Preimages for Reduced SHA-0 and SHA-1

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Agenda

Background

Iteration 1 (High level)

- Inverting the compression function
- From P3 to preimage
- Putting everything together

Iteration 2 (Low level)

- Fixing the columns
- Preimage method conclusions
- Outlook

Background

Recollection

- Preimage
- Second preimage
- SHA

Previous research

- All currently known generic preimage attacks require either:
  - Impractically long first preimages
  - A first preimage lying in a very small subset of the set of all possible preimages
  - A target digest constructed in a very special way

Our results

- SHA-0
  - 37 rounds – 2^{75}
  - 49 rounds – 2^{159}
- SHA-1
  - 34 rounds – 2^{80}
  - 44 rounds – 2^{157}

Iteration 1

- Inverting the compression function
- From P3 to preimage
- Putting everything together

Inverting the compression function

- Goal:
  - Find a message that transforms a given IV to a given result of the compression function
- Different(ial) approaches:
  - For second preimage - Reuse the differential characteristics used in collision attacks
  - Compute the hash value of a related message and then steer the result towards the target value

Used method

- Changing the representation and tweaking the states

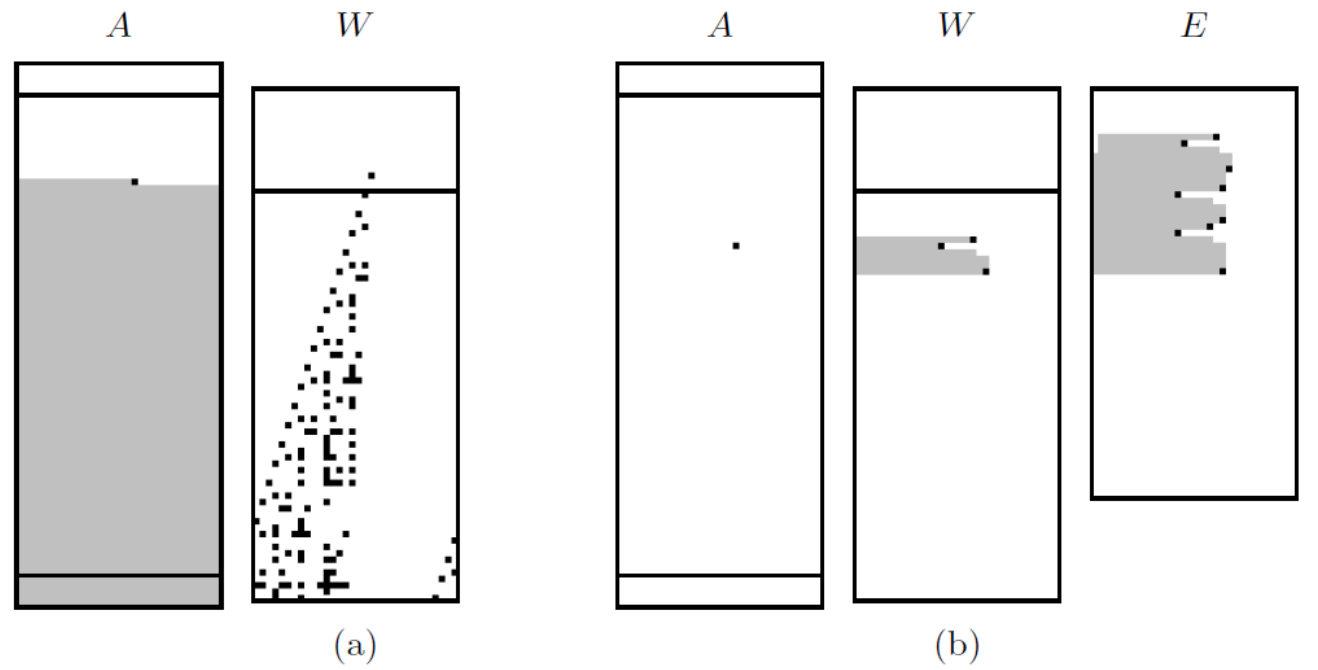


Fig. 5. Bits affected by a single bit flip at the input (SHA-1). Black bits are guaranteed to flip; gray bits may be flipped; white bits are unaffected

Defining Partial-Pseudo-Preimage

Pseudo → Partially controlled input

and

Partial → Partially matching output

P3 to preimage

- Goal:
  - Transform the attack on the compression function that gives a P3 to an attack on the hash function leading to the preimage

- Different approaches:
  - Meet in the middle
  - Layered Tree method
  - Alternative Backward-Forward Tree

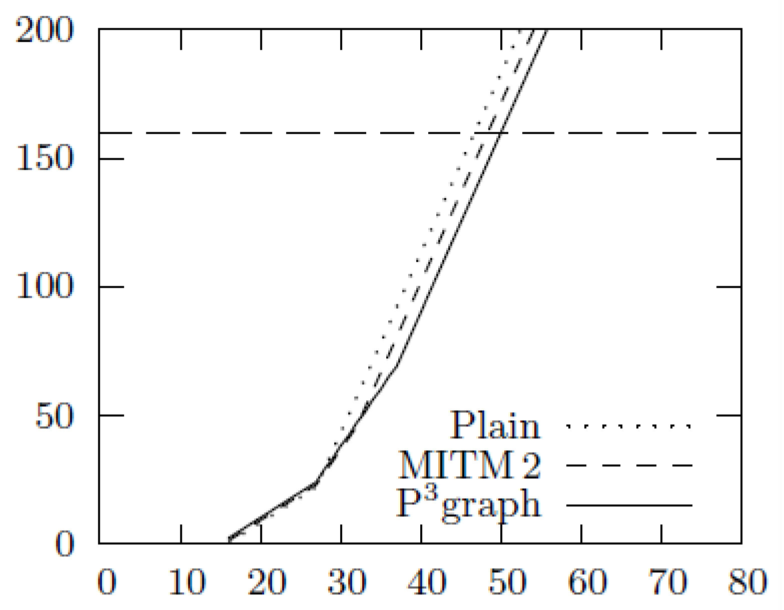
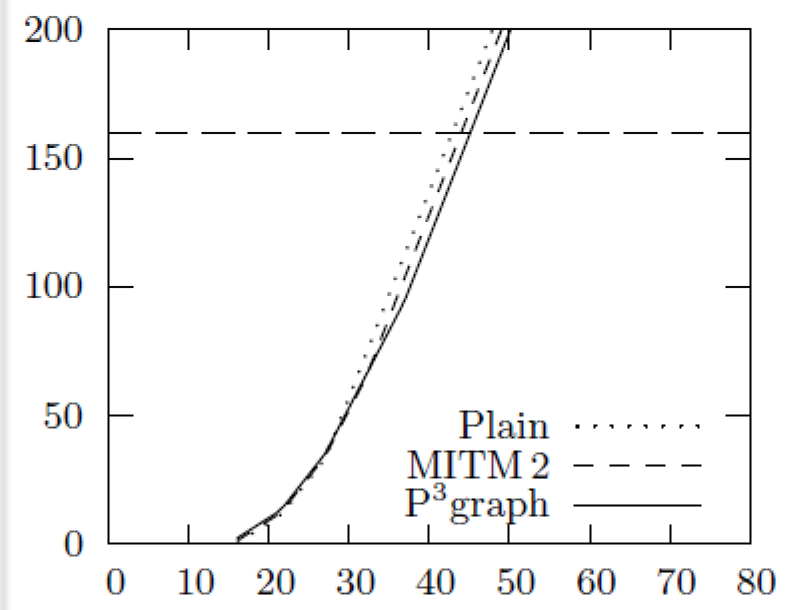
Used method

- P3 graph
  - Nodes: $(h_{(i)}, m_{(i)})$
  - Edges: Mapping between $h_{(i)}$ and $f(h_{(i)}, m_{(i)})$
  - First message block – forward direction
  - Last message block – backward direction
- Finding the preimage
  - Finding a connection (a path) between the entry node and the exit node in the graph

Putting everything together

- Goal:
  - Combine the two methods to receive a correctly padded message
- Different approaches:
  - Restrict the degrees of freedom in the compression function attack to receive correct length
  - Construct expandable messages using:
    - Multicollisions
    - Flexibility of the P3 graph method

Visual results

SHA-0	SHA-1
	

Iteration 2

- Fixing the columns
- Preimage method conclusions
- Outlook

Fixing the columns

Old representation vs. New representation

Goal: Zeroing the E words

Bit flip observation

Stage 1 & Stage 2 – Number of free bits

Preimage method conclusions

- No structure imposed
- Precomputation
- The effort for every additional preimage attack is 2^{b+c}

Outlook

Parameter	Preimage	Collision
Step-reduced variants (SHA-1)	45 Steps	58 Steps
Degrees of freedom	Not all degrees of freedom are used	Limiting factor
Sensitivity for different choices of rotation constants	Strong dependency to constants	Not such a strong dependency as used to be

Summery

- Inverting the compression function
- P3 graphs for hash preimages
- Dealing with padding
- Results and outlook

Questions?

Thank you