LiKe: Lightweight Certificateless Key Agreement for Secure IoT Communications

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LiKe

LiKe is
a lightweight pairing-free[1] certificateless key agreement protocol

[1]Pairing-based cryptography: pairing between elements of two cryptographic groups to a third group with a mapping $e : G_1 \times G_2 \rightarrow G_T$.

LiKe Protocol Features

- ephemeral cryptographic materials
- support for intermittent connectivity with the Trusted Third Party(TTP)
- lightweight *re-keying* operations
- robustness against impersonation attacks (even when information stored on the TTP are leaked)
- formally secure (via the *ProVerif* tool)
- compatible with real IEEE 802.15.4 devices
- suitable for integration in Zigbee 3.0
- bandwidth and energy efficient

Open Issues

- Certification Management in traditional public key infrastructure (PKI) is inefficient
- Key-escrow problem in Identity Based Encryption

Certificateless Cryptography

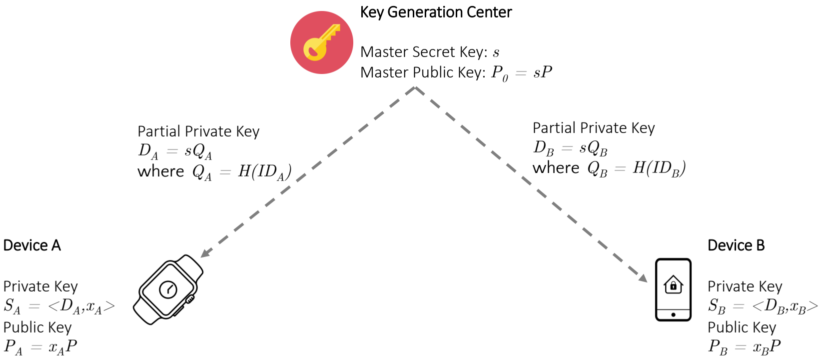


Figure: Certificateless Cryptography - An overview.

Scenario

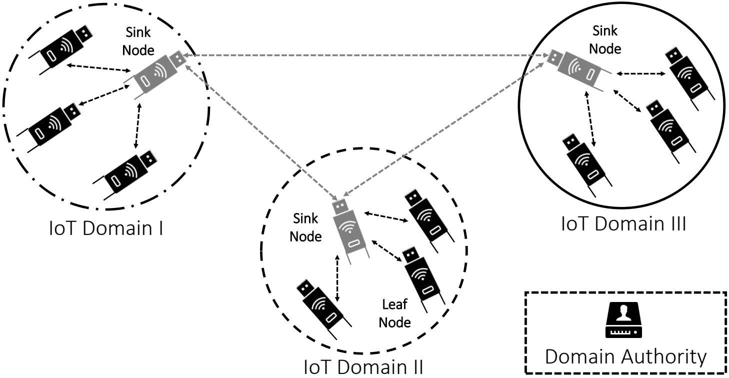


Figure: Reference Scenario: multiple IoT domains, managed by a unique Domain Authority (DA), where each domain is organized in a single sink IoT node and several leaf IoT nodes.

Pre-Deployment Phase

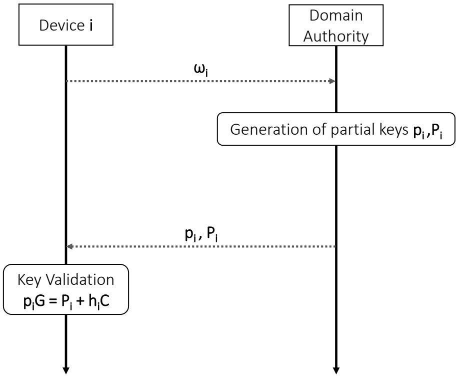


Figure: LiKe: Sequence Diagram of the Setup Phase.

$$\omega_i = (ID_i \parallel t_i \parallel X_i) \qquad P_i = r_i G$$
$$h_i = H(\omega_i \parallel P_i) \qquad p_i = r_i + h_i c \bmod n$$

Key Agreement Protocol

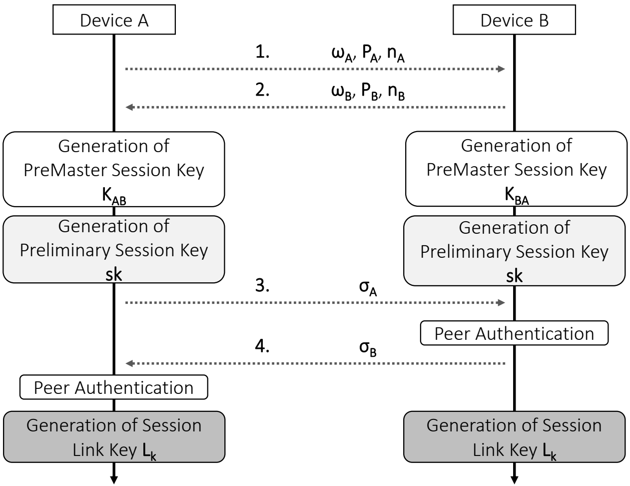


Figure: LiKe: Sequence Diagram of the Key Agreement Phase.

Security Properties

Protection Against Leakage of Secret DA Information

Ephemeral Cryptography Materials

Protection Against Man-in-the-Middle Attacks

Protection Against Replay Attacks

Protection Against Known-Key Attacks

Formal Verification

```
:~$ proverif LiKe_test_1.pv | grep "RESULT" | nl
1  RESULT not attacker(xA[]) is true.
2  RESULT not attacker(xB[]) is true.
3  RESULT not attacker(pA[]) is true.
4  RESULT not attacker(pB[]) is true.
5  RESULT inj-event(end_LiKe_B(x)) ==> inj-event(begin_LiKe_A(u,v_13,y,w,n)) is true.
6  RESULT inj-event(end_LiKe_A(x_14)) ==> inj-event(begin_LiKe_B(u_15,v_16,y_17,w_18,n_19)) is true.
```

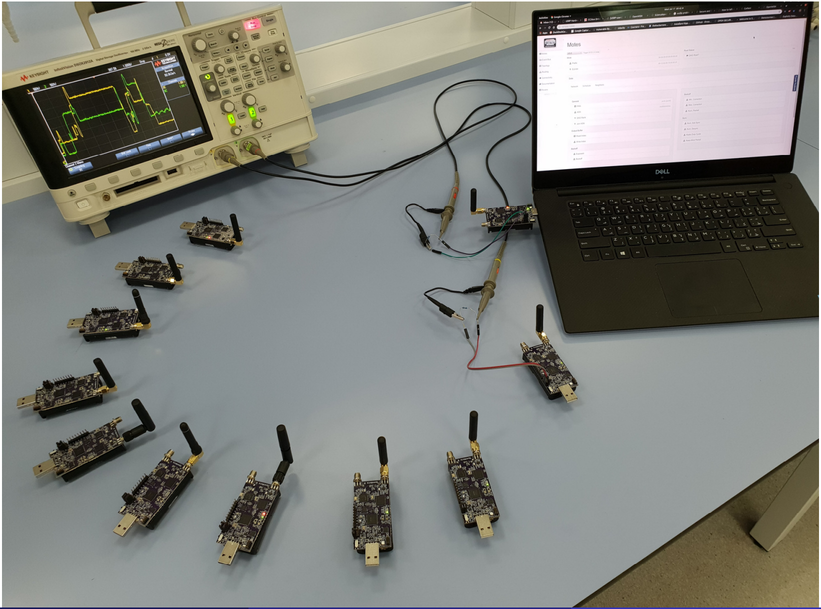
(a) Test 1: Security Verification of LiKe when the private keys of the involved devices are assumed to be secret.

```
:~$ proverif LiKe_test_2.pv | grep "RESULT" | nl
1  RESULT not attacker(xA[]) is true.
2  RESULT not attacker(xB[]) is true.
3  RESULT not attacker(pA[]) is false.
4  RESULT not attacker(pB[]) is false.
5  RESULT inj-event(end_LiKe_B(x)) ==> inj-event(begin_LiKe_A(u,v_13,y,w,n)) is true.
6  RESULT inj-event(end_LiKe_A(x_14)) ==> inj-event(begin_LiKe_B(u_15,v_16,y_17,w_18,n_19)) is true.
```

(b) Test 2: Security Verification of LiKe when the partial private keys of the involved devices maintained by the DA are assumed to be leaked to the adversary.

Figure: Output provided by *ProVerif*.

Experimental Testbed



Temporal Results

- LiKe Protocol Duration: 340.478ms
- Preliminary Session Key Generation: 243.392ms
- Mutual Authentication and Session Key Generation: 97.086ms

[Comparison] - MAC-Layer Exchanged Messages

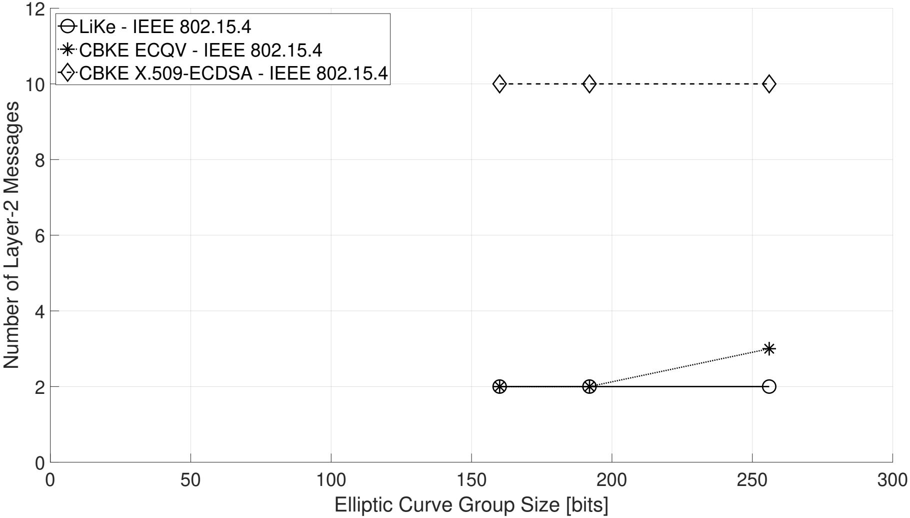


Figure: MAC-layer messages required to complete the key agreement, considering X.509-ECDSA, ECQV, and LiKe.

[Comparison] - Other Approaches

Feature	**X.509-ECDSA**	**ECQV**	**LiKe**
Robustness to Man-In-The-Middle	✓	✓	✓
No. of messages to detect an attack	9	2	2
Message Overhead per Key Agreement Instance	10	3	2
Energy Consumption per Key Agreement Instance (mJ)	$38,953$	$36,080$	$35,726$
Robustness to DA Secret Information Disclosure	✗	✗	✓

Figure: Comparison of LiKe against CBKE Approaches based on X.509-ECDSA and ECQV, assuming a 256-bit Elliptic Curve.

Energy Consumption

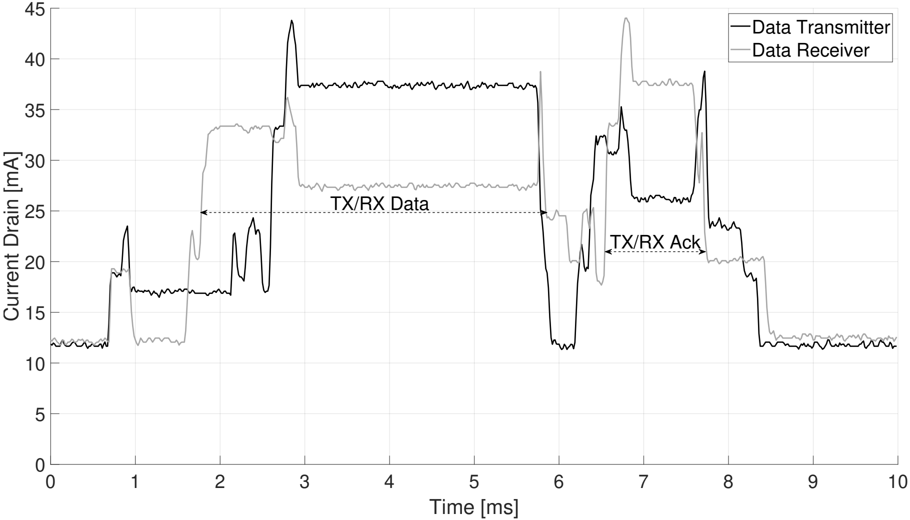


Figure: Current Consumption of a Data Transmission and a Data Reception Operation within the duration of a IEEE 802.15.4 time-slot (10 ms).

Related Work

Feature	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	LiKe
Pairing-free	✗	✗	✓	✗	✓	✓	✗	✓	✓
Non-persistent Connection with Domain Authority	✗	✗	✓	✗	✗	✓	✓	✓	✓
Ephemeral Cryptograhy Material	✗	✗	✓	✗	✓	✓	✗	✗	✓
Integration in a Real IoT Enabling Technology	✗	✗	✗	✗	✗	✓	✗	✗	✓
Implementation on Real IoT Devices	✗	✗	✗	✗	✗	✓	✗	✗	✓
Real Performance Evaluation	✗	✗	✗	✗	✗	✓	✗	✗	✓
Energy Friendly Approach	-	-	-	-	-	✗	-	-	✓
Suitability for Autonomous IoT Domains	✗	✗	✗	✗	✗	✗	✗	✗	✓
Lightweight Re-Keying	✗	✗	✗	✗	✗	✗	✗	✗	✓
Open-Source Code	✗	✗	✗	✗	✗	✗	✗	✗	✓

Figure: Comparison of LiKe against state-of-the-art approaches using **CL-PKC** techniques. A ✓ symbol indicates the fulfillment of a particular feature, a ✗ symbol denotes the miss of the feature, while the symbol – indicates that the feature is not applicable.

Questions?

Any Questions?
Thank you!