Security of Hedged Fiat–Shamir Signatures under Fault Attacks

Eurocrypt 2020
ePrint `https://ia.cr/2019/956`

Diego F. Aranha[1] Claudio Orlandi[1]
Akira Takahashi[1] Greg Zaverucha[2]

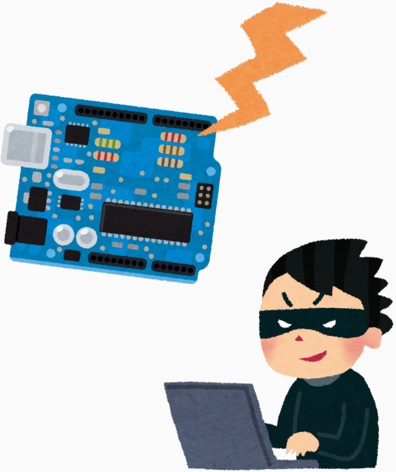
May 14, 2020

[1]Aarhus University, Denmark

[2]Microsoft Research, United States

Goal of Our Work

- Formally analyze the fault-resilience of existing Fiat–Shamir signatures
  - Provable security methodology.
  - Motivated by actual fault attacks on concrete schemes.



How to Protect Fiat–Shamir from Randomness Failure?

1. Randomized signature : $r \leftarrow \mathtt{RNG}(\cdot)$

- Nonces don't need to be uniform: low-quality RNG or counter should suffice.
- Randomness r doesn't repeat on the same message.

To what extent are hedged FS signatures secure against fault attacks?

How to Protect Fiat–Shamir from Randomness Failure?

1. Randomized signature : $\cancel{r \leftarrow \mathsf{RNG}(\cdot)}$ ☹ Risk of randomness bias!

- Nonces don’t need to be uniform: low-quality RNG or counter should suffice.
- Randomness r doesn’t repeat on the same message.

To what extent are hedged FS signatures secure against fault attacks?

How to Protect Fiat–Shamir from Randomness Failure?

1. Randomized signature : ~~$r \leftarrow \mathsf{RNG}(\cdot)$~~ ☹ Risk of randomness bias!
2. Deterministic signature : $r \leftarrow \mathsf{H}(sk, m)$

- Nonces don't need to be uniform: low-quality RNG or counter should suffice.
- Randomness r doesn't repeat on the same message.

To what extent are hedged FS signatures secure against fault attacks?

How to Protect Fiat–Shamir from Randomness Failure?

1. Randomized signature : $\cancel{r \leftarrow \mathsf{RNG}(\cdot)}$ ☹ Risk of randomness bias!
2. Deterministic signature : $\cancel{r \leftarrow \mathsf{H}(sk, m)}$ ☹ Vulnerable to fault attacks!

- Nonces don't need to be uniform: low-quality RNG or counter should suffice.
- Randomness r doesn't repeat on the same message.

To what extent are hedged FS signatures secure against fault attacks?

How to Protect Fiat–Shamir from Randomness Failure?

1. Randomized signature : $\cancel{r \leftarrow \mathsf{RNG}(\cdot)}$ ☹ Risk of randomness bias!
2. Deterministic signature : $\cancel{r \leftarrow \mathsf{H}(sk, m)}$ ☹ Vulnerable to fault attacks!
3. Hedged signature : $r \leftarrow \mathsf{H}(sk, m, nonce)$ ☺ Seems secure?

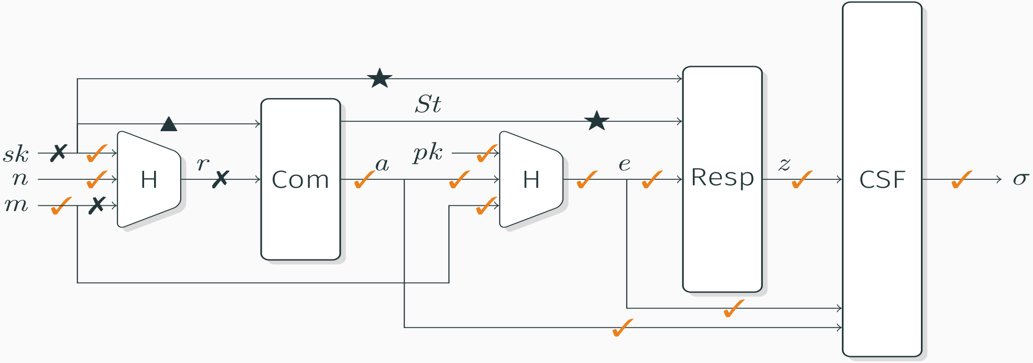
- Nonces don't need to be uniform: low-quality RNG or counter should suffice.
- Randomness r doesn't repeat on the same message.

To what extent are hedged FS signatures secure against fault attacks?

Contributions

- Formal attacker model and security notions to capture the corrupted nonces and previous fault attacks.
- Proved that hedged FS schemes in general are secure against single-bit fault attacks on many intermediate wire values in the signing algorithm.
    - + Negative results for a few wires.
- Application to concrete instantiations.
    - XEdDSA: Hedged variant of EdDSA used in Signal
    - Picnic2: NIST PQC competition round 2 candidate

Overview of Our Results



If $\mathcal{A}$ doesn't query the same (m, n) pair more than once

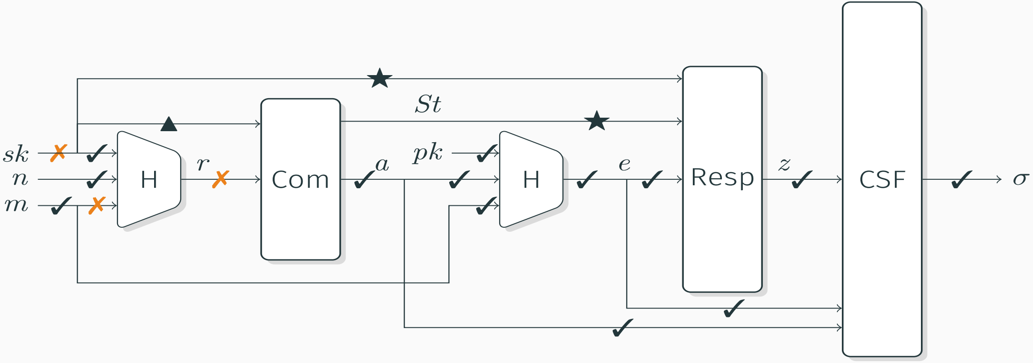
✓ secure against single-bit flip/stuck-at faults.

✗ insecure against single-bit flip/stuck-at faults.

★ security only holds for signatures from subset-revealing ID (e.g., Picnic).

▲ security only holds for signatures from input-delayed ID (e.g., XEdDSA).

Overview of Our Results



If $\mathcal{A}$ doesn't query the same (m, n) pair more than once

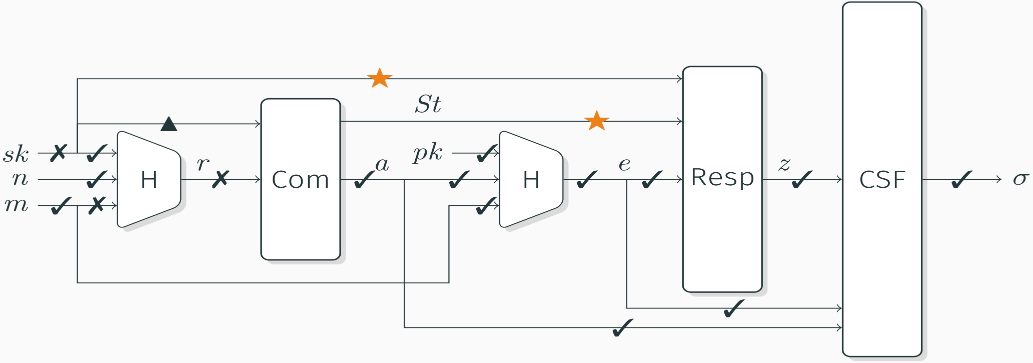
✓ secure against single-bit flip/stuck-at faults.

✗ insecure against single-bit flip/stuck-at faults.

★ security only holds for signatures from subset-revealing ID (e.g., Picnic).

▲ security only holds for signatures from input-delayed ID (e.g., XEdDSA).

Overview of Our Results



If $\mathcal{A}$ doesn't query the same (m, n) pair more than once

✓ secure against single-bit flip/stuck-at faults.

✗ insecure against single-bit flip/stuck-at faults.

★ security only holds for signatures from subset-revealing ID (e.g., Picnic).

▲ security only holds for signatures from input-delayed ID (e.g., XEdDSA).

Conclusion

- Hedged FS is provably more resilient than the randomized/deterministic FS!
    - Negative results show where practitioners pay the most attention.
- Open questions
    - Extension to more advanced fault attacker model.
        - Multi-bit/position faults. Partially handled by Fischlin and Günther (CT-RSA'20) for generic signatures.
        - Fault within Com, Resp or public parameters.
        - Model for instruction skipping faults.
        - Fault + QROM.
    - Lattice signatures from FS with aborts.

Thank you!

More details at `https://ia.cr/2019/956`