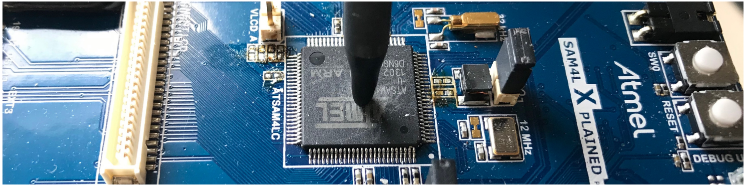

Systematic Study of Decryption and Re-Encryption Leakage: the Case of Kyber

Melissa Azouaoui, Olivier Bronchain, Clément Hoffmann,
Yulia Kuzovkova, Tobias Schneider, François-Xavier Standaert

12 April 2022

UCLouvain NXP

Content

Why Post-Quantum Cryptography (PQC) & SCA ?

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[1] https://www.ssi.gouv.fr/publication/anssi-views-on-the-post-quantum-cryptography-transition/

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- PQC is expensive on Cortex-M4:
  - ≈ 800 `kCycles` for unprotected Saber.
  - $\approx 13,000$ `kCycles` for 4-share Saber.

---

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Goal:

How:

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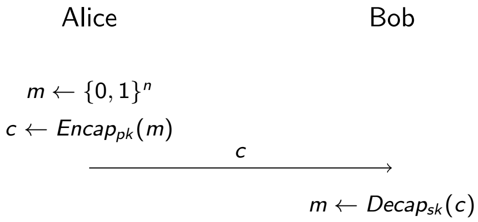

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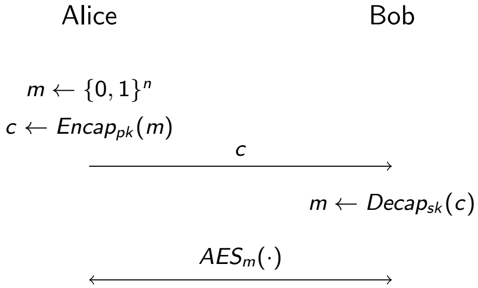

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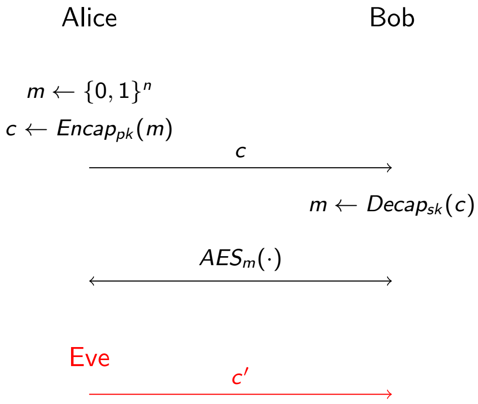

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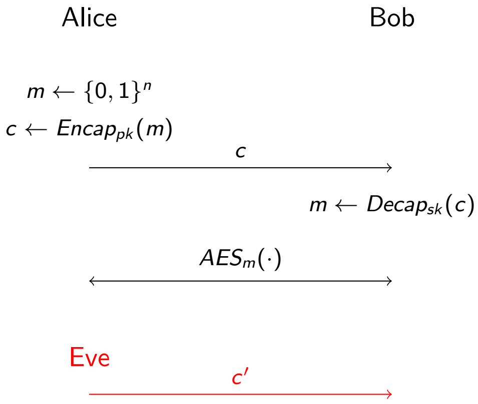

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With a CPA PKE:

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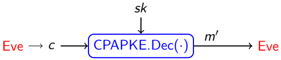

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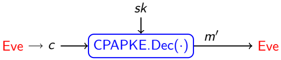

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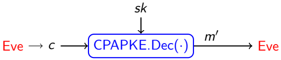

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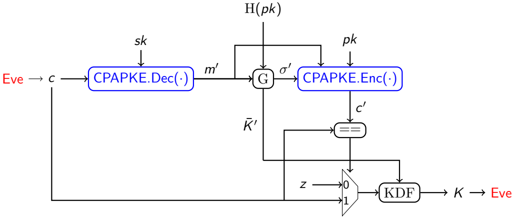

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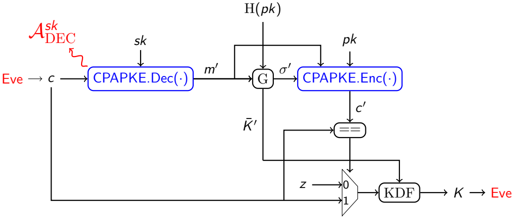

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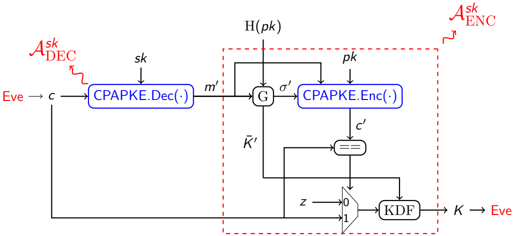

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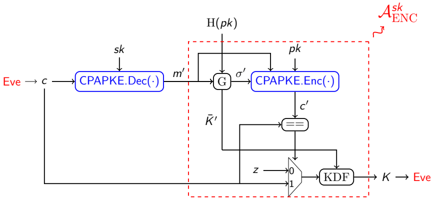

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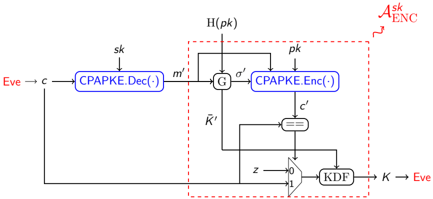

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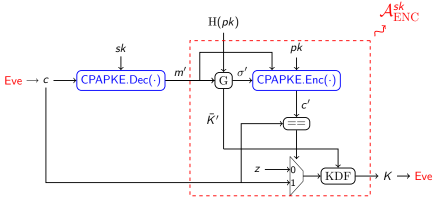

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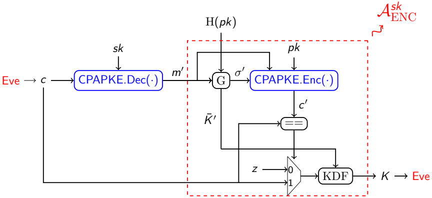

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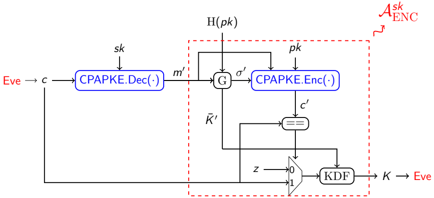

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→ CCA attack on CPA-secure PKE thanks to leakage.

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Pro & cons:

+ Easy and fast way to explore the design space.
- Model / approximatereal attacks.

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- Model SCA attacks with information theoretic metrics.
- Model cost with paper & pencil approximations.
- Compare the impact of attacks on security of designs.

Pro & cons:

+ Easy and fast way to explore the design space.
- Model / approximatereal attacks.

→ We provide trends and not exact numbers.

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Take Home Message

How to model attacks ?

Attack complexity

$$N \approx —$$

A few parameters:

N Data complexity of the attack.

2

How to model attacks ?

Attack complexity

$$N \approx \frac{}{\lambda}$$

Physi. param.

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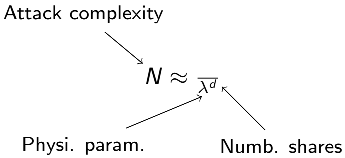
- N Data complexity of the attack.
- λ Platform dependent parameter (inverse of noise).

---

[2]

How to model attacks ?



Attack complexity

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Numb. shares

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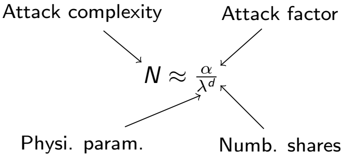

Attack complexity

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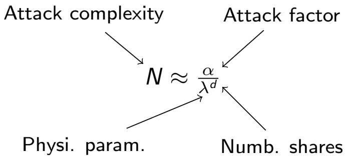

A few parameters:

N	Data complexity of the attack.
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d	Number of shares used in the implementations.
α	Constant factor related to the attack methodology.

→ For each attacks, we will evaluate α[2].

---

[2] See full paper for more detailed attack modeling.

Modeling $\mathcal{A}^{sk}_{\mathrm{ENC}}$ and $\mathcal{A}^{sk}_{\mathrm{DEC}}$

Attacks against CPAPKE.Dec ($\mathcal{A}^{sk}_{\mathrm{DEC}}$)

Attacks against CPAPKE.Enc ($\mathcal{A}^{sk}_{\mathrm{ENC}}$)

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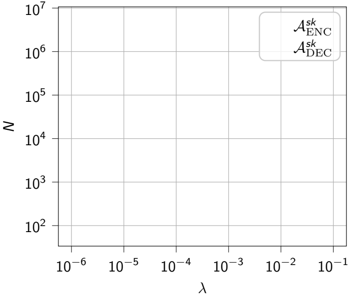
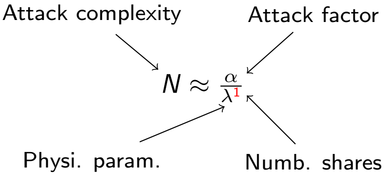
Comparing attacks for unprotected implem. ($d = 1$)

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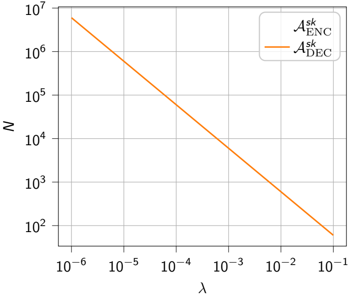

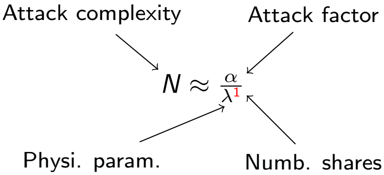

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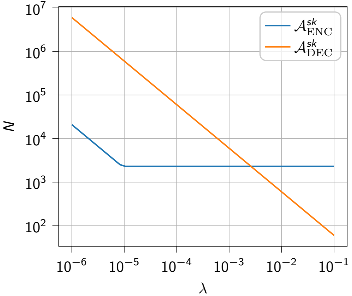

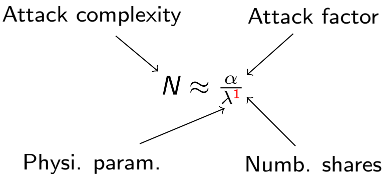

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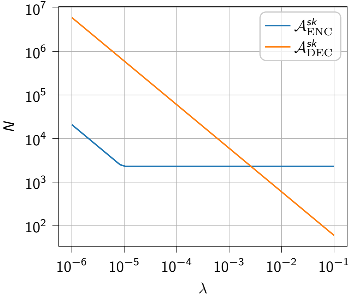

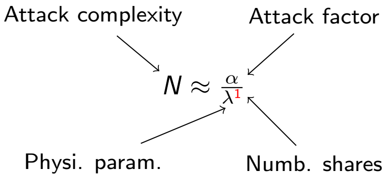
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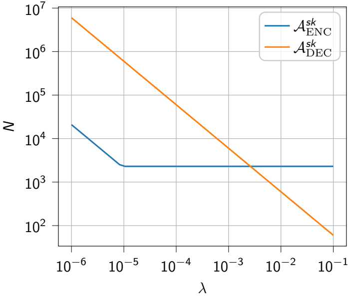

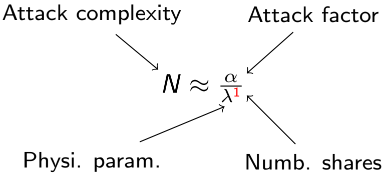

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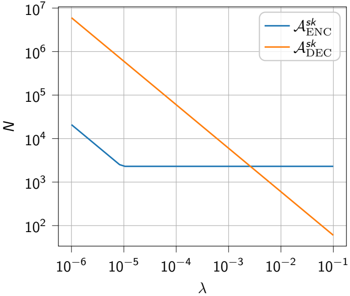

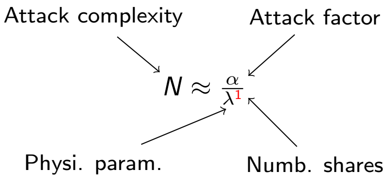
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- $\mathcal{A}^{sk}_{\mathrm{ENC}}$ more efficient than $\mathcal{A}^{sk}_{\mathrm{DEC}}$ by a factor ≈ 100.

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Modeling CPAPKE.Dec and CPAPKE.Enc costs (1)

Cost of CPAPKE.Dec

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Modeling CPAPKE.Dec and CPAPKE.Enc costs (2)

$$\frac{\beta_{Enc}}{\beta_{Dec}}$$

---

[3] Bos et al. “Masking Kyber: First- and Higher-Order Implementations”. In: *TCHES 2021* ().

[4] Bronchain and Cassiers. “Bitslicing Arithmetic/Boolean Masking Conversions for Fun and Profit with Application to Lattice-Based KEMs”. In: *eprint 2022/158* ().

Modeling CPAPKE.Dec and CPAPKE.Enc costs (2)

Software implementation of Kyber768 from[3]:

Operation	**Number of shares**					
	2	*3*	*4*	*5*	*6*	*7*
`crypto_kem_dec`	3 178	57 141	97 294	174 220	258 437	350 529
`indcpa_dec`	200	4 203	7 047	13 542	20 323	27 230
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`comparison`	693	32 293	54 725	102 922	156 075	210 518

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Caution: Numbers can change between implementations:

- $\beta_{Enc}/\beta_{Dec} \approx 40$ with numbers from[4]

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Take Home Message

What is the impact of attacks on costs ?

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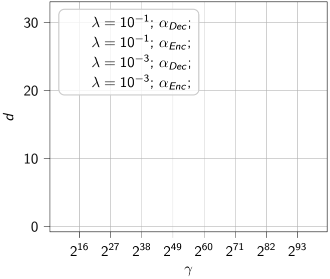
We use the ratio:

$$\frac{\zeta_{Enc}}{\zeta_{Dec}} = \frac{\beta_{Enc} \cdot d_{Enc}^2}{\beta_{Enc} \cdot d_{Enc}^2}$$

How many of shares to secure Enc & Dec:



More shares for:

$$d \geq \frac{\log(\alpha) - \log(\gamma)}{\log(\lambda)}$$

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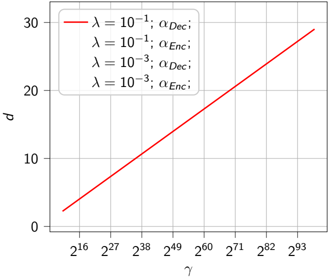

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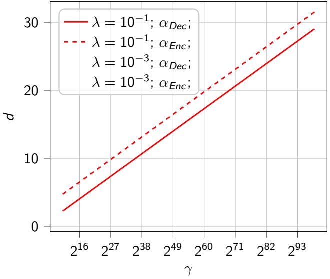

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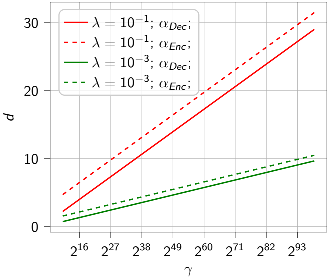

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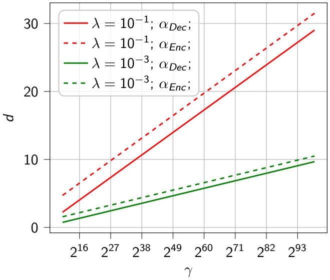

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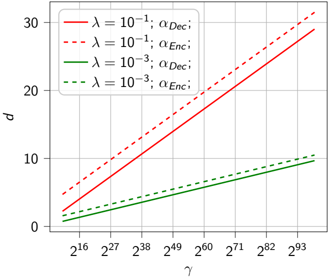

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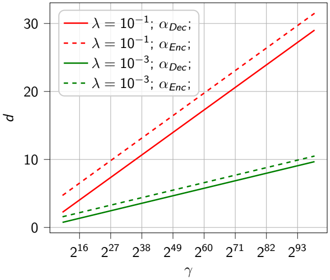

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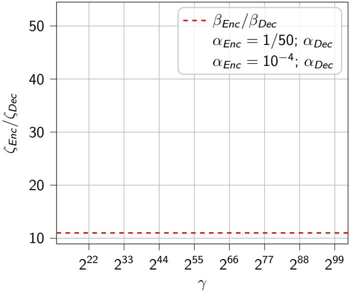

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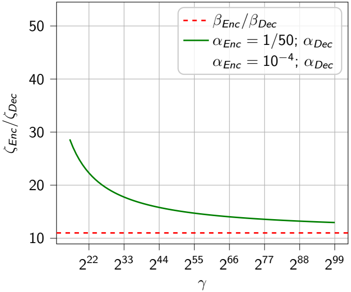

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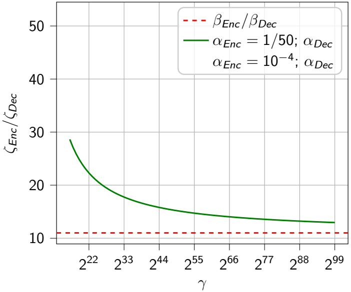

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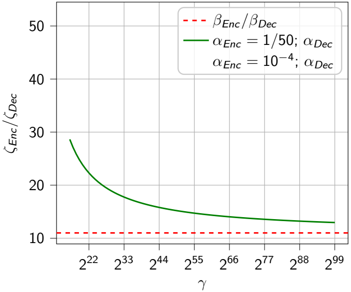

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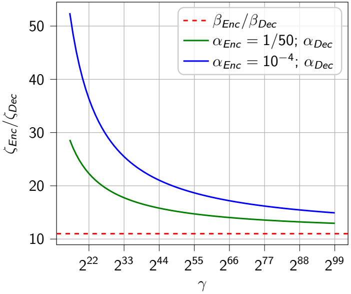

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→ Same holds for more efficient $\mathcal{A}^{sk}_{\mathrm{ENC}}$.

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Take home message

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Thanks !

@BronchainO