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Applied PQC in Software Security

CHESS

Cyber-security Excellence Hub in Estonia and South Moravia

Post Quantum Transition Workshop (PQT)

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[This presentation includes clickable links]

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Introduction

- Use case:
  - **Threat actor:** someone with sufficient quantum computer
  - **Operational cost:** enormous
  - **Main target:** probably important/valuable systems
  - **Cryptography implementation:** more advanced, probably hardware based
- Is PQC required everywhere, especially in every software application?

Introduction

- **SW cryptography is everywhere**
  - TLS, VPN, cloud services, password managers, certificates, digital signatures, 5G
- **Do/Should we bother with non-critical, low-level target systems?**
  - cheap
  - cryptography evolution
  - gateway to critical systems
  - makes sense

Our Experience

- **What:** PQ proof-of-concept implementations of existing applications (SW)
- **Why:** PQC research → Research&Development → exciting
- **Since:** almost 2 years ago
- **Applications:**
    - Web-eID (authentication)
    - CDOC2 (encryption)
    - IVXV (e-voting)
    - eID (certificates, OCSP, TSA)
    - supporting projects (library wrappers, lattice-helper, custom protocols)

Our Intentions

- More then just *"PQ-ize e-government applications"*
    - **explore** and support current PQC open-source
    - **focus on engineering aspects** of PQ implementations
    - **gather** experience, problems, and remarks
    - **learn**
    - **disseminate**

Applied PQC

Cryptography Libraries, Applications

PQClean and libOQS

- Well known, developed, and maintained
- PQClean (C)
  - cleaned aggregation of NIST-submitted algorithms (and FIPS standards)
  - source of source-code (i.e. not a library)
- libOQS (C)
  - + wrappers for C++, Python, Java, Go, .NET, Rust, and PHP
  - + applications built with libOQS (OpenSSL, OpenSSH, OpenVPN forks)

Bouncy Castle (Java)

- Quite hidden, not well documented, very early
- Java
  - needs to be full-featured → a lot of shortcuts
  - workflow different from others
- The implementation seems to go smoothly after some time
- Useful "Java Keytool" benefits too

CIRCL (Go)

- "Cloudflare Interoperable Reusable Cryptographic Library"
- Pure implementations in Go language by Cloudflare
- libOQS
  - similar workflow and API
  - objects are compatible with libOQS
- Works well with "crypto" standard library

Other Libraries

- rustpq/pqcrypto (Rust)
- smuellerDD/leancrypto (C with minimal dependencies)
- air-crypto/botan-pq (C++, PQ version of popular Botan library)
- terra-quantum-public/tq42-pqc-oss (C++, looks promising)
- many others
  - FIPS 203-205 contain detailed implementation instructions

OpenQuantumSafe organization

- Many applications built with libOQS
- **OpenSSL with PQ provider (extension)**
  - → TLS
  - → SSH
  - → certificates, OCSP, timestamping servers
  - → C API
  - → basically everything
- Many external users of libOQS
  - Microsoft, Thales, Cisco, IBM, Entrust, etc.

Transport Layer Security (TLS)

- **Biggest target of PQC implementation**
  - attempts to introduce KEM-TLS
- Cloudflare
  - documents PQ TLS
  - monitors clients connecting via PQ TLS (16 %)
- OpenQuantumSafe
  - provides PQ-TLS implementations for many server and client solutions
- Google
  - first hybrid TLS in Google Chrome

Virtual Private Networks

- Experiments together with Brno University of Technology
    - includes also pre-quantum (and quantum) key exchange
- Microsoft PQ VPN (but archived)
- Rosenpass
    - PQ key-exchange extension for WireGuard VPN
    - seems well maintained
- ExpressVPN, QAL VPN (paid solutions)

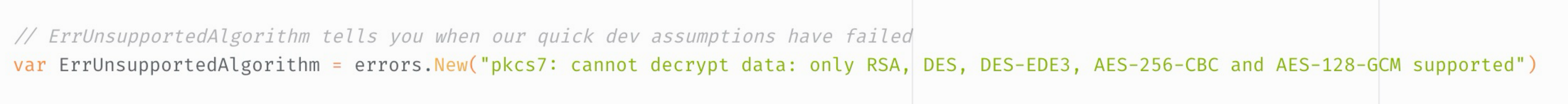
Engineering Obstacles

- Inconsistent PQ object encodings
- Inconsistent key handling
- Inconsistent naming
- Hash-then-Sign dilemma
- Standard vs external libraries
- Deep dependency chains
- Interoperability issues
- PQC in all layers of SW - it is NOT just an algorithm switch

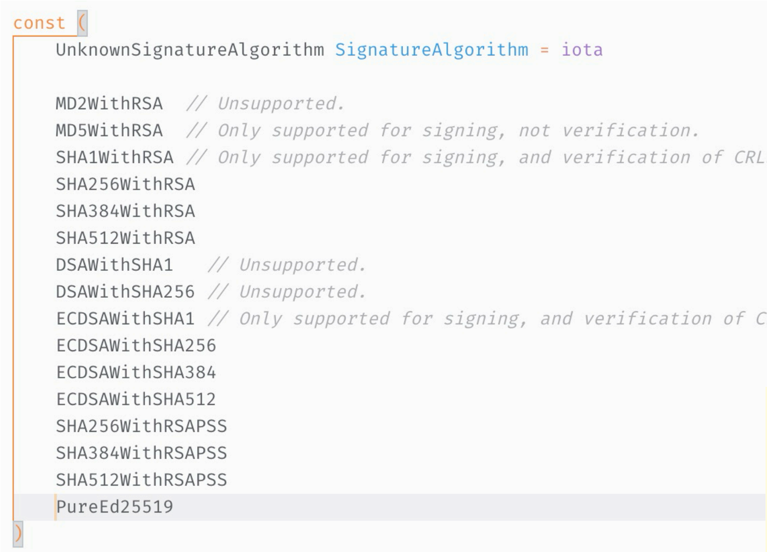
Crypto Agility

- **Hardcoded cryptography implementation**
  - *"ERROR: only X, Y, Z are supported, nothing else!"*
- **Introducing new algorithm** often requires adapting whole application codebase (demanding)
- **Crypto agile** application
  - zero knowledge about cryptography algorithms
- Thankfully, we still have time to figure this out

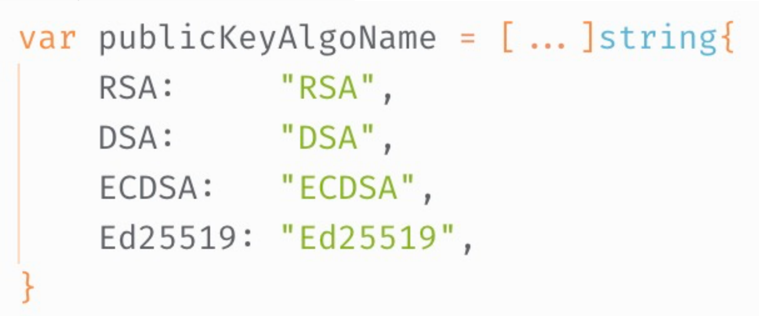
Crypto Agility



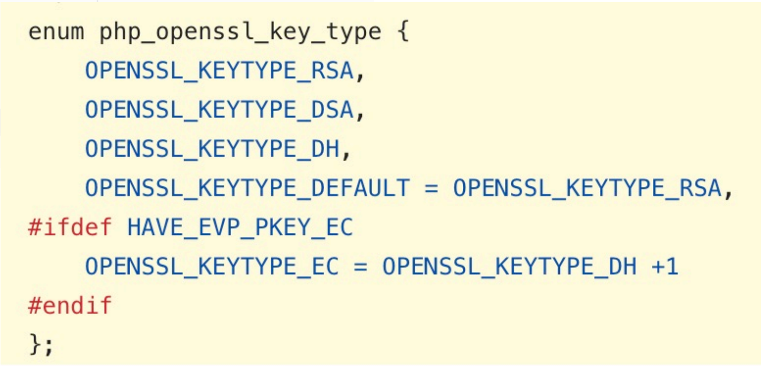
```
// ErrUnsupportedAlgorithm tells you when our quick dev assumptions have failed
var ErrUnsupportedAlgorithm = errors.New("pkcs7: cannot decrypt data: only RSA, DES, DES-EDE3, AES-256-CBC and AES-128-GCM supported")
```



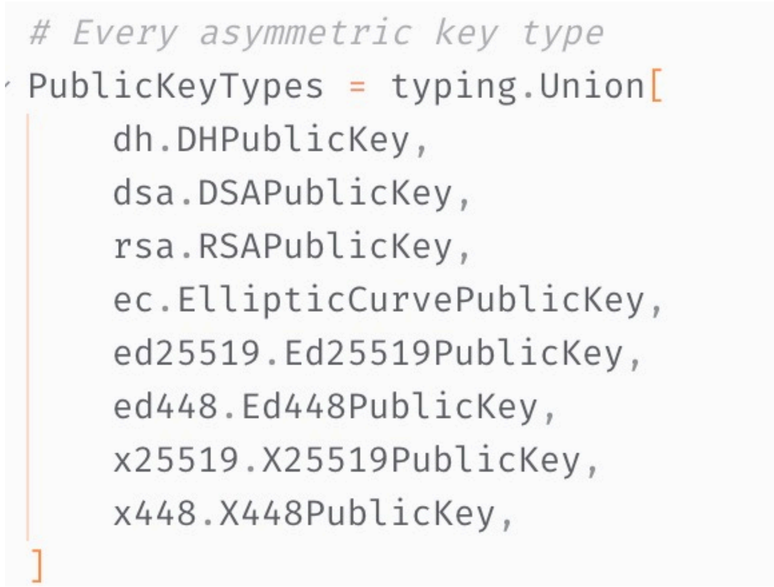
```
const (
	UnknownSignatureAlgorithm SignatureAlgorithm = iota

	MD2WithRSA  // Unsupported.
	MD5WithRSA  // Only supported for signing, not verification.
	SHA1WithRSA // Only supported for signing, and verification of CRLs,
	SHA256WithRSA
	SHA384WithRSA
	SHA512WithRSA
	DSAWithSHA1   // Unsupported.
	DSAWithSHA256 // Unsupported.
	ECDSAWithSHA1 // Only supported for signing, and verification of CRL
	ECDSAWithSHA256
	ECDSAWithSHA384
	ECDSAWithSHA512
	SHA256WithRSAPSS
	SHA384WithRSAPSS
	SHA512WithRSAPSS
	PureEd25519
)
```



```
var publicKeyAlgoName = [...]string{
	RSA:     "RSA",
	DSA:     "DSA",
	ECDSA:   "ECDSA",
	Ed25519: "Ed25519",
}
```



```
enum php_openssl_key_type {
	OPENSSL_KEYTYPE_RSA,
	OPENSSL_KEYTYPE_DSA,
	OPENSSL_KEYTYPE_DH,
	OPENSSL_KEYTYPE_DEFAULT = OPENSSL_KEYTYPE_RSA,
#ifdef HAVE_EVP_PKEY_EC
	OPENSSL_KEYTYPE_EC = OPENSSL_KEYTYPE_DH +1
#endif
};
```



```
# Every asymmetric key type
PublicKeyTypes = typing.Union[
    dh.DHPublicKey,
    dsa.DSAPublicKey,
    rsa.RSAPublicKey,
    ec.EllipticCurvePublicKey,
    ed25519.Ed25519PublicKey,
    ed448.Ed448PublicKey,
    x25519.X25519PublicKey,
    x448.X448PublicKey,
]
```

~~PQ~~ → Cryptosystems "Transition"

- Managing Cryptography: Cryptographic Discovery & PQC Migration Panel (NIST 5th PQC Standardization Conference, session 7):
  - *"Don't migrate to PQC, **migrate to better management** of cryptography in your systems"*
  - *"**Cryptography management system was needed years ago**..."*
- Chance to make cryptography in SW better
  - **agile**, **modular**, **adaptive**
  - new **best practices**
  - **IT blindspots**
    - *"What do you mean we are still using SHA1?!"*

Key Takeaways

1. **PQC in software is very much a real thing**, regardless of CRQC
    - not perfect, but developing quite fast
2. **PQ solutions exist**, no need to build from scratch
3. **Very strong community** (forums, orgs, IETF, alliances)
4. Chance to **overhaul cryptography management** in our applications

Resources

- Lot of resources to help make a decision (e.g. PQC Migration Handbook)
- **Where to look as an engineer?**
  - IETF RFC Drafts
    - most are not complete, already expired, contradict each other
    - basics: PQC for engineers RFC
  - pqc-forum Google Group
  - state-of-protocols-and-pqc repository
  - NIST Special Publication series 1800-38 ??
  - NCCoE, PQCA (migration groups/movements)

Thank you for listening!

References:

- links in presentation
- previous slide
- write me an email!

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