Side Channel Analysis of the SHA-3 Finalists

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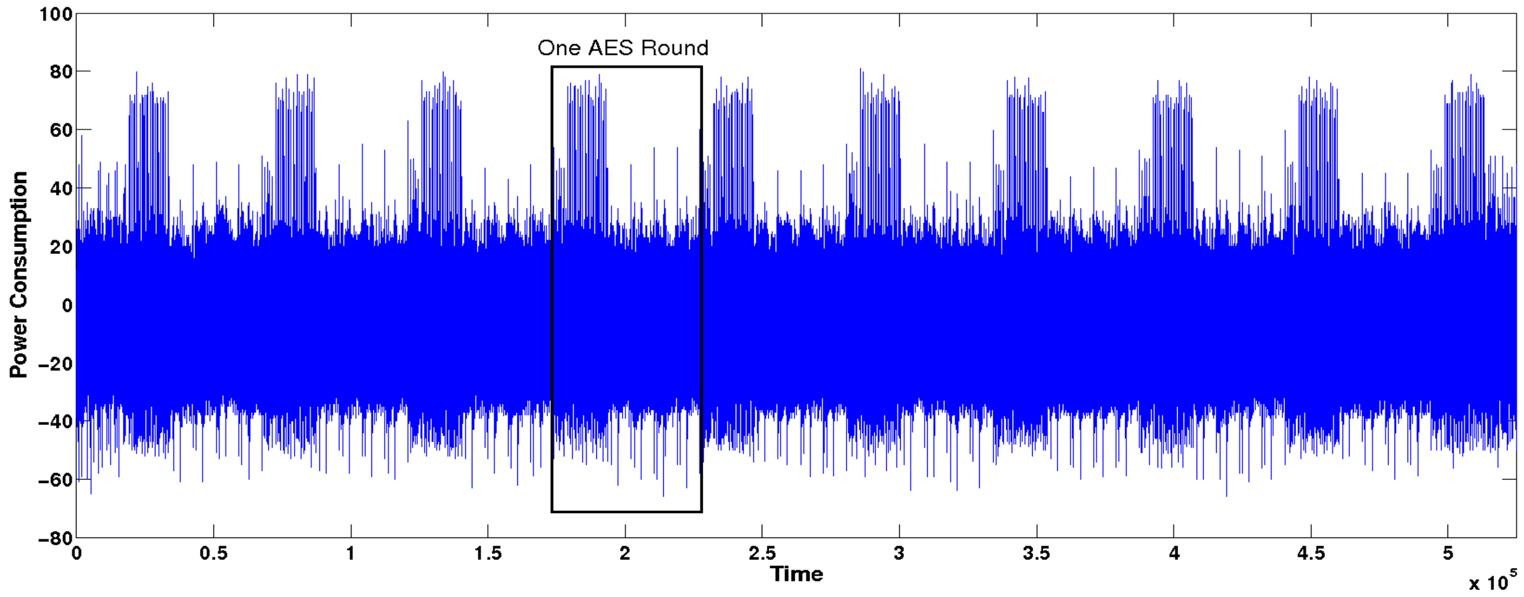
Side Channel Analysis – Power Analysis

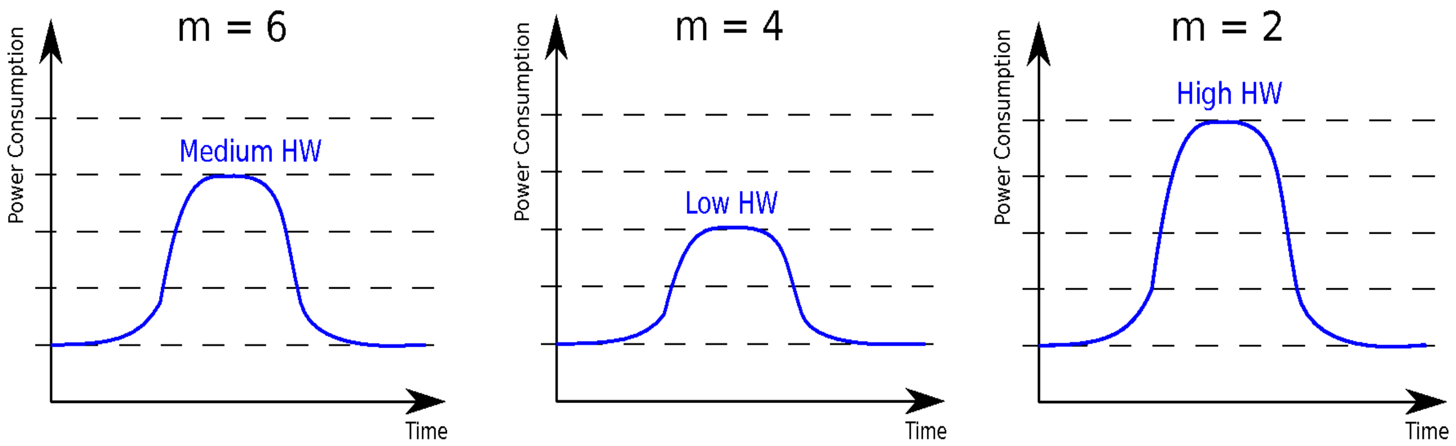
- Power Analysis is based on the dependency of the power consumption on the processed data



AES Power Trace

Differential Power Analysis (DPA)

Device processes m ⊕ key

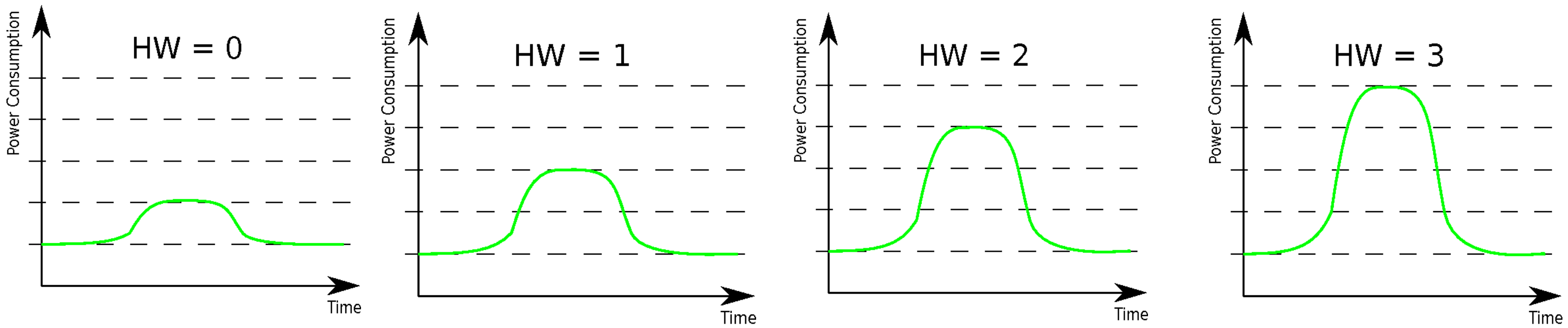


HW(4 ⊕ key) < HW(6 ⊕ key) < HW(2 ⊕ key)

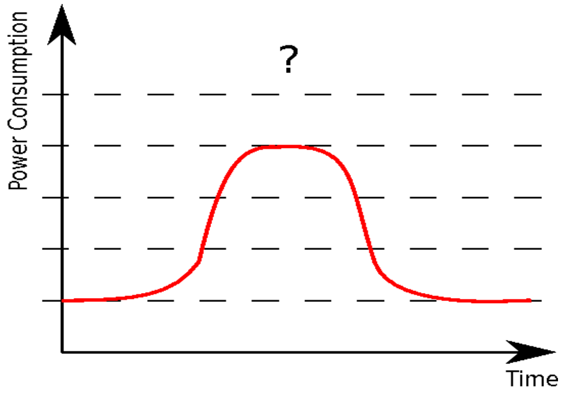
=> key = 5

Profiling Based Attacks

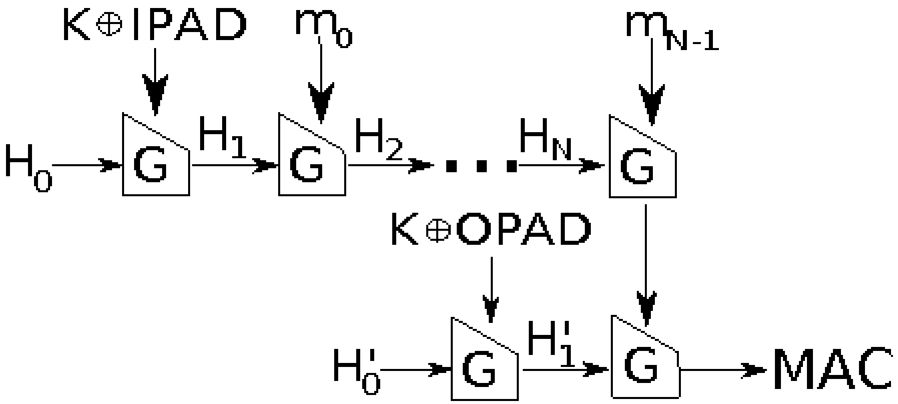
- First phase: profile the power consumption on a fully controllable device



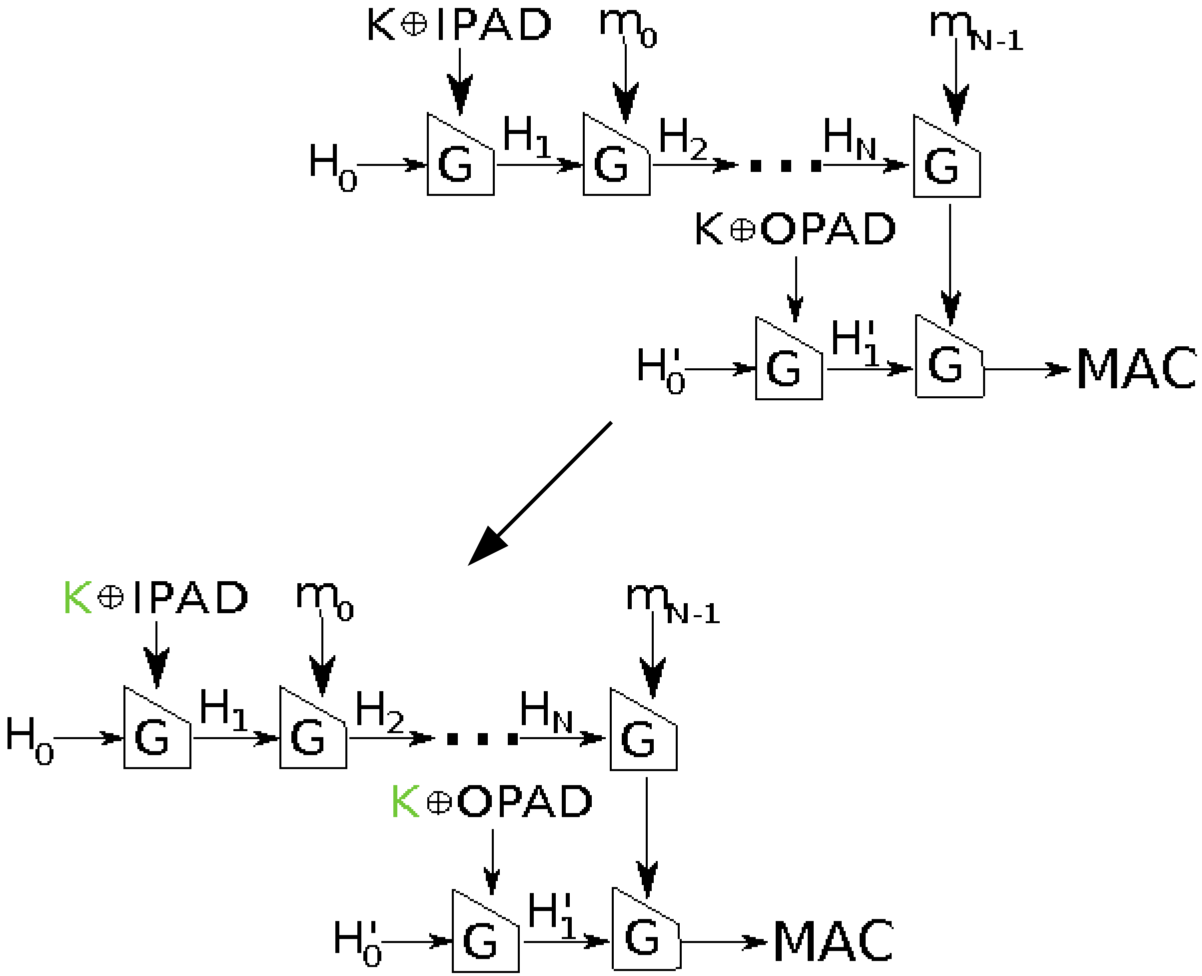
- Second phase: compare profiles to power consumption of attacked device



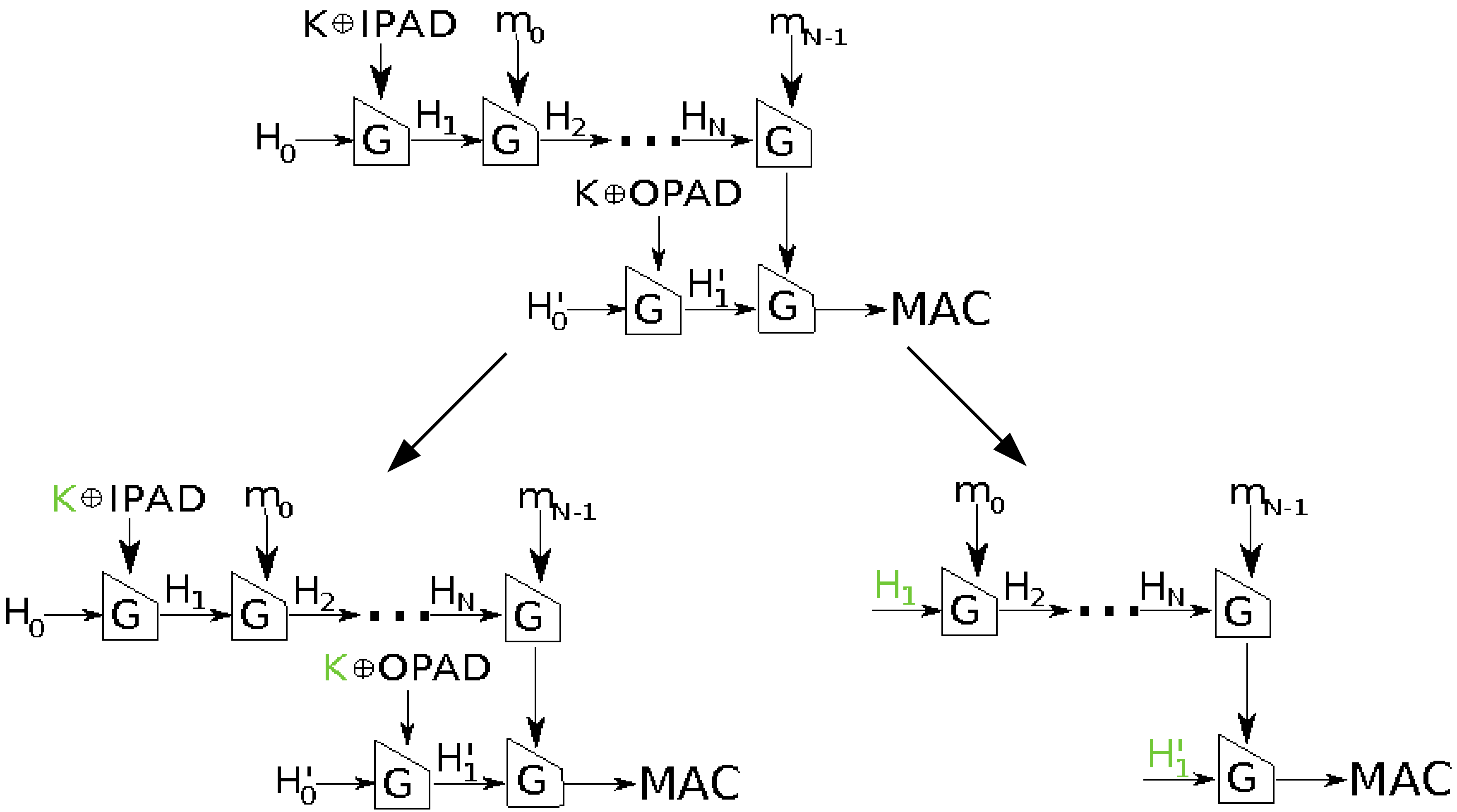
Side Channel Attacks on MAC Functions



Side Channel Attacks on MAC Functions



Side Channel Attacks on MAC Functions



Side Channel Attacks against the SHA-3 Finalists

	Benoît et al. (DPA)
BLAKE	MAC Forgery
Grøstl	MAC Forgery
JH	-
Keccak	-
Skein	-

Background for this Work

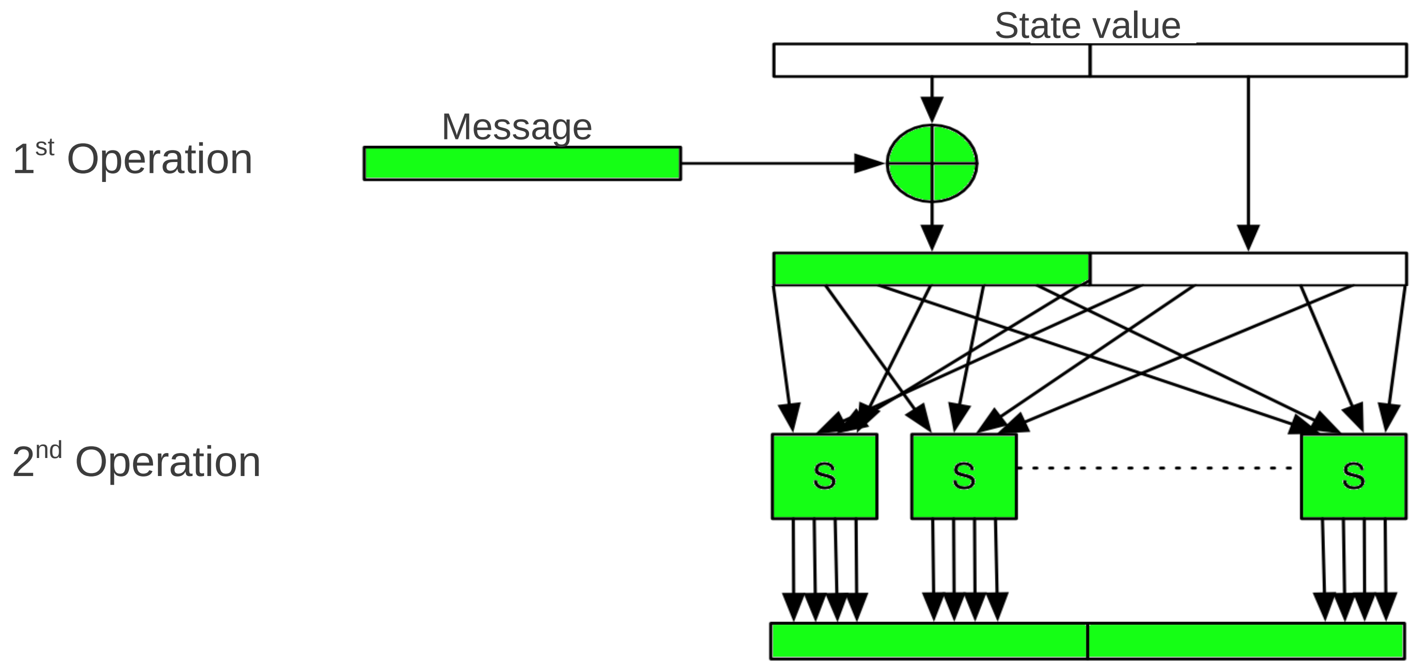
- We use the same power consumption model as Benoît et al., namely the Hamming weight model
- We analyzed:
  - Grøstl-MAC (Envelope MAC)
  - JH-HMAC
  - Keccak-MAC (built in MAC function)
  - Skein-MAC (built in MAC function)
- The attacks were verified on:
  - ATMega 256-1 microcontroller (8 bit register)
  - AVR Cortex M3 (32 bit register)

Analysis of Grøstl

- Grøstl-MAC computes a MAC by hashing **($\overline{K}$ || $\overline{M}$ || K)**
- The attack, suggested by Benoît et al., can be altered to fit Grøstl-MAC
- A successful DPA is able to recover the processed key, since the last key K is processed with variable data

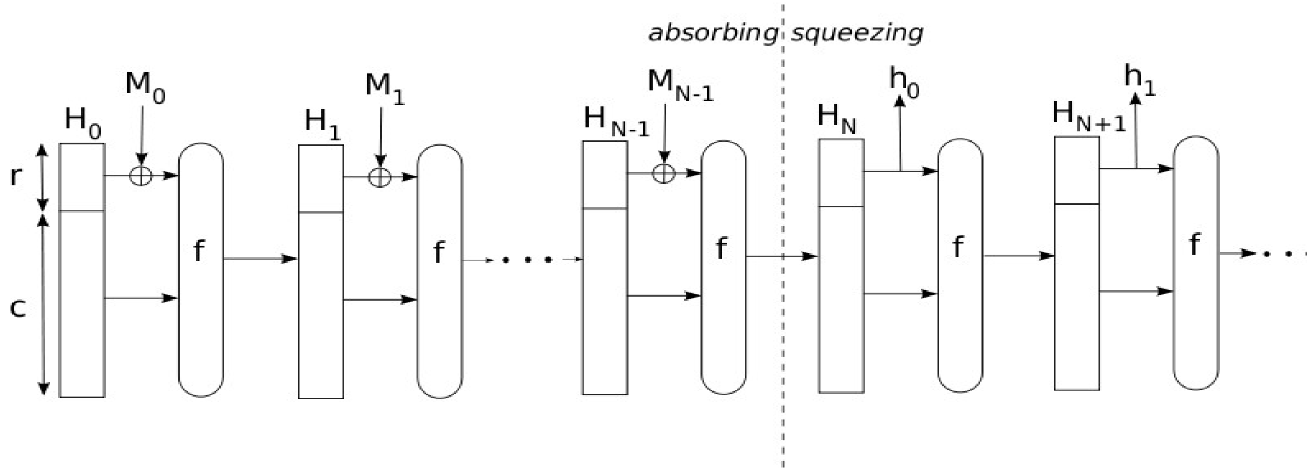
Analysis of JH

- Two state values are needed for inner and outer hash function call
- For each state value, two operations have to be exploited



Analysis of Keccak (1)

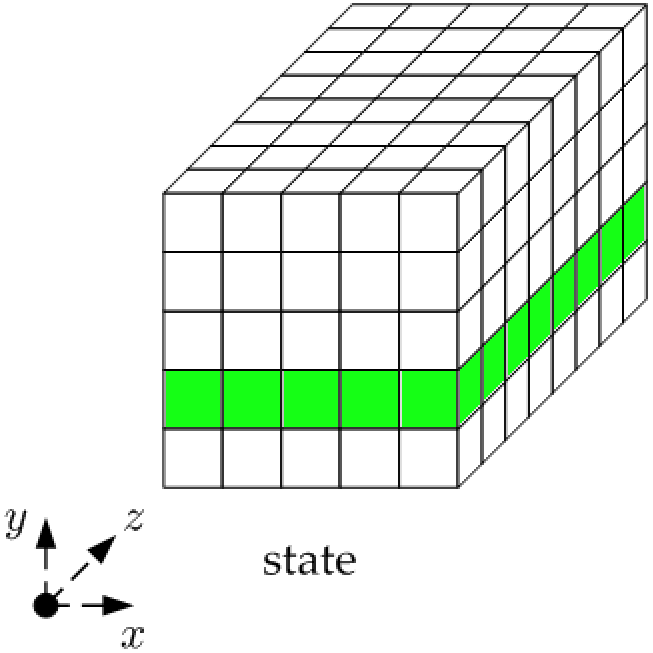
- Keccak-MAC hashes **(K || M)**
- First exploit the XOR between the bitrate and the message



The Sponge Construction based on a permutation f

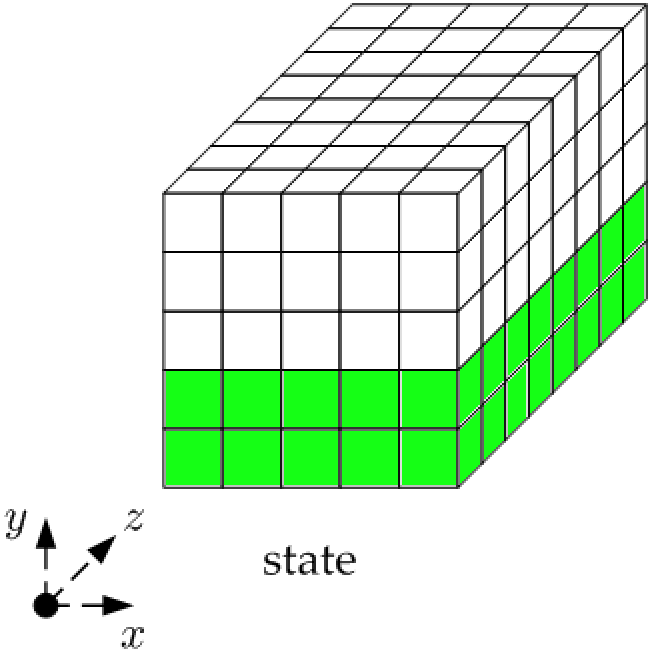
Analysis of Keccak (2)

- Secondly exploit the XOR of the columns during θ until all values are known
- If the key is only few bits long, a key recovery is possible



Analysis of Keccak (2)

- Secondly exploit the XOR of the columns during θ until all values are known
- If the key is only few bits long, a key recovery is possible



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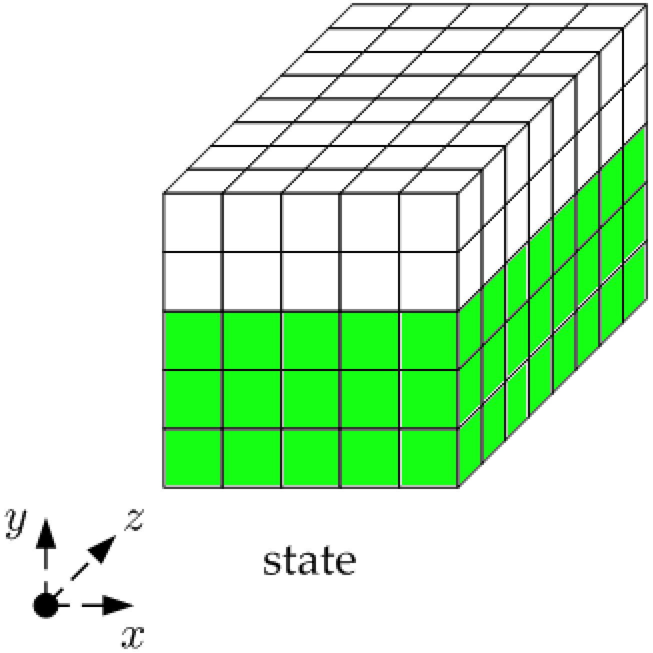

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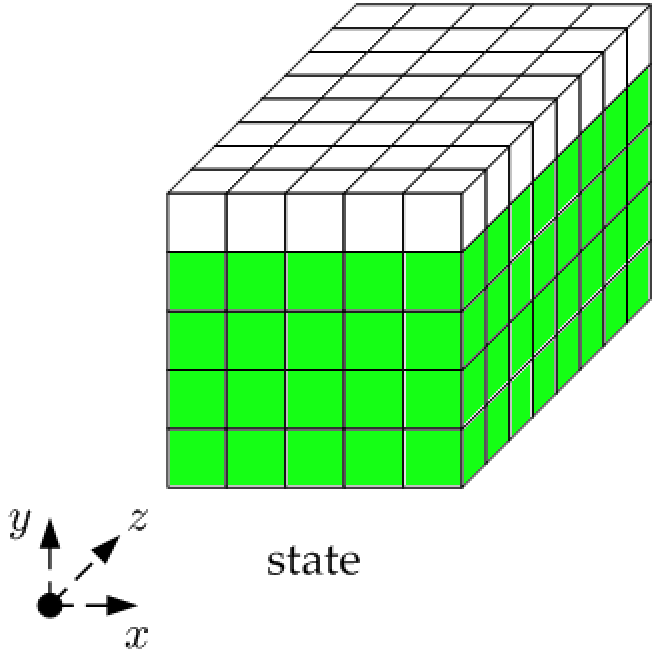

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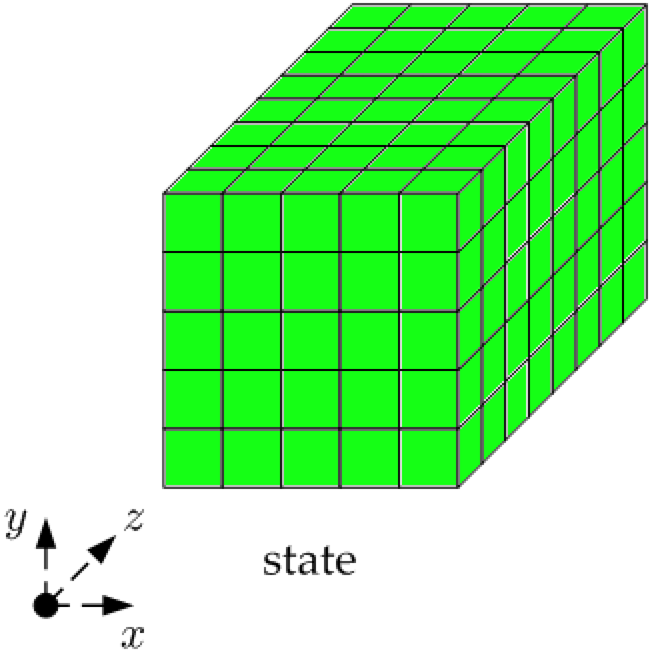
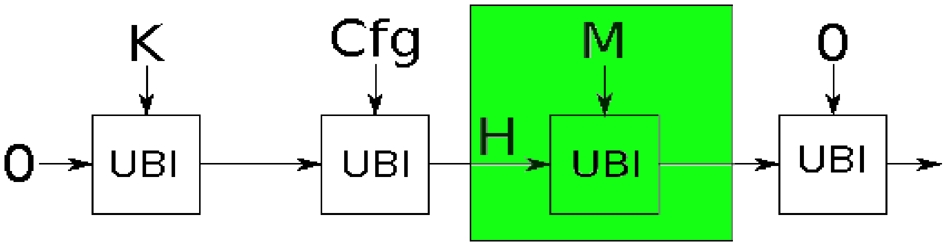
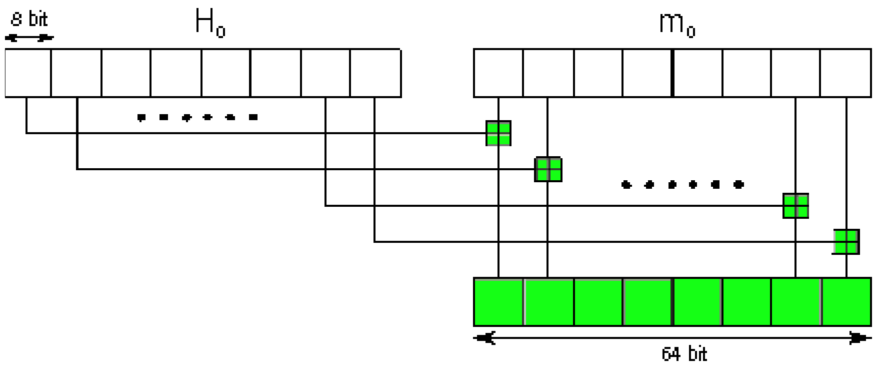


Analysis of Skein

- Target the modular addition between the state value and the message
- Recover the key by dividing each 64 bit addition in eight 8 bit additions and attack them independently



Attacked UBI call



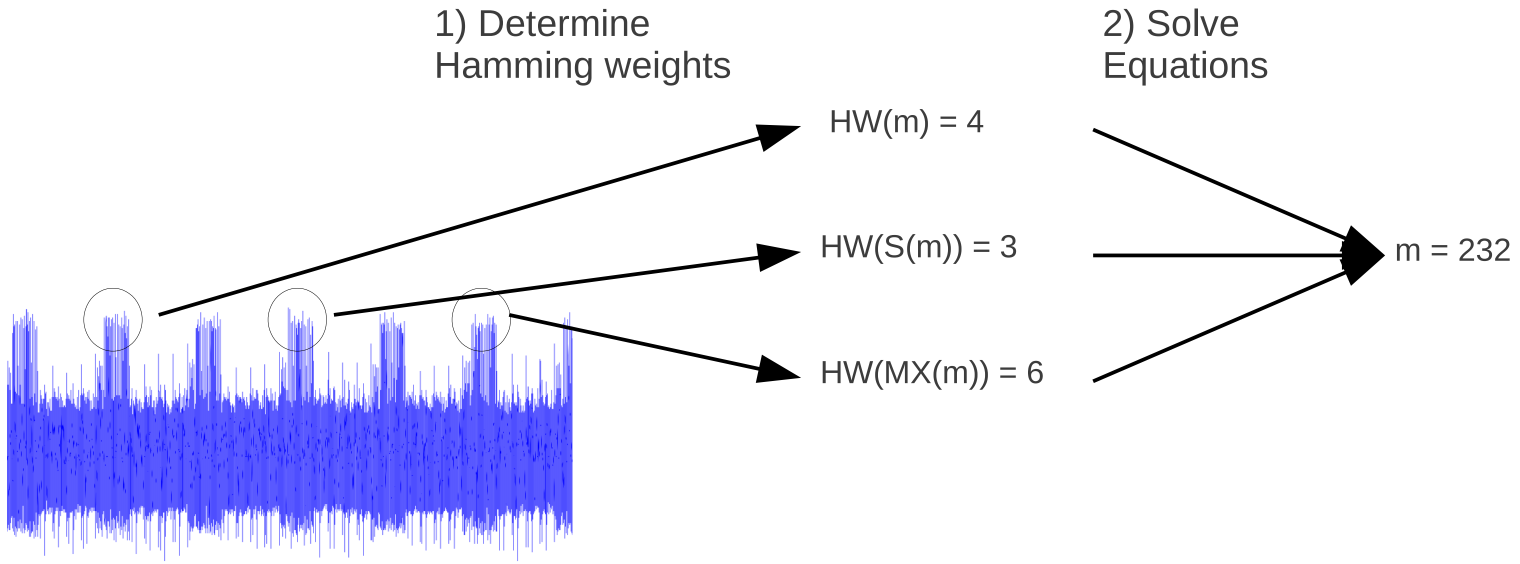
Split the 64 bit modular addition into 8 bit blocks and attack them independently

Side Channel Attacks against the SHA-3 Finalists

	Benoît et al. (DPA)	This work (DPA)
BLAKE	MAC Forgery	-
Grøstl	MAC Forgery	Key Recovery
JH	-	MAC Forgery
Keccak	-	MAC Forgery (Key Recovery)
Skein	-	MAC Forgery

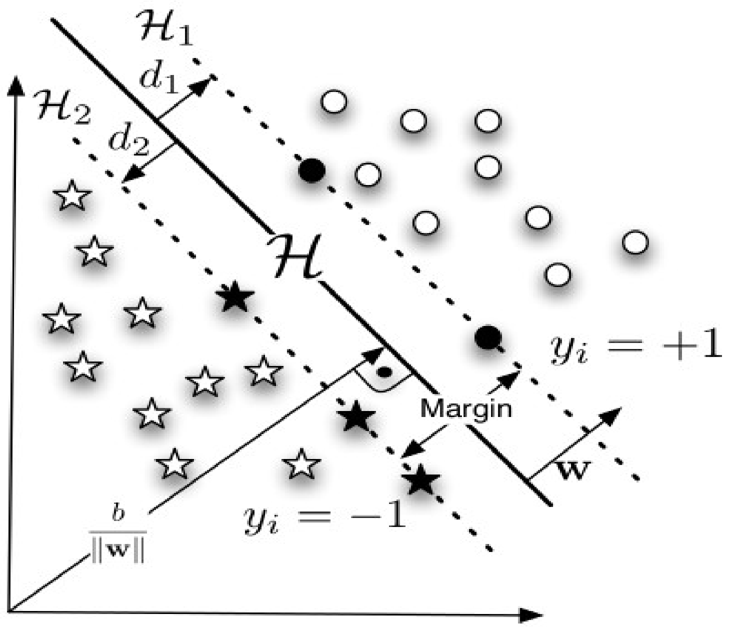
Analysis of Grøstl

- Use algebraic side-channel analysis to recover the hashed message



1) Determine Hamming weight (1)

- Support Vector Machines (SVM) are used for binary classification



1) Determine Hamming weight (2)

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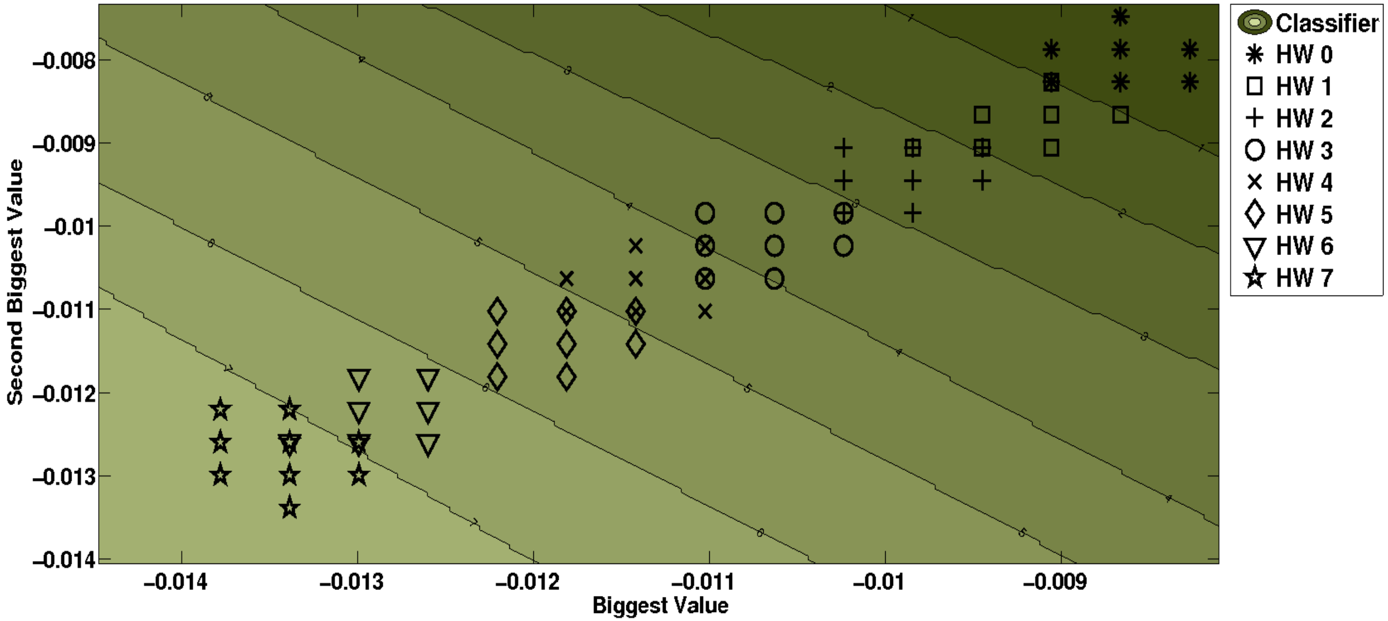
- Profiling Hamming weights using Support Vector Machines



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2) Solve Equations

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- The variables in the equation system are composed of:
  - HW of the input
  - HW of the S-box input
  - HW of the S-box output
  - HW of the MixBytes output
- Inserting the HW of these variables for the first two rounds (200 HW) allows solving the system

Side Channel Attacks against the SHA-3 Finalists

	Benoît et al. (DPA)	**This work (DPA)**	**This work (Profiling)**
BLAKE	MAC Forgery	-	-
Grøstl	MAC Forgery	Key Recovery	Message Recovery
JH	-	MAC Forgery	-
Keccak	-	MAC Forgery (Key Recovery)	-
Skein	-	MAC Forgery	-

Remarks

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- The side channel analysis was performed for the Hamming weight leakage model, an analysis using a more complex model, such as the Hamming distance model, is more difficult
- Ranking the finalists in terms of side channel resistance is not possible since different implementations have different characteristics
- A feasibility study of the algebraic side channel attack for all finalists still remains

Questions

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