The Design Space of Lightweight Cryptography

Nicky Mouha

[1]ESAT/COSIC, KU Leuven and iMinds, Belgium
[2]Project-team SECRET, Inria, France

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Lightweight Cryptography

What is Lightweight Cryptography?

- “Lightweight” vs “conventional” crypto
- Should not mean weak crypto

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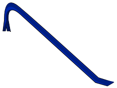
Main Focus: Symmetric-Key Crypto

- Maybe insights for other domains?

Three Topics

How to Measure Security

- Attack models
- Key, block and tag sizes



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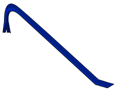
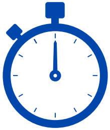


How to Measure Efficiency

- "Theoretical" vs "actual" efficiency
- Scaling law for symmetric-key crypto



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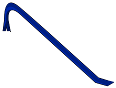

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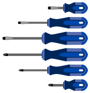
Picking the Right Tool for the Job



- Analyzing lightweight requirements
- Often wrong choices at protocol level!

How to Measure Security: Motivation

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Statements: Often Heard, Seldom Refuted

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Cell Phone Communication

- GSM
- A5/1 algorithm
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Nohl et al.

- Large precomputation (dozens of GPU years)
- Table of 1.6 TB
- Break in ≈ 5 s on commodity hardware
- Data complexity: one 114-bit GSM burst

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Hypothesis Test

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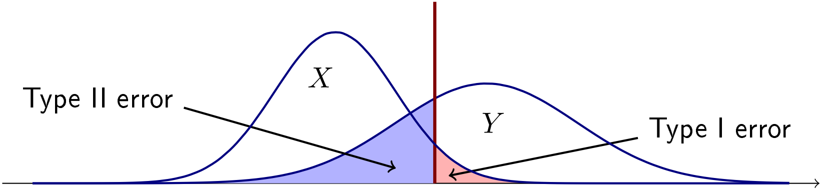

Information-Theoretic Framework

- Deterministic algorithms $\rightarrow$ statistical objects
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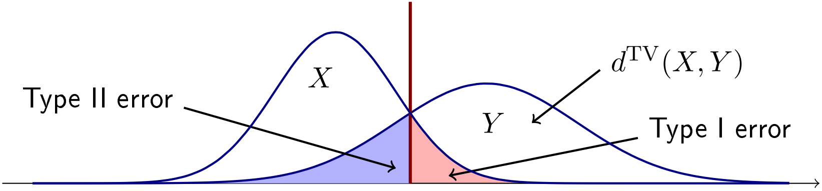
Hypothesis Test $\rightarrow$ Total Variation Distance

- Distinguish between "real world" and "ideal world"



Information-Theoretic Framework

Example (Asiacrypt '14)

Let $\mathbf{D}$ be PA1-adversary for APE, $\mathbf{E}$ be plaintext extractor

$$\mathsf{PA1}^{\mathbf{E}}_{\mathsf{APE}}(\mathbf{D}) \leq \frac{\sigma^2}{2^{r+c}} + \frac{2\sigma(\sigma+1)}{2^c}$$

(σ: total # blocks of all queries, r: rate, c: capacity)

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Interpretation

- Upper bound on success probability of any attack
- "Secure up to about $\sigma = 2^{c/2}$ blocks"

Information-Theoretic Framework

Types of Queries

- Data complexity (D): access to device under attack
  (under *any* key?)
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Do Not Use:

- Short keys: see earlier (GSM)
- Short blocks: degrades security of mode of operation
- Short tags: tag guessing (works regardless of rekeying!)

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Scaling Law

- More refined metric for symmetric-key crypto
- Better understanding of lightweight

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Remarks

- Not intuitive: $b \to b$ bits: $(2^b)^{2^b} = 2^{b2^b}$ functions
- Not rigorous: based on design choices and attacks
- How to count "operations"?

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Next Slides: Scaling Law Examples

Scaling Law: Fixed Word Size

PHOTON: 4-bit Words

- 100/144/196/256-bit permutation: 12 rounds
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Skein: 64-bit Words

- 256/512-bit block/key size: 72 rounds
- 1024-bit block/key size: 80 rounds
- Overdesign? Best (non-biclique) attack is on 36 rounds (Yu et al., SAC '13)

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Keccak

- 800-bit permutation: 22 rounds (32-bit words)
- 1600-bit permutation: 24 rounds (64-bit words)
- Note: zero-sum distinguisher for full-round 1600-bit permutation (Boura et al., Duan-Lai)

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- 272-bit Spongent: 5x lower throughput than 256-bit PHOTON (Bogdanov et al., IEEE Trans. Comp. 2013)

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- Hardware area or code size, RAM, ROM
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Goal of Lightweight Crypto

- When standard solutions fail to satisfy constraints
- Not less secure, but using new academic insights
- Most widely usable algorithm that satisfies all constraints

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Questions?