MPSE - SS2022

Implementing eID protocols

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Agenda

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1 Introduction

- PIN based authentication might be threatened by quantum computers
- Find a scheme without any connection between PIN and encryption key
- Only use quantum safe components
- Implement POC

2 Where we began

Decisions:

- CRYSTALS - Kyber as PQC scheme
- Which boards to use

Implementations:

- PACE and Kyber on Linux (Mint)
- Kyber on board

Proposals:

- Idea to incorporate nonce

3 Goals

First goal:

- Develop a working prototype

Second goal:

- Make it run on a development board

Side goals:

- Fix issues left over from the previous semester

4 Our Work

4.1 Theory

Exchange of PACE protocol

- New Kyber-Ding-PACE based on Ding PAKE
- Solves nonce problem

Additionally

- Human readable run on paper
- Look into attacks

4.1 Kyber Ding PACE

Alice		**Bob**
password π		password π
	Exchange nonce	
$K_\pi = \mathcal{H}(\pi\|\|0)$ choose $n \leftarrow \mathbb{Z}_q$ $z = \mathcal{C}(K_\pi, n)$ generate $\mathbf{A} \in \mathbb{R}^{k\times k}_{q=3329}$		$K_\pi = \mathcal{H}(\pi\|\|0)$
	$\xrightarrow{\mathbf{A}, z}$	
		$n = C^{-1}(K_\pi, z)$
	Mapping	
generate $\mathbf{s}_a, \mathbf{e}_a \in \mathbb{R}^k_{\eta=3}$ $\mathbf{t}_a = \mathbf{A}\mathbf{s}_a + \mathbf{e}_a$		generate $\mathbf{s}_b, \mathbf{e}_b \in \mathbb{R}^k_{\eta=3}$ $\mathbf{t}_b = \mathbf{A}\mathbf{s}_b + \mathbf{e}_b$
	$\xleftarrow{\mathbf{t}_b}$ with hash $\mathbf{H}$: $\{0,1\}^{256} \to \mathbb{R}^k_{q=3329}$	
$\mathbf{p}_a = \mathbf{t}_a + \mathbf{H}(n)$	$\xrightarrow{\mathbf{p}_a}$	$\mathbf{t}_a = \mathbf{p}_a - \mathbf{H}(n)$
	two-path preKeys	
generate $m_a \leftarrow \{0,1\}^{256}$ $(\hat{K}_a, (\mathbf{r}_a, \mathbf{e}_{a1}, e_{a2})) = \mathbf{G}(\mathbf{H}(\mathbf{t}_b), m_a)$		generate $m_b \leftarrow \{0,1\}^{256}$ $(\hat{K}_b, (\mathbf{r}_b, \mathbf{e}_{b1}, e_{b2})) = \mathbf{G}(\mathbf{H}(\mathbf{t}_a), m_b)$
	with hash $\mathbf{G}$: $\mathbb{R}^k_{q=3329}, \{0,1\}^{256} \to$ $\{0,1\}^{256}, (\mathbb{R}^k_{\eta=3}, \mathbb{R}^k_{\eta=3}, \mathbb{R}^k_{\eta=3})$	
$c_a = \begin{cases} \mathbf{u}_a = (\mathbf{A}^T\mathbf{r}_a + \mathbf{e}_{a1}) \\ v_a = \mathbf{t}_b^T\mathbf{r}_a + e_{a2} + \lceil \frac{q}{2} \rfloor \cdot m_a \end{cases}$		$c_b = \begin{cases} \mathbf{u}_b = (\mathbf{A}^T\mathbf{r}_b + \mathbf{e}_{b1}) \\ v_b = \mathbf{t}_a^T\mathbf{r}_b + e_{b2} + \lceil \frac{q}{2} \rfloor \cdot m_b \end{cases}$
	$\xrightarrow{c_a=(\mathbf{u}_a, v_a)}$ $\xleftarrow{c_b=(\mathbf{u}_b, v_b)}$	
$m_b^* = (v_b - \mathbf{s}_a^T\mathbf{u}_b)$ $\hat{K}_b^*, (\mathbf{r}_b^*, \mathbf{e}_{b1}^*, e_{b2}^*)) = \mathbf{G}(\mathbf{H}(\mathbf{t}_a), m_b^*)$ $c_b^* = \begin{cases} \mathbf{u}_b^* = (\mathbf{A}^T\mathbf{r}_b^* + \mathbf{e}_{b1}^*) \\ v_b^* = \mathbf{t}_a^T\mathbf{r}_b^* + e_{b2}^* + \lceil \frac{q}{2} \rfloor \cdot m_b^* \end{cases}$ generate $z_a \leftarrow \{0,1\}^{256}$ $\hat{K}_b = \begin{cases} \hat{K}_b^* \text{ if } c_b = c_b^* \\ z_a \text{ if } c_b \neq c_b^* \end{cases}$		$m_a^* = (v_a - \mathbf{s}_b^T\mathbf{u}_a)$ $\hat{K}_a^*, (\mathbf{r}_a^*, \mathbf{e}_{a1}^*, e_{a2}^*)) = \mathbf{G}(\mathbf{H}(\mathbf{t}_b), m_a^*)$ $c_a^* = \begin{cases} \mathbf{u}_a^* = (\mathbf{A}^T\mathbf{r}_a^* + \mathbf{e}_{a1}^*) \\ v_a^* = \mathbf{t}_b^T\mathbf{r}_a^* + e_{a2}^* + \lceil \frac{q}{2} \rfloor \cdot m_a^* \end{cases}$ generate $z_b \leftarrow \{0,1\}^{256}$ $\hat{K}_a = \begin{cases} \hat{K}_a^* \text{ if } c_a = c_a^* \\ z_b \text{ if } c_a \neq c_a^* \end{cases}$
	Authentication	
$K = \mathbf{KDF}(\hat{K}_a, \hat{K}_b)$ $K_{enc} = \mathcal{H}(K\|\|1)$ $K_{mac} = \mathcal{H}(K\|\|2)$ $K'_{mac} = \mathcal{H}(K\|\|3)$ $T_A \leftarrow \mathcal{M}(K'_{mac}, (\mathbf{t}_b, \mathbf{A}))$		$K = \mathbf{KDF}(\hat{K}_a, \hat{K}_b)$ $K_{enc} = \mathcal{H}(K\|\|1)$ $K_{mac} = \mathcal{H}(K\|\|2)$ $K'_{mac} = \mathcal{H}(K\|\|3)$ $T_B \leftarrow \mathcal{M}(K'_{mac}, (\mathbf{t}_a, \mathbf{A}))$
	$\xrightarrow{T_A}$ $\xleftarrow{T_B}$	
abort if T_B invalid		abort if T_A invalid
	Establish Session	
key $= (K_{enc}, K_{mac})$ sid $= (\mathbf{t}_a, \mathbf{t}_b, \mathbf{A})$ pid $= \epsilon$		key $= (K_{enc}, K_{mac})$ sid $= (\mathbf{t}_a, \mathbf{t}_b, \mathbf{A})$ pid $= \epsilon$

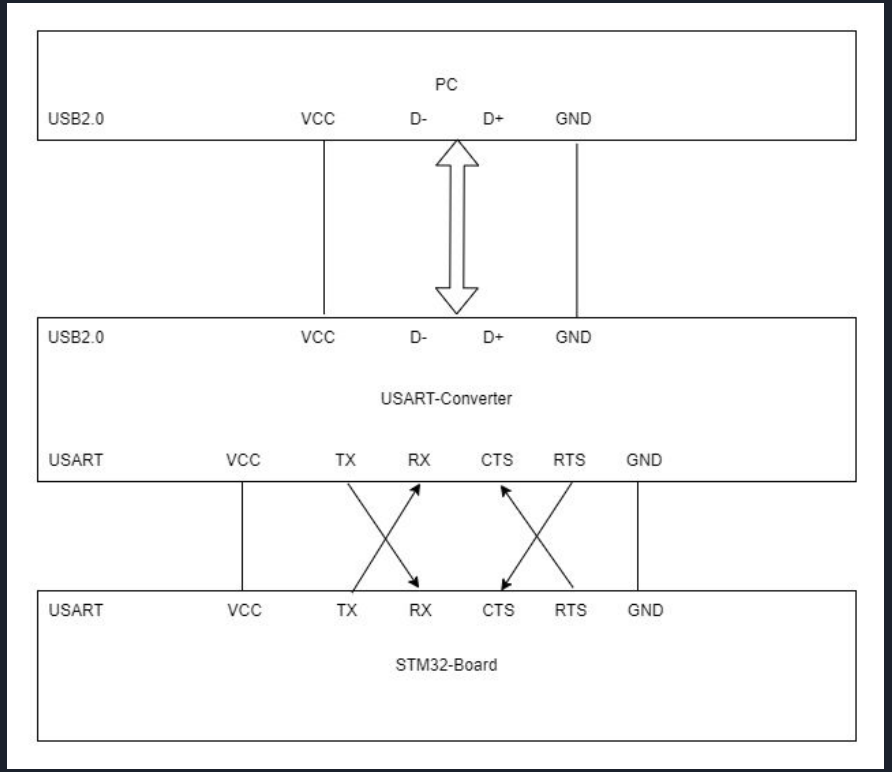
4.2 Code

- New class structure
  - Easier to use
  - Create session key object
  - Use this to send and receive encrypted messages
- Abstraction layer for the communication types
- Socket / USART
- TODO: (Bluetooth / NFC)

4.2 Code - Demo

4.3 Board

- Runs on STM32L4R5ZI
- Connected to PC via USART-Converter
- pqm4 project implements optimized Kyber for Cortex-M4



4.4 Problems

- USART communication
- Board -> PC
  - works
- PC -> board
  - does not receive any data or only incomplete data
- Possible cause:
  - PC delivers data too fast
- Possible solutions:
  - Usage of flow control
  - Reduce baudrate

5 Future Work

Formal proof of security:

- Security of the protocol has been examined, but a formal proof is still missing

Kyber implementations:

- Only the reference implementation is used, there are more optimized implementations available

Board:

- Fix technical issues so the program can be tested
- Run a benchmark

6 Conclusion

- First goal: Develop a working prototype
  - ✓ Achieved
  - ✓ In a development environment

- Second goal: Make it run on a development board
  - ✓ The program can be flashed onto the board and runs.
  - ✖ Communication doesn't work properly

- Side goals: Fix issues left over from the previous semester
  - ✓ Nonce no longer part of the keying material
  - ✓ Protocol has been adapted
  - ✓ Dependency issues are resolved

Agenda	Martyna
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