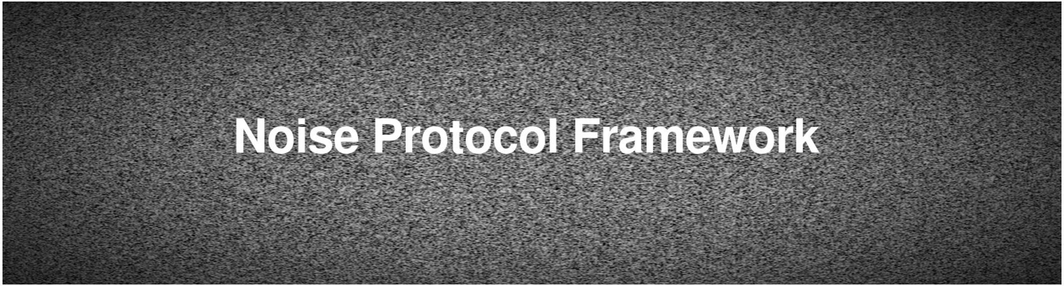
Post Quantum Noise

Yawning Angel Benjamin Dowling Andreas Hülsing Peter Schwabe
Florian Weber

(author-list in alphabetical order)

Noise

- Framework for Key Exchange Protocols
- Users include: WhatsApp, Wireguard, Lightning, I2P
- Diffie-Hellman based $\rightarrow$ not Quantum-safe



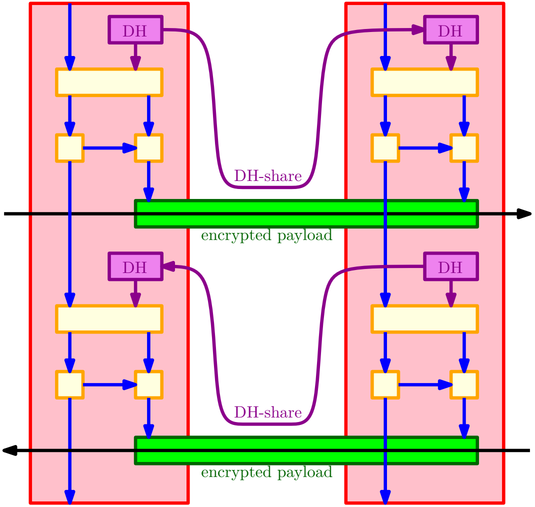
Noise

- Static and Ephemeral keys
- Fed into a hash-chain
- Hash-chain produces keys for symmetric encryption
- Messages can be sent early (with reduced security)

Patterns

- Used to describe specific exchanges
- s → static key, e → ephemeral key.
- Textual Format: For example:

```
XX:
    -> e
    <- e, ee, s, es
    -> s, se
```



Post Quantum Noise - Challenges

Goal: Same Security as Noise, but in a Post-Quantum-Setting

Idea: Replace the DH-key-exchanges with KEMs

- `e` and `s` works as before, sending KEM-PKs
- `ekem` sends an unencrypt KEM-ciphertext for `e`.
- `skem` sends an, if possible encrypted, KEM-ciphertext for `s`.

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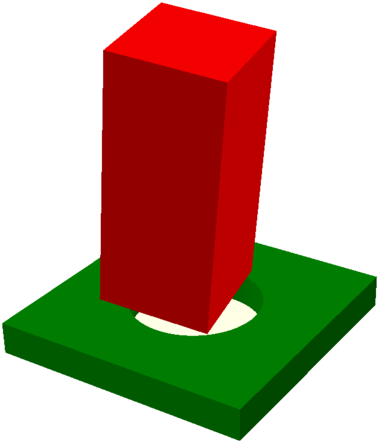
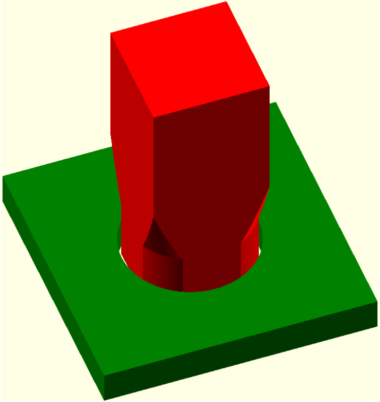


Problem: DH allows for non-interactive KX (NIKE)
Problem: DH creates bidirectional authenticity
Problem: DH keys can be freely combined.

Post Quantum Noise

- Some cases are trivial.
  - “`ee`”, “`-> es`”, “`<- se`”
  - $\rightarrow$ “`ekem`”, “`-> skem`”, “`<- skem`”.
- Some are challenging
  - “`<- es`”, “`-> se`”
  - switch parties and send the other way.
  - potentially adds a roundtrip
- Some are “impossible”
  - “`ss`” (combination of two long-term keys)
  - Cheat! (Next Slide)

Works but not always optimal.



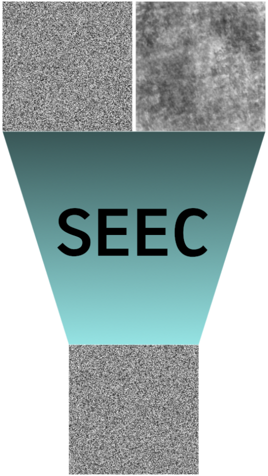
$\Rightarrow$ We also provide (conjectured) optimal solutions for all standard patterns.

Static-Ephemeral Entropy-Combination (SEEC)

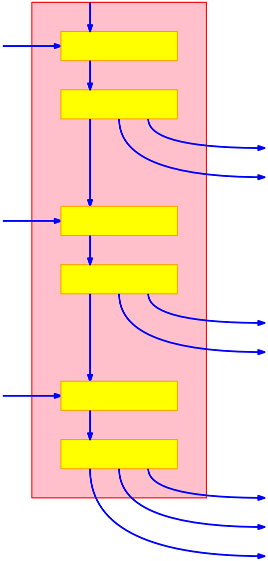
- Strengthen ephemeral randomness with static secret.

- Established: “NAXOS-trick”, “Twisted PRF-trick”, RFC 8937
- Previous formalizations implicit or tied to instantiation.

- Intentionally weak notion to cover existing schemes.
- Generic analysis with (insecure) identity possible



Analysis



- fACCE-model.
  - Used by previous analysis of Noise.
- Analyse Hash-chains as “Pseudorandom Hashobject”
  - Noise uses final state as output.
    $\rightarrow$ “Noise Pseudorandom Hashobject”
  - Allows for generic proof of all patterns in one go
- Previous Noise-analysis limited to specific patterns.
  - We match all proven and conjectured claims.
- KEMs all treated seperately.
  - Mixed-KEM-hybrids are covered (compare PQWireGuard)
  - Applicable to Classic-Noise+PQNoise-hybrids

Results

The following (generic!) statements also apply for non-composite hybrid patterns:

Ephemeral KEM

- All messages sent after `ekem` are confidential, if:
  - Both ephemeral keys are uncorrupted. ($\rightarrow$ Forward Secrecy)

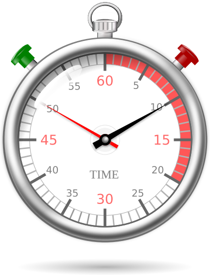
Initiator/Responder KEM

- All messages sent after `skem` are confidential, if:
  - The sender's ephemeral and the receivers static keys are uncorrupted.
- The sender is authentic, if s/he can continue for one more roundtrip, if:
  - The sender's ephemeral and the receivers static keys are uncorrupted.

SEEC

If a party uses SEEC, an uncorrupted static key can act as an uncorrupted ephemeral key.

Performance



- Implement in Nyquist
- Using Kyber-768 (Level 3) as KEM

	Initiator (fast NW)	Responder (fast NW)	Initiator (slow NW)	Responder (slow NW)
KK	16.35ms	0.42ms	98.73ms	0.41ms
PQKK	16.07ms	0.25ms	100.28ms	0.27ms
XX	16.02ms	16.1ms	98.47ms	98.6ms
PQXX	31.83ms	16.1ms	199.31ms	100.36ms

- Comparable for patterns that are trivial translations.
- Worse but acceptable for patterns with additional messages.

Thanks for your Attention!

And to Trevor Perrin and Denisa Greconici for many helpful discussions.