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Incorporating Post-Quantum Cryptography in a microservice architecture

Research Project 2

Why think about post-quantum cryptography

W. Buchanan et. al concluded

- Gate-based quantum computers pose a significant threat to a-symmetrical encryption (which is used in PKI)
  - Shor's algorithm
- Likely theoretical → practical <10 years

A-symmetric keys are used by:

- (D)TLS
- SSH
- WPA & WPA2
- DNSSec
- IKEv2 (IPSec & VPN)
- S/MIME

Research questions

What are the **implications** of **transitioning** to **post-quantum cryptography** in many-to-one **microservice architectures** where certificates are used for both **encryption** and **mutual authentication**?

Two sub questions:

1. **Suitable algorithms**
2. **Practical feasibility**

Related work

National Institute of Standards and Technology (NIST)

- 2nd round with Post Quantum Cryptography (PQC)
    - 17 different Post Quantum Key Exchange Algorithms
    - 9 different Post Quantum Signature Algorithms

E. Crockett et. al - OpenQuantum Safe

- Forked OpenSSH
- Forked OpenSSL
    - 8 different Post Quantum Key Exchange Algorithms
    - 3 different Post Quantum Signature Algorithms

Related work (cont)

J. Kreps et. al - detailed insight about inner workings of Kafka

K. Sheykh Esmaili et. al - important aspects of microservices:

- Correctness - Delivery guarantees & Ordering guarantees
- Availability - Maximize its uptime
- Transactions - Group messages into units
- Scalability - Evolve with growing amount of tasks
- Efficiency
    - Latency of a packet / message
    - Throughput (number / bytes of packets per time unit)

Background

- What is Kafka?
  - Publish / subscribe mechanism
  - Developed by LinkedIn
  - Stands out in bulk messaging
  - Passive and stateless
    - Publisher (delivers data) pushes data
    - Consumer (requests data) pulles data
- What is Post Quantum Cryptography?
  - Classical key exchange relies on factorization (e.g. RSA) or logarithmic (e.g. DH and ECC) mathematical problems
  - PQC relies on other mathematical problems
    - Not yet solvable by quantum computers

Open Quantum Safe OpenSSL fork

Level	Post Quantum Key Exchange Mechanisms	Post Quantum Digital Signature Algorithms
I	bike1l1cpa, bike1l1fo, frodo640aes, frodo640shake, Kyber512, newhope512cca, ntru_hps2048509, lightsaber, sidhp434, sikep434	dilithium2 picnicl1fs qteslapi
II	Sidhp503, sikep503	dilithium3
III	Bike1l3cpa, bike1l3fo, frodo976aes, frodo976shake, ntru_hps2048677, ntru_hrss701, Saber, Sidhp610, sikep610	dilithium4 qteslapiii
IV	None	None
V	frodo1344aes, frodo1344shake, kyber1024, newhope1024cca, Ntru_hps4096821, Firesaber, Sidhp751, sikep751	None

Open Quantum Safe OpenSSL fork Hybrid Algorithms

Level	Hybrid Post Quantum Key Exchange Mechanisms	Hybrid Post Quantum Digital Signature Algorithms
I	p256_bike1l1cpa, p256_bike1l1fo, p256_frodo640aes, p256_frodo640shake, p256_kyber512, p256_newhope512cca, p256_ntru_hps2048509, p256_lightsaber, p256_sidhp434, p256_sikep434.	rsa3072_dilithium2, p256_dilithium2, rsa3072_picnicl1fs, p256_picnicl1fs, rsa3072_qteslapi, p256_qteslapi
II	None	None
III	None	p384_dilithium4, p384_qteslapiii
IV	None	None
V	None	None

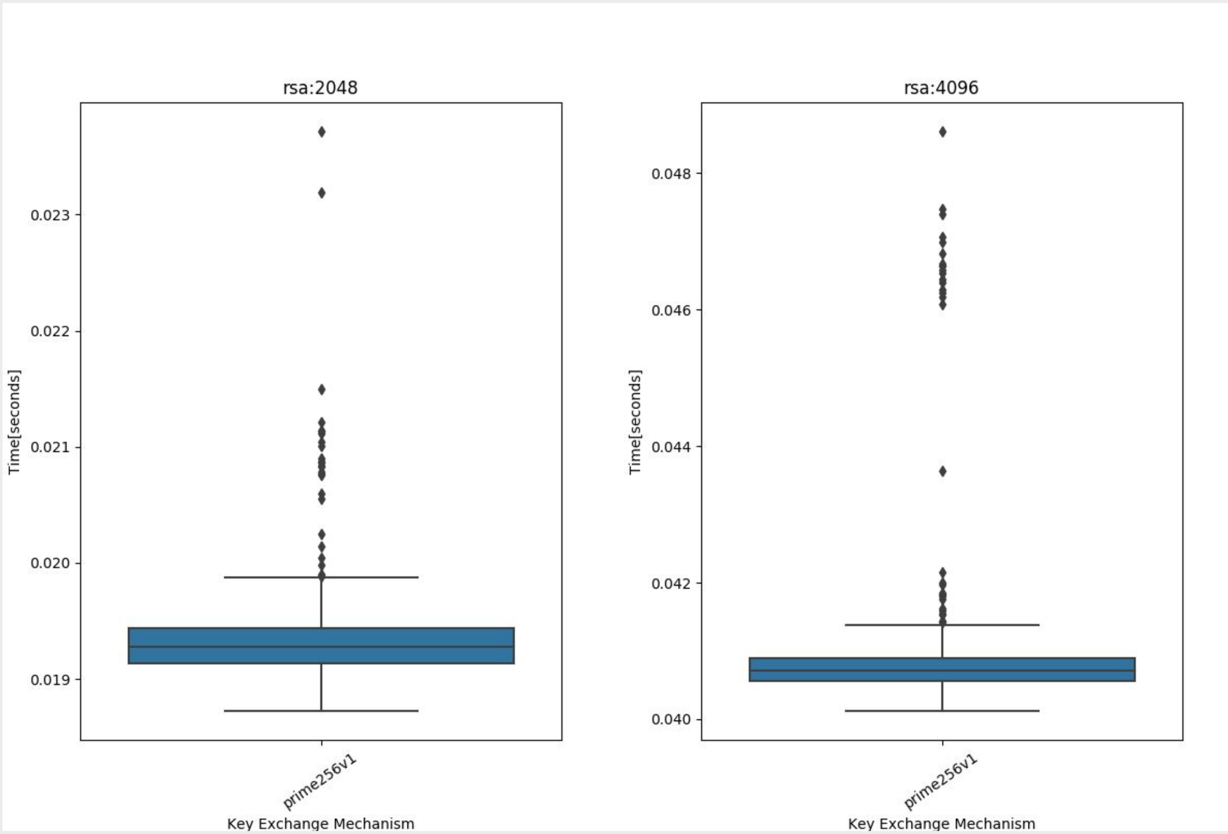
Methodology:

- What are the handshake differences (elapsed time, peak heap memory) between
  - Classical cryptography
  - Post-Quantum Cryptography
  - Hybrid-Post-Quantum Cryptography
- Divide the algorithms per security level (provided by NIST)

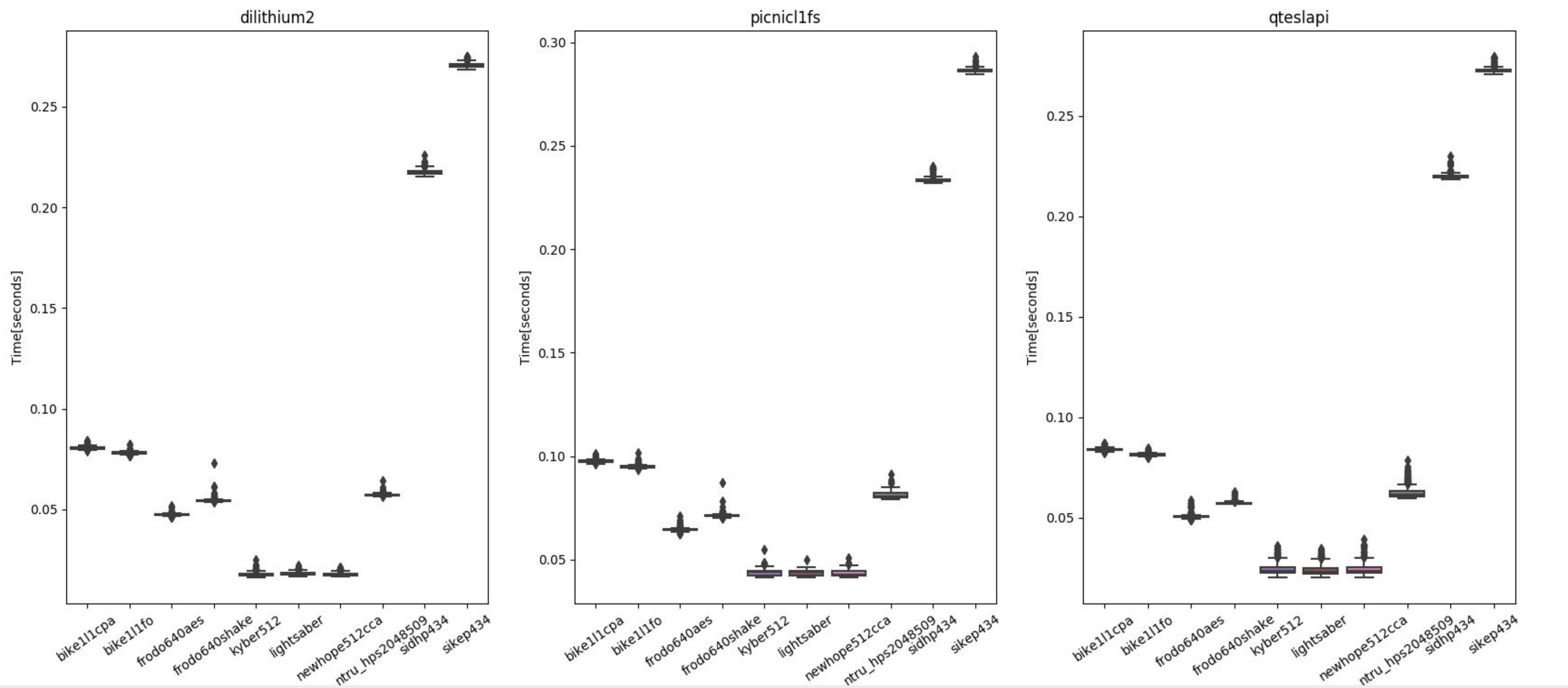
Level	Security Description
I	**At least as hard to break as AES128 (exhaustive key search)**
II	**At least as hard to break as SHA256 (collision search)**
III	**At least as hard to break as AES192 (exhaustive key search)**
IV	At least as hard to break as SHA384 (collision search)
V	At least as hard to break as AES256 (exhaustive key search)

(NIST, 2019)

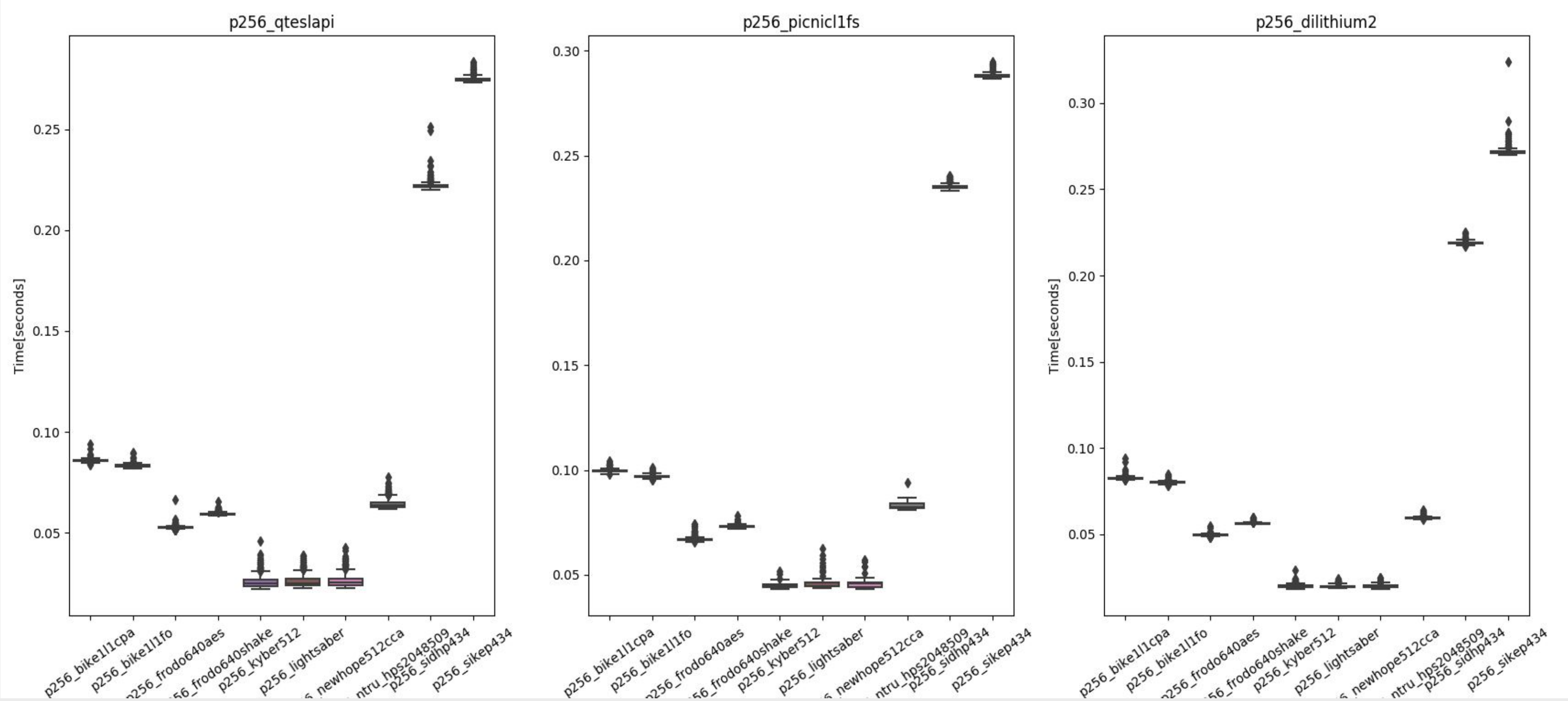
Results
Classical Cryptography algorithms



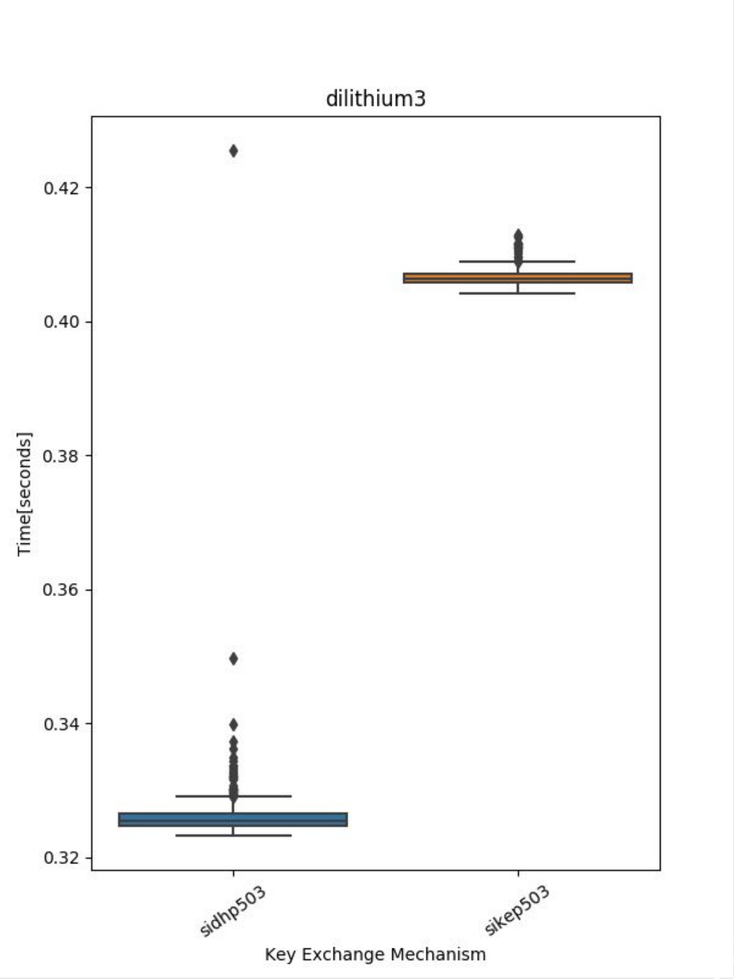
Results
Handshake Level 1 - PQC



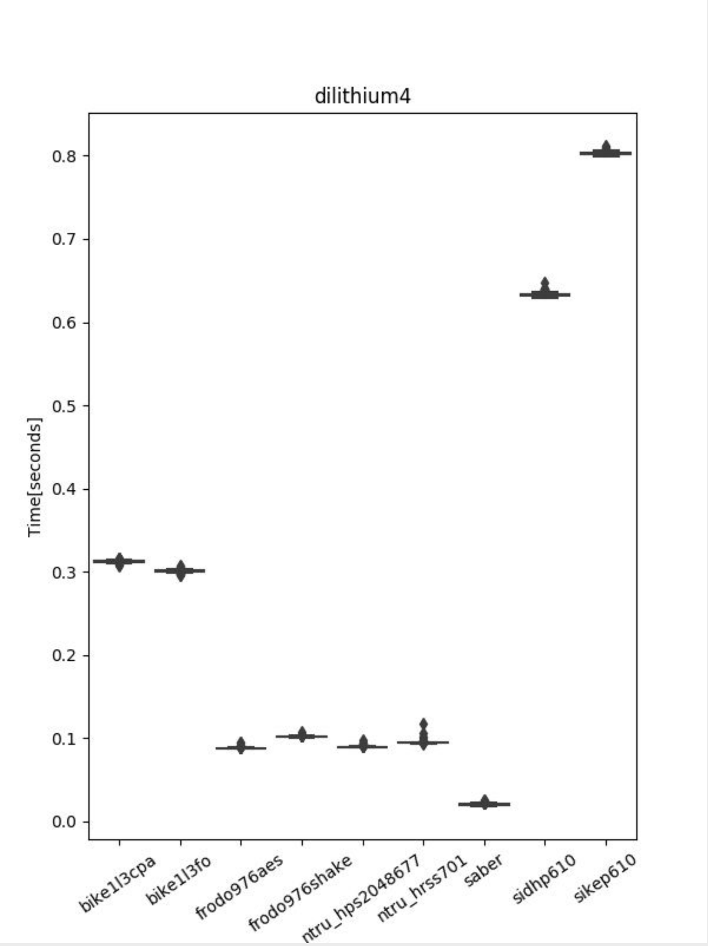
Results
Handshake Level 1 - Hybrid PQC

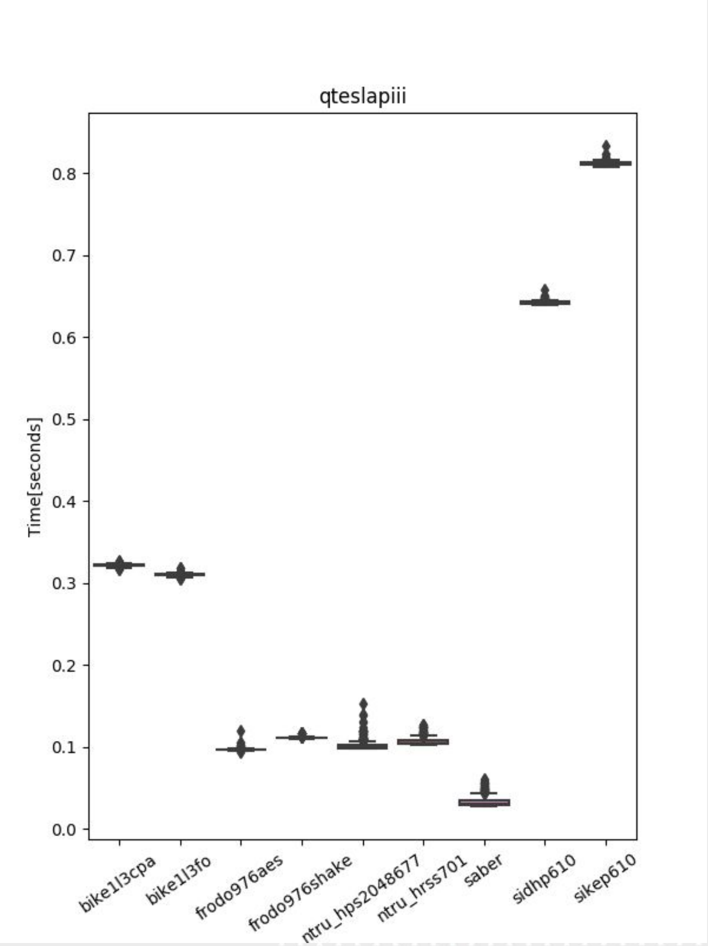


Results
Handshake Level 2 - PQC



Results
Handshake Level 3 - PQC





Preliminary conclusions

What are the **implications** of **transitioning** to **post-quantum cryptography** in many-to-one **microservice architectures** where certificates are used for both **encryption** and **mutual authentication**?

- **Suitable algorithms**
  - L1
    - Dilithium2 - Kyber512 / Lightsaber / NewHope512cca
    - Picnicl1fs - Kyber512 / Lightsaber / NewHope512cca
    - qTeslapi - Kyber512 / Lightsaber / NewHope512cca
  - L2
    - Dilithium3 - SiDHp503
  - L3
    - Dilithium4 - Saber / Frodo / NTRU
    - qTeslapiii - Saber / Frodo / NTRU

Preliminary conclusions (cont)

What are the **implications** of **transitioning** to **post-quantum cryptography** in many-to-one **microservice architectures** where certificates are used for both **encryption** and **mutual authentication**?

- **Practical feasibility**
  - Kafka relies on Java
    - PQC not yet implemented in Java Security stack
    - Using the OpenSSL fork for Kafka requires additional customization
  - Using the OpenSSL fork
    - Using Hybrid for transitioning
    - Handshake time is not that much longer

Discussion

- Algorithms still in development
  - NIST Round 2 still in progress

- We did not test these algorithms in a microserver environment
  - CPU measurements not taken into account
  - Our setup was optimal, we did not test multiple concurrent sessions

Future work

- Experiment with Java Security stack
  - development of general interface for third party libraries

- Experiment with liboqs algorithms in the OpenSSL fork
  - Still in development
  - Not all are available for proper testing