Rebound Attack on Reduced-Round Versions of JH

Vincent Rijmen Deniz Toz Kerem Varıcı

K.U.Leuven, Dept. of Electrical Engineering, ESAT/SCD/COSIC and IBBT

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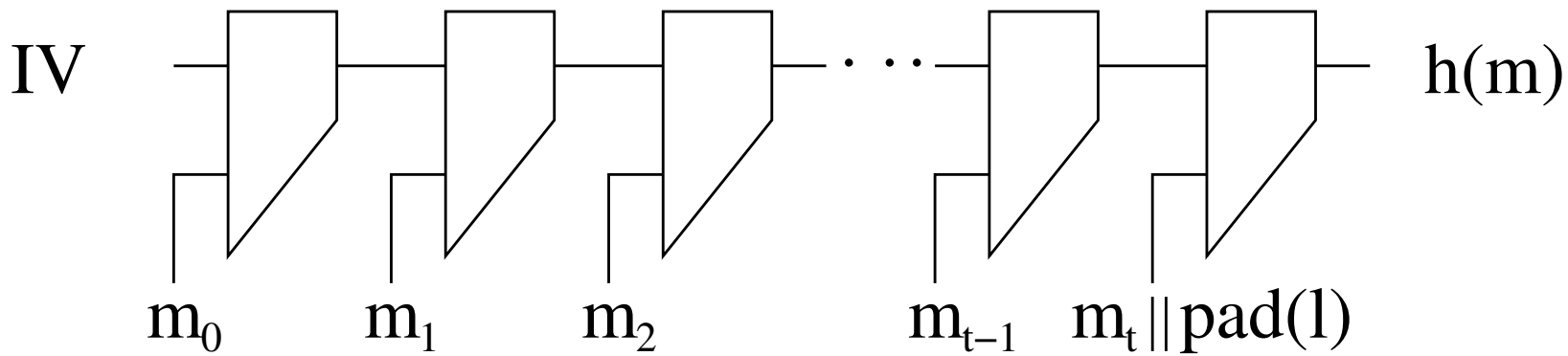
Outline

Outline

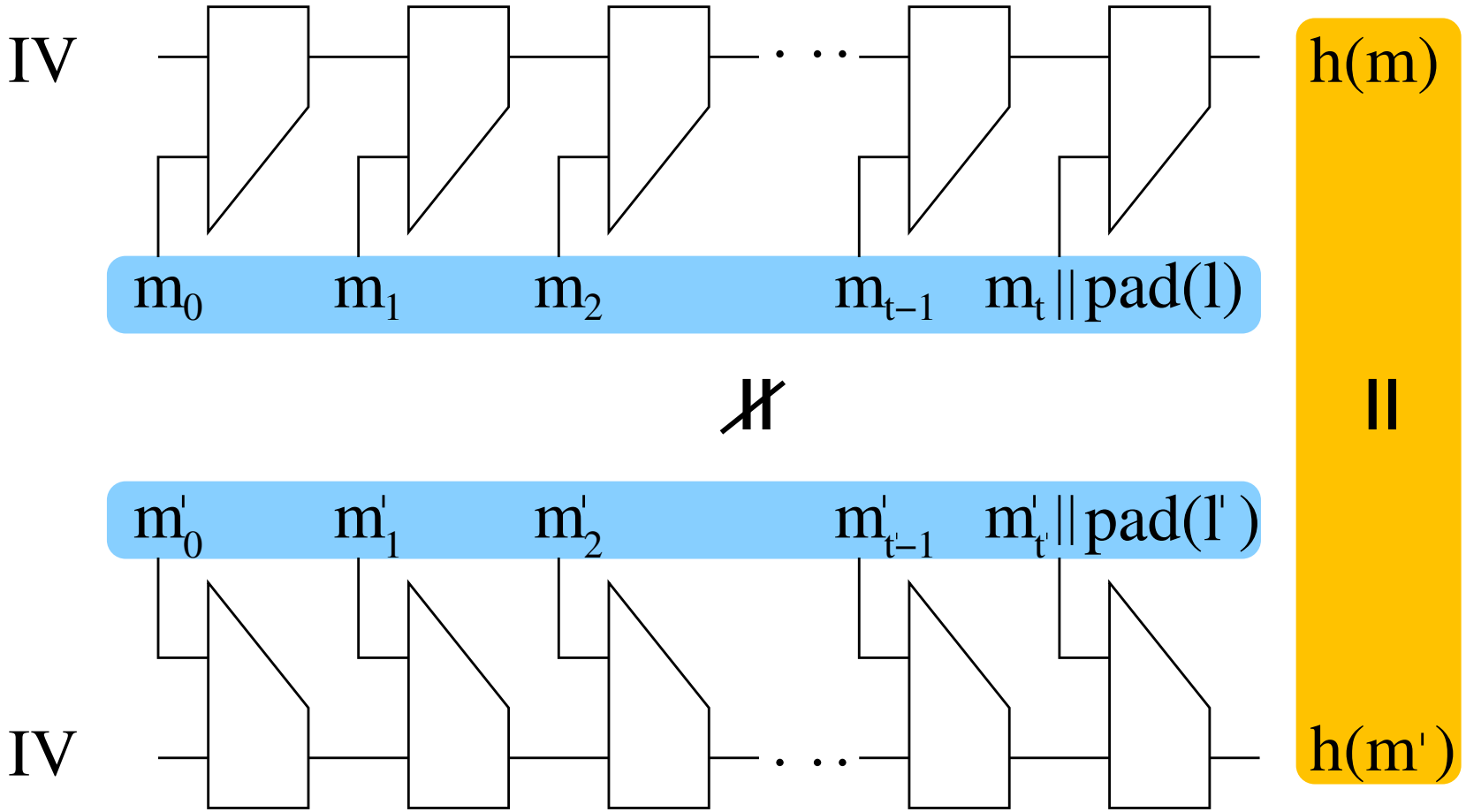
Collision Attacks on Iterated Hash Functions

Iterated hash function



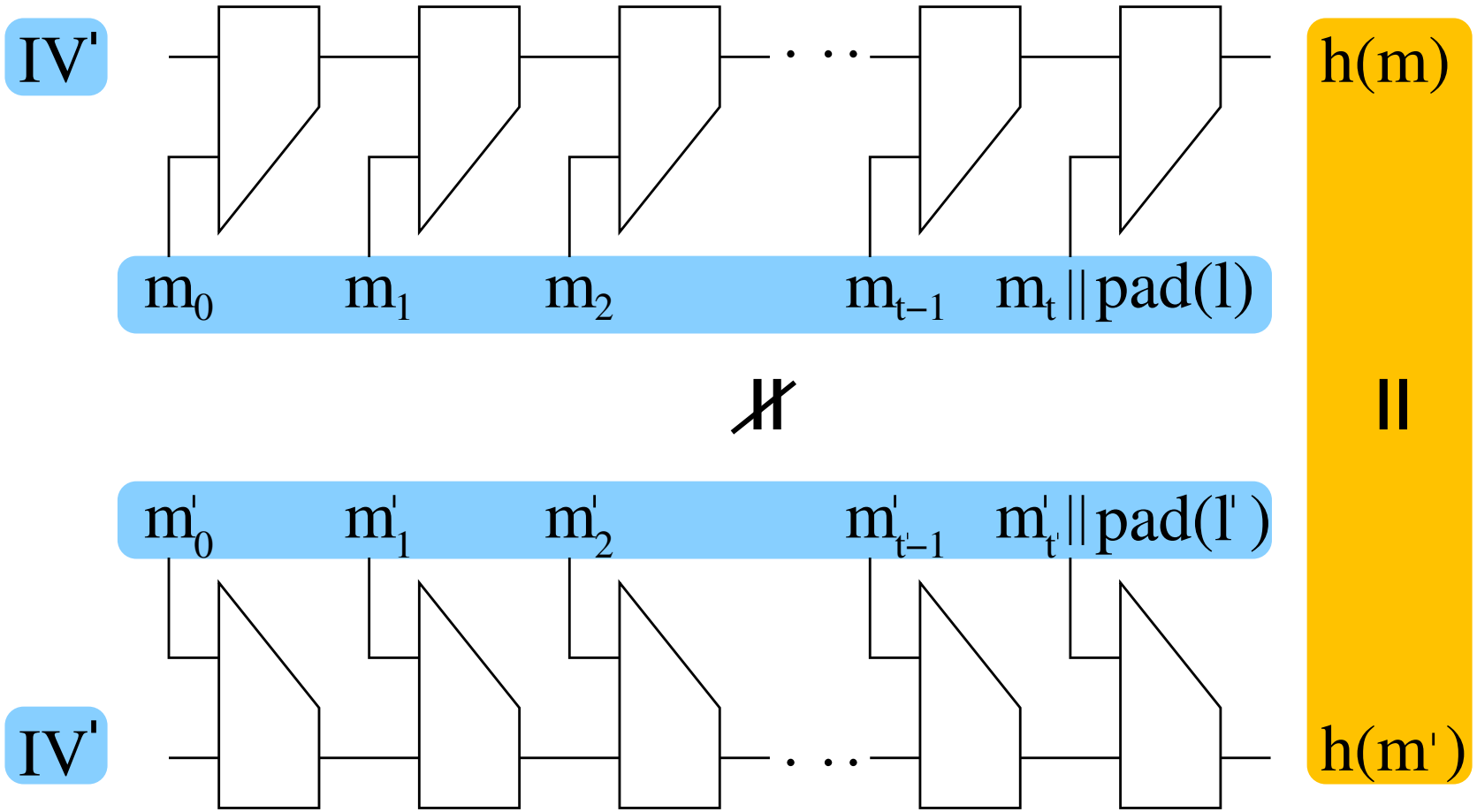
Collision Attacks on Iterated Hash Functions

Collision



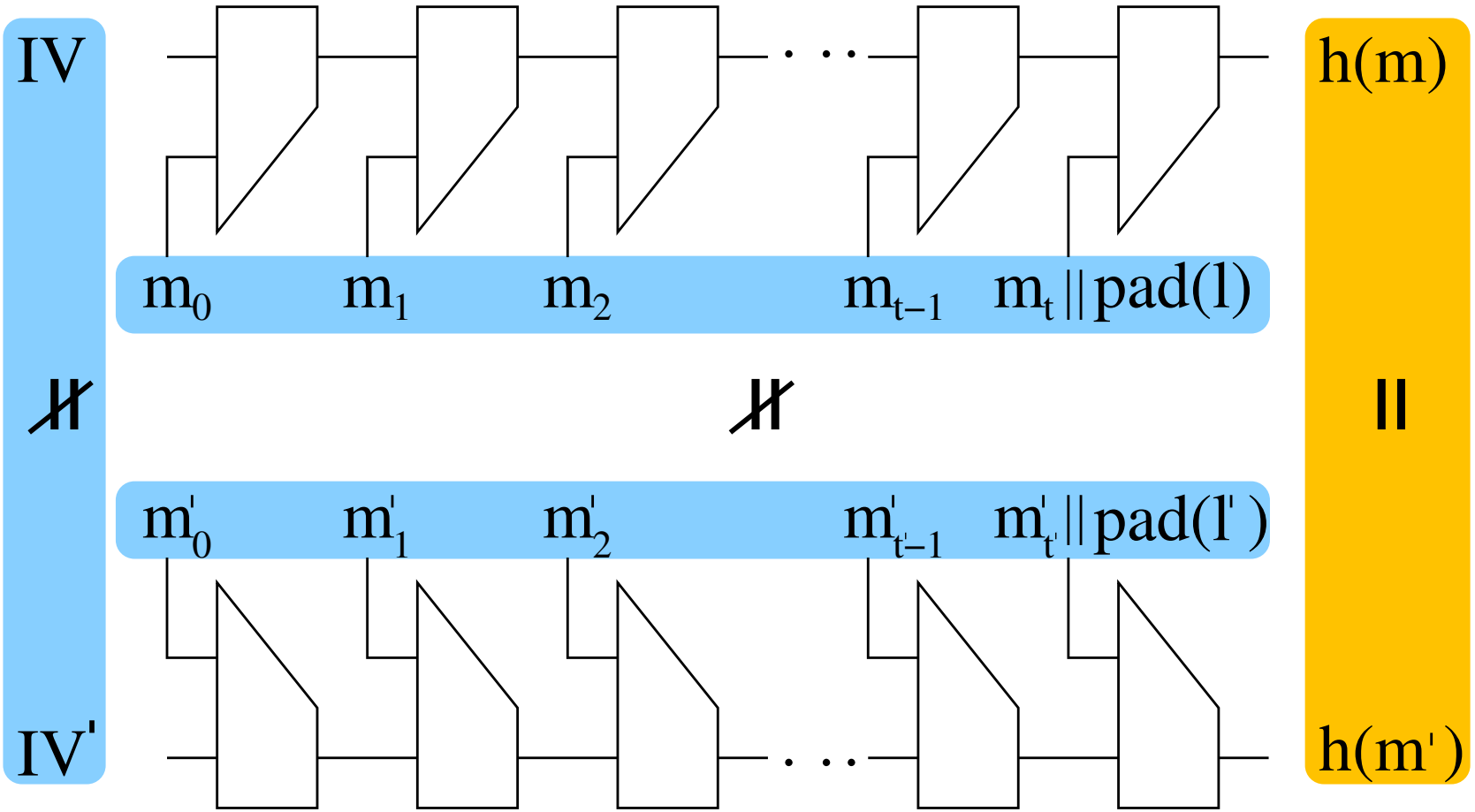
Collision Attacks on Iterated Hash Functions

Semi-free-start collision



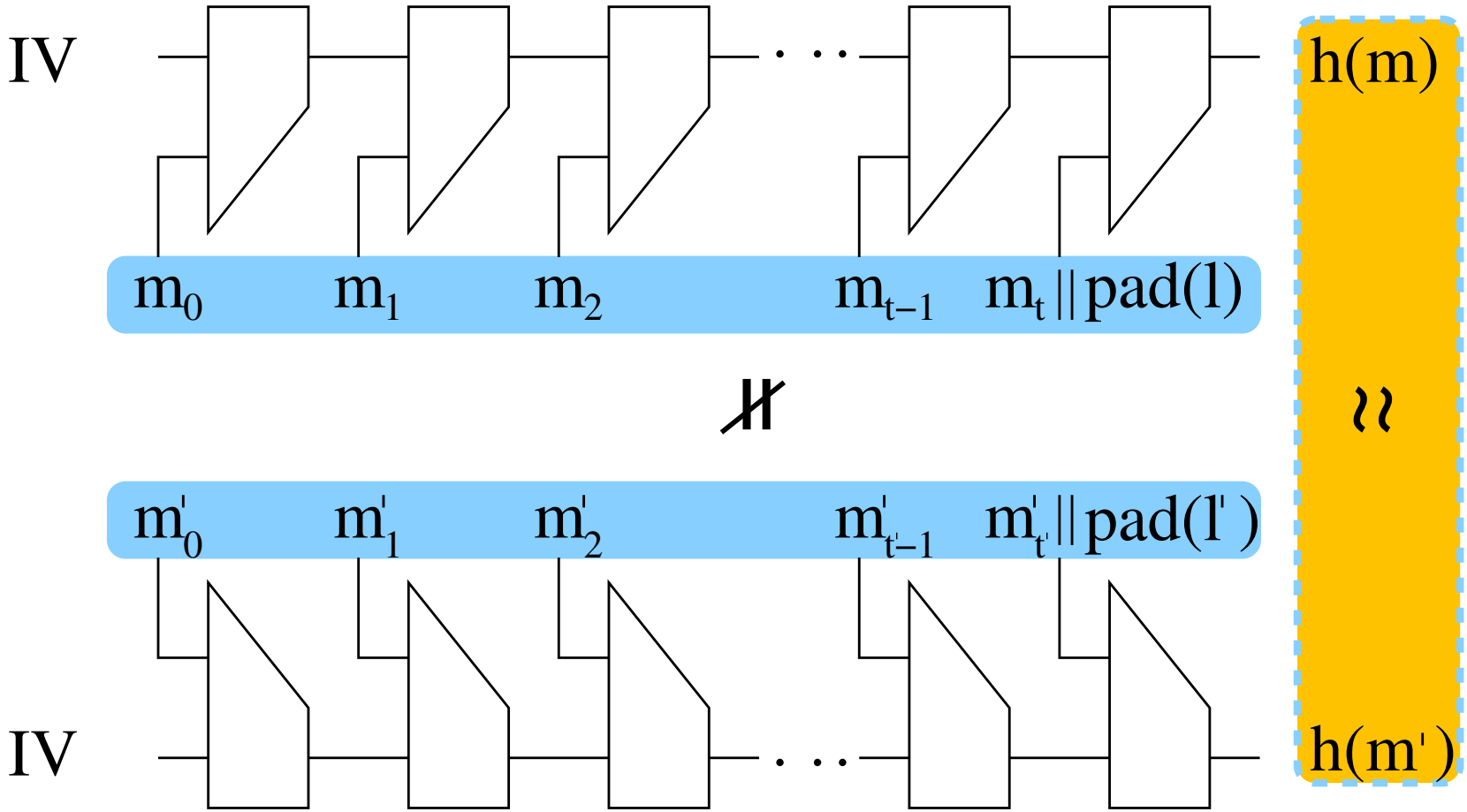
Collision Attacks on Iterated Hash Functions

Free-start collision

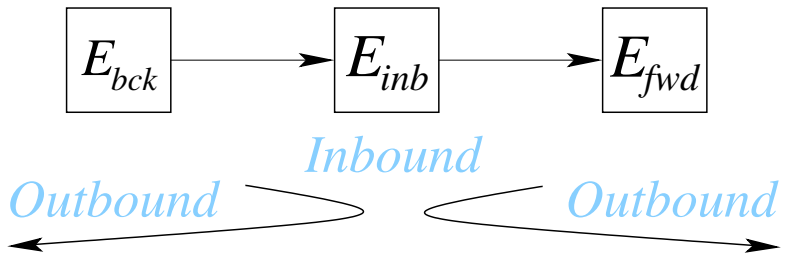


Collision Attacks on Iterated Hash Functions

Near-collision

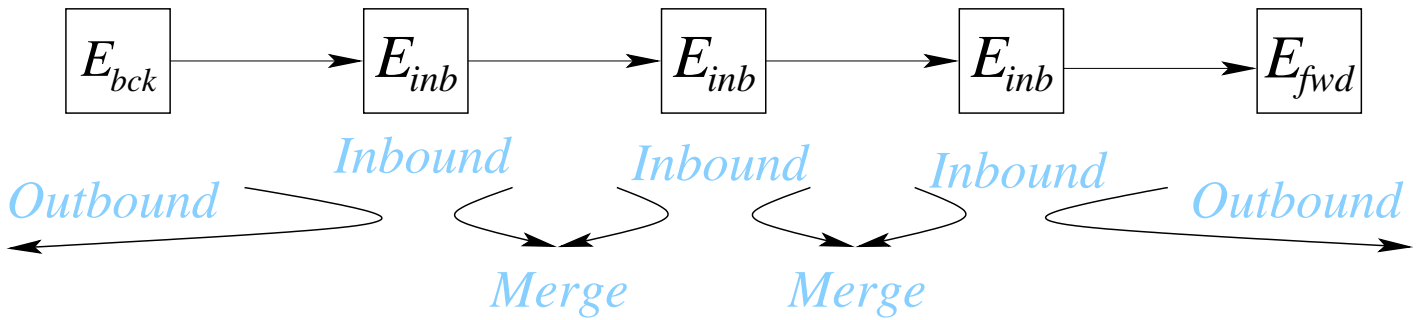


Rebound Attack



- Introduced by Mendel et al. in FSE 2009
- Combination of "Meet-in-the-Middle attack" and "Inside-Out approach".
- It consists of two main phases
  - Inbound Phase
  - Outbound Phase
- Applied to Whirlpool, Grøstl, LANE, ECHO ...

Improved Rebound Attack



- Lamberger et al. and Matusiewicz et al. in Asiacrypt 2009
- Mainly combination of "Meet-in-the-Middle attack" and "Inside-Out approach".
- It consists of three main phases
  - Inbound Phase
  - Merge Phase
  - Outbound Phase

Outline

JH

Designed by Wu

Second round SHA-3 candidate

Sponge based construction.

16.2 cycles/byte on 64-bit Core2 microprocessor

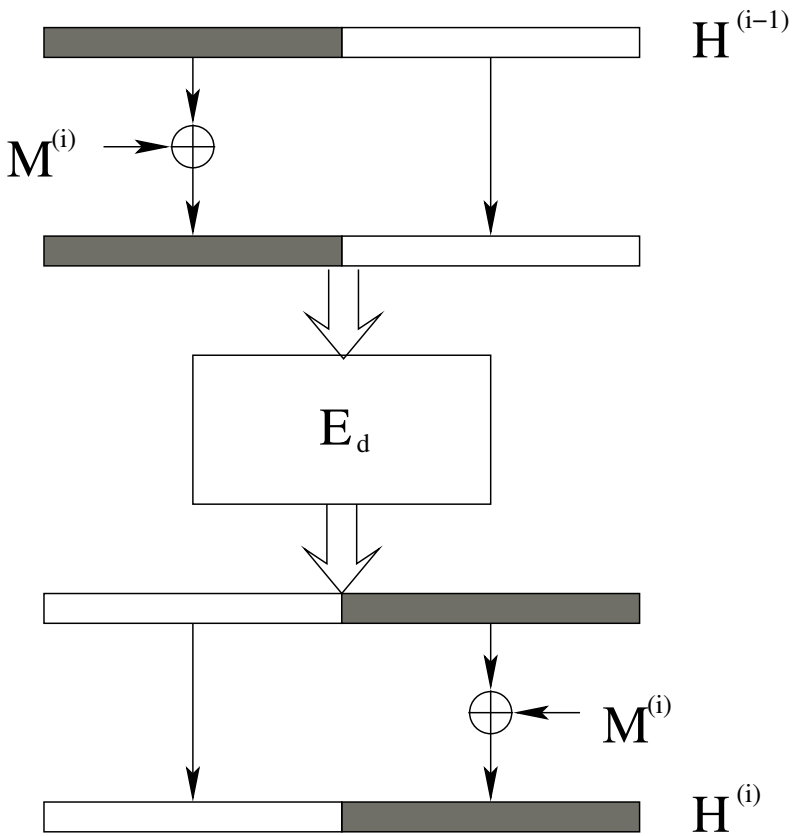
21.3 cycles/byte on 32-bit Core2 microprocessor

Our Contribution

Up to 16 round JH is not semi-free-start collision resistant.

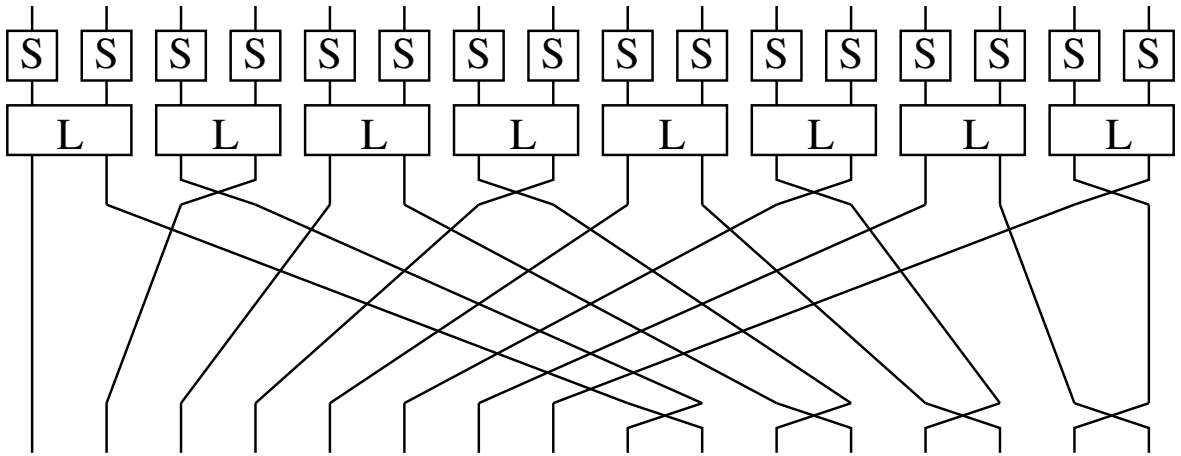
From 19 round to 22 round, semi-free-start near-collisions can be found for the compression function of JH.

JH



d	State Size	Message Block Size	# of Rounds
n	2^{n+2}	2^{n+1}	$5 \cdot (n-1) + 0.5$ $6 \cdot (n-1) + 0.5$
4	64	32	15.5
6	256	128	30.5
8	1024	512	35.5

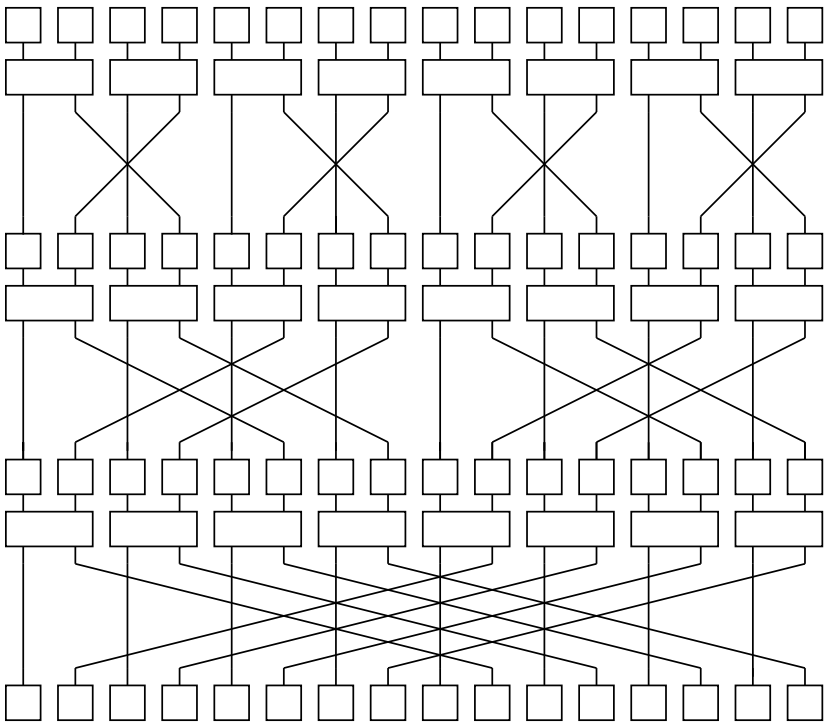
Round Function of JH



- 4-bit-to-4-bit S-Boxes (S_0-S_1)
- Linear Transformation based on $[4, 2, 3]$ MDS code
- Permutation P_d
- Round function with different round constants

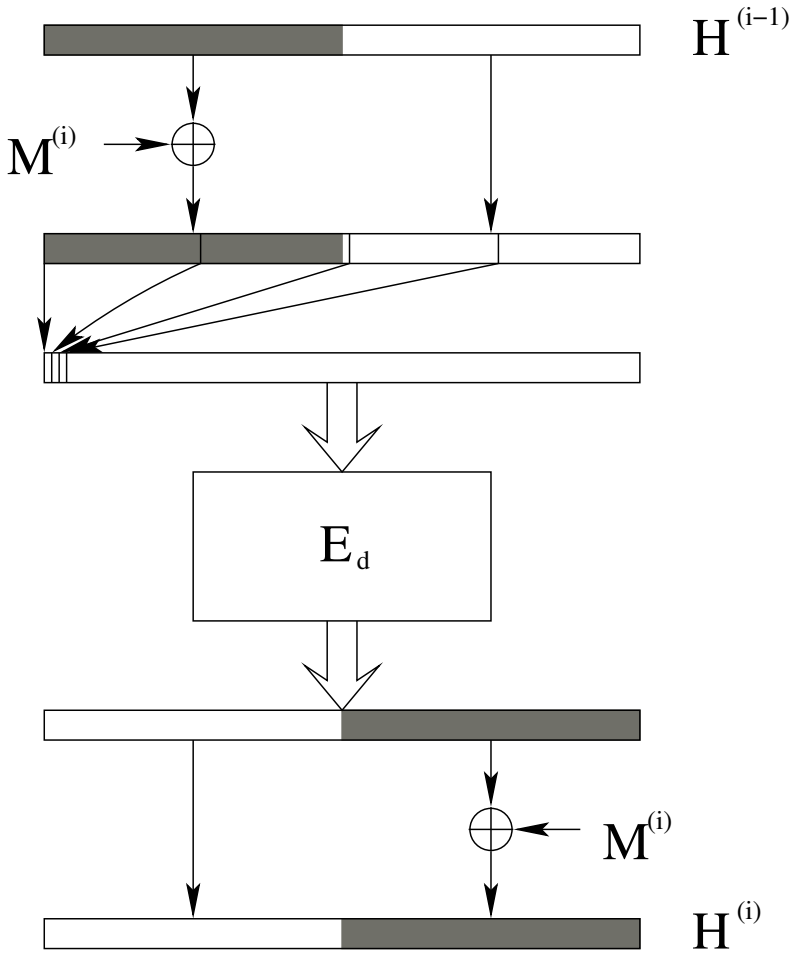
Bit-Slice Round Function of JH ($d = 4$)

Figure: 3 different round functions of bit slice



Grouping - De-grouping

Grouping



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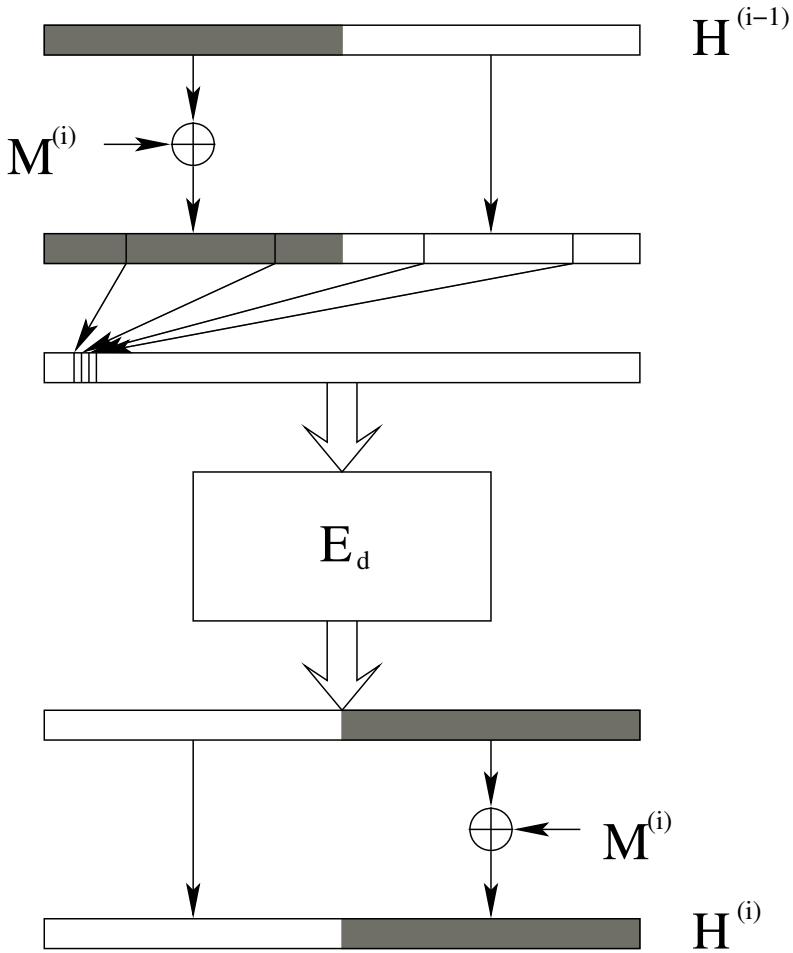

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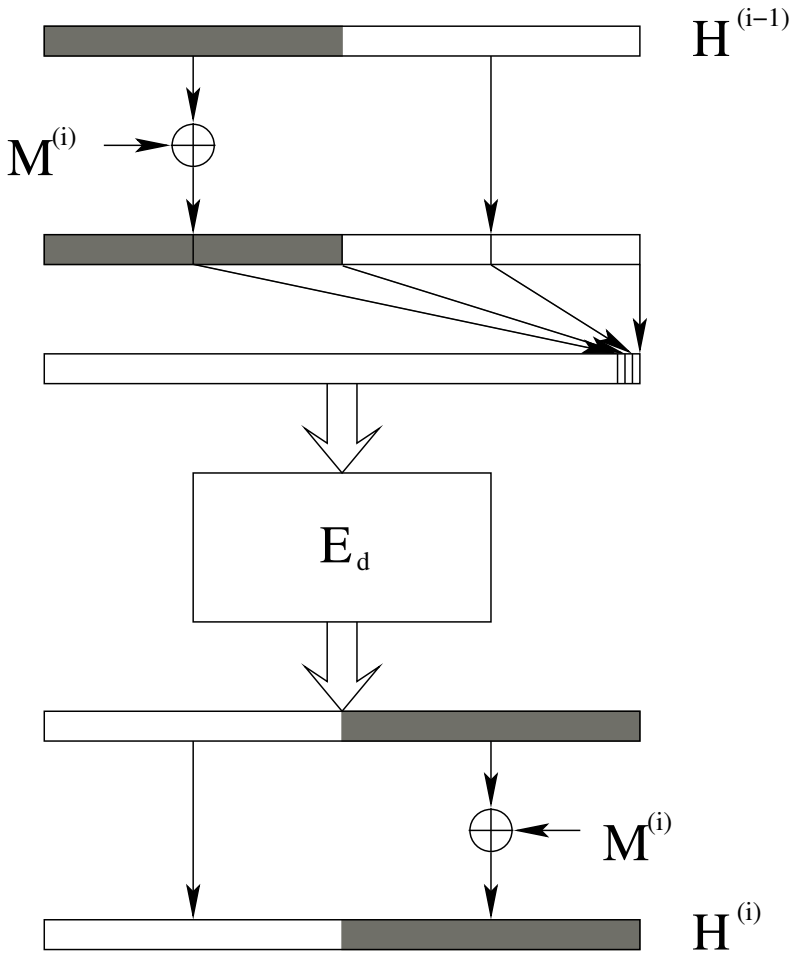

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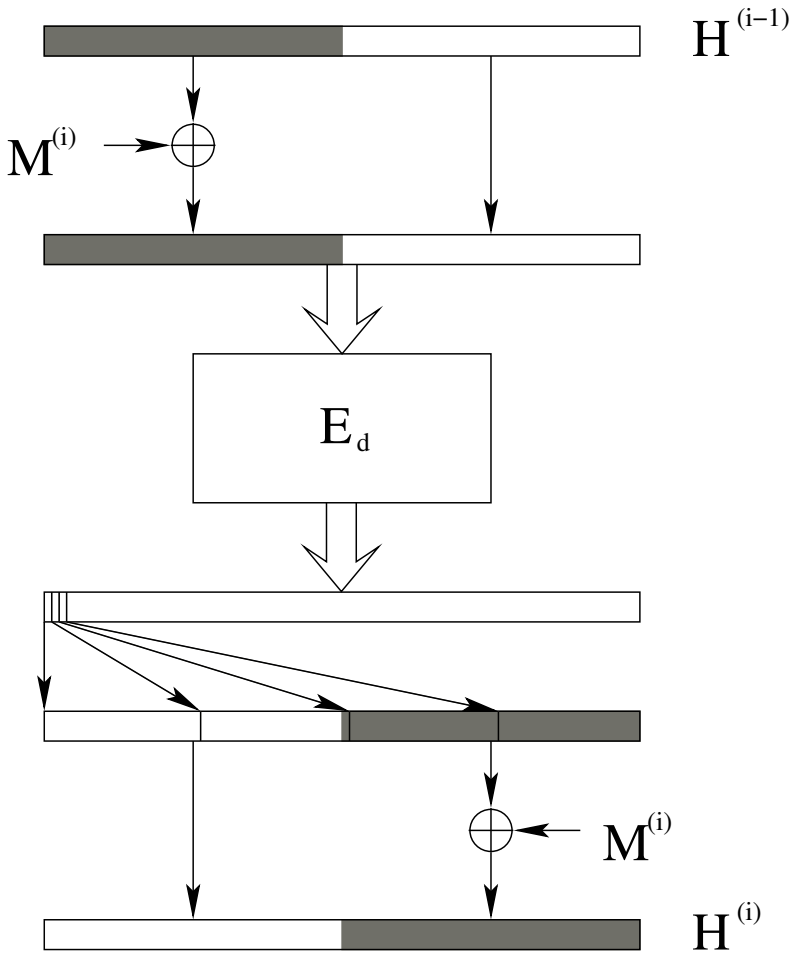

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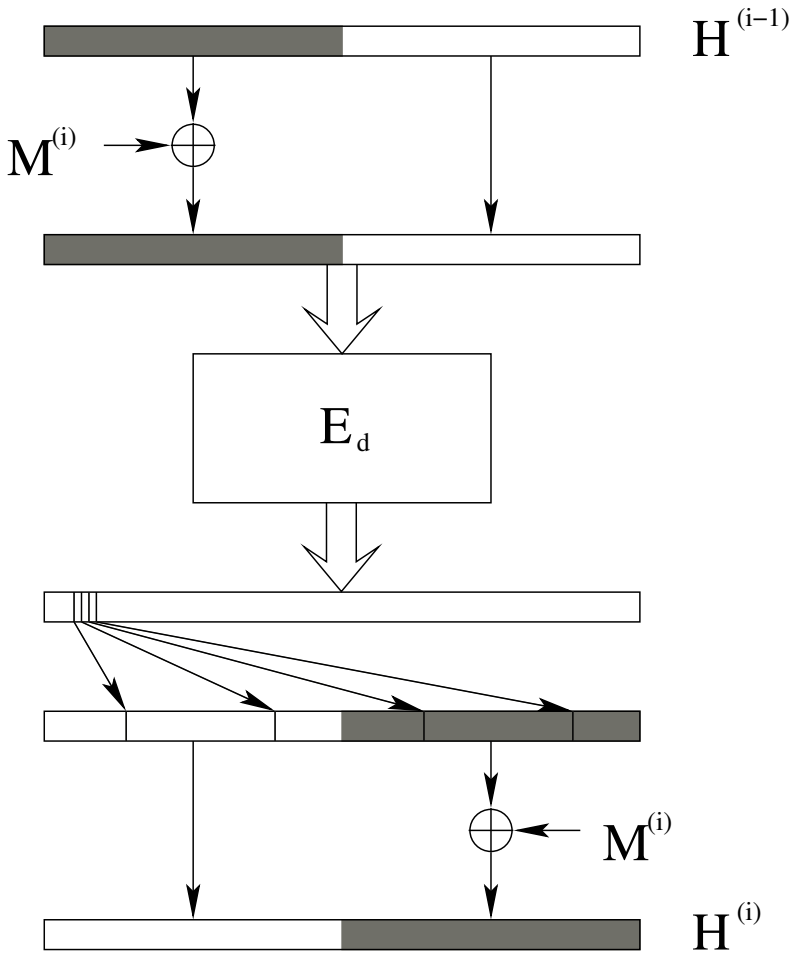

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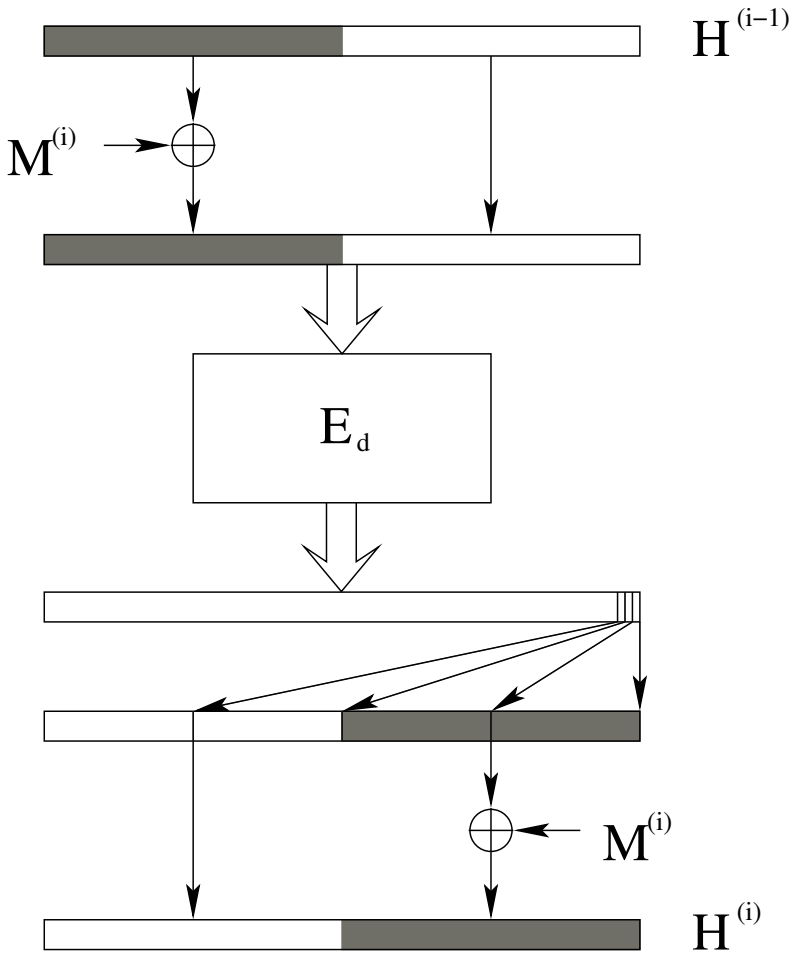
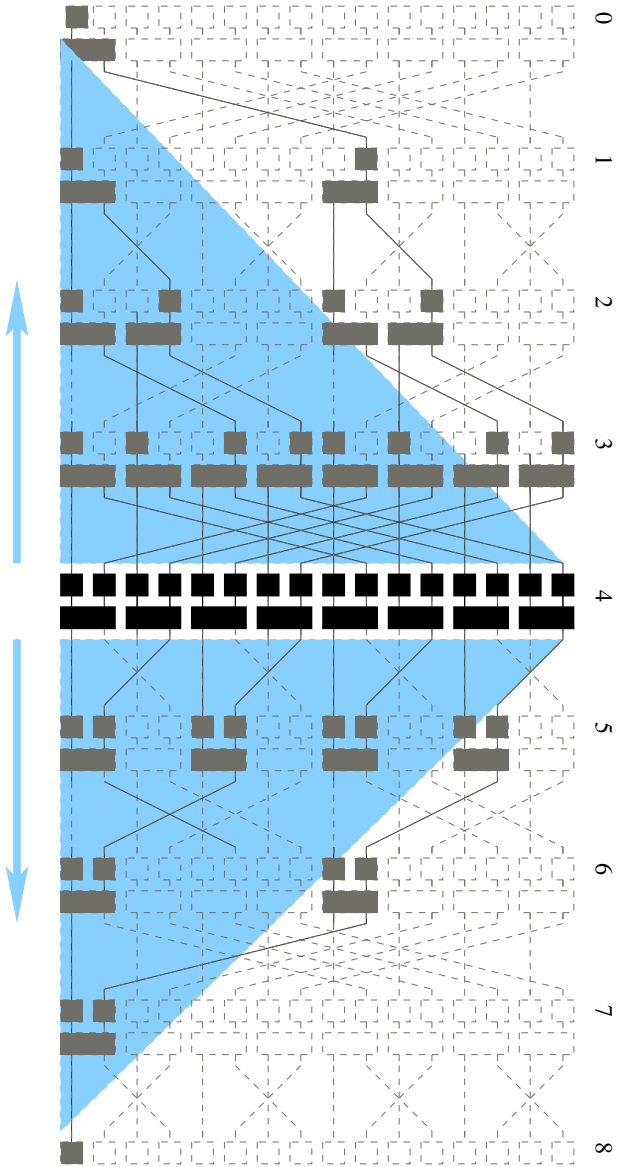


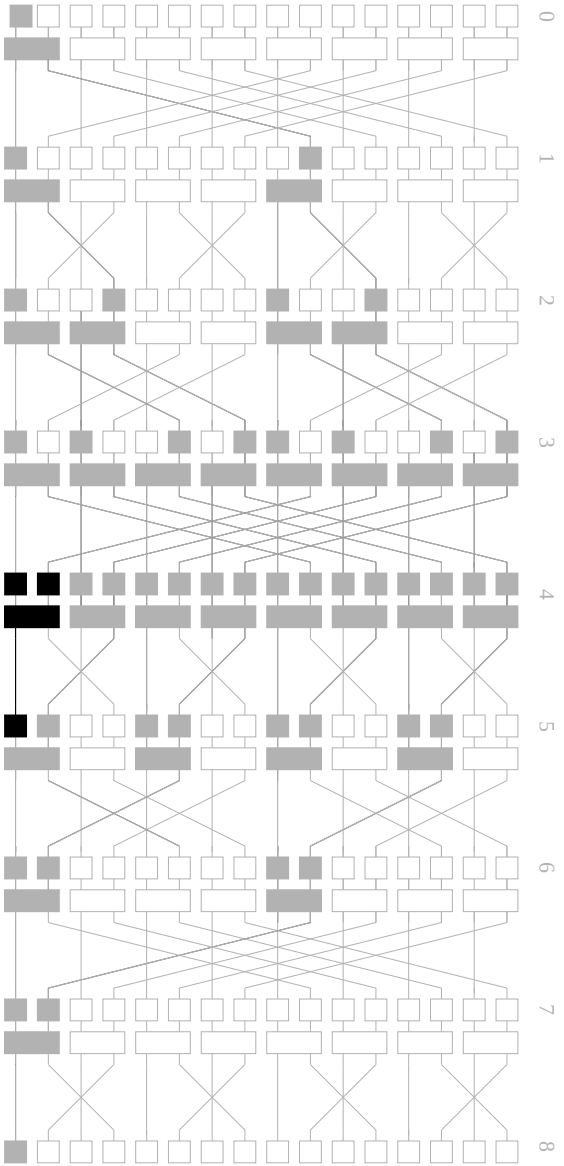
Outline

Overview of the Attack



- Attack is first implemented to small version of JH $d = 4$.
- Same technique applied to the submitted version of JH with $d = 8$.
- Semi-free-start collisions found for reduced number of rounds.
- To improve the attack, a semi-automatic code is used.

Constructing Differential Path on Round Function



- Try all possible values, keep only the ones that satisfy the desired pattern

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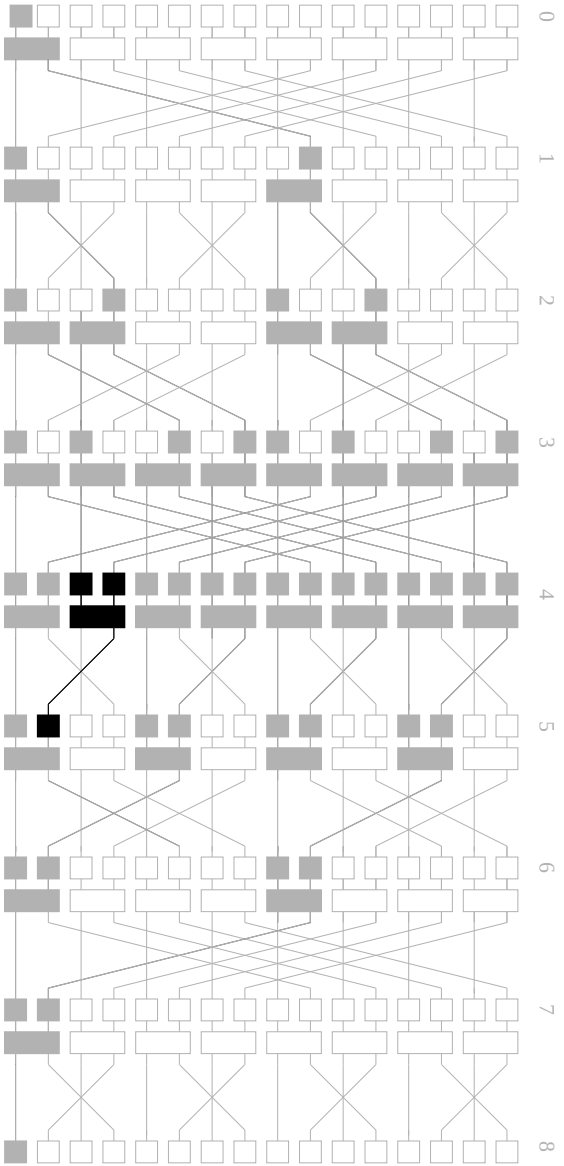

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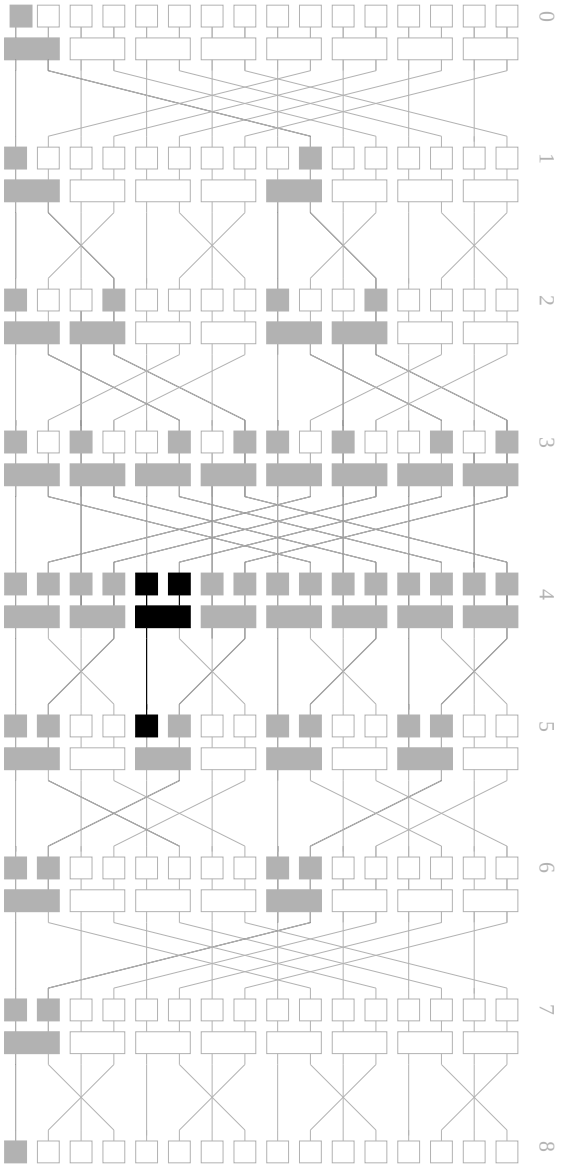

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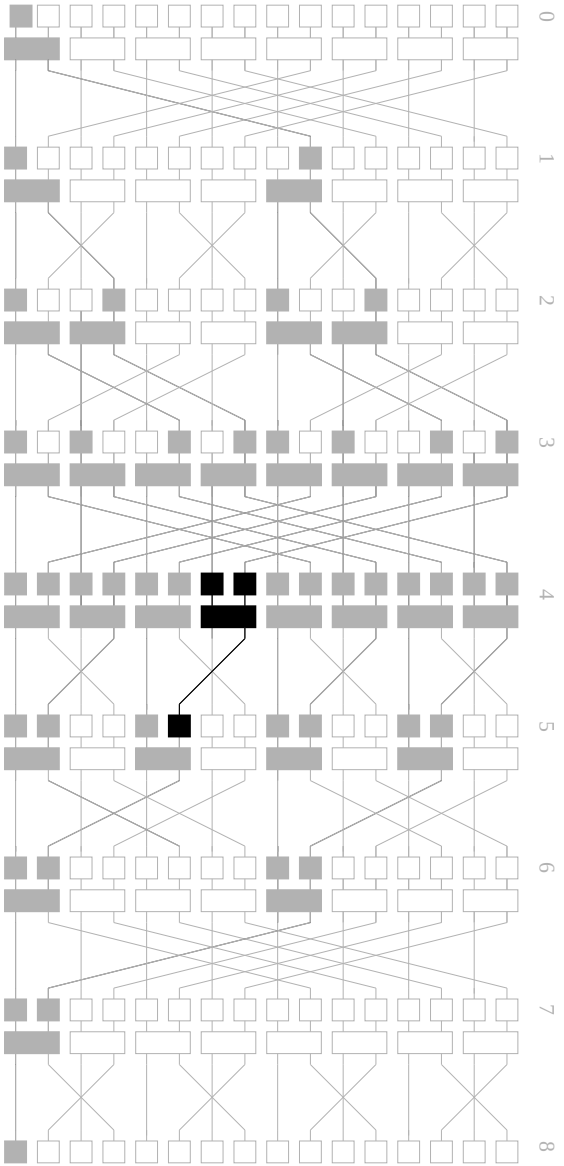

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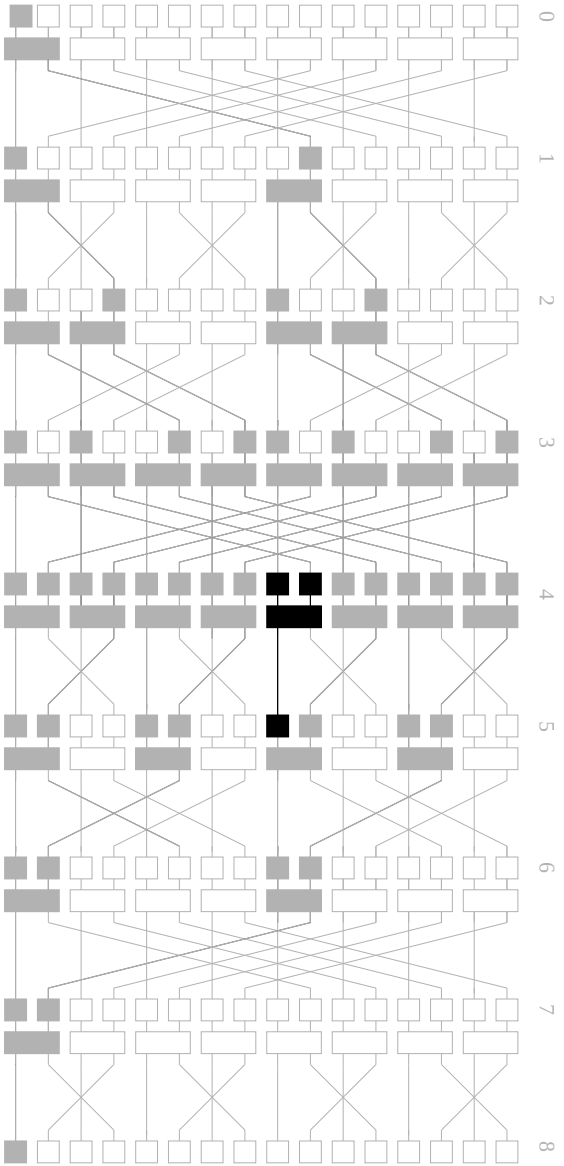

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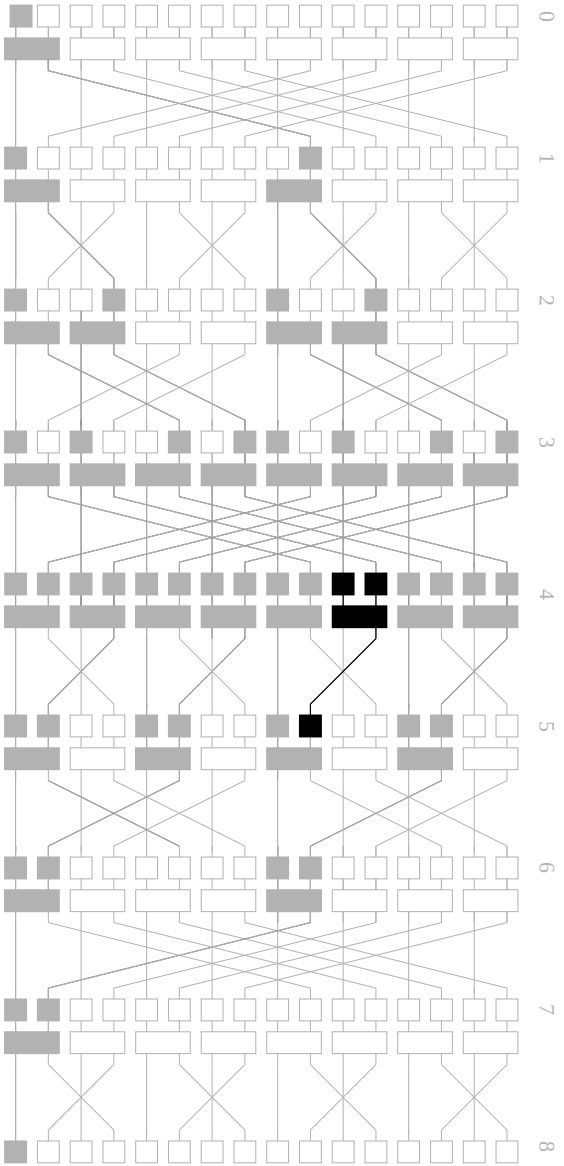

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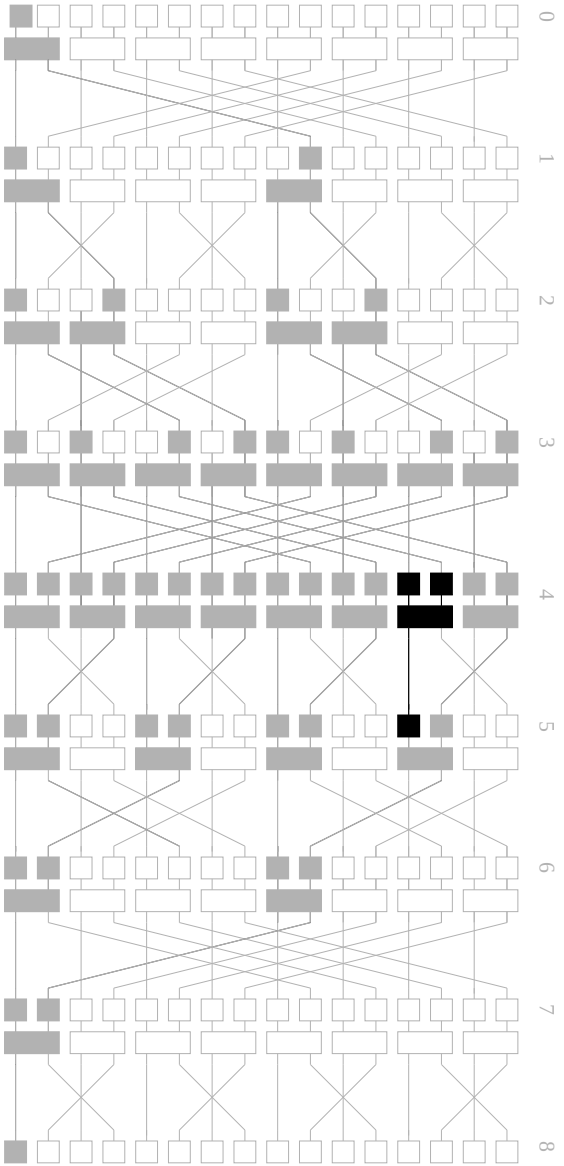

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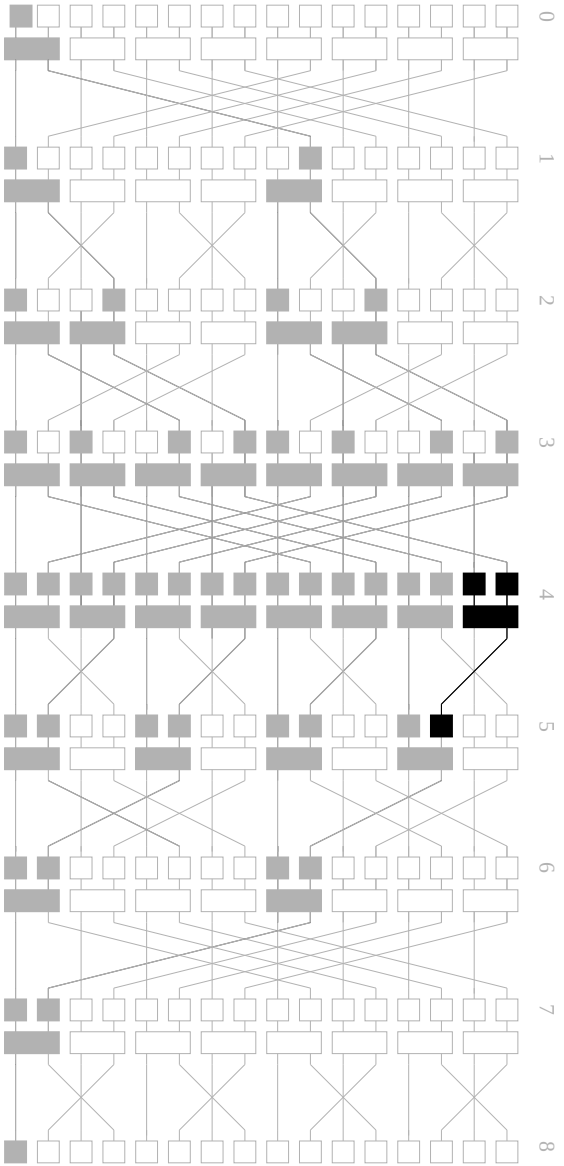

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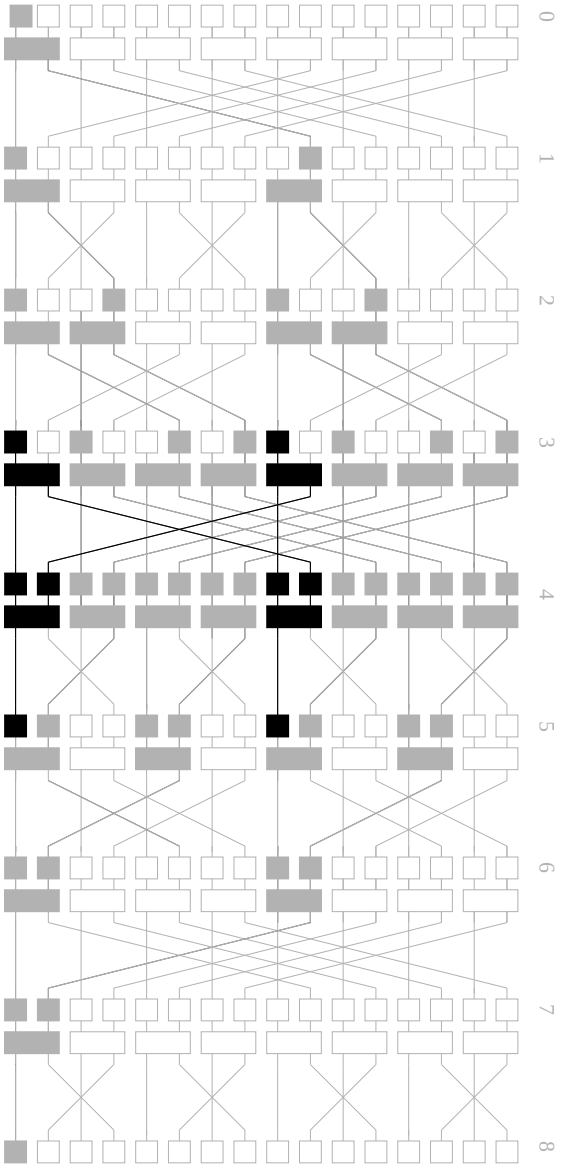

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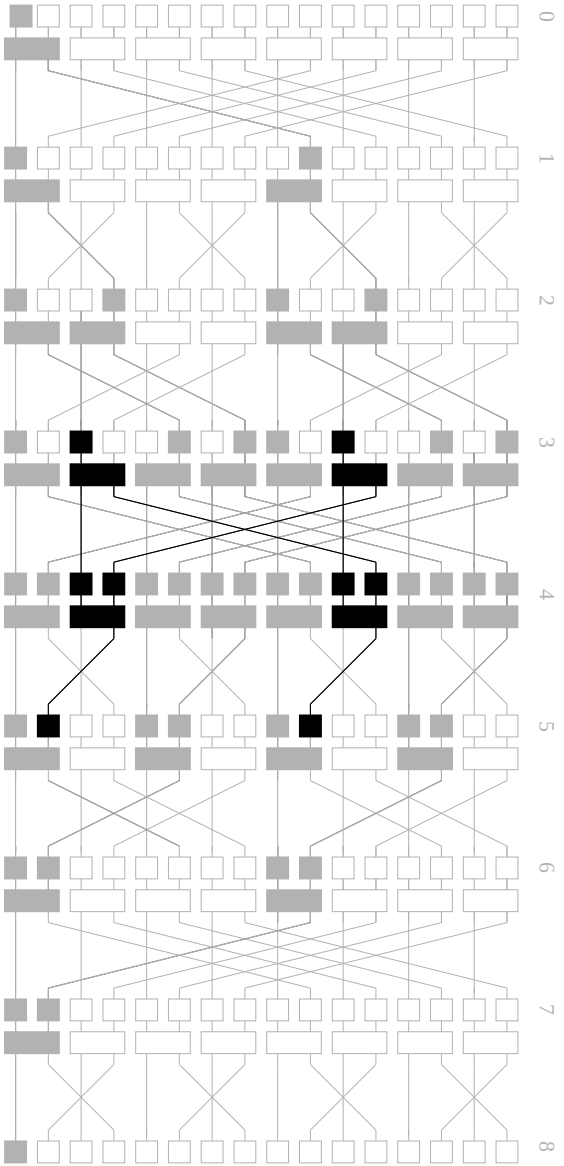

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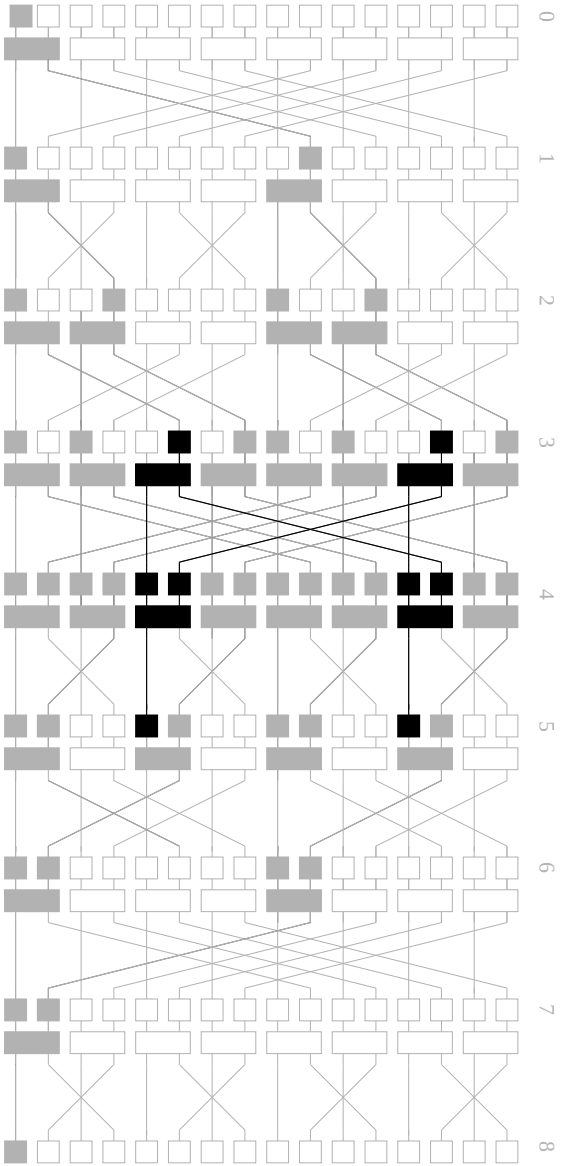

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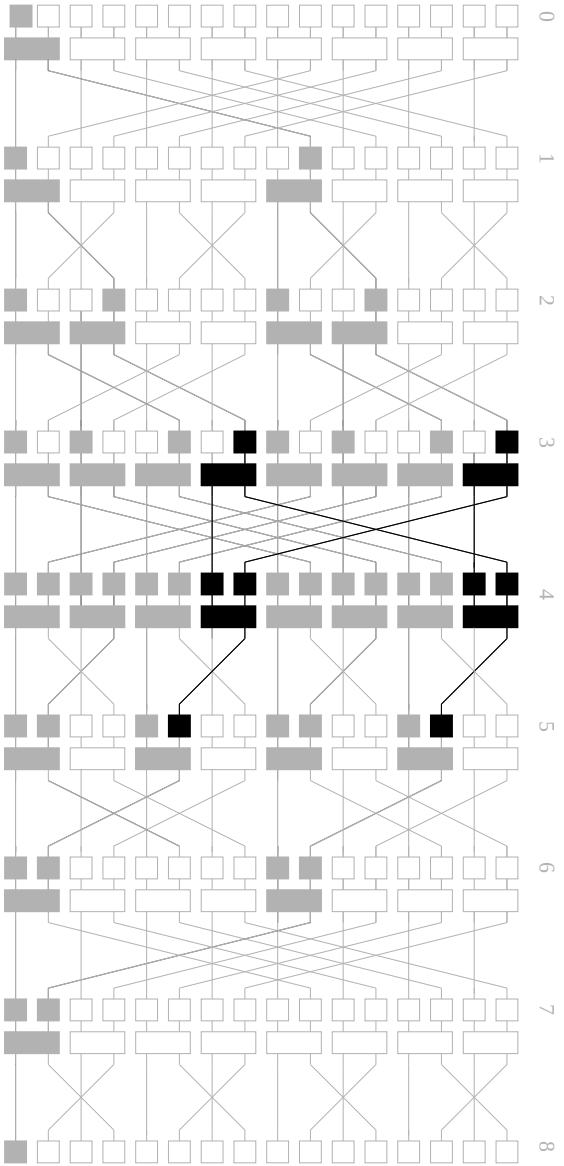

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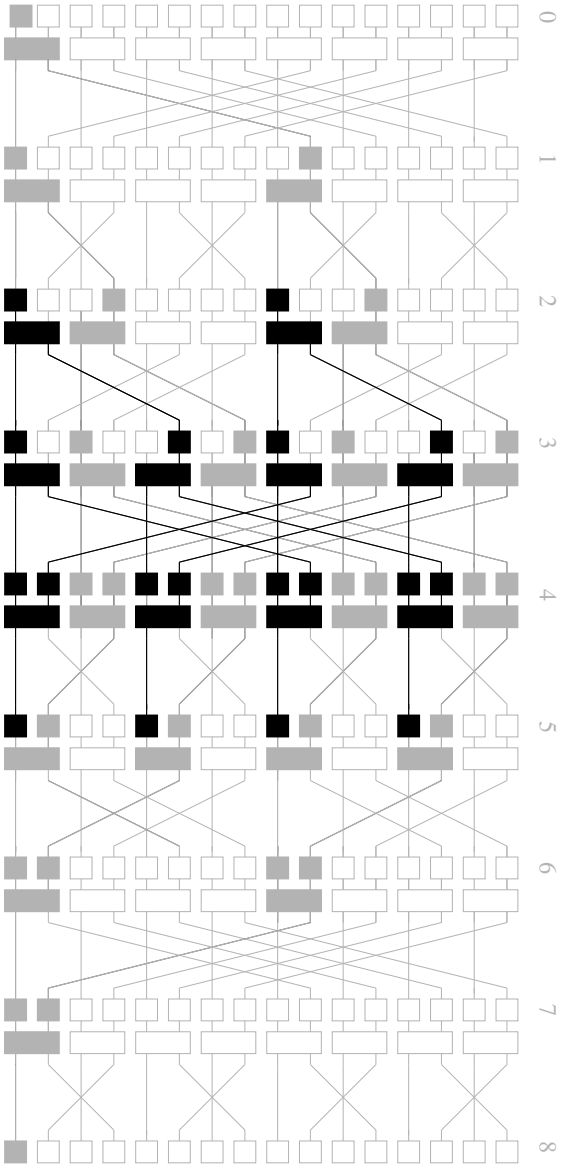

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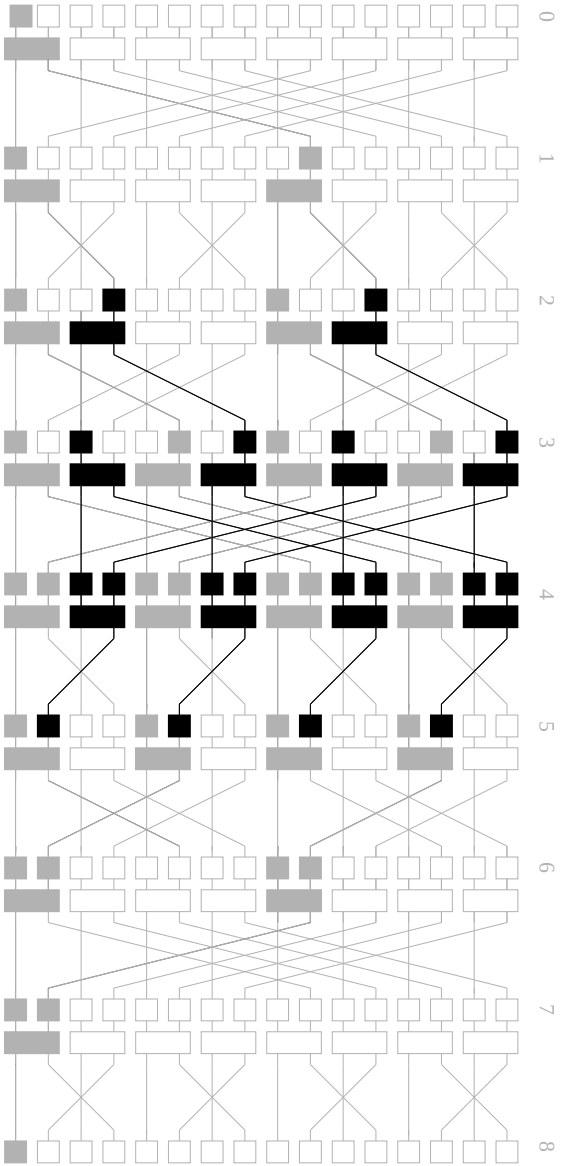

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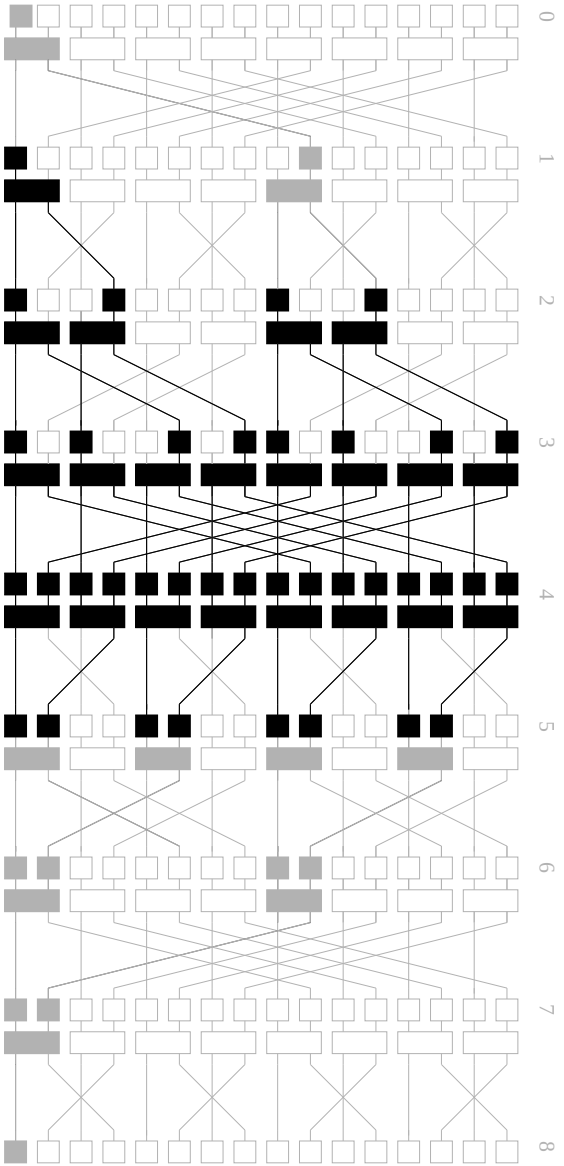

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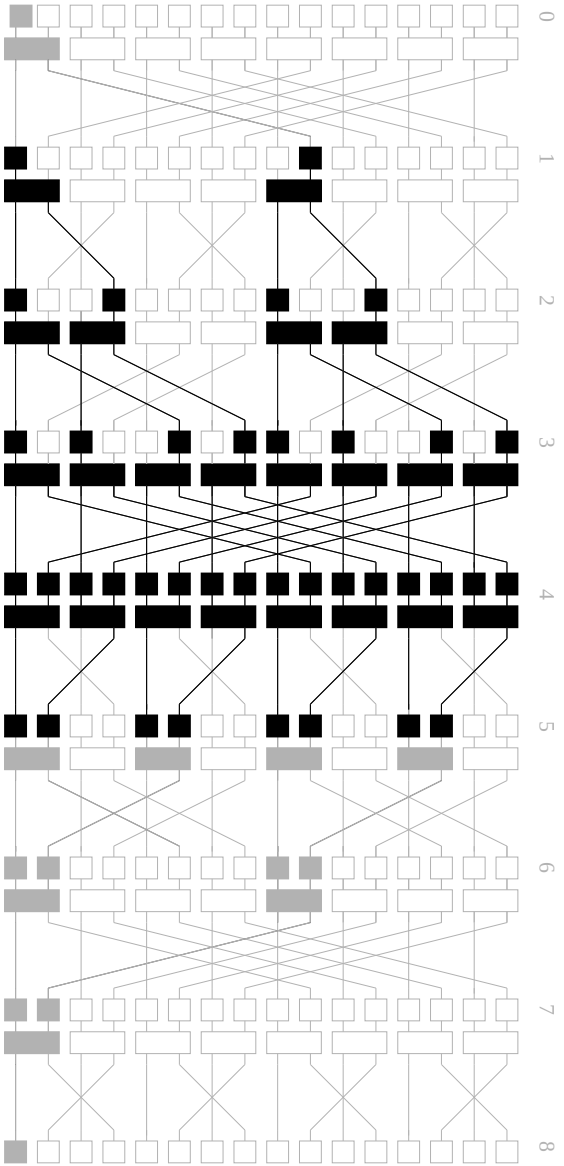

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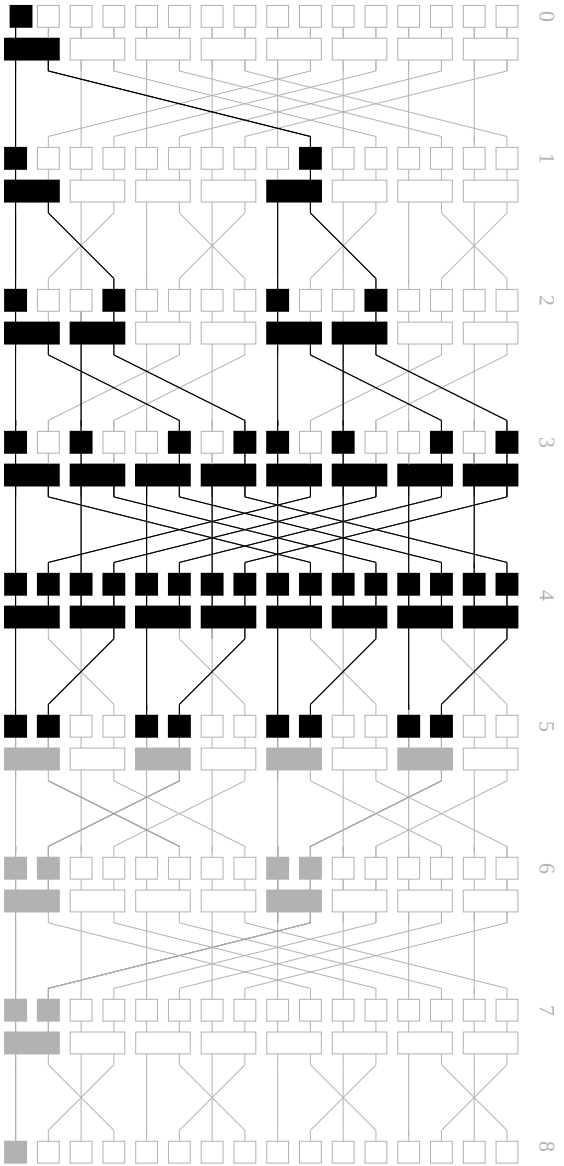

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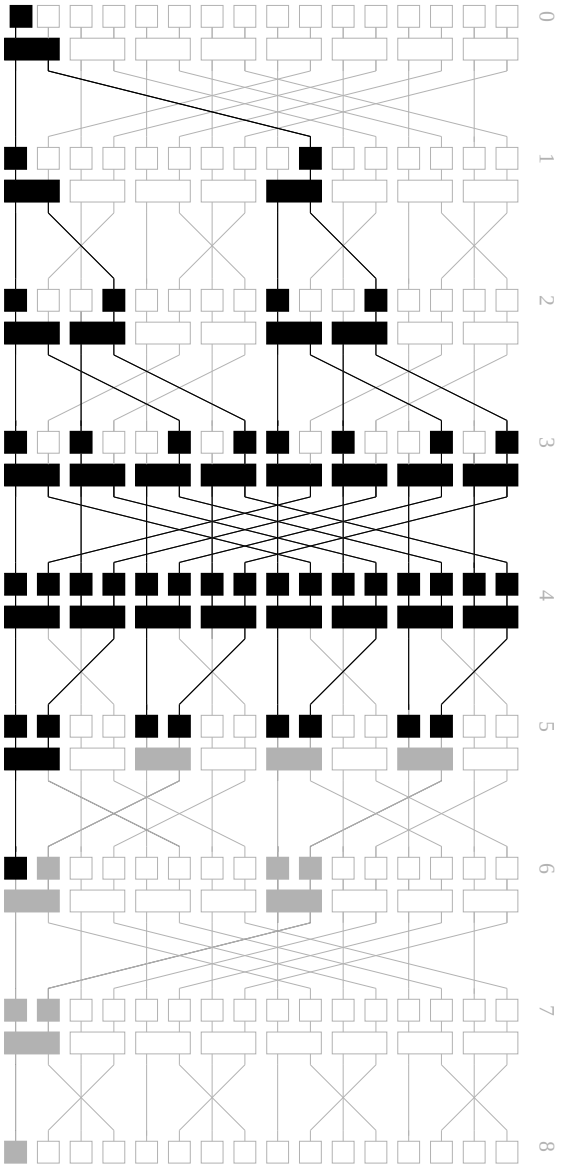

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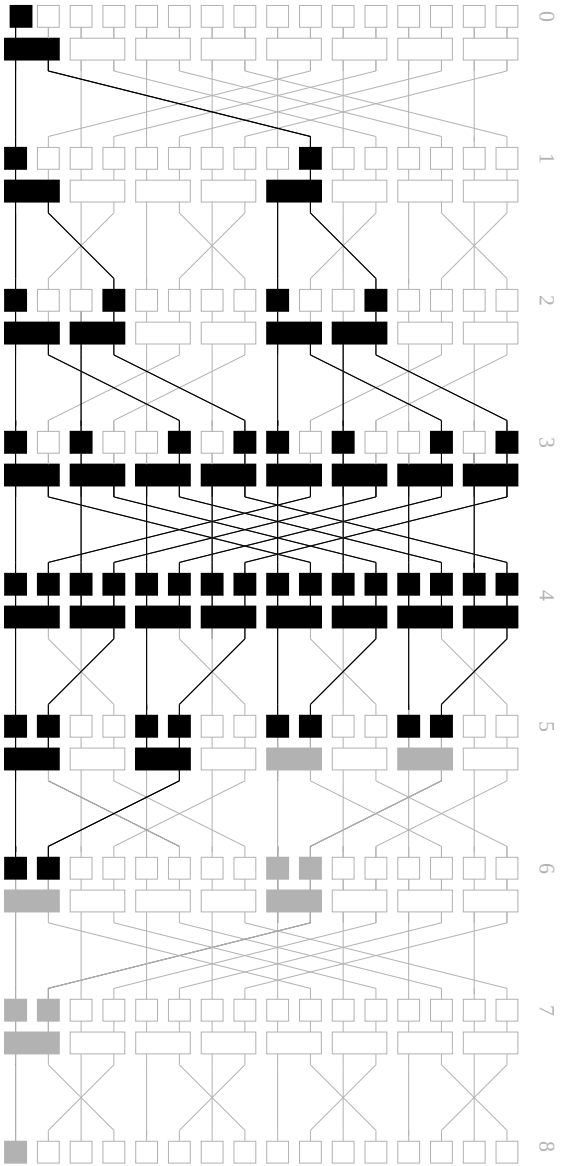

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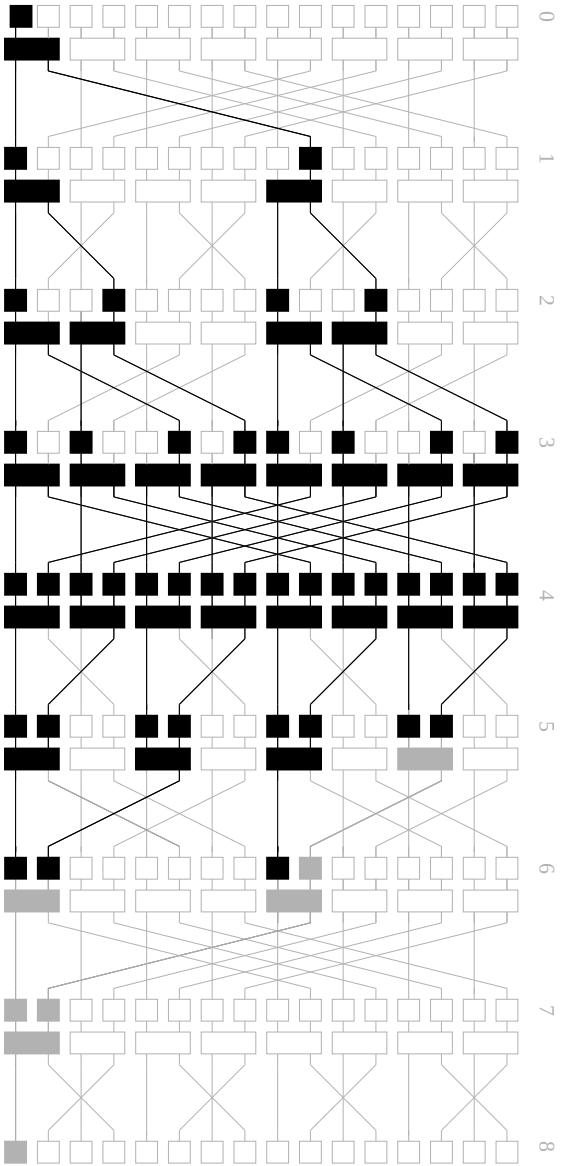

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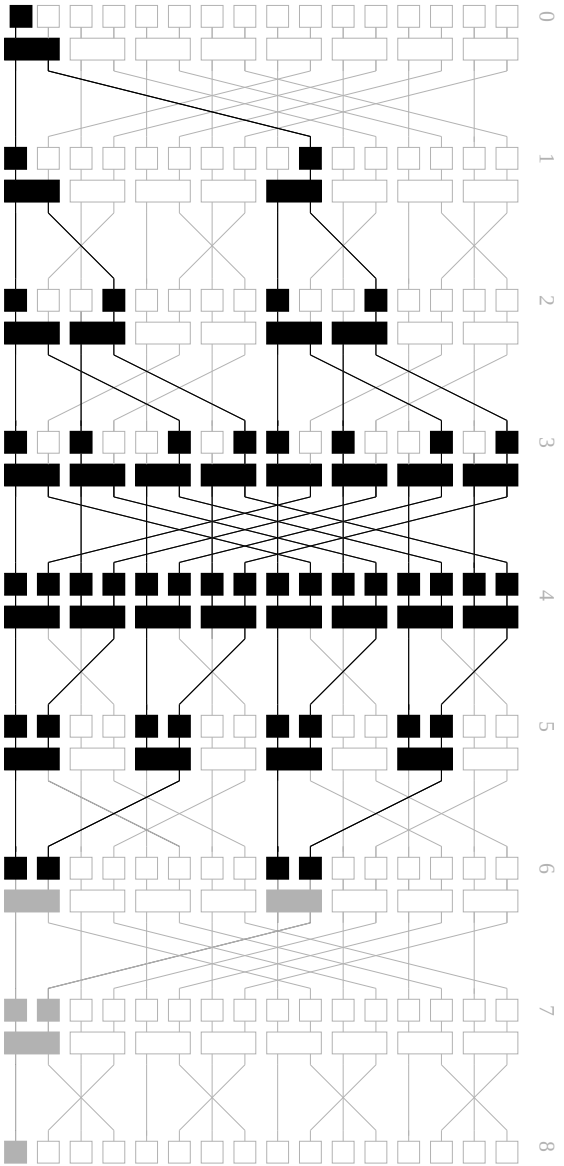

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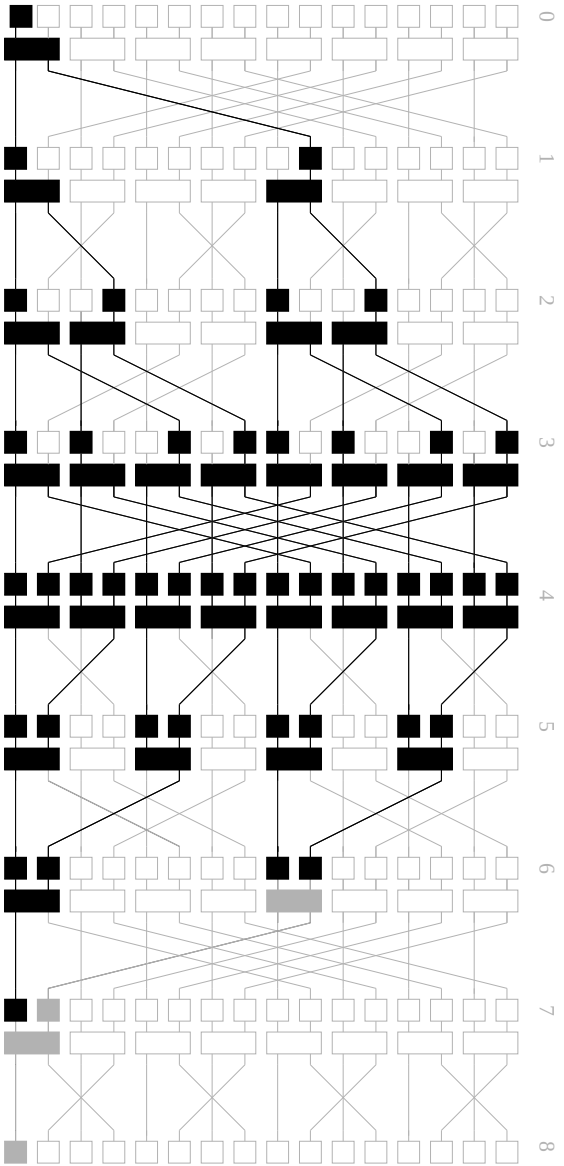

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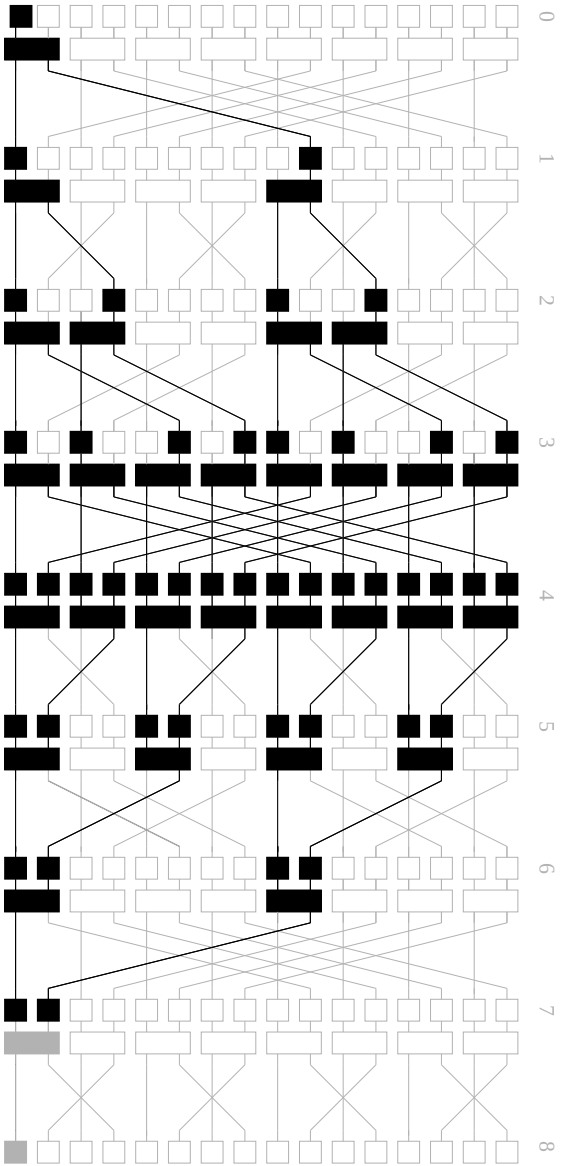

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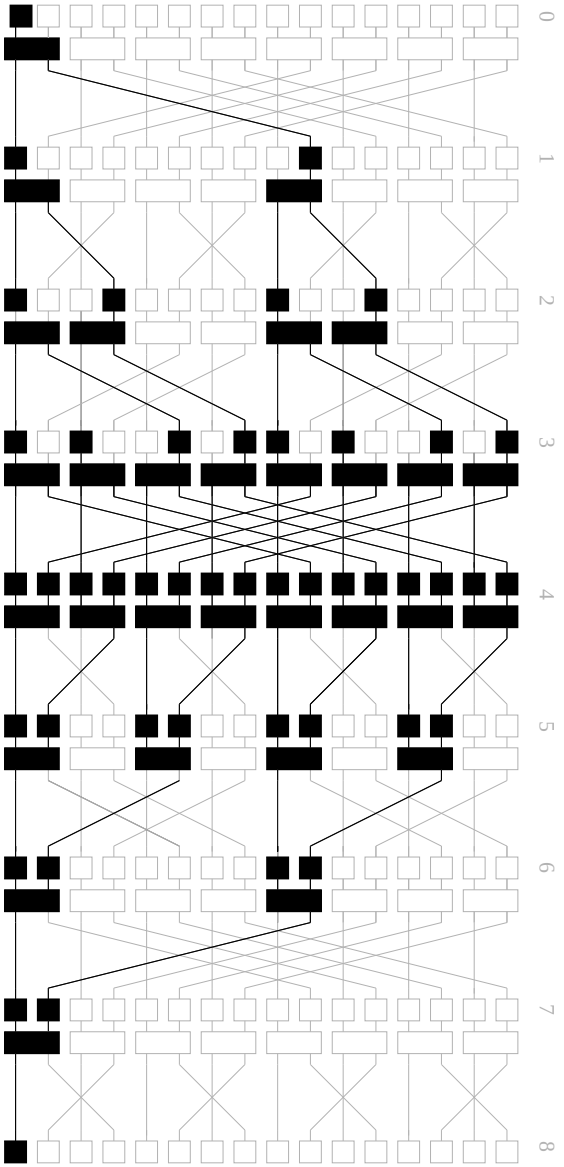

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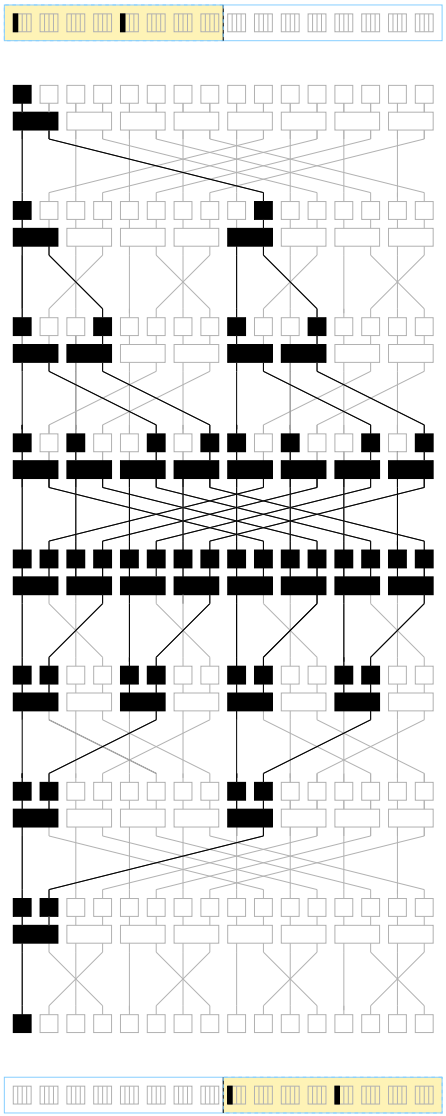
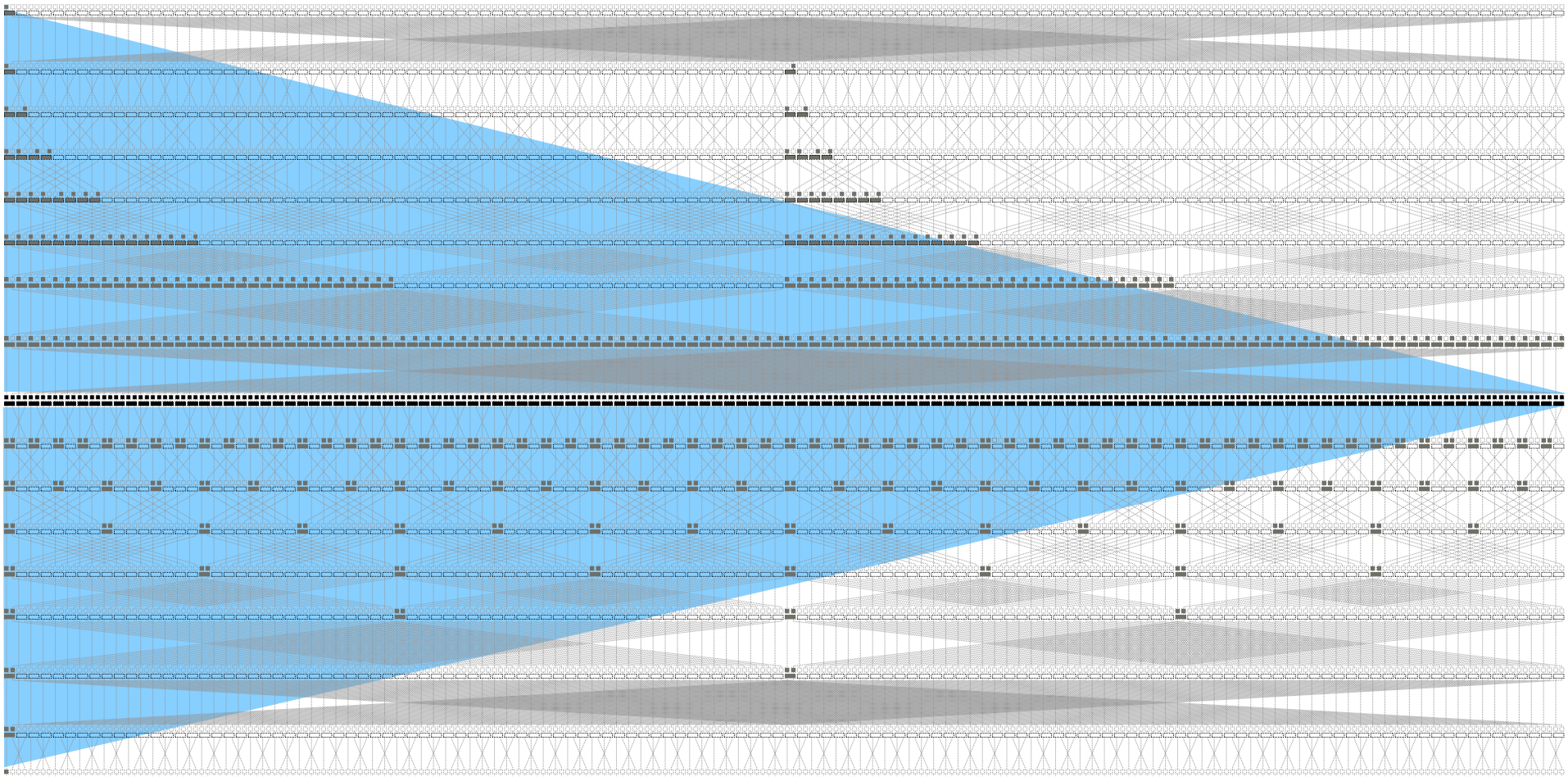
Grouping - De-grouping



- Combine all possible values, keep only the ones that satisfy the desired pattern
- Compute the cross-product of the shown sets and check if the differences satisfy the filtering conditions.
- Expand the sets by computing the cross-product the highlighted sets.
- Compute the cross-product of last two sets and check whether remaining 10 filtering conditions satisfy or not.
- Calculate the differences through grouping and de-grouping part.

Attack on JH $d = 8$

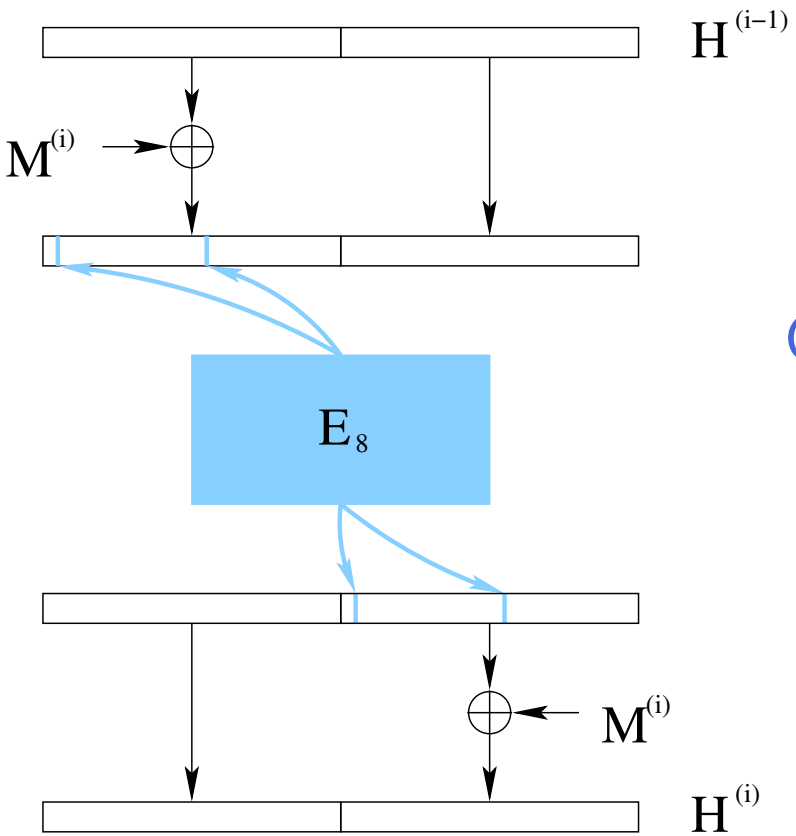


Attack on JH $d = 8$

Table: The overview of the attack on Round Function

Step	Size (bits)	Sets	Filtering Conditions	Pairs Remain	Time Complexity	Direction
0	8	128	1	$2^{11.75}$	$2^{15.84}$	*fwd*
1	16	64	1	$2^{19.59}$	$2^{23.50}$	*bck*
2	32	32	4	$2^{23.54}$	$2^{39.18}$	*fwd*
3	64	16	4	$2^{31.44}$	$2^{47.08}$	*fwd*
4	128	8	4	$2^{47.24}$	$2^{62.88}$	*fwd*
5	256	4	8	$2^{63.20}$	$2^{94.48}$	*fwd*
6	512	2	8	$2^{95.12}$	$2^{124.40}$	*fwd*
7	1024	1	46	$2^{10.38}$	$2^{190.24}$	*fwd* + *bck*

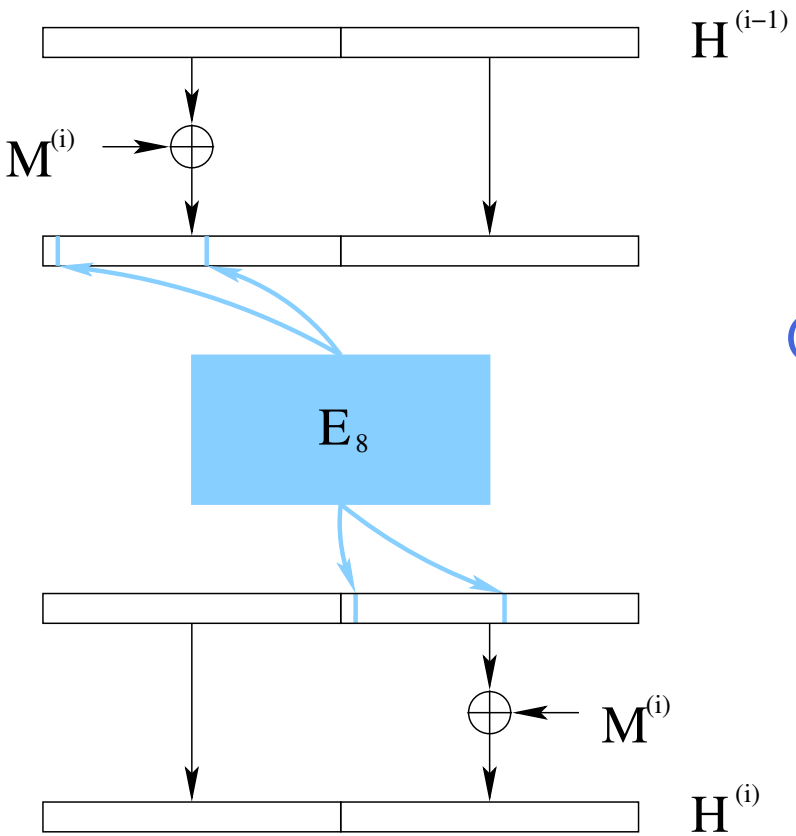
Attack on JH $d = 8$



Grouping and degrouping

- $2^{10.38} \cdot 2^{-1} \cdot (3/15)^2$
-

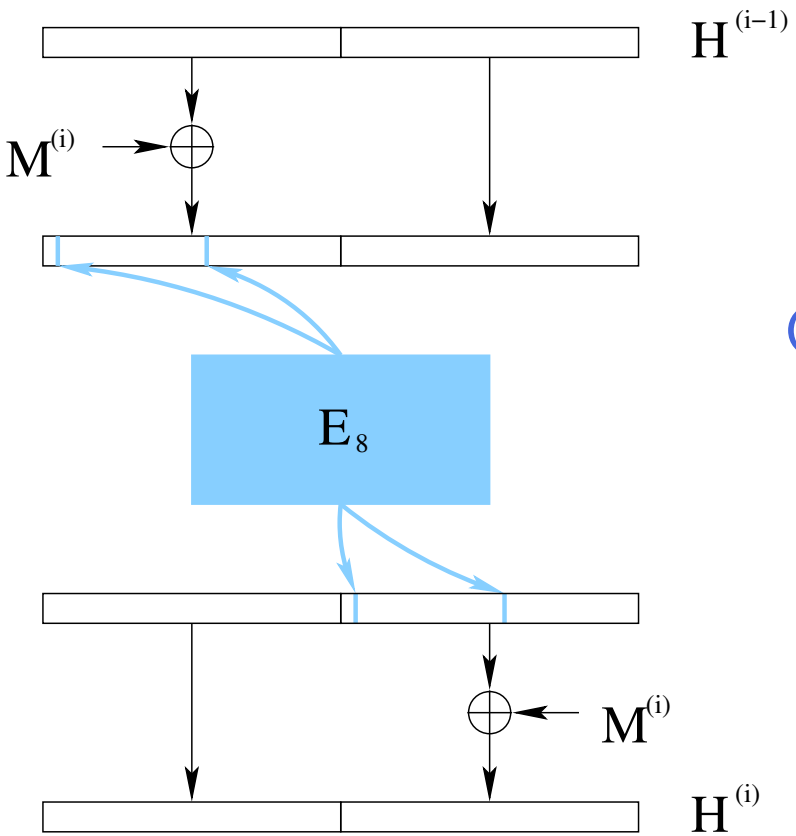
Attack on JH $d = 8$



Grouping and degrouping

- $2^{10.38} \cdot 2^{-1} \cdot (2^{-2.32})^2 \simeq 2^{4.74}$
-

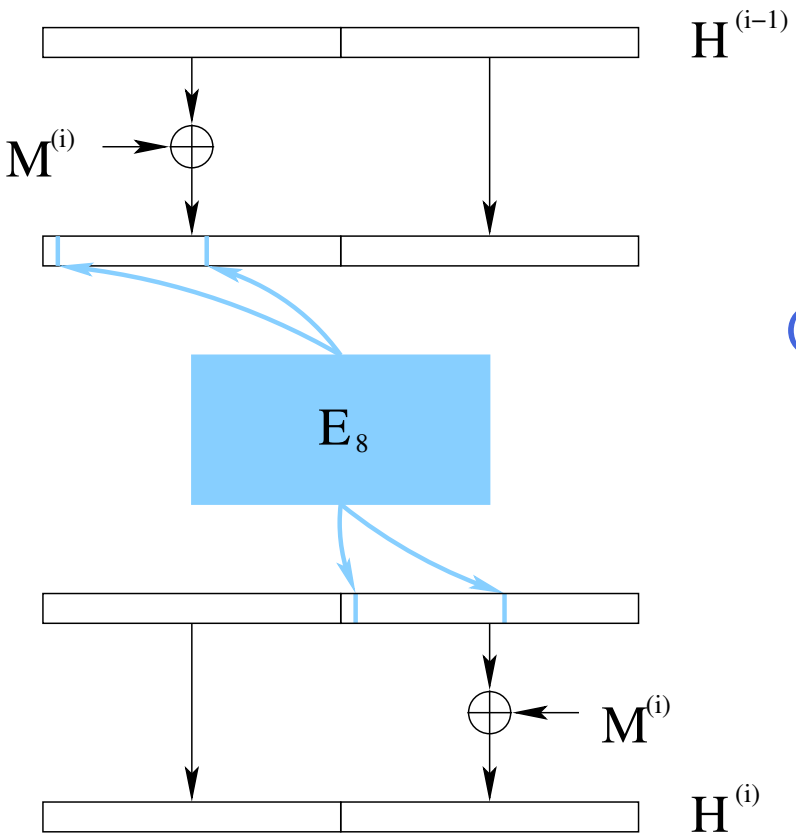
Attack on JH $d = 8$



Grouping and degrouping

- $2^{10.38} \cdot 2^{-1} \cdot (2^{-2.32})^2 \simeq 2^{4.74}$
- $2^{4.74} \cdot (1/3)$

Attack on JH $d = 8$

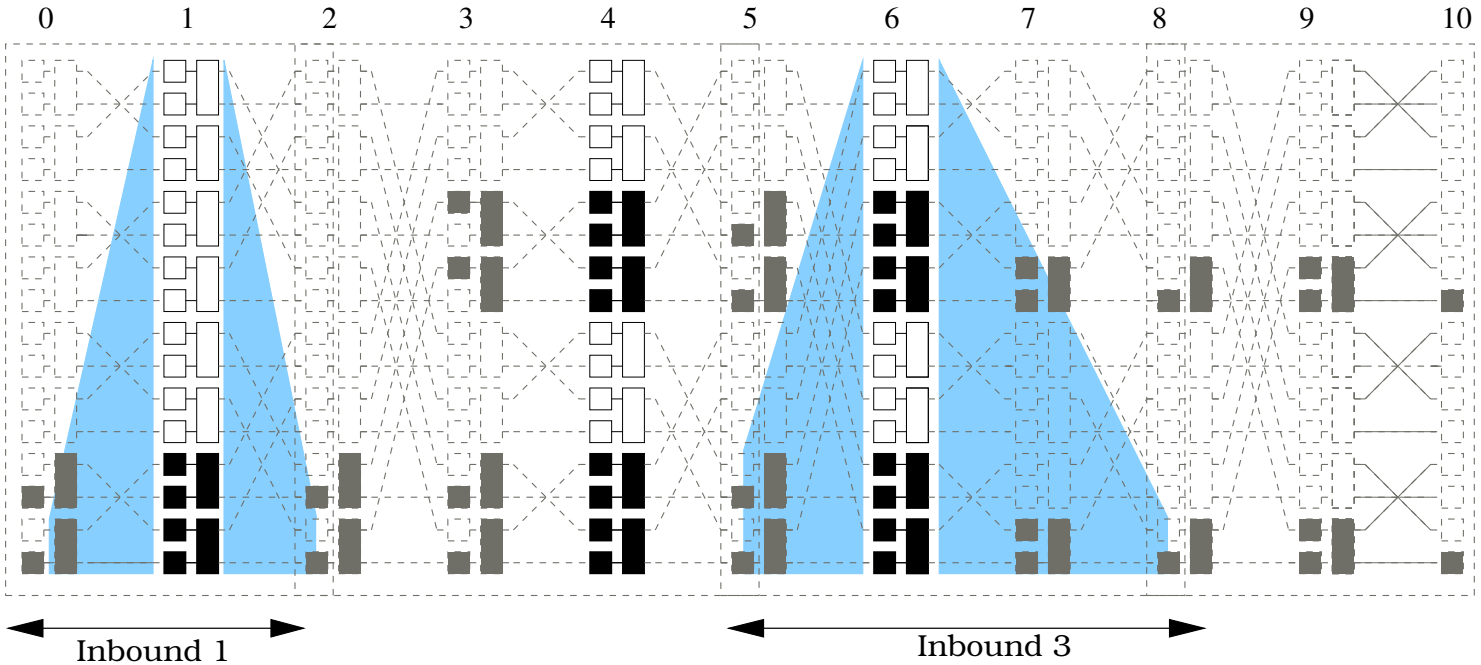


Grouping and degrouping

- $2^{10.38} \cdot 2^{-1} \cdot (2^{-2.32})^2 \simeq 2^{4.74}$
- $2^{4.74} \cdot (2^{-1.59}) \simeq 2^{3.15}$

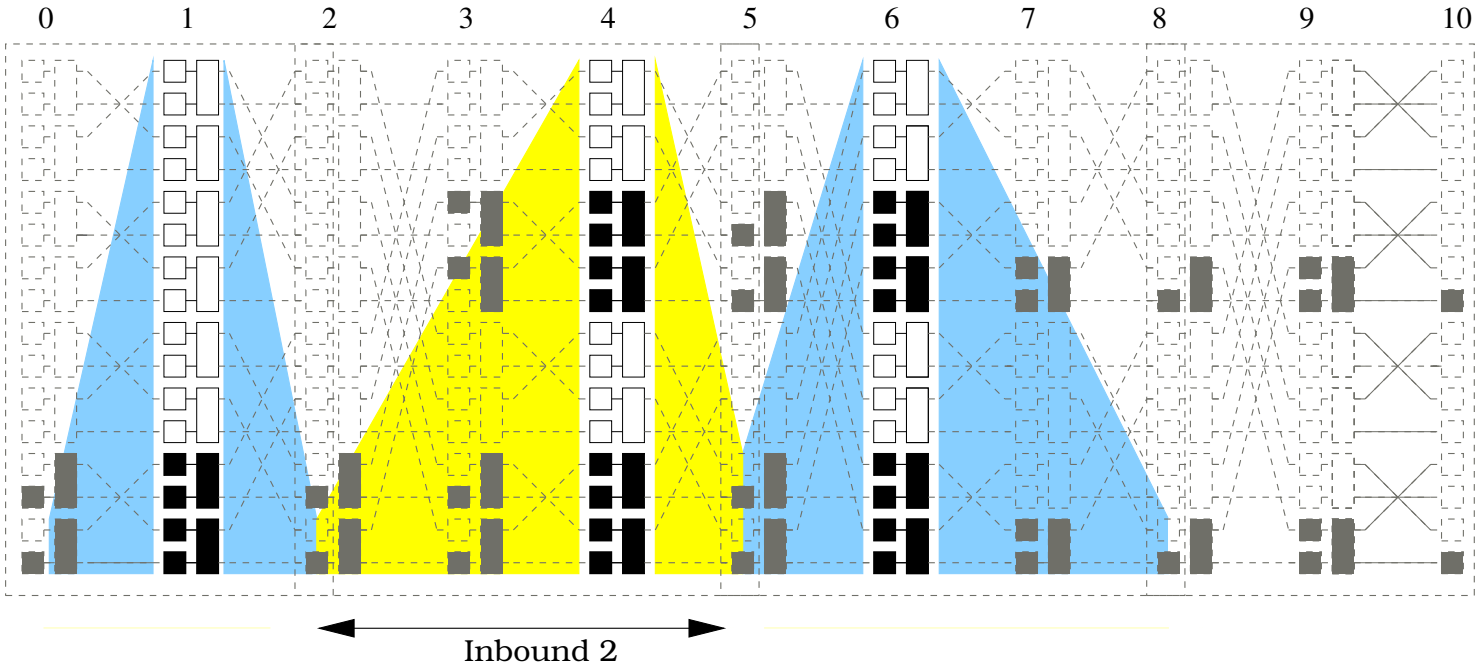
Outline

Overview of the Attack



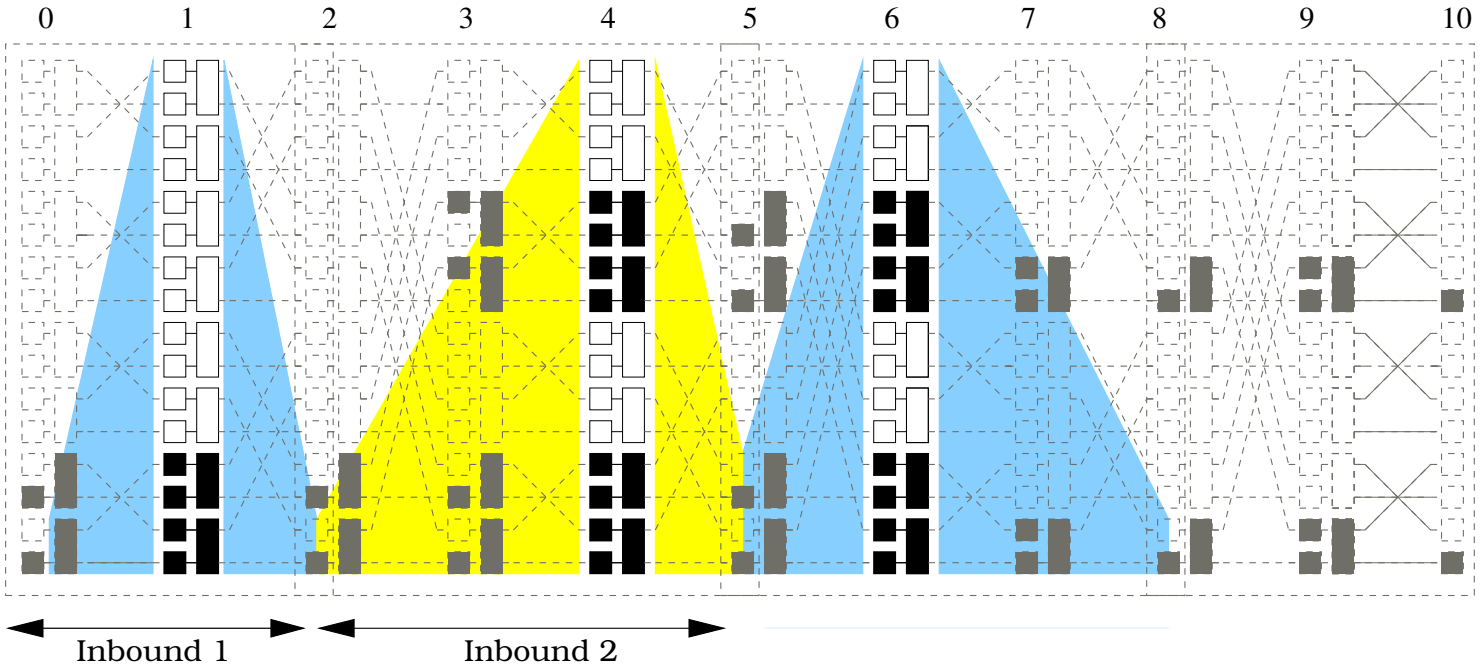
- Compute the first and the third inbound phases

Overview of the Attack



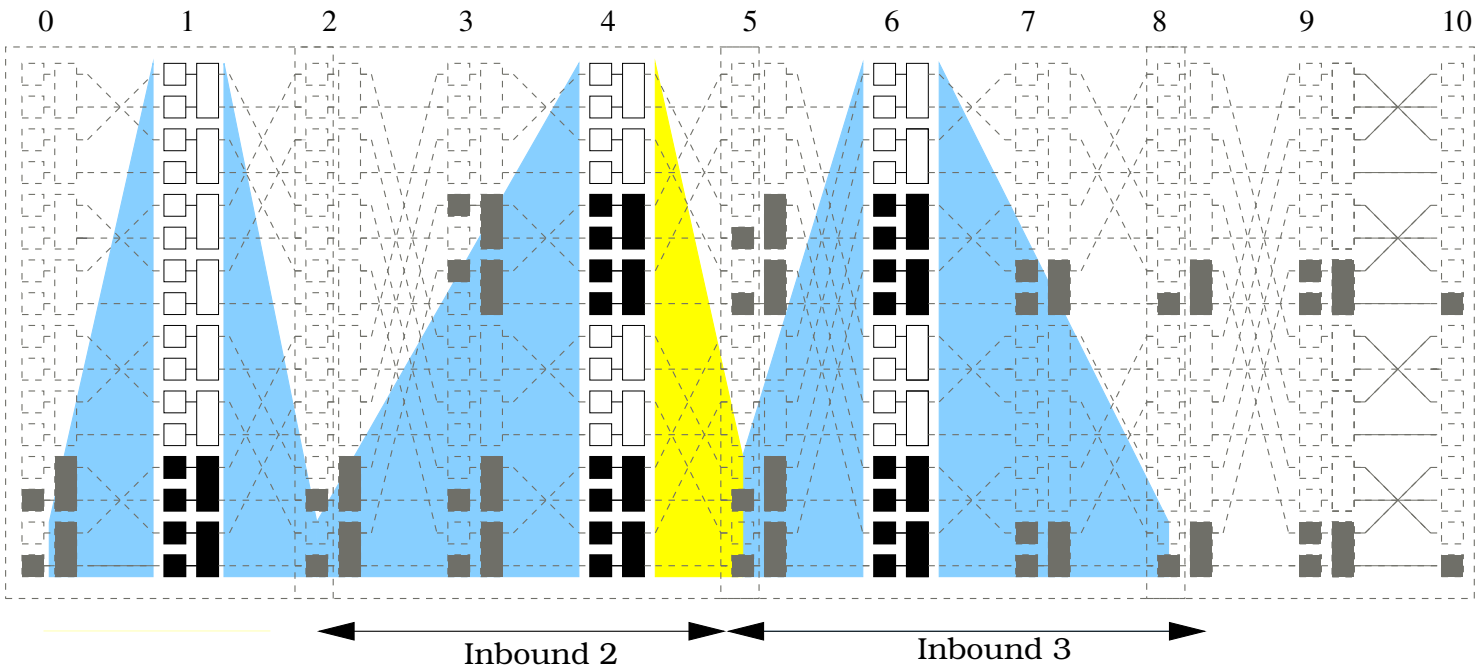
- Compute the first and the third inbound phases
- Compute the second inbound phase

Overview of the Attack



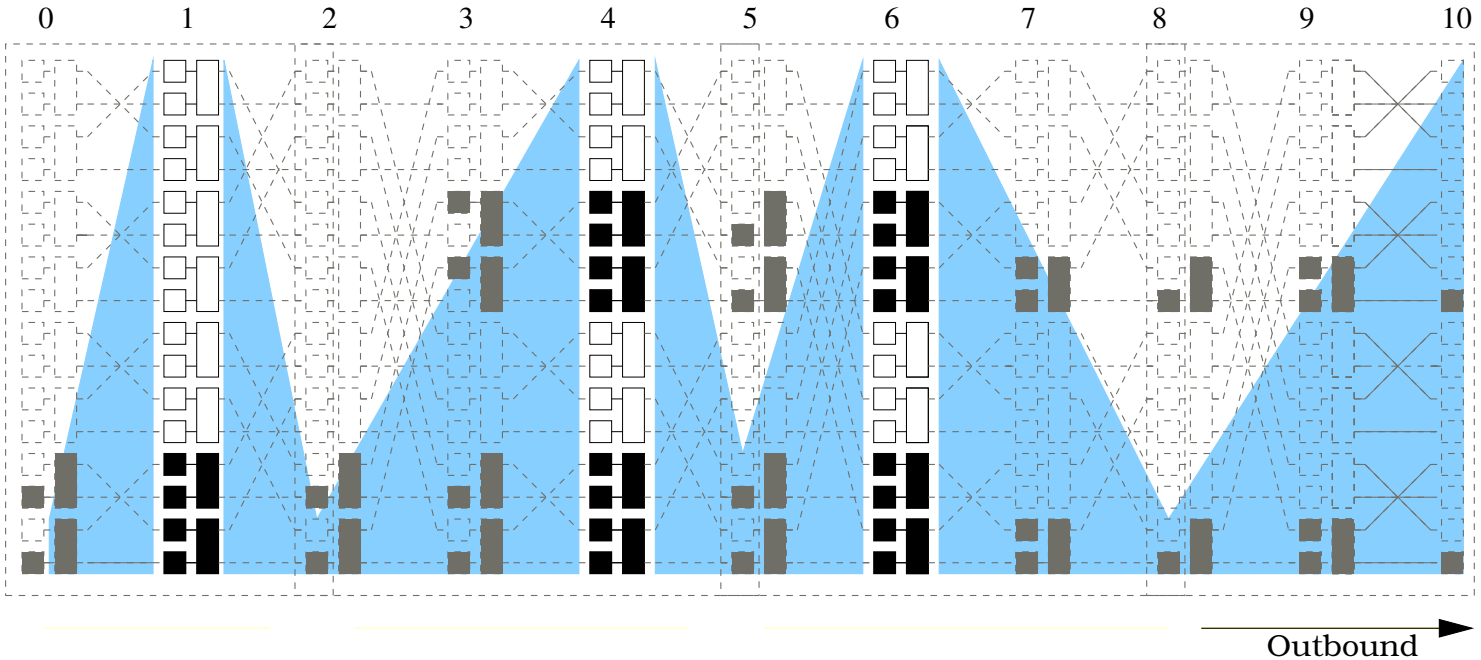
- Compute the first and the third inbound phases
- Compute the second inbound phase
- Merge the first and the second inbound phases

Overview of the Attack



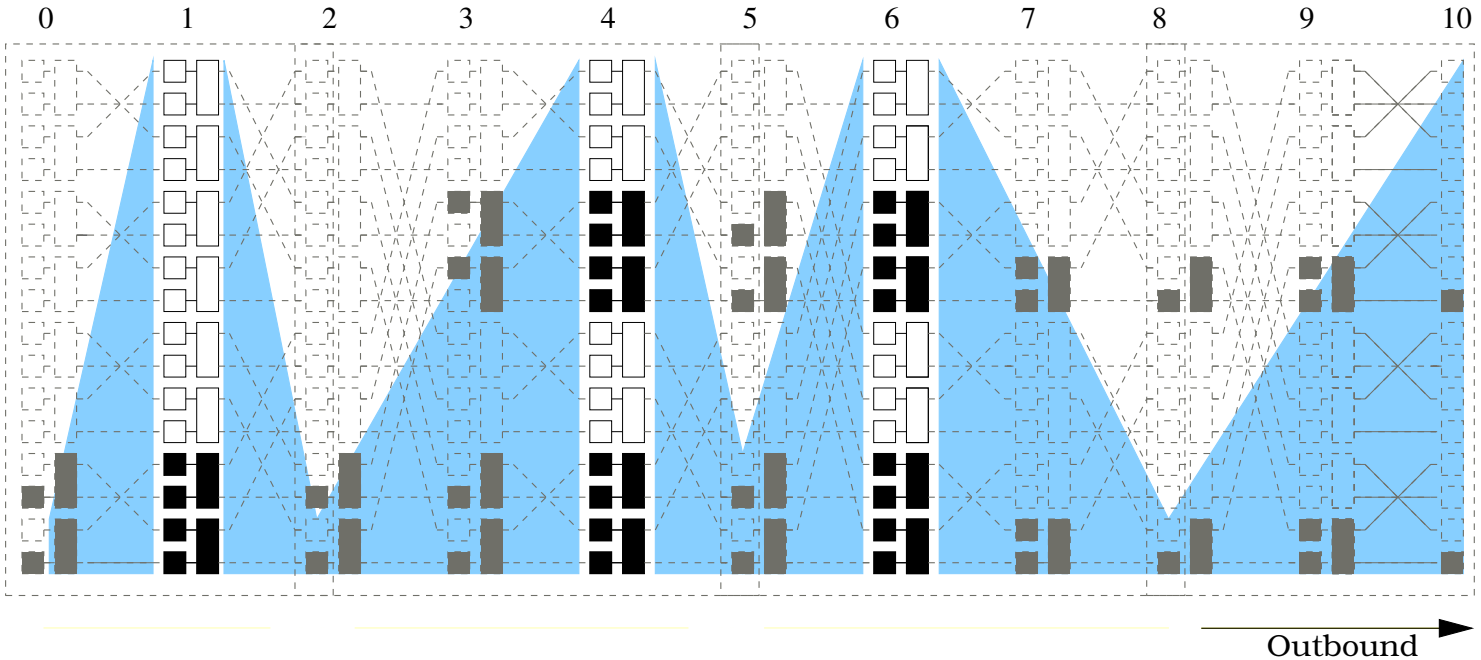
- Compute the first and the third inbound phases
- Compute the second inbound phase
- Merge the first and the second inbound phases
- Merge the second and the third inbound phases

Overview of the Attack



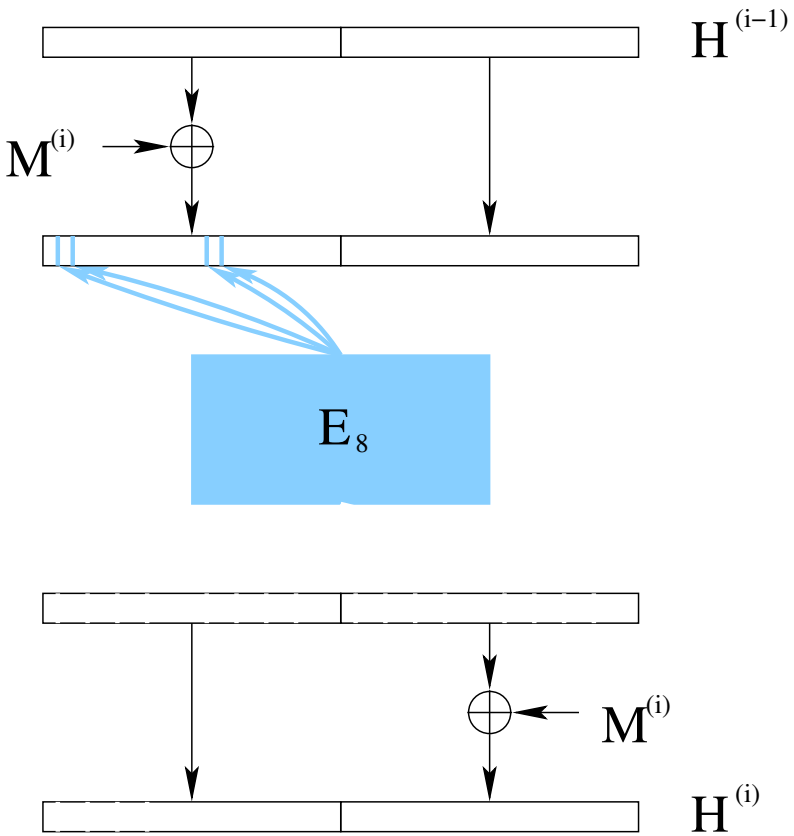
- Compute the first and the third inbound phases
- Compute the second inbound phase
- Merge the first and the second inbound phases
- Merge the second and the third inbound phases
- Compute the outbound phase

Overview of the Attack



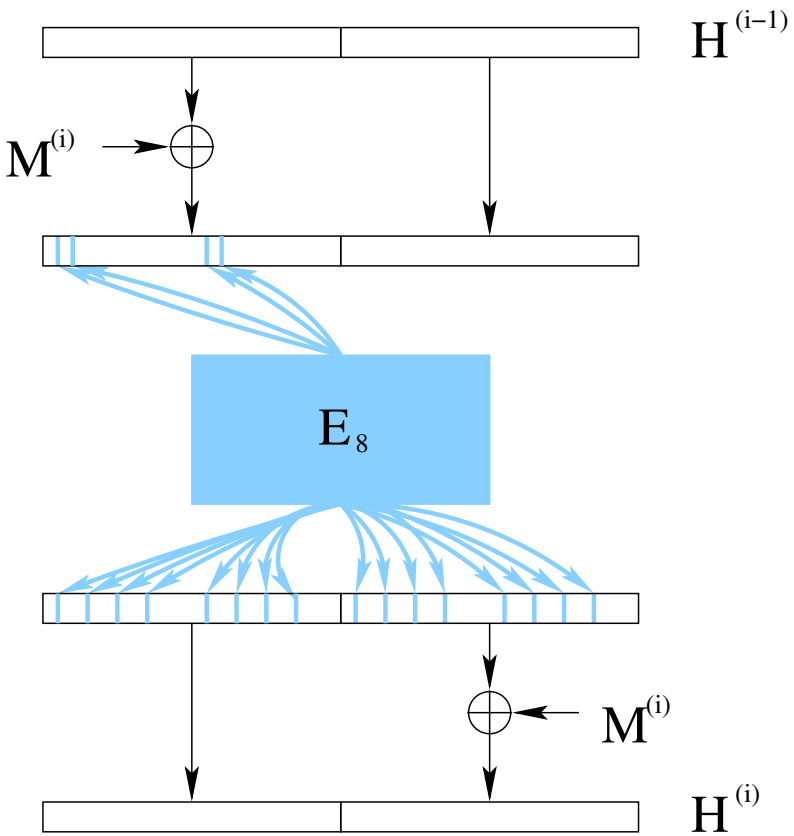
- Compute the first and the third inbound phases
- Compute the second inbound phase
- Merge the first and the second inbound phases
- Merge the second and the third inbound phases
- Compute the outbound phase
- **Result:** Reduced round semi-free-start near-collisions on the compression function of *JH*

Attack on JH $d = 8$



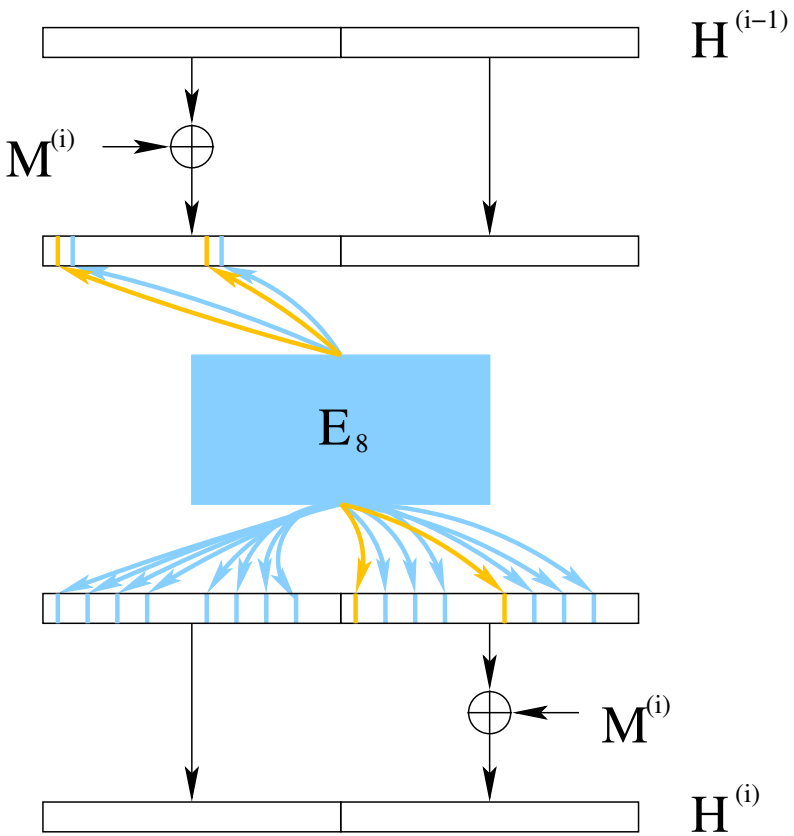
- 4 bit message difference

Attack on JH $d = 8$



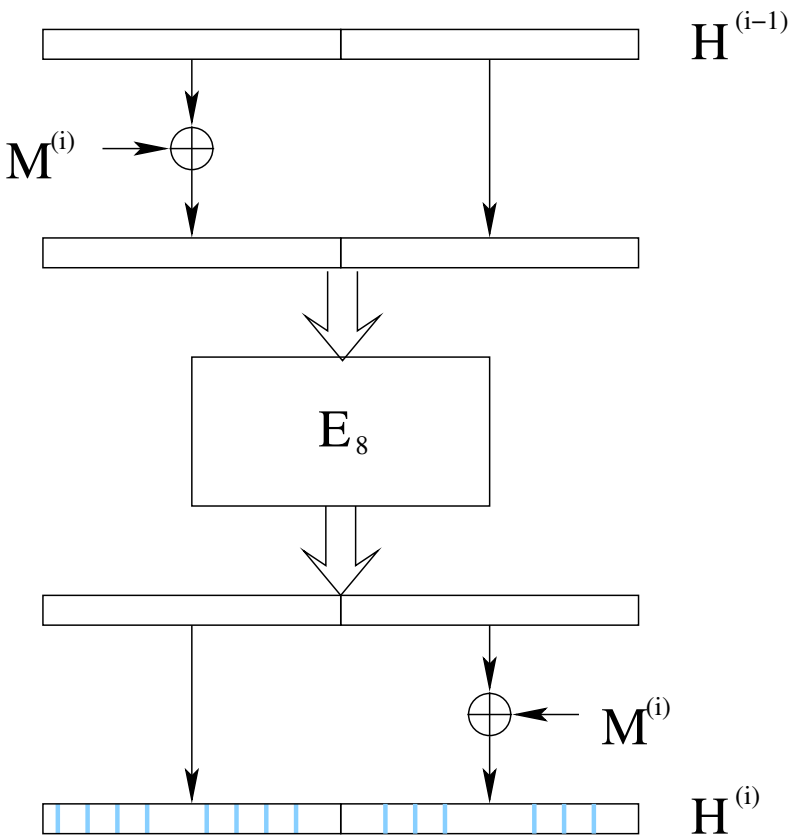
- 4 bit message difference
- 16 bit difference from output

Attack on JH $d = 8$



- 4 bit message difference
- 16 bit difference from output
- Two of which collide

Attack on JH $d = 8$



- 4 bit message difference
- 16 bit difference from output
- Two of which collide
- $4 + 16 - 4 = 16$ bit difference left in the state.

Outline

Results and Conclusion

Table: Summary of results for JH (CFC - Compression Function Call)

	#Rounds	Time Complexity	Memory Complexity	Collision Type
Hash Func.	16/35.5	$2^{178.24}$ CFC	$2^{101.12}$ byte	semi-free-start collision
Comp. Func.	19/35.5	$2^{156.77}$ CFC	$2^{143.70}$ byte	semi-free-start near-collision (1008 bits)
Comp. Func.	22/35.5	$2^{156.56}$ CFC	$2^{143.70}$ byte	semi-free-start near-collision (768 bits)

Results and Conclusion

Table: Summary of results for JH (CFC - Compression Function Call)

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Further Work

Working on ways to improve the complexity to increase the attack with a couple of rounds

Results and Conclusion

Thank You!...