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Error Correction for Physical Unclonable Functions Using Generalized Concatenated Codes

Sven Müelich*, Sven Puchinger*, Martin Bossert*, Matthias Hiller◇, Georg Sigl◇

*Institute of Communications Engineering, Ulm University, Germany
◇Institute for Security in Information Technology, TU Munich, Germany

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Outline

Motivation

Challenges when implementing a cryptosystem:

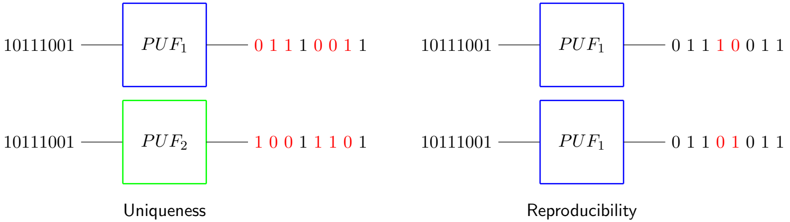
- Secure key generation
  - Random, unique and unpredictable keys
  - Satisfying these properties is hard to achieve
- Secure key storage
  - Key bits in a non-volatile memory
  - Adversaries can gain physical access to (protected) memories

Physical Unclonable Functions (PUFs) can be used to realize secure key generation and secure key storage

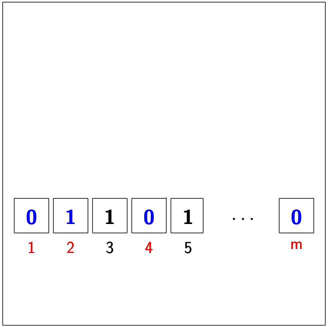
Physical Unclonable Functions (PUFs)

What is a PUF?

- Physical entity with challenge-response behavior
- Properties:
  - Uniqueness
  - Reproducibility



Physical Unclonable Functions (PUFs)



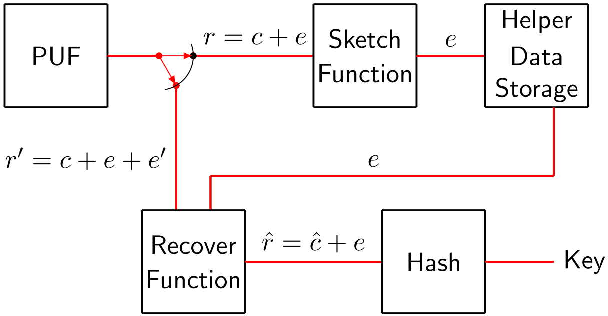
Example: SRAM PUFs

- device with memory cells
- random initialization when powering on
- randomness static over lifetime
- Challenge: Subset of memory cells
- Response: Values in selected memory cells

Physical Unclonable Functions (PUFs)

Why coding theory?

- Responses are not perfectly reproducible and hence cannot be used as key directly



Example Code construction

Challenge: Find good codes for Secure Sketches

Constraints:

- Time and area consumption
- Binary codes
- Dimension $\geq$ key length
- Codelength as small as possible

Example Code construction

Existing scheme given in [Maes2012][1]:

- Binary Symmetric Channel with $p = 0.14$
- Generate 128 bit key with block error probability $\mathrm{P}_{\mathrm{err}} = 10^{-9}$
- Concatenation of $(318, 174, 35)$ BCH code and $(7, 1, 7)$ code

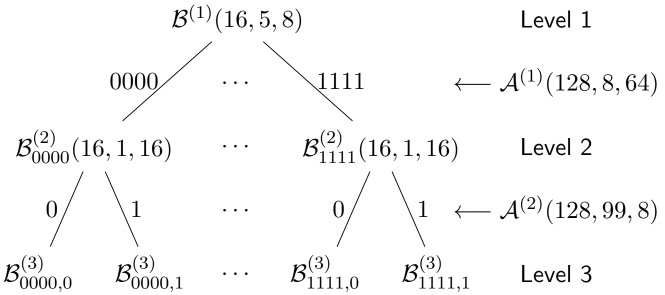
What is our goal?

- Generate 128 bit key with block error probability $\mathrm{P}_{\mathrm{err}} < 10^{-9}$
- Improve existing scheme in
  - Codelength
  - Block error probability
  - Simple implementation

[1] R. Maes, A. Herrewege, I. Verbauwhede, "PUFKY: A Fully Functional PUF-Based Cryptographic Key Generator", CHES, 2012

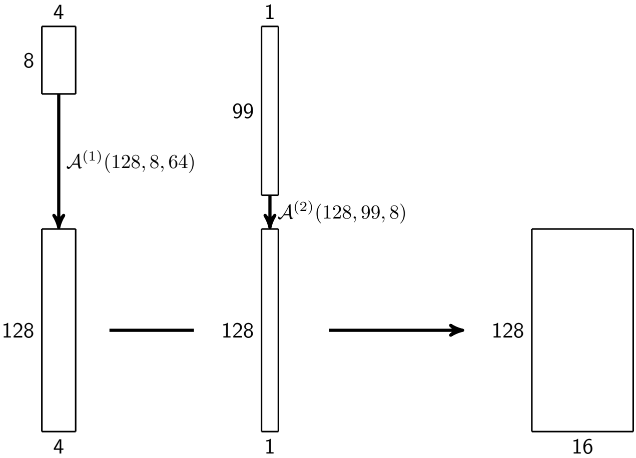
Reed-Muller Example Code Construction

Partitioning:



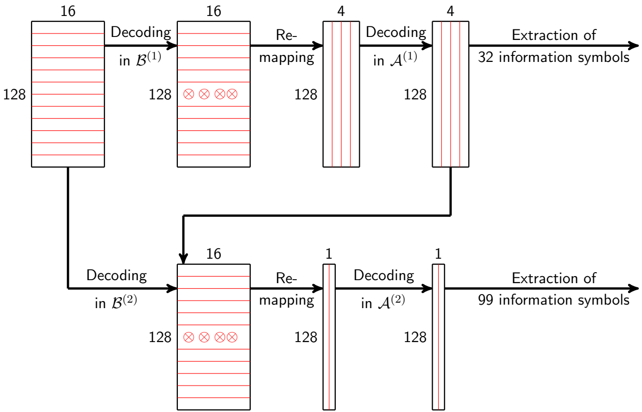
Reed-Muller Example Code Construction

Encoding:



Reed-Muller Example Code Construction

Decoding:



Reed-Muller Example Code Construction

Used decoding methods:

- Generalized Concatenated Codes (GC Codes)
- RM Error Erasure Decoding
- Generalized Minimum Distance (GMD) Decoding

Conclusion

How good is our code construction?

Code	P_{err}	Length	Largest Field
[Maes2012]	$\approx 10^{-9}$	2226	$\mathbb{F}_{2^8}$ (BCH)
New	$\approx 5.37 \cdot 10^{-10}$	2048	$\mathbb{F}_2$

Thank you for your attention.