Skein

More than just a hash function

Third SHA-3 Candidate Conference

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Washington DC

Skein is Skein-512

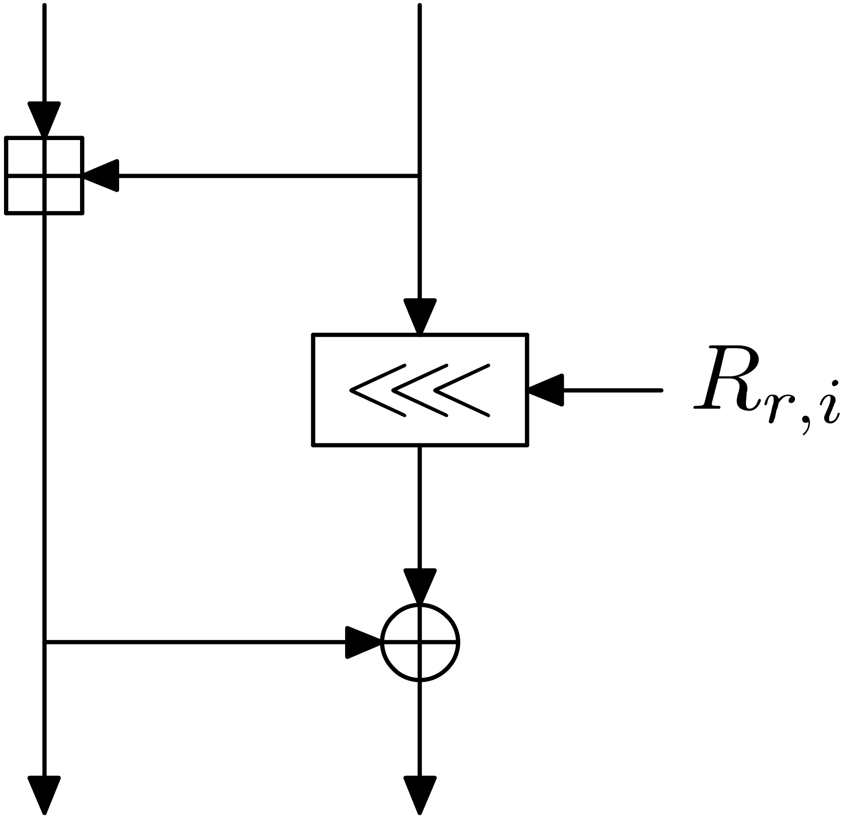
- Confusion is common, partially our fault
- Skein has two special-purpose siblings:
  - Skein-256 for extreme memory constraints
  - Skein-1024 for the ultra-high security margin

- But for SHA-3, Skein is Skein-512
  - One hash function for all output sizes

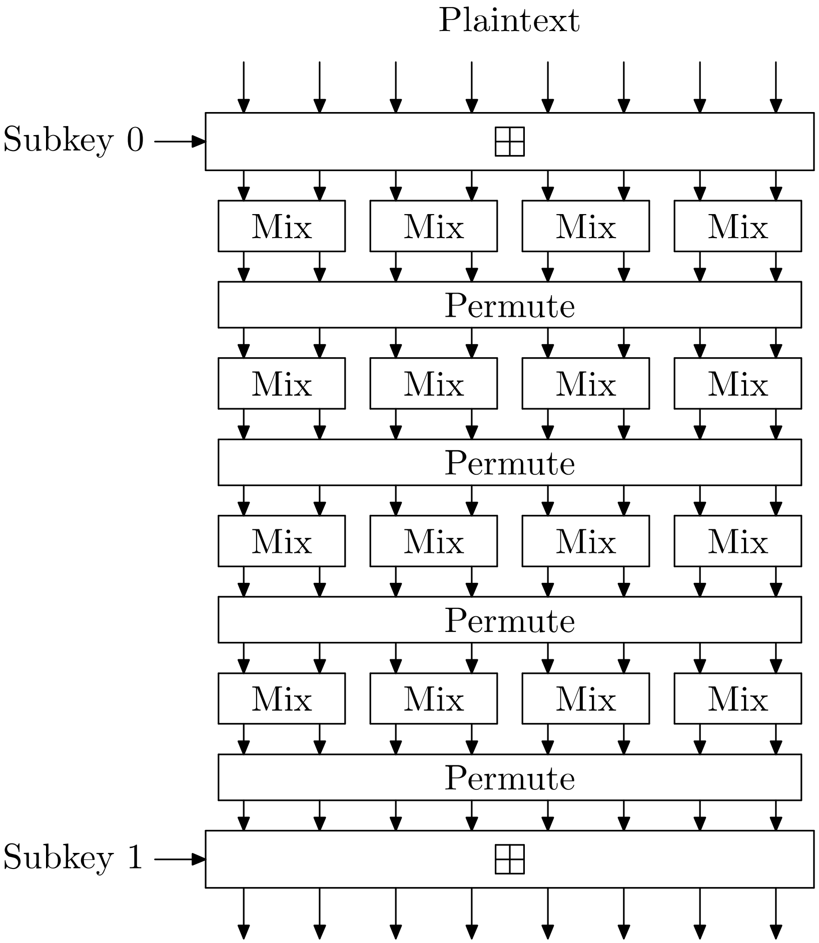
Skein Architecture

- Mix function is 64-bit ARX
- Permutation: relocation of eight 64-bit words
- Threefish: tweakable block cipher
  - Mix + Permutation
  - Simple key schedule
  - 72 rounds, subkey injection every four rounds
  - Tweakable-cipher design key to speed, security
- Skein chains Threefish with UBI chaining mode
  - Tweakable mode based on MMO
    - Provable properties
  - Every hashed block is unique
- Variable size output means flexible to use!
  - One function for any size output

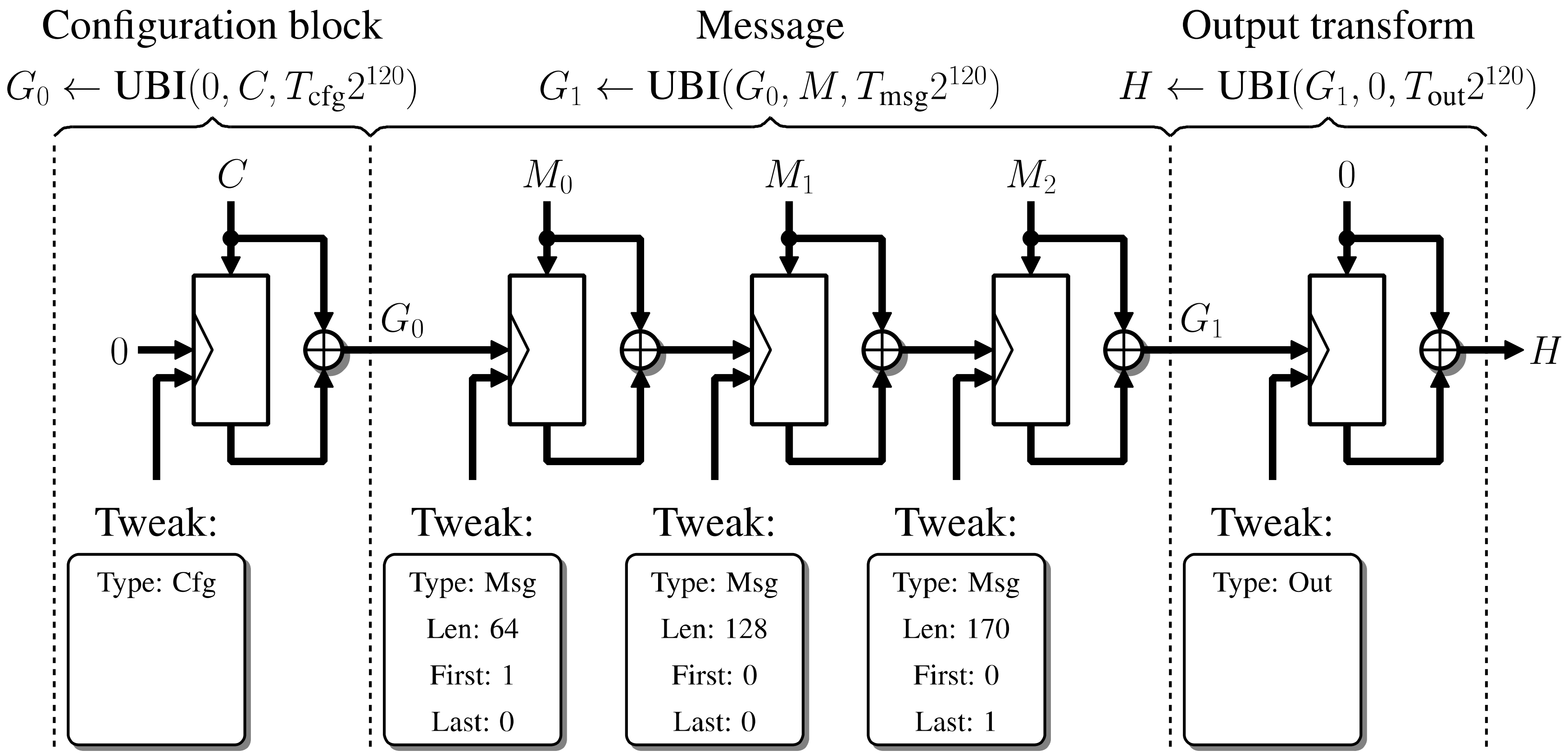
The Skein/Threefish Mix



Four Threefish Rounds



Skein and UBI chaining



Fastest in Software

- 5.5 cycles/byte on 64-bit reference platform
- 17.4 cycles/byte on 32-bit reference platform

- 4.7 cycles/byte on Itanium
- 15.2 cycles/byte on ARM Cortex A8 (ARMv7)
  - New numbers, best finalist on ARMv7 (iOS, Samsung, etc.)

Fast and Compact in Hardware

- Fast
  - Skein-512 at 32 Gbit/s in 32 nm in 58 k gates
  - (57 Gbit/s if processing two messages in parallel)
- To maximize hardware performance:
  - Use a fast adder, rely on simple control structure, and exploit Threefish's opportunities for pipelining
  - Do not trust your EDA tool to generate an efficient implementation
- Compact design:
  - Small FPGA implementation (At et al.)
  - 132 slices and two memory blocks on Virtex-6 FPGA
  - Threefish block cipher “for free” (support ALL symmetric crypto primitives in a single hw system)

Secure

- Conservative design
  - 2x security margin
  - UBI defends against attacks
- Builds on well-understood primitives
- Easy to understand and analyze
  - Only changes have been better constants
- Formal security arguments for the mode
  - Mathematical proof that a weakness in Skein implies a weakness in Threefish
  - We know how to analyze block ciphers

Secure — Best Attacks

- Rotation (Khovratovich et al.) attacks fixed with new constant
- Differential attack against 34 rounds of Threefish (Aumasson et al.)
- Biclique attack, pseudo-preimages on Skein512 at 37 rounds with $2^{511.2}$ steps (Khovratovich et al.)

- We believe Skein/Threefish is ready to use

Design Maximizes Diffusion

Hash Function	Full Diffusion After	Diffusion Factor
Skein	10 rounds (of 72)	7.2
SHA-1	30 steps (of 80)	2.7
SHA-256	14 steps (of 64)	4.6
SHA-512	18 steps (of 80)	4.4

Full diffusion is number of rounds to propagate a single-bit change to all bits

Flexible

- Hash functions are the utility functions of crypto
- Skein has formalizations of many common uses:
- Any output size
  - Simplifies a lot of applications from networks to OAEP
- Extra features:
  - One-pass (zero per-message overhead) MAC
  - KDF, PRNG, stream cipher
  - Tree hash and tree MAC
    - Unlimited throughput through parallelism
    - Random-access hash and MAC

Free Block Cipher

- Threefish is the block cipher at the heart of Skein
  - Free: the security of Skein assumes the security of Threefish
- Wide block
  - Solves the birthday bound problems we have with 128-bit block ciphers
- Tweakable: extra flexibility
  - Tweaks + wide block is good for storage and networks
- Provides a fallback for AES

Implementation

- One implementation for any output size!
- Existing implementations in
  - Python, C, C++, C#, Spark, Atmel AVR, x86, x64, ARM, Java, Ada, Cryptol, FPGA, ASIC and more
  - Parallel tree hashing in Java
- Implementation in Spark adds a formal automated correctness-of-implementation proof

Skein: Fast, Secure, Flexible

- Fastest in software, fast in hardware
- Wider security margin than existing primitives
- Skein is designed for the many ways people *use* hash functions *now*
- We don't know what *future* applications hash functions will have, so the best standard is a flexible one