Post-Quantum

Cryptography Conference

Update on end-to-end PKI and HSM integrations with ML-DSA

At last years PQC Conference we benchmarked Hardware Securtiy Modules with Dilithium. Now that FIPS-204 is released, it is time to forget about Dilithium and do production level integrations using ML-DSA. This session shows PKI application integration for issuing certificates, with a number of HSMs that are ready for ML-DSA. We will highlight how easy, or hard, it is to integrate using PKCS#11 or REST APIs. Of course there will be benchmarks of certificate issuance comparing ML-DSA against classic algorithms. Let's see what else we are able to squeeze in until January.

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SSL.com PQ SHIELD HID KEYFACTOR ENTRUST

January 15 and 16, 2025 - Austin, TX (US) | Online

PKI Consortium

End-to-end PQC and HSM integrations (with PKI)

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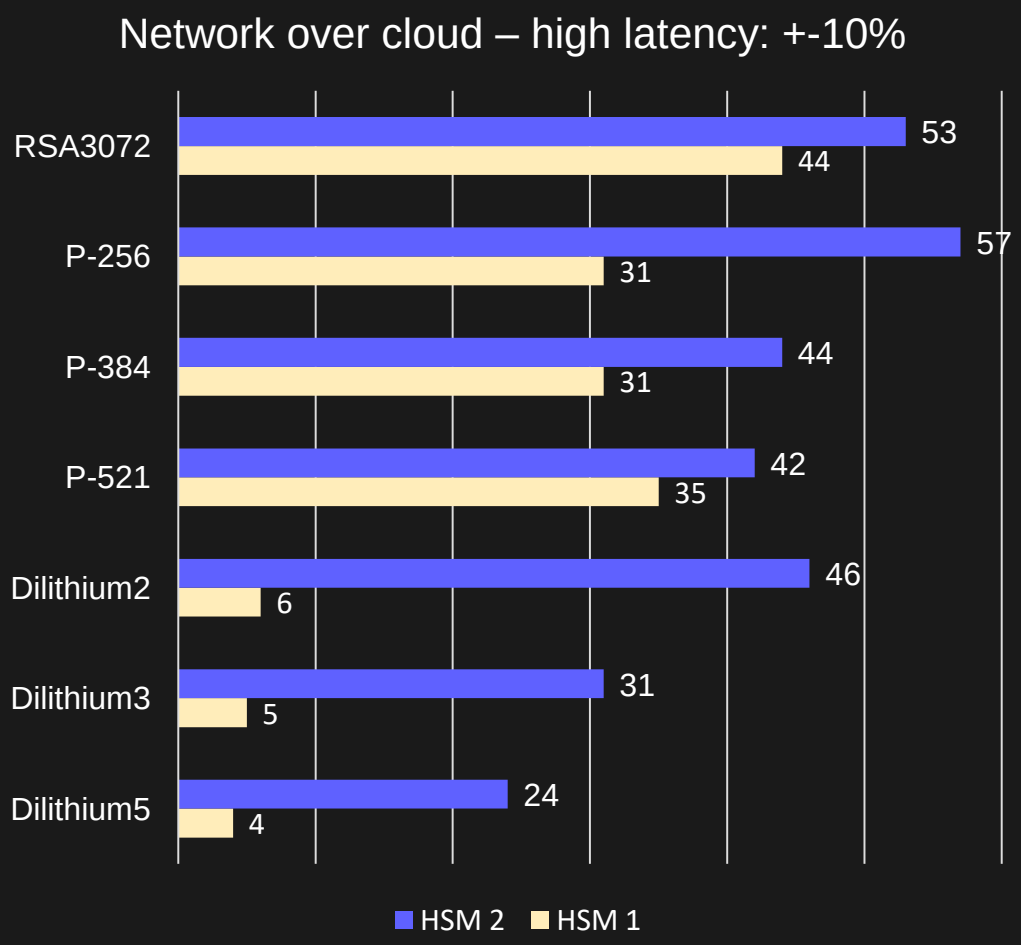
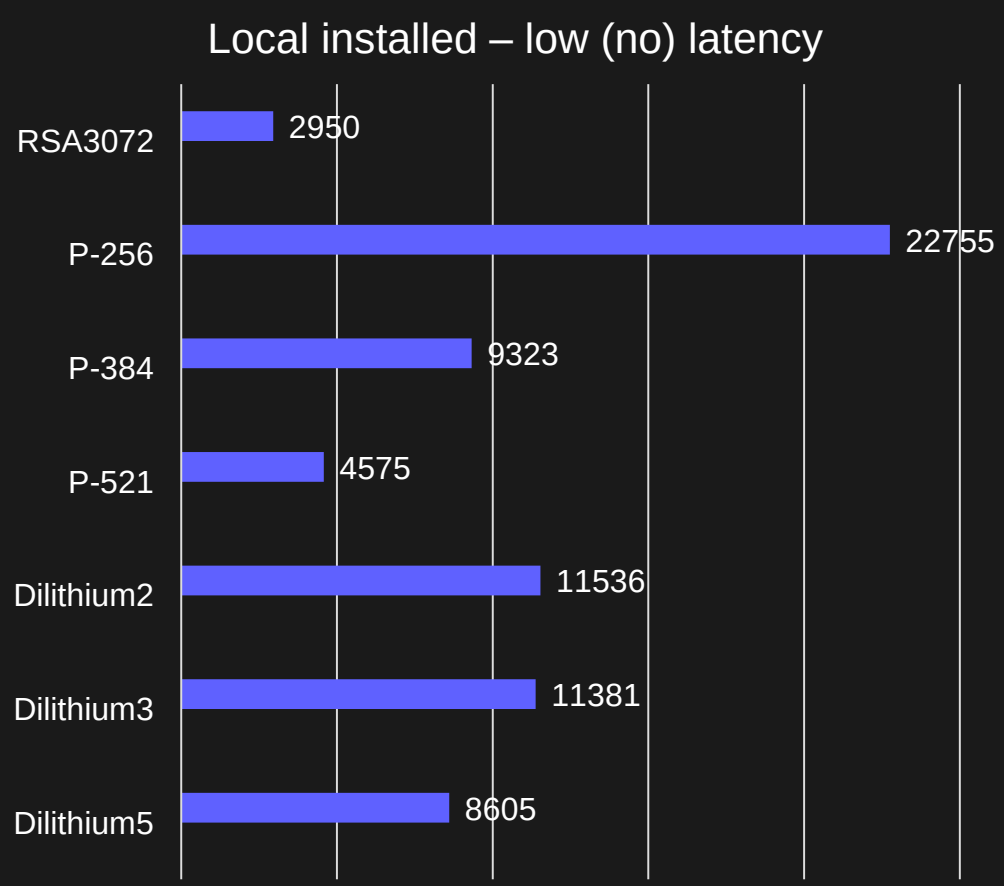
Keyfactor

Signing Speed – Recap





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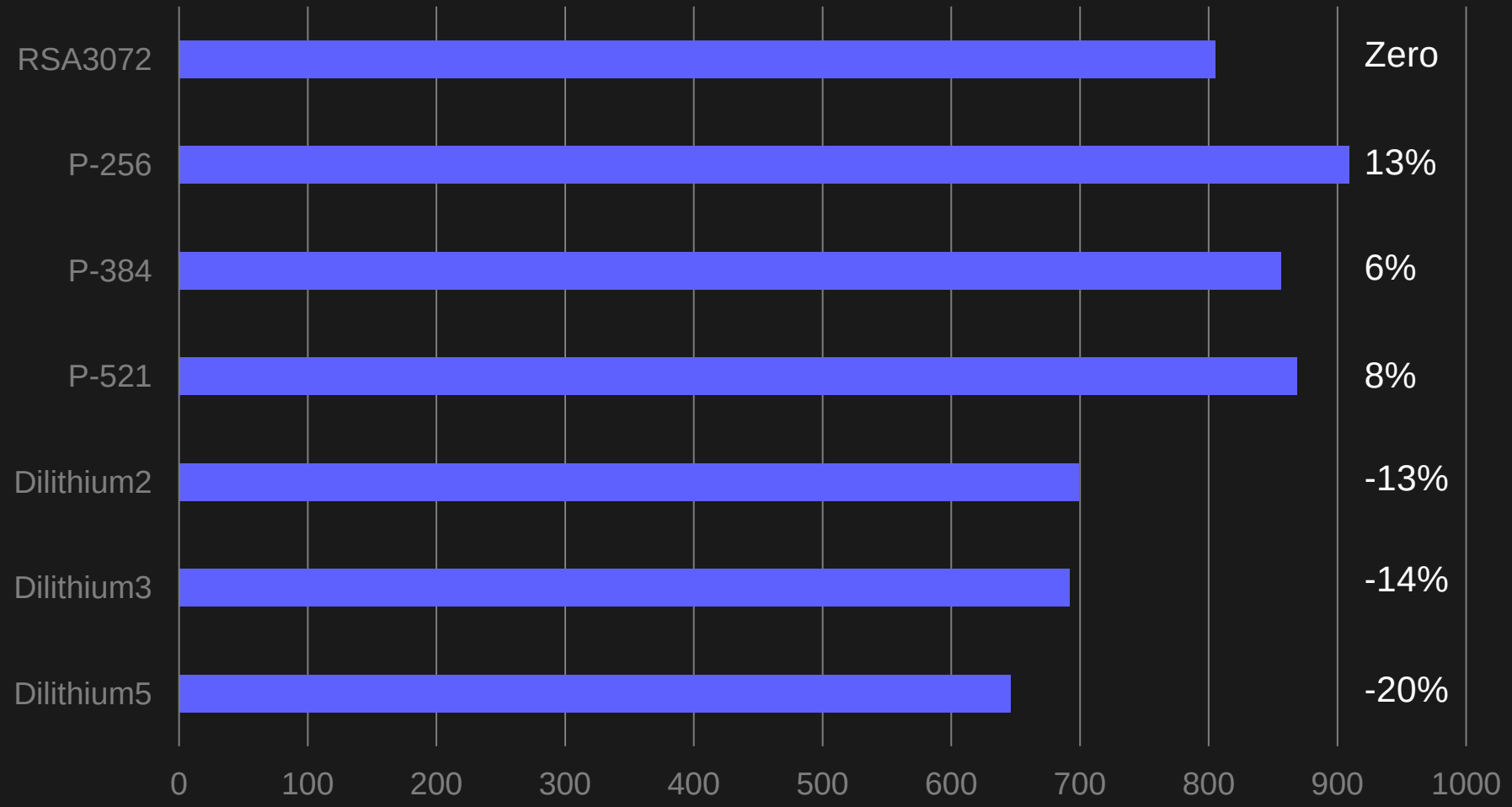
Certificate Issuance - Recap



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~~Dilithium~~
ML-DSA / FIPS 204
Quantum ready algorithms
~~SPHINCS+~~
SLH-DSA / FIPS 205
~~Kyber~~
ML-KEM / FIPS 203
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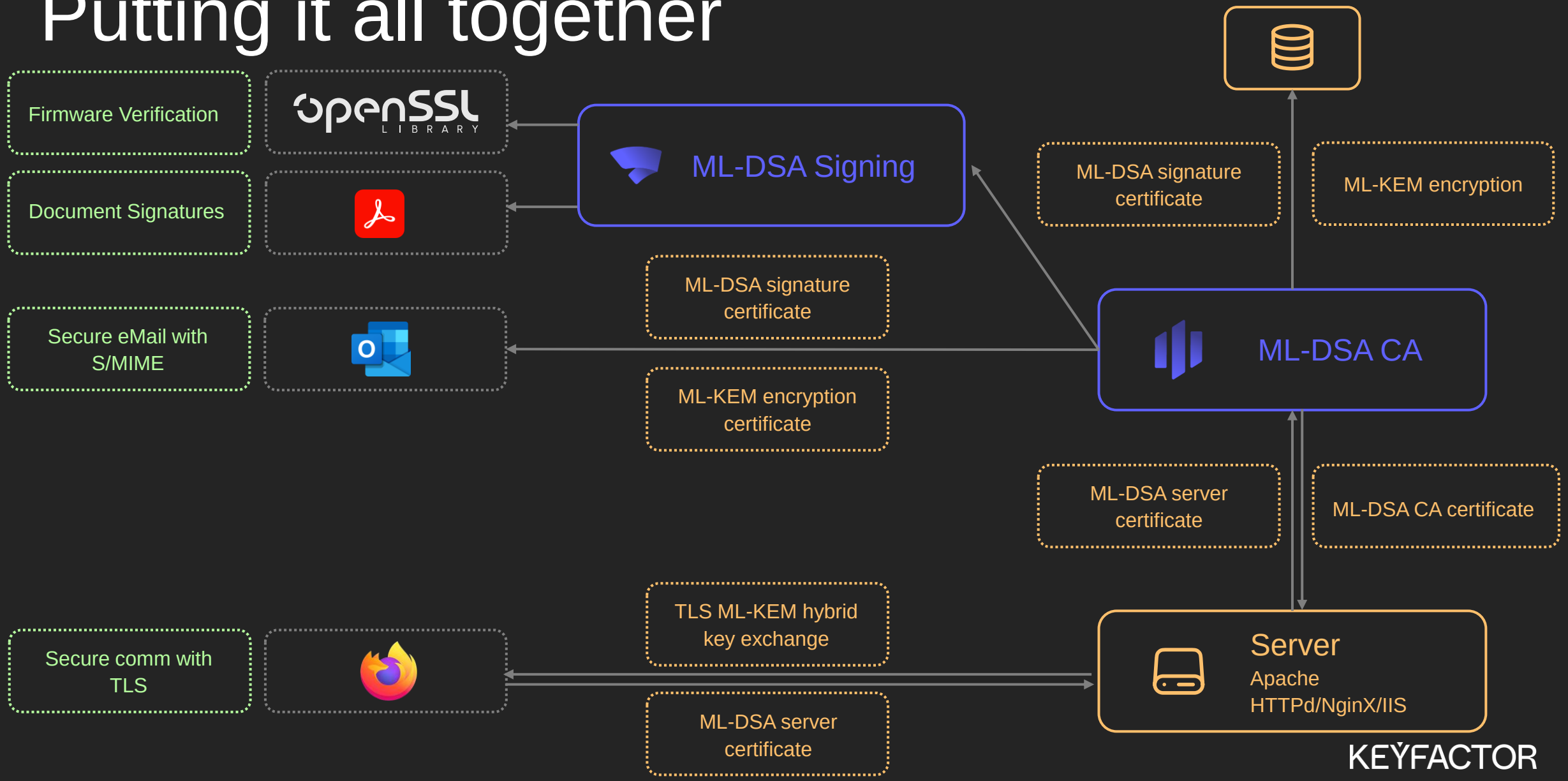
Putting it all together



What about PKI and Signing?

PKI and Digital Signatures always use HSMs in production.

You will notice the difference between different tokens...

- Using SoftHSM is in-memory
- PCI HSMs are in-memory
- Network based HSMs pass the network stack and wire (latency)
- Cloud HSMs pass the Internet

There is a reason why hash-and-sign is efficient

There is also a reason why hash-and-sign is legacy

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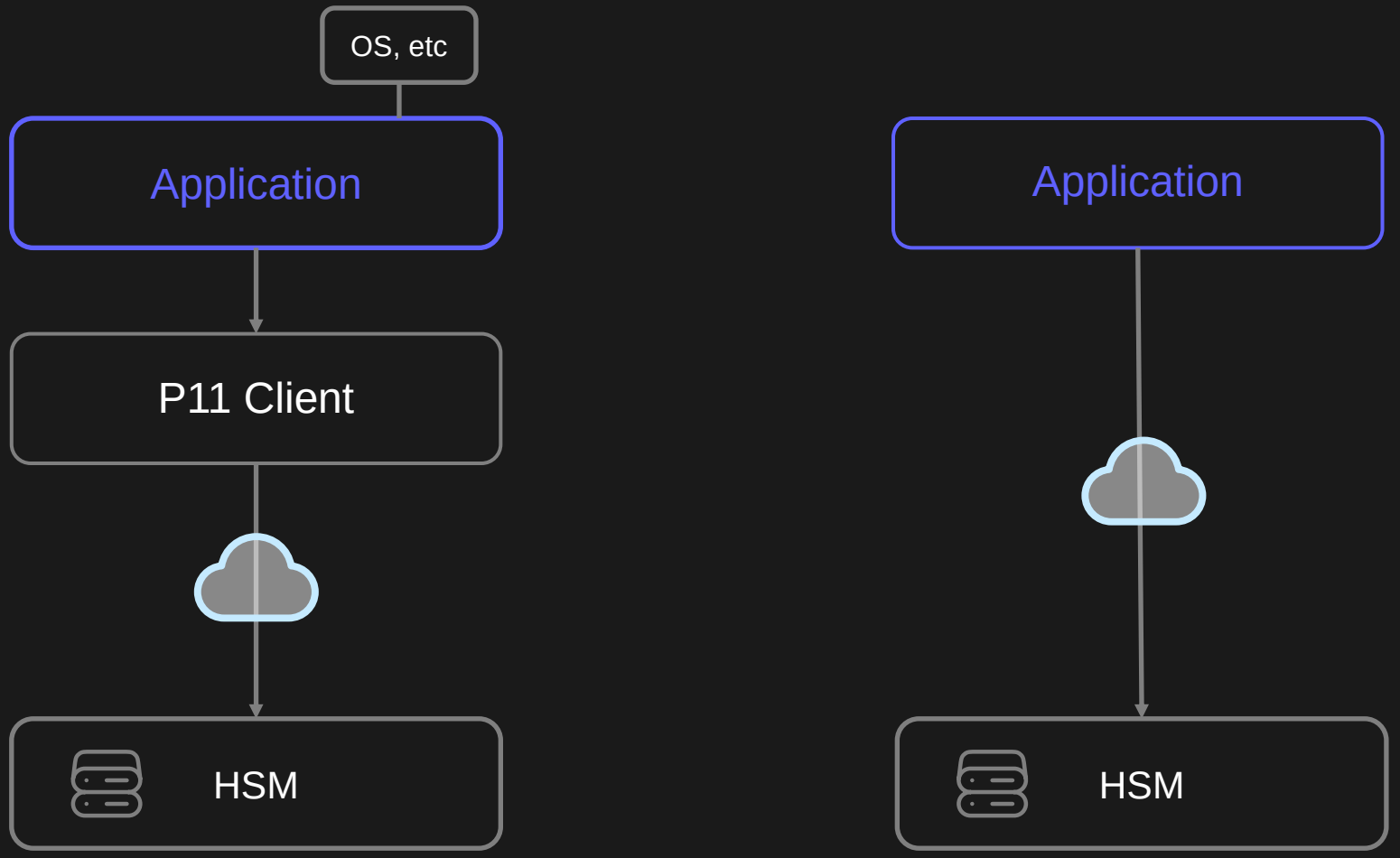
REST vs PKCS#11



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PQC
in Practice
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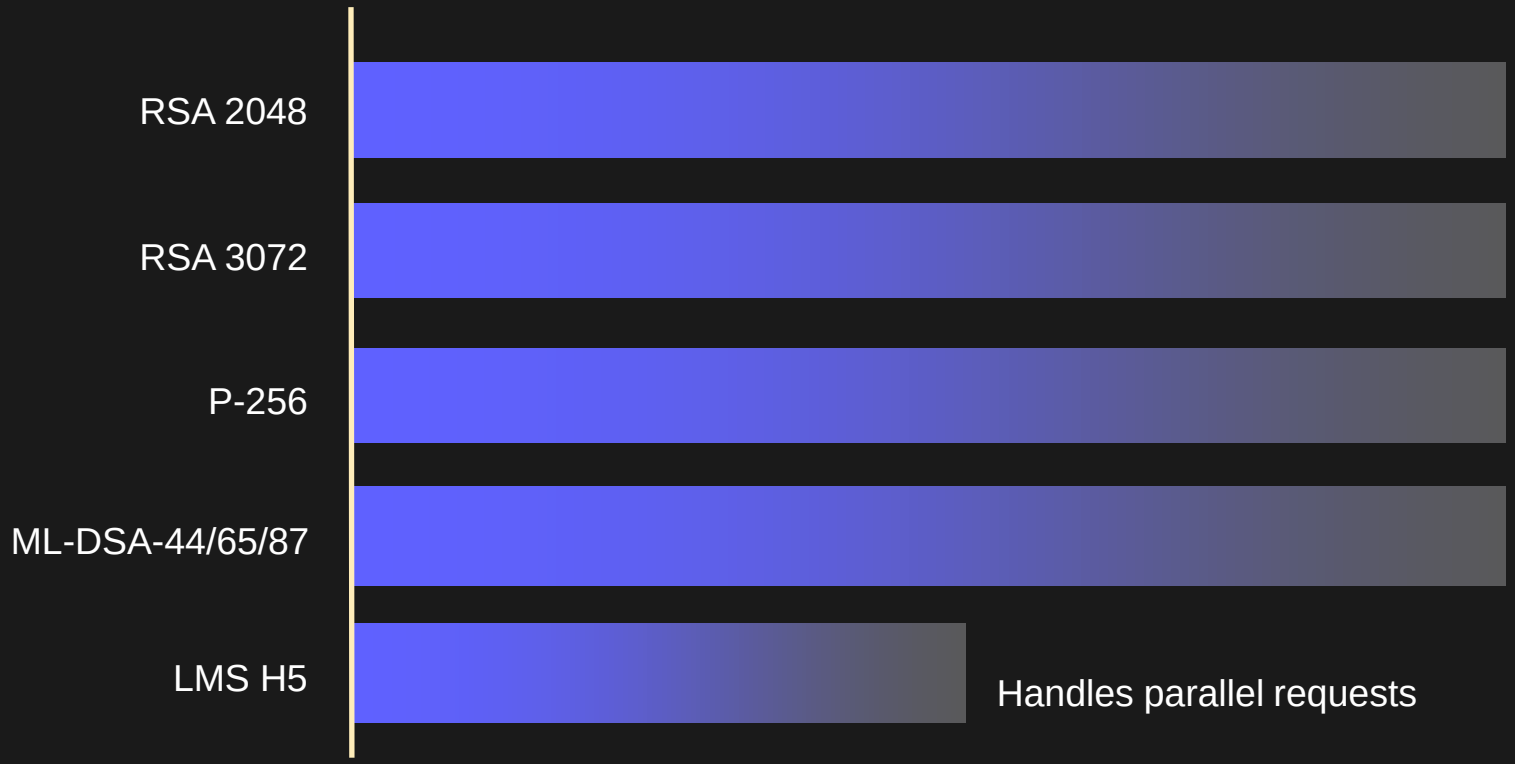
Certificate Issuance HSM 1

REST remote Internet



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Certificate Issuance HSM 2

REST remote Internet

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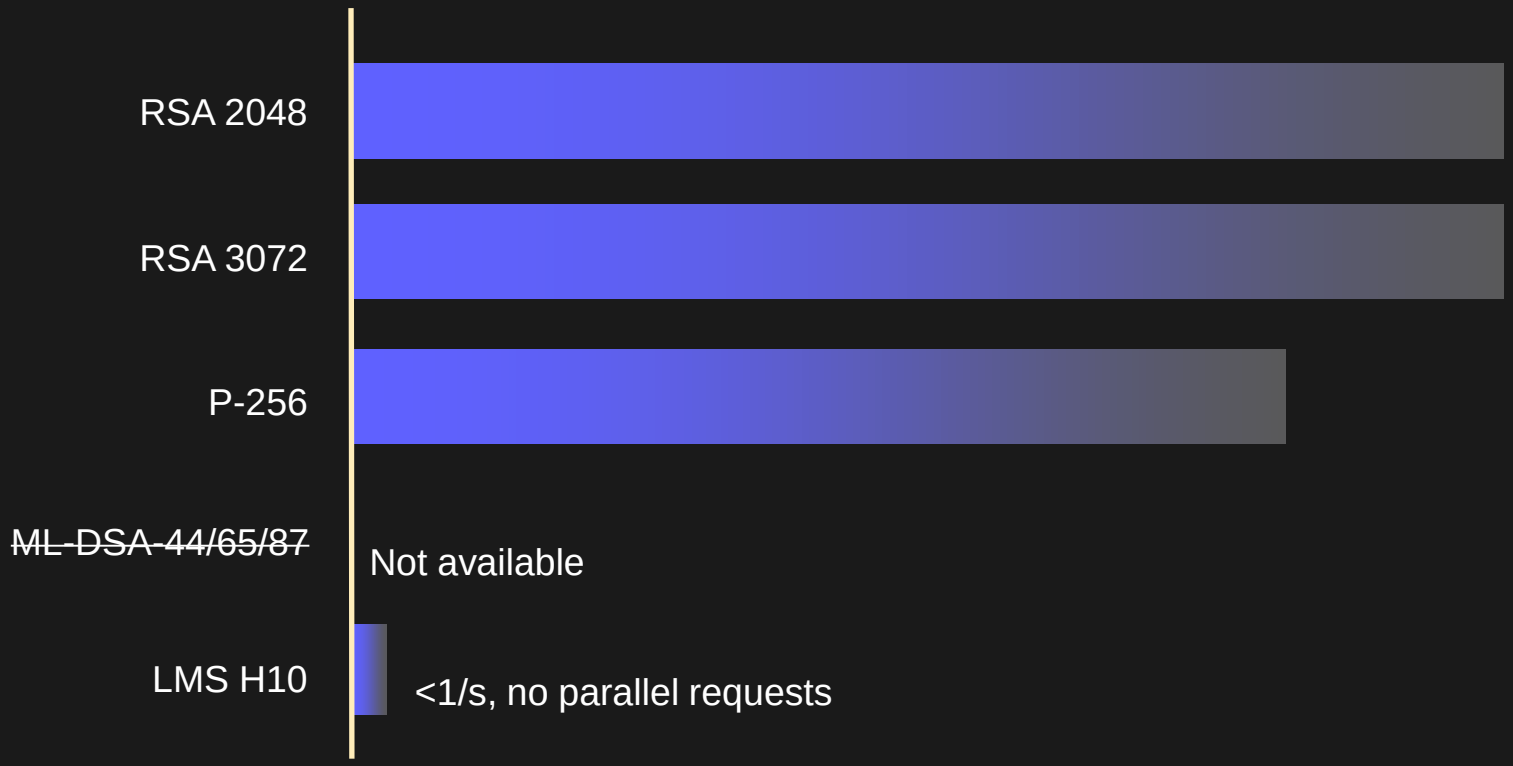
Certificate Issuance HSM 3

PKCS#11 remote Internet



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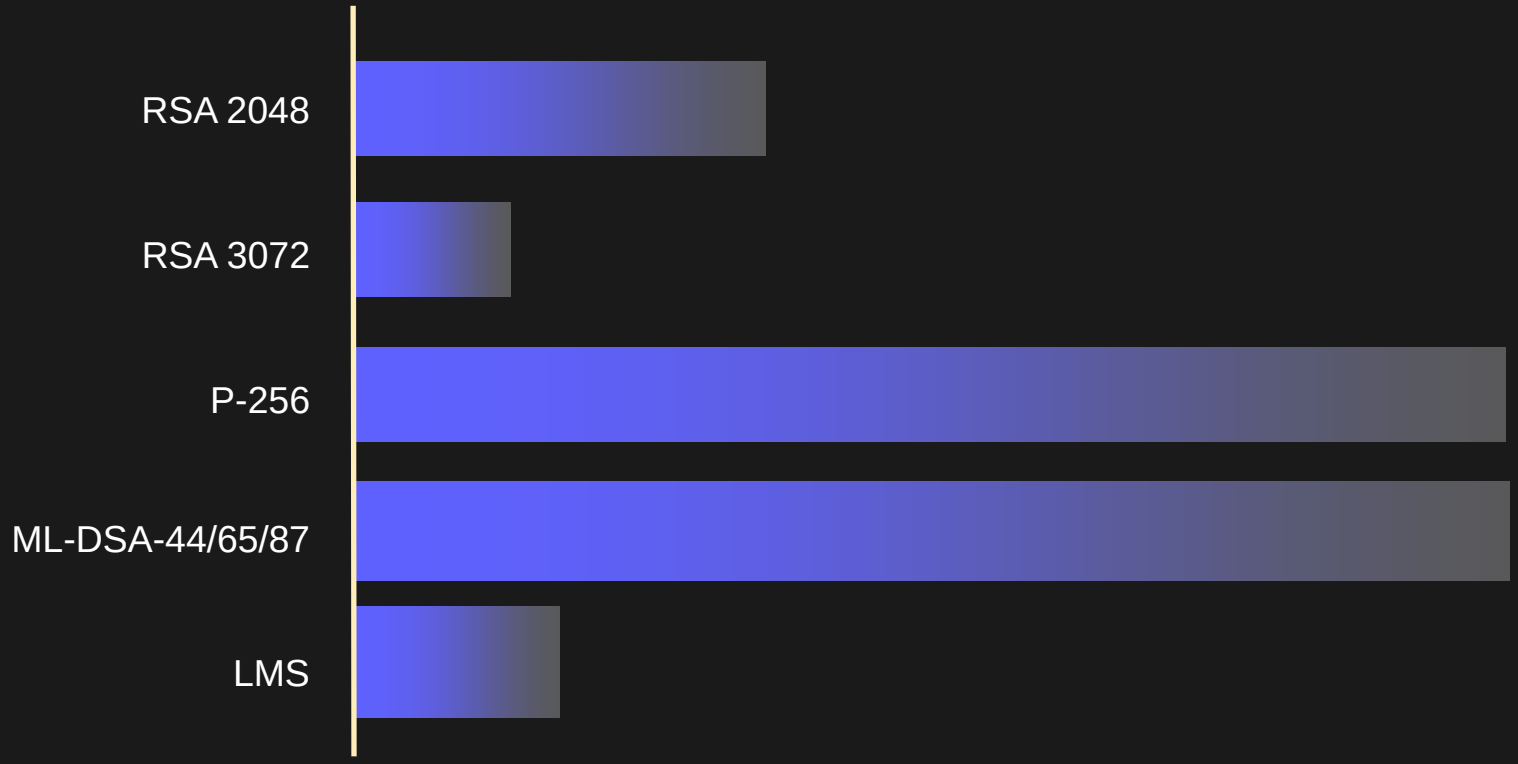
Certificate Issuance HSM 4

PKCS#11 local container



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Certificate Issuance HSM 5

PKCS#11 – local SW

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Signing what? How much?

Sizes vary

- Certificates are small
- CRLs are small to large
- Bank transactions are small
- Documents are small to medium
- Firmware is large to huge

There is a limit on the data we can stream to a network connected HSM and expect it to work.

Some popular options currently have 4KB limit of the signature payload.

The new algorithms ~~are~~ were all just-sign (not hash and sign)

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CRL size limits

ML-DSA-44 / LMS

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Lessons. Learned.

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What about PKI and Signing?

FIPS 204: ML-DSA + HashML-DSA

FIPS 205: SLH-DSA + HashSLH-DSA

PKI

- draft-ietf-lamps-dilithium-certificates stipulates ML-DSA and introduces ExternalMu-ML-DSA to cope with CRLs
- In theory, you could have different algorithms for certificates and CRLs
  - Not seen before
- Compare Ed25519 and phEd25519 (hint, it's not fun)

Signing

- CMS have always had a workaround – using signed attributes – signs a hash.
- Easy, always include some signed attributes – but debate is on-going.
- Other signature formats?

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FIPS 203, 204, 205

When can we start with ML-DSA and friends?

- Pre standard OIDs
  - 1.3.6.1.4.1.2.267.7.4.4 – Dilithium2 / ML-DSA-IPD-44
  - 1.3.6.1.4.1.2.267.7.6.5 - Dilithium3 / ML-DSA-IPD-65
  - 1.3.6.1.4.1.2.267.7.8.7 - Dilithium5 / ML-DSA-IPD-87

Confused yet?

- Must be changed to Standard OIDs (≠ML-DSA-IPD)
  - 2.16.840.1.101.3.4.3.17 ML-DSA-44
  - 2.16.840.1.101.3.4.3.18 ML-DSA-65
  - 2.16.840.1.101.3.4.3.19 ML-DSA-87
  - + HashML-DSA...2.16.840.1.101.3.4.3.32/33/34

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HSMs – PKCS#11 (v3.1) LMS

Same code tested with 2 HSMs so far.

```
final CKA ckaType = getAttribute(session, publicKeyRef, CKA.KEY_TYPE);
    if (CKK.HSS == ckaType.getValueLong()) {
        CKA ckaValue = getAttribute(session, publicKeyRef, CKA.VALUE);
        final HSSPublicKeyParameters params = HSSPublicKeyParameters.getInstance(keyBytes);
        final BCLMSPublicKey pub = new BCLMSPublicKey(params);
    }
```

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HSMs – PKCS#11 (v3.2 - draft) ML-DSA

```
CKA ckaKeyType = getAttribute(session, publicKeyRef, CKA.KEY_TYPE);
if (ckaKeyType.getValueLong() = CKK.ML_DSA) {
    CKA ckaValue = getAttribute(session, publicKeyRef, CKA.VALUE);
    final byte[] keyBytes = ckaValue.getValue();
    final MLDSAPublicKeyParameters params;
    switch (keyBytes.length) {
    case 1312:
        params = new MLDSAPublicKeyParameters(MLDSAParameters.ml_dsa_44, keyBytes);
        break;
    <snip>
    default:
        throw new InvalidKeySpecException("Invalid length of ML-DSA public key");
    }
    final BCMLDSAPublicKey pub = new BCMLDSAPublicKey(params);
}
```

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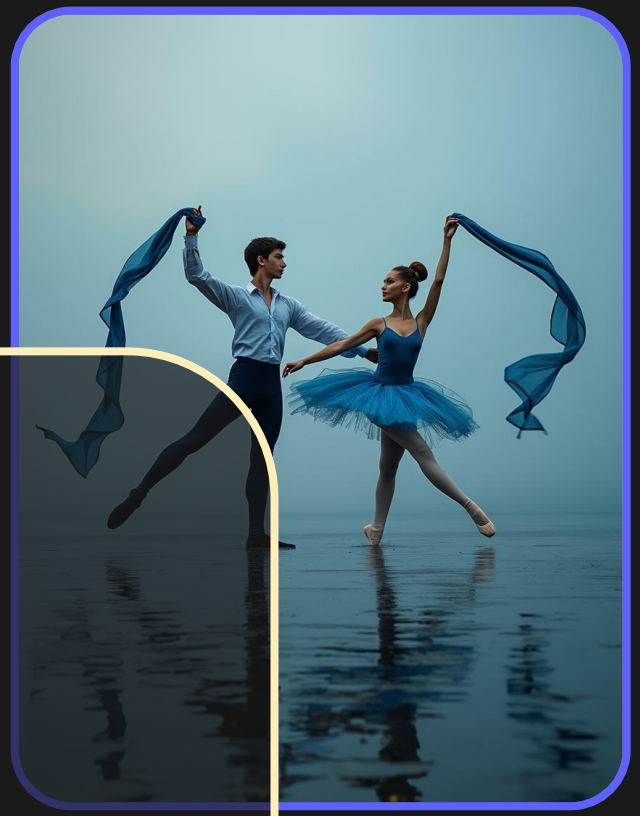
HSMs – REST



```
Object jsonObjType = jsonKey.get("obj_type");
if (jsonObjType != null && jsonObjType.equals("RSA")) {
    <snip>
} else if (jsonObjType != null && jsonObjType.equals("MLDSA")) {
    Object jsonPublicKey = jsonKey.get("pub_key");
    JSONObject mldsa = (JSONObject)jsonKey.get("mldsa");
    Object parameterString = mldsa.get("param_set");
    if (parameterString == null) {
        log.info("ML-DSA key does not have parameters:" + mldsa);
    } else {
        MldsaParamSet parameterSet = MldsaParamSet.valueOf((String) parameterString);
        return Optional.of(new AsymmetricKey((String) jsonName, (String) jsonKeyId,
                Base64.getDecoder().decode(((String) jsonPublicKey)),
                parameterSet));
    }
}
return Optional.empty();
```

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Issues Encountered

LMS/HSS public key encoding

- SubjectPublicKeyInfo vs SubjectPublicKeyInfo-like
- ASN.1 OctetString vs BitString – Internet drafts changed

LMS vs HSS key and signature

- ACVP only have LMS signatures

LMS results are inconsistent

- Slow to very slow, multithreaded or not – not general use

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Issues Encountered

ML-DSA vs ML-DSA-IPD – things are not what they seem to be

- Context was added in the last minute, when verification fails you know it 'ipd'

ML-DSA vs HashML-DSA – last minute decision

- ExternalMu-ML-DSA
- SLH-DSA, LMS, …
- Different algorithm for certificates and CRLs?

Signing large data

- Careful testing needed – expect different limits on different HSMs
- How to document this so that users understand?

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Where are we now?

- ACVP testing is stable for FIPS standards
- BC 1.79 released with FIPS OIDs and 1.80 with interop fixes
- IETF interop going well – few releases yet
- Some HSMs with FIPS 204 IPD
- Few HSMs with FIPS 204
- Some HSMs with LMS - inconsistent
- Unwise with Production until RFCs
- Start testing early

Removed Dilithium completely – it is not ML-DSA

This is the starting point on the PQC migration journey.

- New algorithms will come in the future.
- Maintaining crypto agility is a must.

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Quantum-safe Cryptography, HSMs and Experiences

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