Non-Malleable Codes for Partial Functions with Manipulation Detection

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Outline

- Introduction to non-malleable codes
- Adversarial model, motivation
- Results, constructions
- Intuition

Encoding schemes

An *encoding scheme* is a pair of algorithms $(\mathsf{Enc}, \mathsf{Dec})$, satisfying *correctness*:

$$\text{for any message } s,\ \mathsf{Dec}(\mathsf{Enc}(s)) = s$$

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Error-correction codes: guarantee correctness in the presence of faults

Non-malleable codes [DPW10,18]

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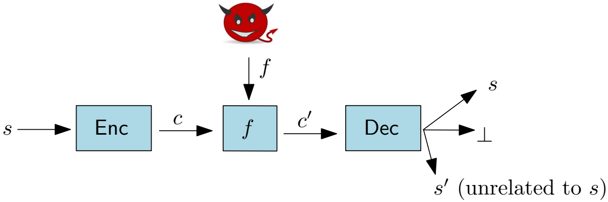
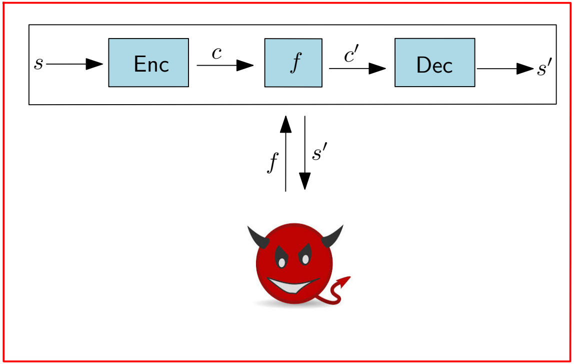


Non-malleability [DPW10,18]

Real



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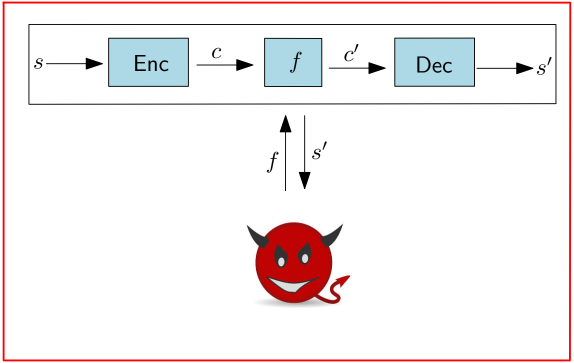
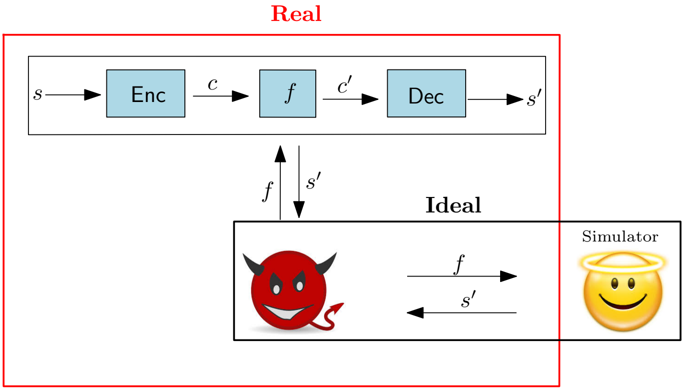


Simulator

Non-malleability [DPW10,18]



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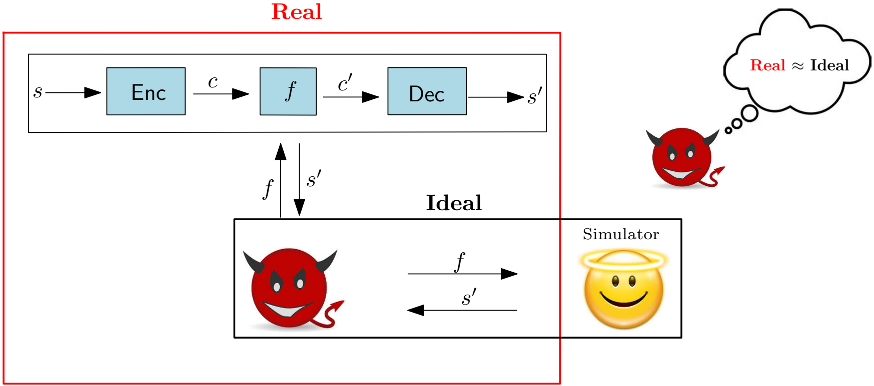
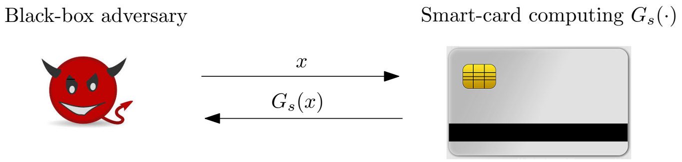


Application of NMC



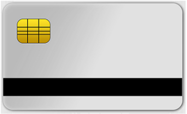
Application of NMC

Black-box adversary

Smart-card computing $G_s(\cdot)$

x →

← $G_s(x)$

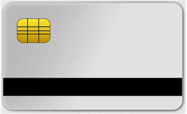


Tampering adversary

Smart-card computing $G_s(\cdot)$

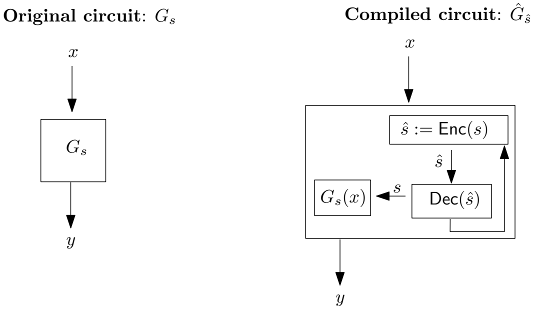
f, x →

← $G_{f(s)}(x)$



Application of NMC

Assuming (Enc, Dec) is a non-malleable code w.r.t. $\mathcal{F}$.



Non-malleability: for any $f \in \mathcal{F}$, $f(\hat{s})$ is simulatable and independent of s

Admissible function classes

Non-malleability is impossible against arbitrary tampering function classes

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For instance, consider a class containing the function $f(c) := \mathsf{Enc}(\mathsf{Dec}(c) + 1)$

Admissible function classes

Proposed function classes: Split-state functions [ADL14, DKO13, ADKO15, LL12, AAG+16, DPW10, KLT16], bit-wise tampering and permutations [DPW10, AGM+15a, AGM+15b], bounded-size function classes [FMVW14], bounded depth/fan-in circuits [BDKM16], space-bounded tampering [FHMV17,BDKM18], block-wise tampering [CKM11,CGM+15], AC0 circuits, bounded-depth decision trees and streaming adversaries [BDKM18], small-depth circuits [BDGMT18], and others.

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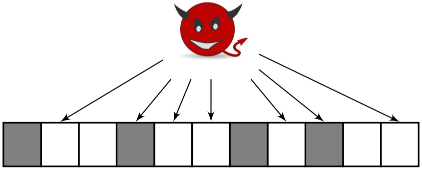
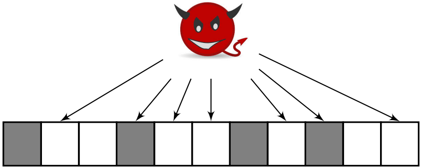
This work: Partial functions

NMC for Partial Functions



We allow *read/write* access to arbitrary subsets of codeword locations, with bounded cardinality.

Basic definitions



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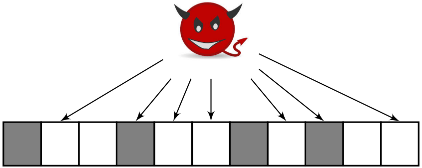

- **Information rate**: the ratio of message to codeword, length, as the message length goes to infinity.

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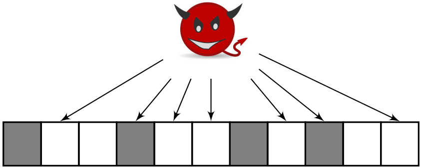

- **Information rate**: the ratio of message to codeword, length, as the message length goes to infinity.
- **Access rate**: the fraction of the number of bits (symbols) the attacker is allowed to access over, the total codeword length.

Main Goal

Is it possible to construct efficient (high information rate) non-malleable codes for partial functions, while allowing the attacker to access almost the entire codeword (high access rate)?

Motivation

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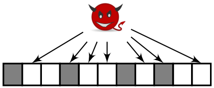

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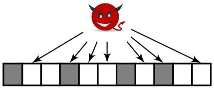

- Constant functions are excluded from the model, thus it potentially allows stronger primitives

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- Our results imply efficient All-Or-Nothing-Transforms under standard assumptions

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- **Impossibility on the information-theoretic setting [CG14]**: assuming constant access/information rate, security is achievable only with constant probability

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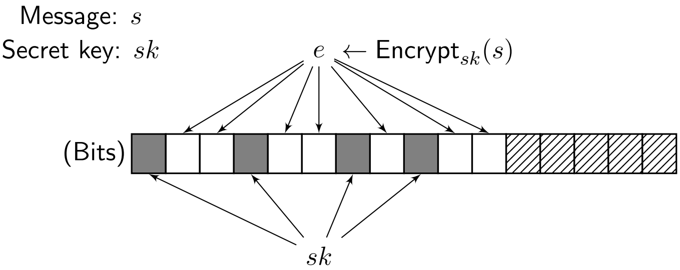

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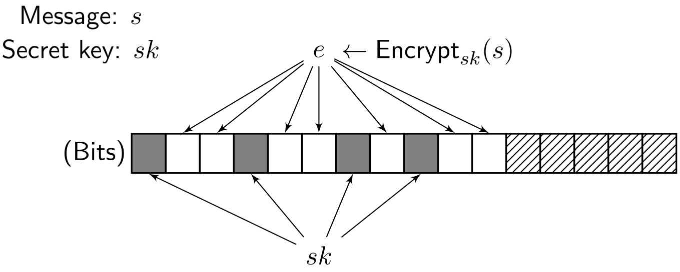

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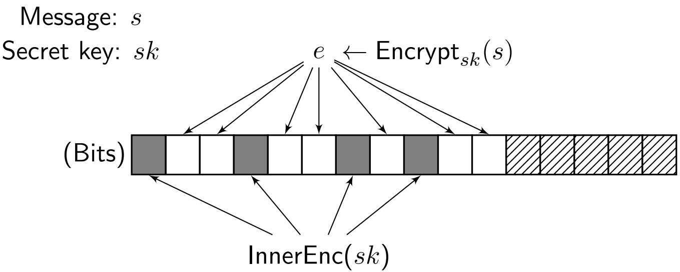

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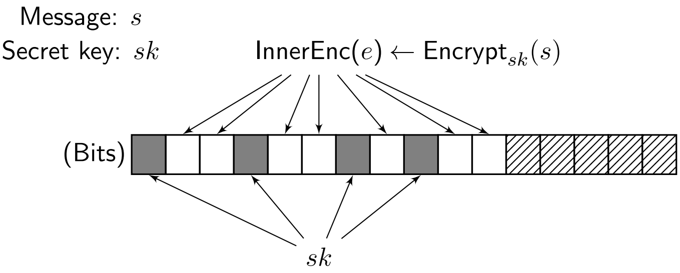

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Question: Is it possible to achieve access rate greater than $O(|sk|/|c|)$?

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More generally: Can we achieve access rate greater than what our weakest primitive sustains?

Challenges

Main observation: the structure of the codeword is fixed and known to the attacker

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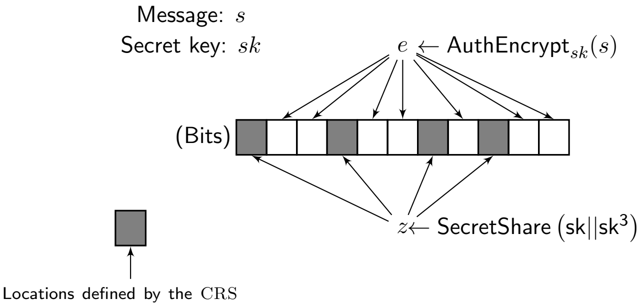
Idea: hide the structure via randomization

Construction in the CRS model



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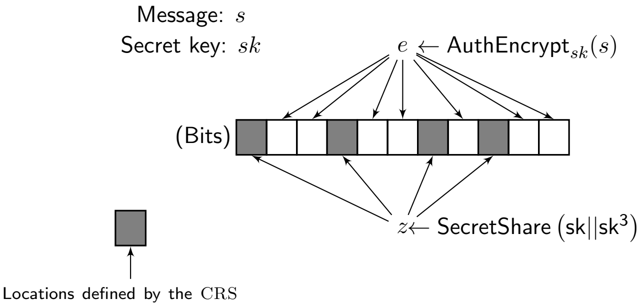

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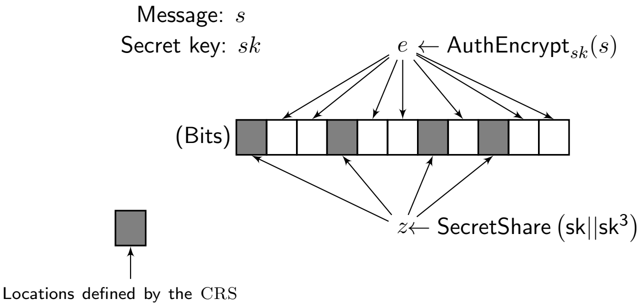

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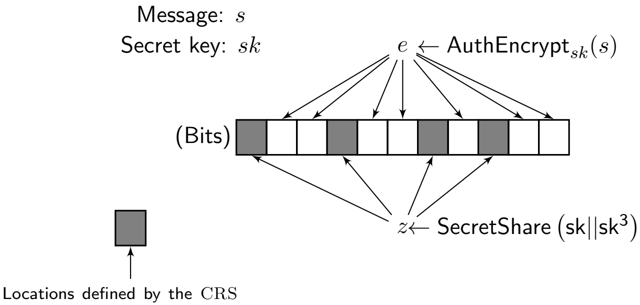

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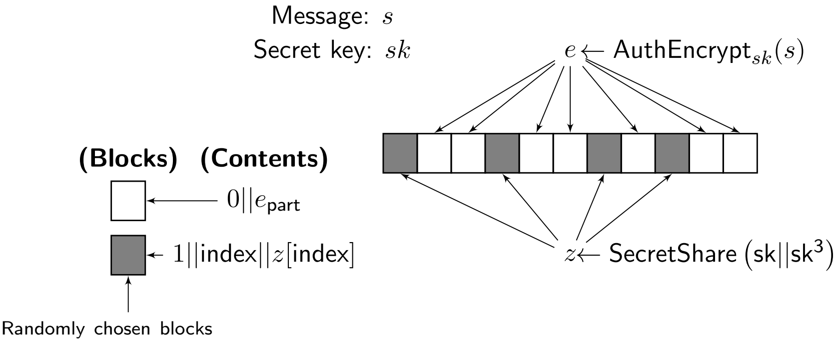
- If $(sk, sk^3) \neq (sk', sk'')$, then $\Pr[sk'^3 = sk''] \leq$ negl, otherwise we can recover sk
- Thus, if $sk \neq sk'$ or $sk^3 \neq sk''$, the simulator outputs $\perp$, otherwise, security follows by the authenticity property of the encryption scheme

Removing the CRS



Block size: $\log(k)$

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- **Applications**: tamper-resilient cryptography (boolen/aritmetic circuits), secure communication over adversarial channels (Wire-Tap channels), AONTs

Thank you!