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Migrating Some Legacy e-Governance Applications to Post-Quantum Cryptography

Cyber-security Excellence Hub in Estonia and South Moravia

NIST - Fifth PQC Standardization Conference

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Presentation Outline

- **Introduction**
- **Our Methodology**
- **e-Governance Applications**
- **PQ Engineering Obstacles**
- **Conclusions**

Presentation includes hypertext links.
PDF available at https://csrc.nist.gov/Presentations/2024/migrating-legacy-e-governance-applications-to-pqc

Introduction

- **Standardization of PQC** = first step in the process of actual deployment
- **Existing work:**
  - Timelines, "Migration Challenges", PQC Migration Handbook
- **The Issue:**
  - How to actually migrate? Does a general security engineer have everything in his disposal for that?
- **Our work:**
  - Exploring and supporting current FOSS state-of-the-art
  - Focus on engineering aspects of PQ implementations
  - Gather experience, problems, and remarks

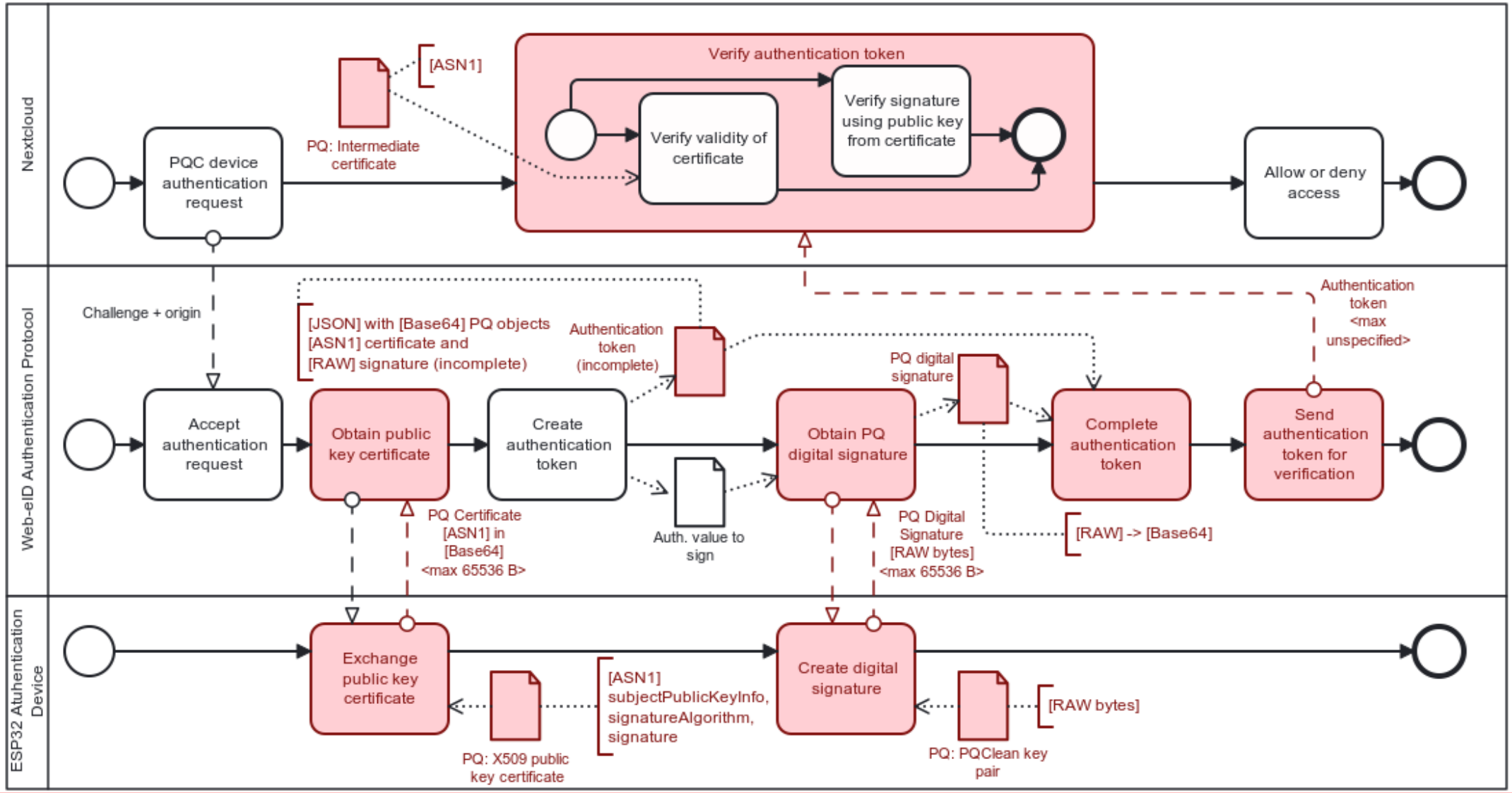
Our Methodology

Identify, Prepare, Implement, Adapt

Our Methodology

- **Identify**
  - All PKI objects and their lifetime in the system
- **Prepare**
  - MTUs, data formats (DER, PEM, JOSE, serialized, etc.)
  - Technological constraints
- **Implement**
  - Utilize available open source tools step-by-step
- **Adapt**
  - Custom wrappers, pull requests
  - Expect future changes

Our Methodology: BPMN Example

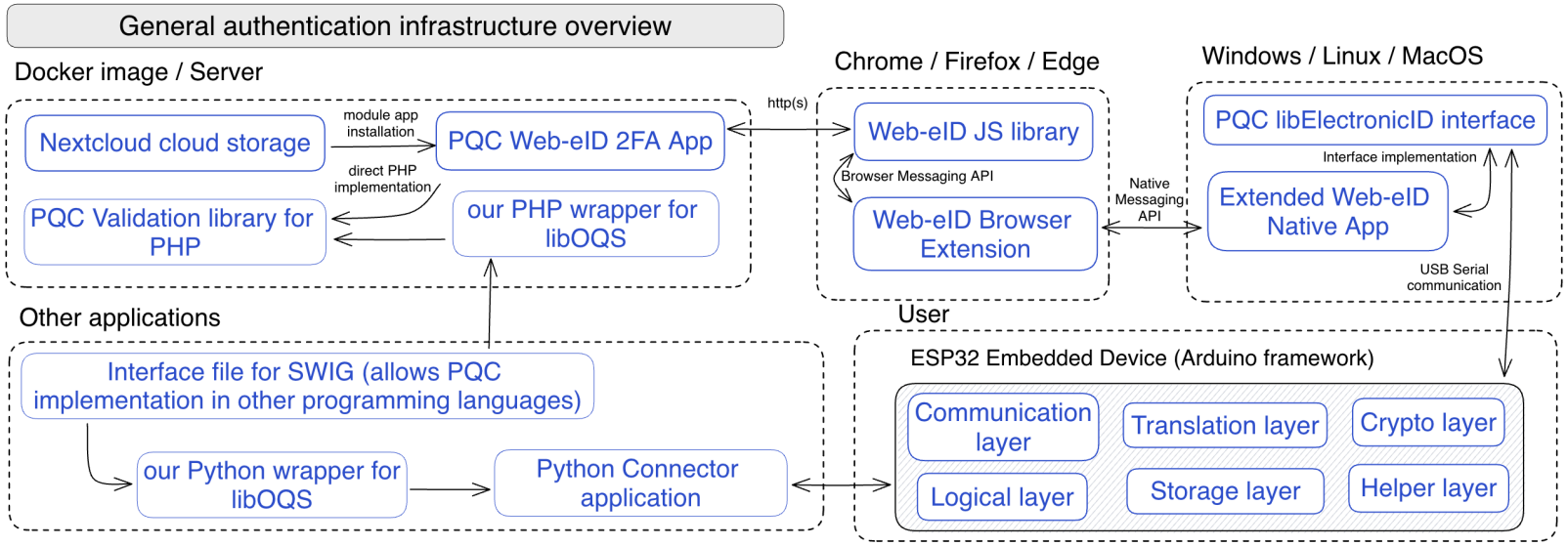


e-Governance Applications

Authentication, Encryption, Digital Signature, and e-Voting Frameworks

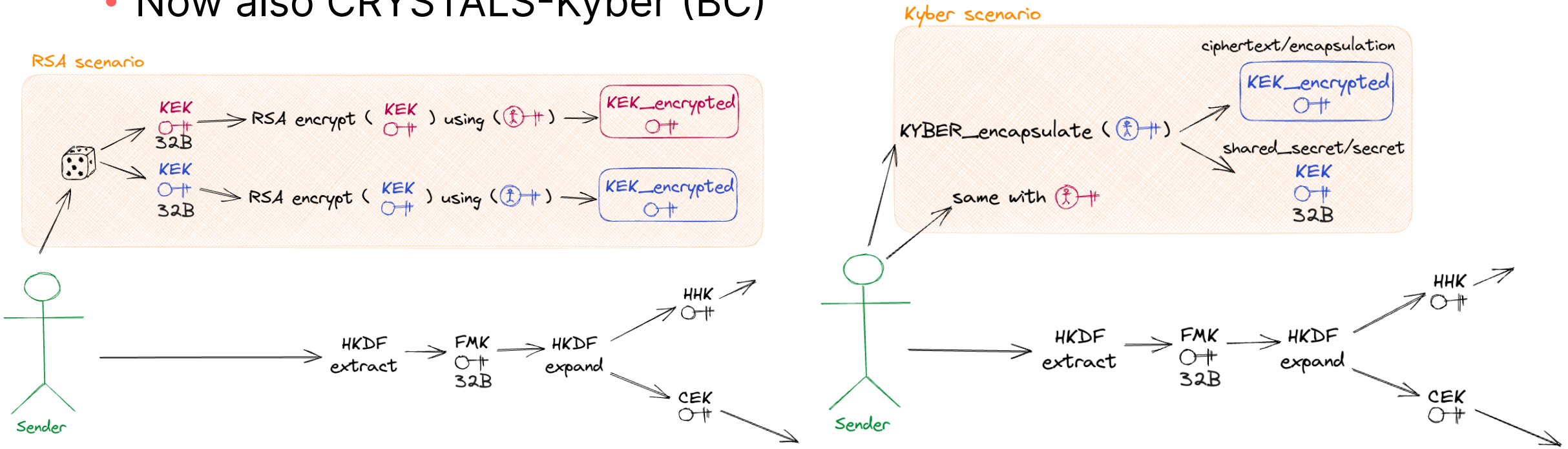
Web-eID (Authentication Framework)

- Authenticate users to **web application via browser interface**
- Web service + authentication framework + authentication device
  - Nextcloud file server
  - ID cards → ESP 32 embedded device (Dilithium5 or Falcon1024)



CDOC2 (Encryption Framework)

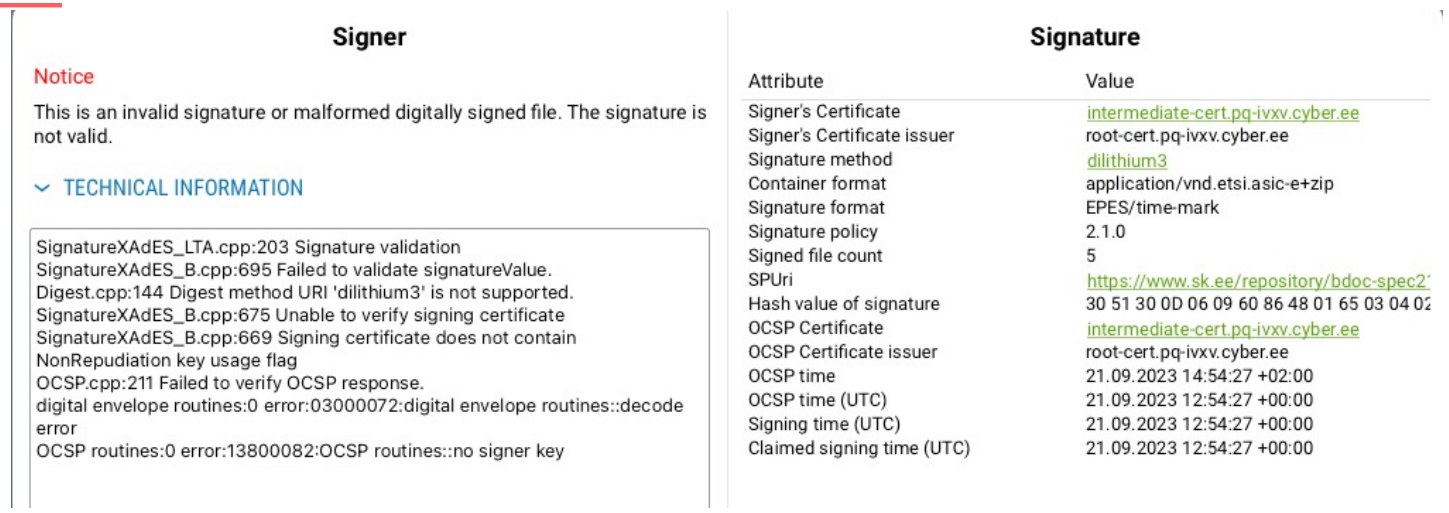
- = specification defining the process of **securing**, **storing**, and **exchanging encrypted messages** (.cdoc files)
- 1-to-many, expects RSA, EC or symmetric keys
  - Now also CRYSTALS-Kyber (BC)



CYBERNETICA

ASiC-E (Digital Signature Framework)

- = file and structure (container) specification **binding one or more digitally signed objects together** (.asice files) under eIDAS regulation
  - ETSI TS 102 918 v1.2.1
- Long-term availability and integrity of files within the container
- PQ version of thorgate/pyasice
  - Custom wrapper of libOQS
  - CMD app
  - Container creation



Signer

Notice

This is an invalid signature or malformed digitally signed file. The signature is not valid.

TECHNICAL INFORMATION

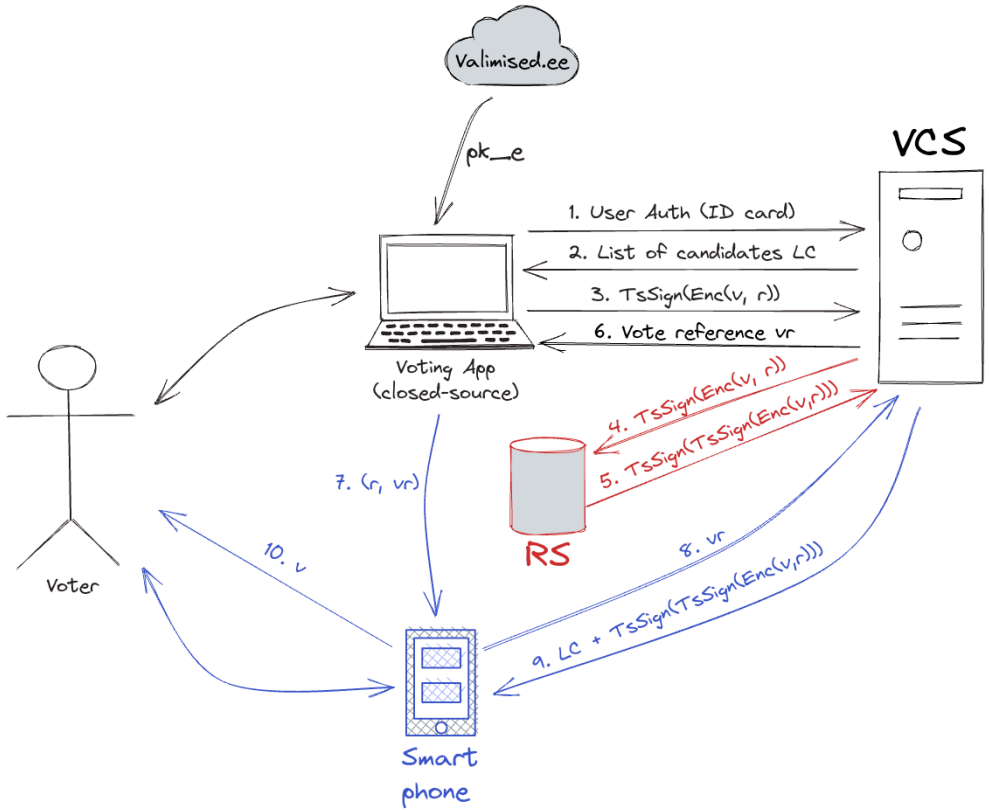
```
SignatureXAdES_LTA.cpp:203 Signature validation
SignatureXAdES_B.cpp:695 Failed to validate signatureValue.
Digest.cpp:144 Digest method URI 'dilithium3' is not supported.
SignatureXAdES_B.cpp:675 Unable to verify signing certificate
SignatureXAdES_B.cpp:669 Signing certificate does not contain
NonRepudiation key usage flag
OCSP.cpp:211 Failed to verify OCSP response.
digital envelope routines:0 error:03000072:digital envelope routines::decode
error
OCSP routines:0 error:13800082:OCSP routines::no signer key
```

Signature

Attribute	Value
Signer's Certificate	intermediate-cert.pq-ivxv.cyber.ee
Signer's Certificate issuer	root-cert.pq-ivxv.cyber.ee
Signature method	dilithium3
Container format	application/vnd.etsi.asic-e+zip
Signature format	EPES/time-mark
Signature policy	2.1.0
Signed file count	5
SPUri	https://www.sk.ee/repository/bdoc-spec2
Hash value of signature	30 51 30 0D 06 09 60 86 48 01 65 03 04 02
OCSP Certificate	intermediate-cert.pq-ivxv.cyber.ee
OCSP Certificate issuer	root-cert.pq-ivxv.cyber.ee
OCSP time	21.09.2023 14:54:27 +02:00
OCSP time (UTC)	21.09.2023 12:54:27 +00:00
Signing time (UTC)	21.09.2023 12:54:27 +00:00
Claimed signing time (UTC)	21.09.2023 12:54:27 +00:00

IVXV (e-Voting Framework)

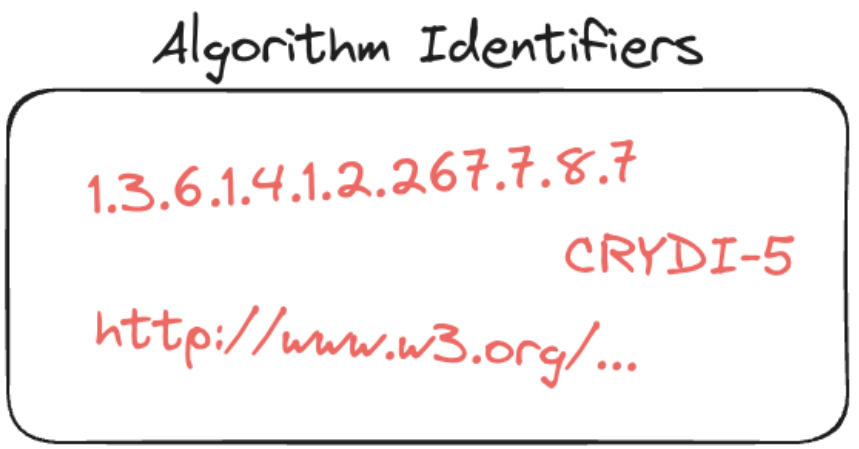
- = ongoing development of **Estonian e-Voting framework** named IVXV
- Components:
  - PQ-IVXV source distribution
  - PQ-ASiC-E
  - Vote application, Vote verification
  - Registration service TSA
  - Citizen PKI, OCSP, and TSA
- Custom lattice-based protocols
  - Vote Encryption, MixNets, MPC, ...



PQ Engineering Obstacles

Algorithm Identifiers, Object Encoding, Interoperability Awareness, Cryptographic Tokens, Maturity of PQC, and Misc.

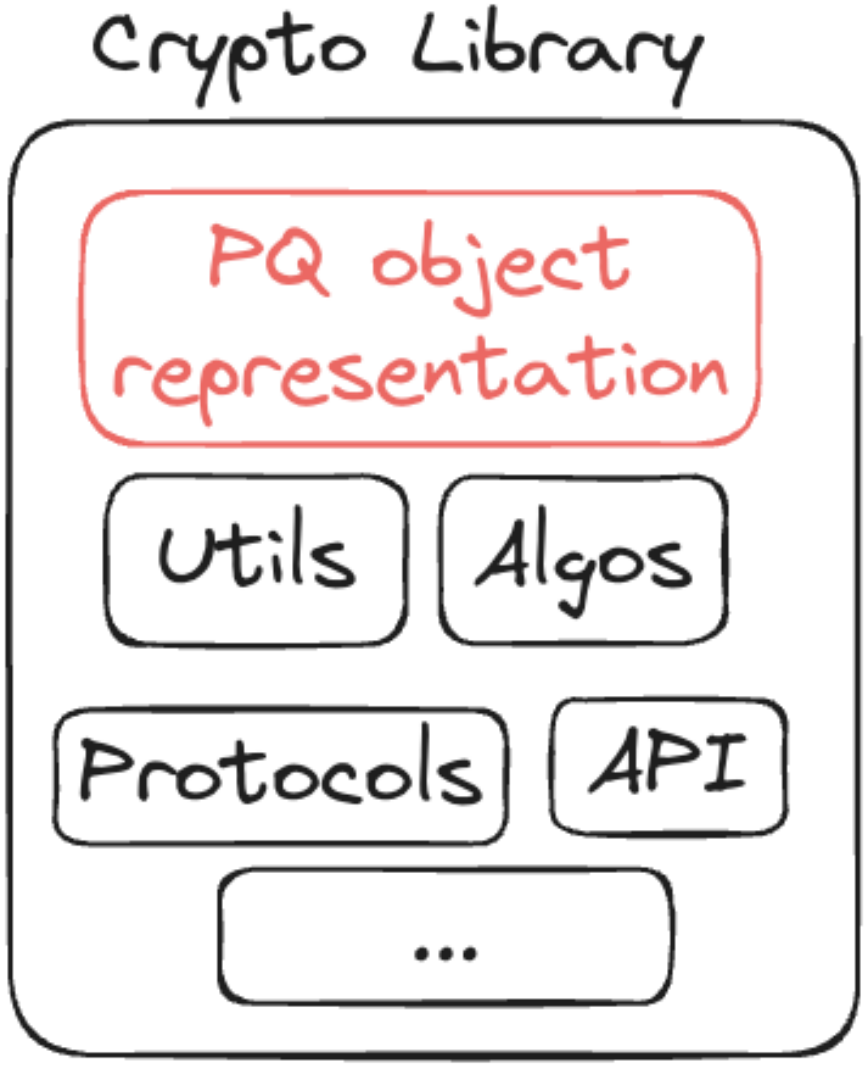
Algorithm Identifiers



- **ASN.1 Object Identifiers**
  - Wild West
  - OQS → BouncyCastle → OQS → IETF Hackathon → ???
  - ML-KEM vs CRYSTALS-Kyber?
- **JSON Web Algorithms**
  - PQ alternative to *ES256*?
  - Recent RFC, but only for KEMs
- **XML Signature Syntax Algorithms**
  - Defined URLs for digital signature algos
  - E.g.: http://www.w3.org/2001/04/xmldsig-more#rsa-sha256

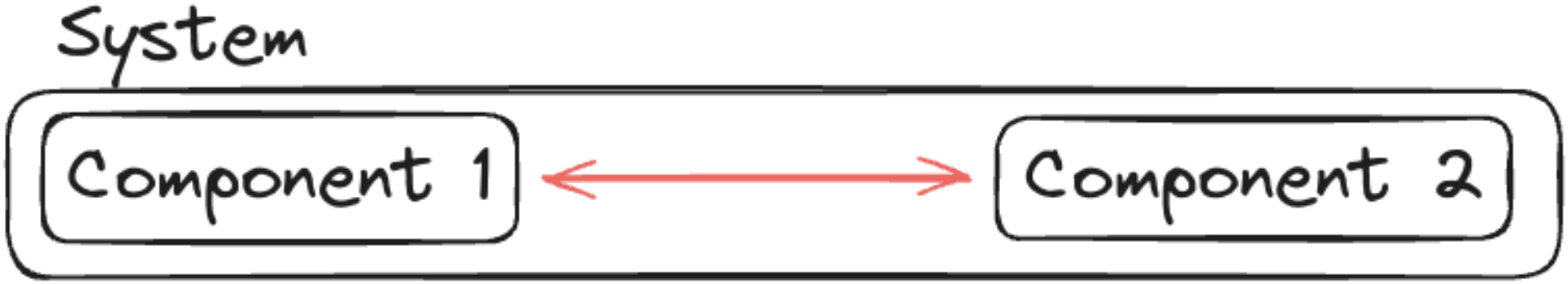
Object Encoding

- **Raw bytes** → interoperability heaven
- Already implemented **ASN.1 RFC drafts**? Why?
- Most crypto libraries have classical algorithms **hard-coded**
  - PHP extension for OpenSSL, PHPSecLib
  - cryptography, asn1crypto (Python)
  - crypto (Go)
- **Two options**:
  - **Extend** vs **circumvent**



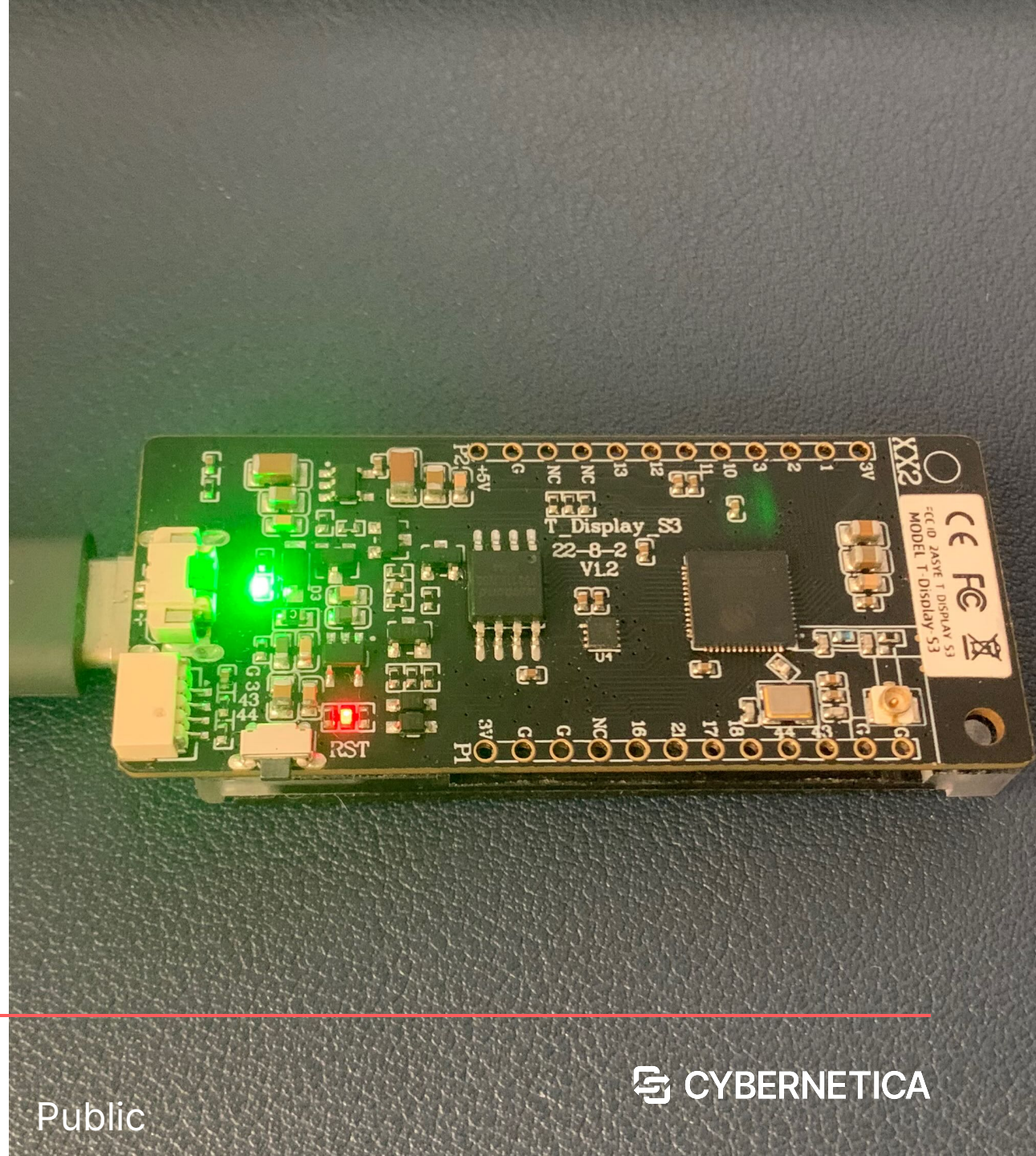
Interoperability Awareness

- Growing with system complexity
- **Active thinking** about all components
  - Identifiers, encoding, MTU, processing



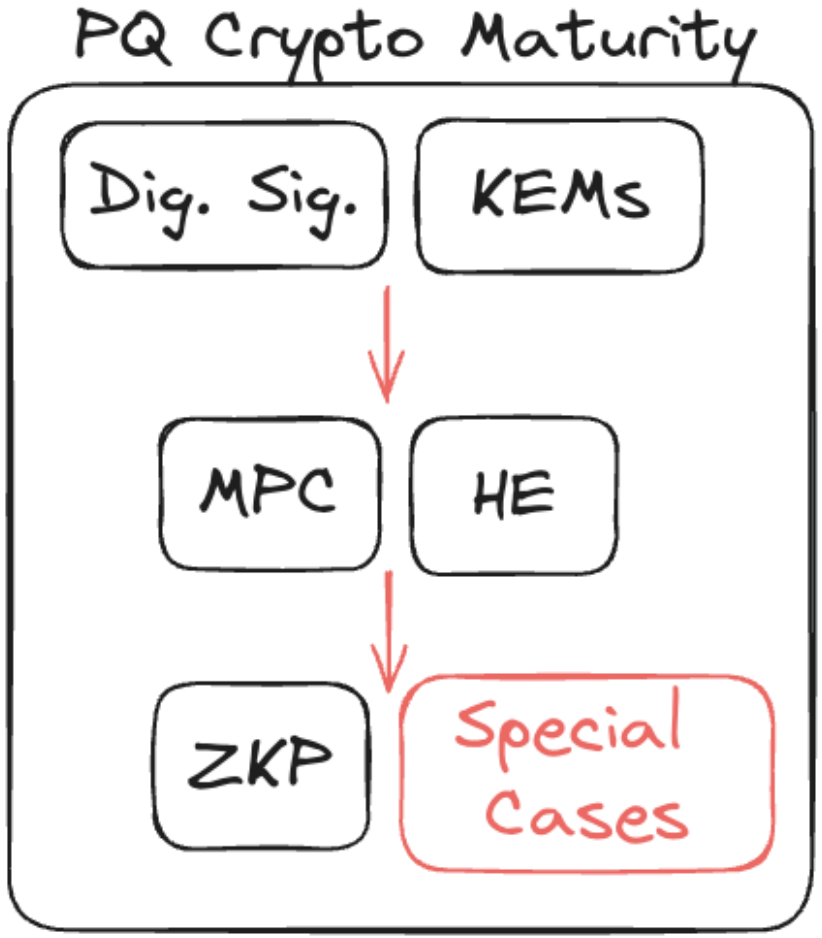
Cryptographic Tokens

- ~~Smart cards~~
- Chip manufacturers?
- Embedded devices for local testing purposes
  - Performance OK (ESP32-S3)
  - Memory OK, but complicated
  - Safety not OK (no HSM, TPM, not certifiable)
- Protocol adjustments might be required (~~stack~~ → heap, streaming)



Maturity of PQ Custom Crypto

- What if application requires:
  - **Multi Party Computation**?
  - **Homomorphic Encryption**?
  - **Special features**?
    - e.g. *ElGamal* in vote encryption - special decryption without private key
- Still lot of **R&D to be done**



Miscellaneous PQ Engineering Efforts

- **All the little things**
  - (OQS-)OpenSSL encodes private keys as:
    - *0×04 or 0×03 || length || private_key || public_key*
  - Custom wrappers → data type conversions
  - Adding single lines into dependencies' files to support PQ
  - Build issues, insufficient or confusing documentation
- **State of PQ-TLS server and client implementations**
- **Hybrid Mode**

Conclusions

- **Experience report**
  - Multiple e-Government projects of various sizes
  - PQC implementation is far from straight-forward
  - Engineering issues that need collective resolution
- **Standardization is crucial**, but considering the general advice is to **start implementing now**:
  - Brace yourself (or your engineers/developers)
  - Document
  - Share
  - Contribute

Thank you for listening!

Resources:
- links in presentation slides
- references in the paper
- Notes on PQC in PHP

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