# Hardware Secured, Password-based Authentication for Smart Sensors for the Industrial Internet of Things

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# Outline

- Introduction
- Design
- Evaluation
- Results
- Conclusion
- Future Work

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# Introduction

- Sensors are a key component for the Internet of Things.
- Decisions depend on the information sensors provide.
- Smart sensors can manipulate the gathered data and make decisions.
- To update the sensors settings, the operator needs to be trusted.
- →Authentication on sensors is vital to trust the sensor data and the connected system.

# Improvement

- Implementing fully functional versions of SPAKE2.
- Deploying SPAKE2 on a Hardware Security Module, and a PC.
- Evaluate the performance of SPAKE2 compared to current authentication mechanisms.
- Evaluate the time performance in absolute numbers.

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# Design

$$\text{public information: } G, H(\cdot), u_A, u_B$$

$$\text{private shared information: } password$$

| User A | User B |
|---|---|
| $x = rand()$ | $y = rand()$ |
| $X = xG;\ M = H(u_A)G$ | $Y = yG;\ N = H(u_B)G$ |
| $X^* = X + (password)M$ | $Y^* = Y + (password)N$ |

$$X^* \rightarrow$$

$$\leftarrow Y^*$$

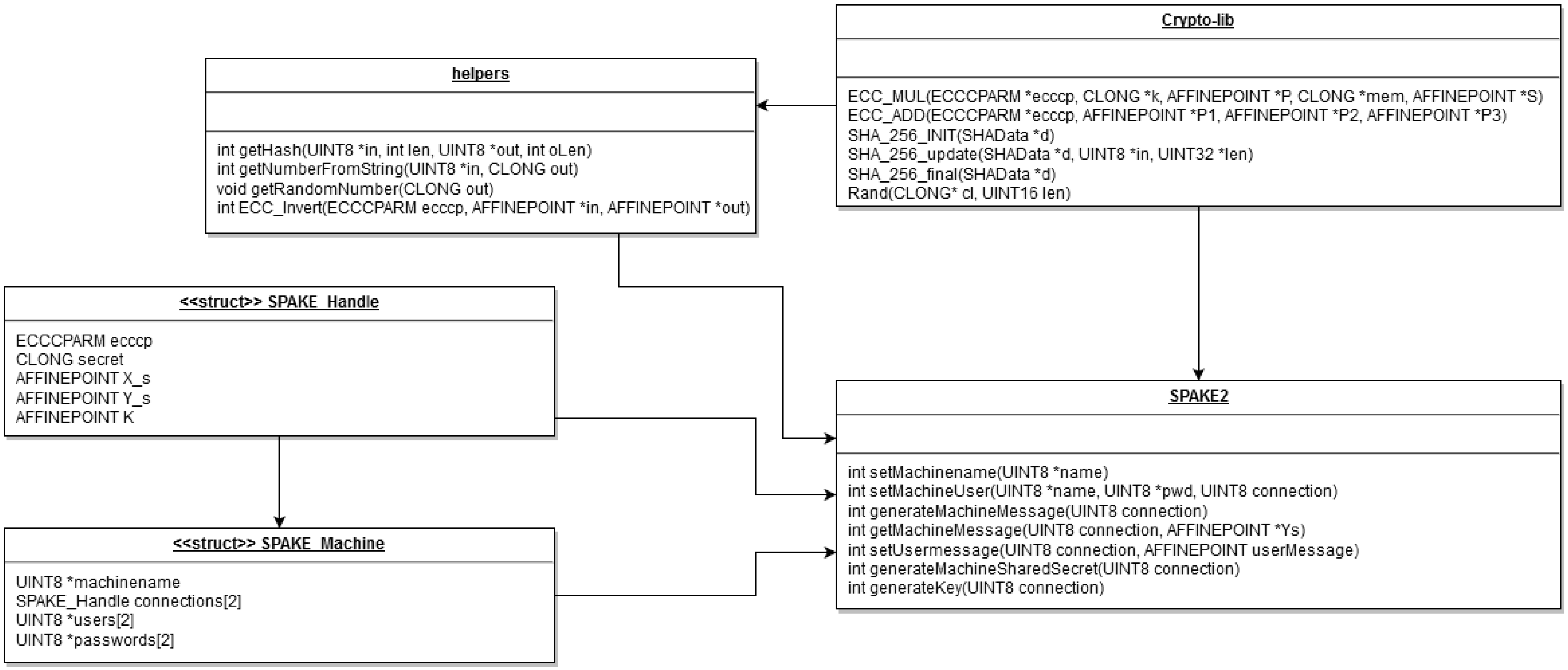
| | |
|---|---|
| $N = H(u_B)G$ | $M = H(u_A)G$ |
| $K_A = x(Y^* + Inv((password)N))$ | $K_B = y(X^* + Inv((password)M))$ |

$$sk_A = H(H(u_A), H(u_B), X^*, Y^*, password, K_A)$$

$$sk_B = H(H(u_A), H(u_B), X^*, Y^*, password, K_B)$$

# Design for the HSM

- Cryptographic primitives performed by Hardware



# Low Memory vs. Low Coputation Time

- Calculate masks when changing credentials
  →only compute once, but use memory to save it

Memory saving Method

| **SPAKE_Credentials** |
| --- |
| UINT8 *machinename<br>UINT8 *username<br>UINT8 *password |

Computation time saving Method

| **SPAKE_Credentials** |
| --- |
| UINT8 H_machinename [32]<br>UINT8 Mx [32]<br>UINT8 My [32]<br>UINT8 Nx [32]<br>UINT8 Ny [32]<br>UINT8 H_password [32]<br>UINT8 H_username [32] |

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# Evaluation

- Current SPAKE implementation of the uWeave project [1] does not allow for testing against it.
  - It uses fixed M and N and does not correctly compute the final key. Additionally only a 224 bit implementation is available.
- →Evaluating performance of SPAKE2 on a HSM

[1] https://github.com/mahmed8003/esp8266-weave-test/blob/master/src/libuweave/src/crypto_spake.c

# Time and Memory Performance

- The communication speed is measured by sending packets with different sized payloads that get returned.
- The different implementations get compared in terms of time and needed cryptographic operations.
- The different implementations get compared in terms of required permanent memory.
- As baseline a password authentication scheme in combination with ECDH is chosen.

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# Results

- The implementation with low computation time is approx. 309 ms faster in normal operation.
- The time savings are generated by performing less operations and performing them early.

| Operation (low-mem) | Mean [$\mu s$] | Sigma [$\mu s$] |
|---|---|---|
| unauthSend(64b) | 8023 | 45 |
| sendKey | 8295 | 61 |
| generatePubKey | 218813 | 205 |
| calculateSharedSecret | 203548 | 142 |
| calculateKey | 42381 | 68 |

| Operation (low-comp) | Mean [$\mu s$] | Sigma [$\mu s$] |
|---|---|---|
| generatePubKey | 74077 | 67 |
| calculateSharedSecret | 67858 | 125 |
| calculateKey | 39554 | 49 |
| initUser | 91002 | 28 |
| initMachine | 12453 + 43542/User | 18 |
| changeMachine | 273919 | 170 |

# Operations

- The Low Computation Time implementation performs 4 of 6 multiplications at initialization and only 1 of 5 Hash computations during the authentication.
- Furthermore, 2 Hash computations are dropped. These are the recomputation of Hashes wehn calculating the inverse mask.

| | SPAKE-low-mem | SPAKE-low-comp |
|---|---|---|
| Crypto-operations ($*; +; H(\ldots); rand()$) | 6; 2; 5; 1 | 2; 2; 1; 1 |
| initialization crypto-operations | 0; 0; 0; 0 | 4; 0; 2; 0 |
| Time authentication [ms] | 426 | 145 |
| Time initialization [ms] | 0 | ~100 |

# Memory

- The Low Memory implementation needs permanent memory for storing the credentials of users (username and password) and HSM (name).
- In the other implementation the credentials are saved hashed and additional 2 EC-Points (masks) have to be saved per user and the name of the HSM is saved hashed.

| | SPAKE-low-mem | SPAKE-low-comp |
|---|---|---|
| Permanent Memory / User | credentials | 2 Hashes + 2 Points |
| Permanent Memory SE | credentials | 1 Hash |

# Comparison

- For comparison, the authentication mechanism of Lee and Hwang [2] in combination with ECDH needs one EC-multiplication less and one Hash and random number more. This is comparable to the Low Memory implementation.

| | ECDH | [2] | SPAKE-low-mem | SPAKE-low-comp |
|---|---|---|---|---|
| Crypto-operations $(*;+;H(\ldots);rand())$ | 2; 0; 1; 1 | 3; 2; 6; 1 | 6; 2; 5; 1 | 2; 2; 1; 1 |
| initialization crypto-operations | 0; 0; 0; 0 | 3; 2; 0; 0 | 0; 0; 0; 0 | 4; 0; 2; 0 |
| Time authentication [ms] | 120 | 279 + ECDH | 426 | 145 |
| Time initialization [ms] | 0 | 203 | 0 | ~100 |
| Permanent Memory / User | 0 | credentials | credentials | 2 Hashes + 2 Points |
| Permanent Memory SE | 0 | credentials | credentials | 1 Hash |

[2] Liao, I. E., Lee, C. C., & Hwang, M. S. (2006). A password authentication scheme over insecure networks. *Journal of Computer and System Sciences*, *72*(4), 727-740.

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# Cunclusion

- The SPAKE2 protocol can be implemented very efficiently to fit on a very restricted device.
- It is advantageous compared to standard solutions that perform key exchange and authentication separately.

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# Future Work

- Restructure the communication between devices to minimize communication overhead.
- Change protocol to enable authentication between machines.

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# Thank you for your attention!