

JH

Hongjun Wu<sup>1,2</sup>

<sup>1</sup>Institute for Infocomm Research

<sup>2</sup>Nanyang Technological University

- Design
- Security
- Performance

# Innovative Design

- New compression function structure
- Proposed the generalized AES design method
- Combining the best of AES and Serpent

# Design: New compression function structure

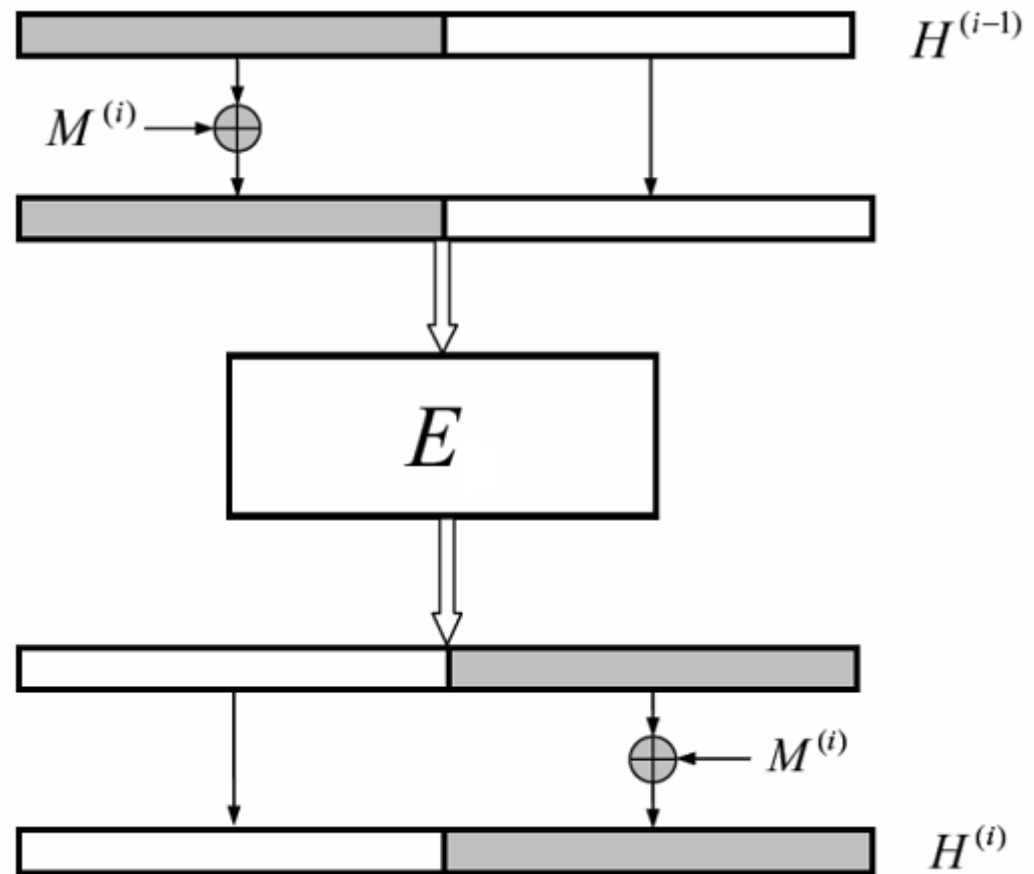
$M^{(i)}$ :  $m$  bits

$H^{(i)}$ :  $2m$  bits

New, simple

efficient

=> does not discard  
part of the output of  $E$



Design: Proposed the generalized AES design method

SPN + MDS code (to a multi-dimensional array)

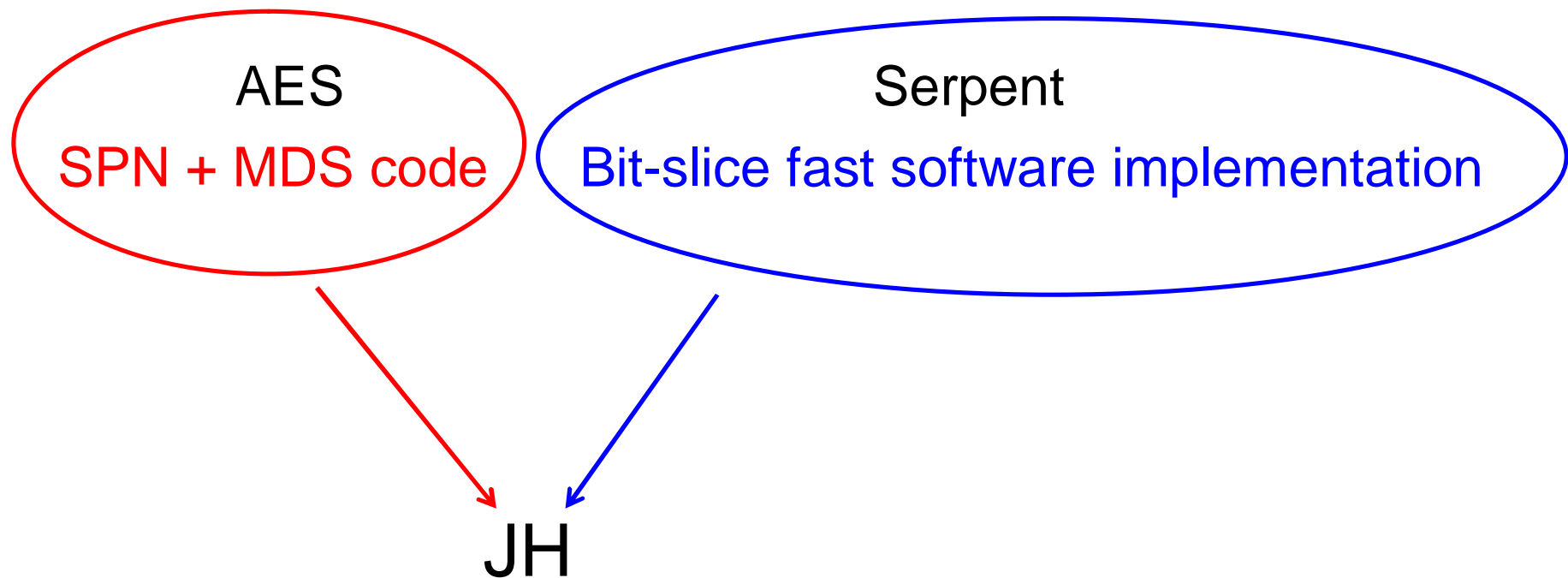
=> A simple, efficient and flexible approach to design a large permutation (block cipher) from small components by increasing dimension

Examples:

AES (2D, 128 bits) => 3D (512 bits) => 4D (2048 bits);

JH (8D, 1024 bits) → bit-slice

## Design: Combining the best of AES and Serpent



# Security

The generalized AES design:

SPN + MDS (to a multi-dimensional array)

- Advantages
  - Analyze a small function to find the best attack
  - Verify the attack on a small function

# Security: Differential attack

a compression function in JH involves:

512 message bits, 9216 Sboxes

a differential path in JH involves more than 600 active Sboxes => strong against differential attack



# Security: Other attacks

- Preimage attack on the mode
  - meet-in-the-middle collision search
  - $2^{507}$  computations +  $2^{507}$  memory +  $2^{526}$  memory accesses  
(Bhattacharyya et al, FSE 2010)
  - more expensive than brute force

# Security: Other attacks (contd.)

- Rebound attacks on JH (Rijmen et al. FSE 2010)
  - Semi-free-start collision
    - 16 out of 35.5 rounds ( $2^{178}$  computations +  $2^{101}$  memory)
  - Semi-free-start near collision
    - 22 out of 35.5 rounds ( $2^{156}$  computations +  $2^{143}$  memory)
- My opinions on rebound attacks
  - Rebound attack is not a threat to JH
    - As stated in the original JH submission, JH compression function is strong against the attack from the middle
  - Rebound attack is only useful for Matyas–Meyer–Oseas-like structure

# Security: Other attacks (contd.)

- 820/1024-bit near collision for 10 out of 35.5 rounds  
( $2^{23}$  computations, Turan et al., the 2nd SHA-3 conference)

# Security: Proof

- JH
  - Indifferentiable with less than  $2^{n/3}$  queries ( $n = 512$ )  
Low bound (Bhattacharyya et al, FSE 2010)

# Performance

- Hardware or resource constrained platform
  - Identical round functions
  - Small components
  - Compute round constants on-the-fly
- Fast software
  - Bit-slice with seven different round functions
- Easy to implement for software and hardware
  - The difficult part is to derive the bit-slice description  
=> I did it already (two years ago in the submission)

# Performance: Fast software

Bit-slice; suitable for the 128-bit SIMD instruction set  
(available on many platforms):

compute 128 Sboxes in parallel

compute 128 MDS codes in parallel

ebash results:

about 17 cycles/byte on the common Intel & AMD processors;  
very close to that of SHA-256

# Performance: Fast software (contd.)

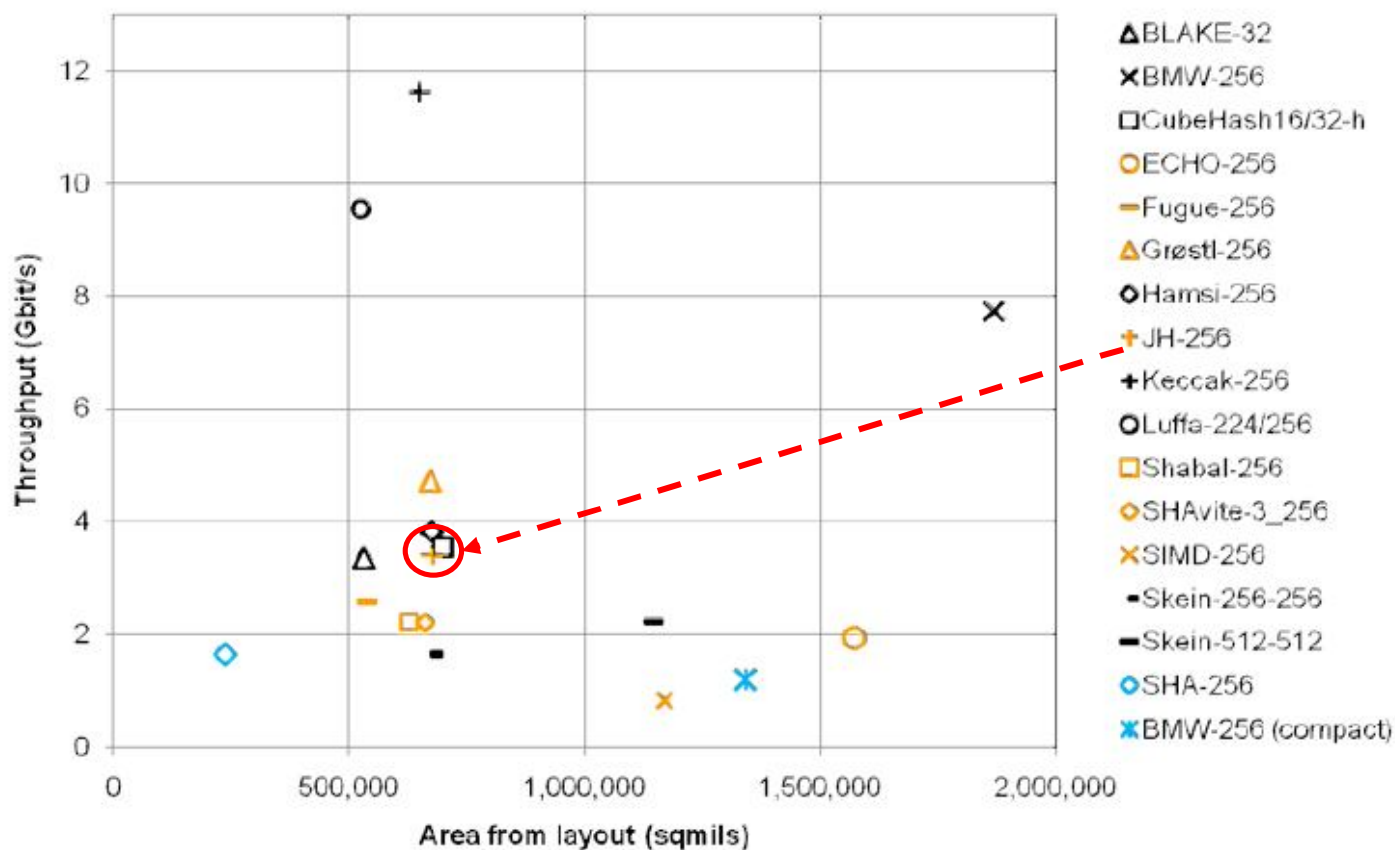
- More efficient on the incoming microprocessors with 256-bit AVX instruction set
  - Intel (Sandy Bridge Q4 2010)
  - AMD (Bulldozer 2011)

Compute 256 Sboxes in parallel

- The size of data register has been gradually increasing  
8 bits → 16 bits → 32 bits → 64 bits → 128 bits → 256 bits →

# Performance: Hardware

- ASIC: Tillich et al (the 2<sup>nd</sup> SHA-3 conference)

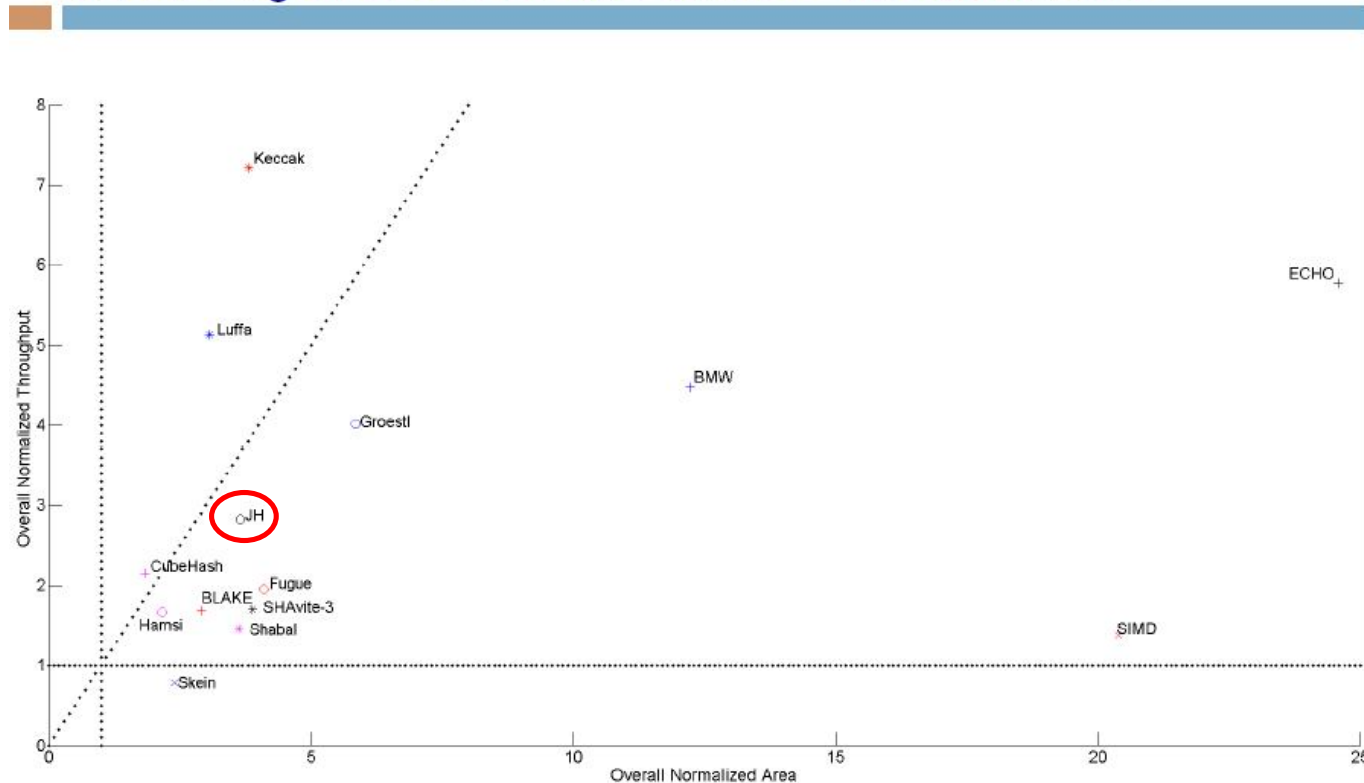




# Performance: Hardware (contd.)

- Gaj et al (the 2nd SHA-3 conference)

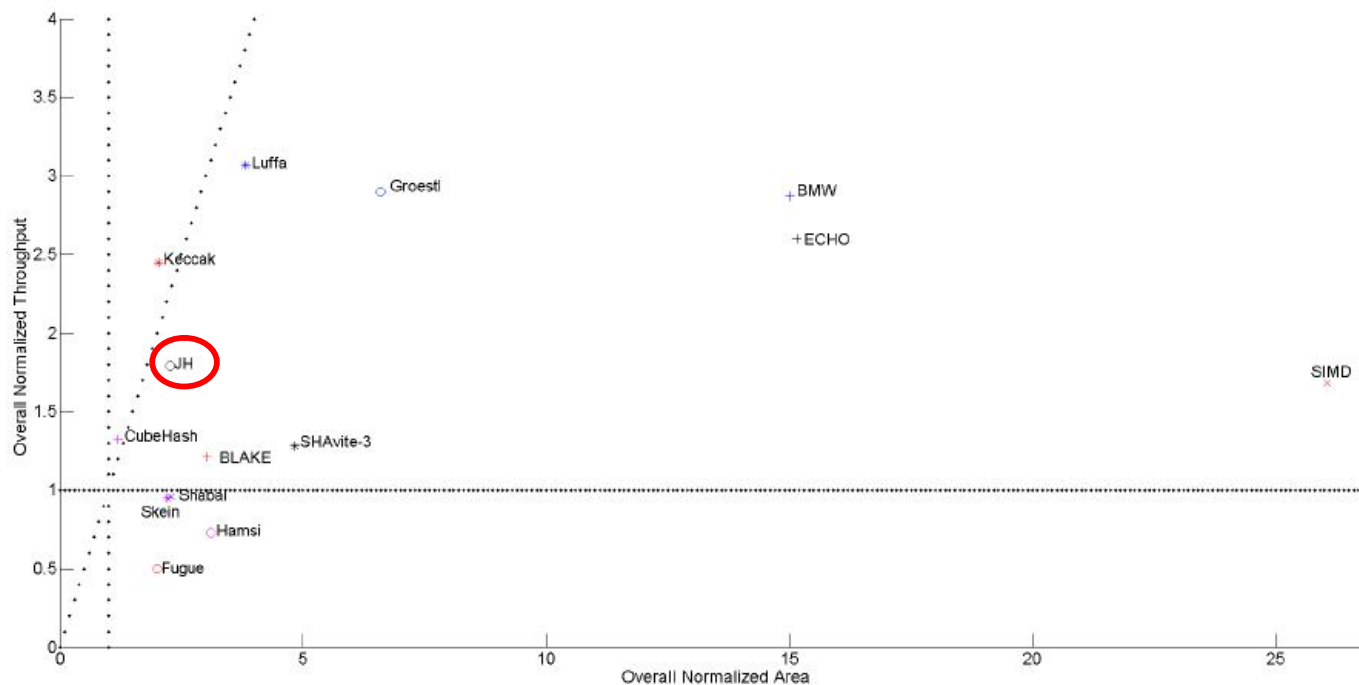
Throughput vs. Area Normalized to Results for SHA-256  
and Averaged over 7 FPGA Families – 256-bit variants



# Performance: Hardware (contd.)

- Gaj et al. (the 2nd SHA-3 conference)

Throughput vs. Area Normalized to Results for SHA-512  
and Averaged over 7 FPGA Families – 512-bit variants



# Performance: Hardware (contd.)

- Baldwin et al. (the 2nd SHA-3 conference)
  - JH is one of the top three candidates in FPGA implementation

# Conclusion

- Design
  - New compression function structure
  - The generalized AES design method
  - Combining the best of AES and Serpent
- Strong
- Efficient for software and hardware