COSIC

FIDES:
Lightweight Authentication Cipher with Side-Channel Resistance for Constrained Hardware

Begül Bilgin, Andrey Bogdanov, Miroslav Knežević, Florian Mendel, and Qingju Wang

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Outline

- Motivation
- Design
  - Structure
  - S-box
- Security Analysis
- Performance

Lightweight Design

Lightweight Design

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Lightweight Design

- Block Ciphers e.g. PRESENT, KATAN, LED, …

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- Stream Ciphers e.g. GRAIN, TRIVIUM, …

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- Hash Functions e.g. Spongent, Quark, ...

Lightweight Design

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Confidentiality OR Authenticity

Lightweight Design

Confidentiality OR Authenticity

Lightweight AE

Confidentiality AND Authenticity

Lightweight AE

Confidentiality AND Authenticity

- OCB mode [Rogaway'01]
- Encrypt/MAC (EtM, MtE)

Lightweight AE

Confidentiality AND Authenticity

- OCB mode [Rogaway'01]
- Encrypt/MAC (EaM, MtE)

Additional operations and memory states

Lightweight AE

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Dedicated lightweight designs

Lightweight AE

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Additional operations and memory states

Dedicated lightweight designs

ALE[Bogdanov'13], Hummingbird-2[Engels'11], Grain-128a[Agren'11]

Side Channel Resistance

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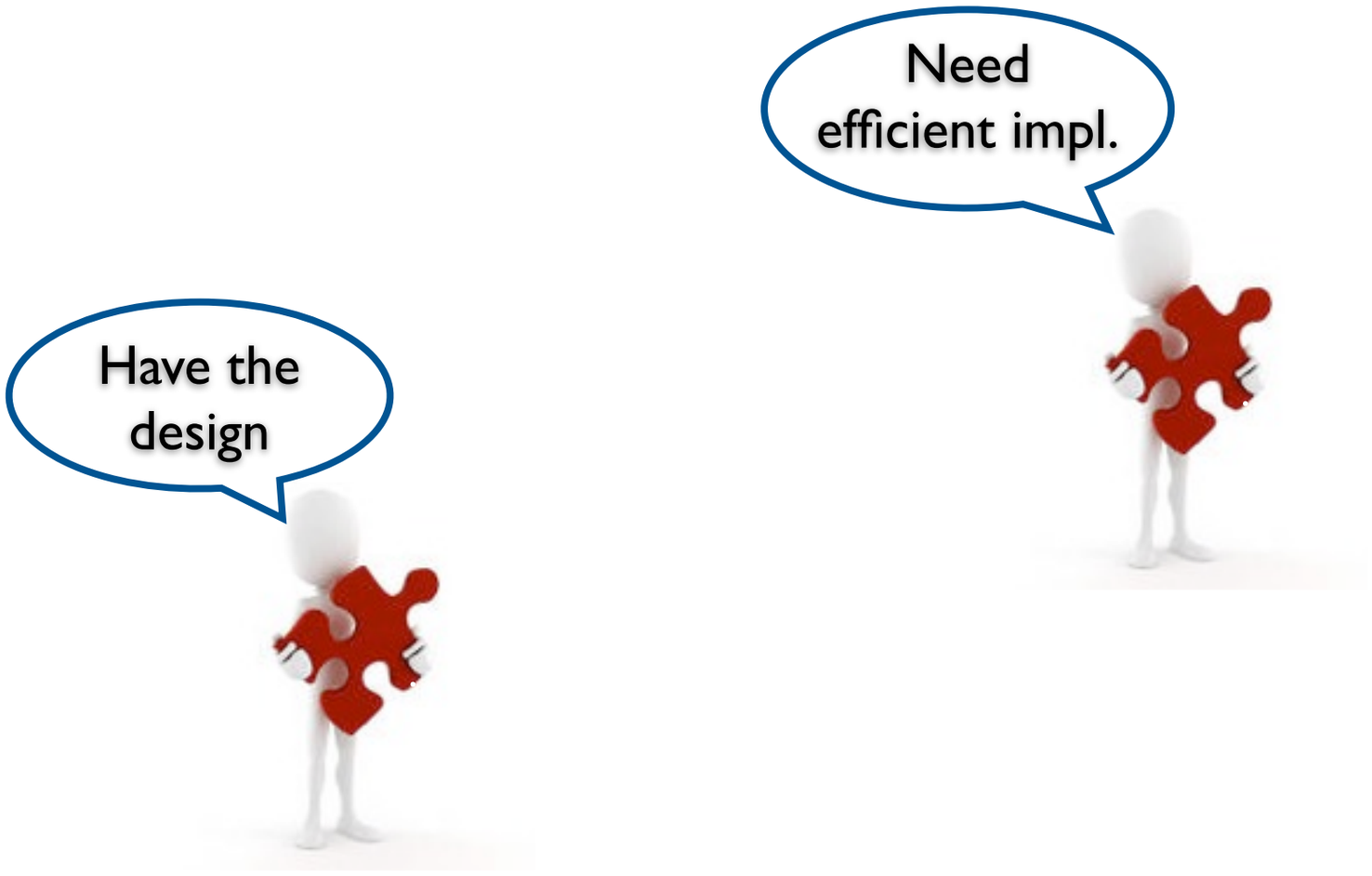
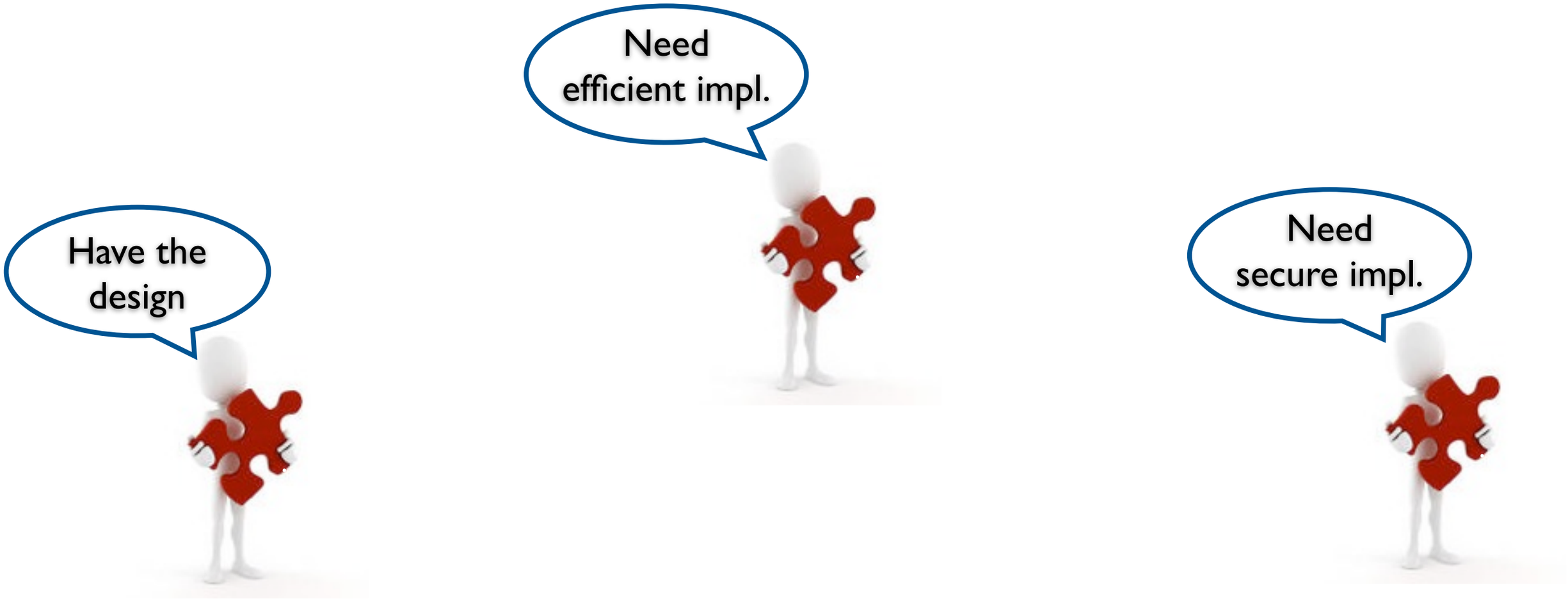
Side Channel Resistance



Side Channel Resistance



Side Channel Resistance

Need efficient impl.

Have the design

Need secure impl.

1st Order

Multipl. Mask

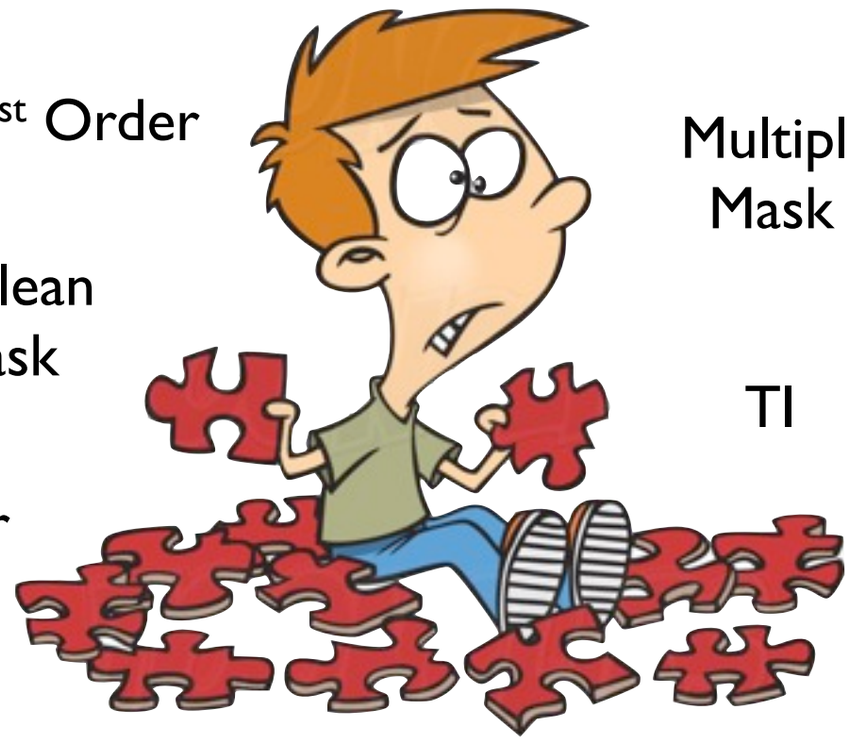
Boolean Mask

TI

2nd Order

SW

HW



?? Still efficient ??

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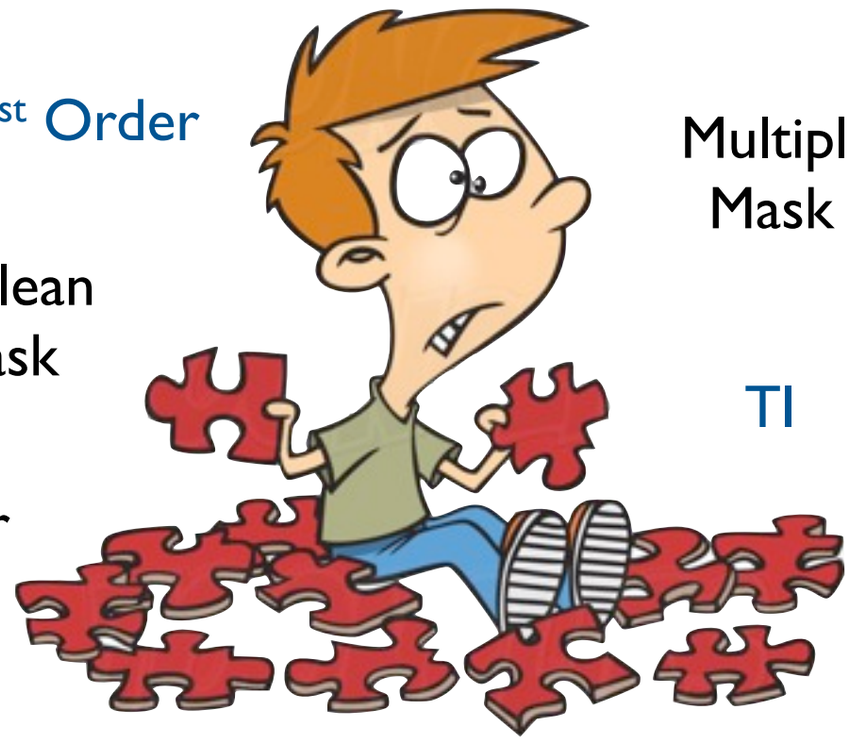
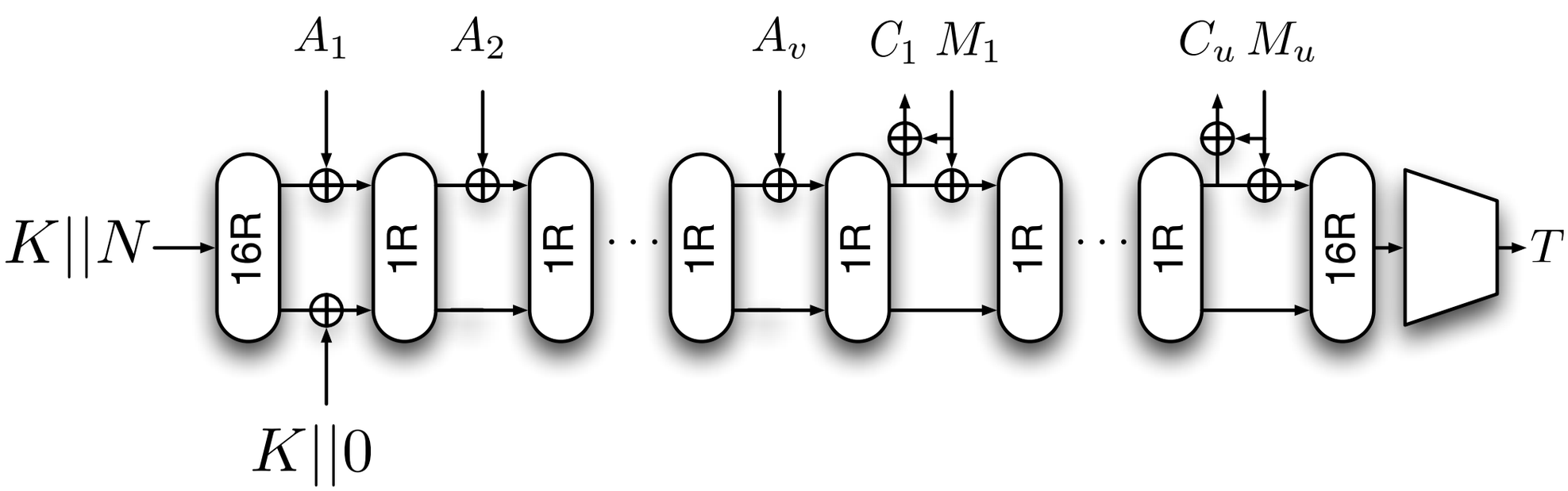


Still efficient

Design - Structure



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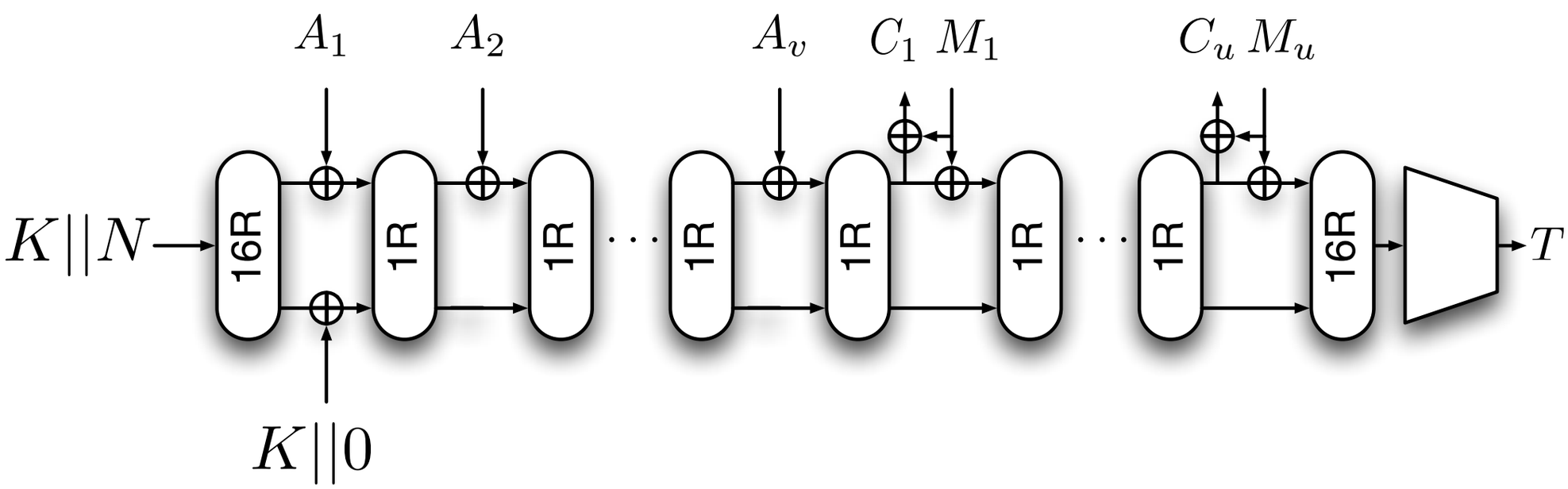
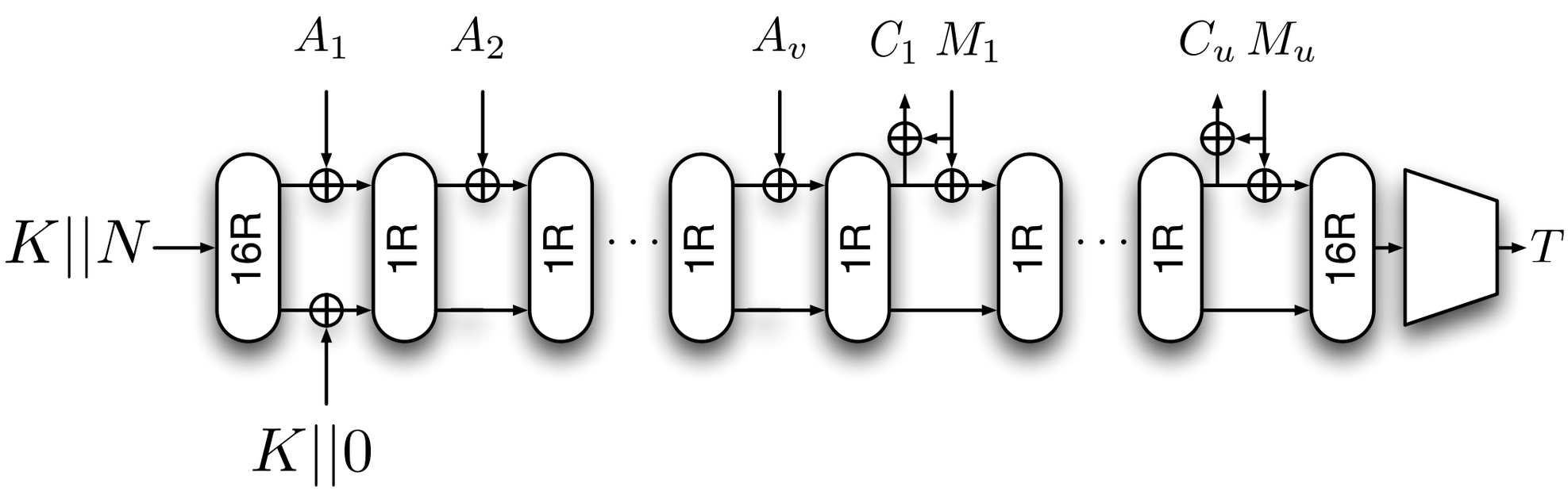


- Similar to duplex sponge

Design - Structure



- Similar to duplex sponge
- Rounds are not keyed

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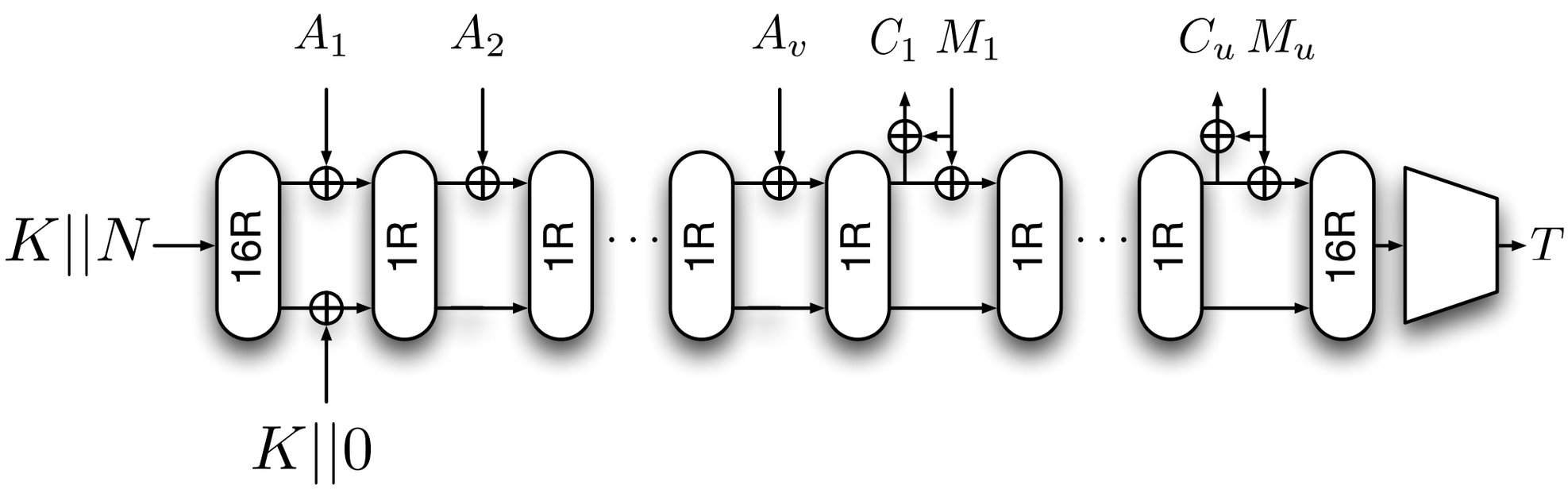
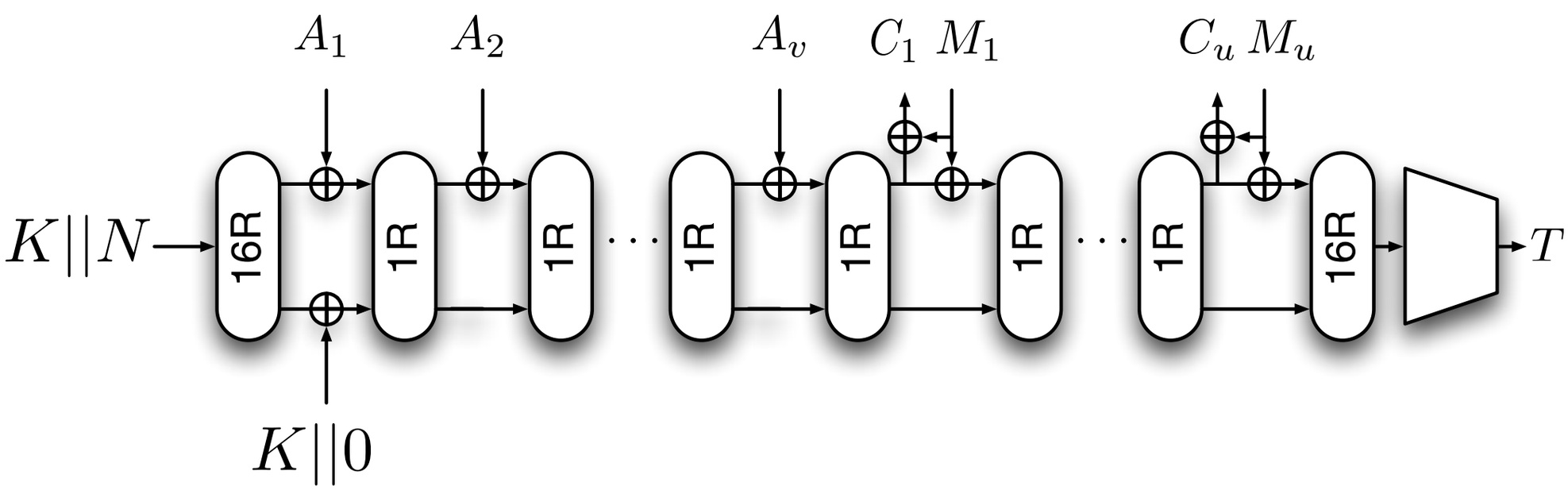


- Similar to duplex sponge
- Rounds are not keyed
- ✓ Online

Design - Structure



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- ✓ Single pass

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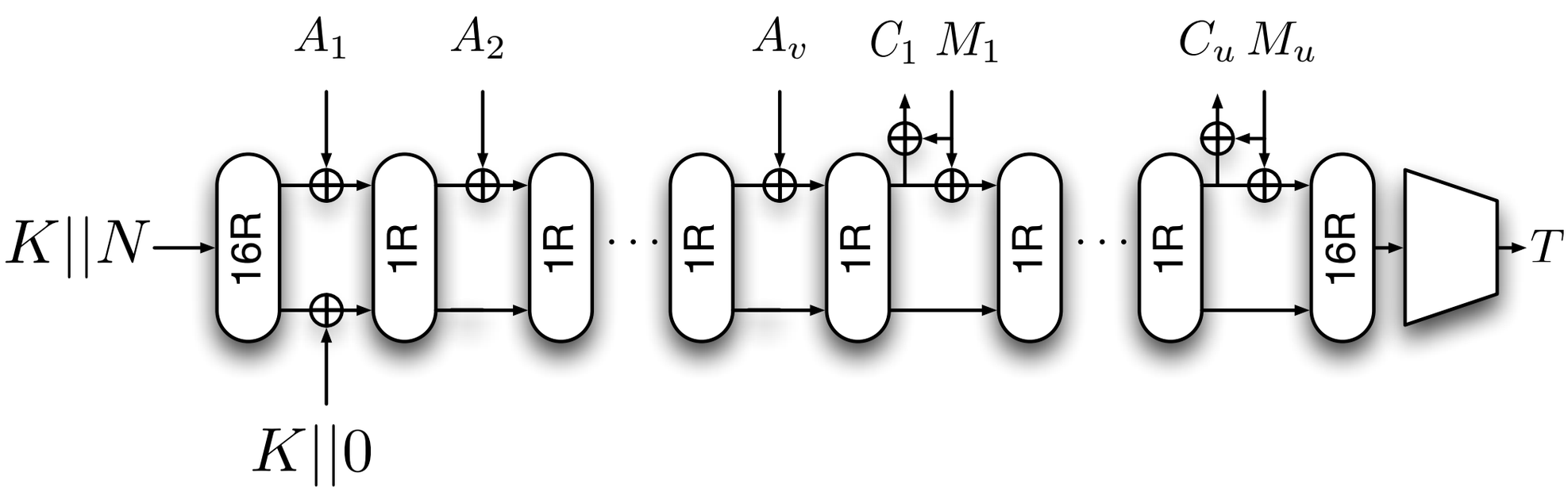

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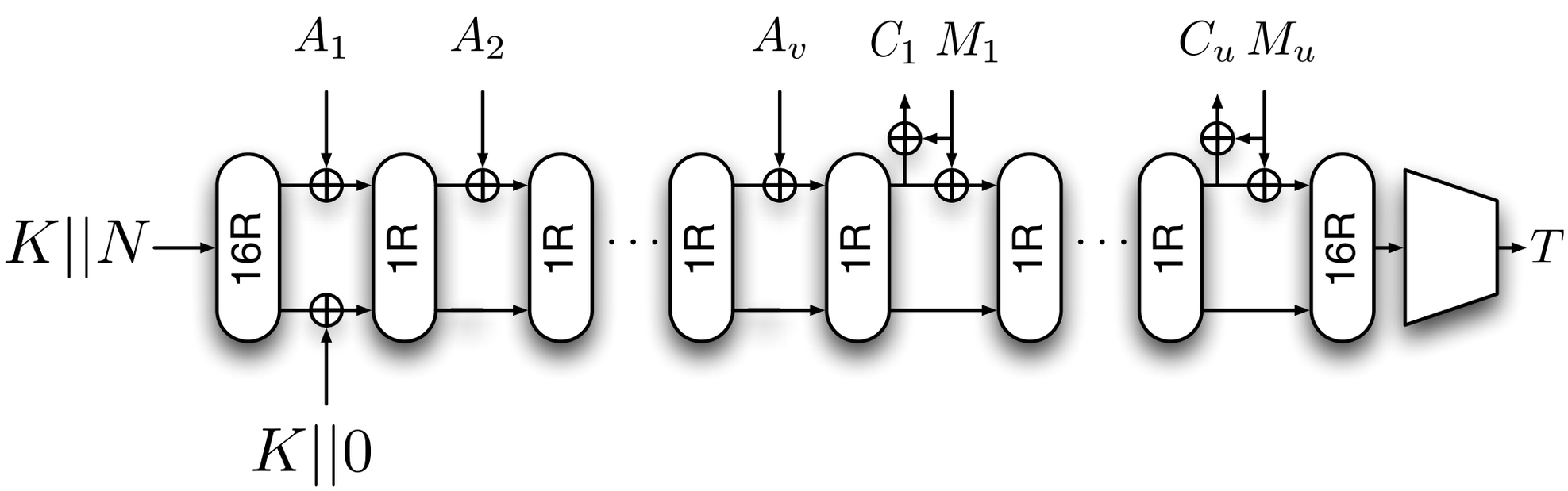
FIDES-80

FIDES-96

Design - Structure



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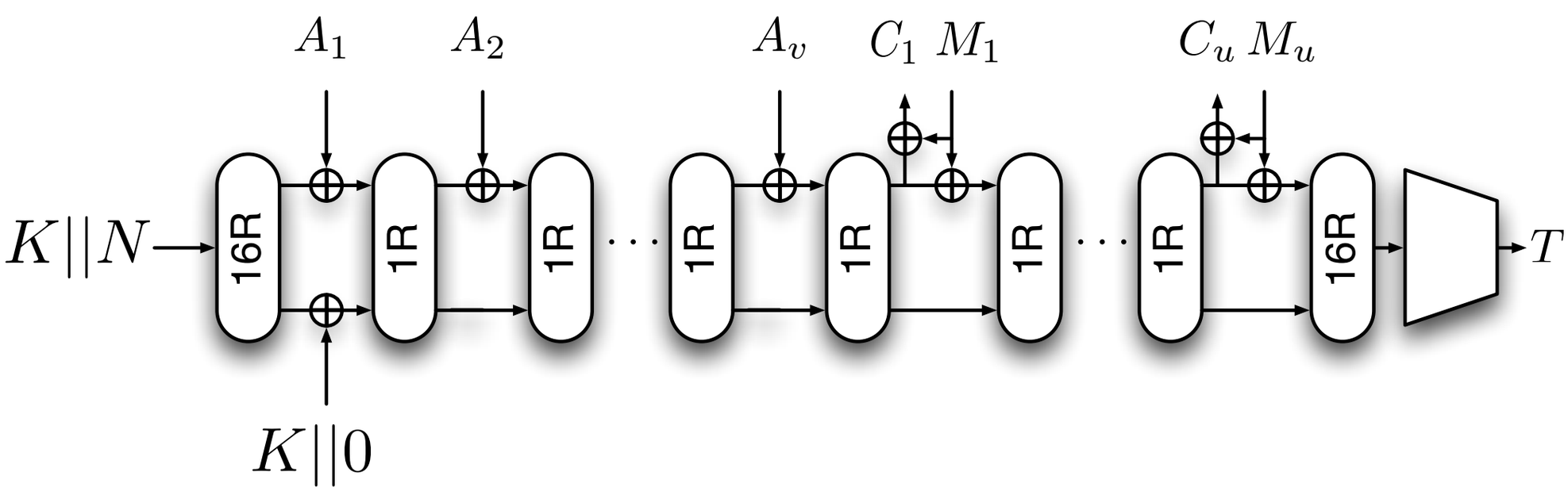
	b
FIDES-80	160
FIDES-96	192

Design - Structure



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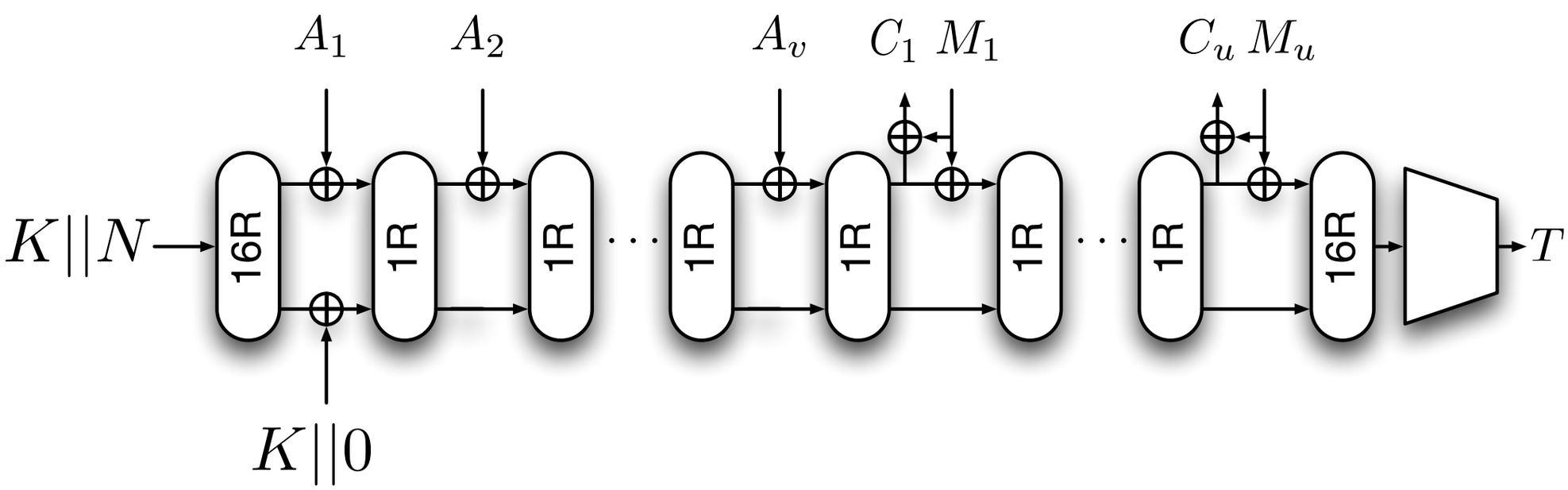
	b	*k/n/t*
FIDES-80	160	80
FIDES-96	192	96

Design - Structure



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	b	*k/n/t*	*r*
FIDES-80	160	80	10
FIDES-96	192	96	12

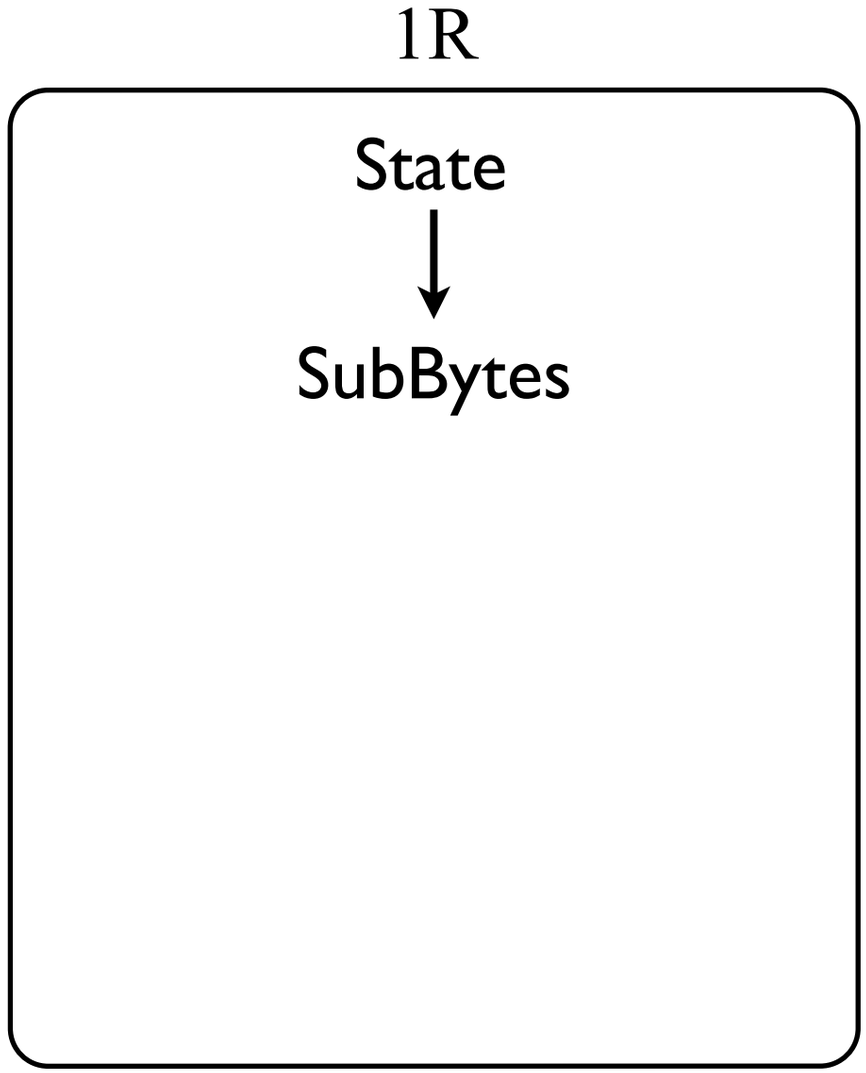
Design - Structure

1R

State

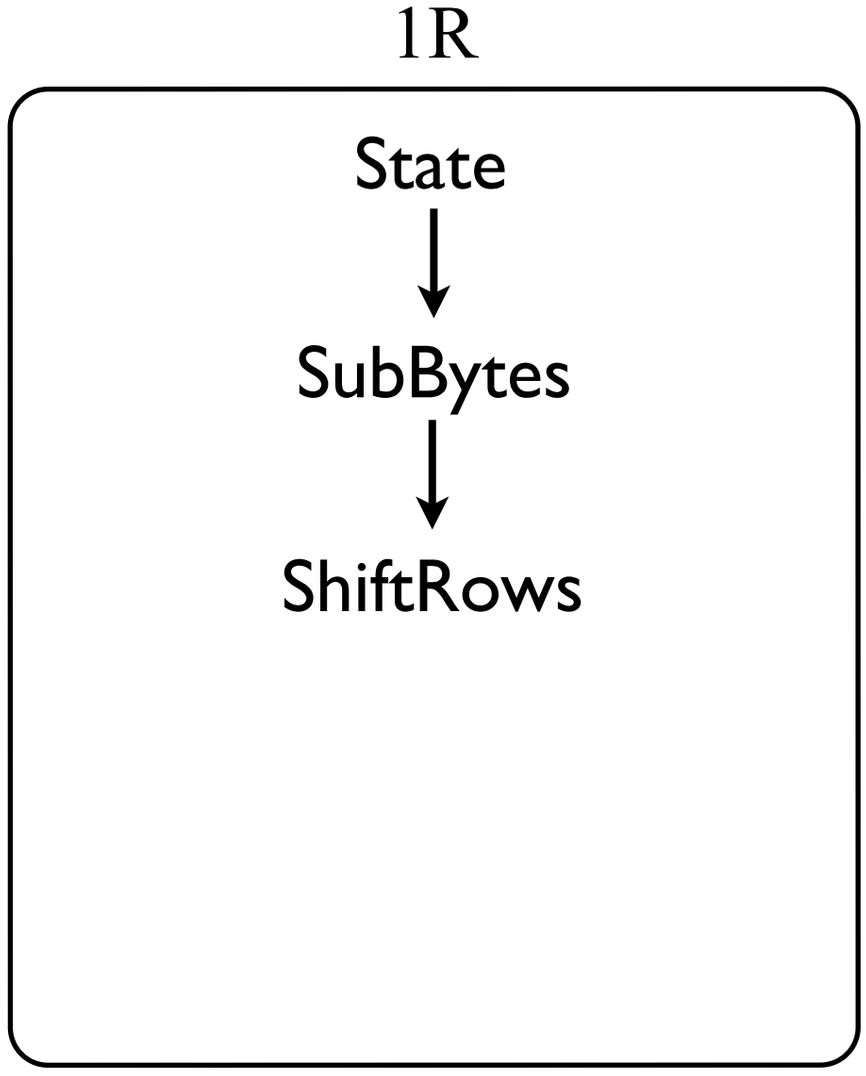
$a_{0,0}$	$a_{0,1}$	$a_{0,2}$	$a_{0,3}$	$a_{0,4}$	$a_{0,5}$	$a_{0,6}$	$a_{0,7}$
$a_{1,0}$	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$a_{1,4}$	$a_{1,5}$	$a_{1,6}$	$a_{1,7}$
$a_{2,0}$	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,5}$	$a_{2,6}$	$a_{2,7}$
$a_{3,0}$	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$	$a_{3,6}$	$a_{3,7}$

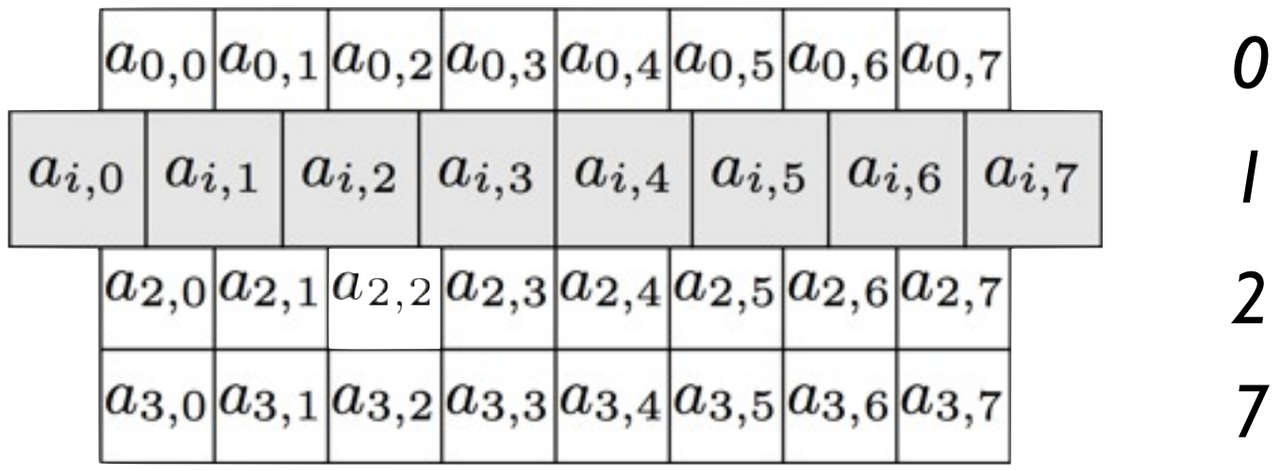
Design - Structure



$a_{0,0}$	$a_{0,1}$	$a_{0,2}$	$a_{0,3}$	$a_{0,4}$	$a_{0,5}$	$a_{0,6}$	$a_{0,7}$
$a_{1,0}$	$a_{1,1}$	$a_{i,j}$	$a_{1,3}$	$a_{1,4}$	$a_{1,5}$	$a_{1,6}$	$a_{1,7}$
$a_{2,0}$	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,5}$	$a_{2,6}$	$a_{2,7}$
$a_{3,0}$	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$	$a_{3,6}$	$a_{3,7}$

Design - Structure





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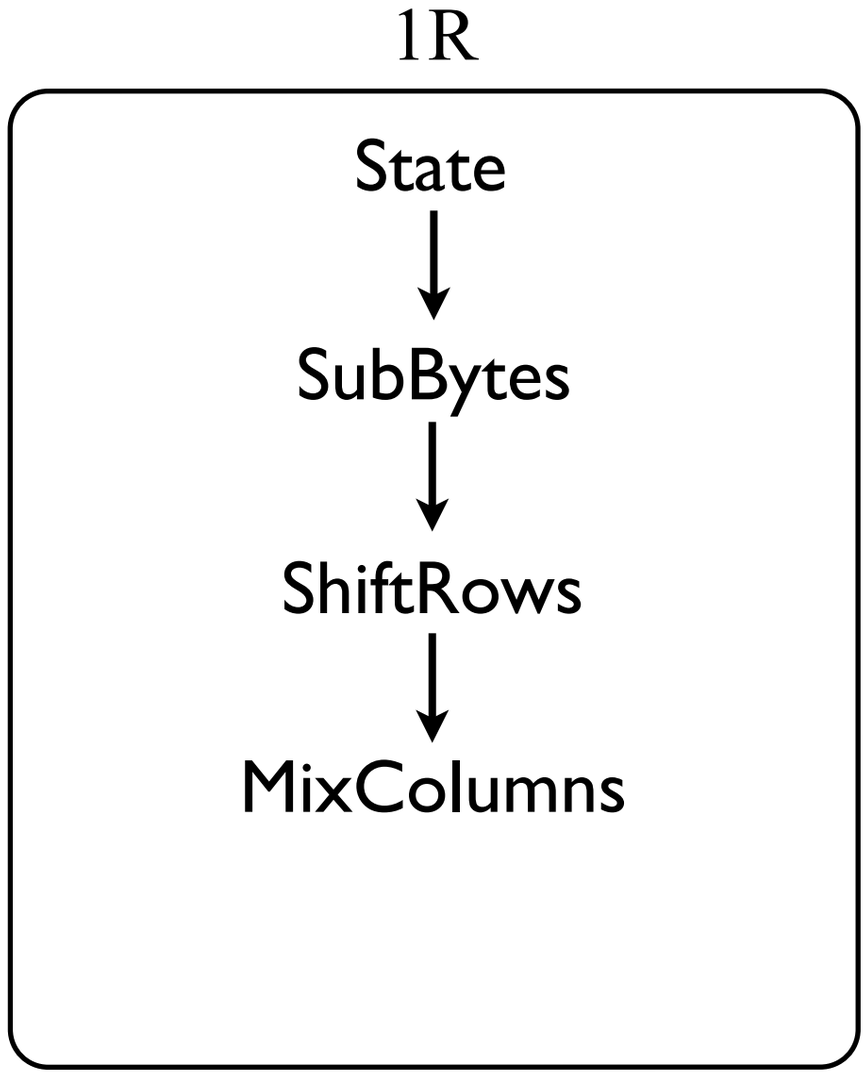
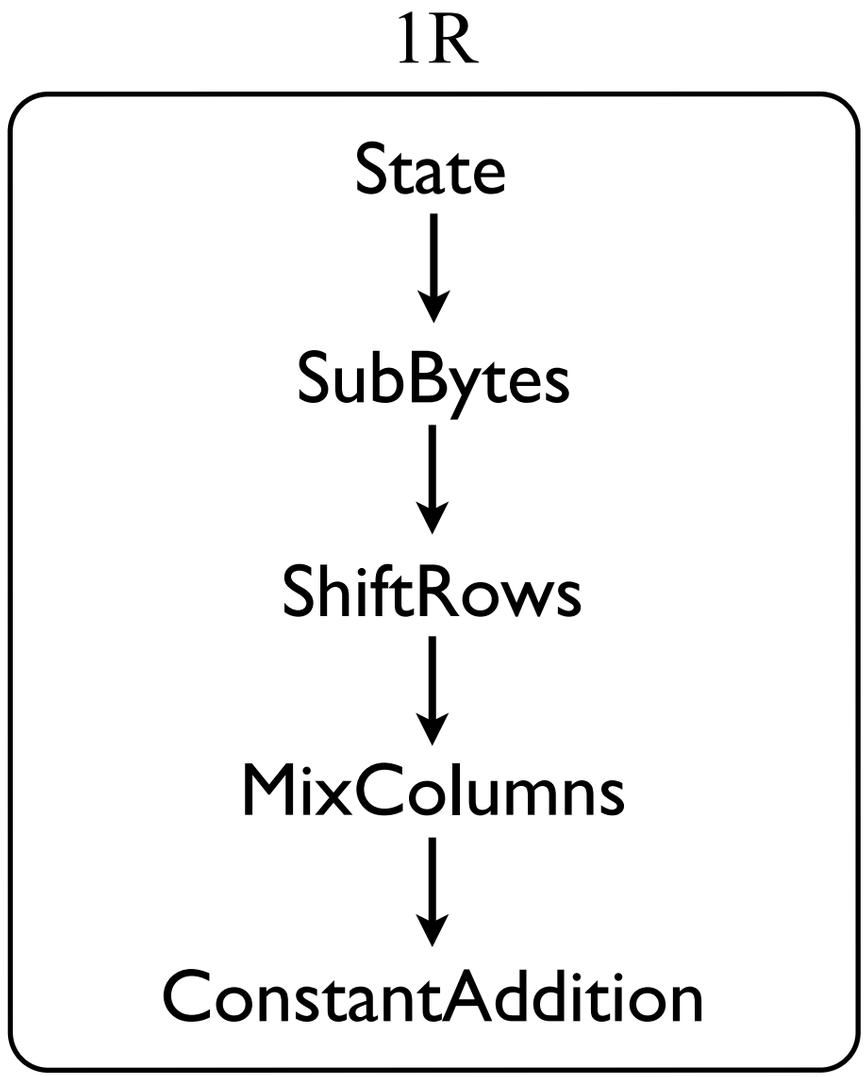


$$\begin{array}{|c|c|c|c|c|c|c|c|}
\hline
a_{0,0} & a_{0,1} & a_{0,j} & a_{0,3} & a_{0,4} & a_{0,5} & a_{0,6} & a_{0,7} \\
\hline
a_{1,0} & a_{1,1} & a_{1,j} & a_{1,3} & a_{1,4} & a_{1,5} & a_{1,6} & a_{1,7} \\
\hline
a_{2,0} & a_{2,1} & a_{2,j} & a_{2,3} & a_{2,4} & a_{2,5} & a_{2,6} & a_{2,7} \\
\hline
a_{3,0} & a_{3,1} & a_{3,j} & a_{3,3} & a_{3,4} & a_{3,5} & a_{3,6} & a_{3,7} \\
\hline
\end{array}$$

$$\otimes \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$$

Almost MDS
branch number is 4

Design - Structure



Design - S-boxes

- FIDES-80: 5-bit Almost Bent (AB)
  - optimal resistance against differential & linear cryptanalysis
- FIDES-96: 6-bit Almost Perfect Nonlinear (APN)
  - optimal resistance against differential cryptanalysis

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++Low latency++

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Affine Equivalent to AB permutation

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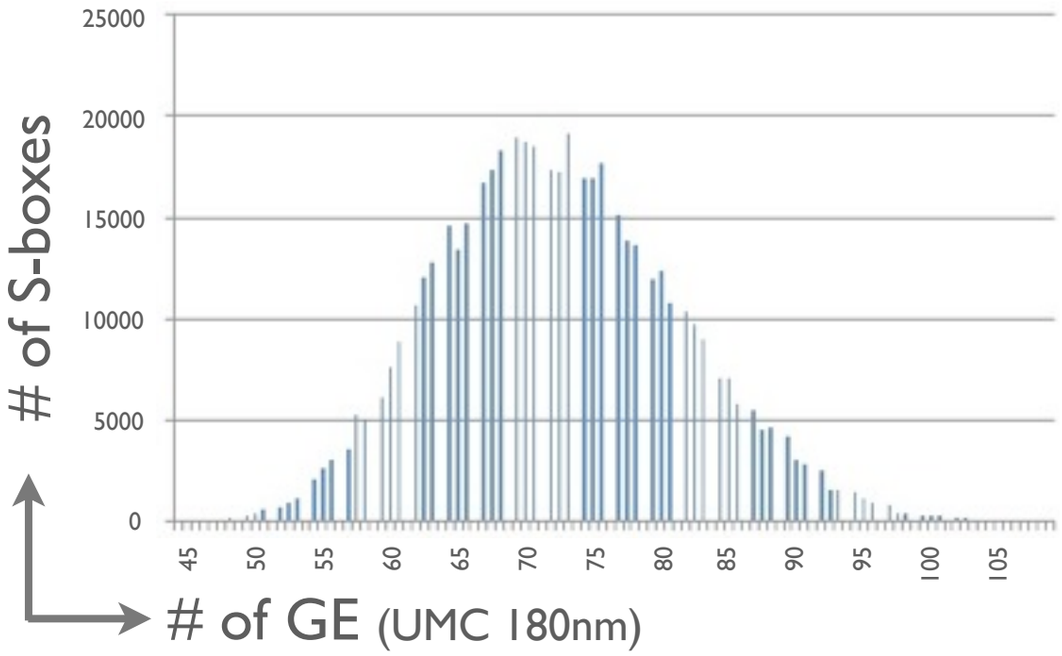
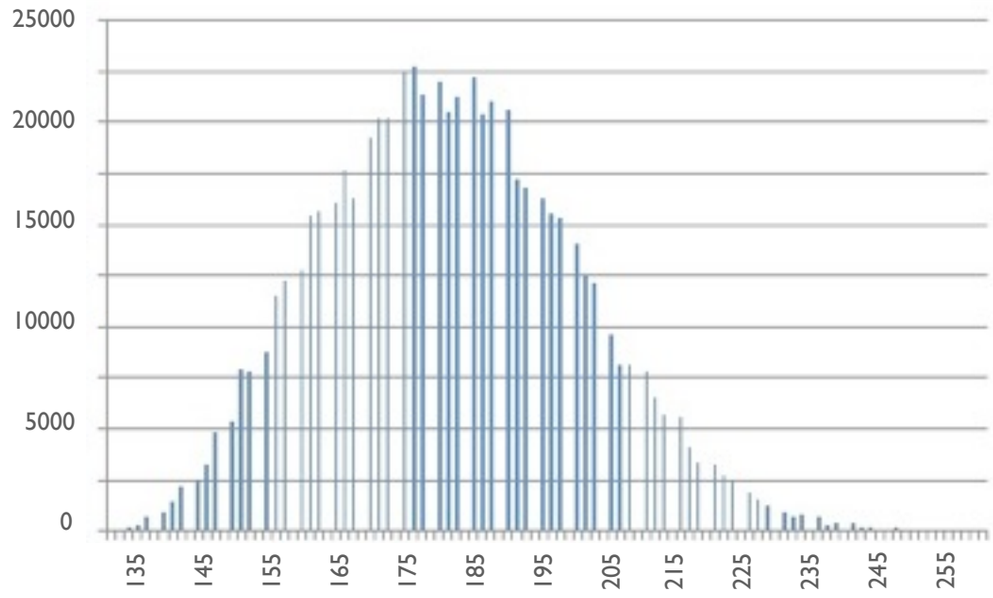
Unshared S-box



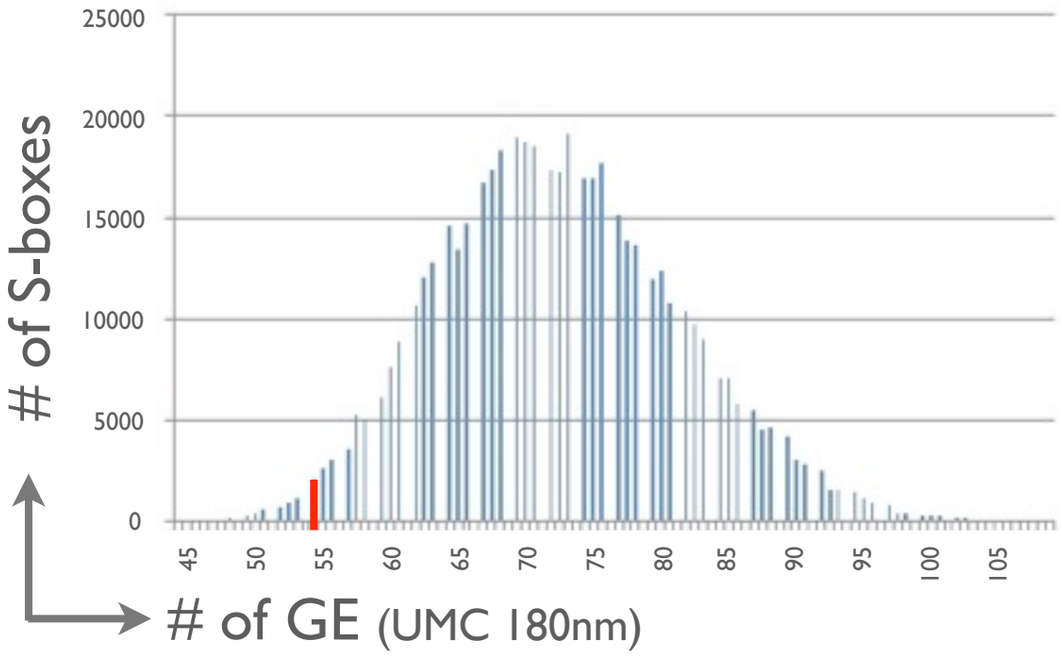
Shared S-box



Design - S-boxes

Affine Equivalent to AB permutation

Unshared S-box



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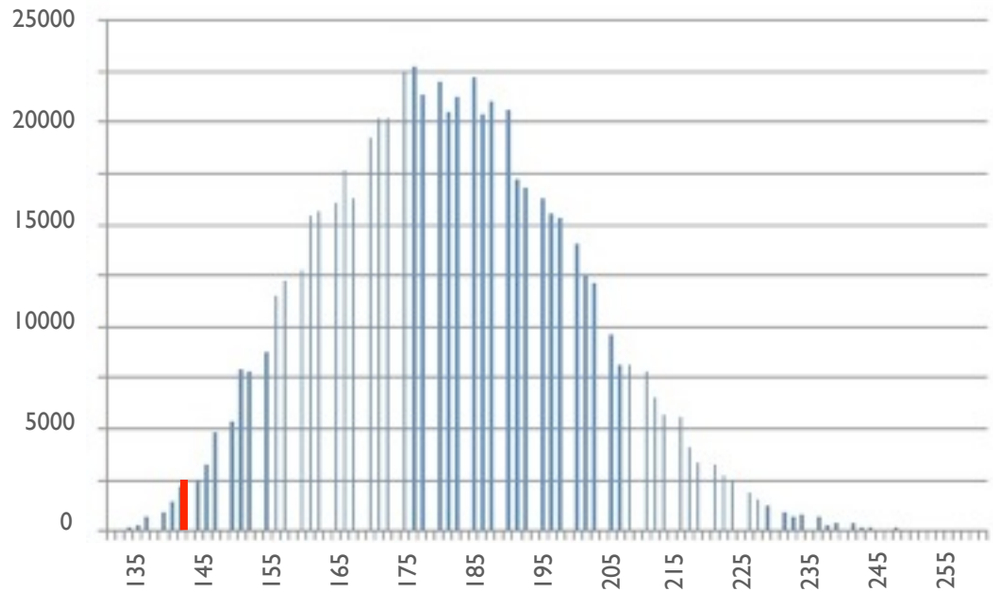

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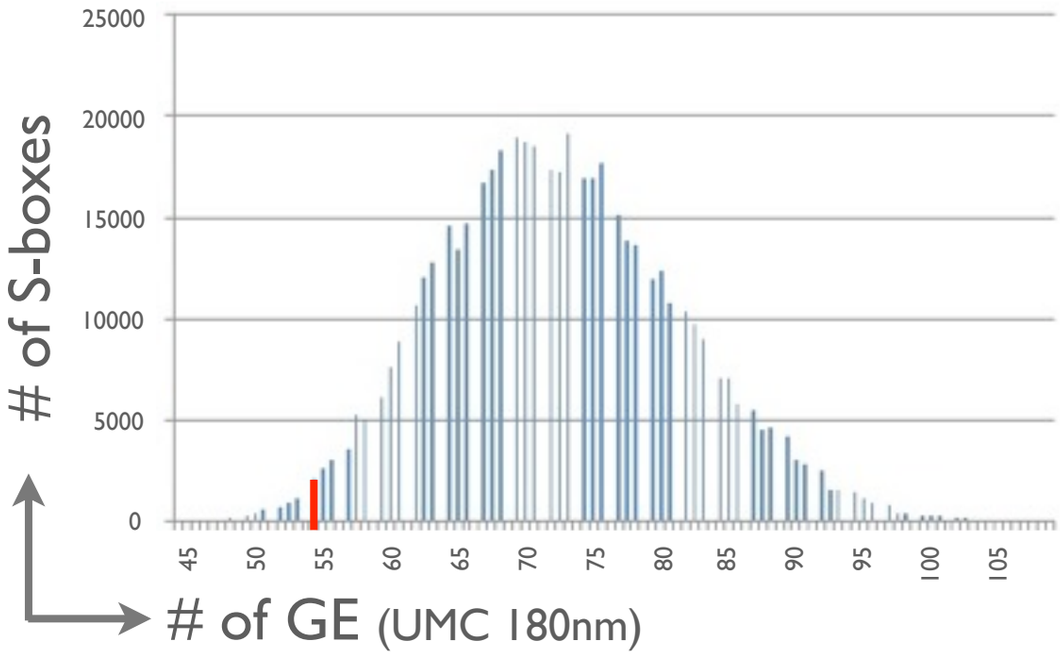

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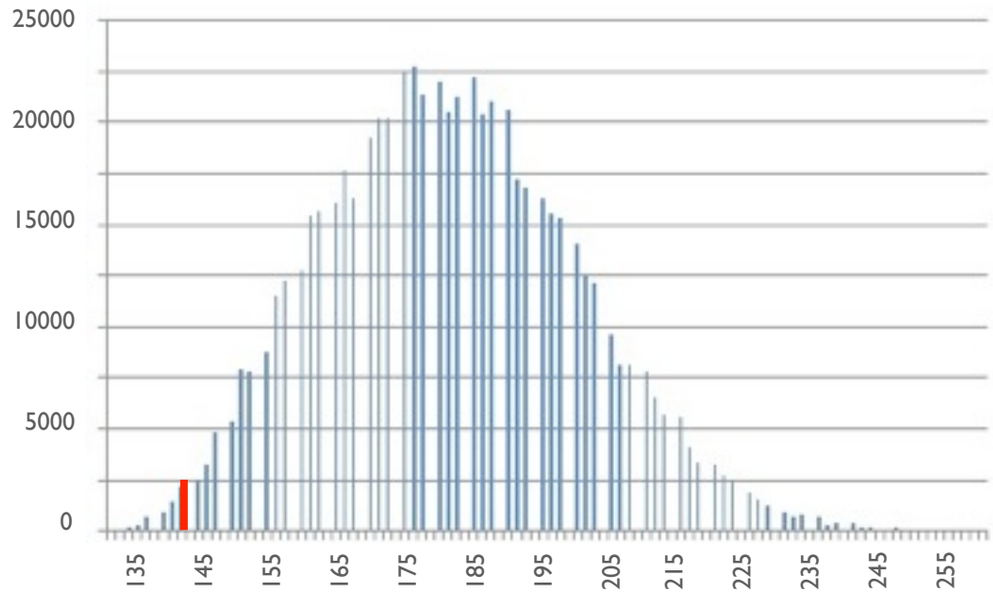

Similar for APN

Security Analysis

# rnd.	# Active S-box	
	any diff.	zero diff.
1	0	-
2	4	-
3	7	-
4	16	-
5	22	-
6	32	52
7	42	49
8	48	48

Security Analysis

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- Differential & Linear Cryptanalysis

Security Analysis

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- Differential & Linear Cryptanalysis
  16 rounds: $2^{-4x48x2} = 2^{-384}$

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- Collision Trails

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- Differential & Linear Cryptanalysis
  16 rounds: $2^{-4x48x2} = 2^{-384}$
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  16 rounds: $2^{-4x(48+48)} = 2^{-384}$

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- Differential & Linear Cryptanalysis
  16 rounds: $2^{-4x48x2} = 2^{-384}$
- Collision Trails
  16 rounds: $2^{-4x(48+48)} = 2^{-384}$
- Impossible Differential
  9 rounds

Implementation

- FIDES-S
- FIDES-4S
- FIDES-R
- FIDES-T

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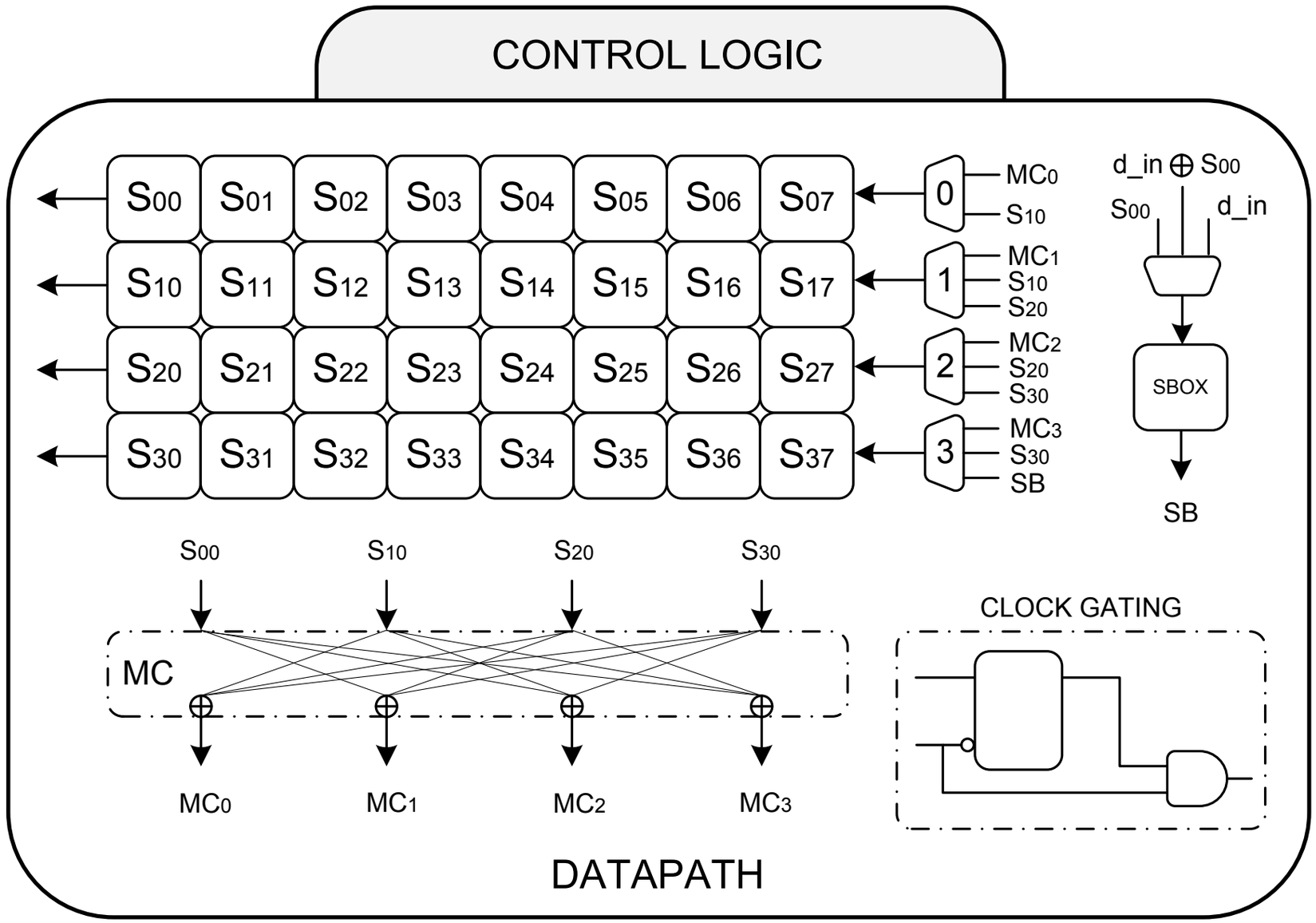

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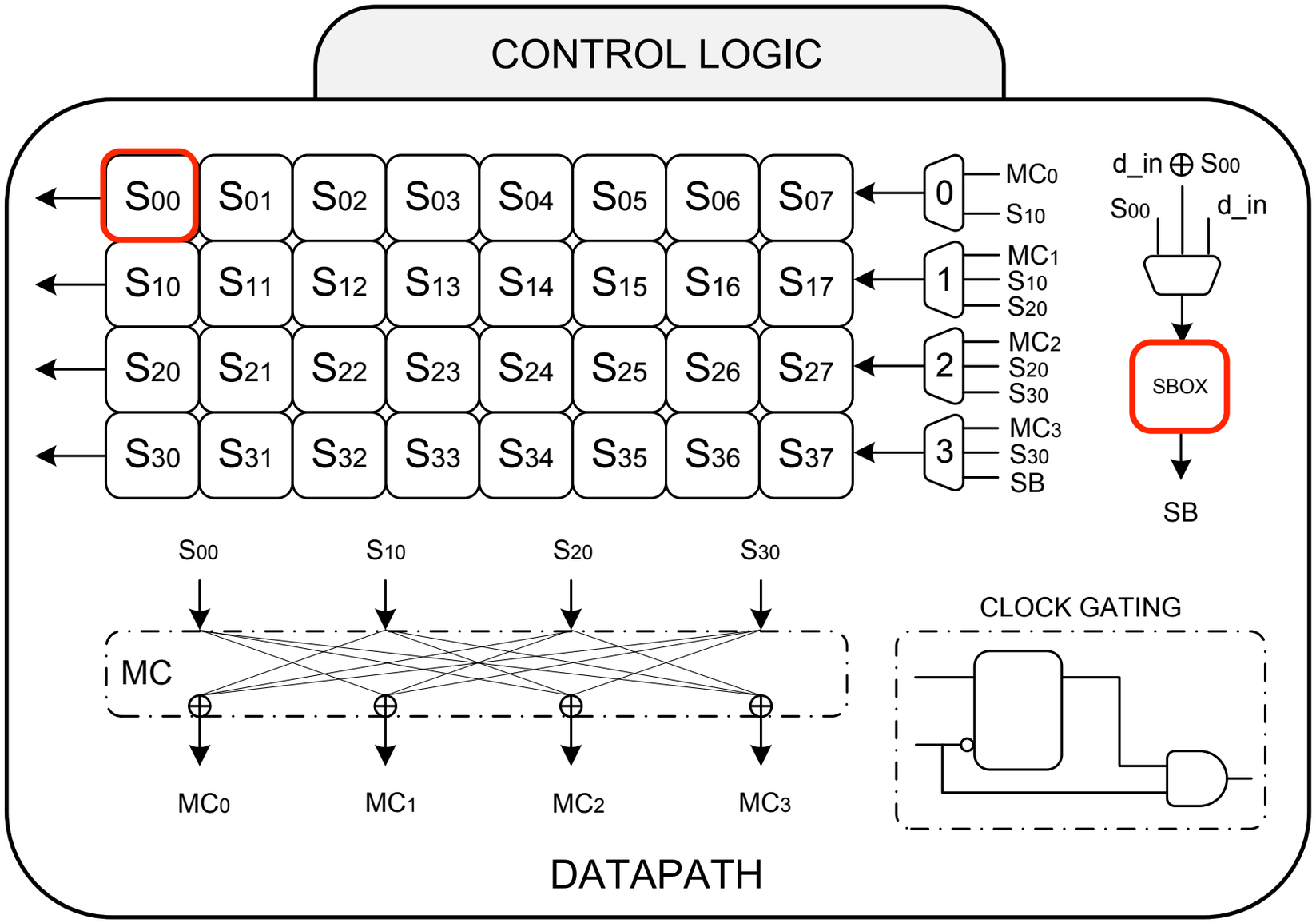

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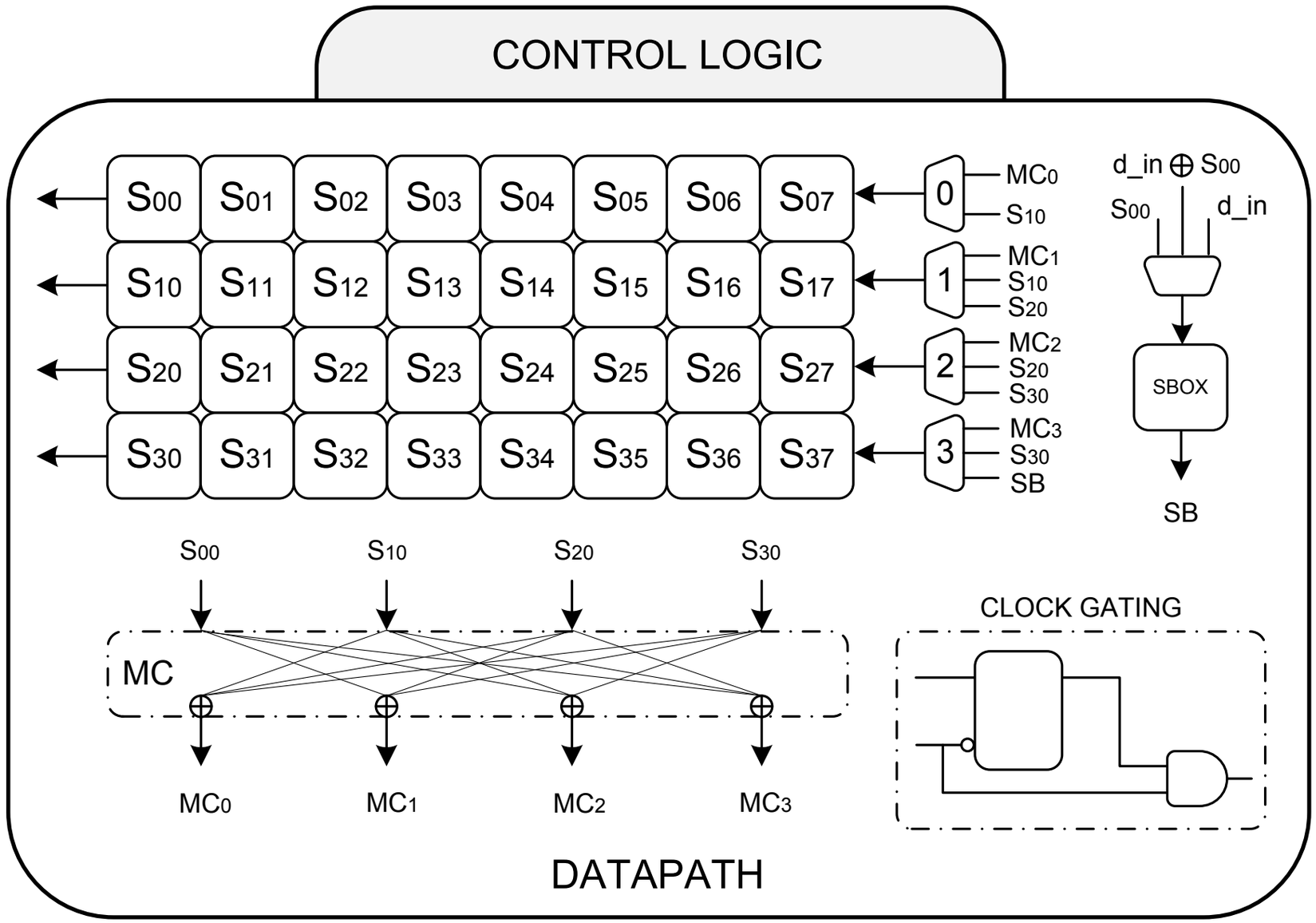

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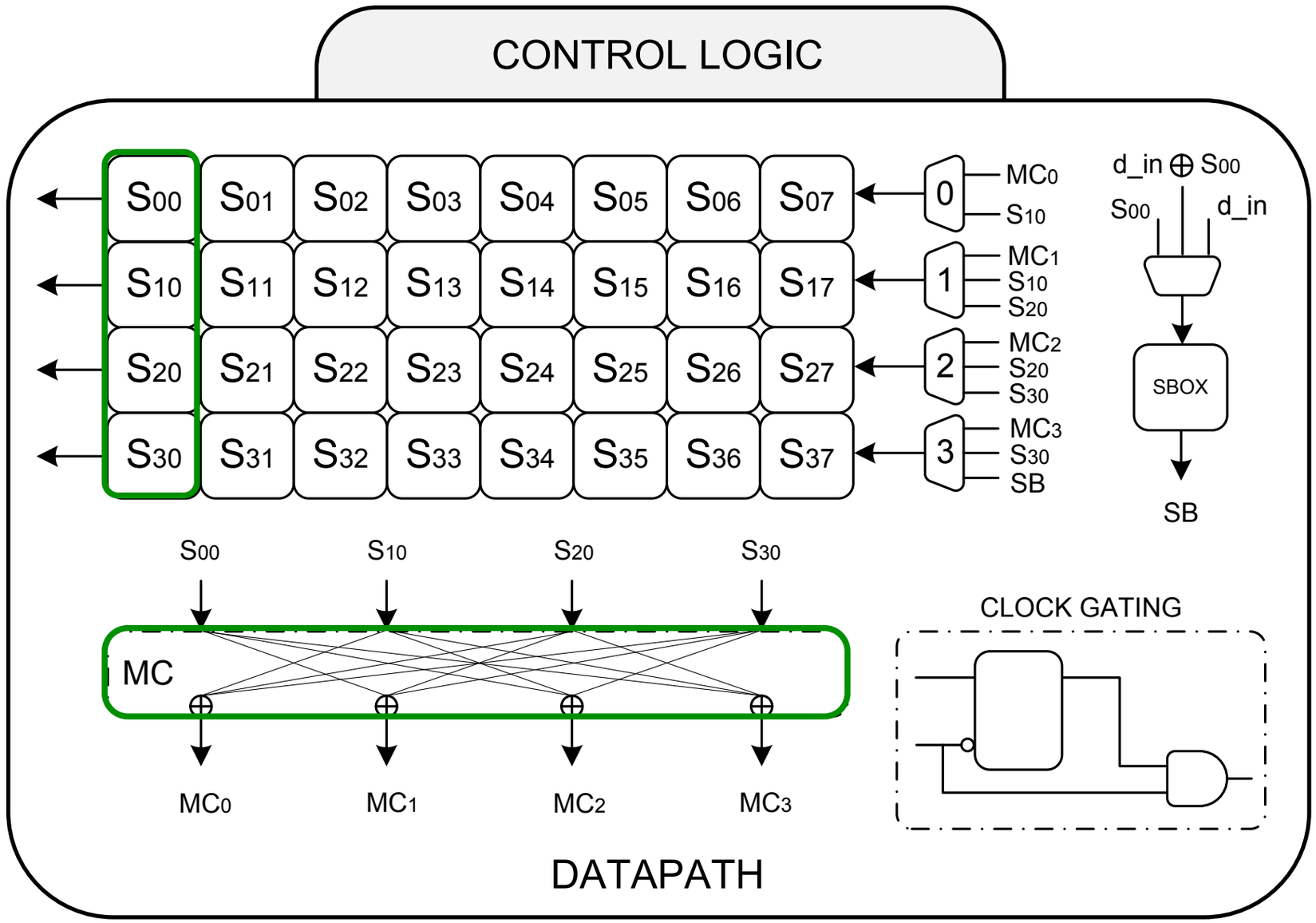

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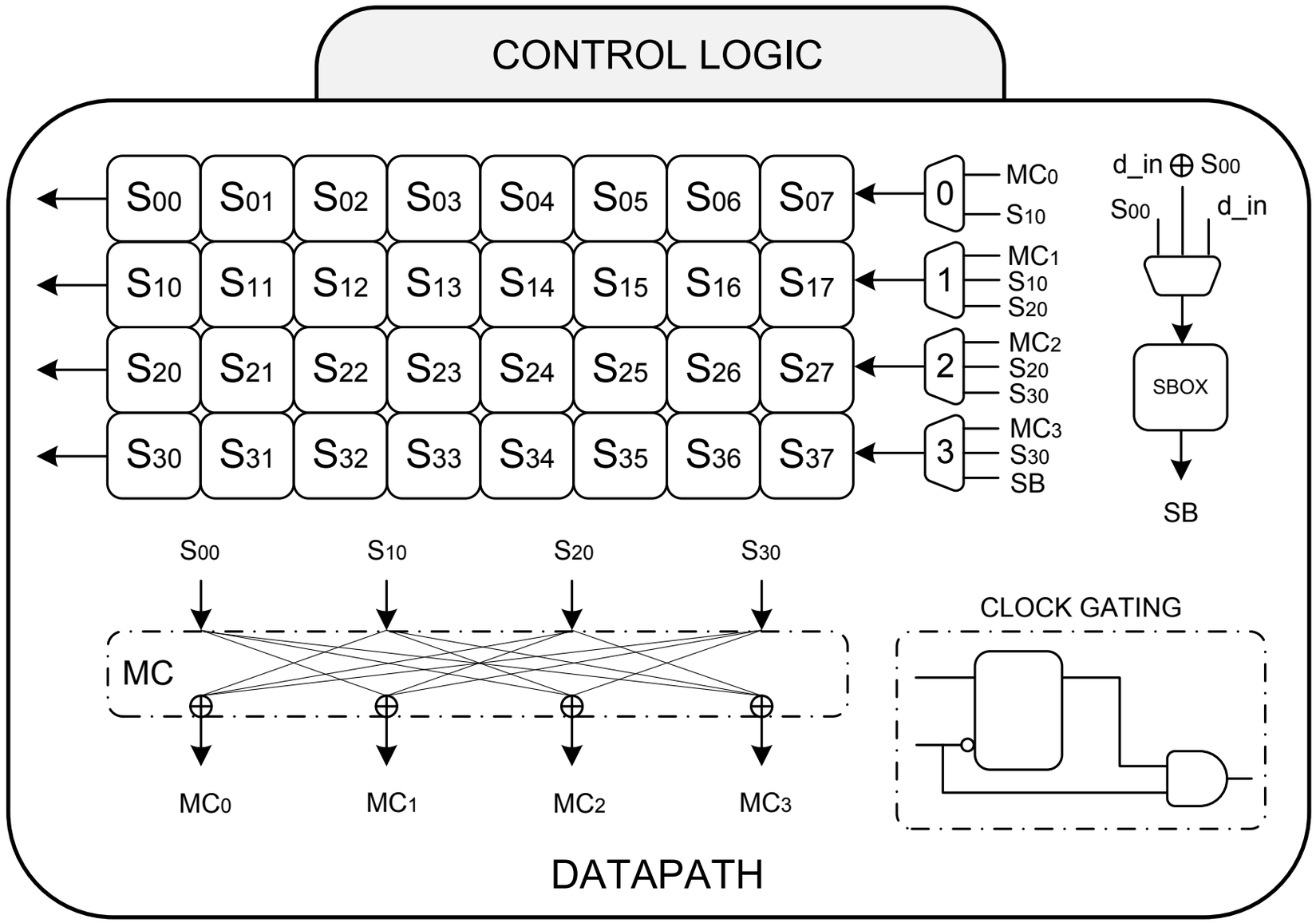

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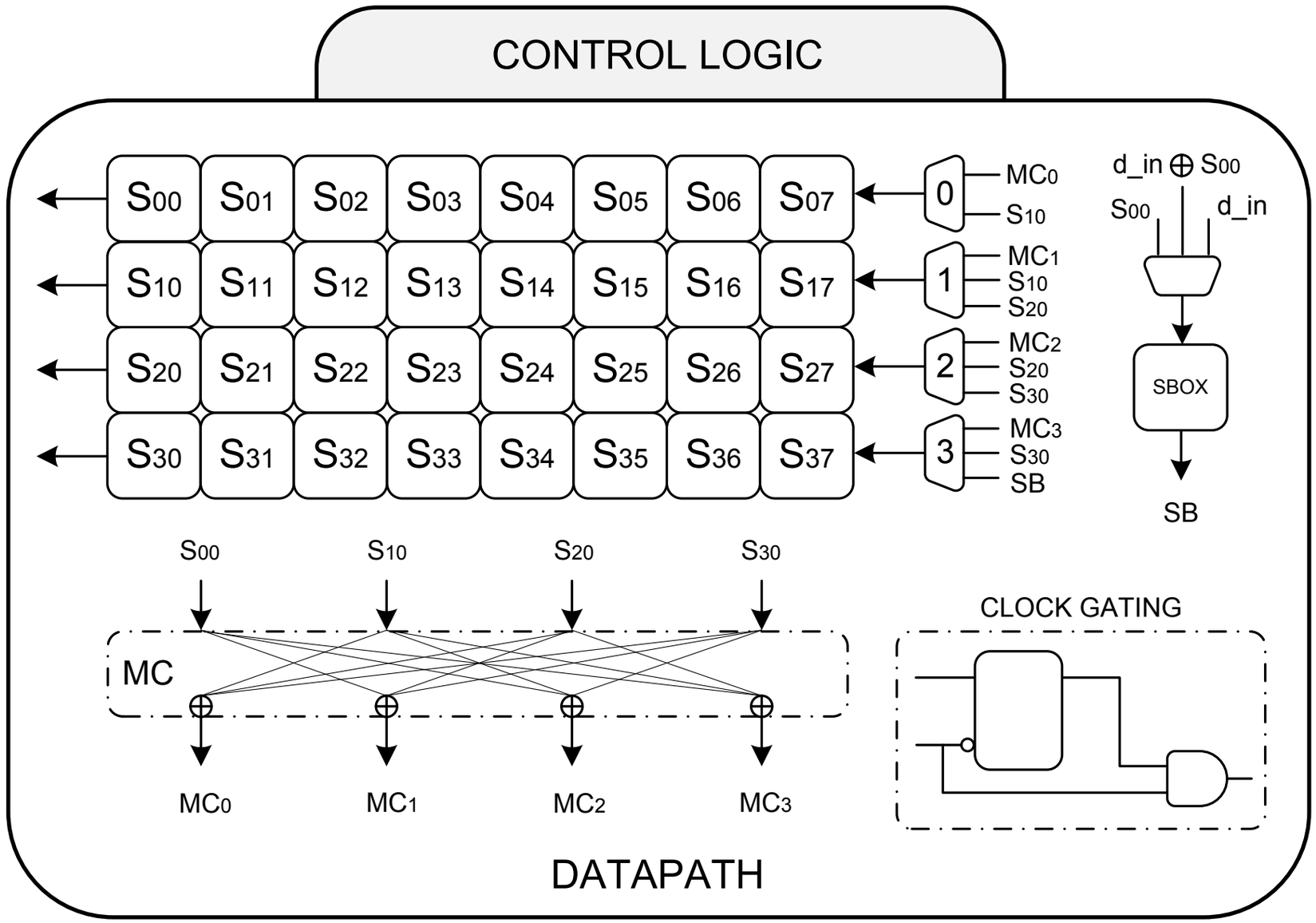

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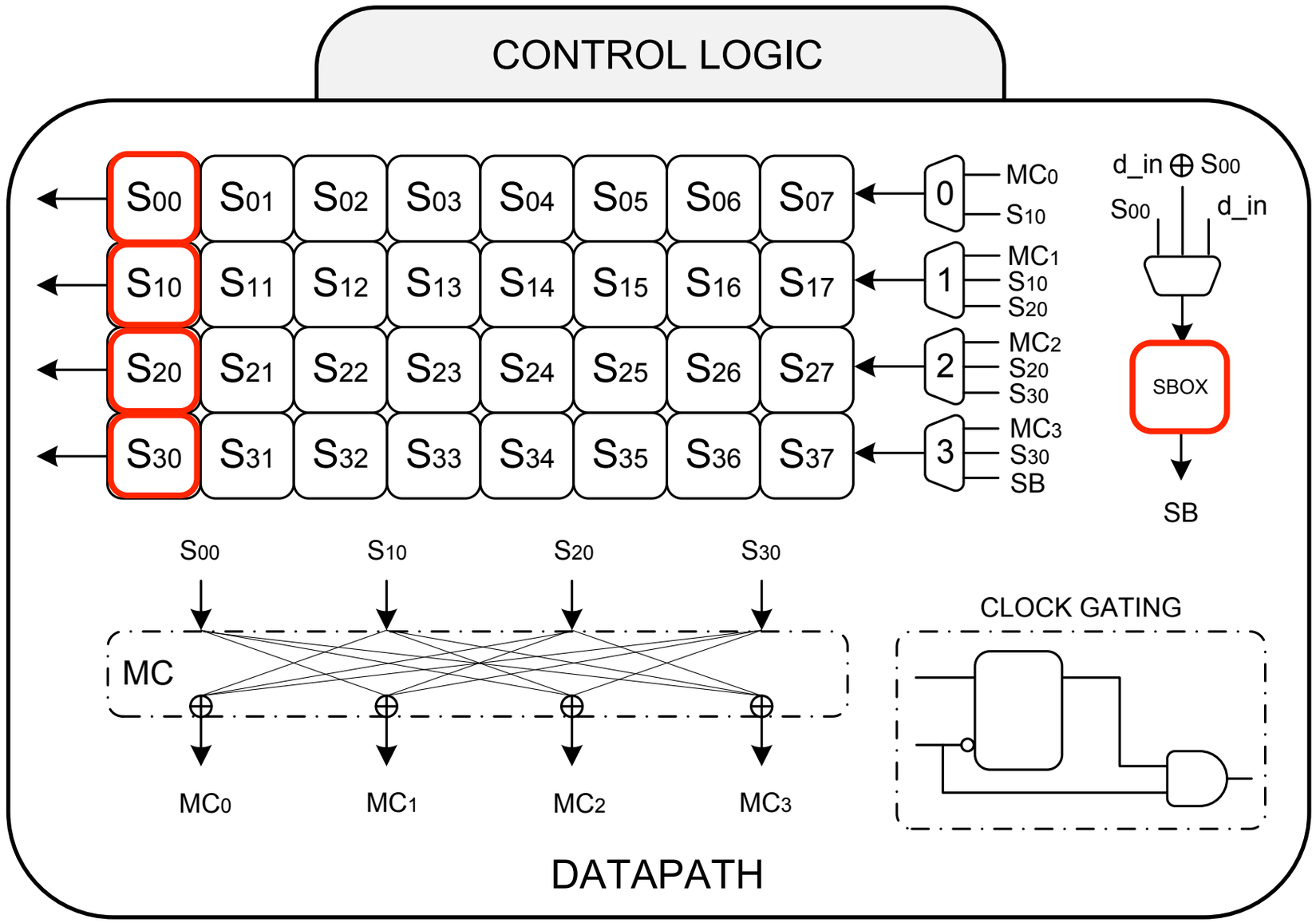

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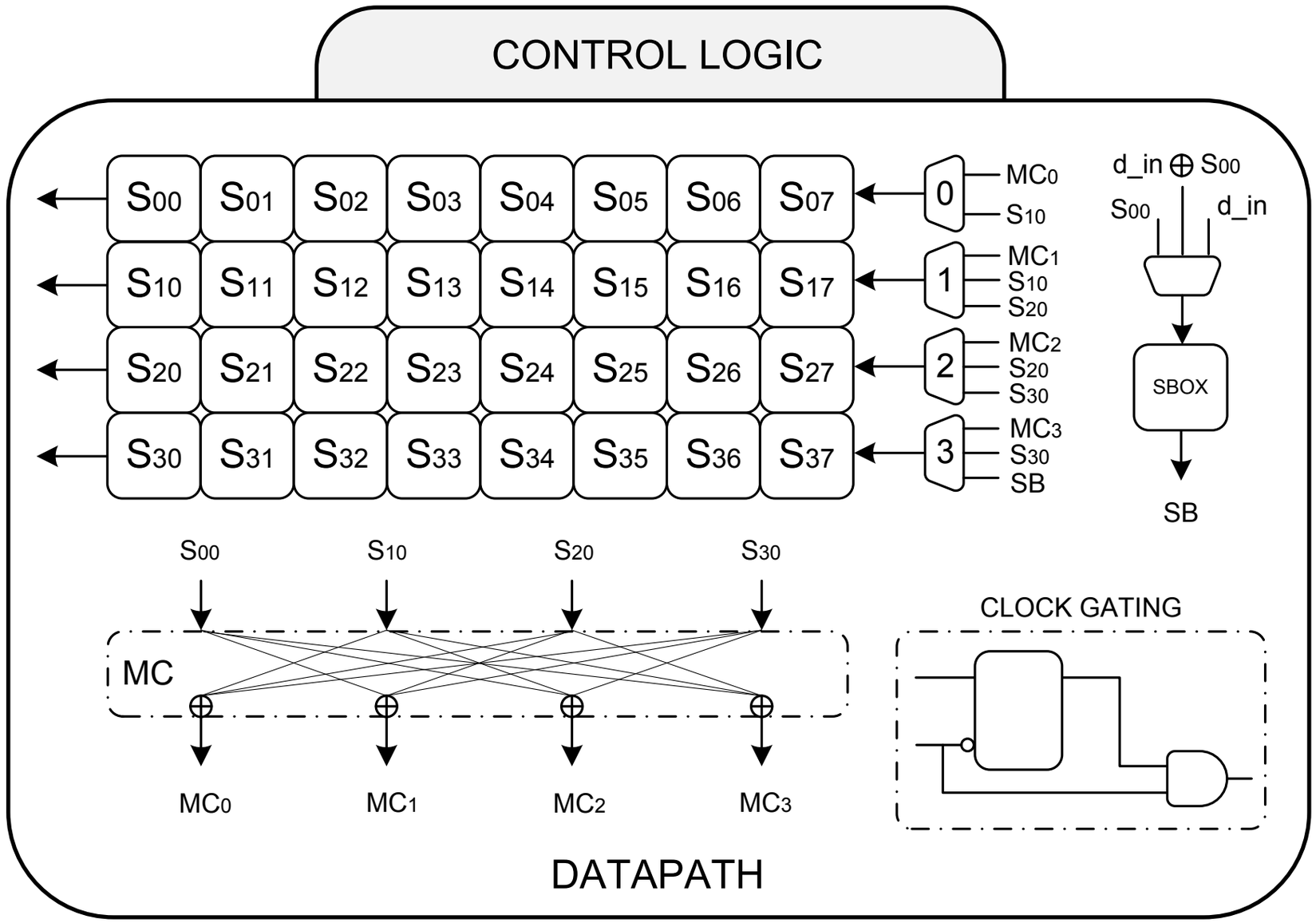

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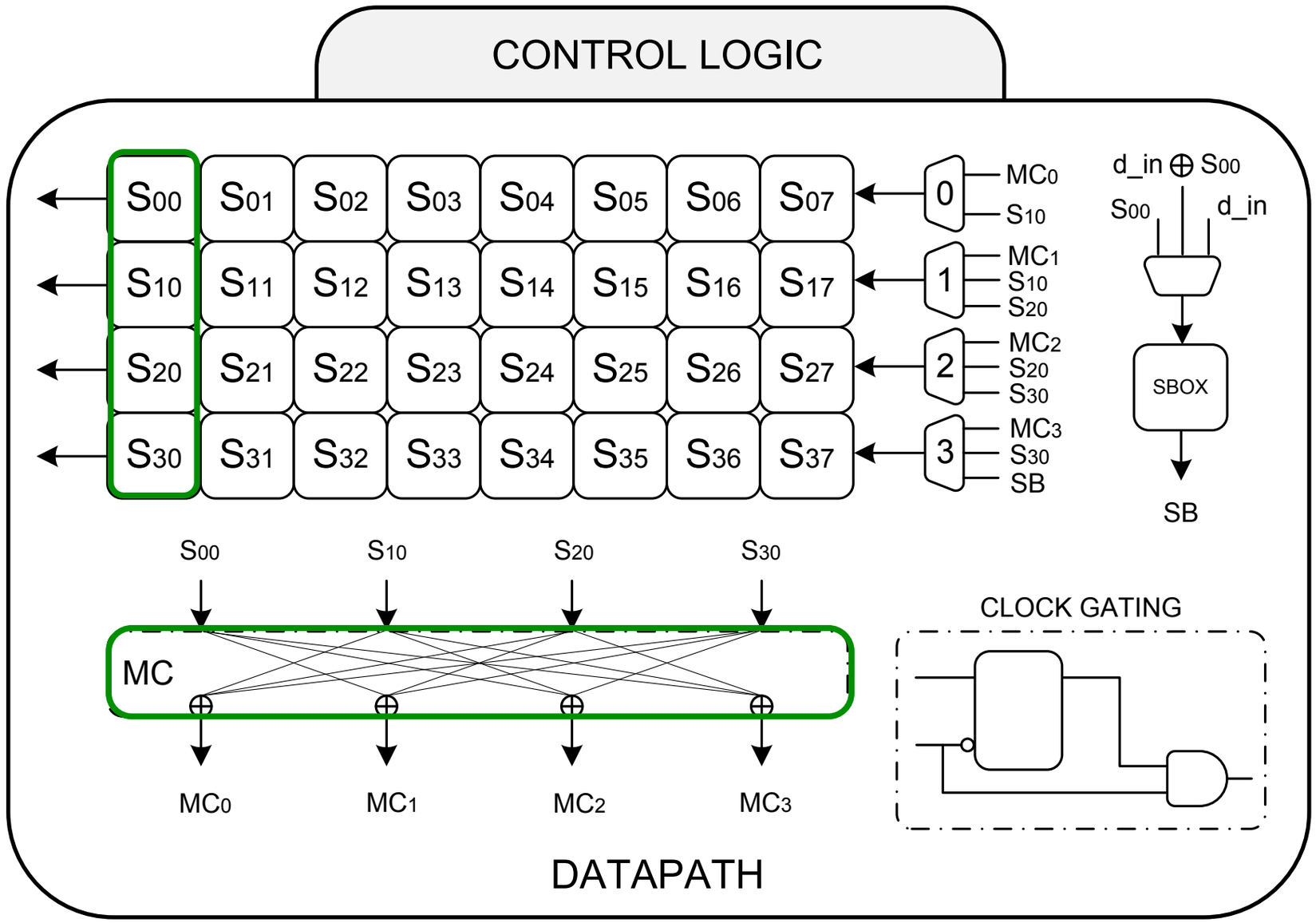

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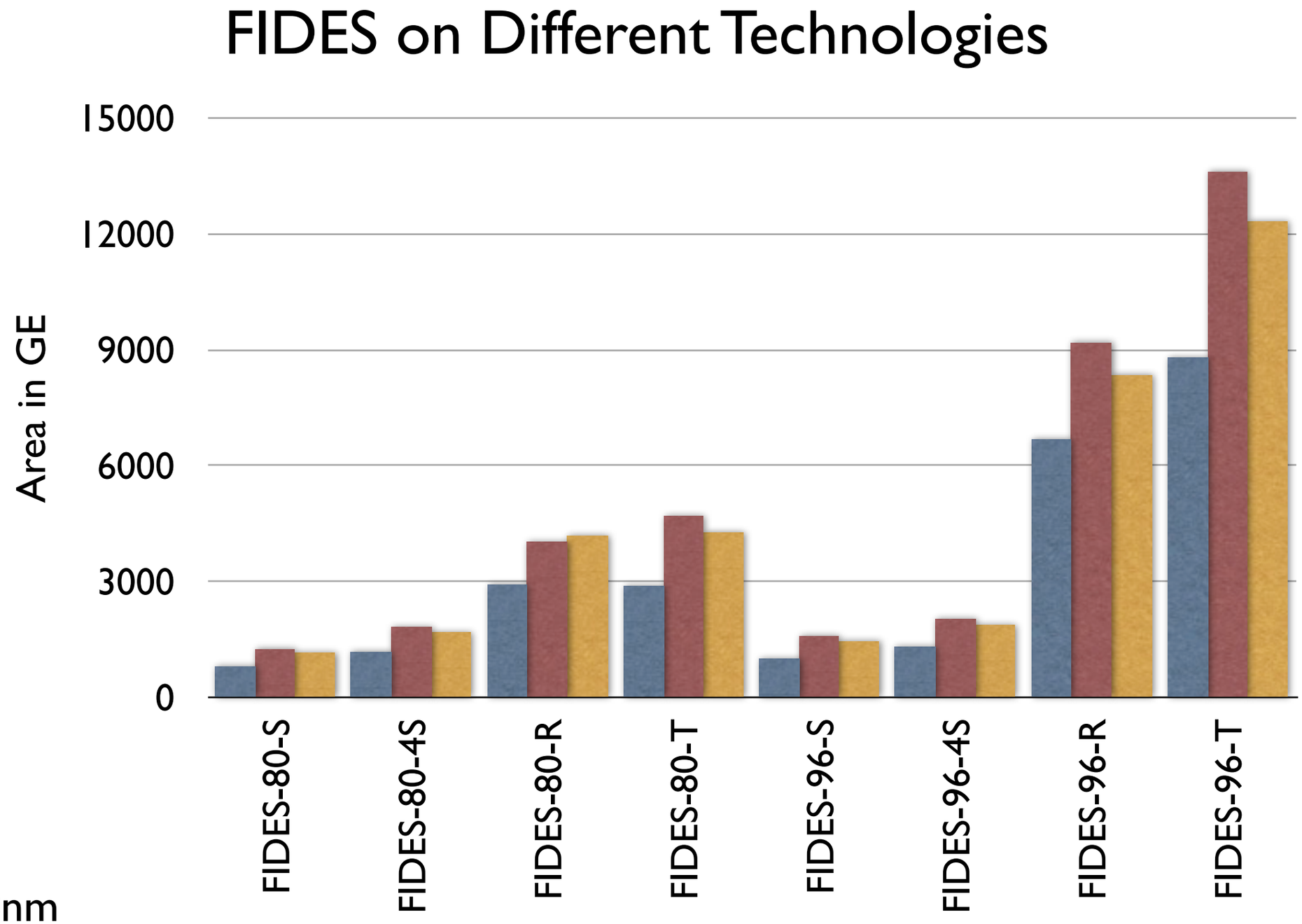
Performance



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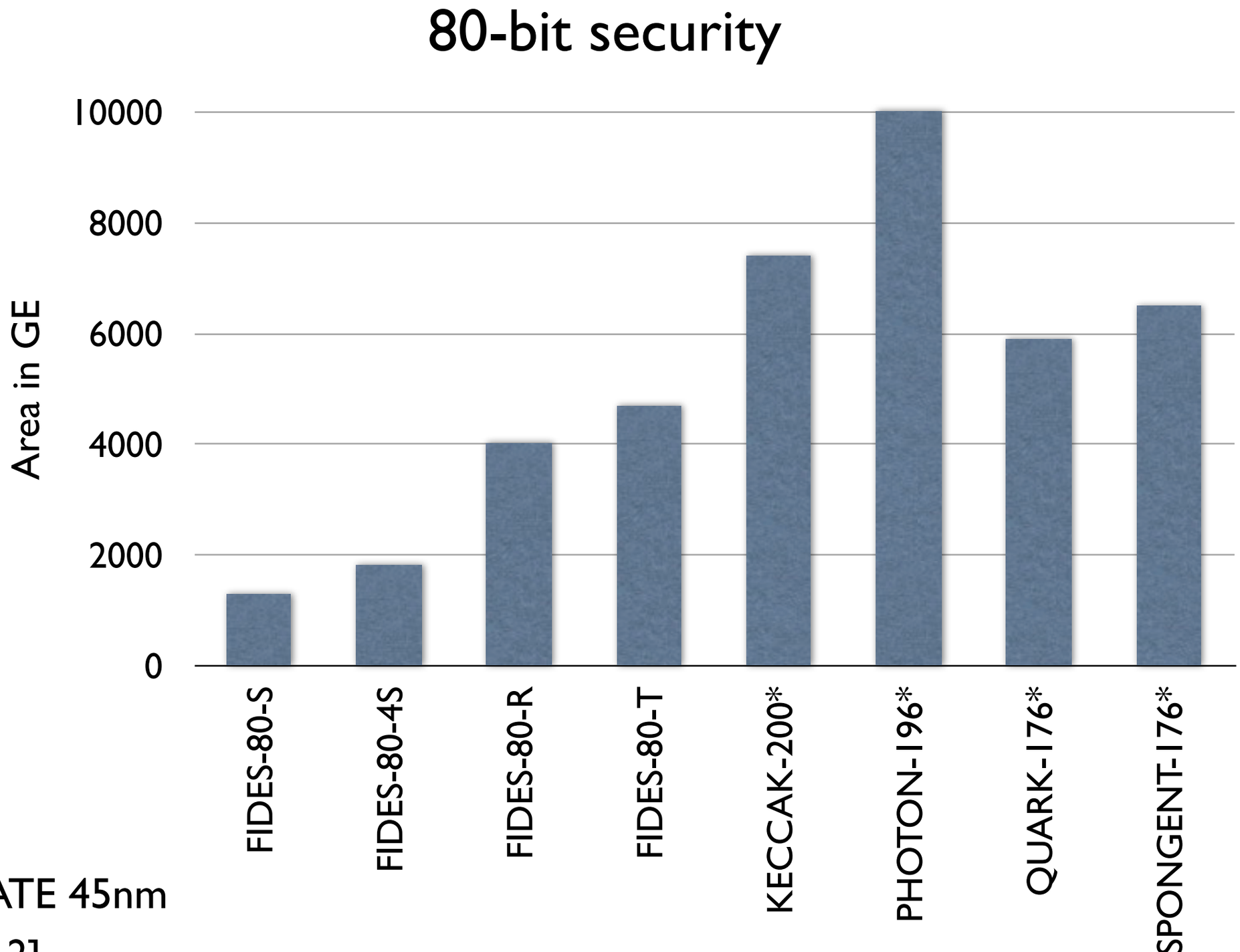

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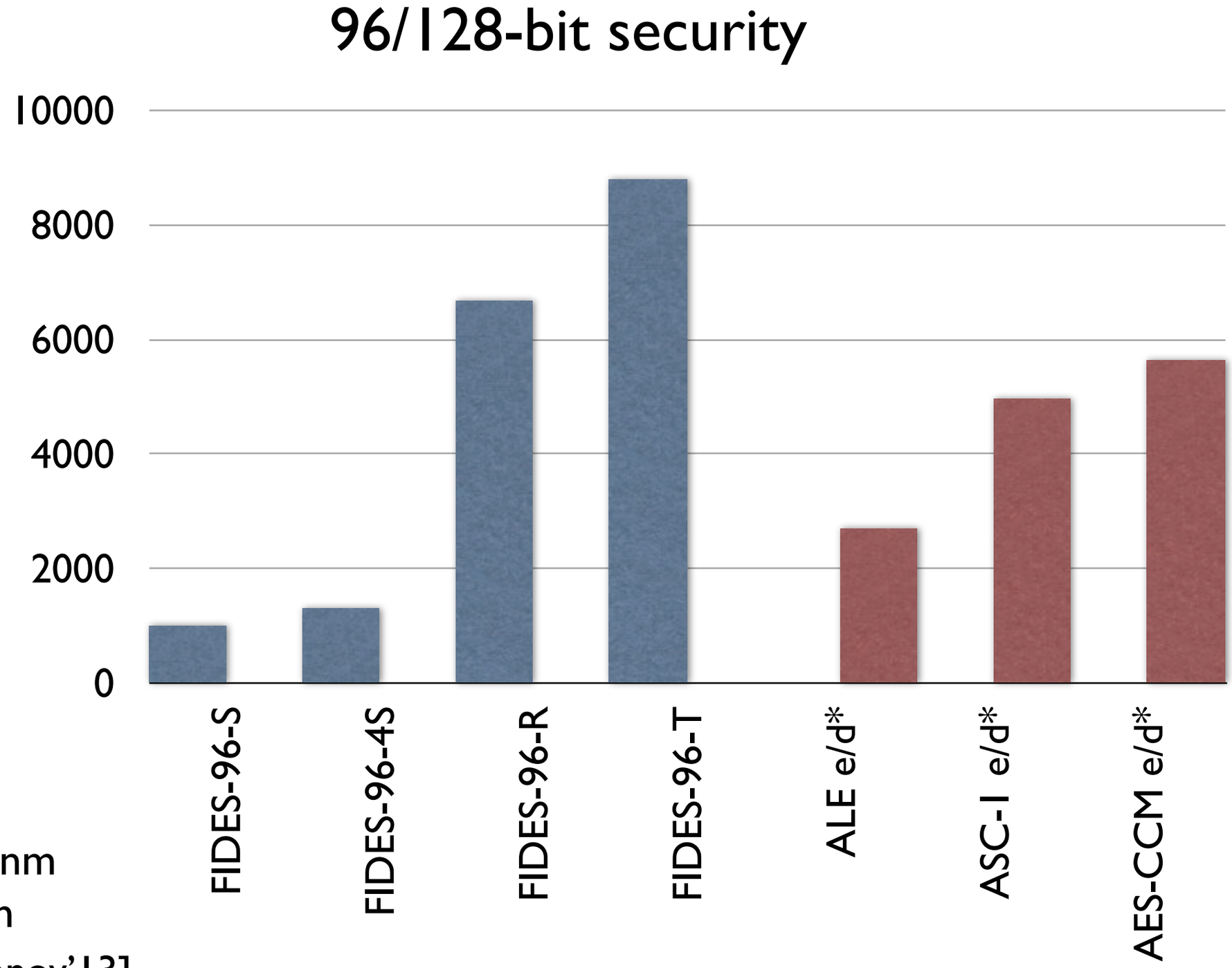
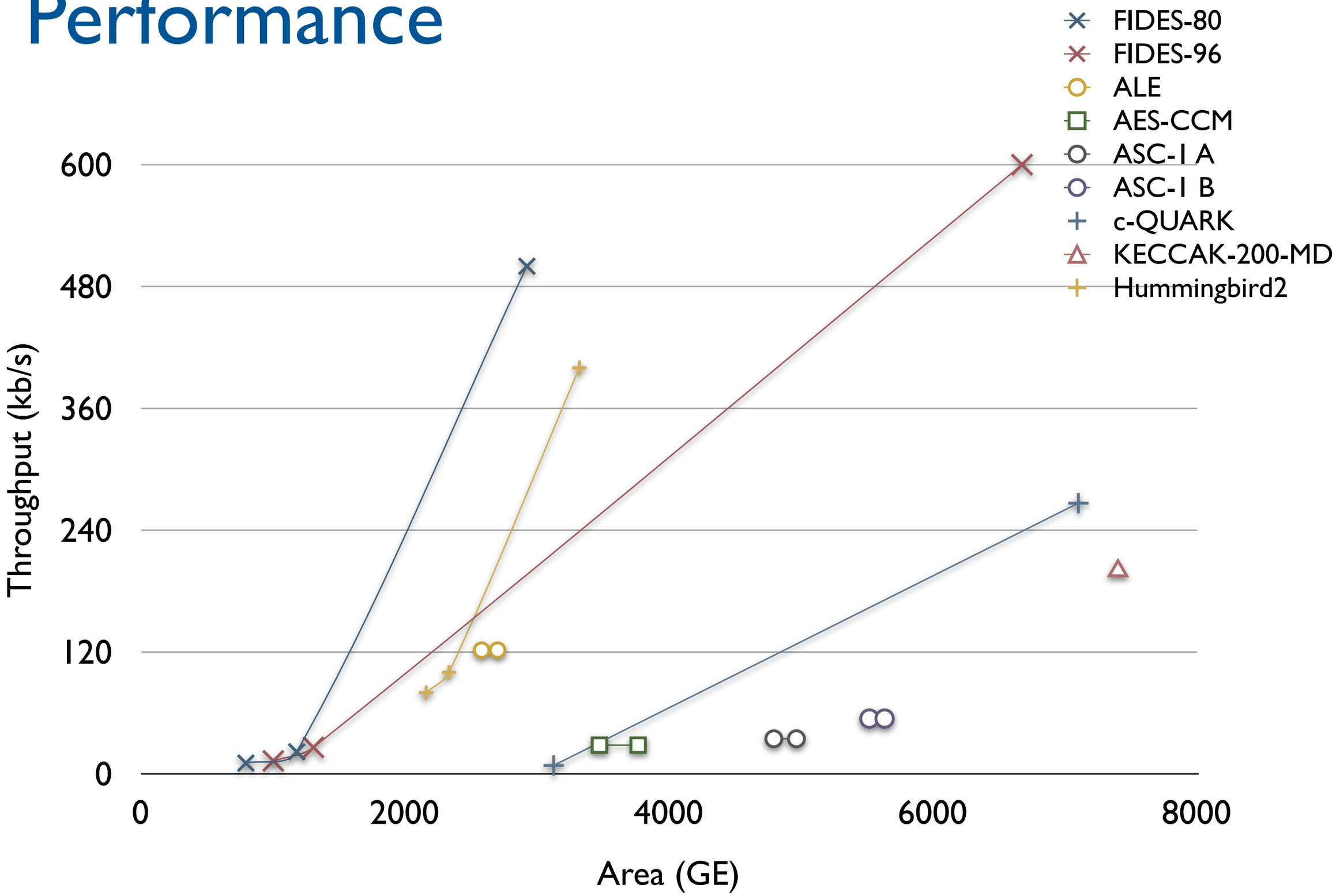


Performance



Conclusion

FIDES

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- Lightweight AE
  - less than 1500GE
  - online, single-pass

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- Lightweight AE
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- with Side Channel Resistance
  - TI less than 5000 GE

Conclusion

FIDES

- Lightweight AE
  - less than 1500GE
  - online, single-pass
- with Side Channel Resistance
  - TI less than 5000 GE
- and 80-bit or 90-bit security
  - AB and APN permutations
  - almost MDS

THANK YOU!