RUHR-UNIVERSITÄT BOCHUM

Block Ciphers and Linear Cryptanalysis

19. August 2015

FluxFingers

Ruhr University Bochum

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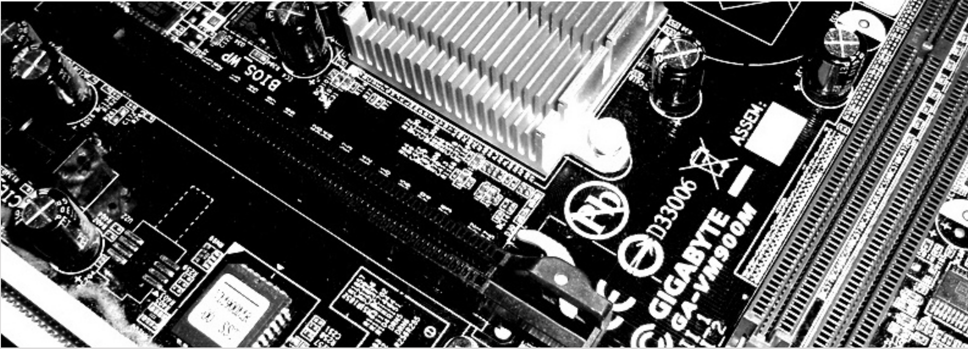

Outline

1. Block Ciphers
   - Overview
   - Design Strategy
   - Lightweight Crypto

2. Linear Cryptanalysis
   - Overview
   - Linear Cryptanalysis
   - Connection to Key Schedule

Overview Block Ciphers

Examples of Block Ciphers

- DES (Feistel Network)
- AES (Substitution Permutation Network)
- PRESENT (Lightweight Block Cipher)

DES

- proposed 1975
- developed: IBM — and NSA ☹

- 56 Bit Key
- 64 Bit Blocksize

- 16 Rounds
- 8 S-boxes: 6 $\rightarrow$ 4 Bit

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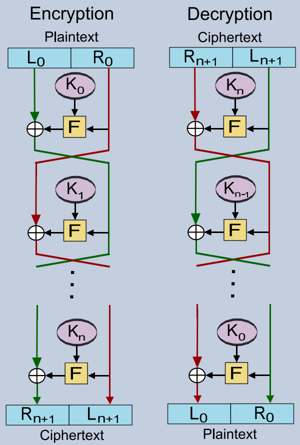
Feistel Network



AES

Substitution Permutation Networks

AES

- proposed 1998
- developed: Daemen and Rijmen

- 128, 192, 256 Bit Key
- 128 Bit Blocksize

- 10, 12, 14 Rounds
- 1 S-box: $8 \rightarrow 8$ Bits

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Substitution Permutation Networks

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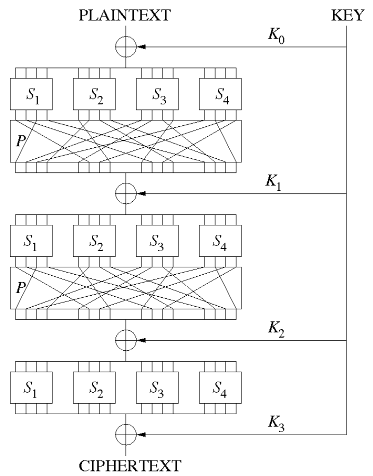
SPN



Design Strategy

The Mathematicians Approach

- based on security proofs
- reduce breaking the cipher to mathematical hard problems

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RUB

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Lightweight Crypto

Buzzword Alarm!

Ubiquitous Computing

- very constrained devices needed for Internet of Things
- need crypto schemes with very low requirements

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How efficient *(small, fast, low power, low latency)* can we be, without sacrificing security?

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- proposed 2007
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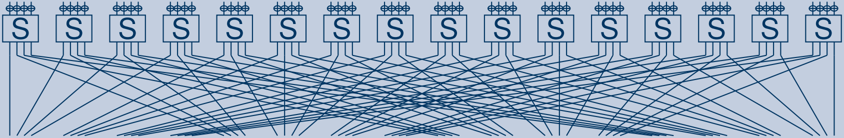
PRESENT Round



Overview Attacks

RUB

Attacks on Block Ciphers

- Differential Cryptanalysis
- *Linear Cryptanalysis*

- Integral,
- Interpolation,
- Statistical Saturation,
- Invariant Subspace,
- Algebraic,
- Related Key,
- ...

Introduction to Linear Cryptanalysis

- invented by Matsui 1993–1994
- broke DES
- together with Differential Cryptanalysis most used attack on block ciphers

Image: http://www.isce2009.ryukoku.ac.jp/eng/keynote_address.html

Basic Idea: Linear Approximations

Dot-Product, Masks and Linear Bias

- Can we linear approximate a function $F : \mathbb{F}_2^n \to \mathbb{F}_2^n$?

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Mask

Let $\alpha, \beta, x \in \mathbb{F}_2^n$ and

$$\langle \alpha, x \rangle = \langle \beta, F(x) \rangle \qquad (1)$$

- We say α is an *input mask* and β is an *output mask*.
- Eq. 1 does not hold for every input/output masks.

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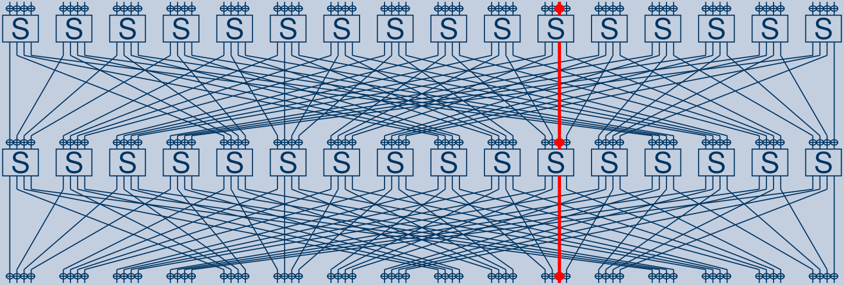
- Eq. 1 does not hold for every input/output masks.
- It is *biased*, i.e., $\Pr[\langle \alpha, x \rangle = \langle \beta, F(x) \rangle] = \frac{1}{2} - \varepsilon(\alpha, \beta)$.

Example

Masks for 2-Round reduced PRESENT

Mask $(21, 21)$ over 2 rounds



Attack

RUB

Approach

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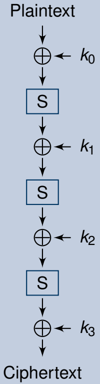
- Hypothesis of Wrong Key Randomization
- Guess last round key and compute experimental bias

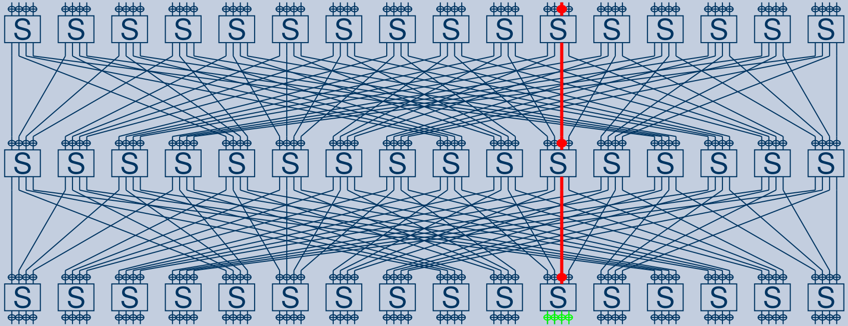
Hypothesis



Example

Linear Cryptanalysis of 3-Round reduced PRESENT

Attacking 3-Round reduced PRESENT



Distributions

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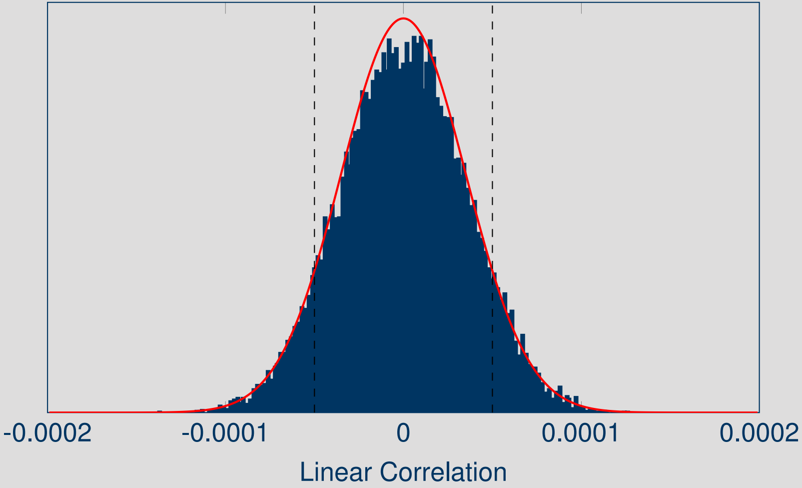
- What happens with different key-schedules?

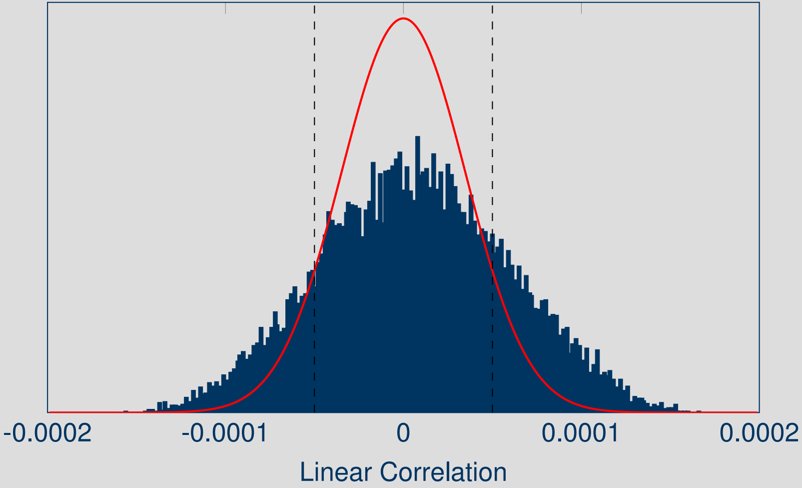
Distributions

Independent Round Keys



Distributions

Constant Round Keys



Questions?

Thank you for your attention!

Mainboard & Questionmark Images: flickr