# The ECHO hash function

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# Outline

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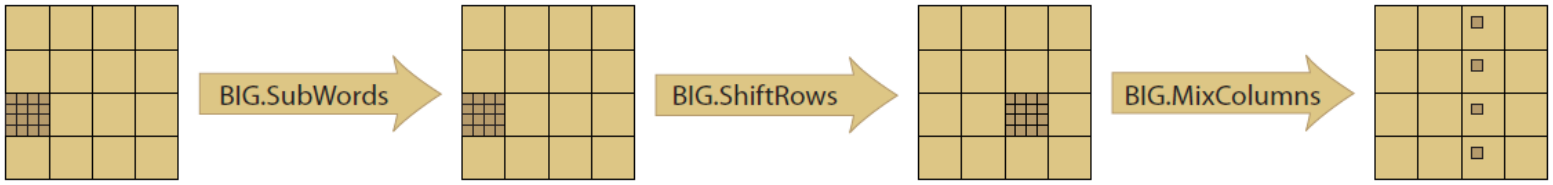
# Description



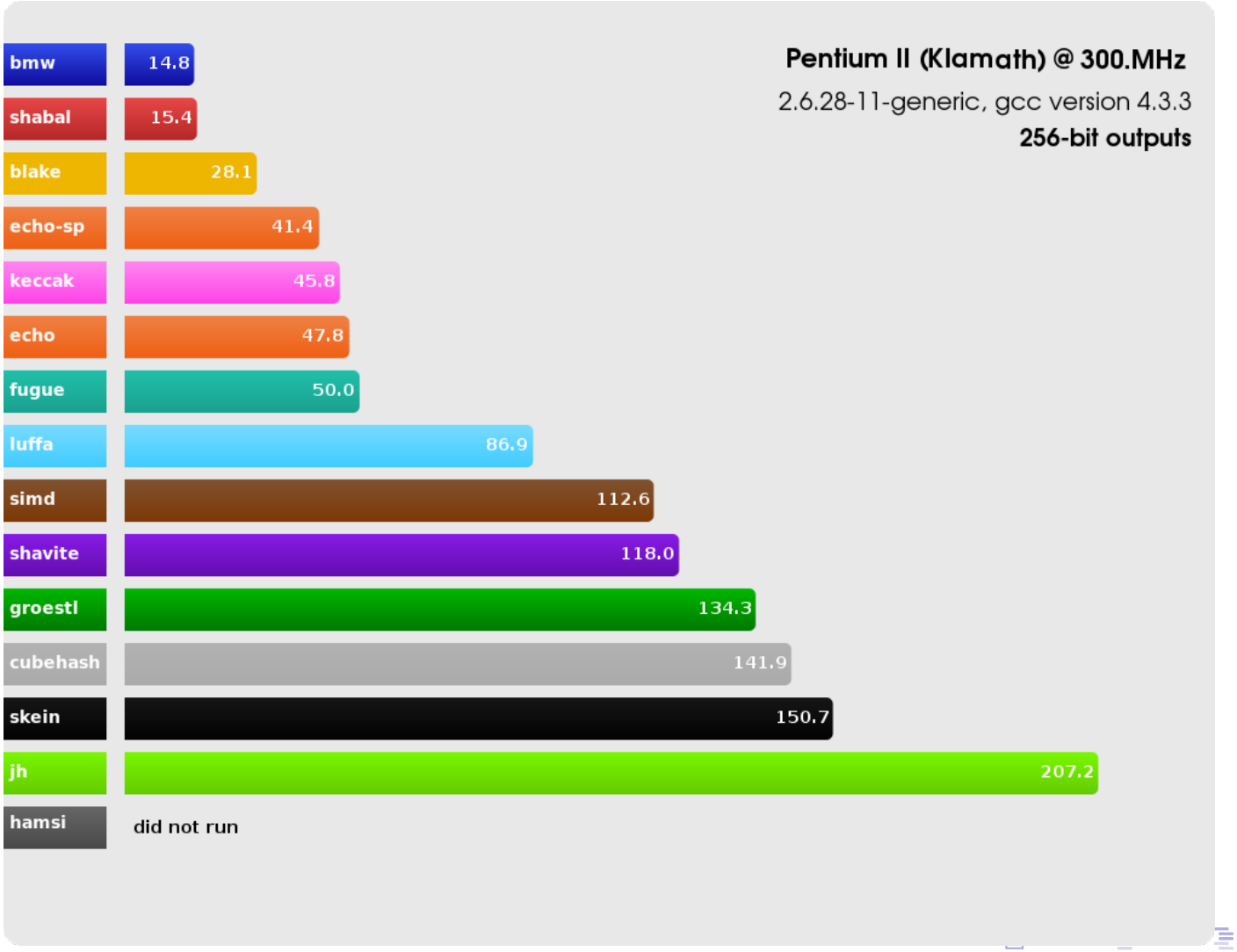

What is ECHO ?

- HAIFA domain extension algorithm + double pipe
- AES-based (reuses full AES rounds and mimics the AES structure)
- clean and simple (to understand, to implement, to analyze)
- same implementation for 256-bit and 512-bit versions
- same implementation for double/simple pipe mode

# Outline

# Software

- **legacy processors:**
  good performance (low cache overhead)



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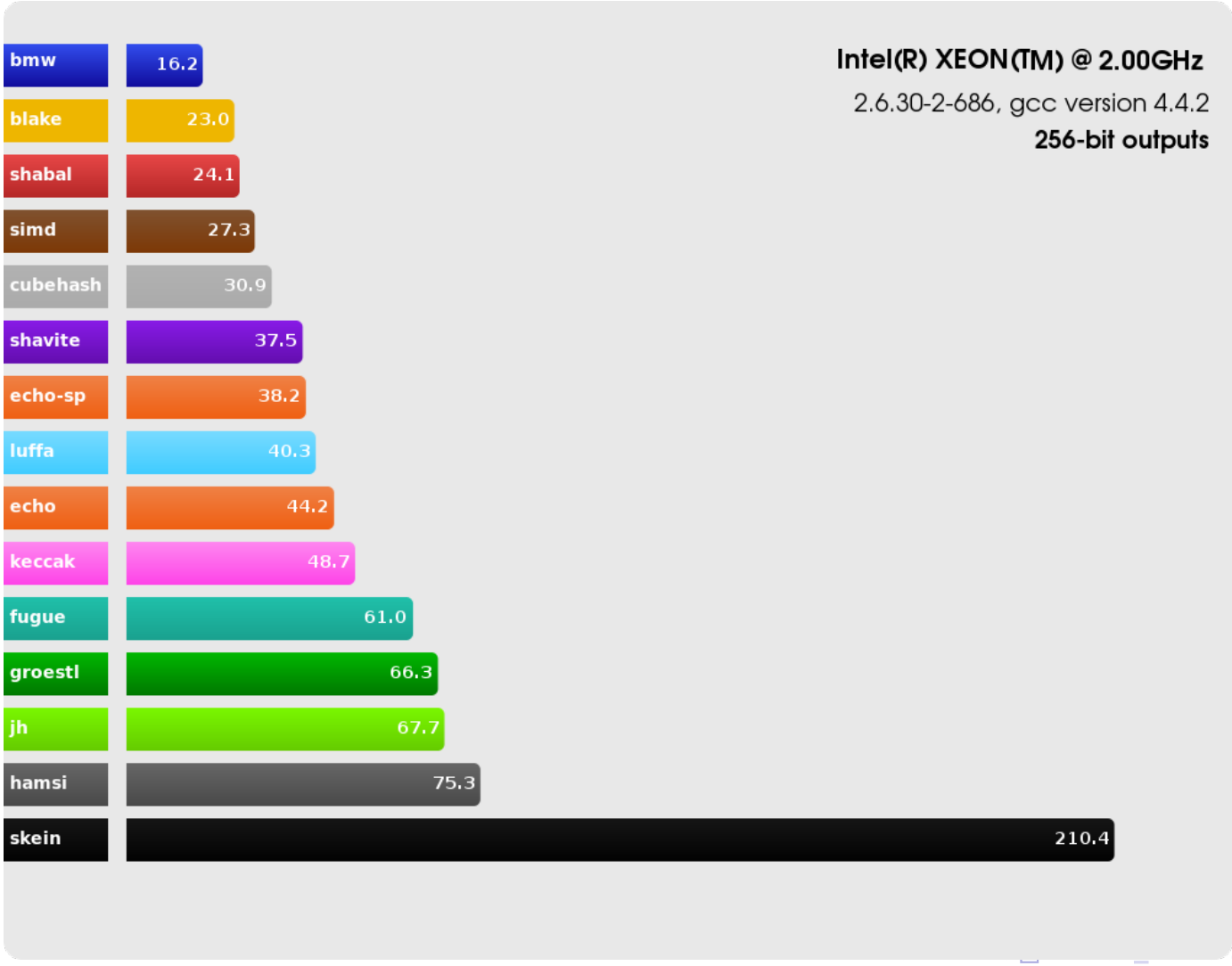


# Software

- **legacy processors:** good performance (low cache overhead)
  - many candidates get good performance on the NIST platform (they exploit all the cache available) ...
  - ... but by going back just one generation of processors, some are severely penalized
- **Core 2 Duo:** average performance
- **current processors (AES-NI):** **one of the fastest candidates**

Example with Core i5 (see eBash or our AES-NI page):

ECHO-256: **6.8 c/B**, ECHO-512: **12.6 c/B**
ECHO-SP-256: **5.8 c/B**, ECHO-SP-512: **8.4 c/B**

# Hardware

ECHO offers a wide range of HW size/speed tradeoffs:

- **high throughput:**
  **one of the fastest FPGA candidates** (26.5 Gbit/s - our website)
  **one of the fastest ASIC candidates** (14.8 Gbit/s - Lu et al.)
- **lightweight:** only 127 slices + 1 memory block on Virtex 5 and even smaller for ECHO-AES coprocessors (Beuchat et al.)
- **balanced throughput/area:** use of BRAM allows high throughput for small/medium area (Francq et al.)

**Note:** in general, ECHO−SP, the simple pipe mode, is faster than the double pipe:

- by a factor 1.16 for the 256-bit version
- by a factor 1.5 for the 512-bit version

# Outline

# Security

- **untweaked** (only 6 other schemes untweaked)
- **double-pipe security** (only 6 other schemes with full double-pipe security)
- **well analyzed:** SAC 2009, FSE 2010, CRYPTO 2010, SAC 2010, SHA-3 conference
- **the simple design encourages the analyst to try a wide-range of old and new techniques:**
  - truncated differential paths
  - rebound attack
  - start-from-the-middle attack and improved variants
  - super-Sbox attack and improved variants
  - multiple inbounds attack
- **Unlike many other candidates, analysis confirms that the hash and the compression function offer a substantial margin for security**

# Cryptanalysis

| | | ECHO | | ECHO-SP | |
|---|---|---|---|---|---|
| | | 256-bit | 512-bit | 256-bit | 512-bit |
| compression function | collision | **38%** | **25%** | **38%** | **30%** |
| | distinguisher | **87%** | **70%** | **75%** | **70%** |
| hash function | collision | **50%** | - | - | **40%** |
| | distinguisher | **63%** | - | - | **50%** |

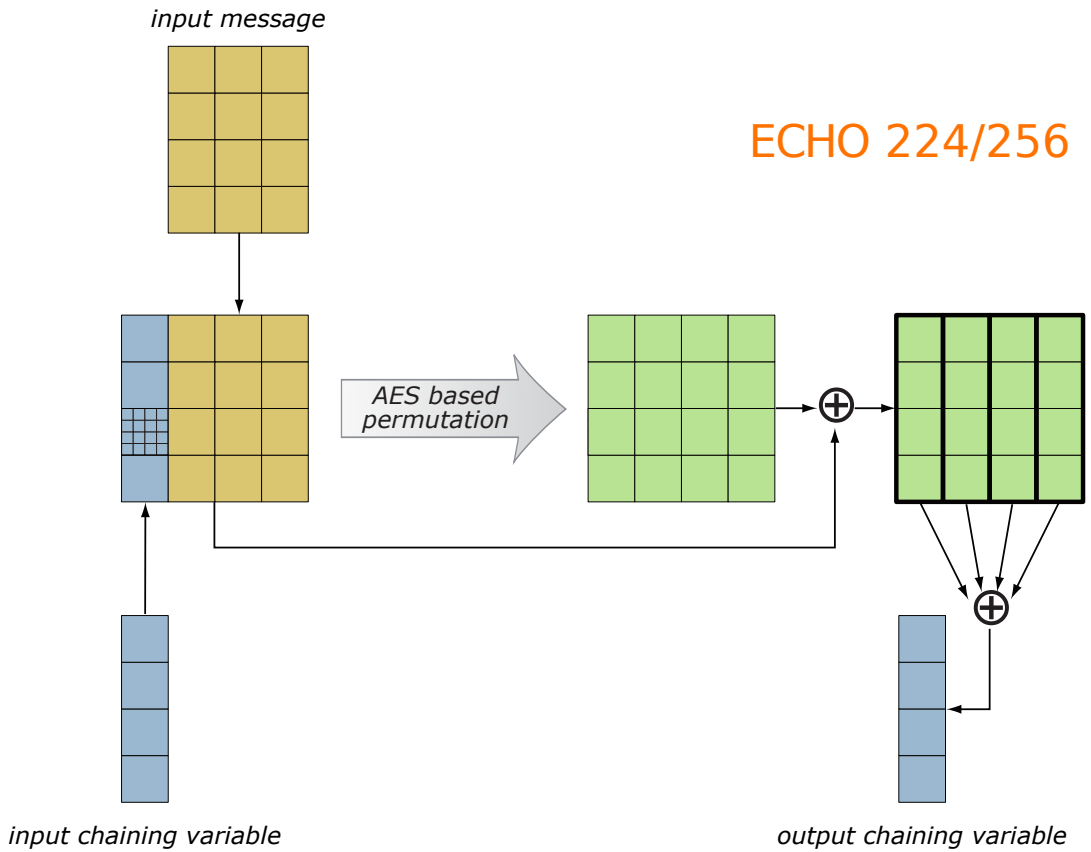
**Current best cryptanalysis**

In chosen-salt setting:

- collision attack against ECHO-512 compression function reduced to 3 rounds

# Cryptanalysis

Distinguishers on internal permutation are interesting, but absolutely not a danger (because of the final folding phase)



# Cryptanalysis

We improved our active Sboxes proofs:

| number of rounds | best known diff. path | old | | new | |
|---|---|---|---|---|---|
| | | bound | gap | bound | gap |
| 1 | 5 | 5 | 0 | 5 | 0 |
| 2 | 40 | 25 | 15 | 40 | 0 |
| 3 | 60 | 45 | 15 | 60 | 0 |
| 4 | 200 | 125 | 75 | 200 | 0 |
| 5 | 250 | 130 | 120 | 205 | 45 |
| 6 | 285 | 150 | 135 | 240 | 45 |
| 7 | 320 | 170 | 150 | 260 | 60 |
| 8 | 445 | 250 | 195 | 400 | 45 |

The paths used for the attacks are almost optimal.

# Outline

# Summary

- **Simple**, **elegant**, **flexible**, easy to understand/implement
- **Performance:** good in every situation, exceptional in some
  - current processors (AES-NI)
  - high throughput hardware
- **Security:**
  - untweaked
  - double-pipe security
  - one of the most studied SHA-3 candidates
  - compression function and hash function offer good margin for security
  - strong security arguments: new analysis shows that attackers are already using paths very close from being the best ones ($>$ 400 active AES S-boxes over 8 rounds)