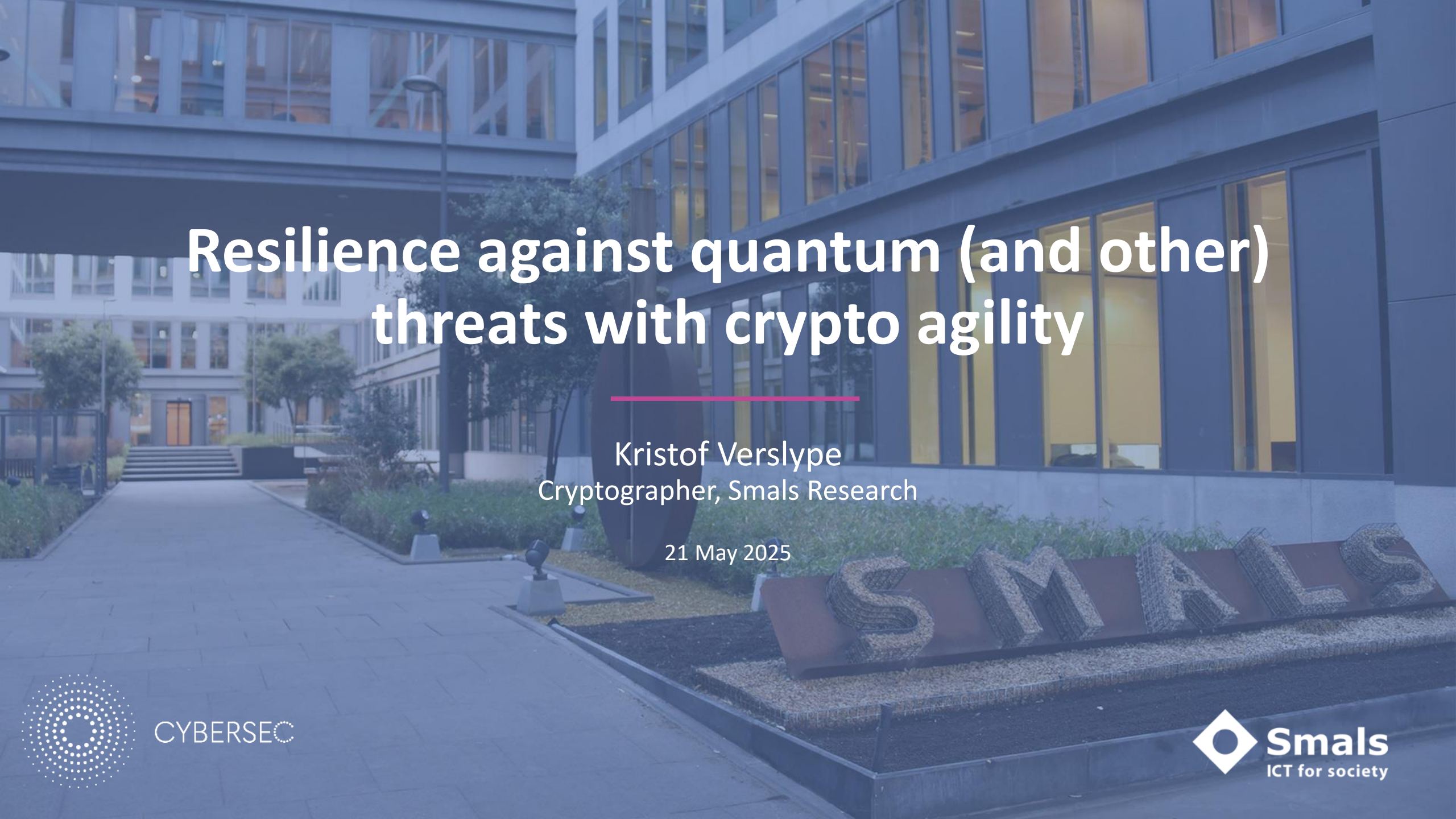

Resilience against quantum (and other) threats with crypto agility

Kristof Verslype
Cryptographer, Smals Research

21 May 2025

CYBERSEC

Smals
ICT for society

Cryptography is Everywhere

Devices

- IoT
- Smartcard (eId, bank)
- Smartphone
- Servers
- House
- Car
- Plane
- Satellite
- …

Interactions

- Financial transactions
- Secure communication
- Document signing
- Authentication
- …

Domain

- Defense / military
- Public sector
- Private sector
- Individuals
- …

WITHOUT SECURE CRYPTOGRAPHY, OUR SOCIETY COLLAPSES

Cryptography Under Threat

Cryptographically relevant quantum computers

Would be able to break modern (public-key) cryptography

"To ensure an acceptable level of readiness, we recommend that [the most sensitive use cases] should be protected against 'store now, decrypt later' attacks as soon as possible, latest by the end of 2030."

Joint statement from partners from 18 EU member states (11/2024)

Other threats

- Increasing computing power
- Cryptanalysis
- Side-channel attacks in implementations

Applies on modern and post-quantum cryptography

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IEEE Spectrum FOR THE TECHNOLOGY INSIDER

NEWS | COMPUTING

“Quantum-Safe” Crypto Hacked by 10-Year-Old PC

›Many challenges still lie ahead for postquantum cryptography

BY CHARLES Q. CHOI | 19 AUG 2022 | 7 MIN READ |

Charles Q. Choi is a contributing editor for IEEE Spectrum.

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TAGS

QUANTUM COMPUTING

CRYPTOGRAPHY | NIST

POST-QUANTUM CRYPTOGRA…

FUTURE QUANTUM COMPUTERS may rapidly break modern cryptography. Now researchers find that a promising algorithm designed to protect computers from these advanced attacks could get broken in just 4 minutes. And the catch is that 4-minute time stamp was not achieved by a cutting-edge machine but by a regular 10-year-old desktop computer. This latest, surprising defeat highlights the many hurdles postquantum cryptography will need to clear before adoption, researchers say.

Cryptography Under Threat

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Joint statement from partners from 18 EU member states (11/2024)

Other threats

- Increasing computing power
- Cryptanalysis
- Side-channel attacks in implementations

Applies on modern and post-quantum cryptography

→ **MIGRATE ON TIME TO RECOMMENDED CRYPTOGRAPHY**

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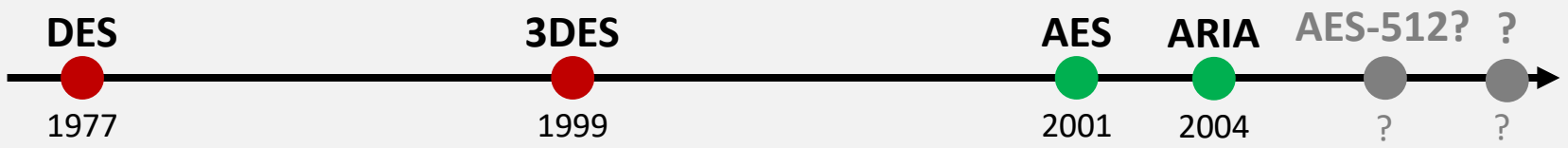
Cryptographic migrations

- Insecure
- Phase-out
- Secure / Recommended
- Planned

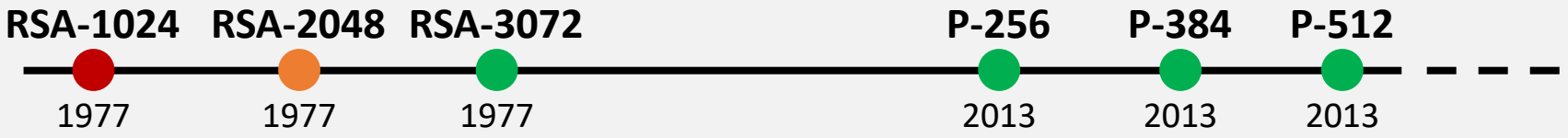
Symmetric encryption



Secure hash function

Public key cryptography

(E.g., digital signatures, key agreement, authentication)



Multiple crypto migrations in the past

Slow, cumbersome and expensive process - Takes 5 to 15 years to migrate

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Cryptographic migrations

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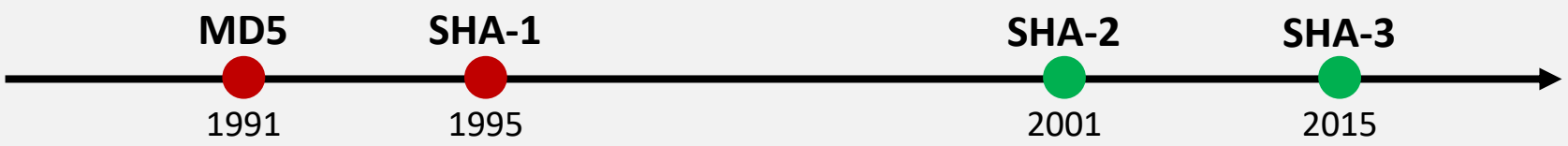
Symmetric encryption

Secure hash function



Public key cryptography

(E.g., digital signatures, key agreement, authentication)

Potentially multiple crypto migrations in the not-so-distant future!

Becoming quantum-ready may not be a one-time shot

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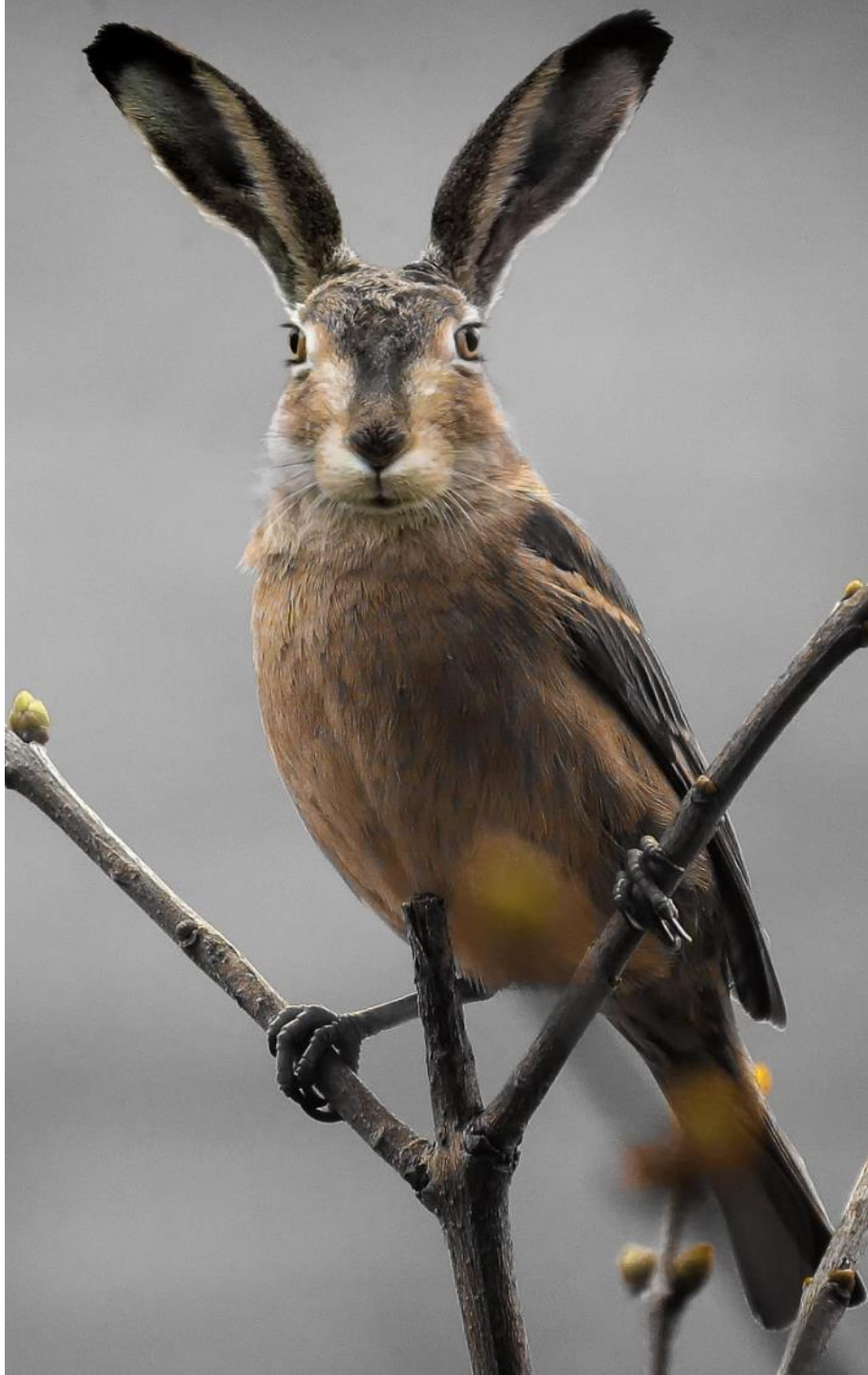
Transitional period in Hybrid Mode

Bundesamt
für Sicherheit in der
Informationstechnik

The quantum-safe algorithms that are currently being standardized are not yet as well researched as the "classical" methods *(for example RSA and ECC). This applies in particular to weaknesses that largely only become apparent in applications, such as typical implementation errors, possible side-channel attacks, etc.* ***BSI therefore recommends that post-quantum cryptography should not be used in isolation if possible, but only in hybrid mode, i.e. in combination with classical algorithms****. […] Hash-based signatures can in principle also be used on its own (i.e., not in hybrid mode).*

Quantum-safe cryptography –fundamentals, current developments and recommendations. October 2022

→ **EVEN MORE MIGRATIONS!**



Crypto migrations

Challenge

- Multiple in the past & multiple in the future
- Slow and cumbersome process - Takes 5 to 15 years to migrate

→ **How to facilitate smooth migrations?**

Approach

Cryptographic algorithms have a life cycle
Recommended → Secure → Phase out → Insecure

Cryptographic mechanisms are assets that need to be managed

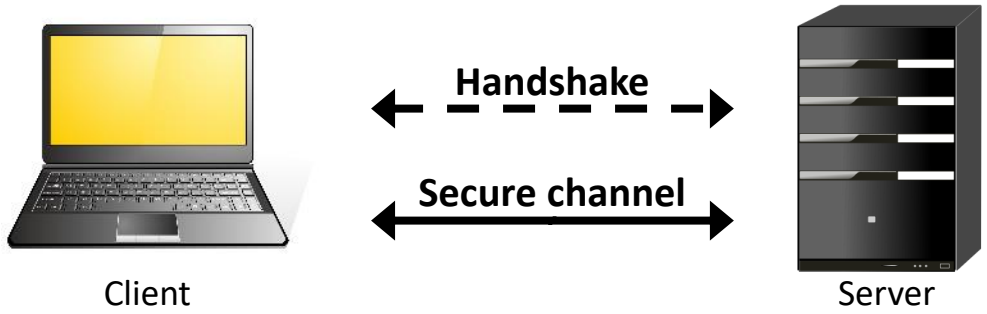
We should accept this and act on it!

Improve cryptographic maturity

Insight	Guidance	Flexibility
Crypto inventory	**Crypto policy**	**Crypto agility**
Where what crypto for which purpose?	What cryptography should (not) be used?	Migrate easily from/to crypto mechanisms

Transport Layer Security (TLS)

Example of cryptographic protocol agility (see RFC7696)



Handshake

- Agree on TLS version (1.2 or 1.3)
- Agree on cipher suite
- Authenticate
- Generate shared session keys

Supported cipher suites

TLS_SM4_GCM_SM3
TLS_AES_128_CCM_SHA256
TLS_AES_128_GCM_SHA256
TLS_AES_256_GCM_SHA384
TLS_AES_128_CCM_8_SHA256
TLS_CHACHA20_POLY1205_SHA256

Supported cipher suites

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TLS_AES_256_GCM_SHA384
TLS_CHACHA20_POLY1205_SHA256
TLS_AES_128_CCM_SHA256
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TLS_SM4_GCM_SM3

Recommended
Secure
Phase out
Insecure
Deactivated

Cryptographic service offers **abstract API** to application / service

Cryptographic functions **selected in real-time**

Add and **remove** Cryptographic functions

Cryptographic functions: *Hardware, software, firmware, algorithms, parameters, …*

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National Academies of Sciences, Engineering, and Medicine (2016) Cryptographic Agility and Interoperability: Proceedings of a Workshop. Forum on Cyber Resilience Workshop Series. (The National Academies Press, Washington, DC). https://doi.org/10.17226/24636

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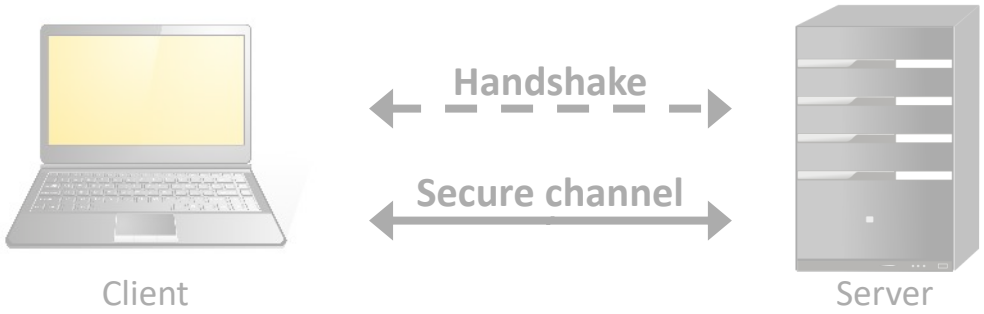

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TLS_CHACHA20_POLY1205_SHA256

Recommended
Secure
Phase out

Cryptographic Agility

On the level of an IT system

Cryptographic service offers **abstract API** to application / service

Cryptographic functions **selected in real-time**

Add and **remove** Cryptographic functions

At runtime – No impact on system availability

Cryptographic functions: *Hardware, software, firmware, algorithms, parameters, …*

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Sepia - Service for digital signatures

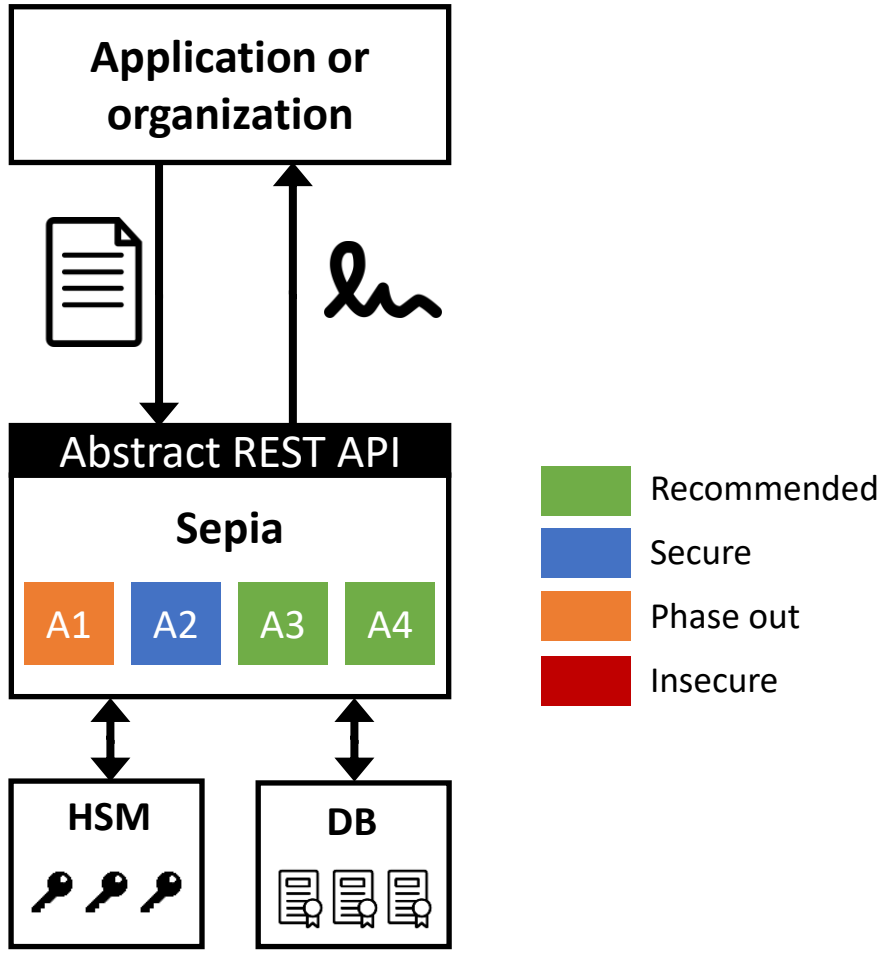
Service developed by Smals

Functionality

- Creates digital signatures on behalf of public sector organisations and services
- Automated or with human intervention
- Storage of signed documents with signature
- Secure storage of certificates and secret keys

Motivation

- **Cost reduction by reuse**
  See reuse catalog [1]
- **Increase security**
- **Crypto agility!**

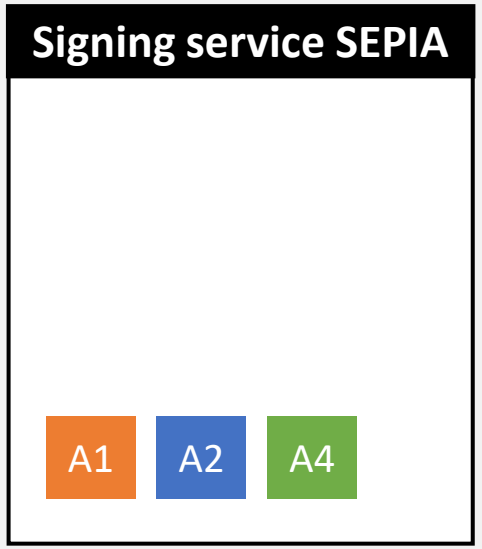


CRYPTO AGILITY AND COST EFFICIENCY CAN COEXIST

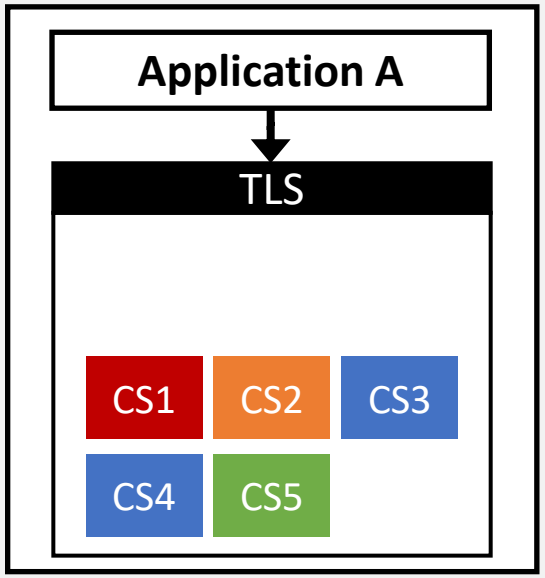
[1] https://www.ict-reuse.be/nl/service/sepiadocumentsigner

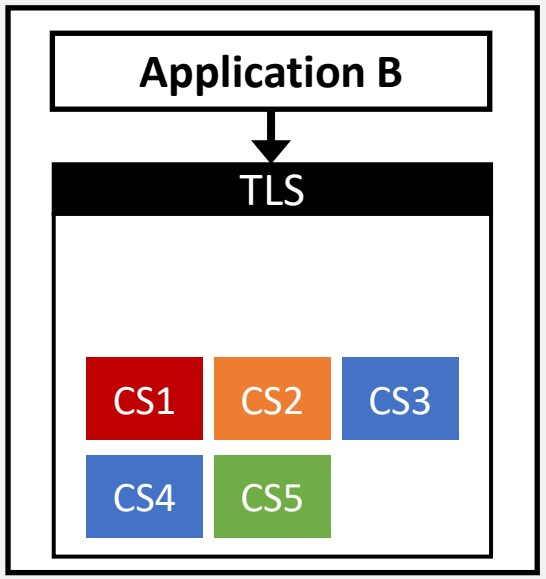
Possible Future Architecture

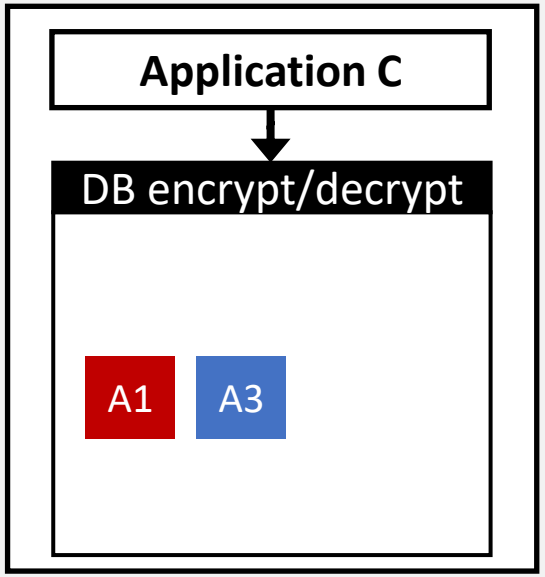
CENTRAL



LOCAL







Possible Future Architecture

CENTRAL

Implementation service

Cipher suites

CS1 CS2 CS3
CS4 CS5 CS6

Algorithms

A1 A2 A3 A4 A5

Policy service

Policy

Policy + Dev. SEPIA = Policy SEPIA

Deviations

Dev. app A
Dev. app B
Dev. SEPIA

Signing service SEPIA

A1 A2 A4

Certificate mgt.

Policy

A1 A2 A3 A4

Crypto inventory

LOCAL

Application A

TLS

Policy app A

CS1 CS2 CS3
CS4 CS5

Application B

TLS

Policy app B

CS1 CS2 CS3
CS4 CS5

Application C

DB encrypt/decrypt

Policy app C

A1 A3

"A1 only to decrypt"

Possible Future Architecture

CENTRAL

Implementation service

Cipher suites

CS1 CS2 CS3 CS4 CS5 CS6

Algorithms

A1 A2 A3 A4 A5

Policy service

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Policy + Dev. SEPIA =

Deviations

Dev. app A Dev. app B Dev. SEPIA

Signing service SEPIA

Policy SEPIA

A2 A4

Certificate mgt.

Policy

A1 A2 A3 A4

Crypto inventory

CRYPTOGRAPHIC AGILITY

IMPLIES

CENTRALIZATION AND AUTOMATED PROCESSES

LOCAL

Application A

TLS

Policy app A

CS1 CS2 CS3 CS4 CS5 CS6

Application B

TLS

Policy app B

CS1 CS2 CS3 CS4 CS5 CS6

Application C

DB encrypt/decrypt

Policy app C

A1 A3 A5

"A1 only to decrypt"

Crypto-Agility Maturity Model (CAMM)

Proposal – not yet standardized or adopted – for IT-systems

Initial / Not possible

At least one subsystem or component violates L1 requirements

0

Possible

Systems can be adapted to respond dynamically to future crypto challenges

1

Knowledge

- System knowledge
- Cryptography inventory

Process

- Updateability
- Reversibility

System property

- Extensibility

Prepared

Actual crypto migration still requires some preparatory work

2

Knowledge

- Algorithm IDs

System property

- Cryptographic modularity (API)
- Algorithm intersection
- Algorithm exclusion
- Opportunistic security
- Usability of crypto agility

Practiced

Crypto migration demonstrable, effectively and securely feasible

3

Knowledge

- Performance awareness
- Secure crypto agility

Process

- Policies
- Compliance testing
- Enforceability of CA
- Transition mechanism
- Effectiveness

System property

- Hardware modularity
- Backwards compatibility

Sophisticated

Enables fast crypto migration, applied on broader infrastructure

4

Process

- Automation
- Scalability
- Real-time

System property

- Context independence
- Cross-system interoperability

https://camm.h-da.io/

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Crypto-Agility Maturity Model (CAMM)

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Knowledge
- Algorithm IDs
- Algorithm modularity (API)
- Cryptographic modularity (alg.)
- Algorithm intersection
- Algorithm exclusion
- Opportunistic security
- Usability of crypto agility

2

Practiced

Crypto migration demonstrable, effectively and securely feasible

Knowledge
- Performance awareness
- Usability of crypto agility

Process
- Policies
- Compliance testing
- Enforceability of CA
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3

Sophisticated

Enables fast crypto migration, applied on broader infrastructure

Process
- Automation
- Scalability
- Real-time

System property
- Context independence
- Cross-system interoperability

4

CRYPTOGRAPHIC AGILITY IS A JOURNEY

(NO OFFICIAL MAPS AVAILABLE YET)

https://camm.h-da.io/

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Challenges & open questions

Research on CA

Performance

Middleboxes

Legacy

Standards

Downgrade attacks

QR-codes

IoT

Incompatibilities

Advanced cryptography

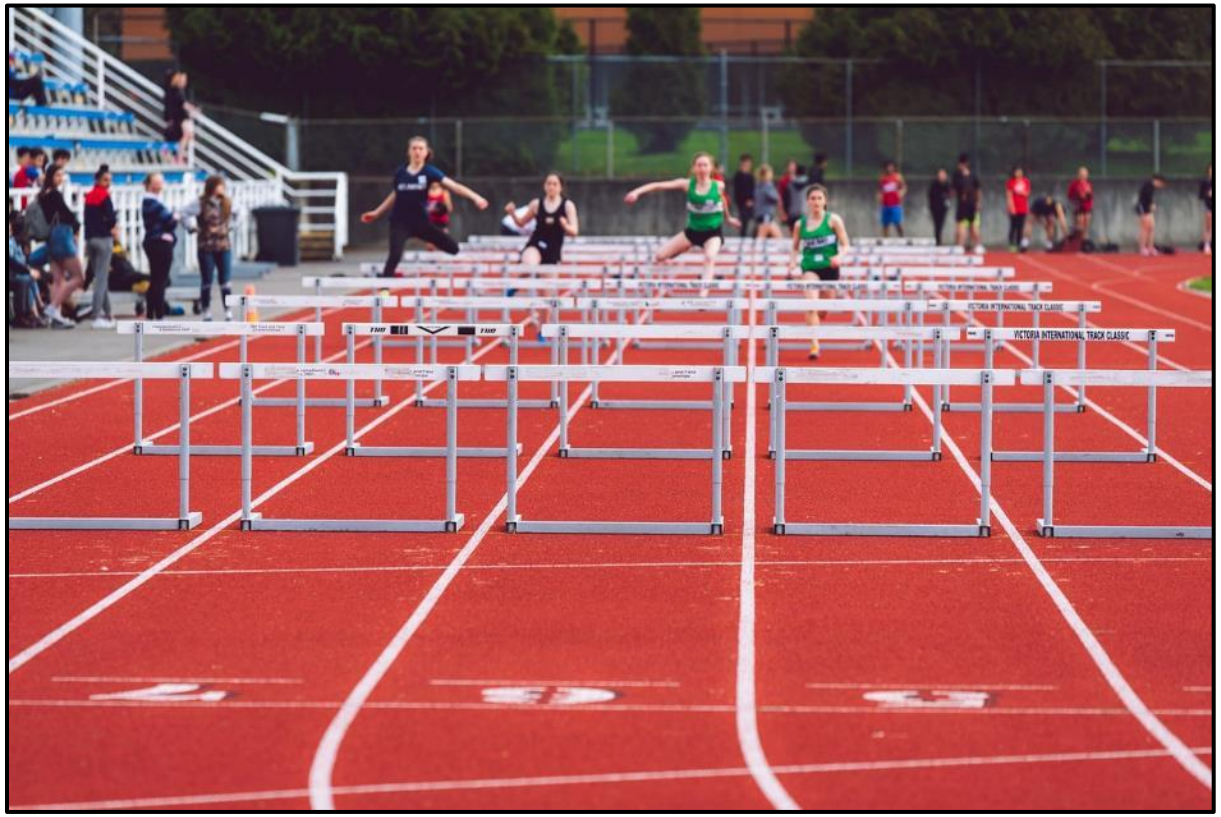
Guidance

X.509 certificates

Smartcards

HSMs

Cryptographic accelerators



BECOMING QUANTUM-READY IS HARD, BECOMING CRYPTO AGILE EVEN HARDER

BUT… IT PAYS OFF IN THE LONG RUN!

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Takeaways

- Crypto migration is not a one-time operation
- Crypto mechanisms have a life cycle
- Crypto migrations can be slow, cumbersome and expensive
- Crypto agility introduces flexibility in your organization to better deal with this
- **We are early**

BECOME A CHEETAH: EMBRACE CRYPTO AGILITY!

IT WILL BE YOUR CORNERSTONE IN ADAPTING TO YOUR FUTURE CRYPTOGRAPHIC NEEDS

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Thanks for your attention!

Feedback / questions / discussions welcome!
See you at our booth (05.F034, next to theatre 1)!

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