Collision Attack on 5 Rounds of Grøstl

Florian Mendel Vincent Rijmen Martin Schläffer

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KU LEUVEN

The Grøstl Hash Function

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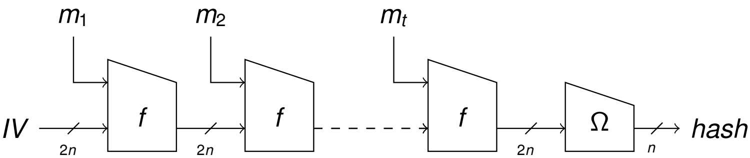
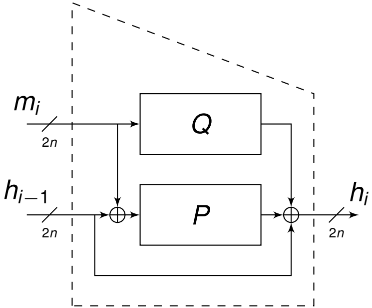


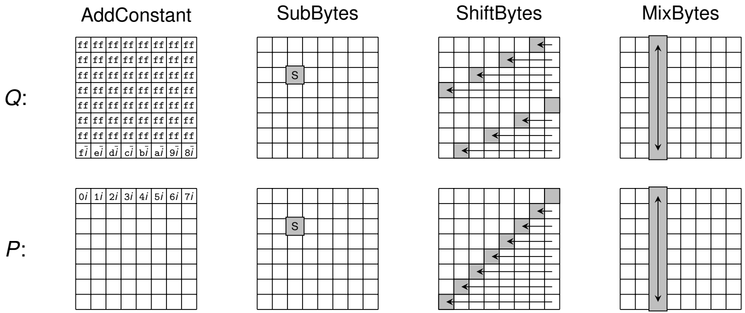
- SHA-3 finalist designed by Knudsen et al.
  - iterative, Merkle-Damgård design principle
  - wide-pipe construction, $2n$-bit chaining value

The Grøstl Compression Function



- Permutation based design
  - 8×8 state and 10 rounds for Grøstl-256
  - 8×16 state and 14 rounds for Grøstl-512

The Grøstl-256 Round Transformations



- AES like round transformation

$$r_i = MB \circ SH \circ SB \circ AC$$

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Existing Analysis of Grøstl I

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Attacks on the Hash Function

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$\Rightarrow$ We will show collision attacks for up to 5 rounds of Grøstl

Basic Attack Strategy

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- Attack uses a new type of truncated differential trail spanning over more than one message block
  - Starting with an (almost) arbitrary difference in the chaining variable
  - Iteratively canceling the differences in the chaining variable
  - Having only differences in one of the two permutations

Equivalent Description of Grøstl

- To simplify the description of the attack we use an equivalent description of Grøstl

$$\begin{aligned} h'_0 &= MB^{-1}(\mathrm{IV}) \\ h'_i &= P'(MB(h'_{i-1}) \oplus m_i) \oplus Q'(m_i) \oplus h'_{i-1} \quad \text{for } 1 \leq i \leq t \\ hash &= \Omega(MB(h'_t)) \end{aligned}$$

  with $h_i = MB(h'_i)$

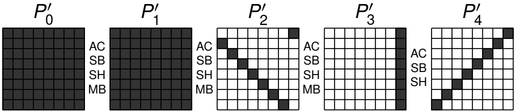
- The last MixBytes transformation of the permutations P and Q are swapped with the XOR operation of the feed-forward

Attack on 4 Rounds of Grøstl-256

- The core of the attack on 4 rounds are truncated differential trails for P' with only 8 active bytes at the output of round r_4

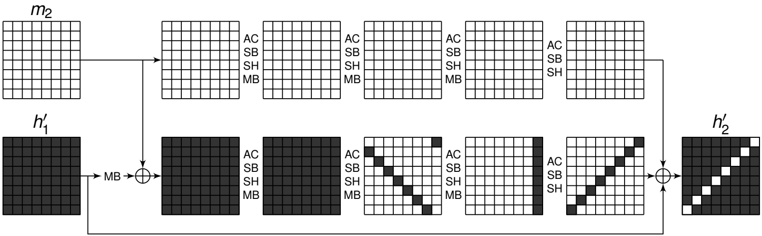
$$64 \xrightarrow{r_1} 64 \xrightarrow{r_2} 8 \xrightarrow{r_3} 8 \xrightarrow{r_4} 8$$

- Using the rebound attack all the 2^{64} solutions for this truncated differential trail with a given/fixed difference difference at the input of P' can be found with complexity 2^{64} in time and memory



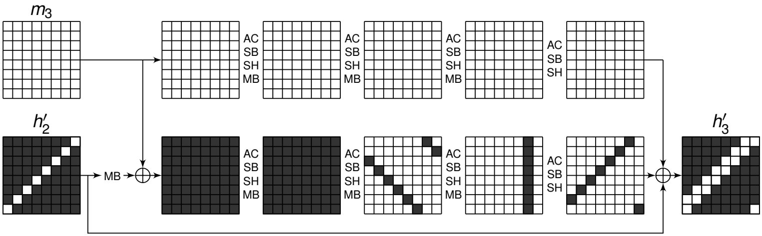
Attack on 4 Rounds of Grøstl-256

- Choose some arbitrary m_1, m_1^* to get a full active state in h_1'
- Construct 2^{64} solutions for the truncated differential trail in P' to find a m_2 such that 8 bytes of the difference in h_2' are canceled



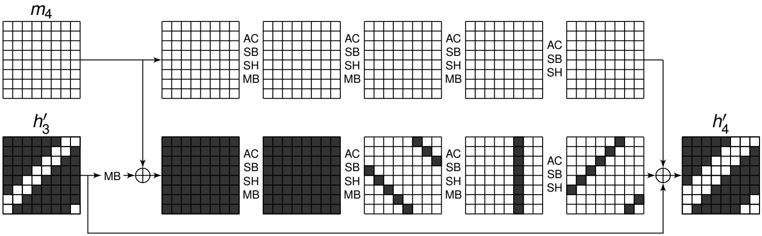
Attack on 4 Rounds of Grøstl-256

- Construct 2^{64} solutions for a rotated variant of the truncated differential trail to cancel another 8 bytes of the difference in h'_3



Attack on 4 Rounds of Grøstl-256

- Repeat this in total 8 times until a collision has been found in h'_9



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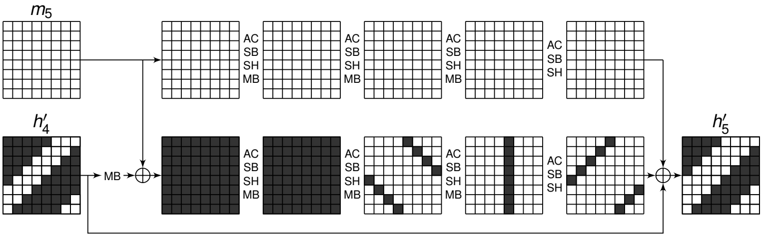

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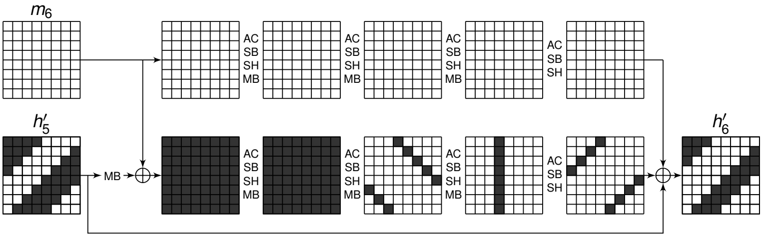

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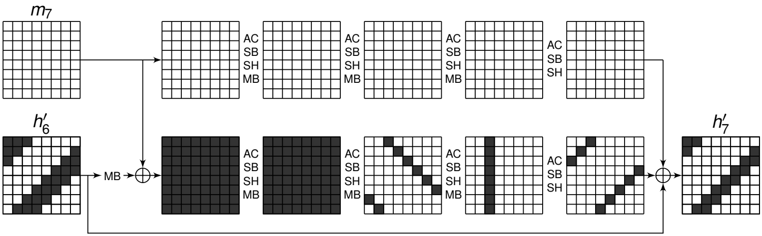

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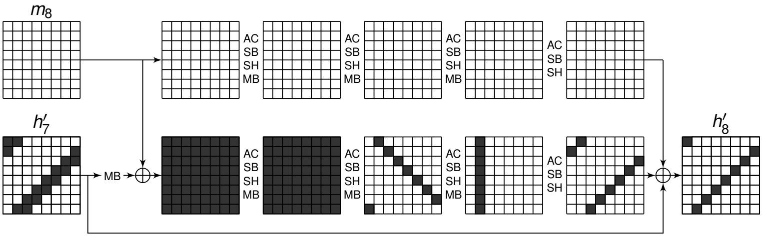

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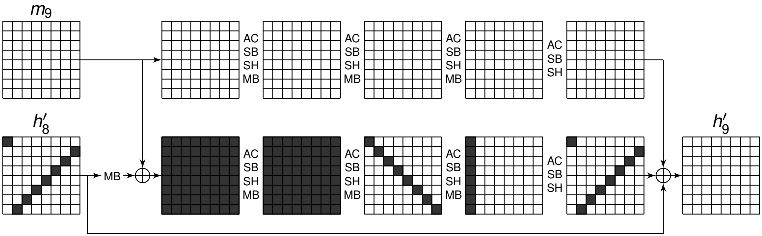

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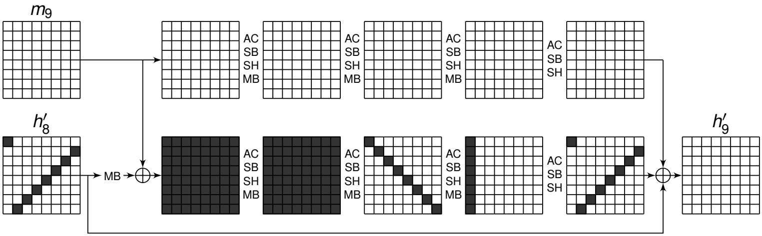

$\Rightarrow$ Collision attack for 4 rounds with complexity of $8 \cdot 2^{64} = 2^{67}$

Extending the Attack to 5 Rounds

Attack on 5 Rounds of Grøstl-256

- For the attack on 5 rounds we use truncated differential trails with only one active byte at the output of round r_3

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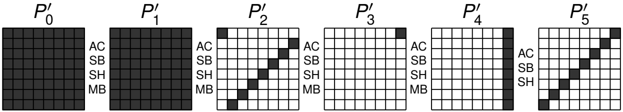

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$\Rightarrow$ Collision attack for 5 rounds with complexity of $8 \cdot 2^{64+56} = 2^{123}$

Summary

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Grøstl-256	3	2^{64}	-
	4	2^{67}	2^{64}
	5	2^{123}	2^{64}

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for the collision attack on 4 rounds, and

$$128 \xrightarrow{r_1} 64 \xrightarrow{r_2} 8 \xrightarrow{r_3} 2 \xrightarrow{r_4} 16 \xrightarrow{r_5} 16$$

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$\Rightarrow$ Collision attack on 4 and 5 rounds of Grøstl-512 with a complexity of 2^{131} and 2^{176}

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	4	2^{67}	2^{64}
	5	2^{120}	2^{64}
Grøstl-512	3	2^{192}	-
	4	2^{131}	2^{64}
	5	2^{176}	2^{64}

Thank you for your attention!