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Quantum-Resistant Security Libraries

CHESS

Cyber-security Excellence Hub in Estonia and South Moravia

Workshop on Post-Quantum Cryptography: Principles and Challenges

27.3.2025, FEKT VUT, Brno

Petr Muzikant

Information Security Research Institute @ Cybernetica AS, Estonia

CYBERNETICA

Public

Introduction - Who Am I?

- Local Information-Security graduate
- Security Engineer
  - focus on PQC implementation and engineering issues
- **Estonian e-government systems** (PoCs)
  - PQ Web-eID (authentication framework)
  - PQ CDOC2 (encryption framework)
  - PQ eID / PKI (CA, OCSP, TSA)
  - PQ IVXV (internet voting framework)
  - supporting side-projects

Assumptions and Preliminary Topics

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    - *pre-hashing dilemma, externalMu modes*

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  - *standards*
  - *hybrid modes, key combiners*
  - *crypto agility*
  - *pre-hashing dilemma, externalMu modes*
  - *interoperability issues*
- **PQC migration is not a simple switch of algorithms / libraries!**
  - **But,** you don't need to know these topics for innocent experimenting

Migration Steps

- *Made the decision*
  - *→ PQC migration plan*
    - *→ crypto discovery/inventory*
      - *→ preliminary analysis of PQC impact*
- Now what?
  - **Start implementing PQC** (*in SW*)
  - Two options:
    - Upgrade existing cryptography libraries
    - Introduce new dependency for PQ-only library

Pure PQ Libraries

One simple note / use case

https://github.com/PQClean/PQClean

PQClean (C)

- Cleaned aggregation of NIST (to-be) standards
  - Unified API and code style
  - Platform-specific optimizations
  - All submitted algorithms at one place
- **Source of source-code** (i.e. not a library)
- No security guarantees

Embedded devices, single algorithm usage https://github.com/open-quantum-safe/liboqs

libOQS (C)

- **Most well-maintained library** out there
- Language wrappers:
  - C++, Python, Java, Go, .NET, Rust, and PHP
- Applications built with libOQS
  - **OpenSSL**, OpenSSH, OpenVPN forks
- No security guarantees
  - Common choice for companies? (including Amazon, Meta, ...)

Default choice for almost everything

https://github.com/cloudflare/circl

CIRCL (Go)

- Developed, maintained, and used by Cloudflare
- Offers same interfaces as `go/crypto` library
- Cloudflare has high influence on upcoming standards
- Joy to pick-up and use :)
- No security guarantees

Great integration with Go applications

Other random projects you might find

- https://github.com/rustpq/pqcrypto (Rust)
  - Bindings to PQClean
- https://github.com/paulmillr/noble-post-quantum (JS)
  - Claims high security
- https://github.com/mupq/pqm4 (C)
  - Optimized for ARM Cortex-M4

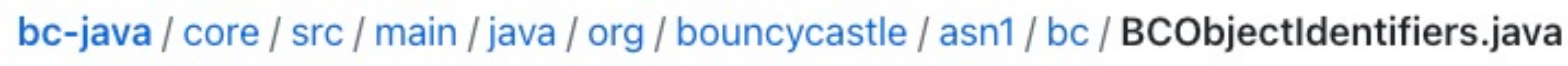
High-assurance Implementations

- PQC Alliance → **PQ Code Package** (https://github.com/pq-code-package)
  - Promises high security guarantees
  - Not so much traction yet
- Formosa Crypto → **Libjade** (https://formosa-crypto.org/tools/libjade)
  - Specially crafted toolboxes for high-assurance and quality code
  - *"If we should do cryptography again, we should make it right"*
- **KyberLib** (https://kyberlib.com)
  - Claims strong security guarantees in Rust

If you need PQC in real-world product: **Libjade**

PQC Support In Existing Libraries

BouncyCastle (Java)

- Not well documented
  - 
    bc-java / core / src / main / java / org / bouncycastle / asn1 / bc / BCObjectIdentifiers.java
  - `org.bouncycastle.pqc.*` packages
- Different workflow from others
- Useful "Java Keytool" benefits too

If you are heavily integrated in Java ecosystem

PQ Java Keytool

- keytool = command for managing a keystore of cryptographic objects
- PQ BouncyCastle → PQ Java Keytool
- e.g. to generate .p12 with Dilithium keypair and self-signed certificate:

```
keytool \
    -providerpath bcprov-jdk18on-175.jar \
    -provider org.bouncycastle.pqc.jcajce.provider.BouncyCastlePQCProvider \
    -genkeypair \
    -keyalg Dilithium5 \
    -alias cdoc20-client-pqc-CA \
    -keystore cdoc20clientpqcCA.p12 \
    -storepass passwd \
    -sigalg Dilithium5 \
    -dname "CN=cdoc20-client-pqc-CA,OU=ISRI,O=CyberneticaAS,L=Brno,S=Czechia,C=CZ"
```

Go/crypto, Python/cryptography, Botan

- go/crypto
  - **Only hybrid TLS by default**
  - ML-KEM implementation is internal
- python/cryptography
  - Depends on OpenSSL
  - No intention to develop anything until OpenSSL is mature
- Botan
  - PQC included

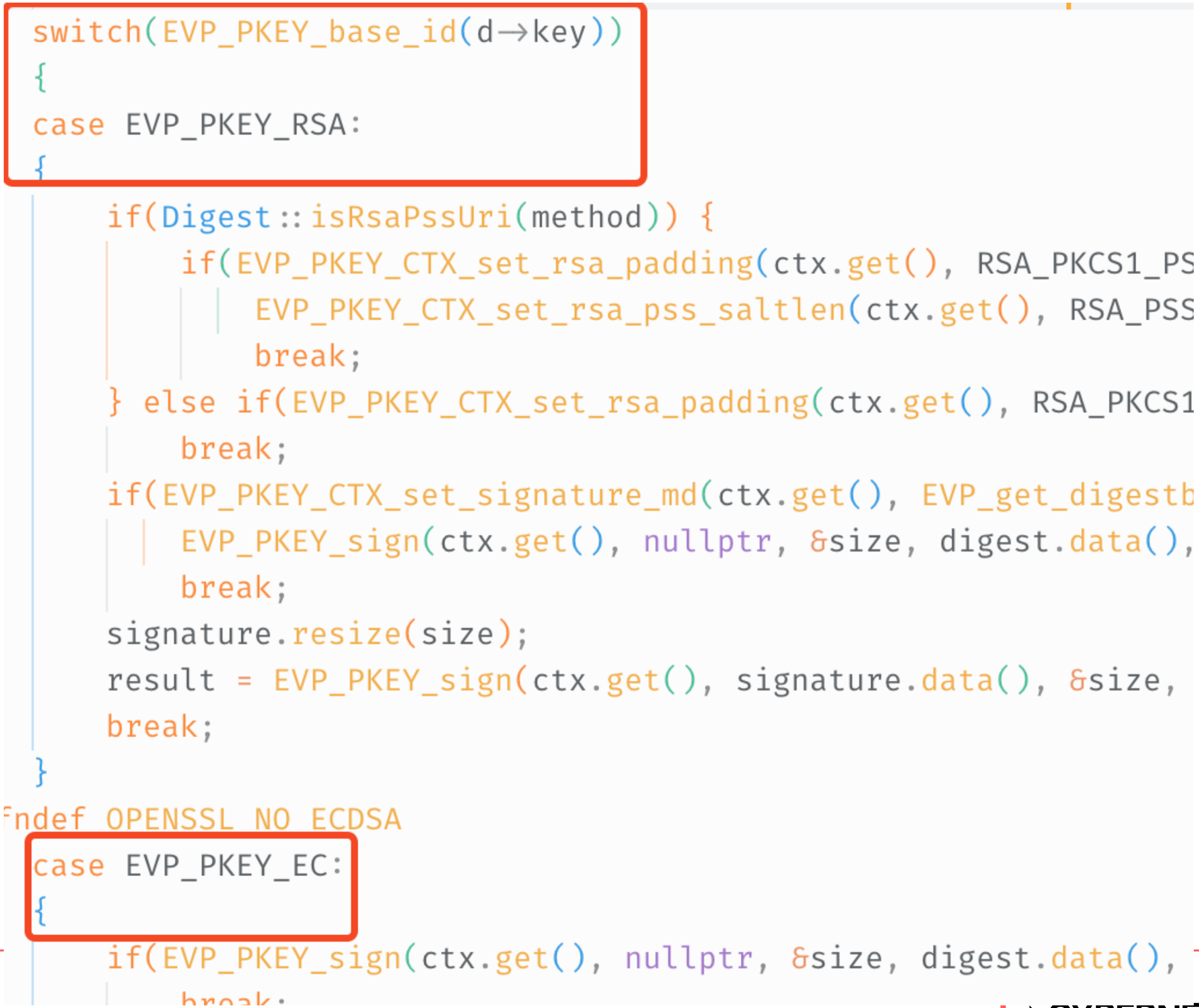
go/crypto: if you just need TLS in Go, **Botan:** if you used it before https://github.com/open-quantum-safe/oqs-provider

OpenSSL

- OpenQuantumSafe - **oqs-provider**
  - integrates **libOQS into OpenSSL v3+**
  - → TLS, SSH, certificates, CA, OCSP, TSA, basically everything
- Michael Baentsch (OQS maintainer and committee member) helps OpenSSL to introduce PQC

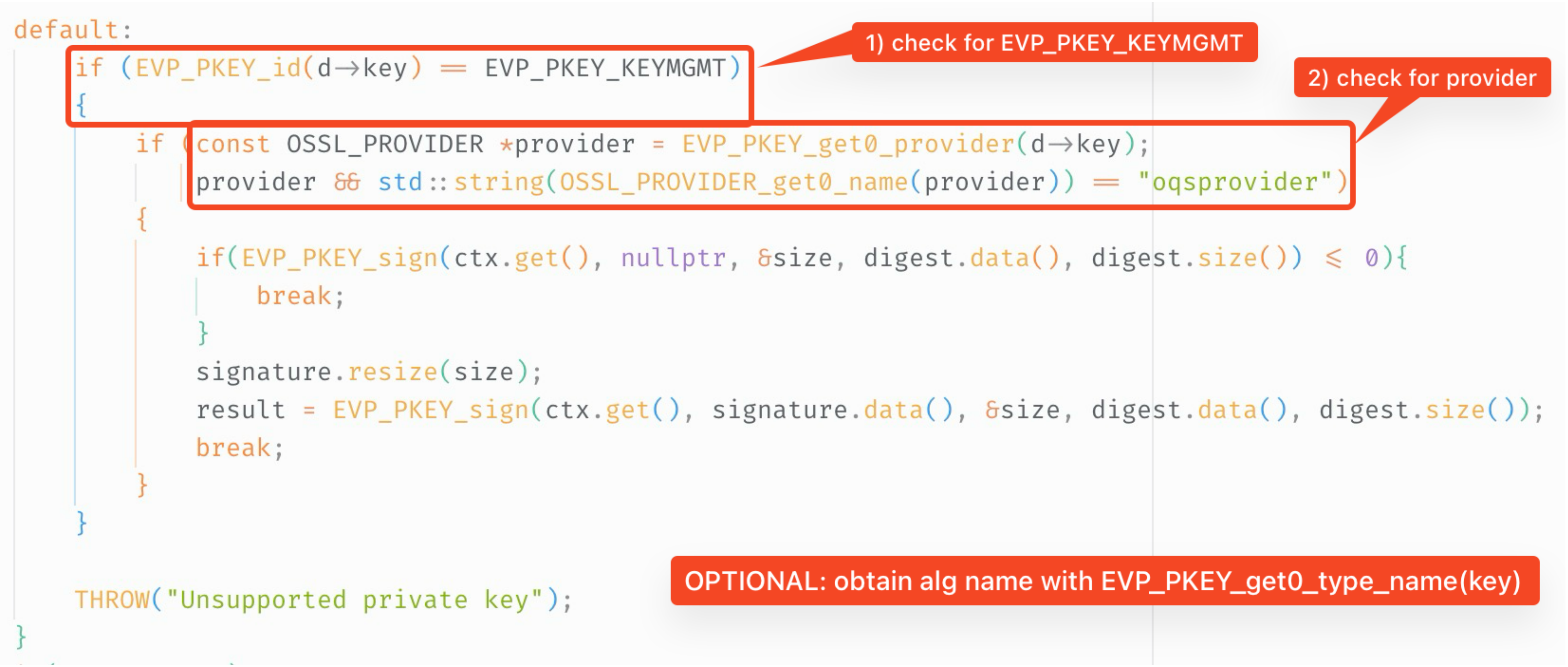
For high-level applications

PQ OpenSSL



```
switch(EVP_PKEY_base_id(d->key))
{
case EVP_PKEY_RSA:
{
    if(Digest::isRsaPssUri(method)) {
        if(EVP_PKEY_CTX_set_rsa_padding(ctx.get(), RSA_PKCS1_PS
            EVP_PKEY_CTX_set_rsa_pss_saltlen(ctx.get(), RSA_PSS
            break;
    } else if(EVP_PKEY_CTX_set_rsa_padding(ctx.get(), RSA_PKCS1
        break;
    if(EVP_PKEY_CTX_set_signature_md(ctx.get(), EVP_get_digestb
        EVP_PKEY_sign(ctx.get(), nullptr, &size, digest.data(),
        break;
    signature.resize(size);
    result = EVP_PKEY_sign(ctx.get(), signature.data(), &size,
    break;
}
fndef OPENSSL_NO_ECDSA
case EVP_PKEY_EC:
{
    if(EVP_PKEY_sign(ctx.get(), nullptr, &size, digest.data(),
        break;
```

PQ OpenSSL



```
default:
    if (EVP_PKEY_id(d->key) == EVP_PKEY_KEYMGMT)
    {
        if (const OSSL_PROVIDER *provider = EVP_PKEY_get0_provider(d->key);
            provider && std::string(OSSL_PROVIDER_get0_name(provider)) == "oqsprovider")
        {
            if(EVP_PKEY_sign(ctx.get(), nullptr, &size, digest.data(), digest.size()) <= 0){
                break;
            }
            signature.resize(size);
            result = EVP_PKEY_sign(ctx.get(), signature.data(), &size, digest.data(), digest.size());
            break;
        }
    }

    THROW("Unsupported private key");
}
```

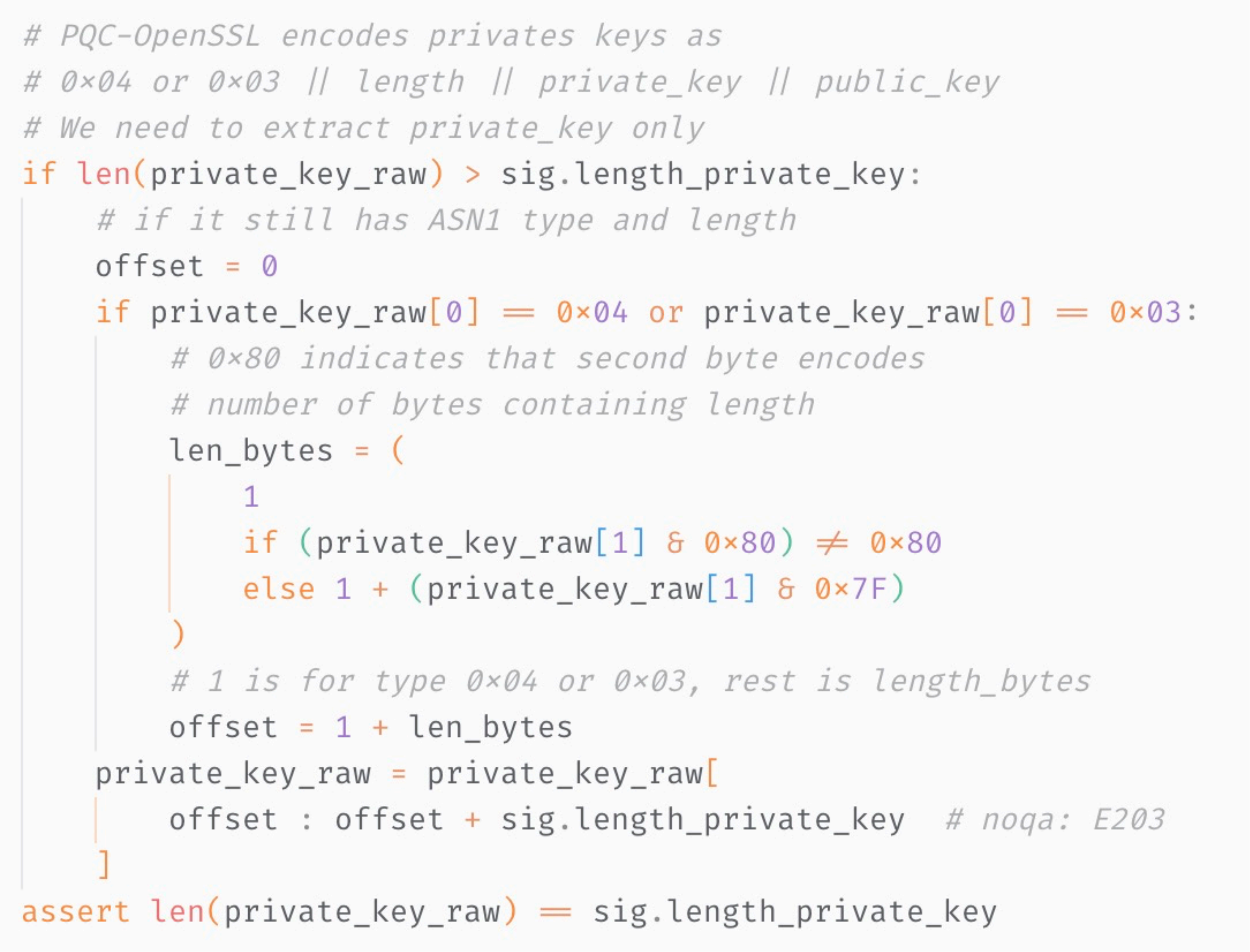
1) check for EVP_PKEY_KEYMGMT

2) check for provider

OPTIONAL: obtain alg name with EVP_PKEY_get0_type_name(key)

PQ OpenSSL
Private key encoding

- OpenSSL outputs the private key as:
    - **privateKey || publicKey**
- This concatenated format is put into the **PrivateKeyInfo** structure



```
# PQC-OpenSSL encodes privates keys as
# 0x04 or 0x03 || length || private_key || public_key
# We need to extract private_key only
if len(private_key_raw) > sig.length_private_key:
    # if it still has ASN1 type and length
    offset = 0
    if private_key_raw[0] == 0x04 or private_key_raw[0] == 0x03:
        # 0x80 indicates that second byte encodes
        # number of bytes containing length
        len_bytes = (
            1
            if (private_key_raw[1] & 0x80) != 0x80
            else 1 + (private_key_raw[1] & 0x7F)
        )
        # 1 is for type 0x04 or 0x03, rest is length_bytes
        offset = 1 + len_bytes
    private_key_raw = private_key_raw[
        offset : offset + sig.length_private_key  # noqa: E203
    ]
assert len(private_key_raw) == sig.length_private_key
```

https://developers.google.com/tink

Bonus: Google's Tink

- Shift in how we understand cryptography
  - Focus on **cryptographic agility and key rotation**
  - Data models are **revolving around the keys, not algorithms**
- *"Think in terms of keys and primitives, not algorithms"*
- Lot of articles on PQC
- Google will ONLY use Tink and BoringSSL from now

If you want to be the cool kid

Bonus: standards

- (BSI, ANSSI, NÚKIB, etc: recommendations and guidelines)
- NIST: algorithms
- IETF: internet protocols (certificates, PKI,T ASN.1 structures)
- ETSI: digital signature legal singing

Standards are useful, libraries will depend on them

Conclusions

- Plenty of options
- **PQC migration is a process** → be interested in it
  - Monitor news (https://groups.google.com/a/list.nist.gov/g/pqc-forum)
  - Watch recordings of conferences
    - PKI Consortium PQC Conference
    - Real World PQC
    - NIST PQC Standardization Conference

Great opportunity to learn about applied cryptography in general

Conclusions

- **Prototype stuff**
  - Pilot project / proof-of-concept is referenced a lot as a great approach
- **Lot of opportunities to help**
  - PQC open-source is quite welcoming community
  - Raise issues, ask about edge cases

PQ engineering = baby that recently learned how to walk, stumbles a lot

Thank you for listening!

- https://cyber.ee/
- @ info@cyber.ee
- cybernetica
- CyberneticaAS
- cybernetica_ee
- Cybernetica

Petr Muzikant, petr.muzikant@cyber.ee