ARMed SPHINCS:
Computing a 41 KB signature in 16 KB of RAM

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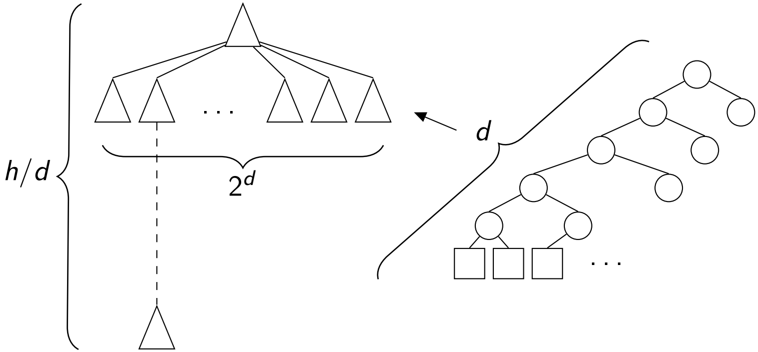
SPHINCS

- SPHINCS: Stateless, practical, hash-based, incredibly nice cryptographic signatures [BHHLNPSW15].
- Post-quantum
  - Hash functions do not fall to Shor (but halved by Grover)
- Hash-based schemes: conservative choice
  - One-way functions necessary for signatures [Rom90]
  - Tight security reductions
- Collision resilient

SPHINCS-256

- Large hash-tree, height $h = 60$
- Every $d = 12$-th layer: sign child node using an OTS
  - Effectively a hypertree of $h/d = 5$ Merkle trees [Mer90]
  - Trade signature size for time
- Sign messages using 2^{60} leaf nodes



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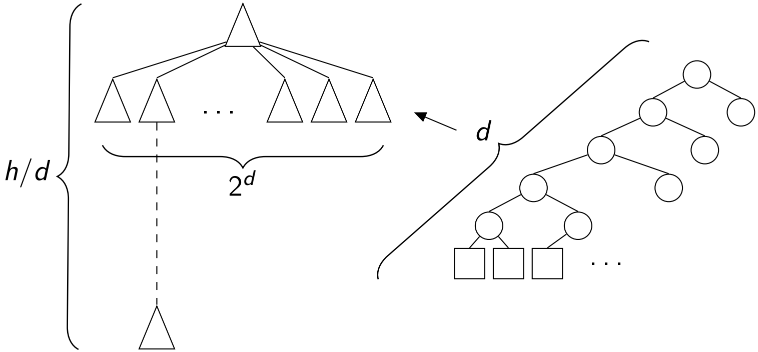
- No need to remember index: **stateless** [Gol87]



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- OTS: *Winternitz OTS variant (WOTS+)* [Hül13]
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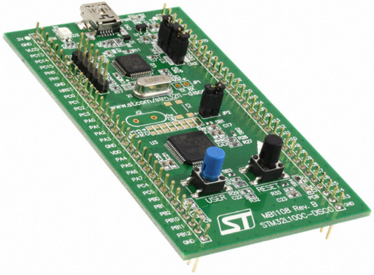
- FTS: *HORST* [BHHLNPSW15]
  - Contains 16-layer Merkle tree (so $2^{16} = 65536$ leafs)
  - Goal: 32 authentication paths, root node
  - Paths start at (deterministically chosen) 'random' leafs
  - Complete tree takes approx. 2MB RAM..

Platform

- STM32L100C development board
- Cortex M3, ARMv7-M
- libopencm3 firmware
- 32MHz, 32-bit architecture
- 16 registers
- 256KB Flash
- **16KB RAM**



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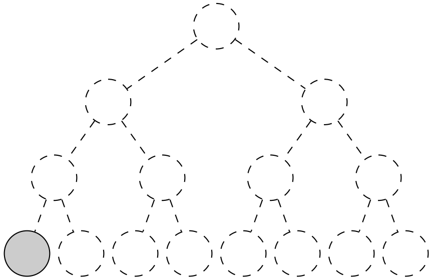

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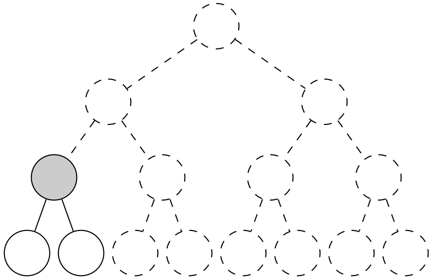

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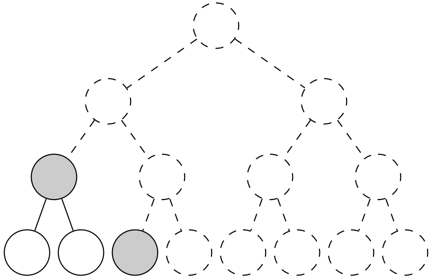

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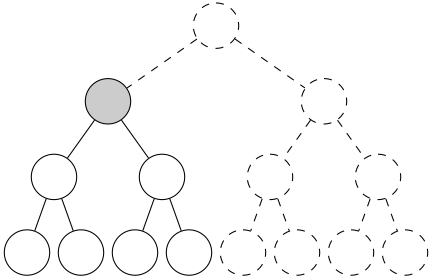

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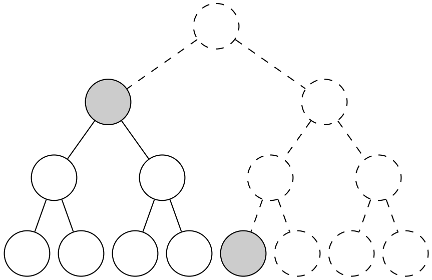

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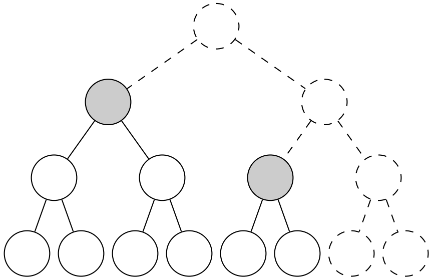

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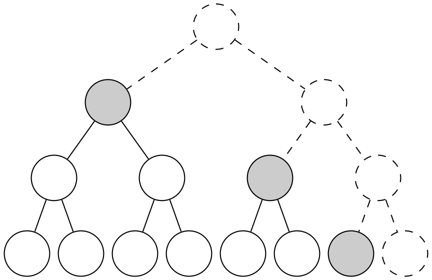

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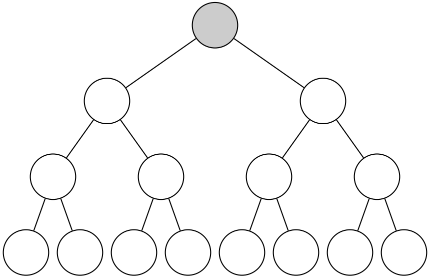

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- Output in the appropriate order..

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- Streaming message input
  - Blockwise BLAKE512
  - Stream twice: once for randomness, once for digest

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- Core computation: ChaCha permutation
  - 685818 calls per signature
  - 65% of all computations
- 48 quarter-rounds of ADD, XOR and ROR
- Costs 542 cycles
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- Rotates on ARMv7 are (almost always) free!
  - `eor r6, r6, r11, ROR #29`

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- Key generation: 28 205 671 cycles (0.88 seconds)
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- On 4-core Haswell:

  "[..] signs hundreds of messages per second."

Cost of the state

- Implemented XMSS^{MT} [HRB13], configured similarly
  - BLAKE and ChaCha primitives, 256 bit
  - Two layers, subtrees with 2^{10} leafs each
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- Key generation: 8 857 708 189 cycles (276.80 seconds)
- Avg. signing: 19 441 021 cycles (0.61 seconds)
- Verification: 4 961 447 cycles (0.16 seconds)
- *Note:* slightly improved since proceedings version

Conclusions

- Stateless is expensive, but not prohibitively so
  - Signing 30x as expensive as XMSS^{MT}
  - Verification similar to XMSS^{MT}
  - (Key generation much cheaper)
- Feasible on limited platforms
  - Verification is practical
  - Non-interactive signatures (high latency)
- Further algorithmic improvements desirable
- Code is available (public domain):
  `https://joostrijneveld.nl/papers/armedsphincs/`

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