SPHINCS:
practical stateless hash-based signatures

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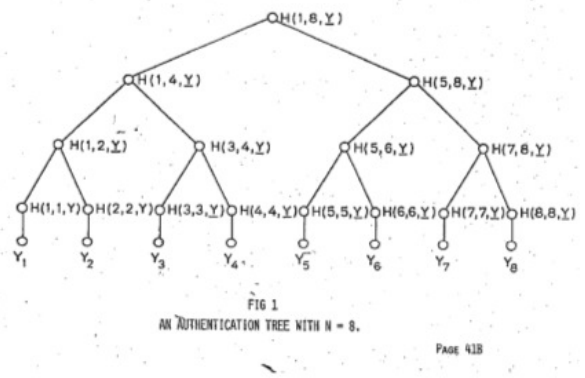
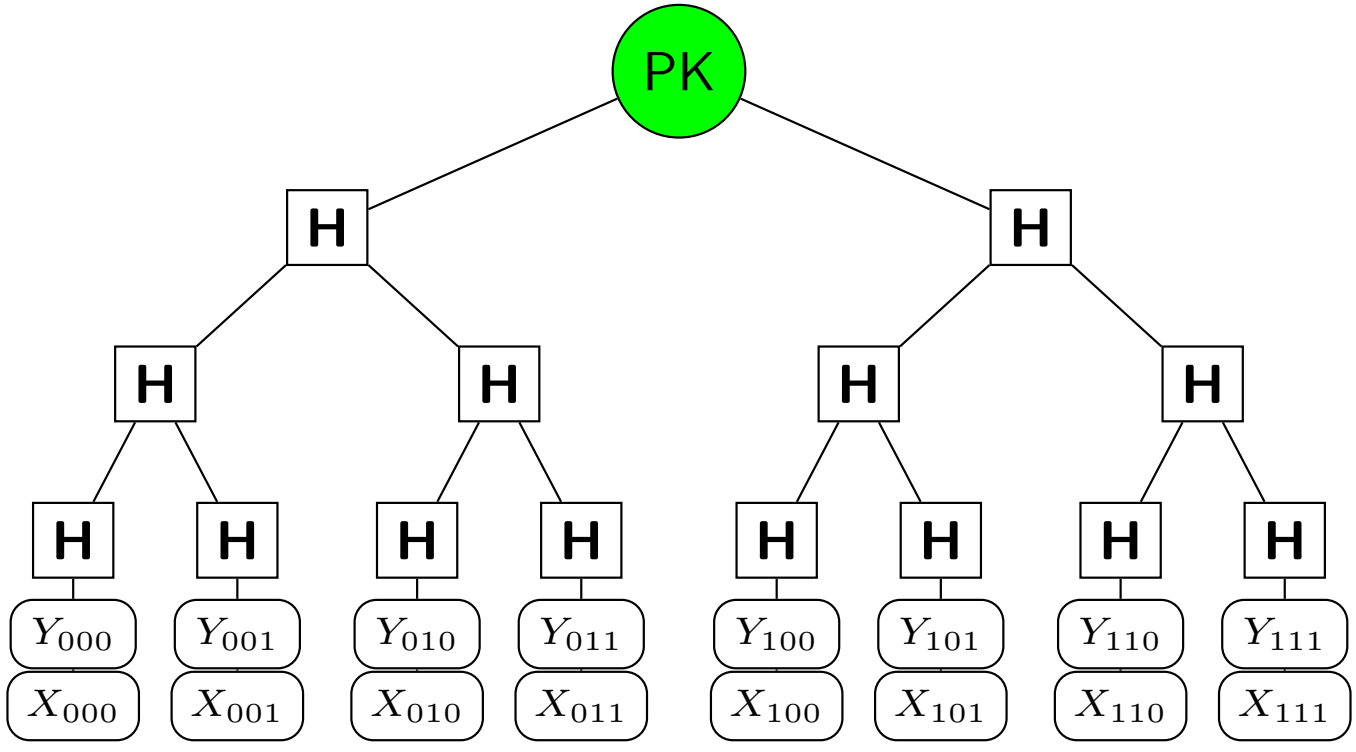
Hash-based signatures [Mer90]

- Security relies only on secure hash function
  - Post-quantum
  - Reliable security estimates
- Fast [BGD+06, BDK+07, BDH11]
- Stateful



Merkle Trees



- Merkle, 1979: Leverage one-time signatures to multiple messages
- Binary hash tree on top of OTS public keys

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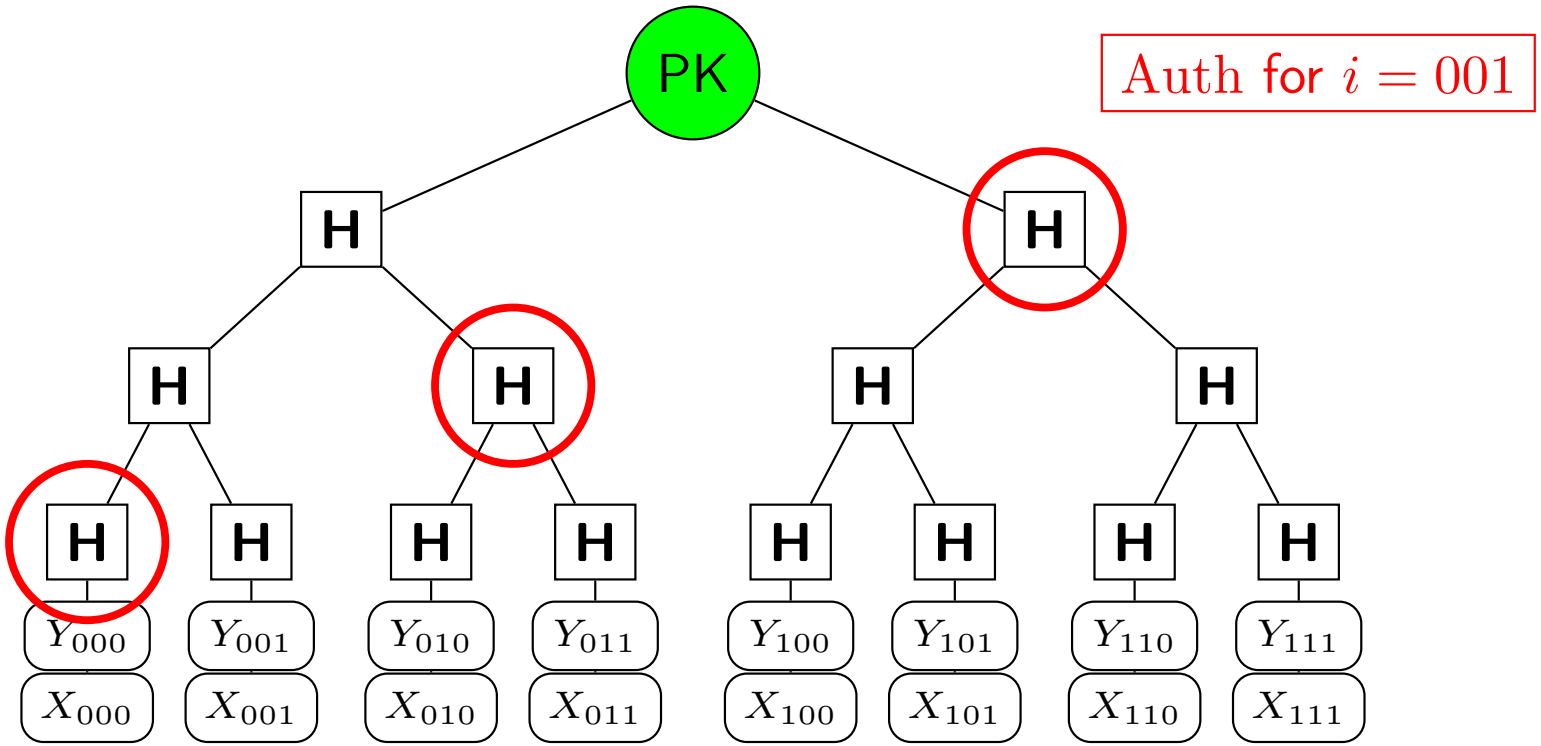

- Use OTS keys sequentially
- $\mathrm{SIG} = (i, \mathrm{sign}(M, X_i), Y_i, \mathrm{Auth})$

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- "Huge foot-cannon" (Adam Langley, Google)
- Not only a hash-based issue!

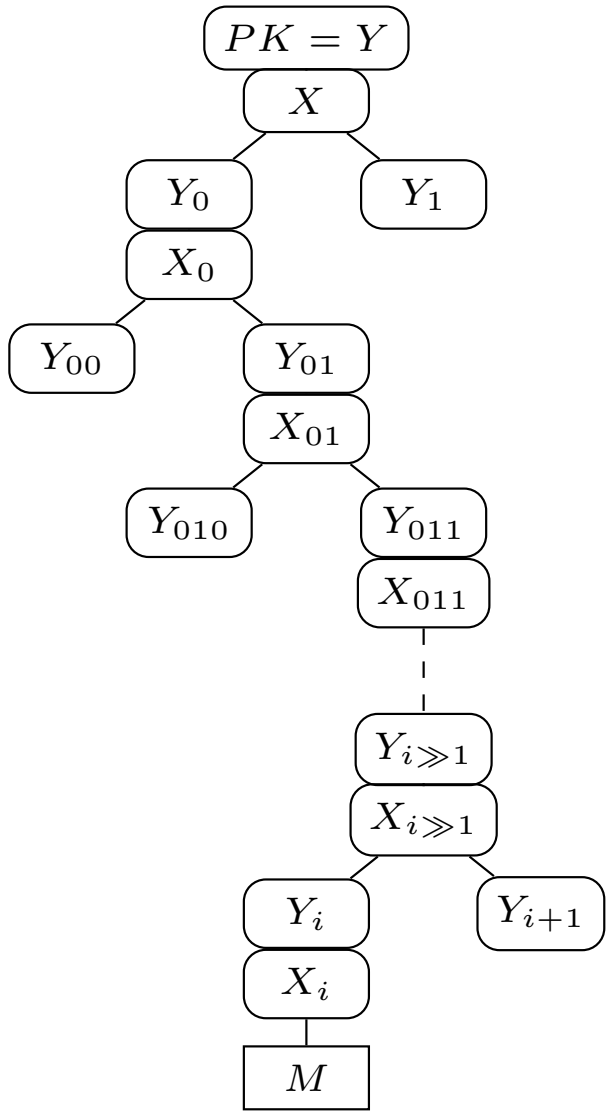

ELIMINATE
THE STATE

Protest?


FEUER UND FLAMME DER REPRESSION
GEGEN SICHERHEITSWAHN UND ÜBERWACHUNGSSTAAT
UNSERE SOLIDARITÄT GEGEN IHRE REPRESSION

Stateless hash-based signatures [NY89, Gol87, Gol04]

Goldreich's approach [Gol04]:
Security parameter $\lambda = 128$
Use binary tree as in Merkle, but...



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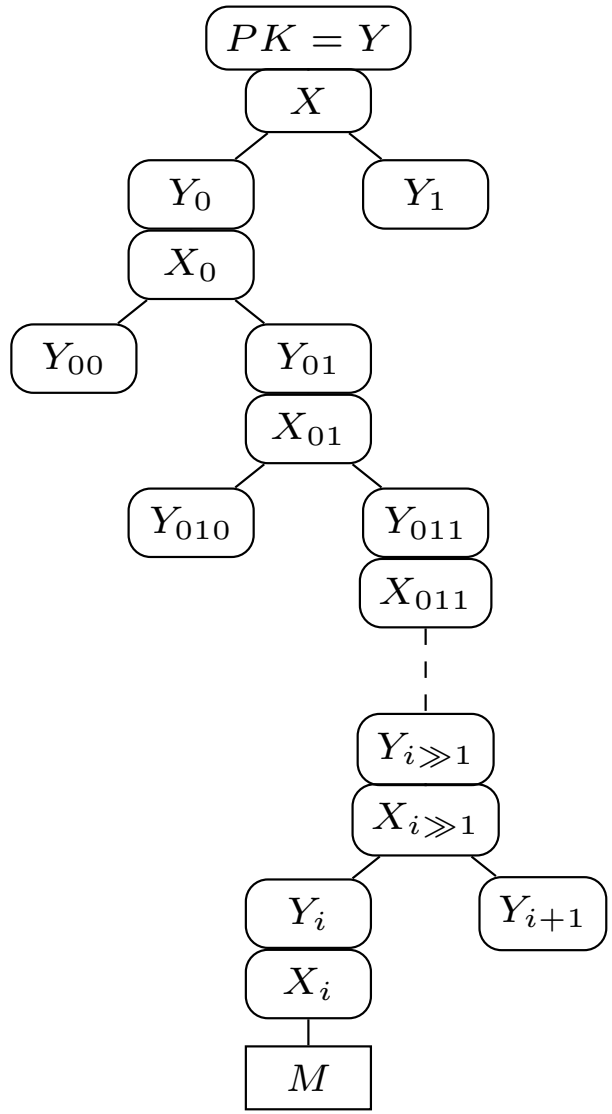

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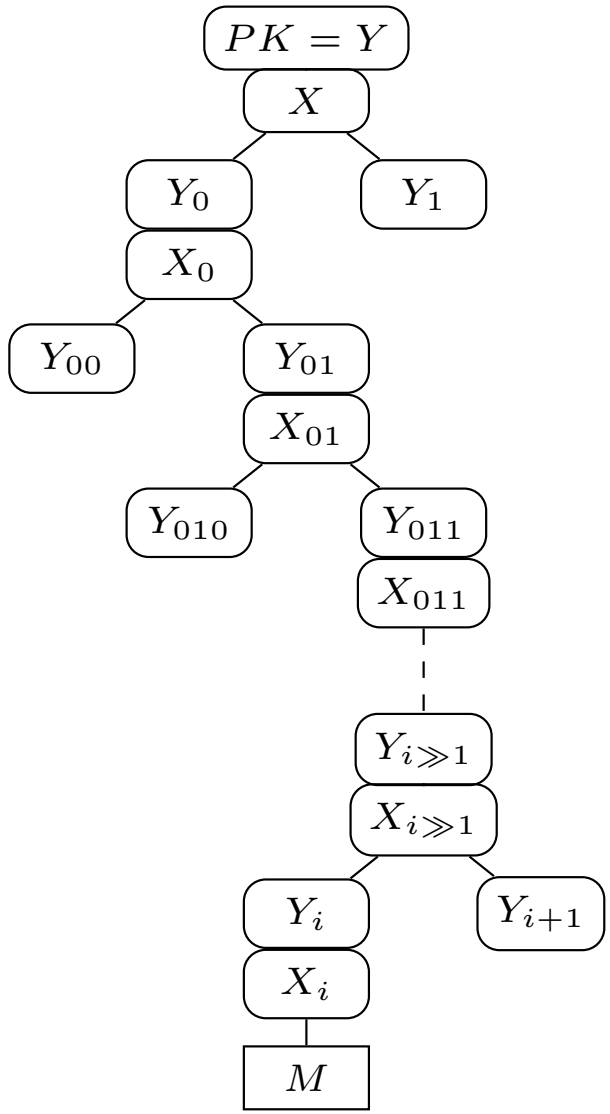
- For efficiency:
  - use binary *certification tree* of OTS;
  - all OTS secret keys are generated pseudorandomly.



It works, but signatures are painfully long

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- Example:
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  - At least one new signature for each upgrade.
  - Typical upgrade: one package or just a few packages.
  - 1.2 MB average package size.
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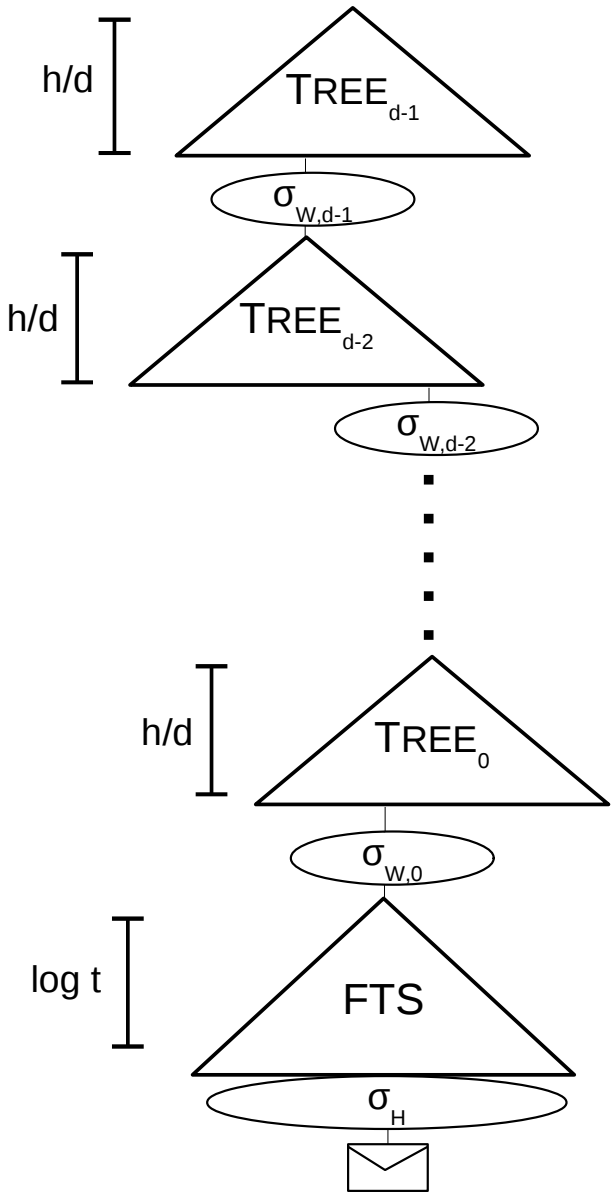
- Example:
  - HTTPS typically sends multiple signatures per page.
  - 1.8 MB average web page in Alexa Top 1000000.

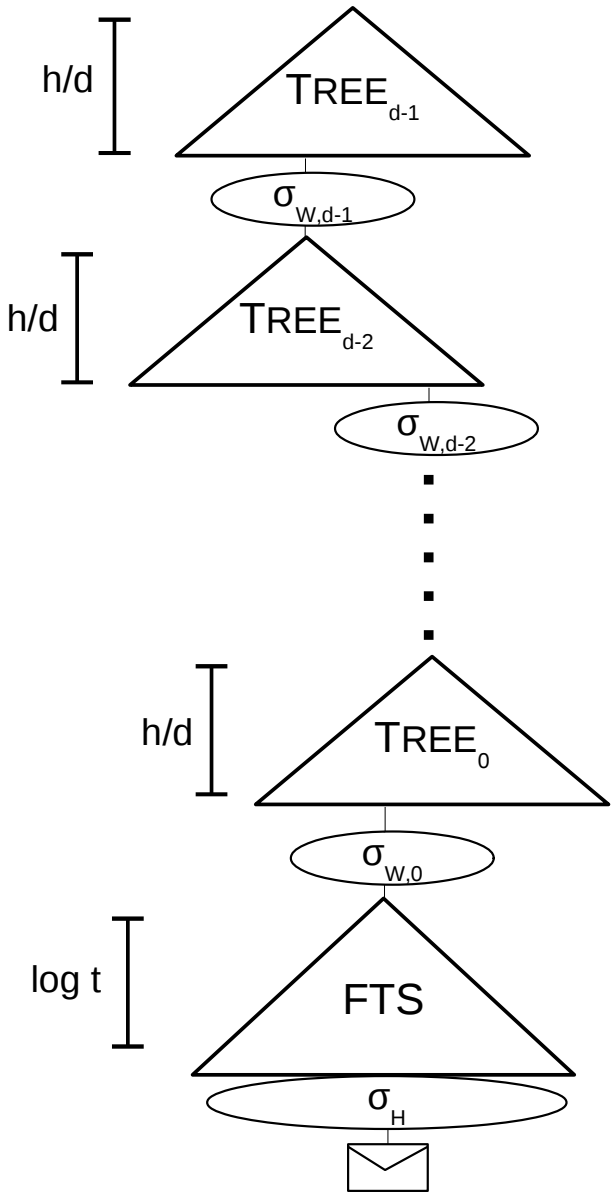
The SPHINCS approach

- Use a "hyper-tree" of total height h
- Parameter $d \geq 1$, such that $d \mid h$
- Each (Merkle) tree has height h/d
- (h/d)-ary certification tree



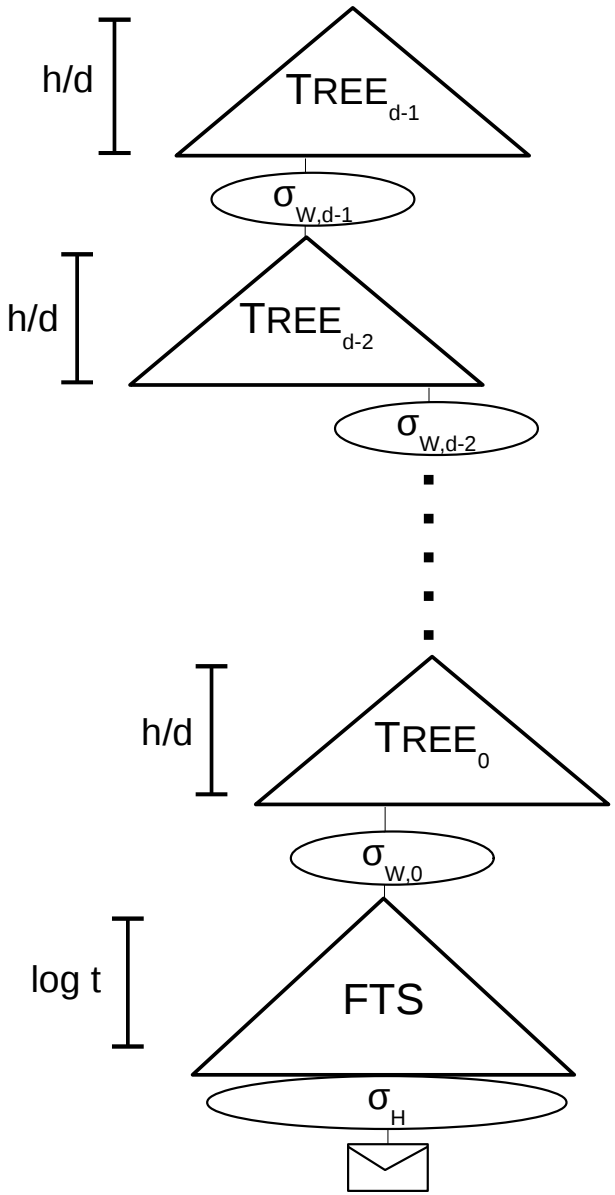
The SPHINCS approach

- Pick index (pseudo-)randomly
- Messages signed with *few-time* signature scheme
- Significantly reduce total tree height
- Require
  Pr[r-times Coll] · Pr[Forgery after r signatures] = negl(n)



The SPHINCS approach

- Designed to be collision-resilient
- Trees: MSS-SPR trees [DOTV08]
- OTS: WOTS$^+$ [Hül13]
- FTS: HORST (HORS [RR02] with tree)



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- $m = 512$ bit message hash (BLAKE-512 [ANWOW13])
- ChaCha12 [Ber08] as PRG

Cost of SPHINCS-256 signing

- Three main componenents:
  - PRG for HORST secret-key expansion to 2 MB
  - Hashing in WOTS and HORS public-key generation: $F : \{0,1\}^{256} \to \{0,1\}^{256}$
  - Hashing in trees (mainly HORST public-key): $H : \{0,1\}^{512} \to \{0,1\}^{256}$
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- Full hash function would be overkill for F and H
- Construction in SPHINCS-256:
  - $F(M_1) = \mathsf{Chop}_{256}(\pi(M_1||C))$
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- Use fast ChaCha12 permutation for π
- All building blocks (PRG, message hash, H, F) built from very similar permutations

SPHINCS-256 speed and sizes

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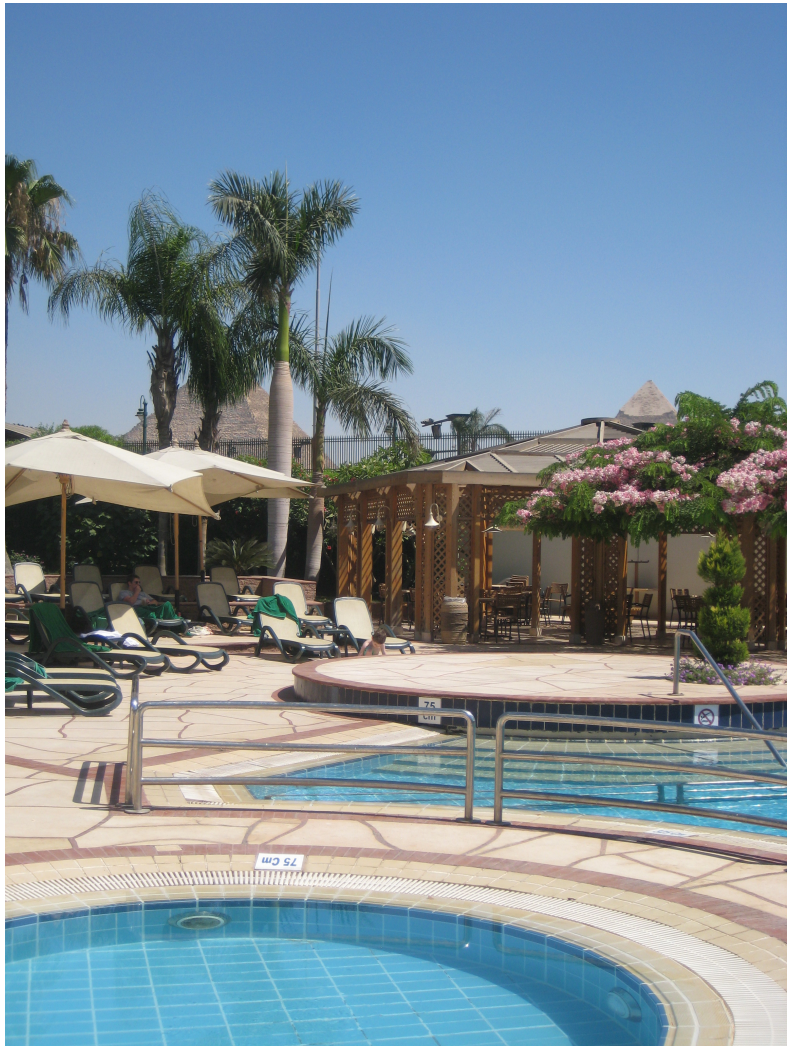
SPHINCS-256 speed

- Signing: < 52 Mio. Haswell cycles (> 200 sigs/sec, 4 Core, 3GHz)
- Verification: < 1.5 Mio. Haswell cycles
- Keygen: < 3.3 Mio. Haswell cycles

SPHINCS: Stateless Practical Hash-based Incredibly Nice Collision-resilient Signatures



http://sphincs.cr.yp.to

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Picture sources

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