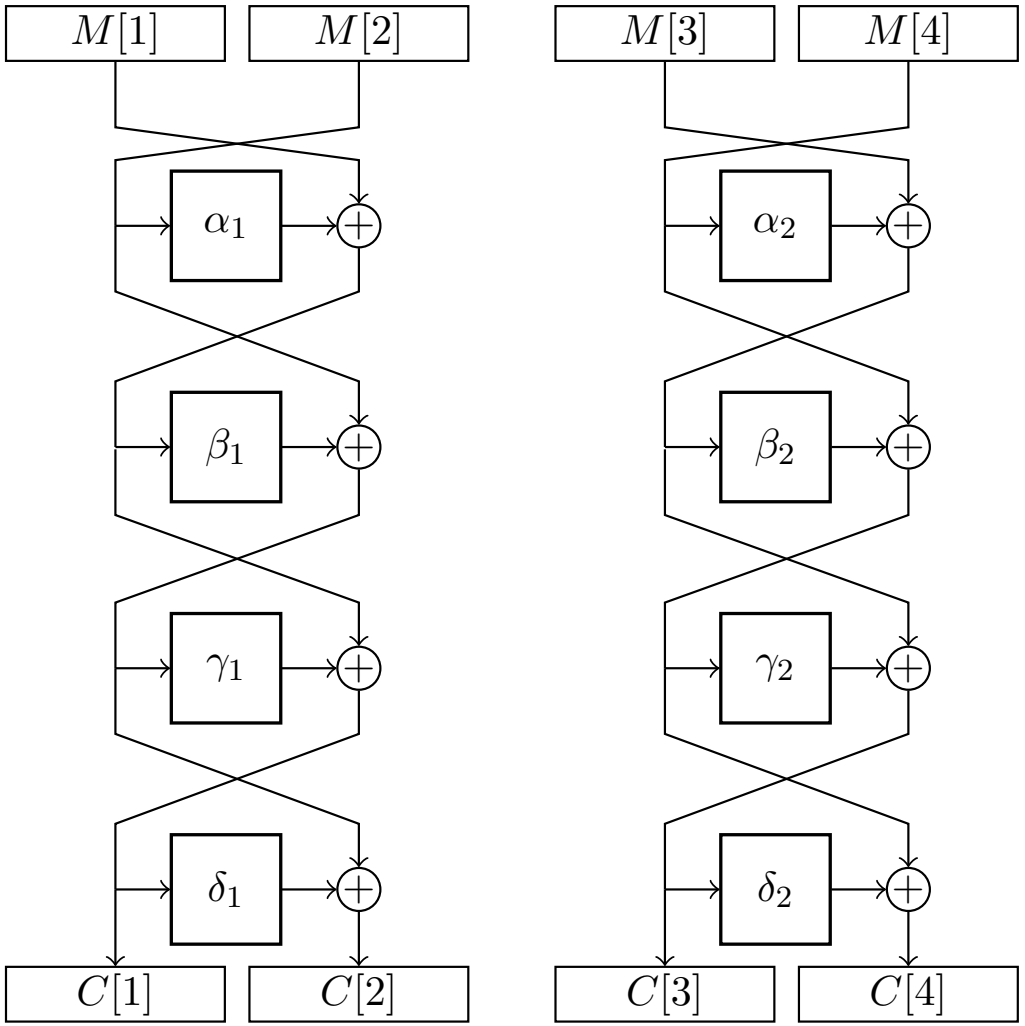

$\alpha_i, \beta_i, \gamma_i, \delta_i$: uniform random functions (URF)

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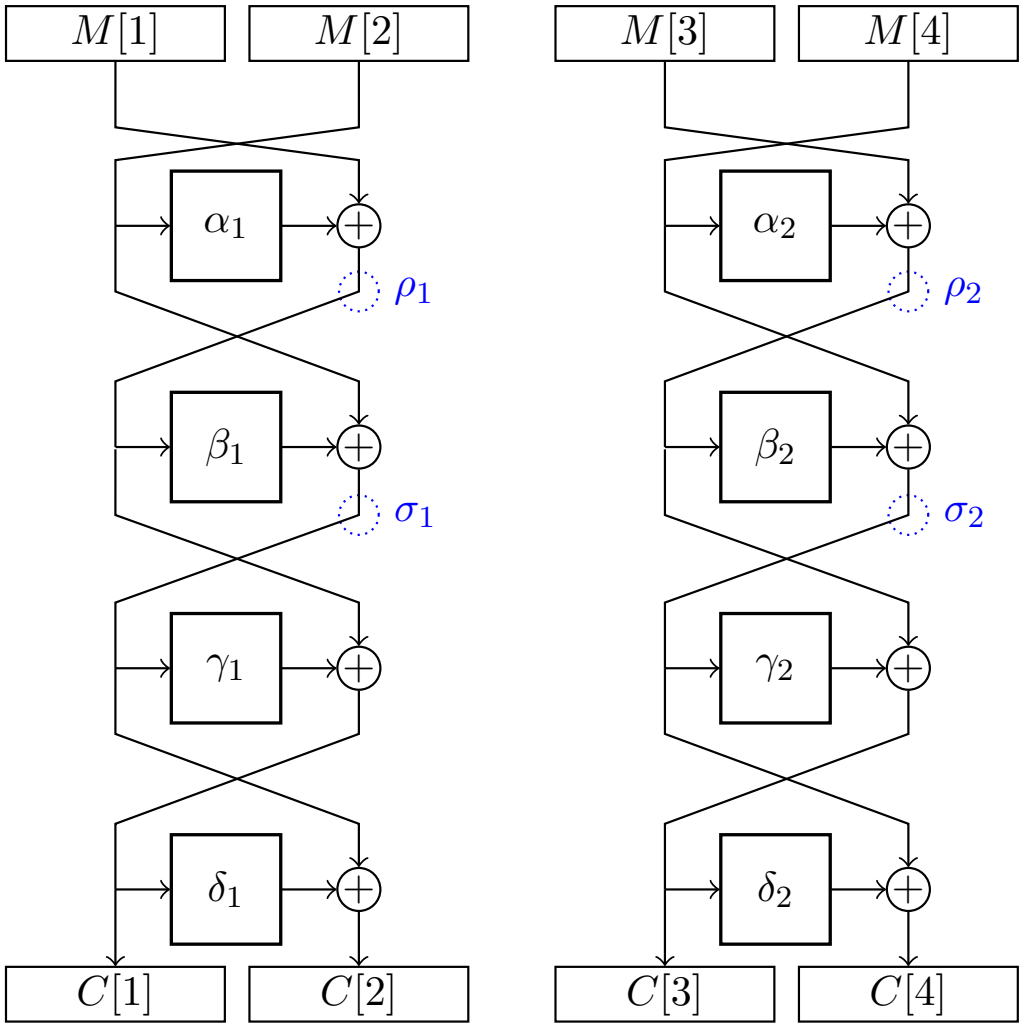

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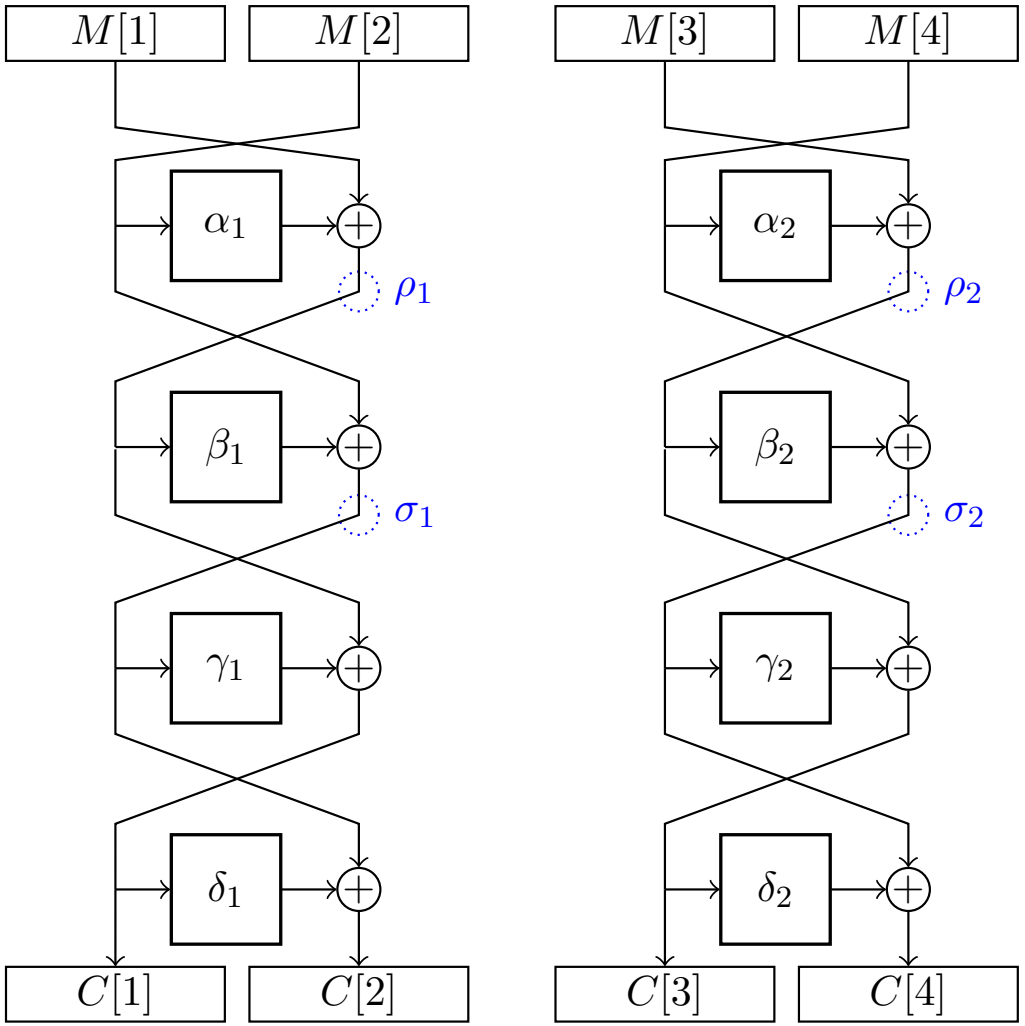

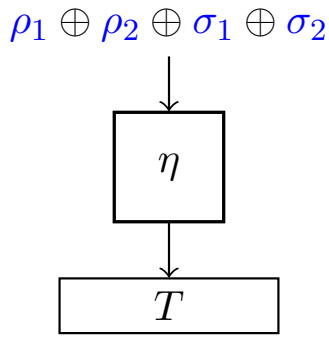

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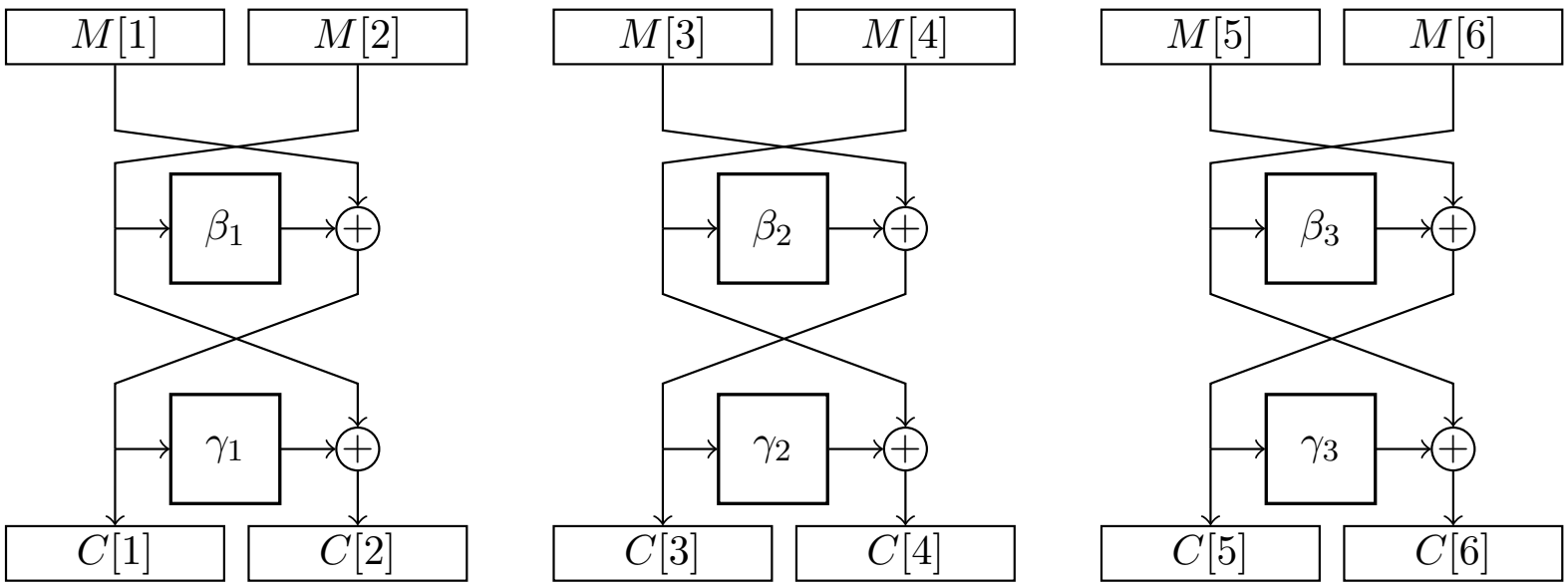

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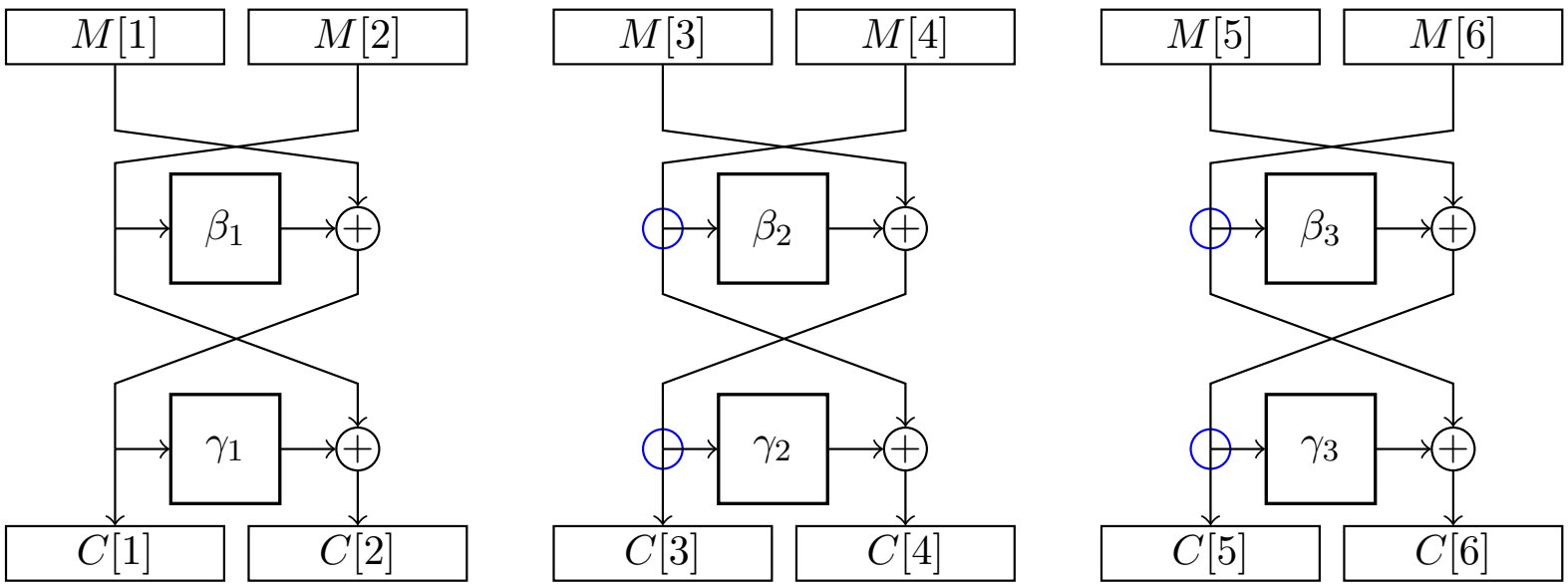

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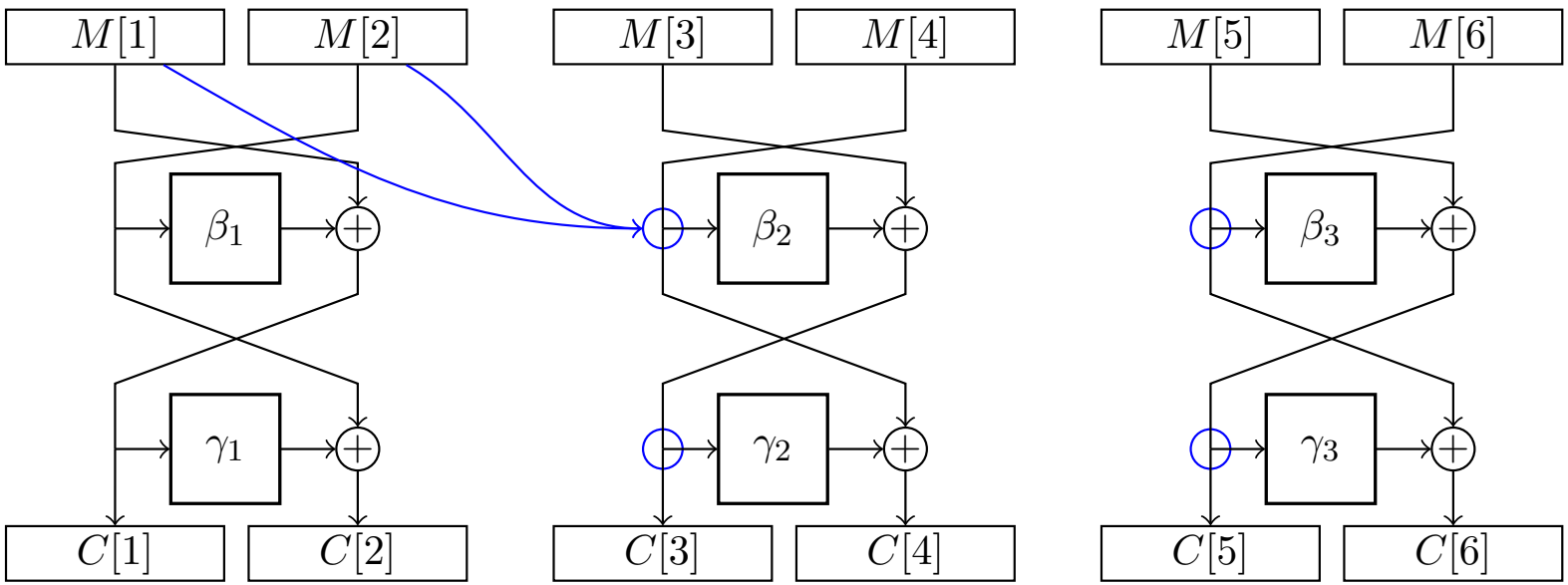

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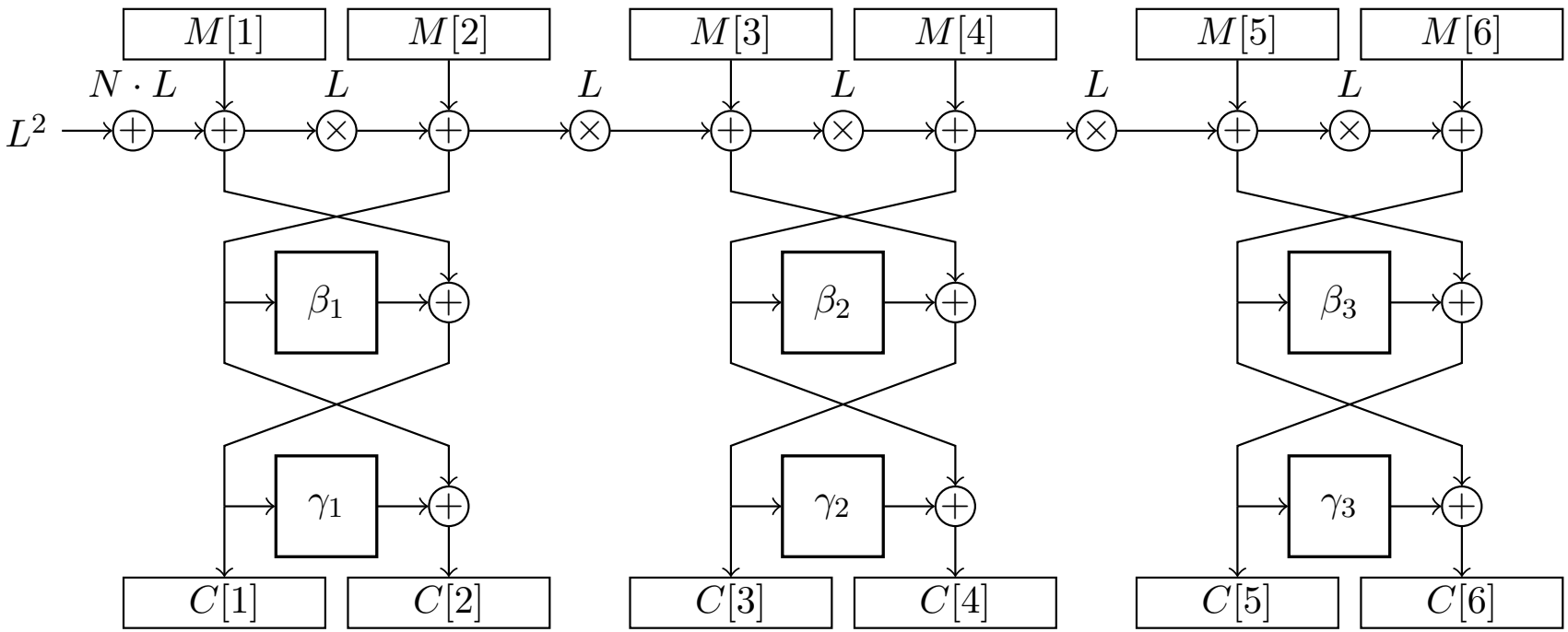

β_i, γ_i: URFs

L: secret value derived from the key

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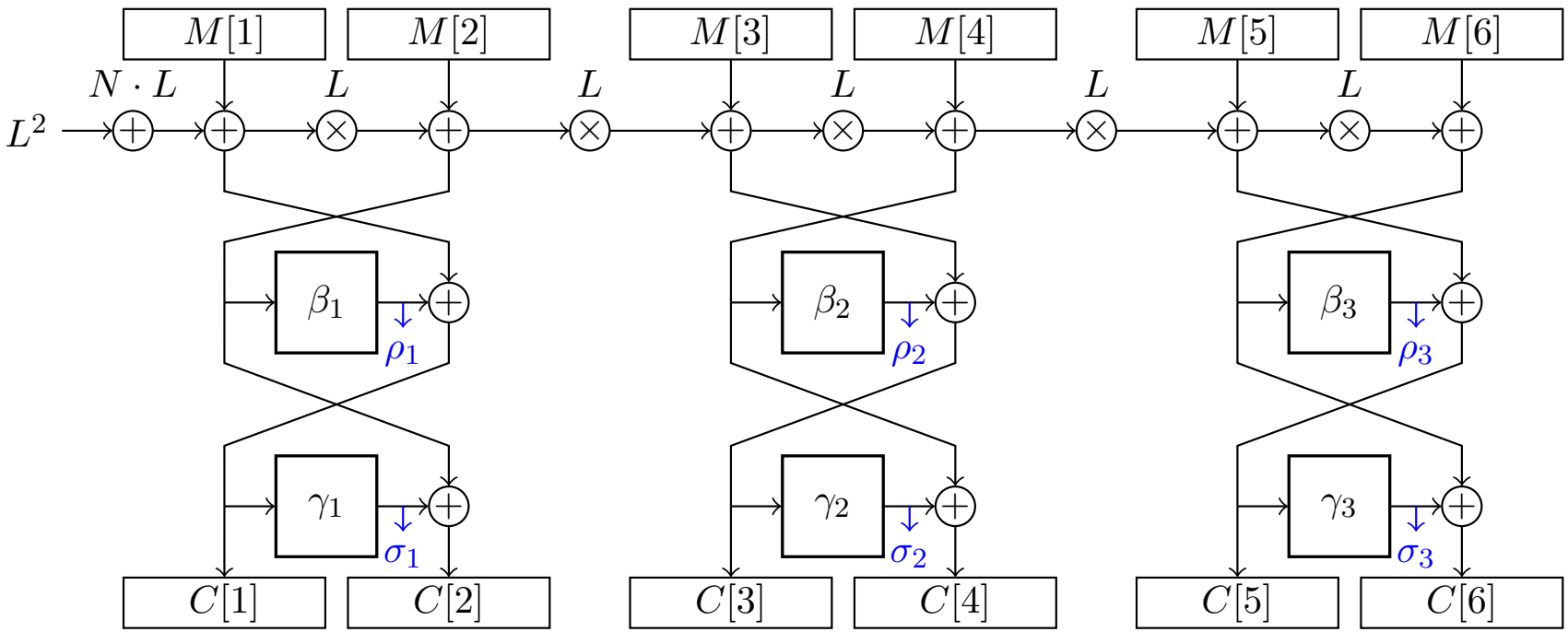

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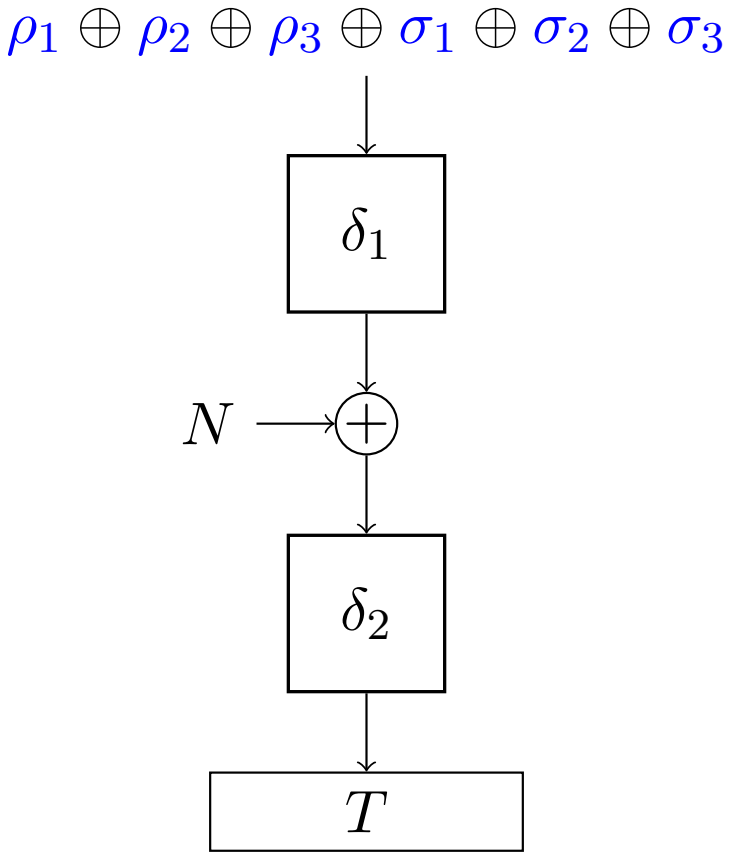
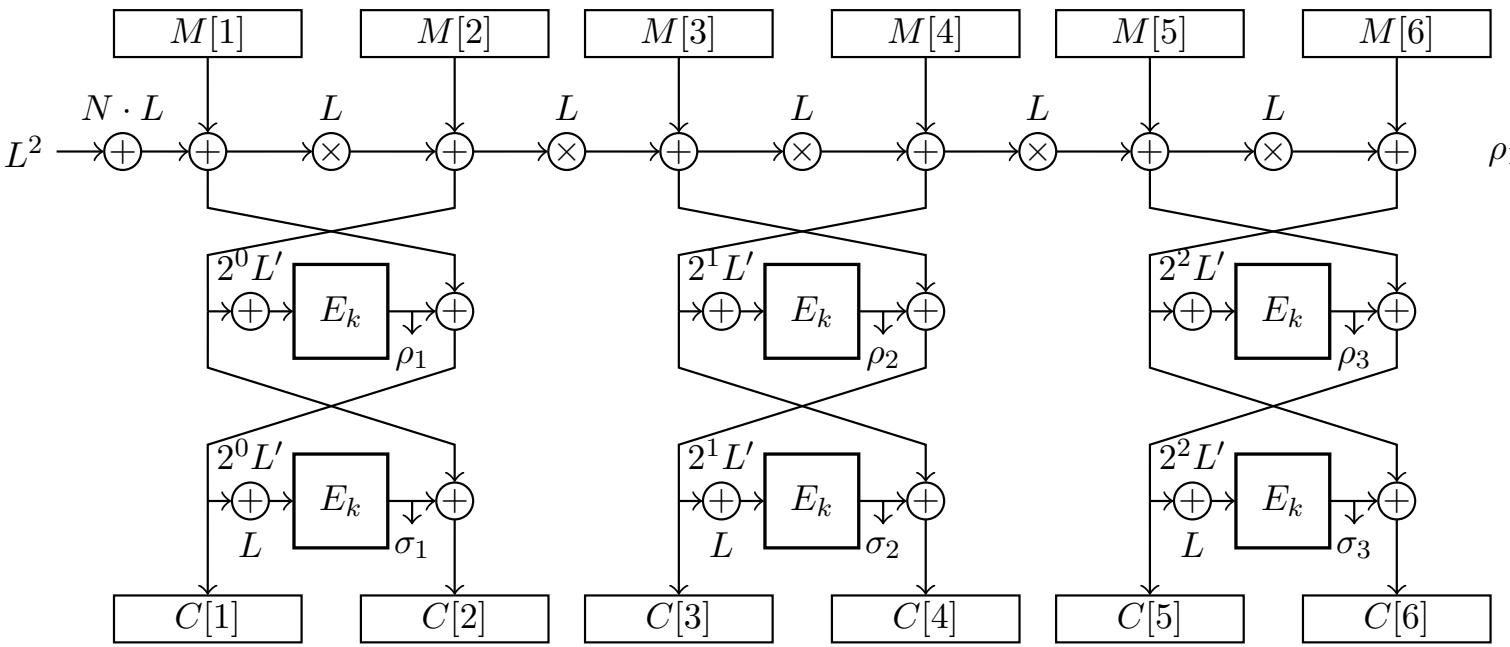


ρ_i, σ_i: outputs of URFs

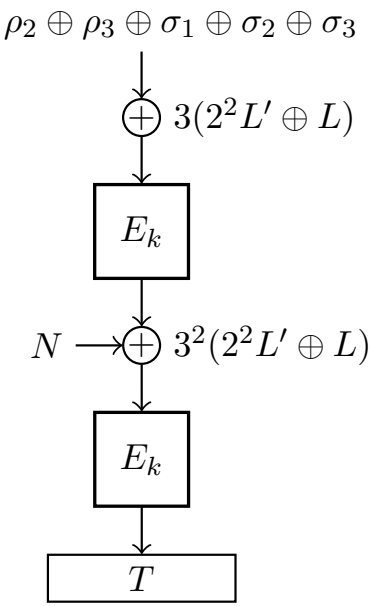
δ_i: URFs

N: nonce

Our Scheme: COBRA



$L := E_k(0), L' = 4L$



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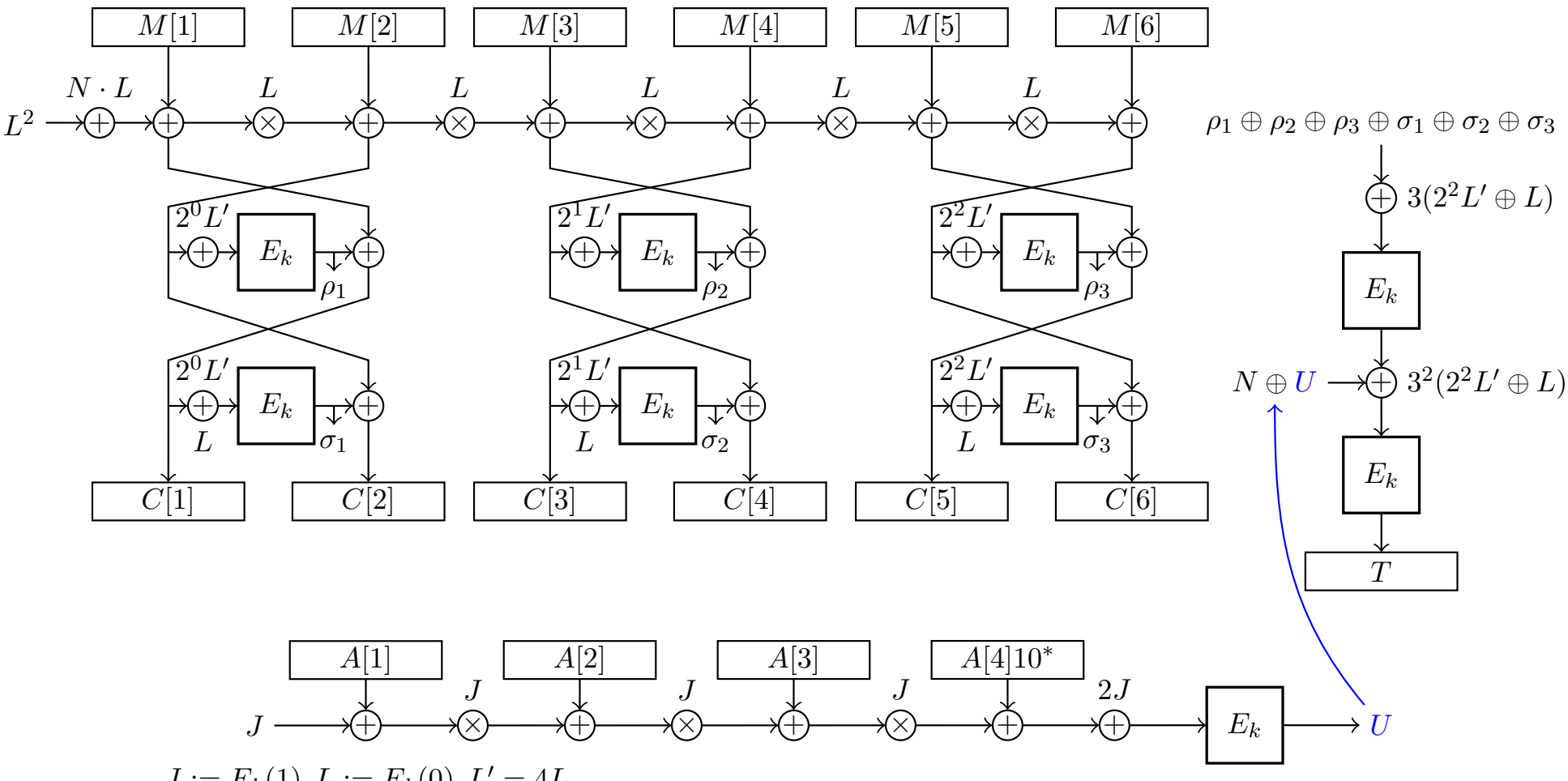

Proof Idea

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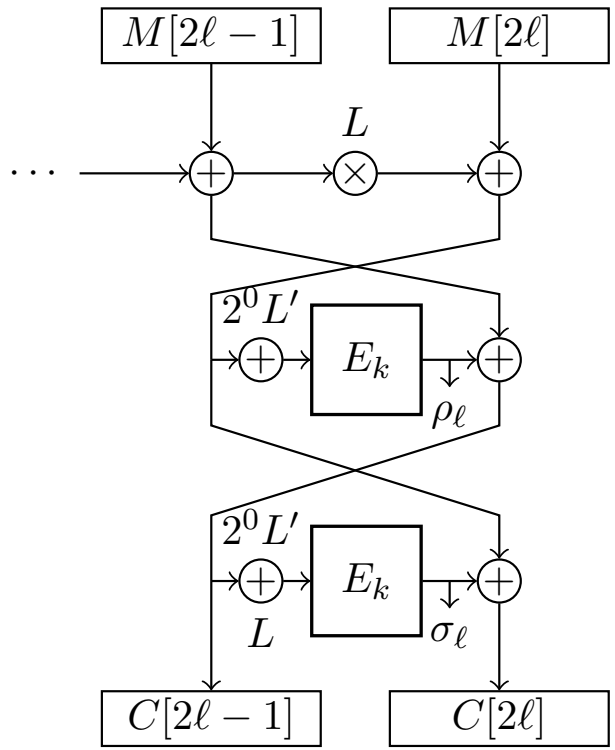

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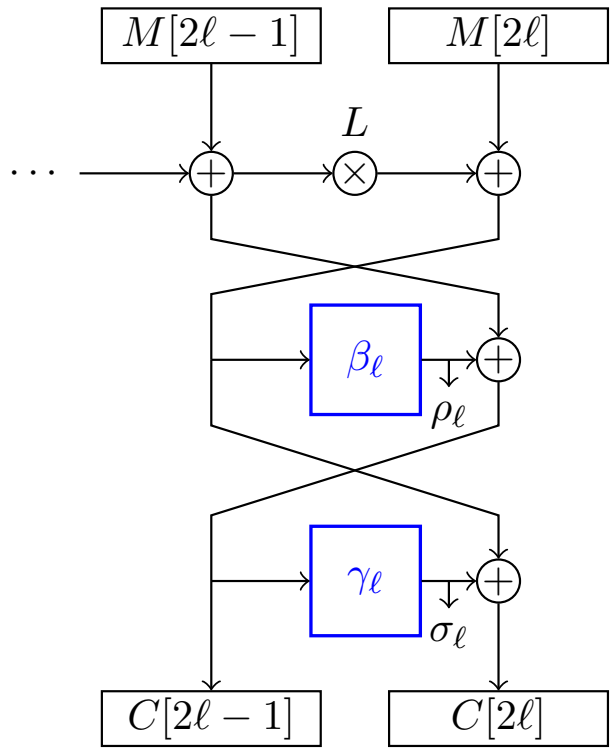

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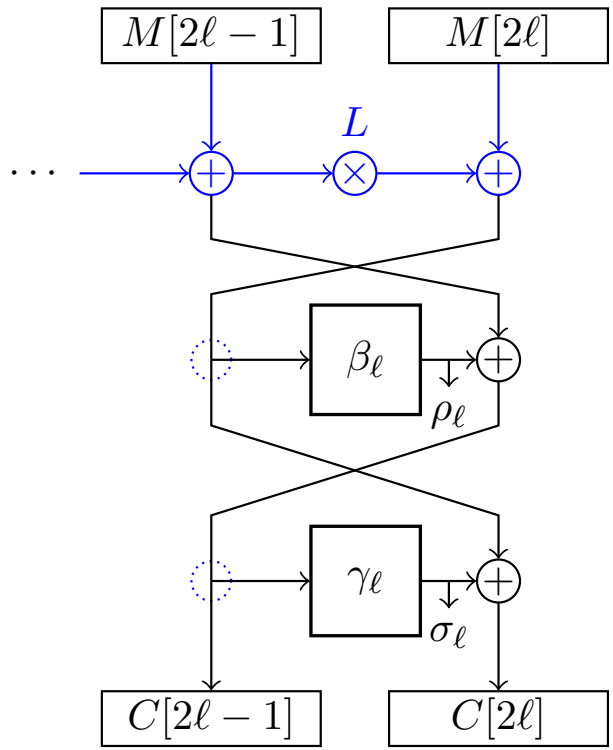

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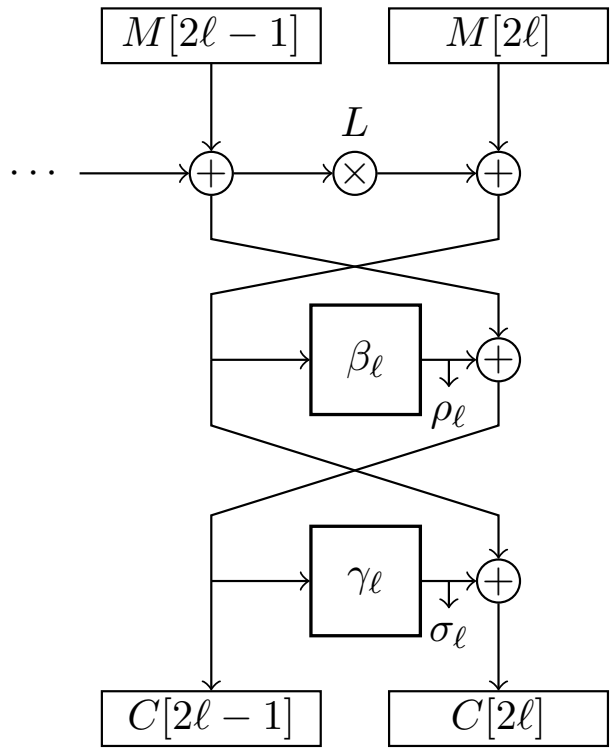

Proof Idea

1. Switch to URFs (at minimal cost)
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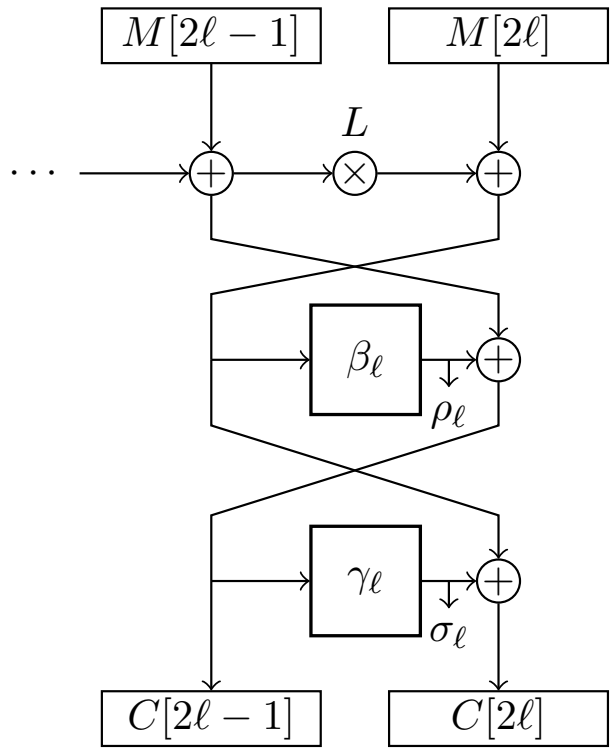
$\Rightarrow$ outputs are uniform and independent
$\Rightarrow$ No relation between block cipher outputs makes forgery difficult



High Level Comparison With Other Misuse Resistant Schemes

Scheme	Year	No BC Inverse	Parallelizable	Online
2 BC				
SIV	2006	✓	✗	✗
COPA	2013	✗	✓	✓
BC + UH				
HBS	2009	✗	✓	✗
BTM	2009	✓	✓	✗
McOE-G	2011	✗	✗	✓
COBRA	**2014**	✓	✓	✓

Table : Comparing misuse resistant AE modes of operation. BC := block cipher, UH := universal hash

Summary and Future Work

COBRA:

1. Misuse resistance
2. Online
3. GCM-like efficiency
    1. One multiplication per block
    2. One block cipher call per block
    3. Parallelizable
4. No block cipher inverse
5. Security reduction to block cipher

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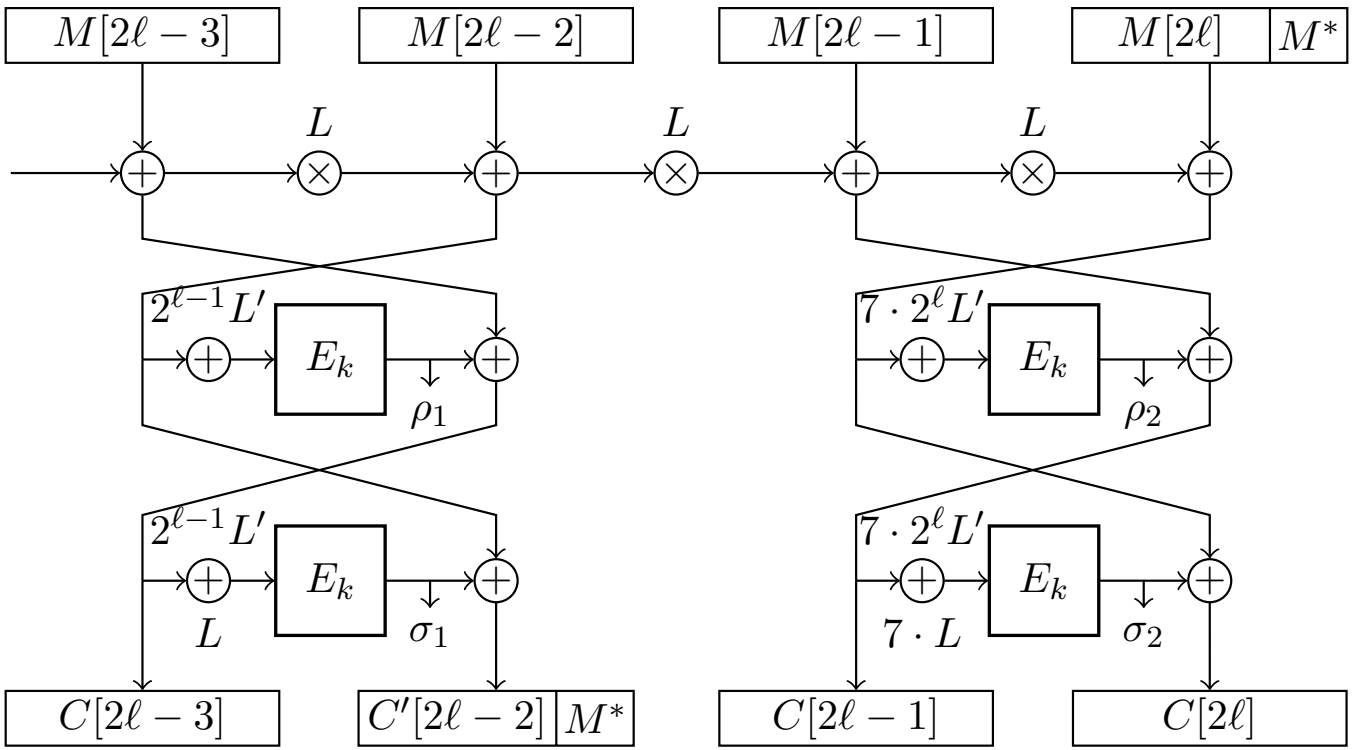
Submission to CAESAR

Software implementation results

Fractional Data: $\ell > 1$, $0 < |M[2\ell]| < n$



Fractional Data: $\ell > 2$ and $0 < |M[2\ell - 1]| \leq n$