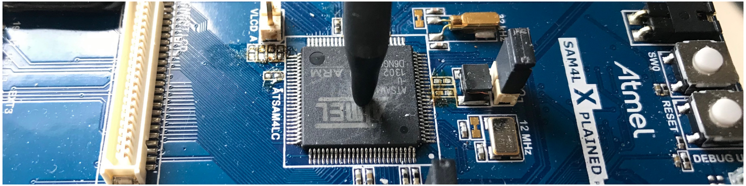

Secure and Efficient Masking of Lightweight Ciphers in Software and Hardware

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LWC NIST Workshop 2020

European Research Council
Established by the European Commission

GROUPE CRYPTO

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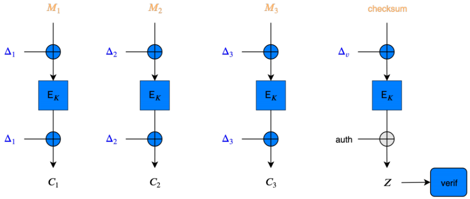
Content

Side-Channel Security at the Mode Level

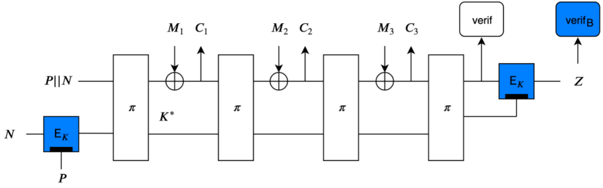
Integrity and confidentiality at the mode level with side-channel:

- Requires different protection levels for parts of an AEAD [Bel+20b].
- Some need DPA (many inputs attack) protection everywhere.
- Some allow a mix of DPA / SPA (few inputs) security and unbounded leakage.

Examples for integrity (qualitatively):



OCB-Pyjamask



Spook

How to Reach DPA Security ?

DPA security is required in many LWC candidates:

- Reach it by reducing DPA security to averaged-SPA security:
  - Isap and DryGascon
- Reach it through the use of masking:
  - Ascon, Spook, OCB-Pyjamask, ...

  Other implementation-level DPA countermeasures: less studied, part of this talk still applies.

In this talk we focus masking since it is well suited for many schemes:

1. How to implement safely and efficiently in software and hardware ?
2. How to compare candidates w.r.t. masking & SCA protections ?

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Masking: general principles

Idea: share variables and replace logic gates with “gadgets”.

$$x = x_1 \oplus x_2 \oplus \cdots \oplus x_d$$

$\perp\!\!\!\perp$ t probes

Masking enables “t-probing secure” implementations [ISW03].

Cost of secure gadgets:

- linear: $\mathcal{O}(d)$ (e.g. XOR gate)
- non-linear: $\mathcal{O}(d^2)$ (e.g. AND gate)
- refresh: $\mathcal{O}(d \log d)$ (sometimes required for secure *composition*)

Robust probing model for physical “imperfections” (i.e. glitches, transitions)

A Brief Timeline of Software Masking

Over the last decade:

CHES10 [RP10]
: Implementation of [ISW03] on MCU.

FSE13 [Cor+13]
: Attack on [RP10]: composition issue due to weak refreshing.

Eurocrypt17 [GR17]
: Efficient bitslice masking (proven secure in [CS20]).

Asiacrypt18 [BGR18]
: *Tight private circuits (TPC)*: improved efficiency (probing secure).

Eurocrypt20 [Bel+20a]
: *Tornado*: TPC with register-probing security & automated code generation.

A Brief Timeline of Hardware Masking

Some *glitch-robust probing* secure schemes from the last decade:

TI [NRS11]

Non-completeness + *uniformity* $\Longrightarrow$ first-order glitch-robust probing secure.

CMS [Rep+15] / DOM [GMK16] / UMA [GM18]

Higher-order glitch-robust optimized AND gadgets.

[Moo+19]

Probing attacks against CMS/DOM/UMA/...

HPC [Cas+20]

Provably secure AND gadgets & *fullVerif* composition verification tool.

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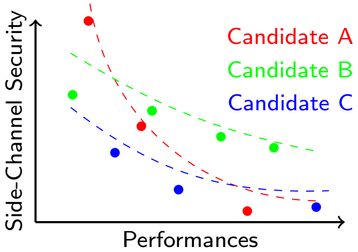
How to Compare Candidates ?



It should go in 3 steps:

1. Implement
2. Evaluate performance
3. Evaluate side-channel security

Challenges:

- Evaluate algorithms and not the masking schemes
  - Many optimized implementations for each candidate
- Accurate security evaluation

Given limited expert bandwidth

Side-Channel Security Evaluation

	Automated	Quantitative Worst-case
Probing security verification ▶ Algorithmic security order reductions	✓	✗
Robust probing security verification ▶ Alg. and some physical order reductions	✓	✗
Test Vector Leakage Assesment (TVLA) ▶ Detects order ▶ Based on measurements ▶ Limited to low order, low dimensionality verification ▶ Risk of false negative	✓	✗
Best attack ▶ Can spot multiple kinds of weaknesses ▶ Highly time consuming and skills required (e.g. Spook CTF)	✗	✓

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Proxy 1: Count masked AND gates

Starting point:

Masked AND gates make most of the cost of (high-order) implementations.

Software Implementation:

- Clock cycles
- Required randomness
- ...

Hardware Implementation:

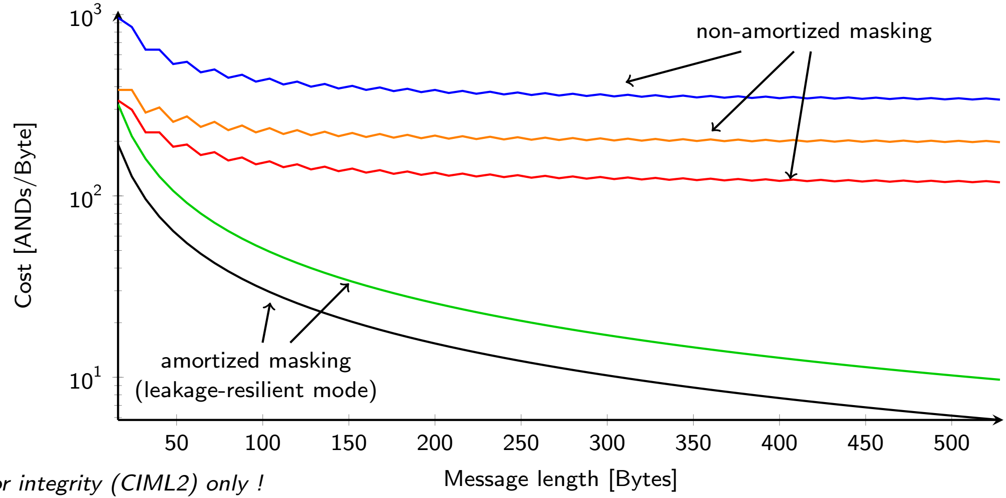
- Latency
- Required randomness
- Area
- ...

Limitations:

- Ignores the rest of the computation (not free!)
- Structure of the cipher also has an impact (e.g. depth)

Integrate counts from [Mey20] with mode-level requirements.

Proxy 1: AND gates per encrypte byte



For integrity (CIML2) only !

Proxy 2: Tornado

Tornado:

- Automated masked C code generation.
- +/-30% overhead w.r.t. hand-optimized.
- Ensure register-probing security.
- TPC+ masking scheme.

Not a magic tool:

- worst-case security (e.g. transitions)?
- optimal performance?
- other masking schemes?

$\Rightarrow$ Tornado implementations hardly comparable to hand-optimized ones.

Suggestion: *Compare Tornado implementations of candidates*

- More realistic than counting masked AND gates
- Easy/Fast implementation: high-level description of primitive
  - 11 candidate's primitives already done by the authors of Tornado

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Conclusion

Approaches to compare SCA robustness of candidates:

- Best implementations and best attacks:
  - **Both implementing and evaluating require expertise and time.**
  - **May evaluate the implementer's skills more than the candidates.**
  - Useful byproduct: good implementation of the winner(s) ?
- Proxies:
  - Counting masked AND gates,
  - Tornado: automated software masking,
  - Others ?

Our opinion

- Proxies are more relevant than best implementation & attacks, esp. given resource constraints.
- The proposed proxies already have a good comparative value.

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