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



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Public



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

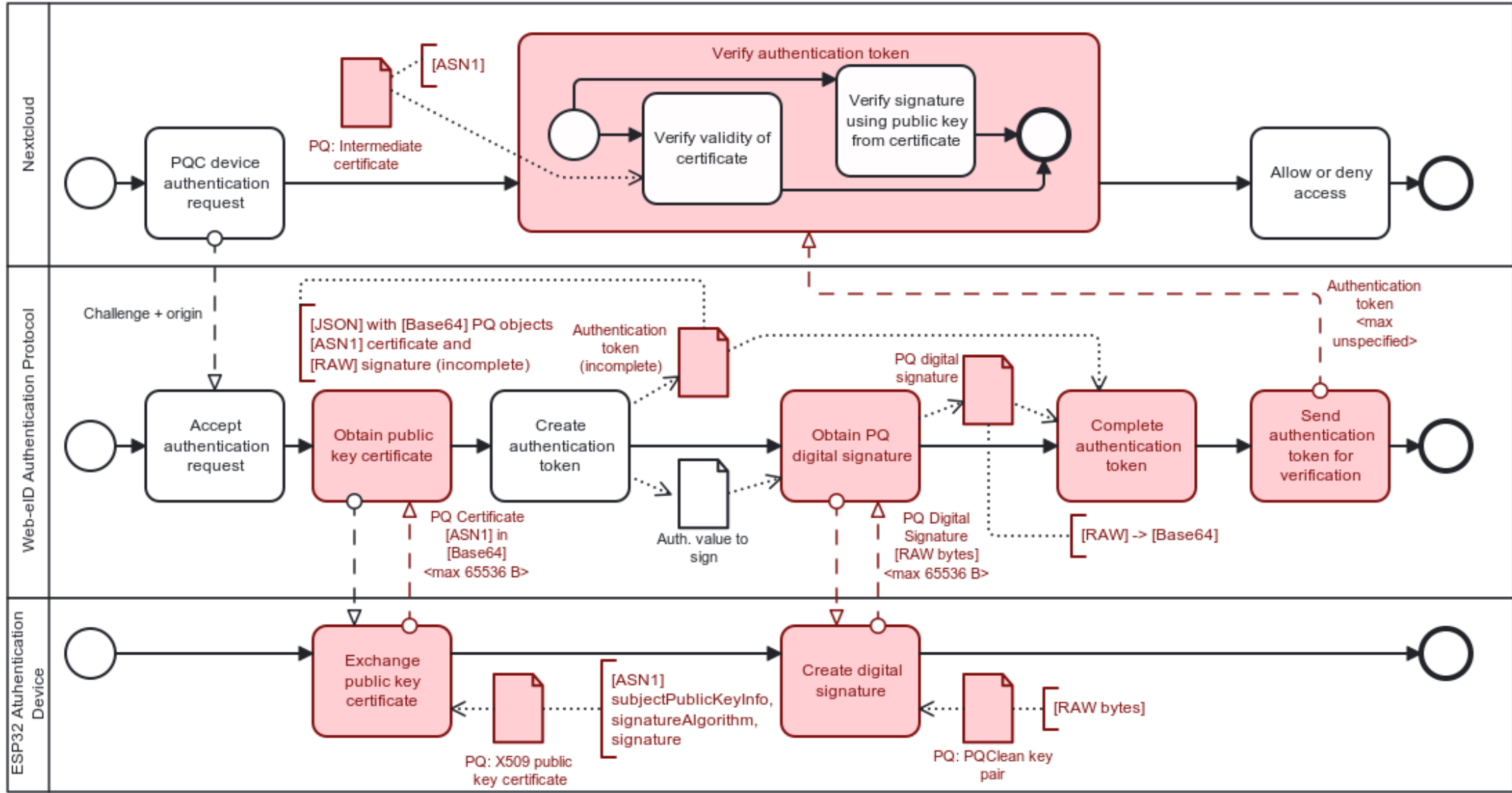
Our Methodology

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

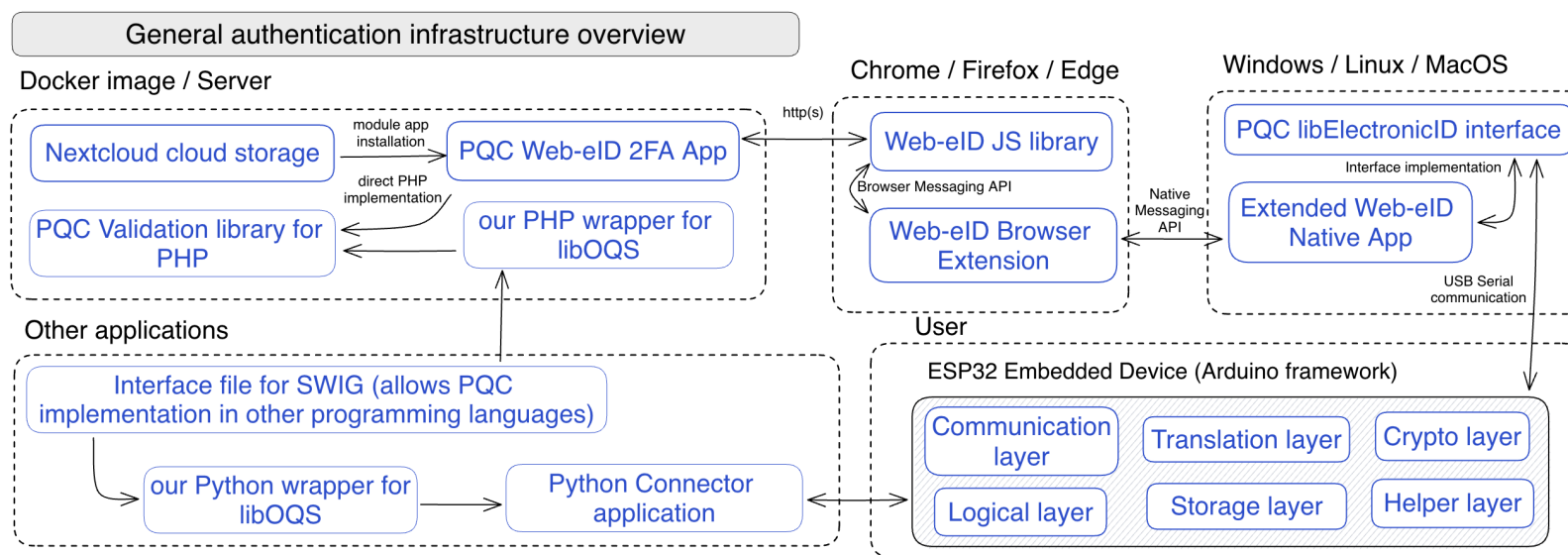


e-Governance Applications

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

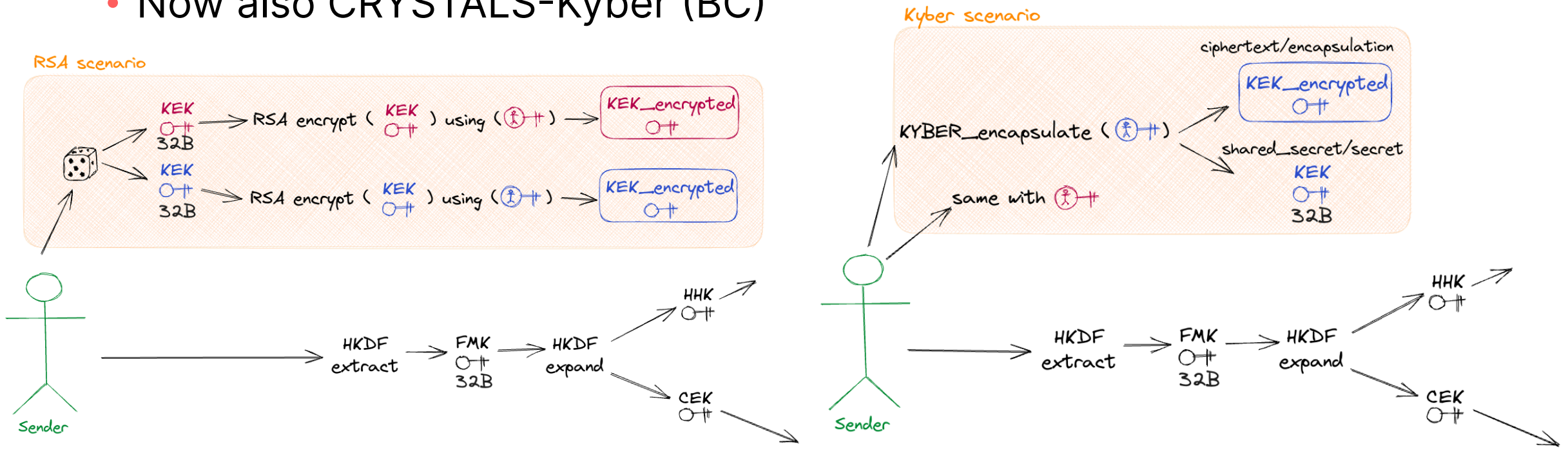
Web-eID (Authentication Framework)

- 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)



ASiC-E (Digital Signature Framework)

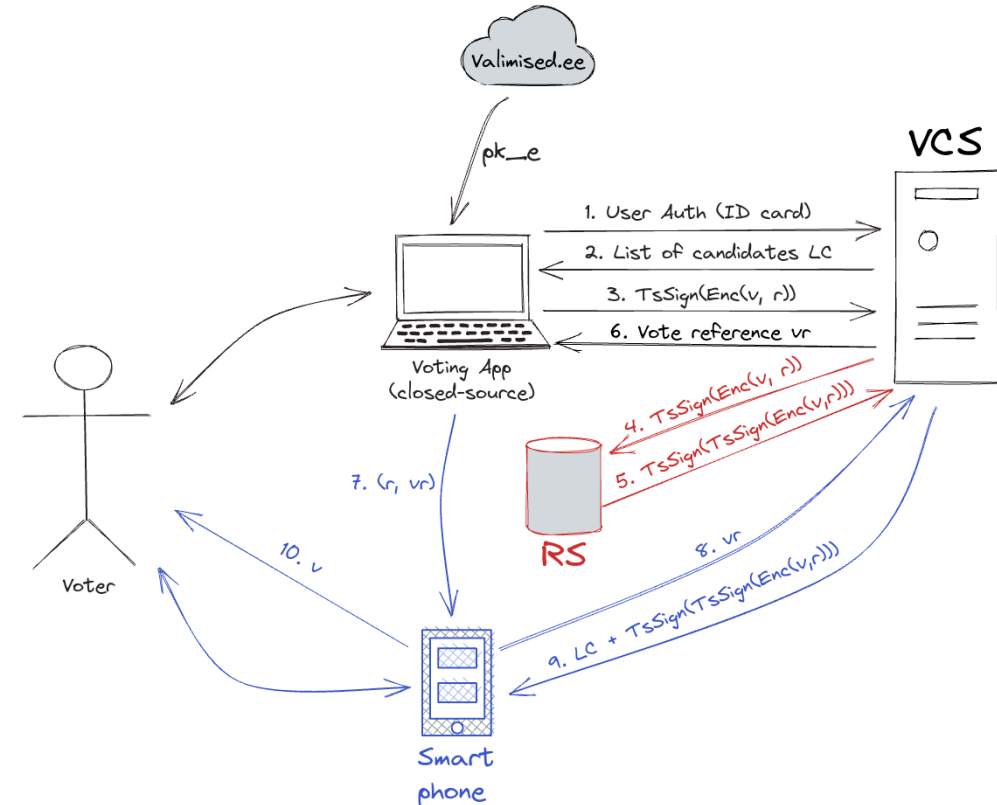
- = file and structure (container) specification **binding one or more digitally signed objects together** (.asice files) under eIDAS regulation
 - ETSI TS 102 918 v1.2.1
- Long-term availability and integrity of files within the container
- PQ version of [thorgate/pyasice](https://github.com/thorgate/pyasice)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

Signer		Signature	
Attribute	Value	Attribute	Value
Notice This is an invalid signature or malformed digitally signed file. The signature is not valid.		Signer's Certificate	intermediate-cert.pq-ivxv.cyber.ee
TECHNICAL INFORMATION		Signer's Certificate issuer	root-cert.pq-ivxv.cyber.ee
SignatureXAdES_LTA.cpp:203 Signature validation		Signature method	dilithium3
SignatureXAdES_B.cpp:695 Failed to validate signatureValue.		Container format	application/vnd.etsi.asic-e+zip
Digest.cpp:144 Digest method URI 'dilithium3' is not supported.		Signature format	EPES/time-mark
SignatureXAdES_B.cpp:675 Unable to verify signing certificate		Signature policy	2.1.0
SignatureXAdES_B.cpp:669 Signing certificate does not contain NonRepudiation key usage flag		Signed file count	5
OCSP.cpp:211 Failed to verify OCSP response.		SPUri	https://www.sk.ee/repository/bdoc-spec2/intermediate-cert.pq-ivxv.cyber.ee
digital envelope routines:0 error:03000072:digital envelope routines::decode error		Hash value of signature	30 51 30 0D 06 09 60 86 48 01 65 03 04 02
OCSP routines:0 error:13800082:OCSP routines::no signer key		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, ...

Voting Period



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

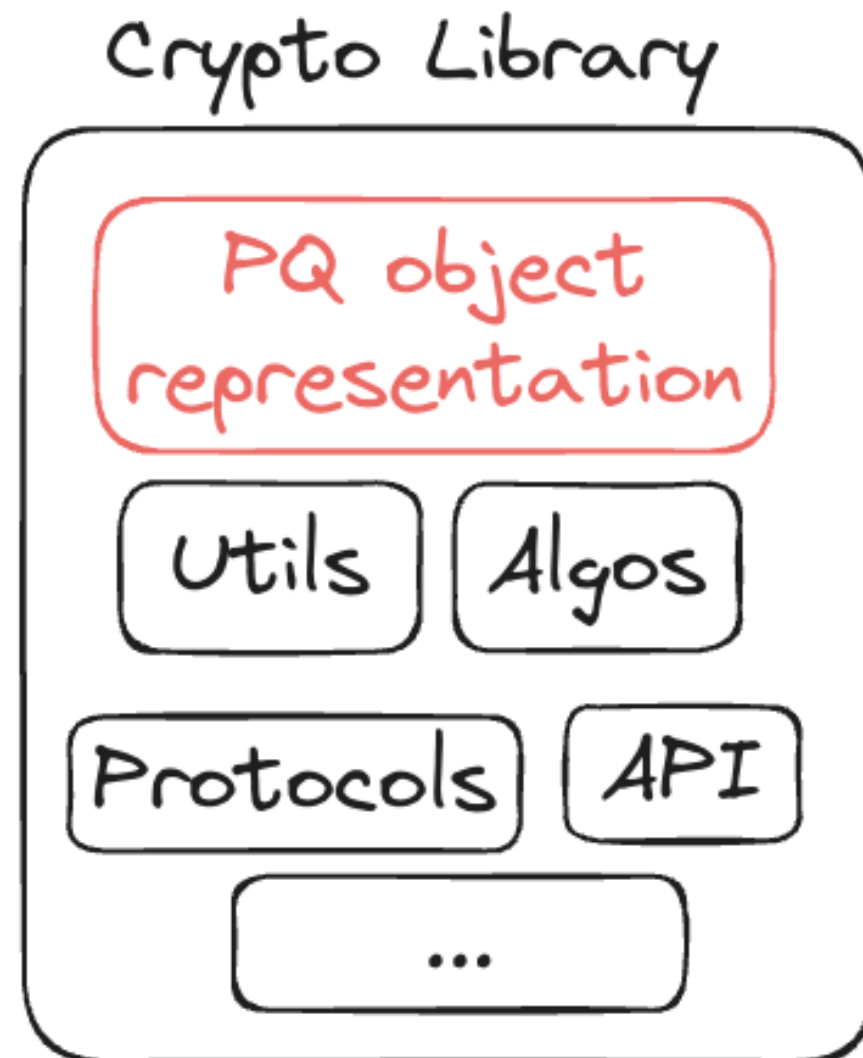
- **XML Signature Syntax Algorithms**

- Defined URLs for digital signature algos
- E.g.: <http://www.w3.org/2001/04/xmldsig-more#rsa-sha256>

1.3.6.1.4.1.2.267.7.8.7
CRYDI-5
<http://www.w3.org/...>

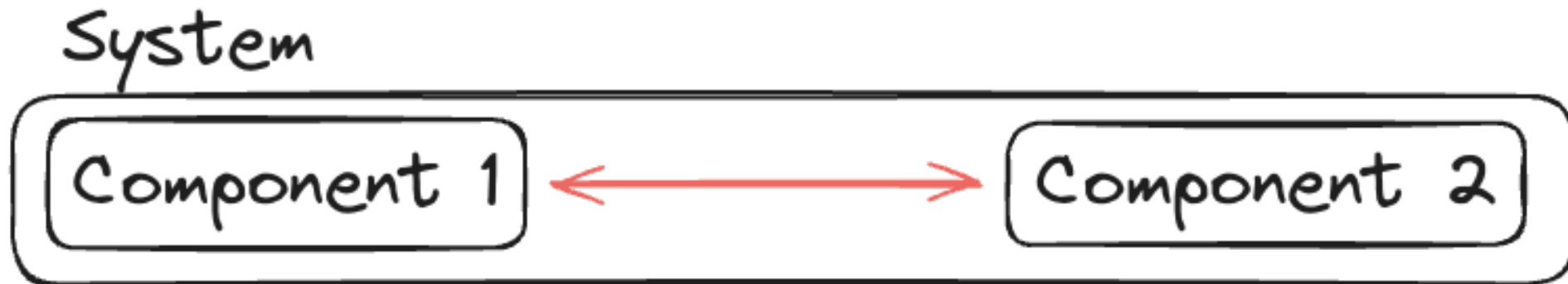
Object Encoding

- **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**



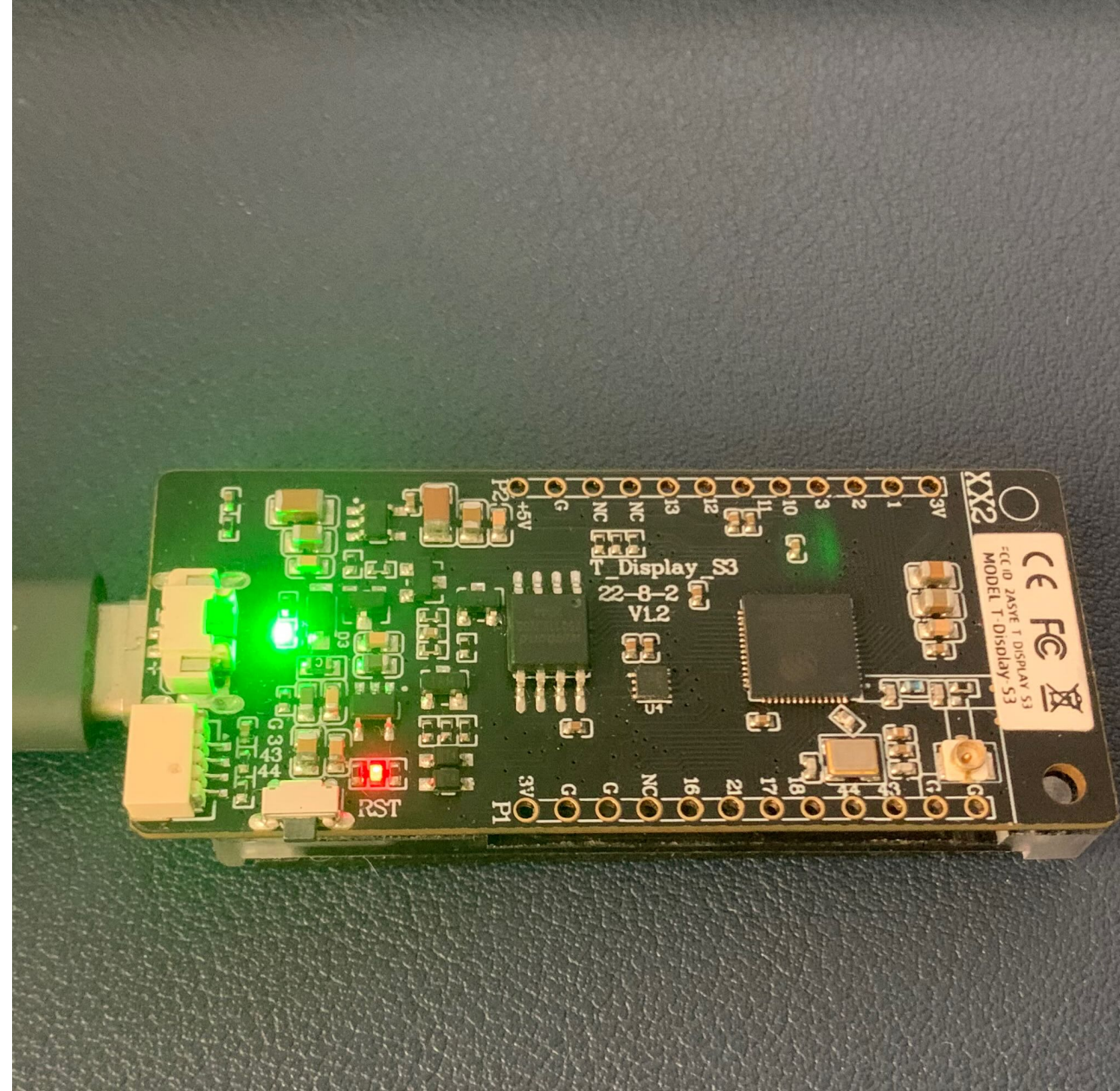
Interoperability Awareness

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



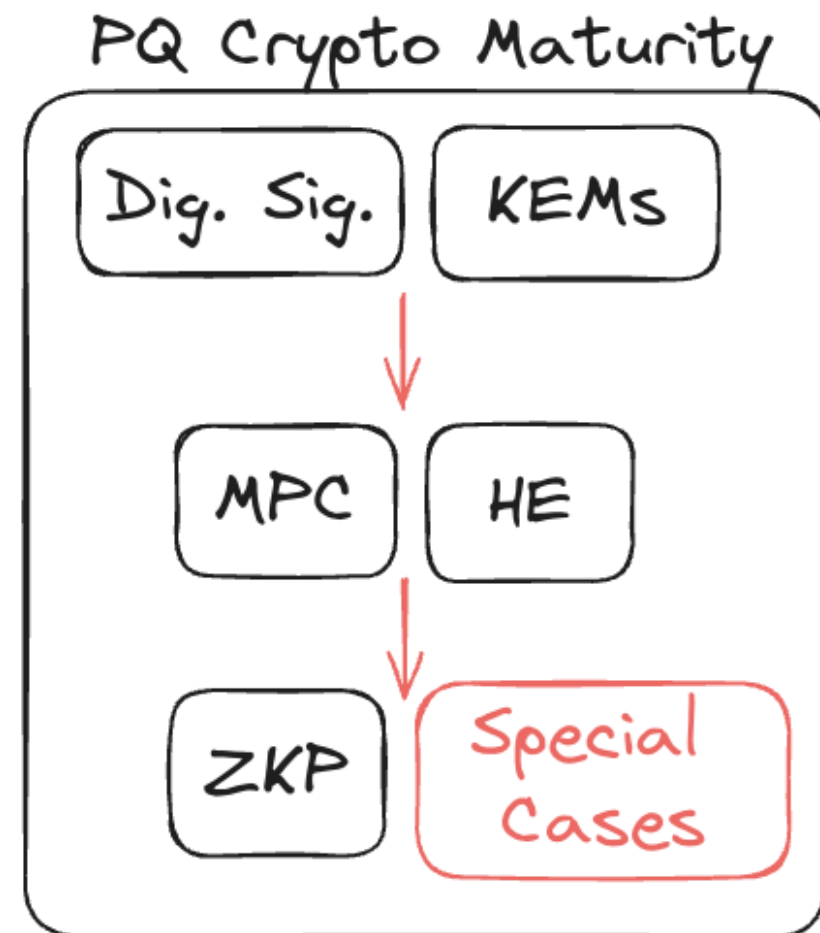
Cryptographic Tokens

- 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:
 - *0x04 or 0x03 // 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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