Quantum-Safe Encryptor

CHESS CA5 Activities

Lukas Malina

Brno University of Technology
malina@vut.cz
https://axe.vut.cz

BRNO UNIVERSITY OF TECHNOLOGY FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

Brno AXE Applied Cryptography & Security Engineering

CHESS

Funded by the European Union

AXE Group at Brno University of Technology

Applied Cryptography and Security Engineering (AXE):

- based in Brno, Czech Republic,
- focused on PQC, PETs, Lightweight Crypto, SCA,
- delivering implementations for specific platforms: FPGA, smart-cards, constrained devices.

Solutions to Quantum Threat

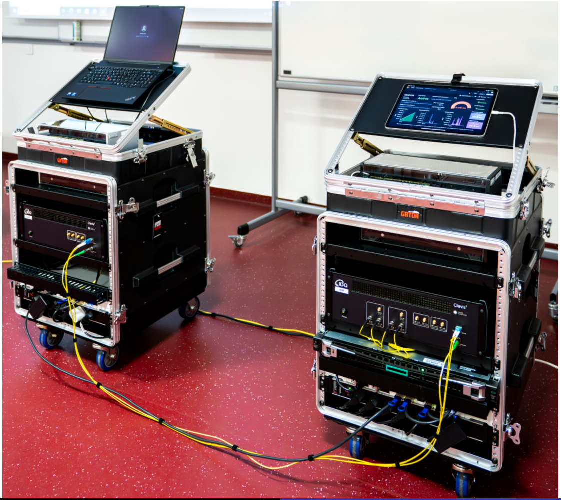
Post-Quantum Cryptography

- *easy* integration with existing ICT, no special HW, cheap,
- existing SW implementations: OpenSSL 3.5, Open Quantum Safe,
- supported by national authorities: UK, US, Germany, France, Sweden, Netherlands, . . . ,
- FIPS standardization: CRYSTALS-Kyber, CRYSTALS-Dilithium, FALCON (lattice-based) and SPHINCS+ (hash-based)

QKD - Quantum Key Distribution - only key establishment.
Hybrid Solutions - combining PQC, classical cryptography, QKD.

FPGA Quantum-Safe Encryptor I

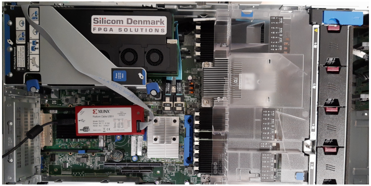
- Demonstrator of FPGA Quantum-Safe Encryptor.



FPGA Quantum-Safe Encryptor II

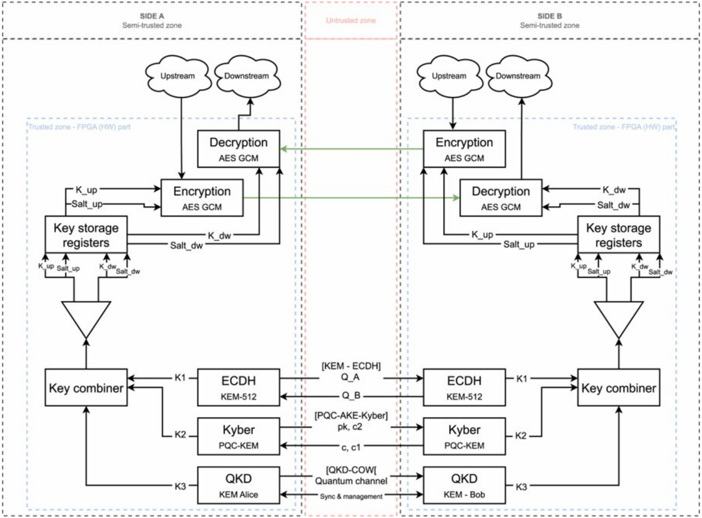
FPGA Quantum-Safe Encryptor

- aim: hardware-accelerate high-speed encryptor for 100 GbE networks using standard TCP/IP protocols,
- hybrid KEM, keys from classical (ECDH), PQC (ML-KEM) and QKD (optional).
- implemented on programmable network interfaces with FPGA,
- supported by the Ministry of Interior (CZ), project NESPOQ #VJ01010008[1], and tested/piloted by CHESS.



[1] https://www.nespoq.cz

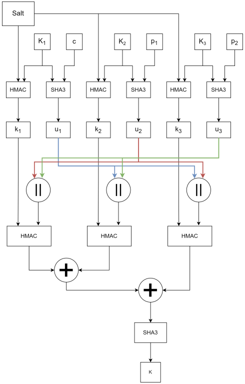
FPGA Quantum-Safe Encryptor III

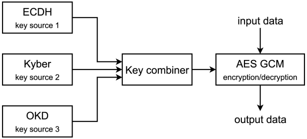


FPGA Quantum-Safe Encryptor IV

Cryptography components:

- Classical cryptography: ECDH-512,
- Quantum Key Distribution: IDQ Clavis 3,
- Post-Quantum: CRYSTALS-Kyber 768,
- Payload Encryption: AES-256-GCM,
- Key Combiner: own[2].

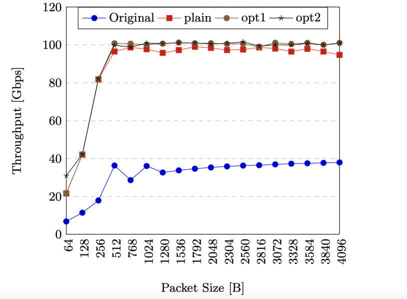


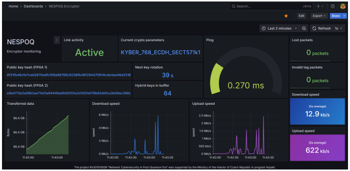

ECDH
key source 1
Kyber
key source 2
OKD
key source 3
Key combiner
input data
AES GCM
encryption/decryption
output data

[2] S. Ricci et Al, "Hybrid Keys in Practice: Combining Classical, Quantum and Post-Quantum Cryptography," in IEEE Access, vol. 12, 2024.

FPGA Quantum-Safe Encryptor V

- Throughput: 117,3 Gbps[3], high parallelism (for AES-GCM).
- Generating 1624 hybrid keys per second (without QKD).
- Monitoring via Grafana GUI.





NESPOQ

Encryptor monitoring

Link activity: Active

Current crypto parameters: KYBER_768_ECDH_SECT571k1

Ping: 0.270 ms

Lost packets: 0 packets

Public key hash (FPGA 1): 8f31fb46cfa7ceb5870edfcf09a98768c9238fb46f294470914cde4aa46d2516

Next key rotation: 39 s

Invalid tag packets: 0 packets

Public key hash (FPGA 2): e9a0713e2a09b2ae71e12a94446ad0d5555a2d1d51e078b83dd1ca3b08ac388c

Hybrid keys in buffer: 64

Transferred data

Download speed

Upload speed

Download speed (5s average) 12.9 kb/s

Upload speed (5s average) 622 kb/s

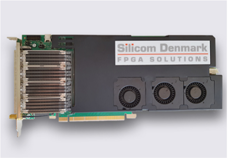
The project #VJ01010008 "Network Cybersecurity in Post-Quantum Era" was supported by the Ministry of the Interior of Czech Republic in program Impakt.

[3] Cibik et al. Quantum-resistant hardware-accelerated IoT traffic encryptor, Internet of Things, 2025.

FPGA Quantum-Safe Encryptor VI

Optimization and Costs:

- originally designed for **Xilinx UltraScale+** FPGA chips,
- implemented and tested on **Silicom Denmark Mango** cards (approx. 10K EUR),
- and adapted for **Intel Agilex** (approx. 4K EUR),
- implemented and tested on **Intel N6010** (approx. 3K EUR),
- since 2025: **IP Cores commercially available**,
- currently: SCA resistance using masking techniques.



Conclusion

- First hybrid encryptor (PQC ML-KEM, ECDH, QKD).
- Extreme performance: up to **100 Gbps**.
- Protected against side channel attacks.
- Piloted between Czechia and Estonia: BUT and CYBERNETICA.
- Supported by CHESS CA5.

Thank you for your attention.

Video: https://www.youtube.com/watch?v=an5DwtZ1BjQ

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