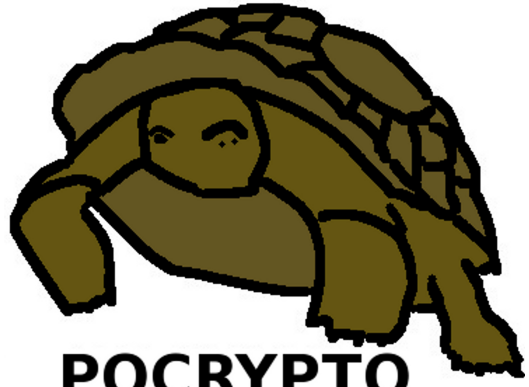
Standardization of post-quantum cryptography

Tanja Lange



08 May 2016

A Workshop About Cryptographic Standards

History of post-quantum cryptography

- 2003 Daniel J. Bernstein introduces term Post-quantum cryptography.
- PQCrypto 2006: International Workshop on Post-Quantum Cryptography.

History of post-quantum cryptography

- 2003 Daniel J. Bernstein introduces term Post-quantum cryptography.
- PQCrypto 2006: International Workshop on Post-Quantum Cryptography.
- PQCrypto 2008, PQCrypto 2010, PQCrypto 2011, PQCrypto 2013.
- 2014 EU publishes H2020 call including post-quantum crypto as topic.
- PQCrypto 2014.
- April 2015 NIST hosts first workshop on post-quantum cryptography
- August 2015 NSA wakes up

NSA announcements

August 11, 2015

> *IAD recognizes that there will be a move, in the not distant future, to a quantum resistant algorithm suite.*

NSA announcements

August 11, 2015

> *IAD recognizes that there will be a move, in the not distant future, to a quantum resistant algorithm suite.*

August 19, 2015

> *IAD will initiate a transition to quantum resistant algorithms in the not too distant future.*

NSA comes late to the party and botches its grand entrance.

NSA announcements

August 11, 2015

> *IAD recognizes that there will be a move, in the not distant future, to a quantum resistant algorithm suite.*

August 19, 2015

> *IAD will initiate a transition to quantum resistant algorithms in the not too distant future.*

NSA comes late to the party and botches its grand entrance.

Worse, now we get people saying "Don't use post-quantum crypto, the NSA wants you to use it!"

Post-quantum becoming mainstream

- PQCrypto 2016: 22–26 Feb in Fukuoka, Japan, with more than 200 participants

- NIST is calling for post-quantum proposals; expect a small competition.
- PQCrypto 2017 planned, will be in Utrecht, Netherlands.

Urgency of post-quantum recommendations

- All currently used public-key systems on the Internet are broken by quantum computers.
- Today's encrypted communication can be (and is being!) stored by attackers and can be decrypted later with quantum computer – think of medical records, legal proceedings, and state secrets.
- Post-quantum secure cryptosystems exist (to the best of our knowledge) but are under-researched – we can recommend secure systems now, but they are big and slow

Urgency of post-quantum recommendations

- All currently used public-key systems on the Internet are broken by quantum computers.
- Today's encrypted communication can be (and is being!) stored by attackers and can be decrypted later with quantum computer – think of medical records, legal proceedings, and state secrets.
- Post-quantum secure cryptosystems exist (to the best of our knowledge) but are under-researched – we can recommend secure systems now, but they are big and slow hence the logo of the PQCRYPTO project.

Urgency of post-quantum recommendations

- All currently used public-key systems on the Internet are broken by quantum computers.
- Today's encrypted communication can be (and is being!) stored by attackers and can be decrypted later with quantum computer – think of medical records, legal proceedings, and state secrets.
- Post-quantum secure cryptosystems exist (to the best of our knowledge) but are under-researched – we can recommend secure systems now, but they are big and slow hence the logo of the PQCRYPTO project.
- PQCRYPTO is an EU project in H2020, running 2015 – 2018.
- PQCRYPTO is designing a portfolio of high-security post-quantum public-key systems, and will improve the speed of these systems, adapting to the different performance challenges of mobile devices, the cloud, and the Internet.

Standardize now? Standardize later?

- Standardize now!
  - Rolling out crypto takes long time.
  - Standards are important for adoption (?)
  - Need to be up & running when quantum computers come.

Standardize now? Standardize later?

- Standardize now!
  - Rolling out crypto takes long time.
  - Standards are important for adoption (?)
  - Need to be up & running when quantum computers come.
- Standardize later!
  - Current options are not satisfactory.
  - Once rolled out, it's hard to change systems.
  - Please wait for the research results, will be much better!

Standardize now? Standardize later?

- Standardize now!
  - Rolling out crypto takes long time.
  - Standards are important for adoption (?)
  - Need to be up & running when quantum computers come.
- Standardize later!
  - Current options are not satisfactory.
  - Once rolled out, it's hard to change systems.
  - Please wait for the research results, will be much better!
- But what about users who rely on long-term secrecy of today's communication?
- Recommend now, standardize later.
- Recommend very conservative systems now; users who care will accept performance issues and gladly update to faster/smaller options later.
- But: standardization takes lots of time, so start standardization processes now.

Initial recommendations of long-term secure post-quantum systems

Daniel Augot, Lejla Batina, Daniel J. Bernstein, Joppe Bos, Johannes Buchmann, Wouter Castryck, Orr Dunkelman, Tim Güneysu, Shay Gueron, Andreas Hülsing, Tanja Lange, Mohamed Saied Emam Mohamed, Christian Rechberger, Peter Schwabe, Nicolas Sendrier, Frederik Vercauteren, Bo-Yin Yang

Initial recommendations

- **Symmetric encryption** Thoroughly analyzed, 256-bit keys:
  - AES-256
  - Salsa20 with a 256-bit key

  Evaluating: Serpent-256, ...
- **Symmetric authentication** Information-theoretic MACs:
  - GCM using a 96-bit nonce and a 128-bit authenticator
  - Poly1305
- **Public-key encryption** McEliece with binary Goppa codes:
  - length $n = 6960$, dimension $k = 5413$, $t = 119$ errors

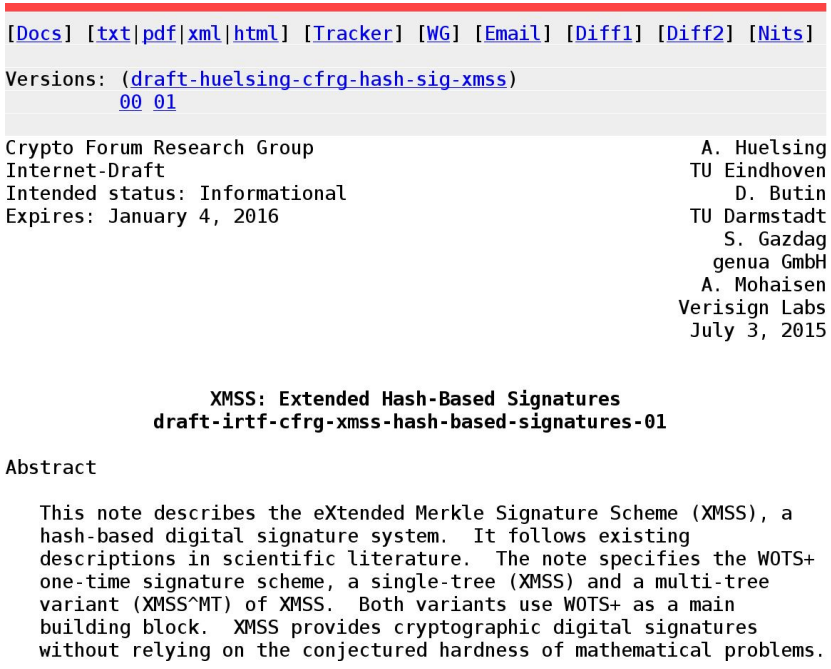
  Evaluating: QC-MDPC, Stehlé-Steinfeld NTRU, ...
- **Public-key signatures** Hash-based (minimal assumptions):
  - XMSS with any of the parameters specified in CFRG draft
  - SPHINCS-256

  Evaluating: HFEv-, ...

Hash-based signatures

Pros:

- Post quantum
- Only need secure hash function, e.g. SHA3-512, ...
- Need signatures anyways.
- Small public key
- Security well understood
- Fast
- Proposed for standards: https://tools.ietf.org/html/draft-irtf-cfrg-xmss-hash-based-signatures-01



[Docs] [txt|pdf|xml|html] [Tracker] [WG] [Email] [Diff1] [Diff2] [Nits]

Versions: (draft-huelsing-cfrg-hash-sig-xmss)
00 01

Crypto Forum Research Group
Internet-Draft
Intended status: Informational
Expires: January 4, 2016

A. Huelsing
TU Eindhoven
D. Butin
TU Darmstadt
S. Gazdag
genua GmbH
A. Mohaisen
Verisign Labs
July 3, 2015

XMSS: Extended Hash-Based Signatures
draft-irtf-cfrg-xmss-hash-based-signatures-01

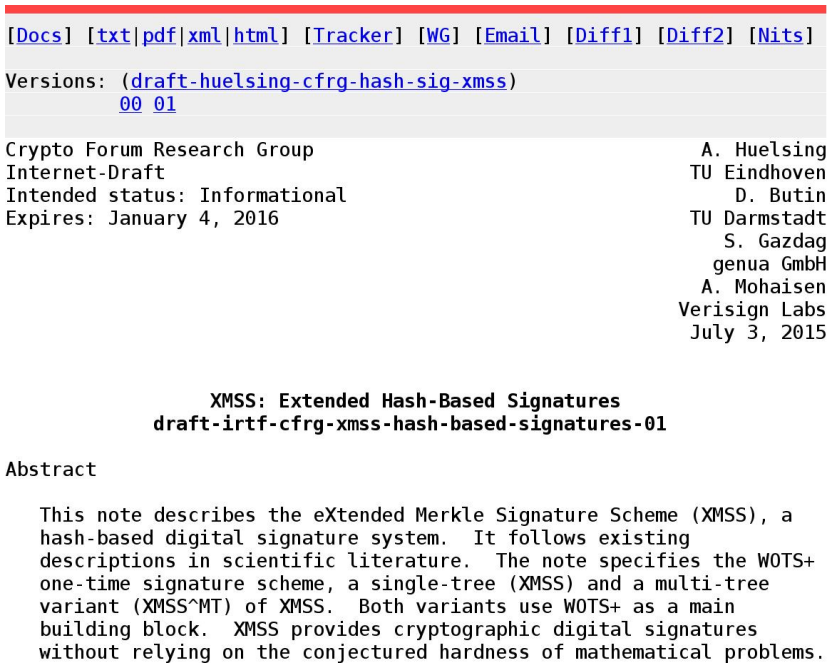
Abstract

This note describes the eXtended Merkle Signature Scheme (XMSS), a hash-based digital signature system. It follows existing descriptions in scientific literature. The note specifies the WOTS+ one-time signature scheme, a single-tree (XMSS) and a multi-tree variant (XMSS^MT) of XMSS. Both variants use WOTS+ as a main building block. XMSS provides cryptographic digital signatures without relying on the conjectured hardness of mathematical problems.

Hash-based signatures

Pros:

- Post quantum
- Only need secure hash function, e.g. SHA3-512, ...
- Need signatures anyways.
- Small public key
- Security well understood
- Fast
- Proposed for standards: https://tools.ietf.org/html/draft-irtf-cfrg-xmss-hash-based-signatures-01



[Docs] [txt|pdf|xml|html] [Tracker] [WG] [Email] [Diff1] [Diff2] [Nits]

Versions: (draft-huelsing-cfrg-hash-sig-xmss)
00 01

Crypto Forum Research Group
Internet-Draft
Intended status: Informational
Expires: January 4, 2016

A. Huelsing
TU Eindhoven
D. Butin
TU Darmstadt
S. Gazdag
genua GmbH
A. Mohaisen
Verisign Labs
July 3, 2015

XMSS: Extended Hash-Based Signatures
draft-irtf-cfrg-xmss-hash-based-signatures-01

Abstract

This note describes the eXtended Merkle Signature Scheme (XMSS), a hash-based digital signature system. It follows existing descriptions in scientific literature. The note specifies the WOTS+ one-time signature scheme, a single-tree (XMSS) and a multi-tree variant (XMSS^MT) of XMSS. Both variants use WOTS+ as a main building block. XMSS provides cryptographic digital signatures without relying on the conjectured hardness of mathematical problems.

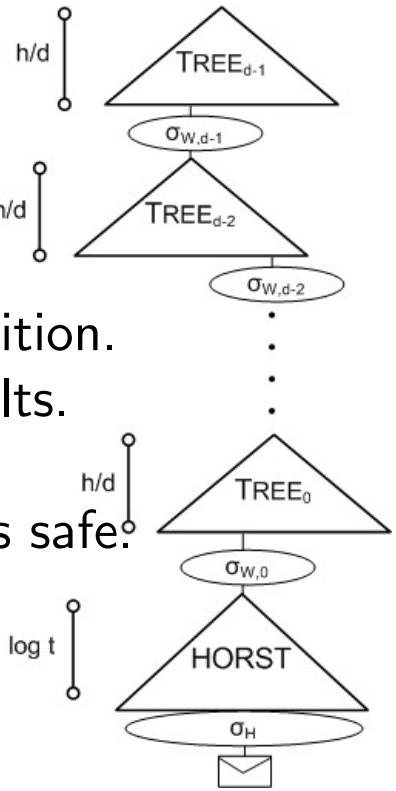
Cons:

- Biggish signature
- Stateful
  Adam Langley "for most environments it's a huge foot-cannon."


ELIMINATE
THE STATE

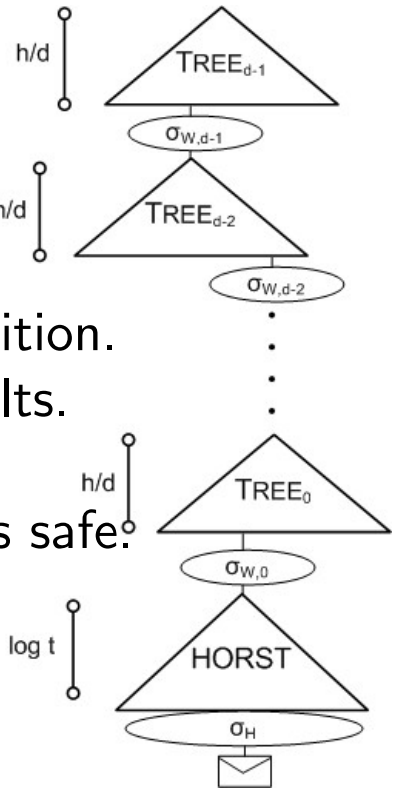
Stateless hash-based signatures

- Idea from 1987 Goldreich:
  - Signer builds huge tree of certificate authorities.
  - Signature includes certificate chain.
  - Each CA is a hash of master secret and tree position.
    This is deterministic, so don't need to store results.
  - **Random** bottom-level CA signs message.
    Many bottom-level CAs, so one-time signature is safe.

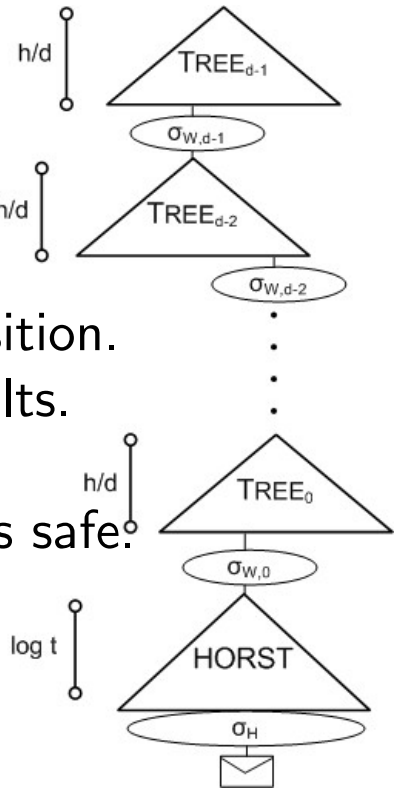


Stateless hash-based signatures

- Idea from 1987 Goldreich:
  - Signer builds huge tree of certificate authorities.
  - Signature includes certificate chain.
  - Each CA is a hash of master secret and tree position.
    This is deterministic, so don't need to store results.
  - **Random** bottom-level CA signs message.
    Many bottom-level CAs, so one-time signature is safe.
- 0.6 MB: Goldreich's signature with good 1-time signature scheme.
- 1.2 MB: average Debian package size.
- 1.8 MB: average web page in Alexa Top 1000000.



Stateless hash-based signatures



- Idea from 1987 Goldreich:
  - Signer builds huge tree of certificate authorities.
  - Signature includes certificate chain.
  - Each CA is a hash of master secret and tree position.
    This is deterministic, so don't need to store results.
  - **Random** bottom-level CA signs message.
    Many bottom-level CAs, so one-time signature is safe.
- 0.6 MB: Goldreich's signature with
  good 1-time signature scheme.
- 1.2 MB: average Debian package size.
- 1.8 MB: average web page in Alexa Top 1000000.

Our (lots of people) proposal: SPHINCS `sphincs.cr.yp.to`
0.041 MB signature; new optimization of Goldreich.
Modular, guaranteed as strong as its components (hash, PRNG).
Well-known components chosen for 2^{128} post-quantum security.

Further resources

- https://pqcrypto.org: Our (Dan and Tanja) survey site.
  - Many pointers: e.g., PQCrypto 2016.
  - Bibliography for 4 major PQC systems.
- https://pqcrypto.eu.org: PQCRYPTO EU project.
  Coming soon:
  - Expert recommendations.
  - Free software libraries.
  - More benchmarking to compare cryptosystems.
  - 2017: workshop and spring/summer school.
- https://twitter.com/pqc_eu: PQCRYPTO Twitter feed.