Mixing Layers in Symmetric Crypto

Ko Stoffelen

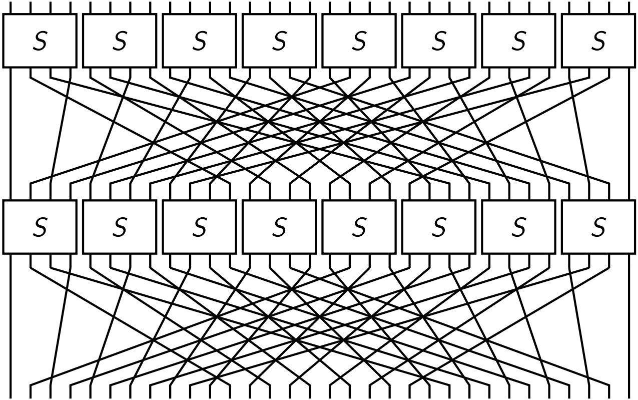
iCIS | Digital Security
Radboud University

Joint work with. . .

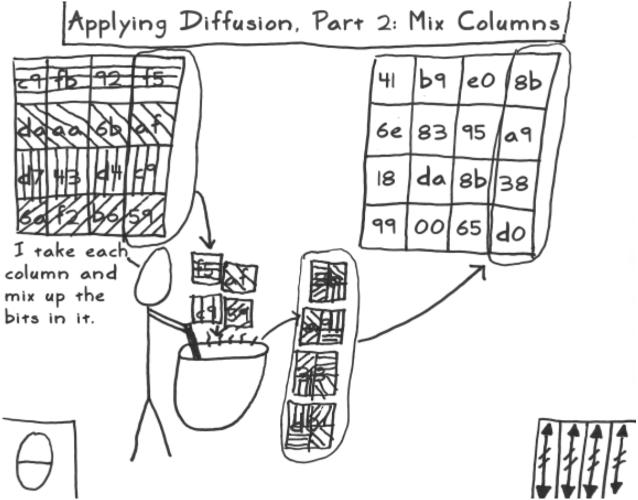
Thorsten Kranz, Gregor Leander, Ko Stoffelen, Friedrich Wiemer. **Shorter Linear Straight-Line Programs for MDS Matrices.** *ToSC 2017 Issue 4.*

Ko Stoffelen, Joan Daemen. **Column Parity Mixers.** *ToSC 2018 Issue 1.*

Diffusion



Diffusion in AES



Diffusion in AES

$$\begin{bmatrix} b_0 \\ b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} 02 & 03 & 01 & 01 \\ 01 & 02 & 03 & 01 \\ 01 & 01 & 02 & 03 \\ 03 & 01 & 01 & 02 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix}$$

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- MixColumns matrix is MDS

Lightweight MDS matrices

Lightweight Multiplication in $GF(2^n)$ with Applications to MDS Matrices

Christof Beierle(✉), Thorsten Kranz, and Gregor Leander

Horst Görtz Institute for IT Security, Ruhr-Universität Bochum, Bochum, Germany
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Abstract. In this paper we consider the fundamental question of optimizing finite field multiplications with one fixed element. Surprisingly,

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Optimizing Implementations of Lightweight Building Blocks

Jérémy Jean[1], Thomas Peyrin[2], Siang Meng Sim[2] and Jade Tourteaux[1,3]

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Lightweight MDS Generalized Circulant Matrices

Meicheng Liu[1,2](✉) and Siang Meng Sim[1](✉)

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Optimizing Implementations ... Building Blocks

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On the Construction of Lightweight Circulant Involutory MDS Matrices

Yongqiang Li[1,2(✉)] and Mingsheng Wang[1]

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[2] Science and Technology on Communication Security Laboratory,
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Abstract. In the present paper, we investigate the problem of constructing MDS matrices with as few bit XOR operations as possible.

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M

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Lightweight MDS Involution Matrices

Siang Meng Sim[1](✉), Khoongming Khoo[2], Frédérique Oggier[1], and Thomas Peyrin[1]

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Abstract. In this article, we provide new methods to look for lightweight MDS matrices, and in particular involutory ones. By proving

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Lightweight Diffusion Layer: Importance of Toeplitz Matrices

Sumanta Sarkar[1] and Habeeb Syed[2]

[1] TCS Innovation Labs, Hyderabad, INDIA, Sumanta.Sarkar1@tcs.com
[2] TCS Innovation Labs, Hyderabad, INDIA, Habeeb.Syed@tcs.com

Abstract. MDS matrices are used as building blocks of diffusion layers in block ciphers, and XOR count is a metric that estimates the hardware implementation cost. In this paper we report the minimum value of XOR counts of 4 × 4 MDS matrices

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- Remove *common subexpressions*, allow *cancellation*

SLP example

$$\begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix} \Rightarrow \left\{ \begin{matrix} x_0 \oplus x_1 \\ x_0 \oplus x_1 \oplus x_2 \\ x_0 \oplus x_1 \oplus x_2 \oplus x_3 \\ x_1 \oplus x_2 \oplus x_3 \end{matrix} \right\}$$

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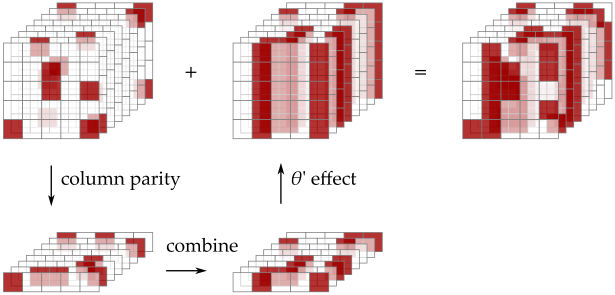
- KECCAK-*f* uses a *column parity mixer* (CPM)



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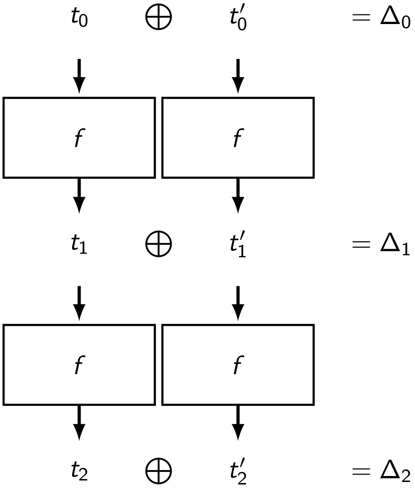
- If m odd, CPMs invertible iff $Z + \mathbf{I}$ is invertible, non-commutative, $\cong GL(n, 2)$ if $Z + \mathbf{I}$ non-singular

Differential cryptanalysis in a nutshell

- If $\Pr[\Delta_0, \ldots, \Delta_r]$ is high, cipher is not random



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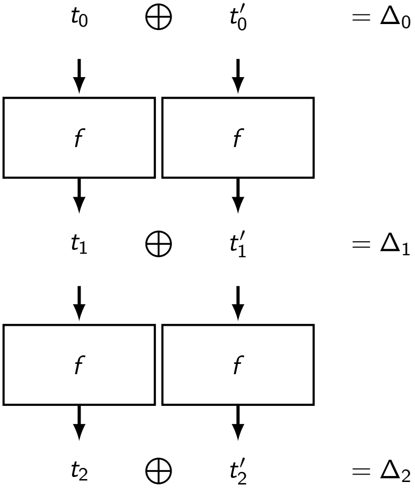

Differential cryptanalysis in a nutshell

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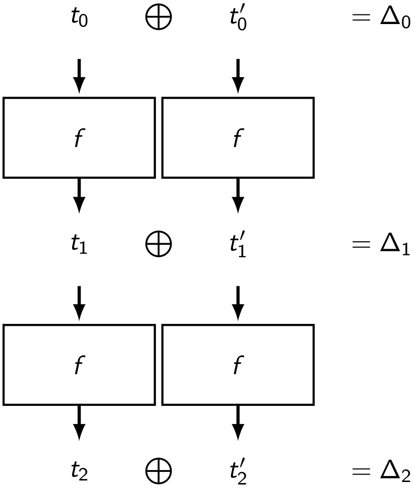
- Leads to key recovery!
- Many variants exist



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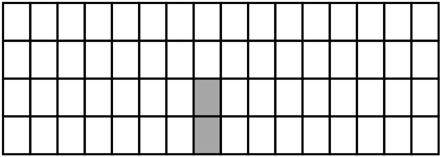

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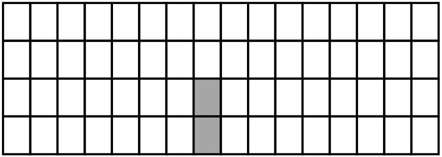

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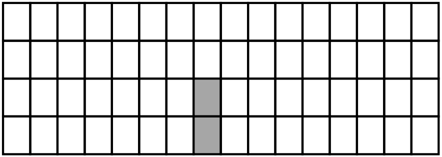

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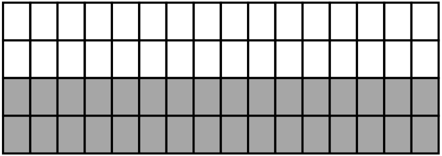

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12. Give it a name

Mixifer

- 16 rounds $(\iota \circ \rho \circ \pi \circ \theta \circ \gamma)$, $4 \times 16 \times 4 = 256$ bits permutation

Mixifer

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Thanks. . .

. . . for your attention