ROSETTA for Single Trace Analysis

Recovery Of Secret Exponent by Triangular Trace Analysis

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1. Introduction
2. Context of the attack
3. Description of Rosetta
4. Countermeasures
5. Conclusion

Introduction

Several Side-Channel Analysis (SCA) apply to RSA modular exponentiation on embedded devices:

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To protect against SCA:

- The exponentiation operands are blinded by randomization
- The choice of the exponentiation method is important

Blinding the exponentiation

Blinding countermeasure

Blinding $s = m^d \bmod n$ makes use of two random λ-bit integers r_d and r_m:
($\lambda \geq 32$ bits)

exponent $d^\star \leftarrow d + r_d \cdot \varphi(n)$

message $m^\star \leftarrow m + r_m \cdot n$

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The exponentiation is computed modulo $2^\lambda n$:

$$s = (m + r_m \cdot n)^{d + r_d \cdot \varphi(n)} \bmod 2^\lambda n$$

followed by a final reduction modulo n.

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- Square always: $2S$
- Atomic multiply-always: $1.5M$

Atomic multiply-always

The fastest regular exponentiation is:

Algorithm 1 Atomic multiply-always exponentiation

Input: $x, n \in \mathbb{N}$, $d = (d_{v-1}d_{v-2}\ldots d_0)_2$
Output: $x^d \bmod n$

1: $R_0 \leftarrow 1$
2: $R_1 \leftarrow x$
3: $i \leftarrow v - 1$
4: $k \leftarrow 0$
5: **while** $i \geq 0$ **do**
6: $\quad R_0 \leftarrow R_0 \times R_k \bmod n$
7: $\quad k \leftarrow k \oplus d_i$ [$\oplus$ stands for bitwise X-or]
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Considered secure exponentiation

We focus on the atomic multiply-always exponentiation protected by exponent and message blindings.

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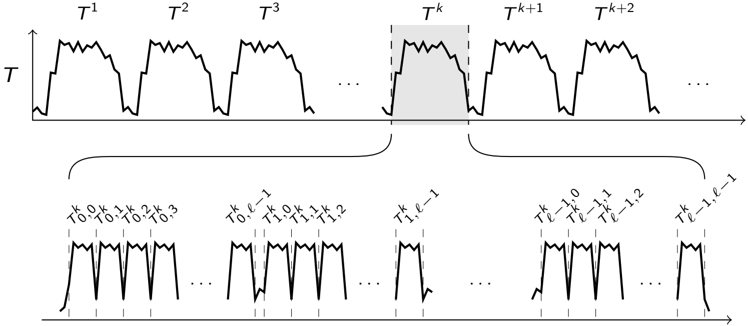

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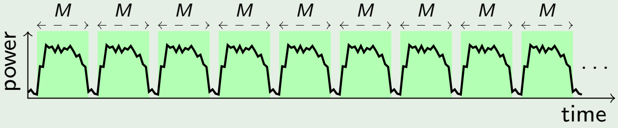

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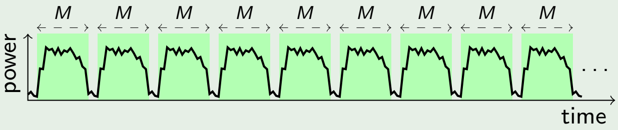

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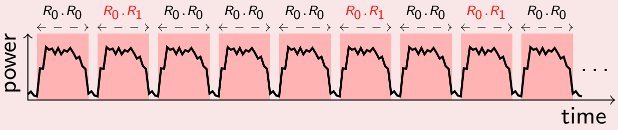

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- Many traces $\rightarrow$ the attack is prevented by exponent blinding
- Authors suggested to apply this distinguisher horizontally on the set of trace segments $\{T_{i,i}^{k}\}_{0 \leq i < \ell}$ (they did not experiment this idea)

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  - the LIM is a square if it is not

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LIM(x, y) in base $b = 2^t$ by classical schoolbook method:

$$x \times y = \sum_{i=0}^{\ell-1} \sum_{j=0}^{\ell-1} x_i y_j b^{i+j}$$

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Example of all single-precision operations with $\ell = 4$:

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Advantage: as much as $(\ell^2 - \ell)/2$ trace segments

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Collision-Correlation

Between two series of trace segments (with same (i,j) ordering):

$\Theta_0 = \{ T_{i,j} \text{ s.t. } 0 \leq i < j \leq \ell - 1 \}$ (upper right triangle)

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Two distinguishers

Mean Euclidean distance

Between pairs of trace segments $T_{i,j}$ and $T_{j,i}$:

$$d = \sqrt{\frac{2}{\ell^2 - \ell} \sum_{0 \leq i < j < \ell} (T_{i,j} - T_{j,i})^2}$$

Collision-Correlation

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$$\hat{\rho}_{\Theta_0,\Theta_1}(t) = \frac{\mathrm{Cov}(\Theta_0(t), \Theta_1(t))}{\sigma_{\Theta_0(t)}\sigma_{\Theta_1(t)}}$$

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- *Big Mac CoCo* (variant with Collision-Correlation)
- *Rosetta ED* (Euclidean distance)
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Success rate with a null noise ($\sigma = 0$)

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Technique	512 bits	768 bits	1024 bits	1536 bits	2048 bits
Big Mac	0.986	0.990	0.993	0.994	0.995
SAC 2008	0.533	0.618	0.734	0.858	0.897
Big Mac CoCo	0.999	1.00	1.00	1.00	1.00
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- All techniques give excellent results except *SAC 2008*
  (The number of trace segments is too small, except for large moduli)

Success rate with a moderate noise ($\sigma = 2$)

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Technique	512 bits	768 bits	1024 bits	1536 bits	2048 bits
Big Mac	0.767	0.775	0.807	0.816	0.818
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Big Mac CoCo	0.981	0.998	0.999	1.00	1.00
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- As for *SAC 2008*, original *Big Mac* does not give good results
- The three new techniques are quite efficient

Success rate with a strong noise ($\sigma = 7$)

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Technique	512 bits	768 bits	1024 bits	1536 bits	2048 bits
Big Mac	0.557	0.577	0.621	0.614	0.632
SAC 2008	0.551	0.577	0.623	0.662	0.702
Big Mac CoCo	0.737	0.855	0.909	0.963	0.981
Rosetta ED	0.711	0.821	0.878	0.953	0.992
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- All three new attacks still give good success rates at strong noise level
- *Big Mac CoCo* (up to 1024 bits) and *Rosetta Coco* (above 1024 bits) are the most efficient ones

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3. Description of Rosetta
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Rosetta applies even if the message blinding is refreshed at each LIM

(as well as single trace *SAC 2008*, but it is less efficient)

And so what. . . ?

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LIM leakage mitigation

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- Square always: $1.5M \rightarrow 2S$ per exponent bit

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Possible future works

- Implement *Rosetta* on a real device
- Design other countermeasures which apply to the atomic exponentiation

The end

Thank you for your attention!

Questions?

ROSETTA for Single Trace Analysis

Recovery Of Secret Exponent by Triangular Trace Analysis

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