Related-key Boomerang Attack on Block Cipher SQUARE

2010. 2.

Bonwook Koo[1], Yongjin Yeom[1], Junghwan Song[2]
[1] : Attached Inistitute of ETRI, [2] : Hanyang Univ.

Boomerang and Rectangle Attacks

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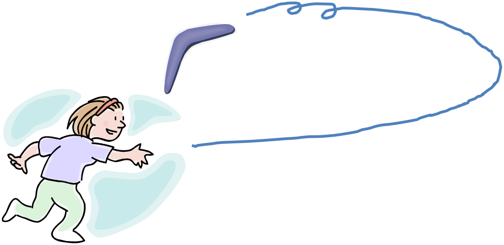

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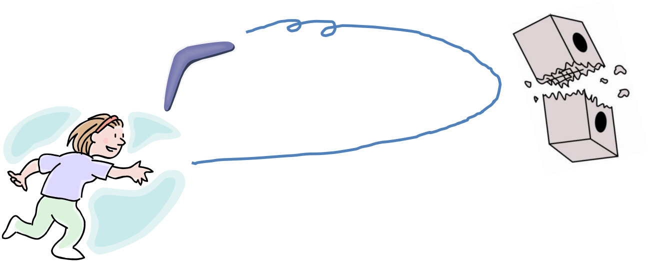

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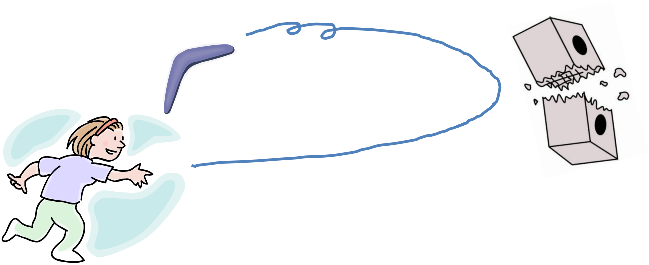
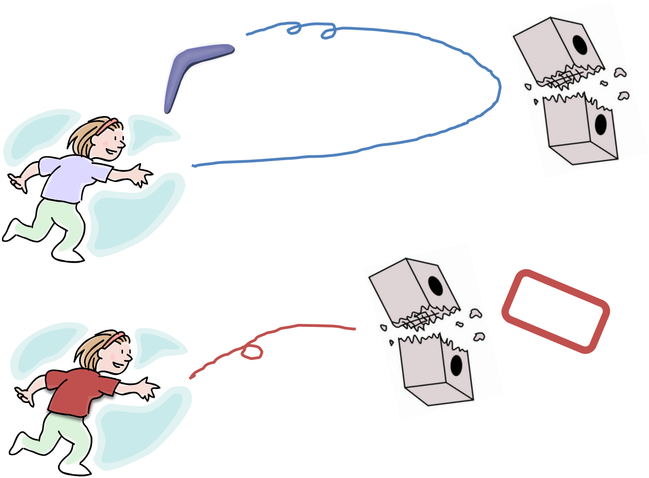


COCONUT98
Khufu
FEAL-6
CAST-256
MARS
SERPENT
....

Boomerang and Rectangle Attacks



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SERPENT
SHACAL
SHACAL-1
....

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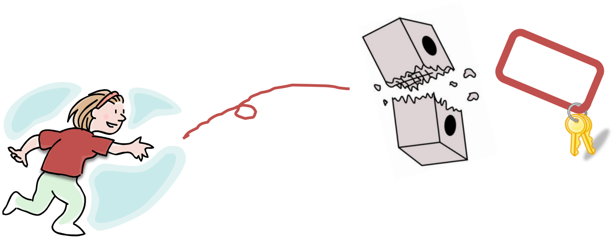

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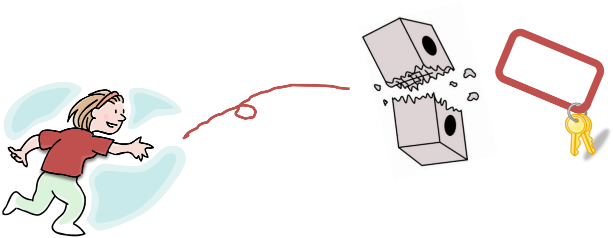

SHACAL-1
AES-192
AES-256
IDEA
KASUMI
....

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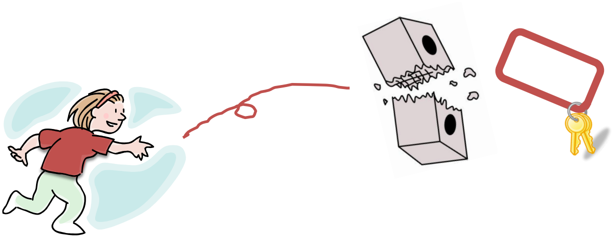

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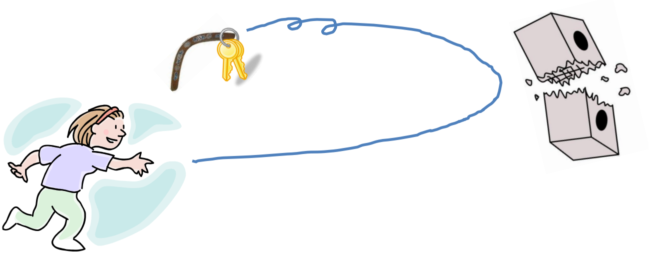

COCONUT98
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Related-Key Sandwich Attack

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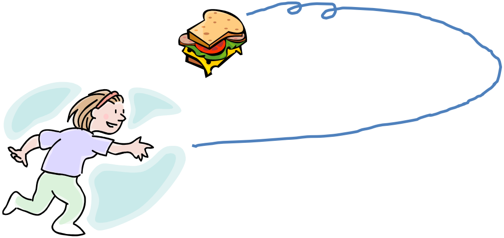

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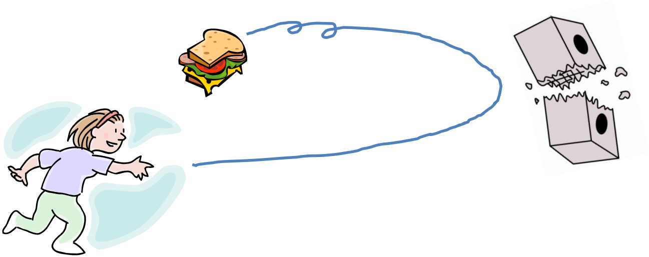
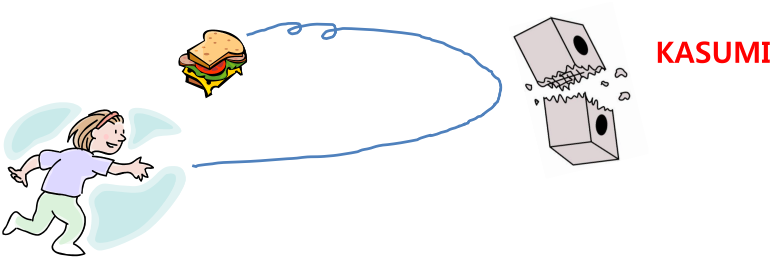


KASUMI

Related-Key Sandwich Attack



PRACTICAL !!

Our Contribution

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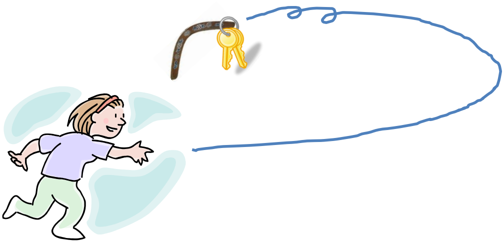
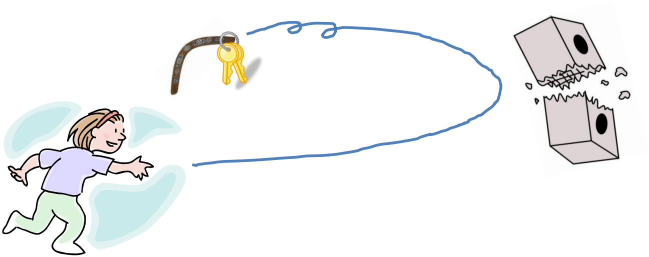


Our Contribution

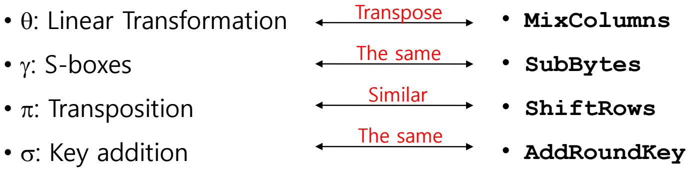


SQUARE

Block Cipher SQUARE

- A predecessor of AES-128
- 8-round SPN structure
- Round functions consist of

- What about AES-128?
  - 10-round SPN structure
  - Round functions consist of



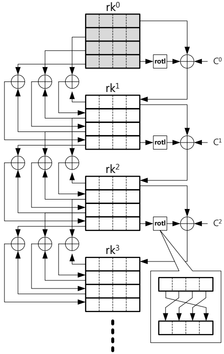
- θ: Linear Transformation ⟷ Transpose ⟷ **`MixColumns`**
- γ: S-boxes ⟷ The same ⟷ **`SubBytes`**
- π: Transposition ⟷ Similar ⟷ **`ShiftRows`**
- σ: Key addition ⟷ The same ⟷ **`AddRoundKey`**

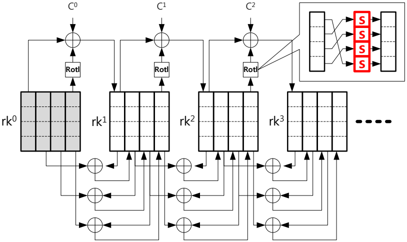
- If a round function $\rho[rk^i] = \sigma[rk^i] \circ \pi \circ \gamma \circ \theta$, then

$$\mathrm{SQUARE}[k]=\rho[rk^8]\circ\rho[rk^7]\circ\rho[rk^6]\circ\rho[rk^5]\circ\rho[rk^4]\circ\rho[rk^3]\circ\rho[rk^2]\circ\rho[rk^1]\circ\sigma[rk^i]\circ\theta^{-1}$$

Block Cipher SQUARE

- What about Key Schedule?

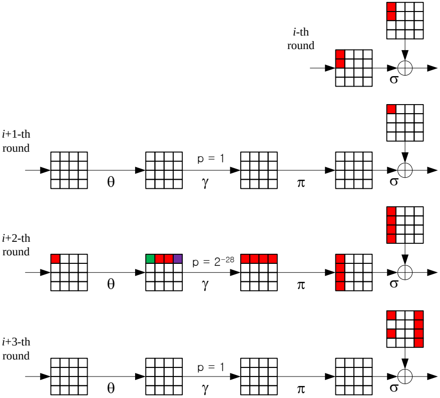




Key schedule of SQUARE ↔ **Key schedule of AES-128**

Transpose and Remove S-boxes

Local Collision of SQUARE



Byte difference values

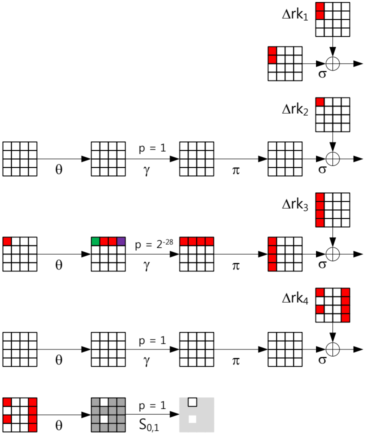
🟥 = α ∈ { 0a, 11, 17, 1d, 20, 3b, 4d, 53, 73, 76, 7c, 87, 9d, a4, a8, ae, c6, d2, d5, e0, ee, fc}

🟩 = 2 · α

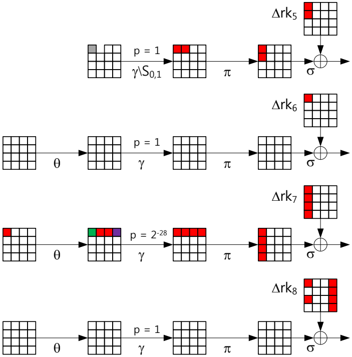
🟪 = 3 · α

□ = 0

Differential Trails for Distinguisher

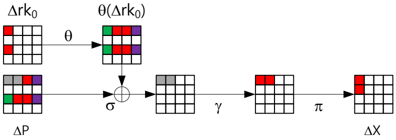


Differential Trail for E0

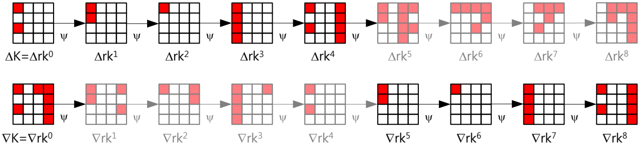


Differential Trail for E1

Differential Trails for Distinguisher

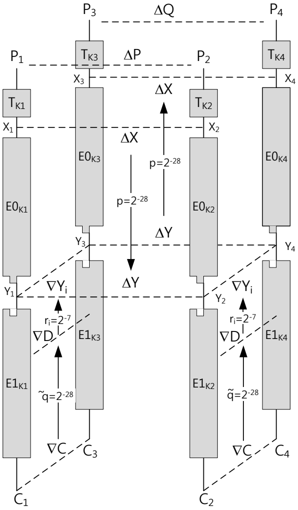


Differential Trail for the first round T



Differential Trail for Round Keys

7-Round Distinguisher of SQUARE



The locally amplified probability of distinguisher is

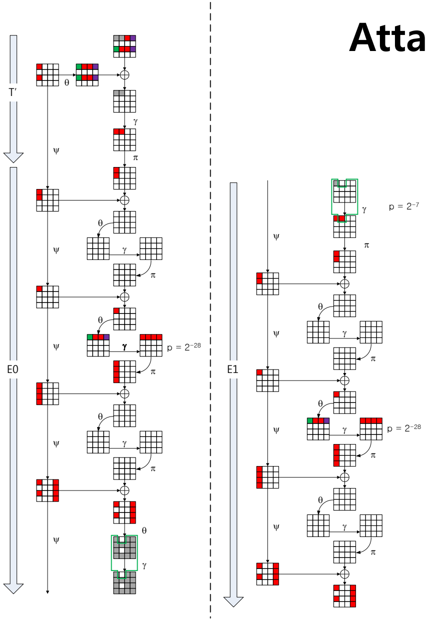
$$p^2 \times \tilde{q}^2 \times \sum_i r_i^2$$

So we have a probability of 7-round distinguisher of SQUARE as

$$2^{-28\times 2} \times 2^{-28\times 2} \times \sum_{i=0}^{126} r_i$$

$$= 2^{-112} \times (2^{-12} + 126 \times 2^{-14}) \geq 2^{-119}$$

Attack for Full SQUARE



We can recover the first two bytes of θ(K1), θ(K2), θ(K3), and θ(K4) with the following complexities.

Data Complexity of this attack is

$$2^{104+17+1+1} = 2^{123}$$

Time Complexity of this attack is

$$2^{23+16+2-5} = 2^{36}$$

The S/N of this attack is

$$\frac{2^{m+33-119-16}}{2^{m-81-14-16}} = \frac{2^{m-102}}{2^{m-111}} = \frac{2^{2}}{2^{-7}} = 2^{9}$$

Thanks to you all and my actors