KEMEDHOC*: A formally verified implementation of quantum-resistant EDHOC key exchange protocol

(Work in progress)

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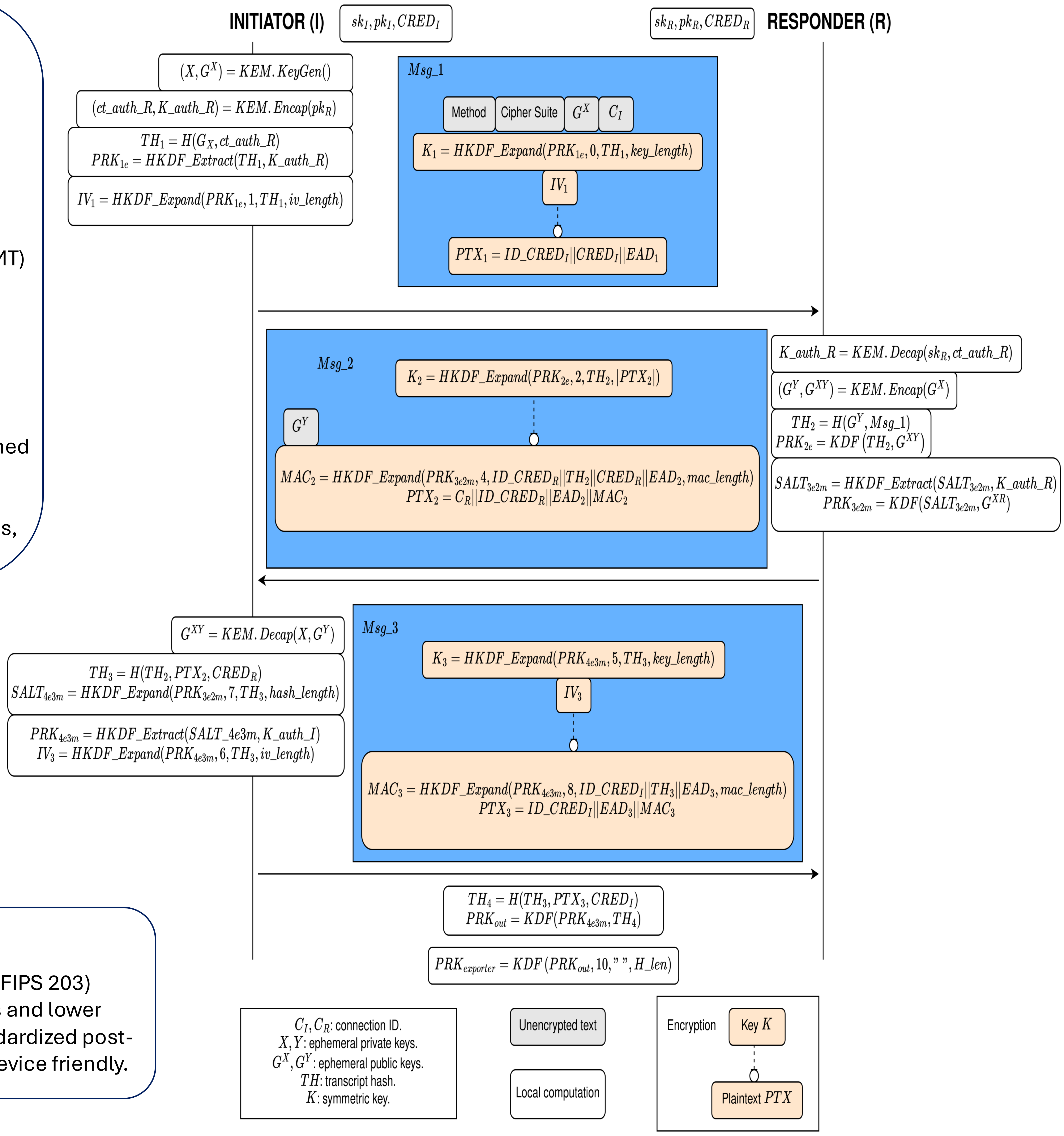
Background:

- Ephemeral Diffie-Hellman Over COSE (**EDHOC**) [RFC 9528] is a lightweight authenticated key exchange.
- **EDHOC** demonstrates low overhead, especially in message size, in resource-constrained settings compared to other lightweight competitors, such as DTLS.
- **Z3** is a Satisfiability Modulo Theories (SMT) solver that automatically check logical formulas for satisfiability under various theories. Z3 is used to discharge proof obligations encoded by F*,
- **F*** is a proof-oriented language with rich type annotations that encode logical properties. **Low*** is a subset of F* designed for low-level code.
- **ProVerif** is an automated tool, based on Dolev-Yao model and applied pi-calculus, for protocol formal verification.

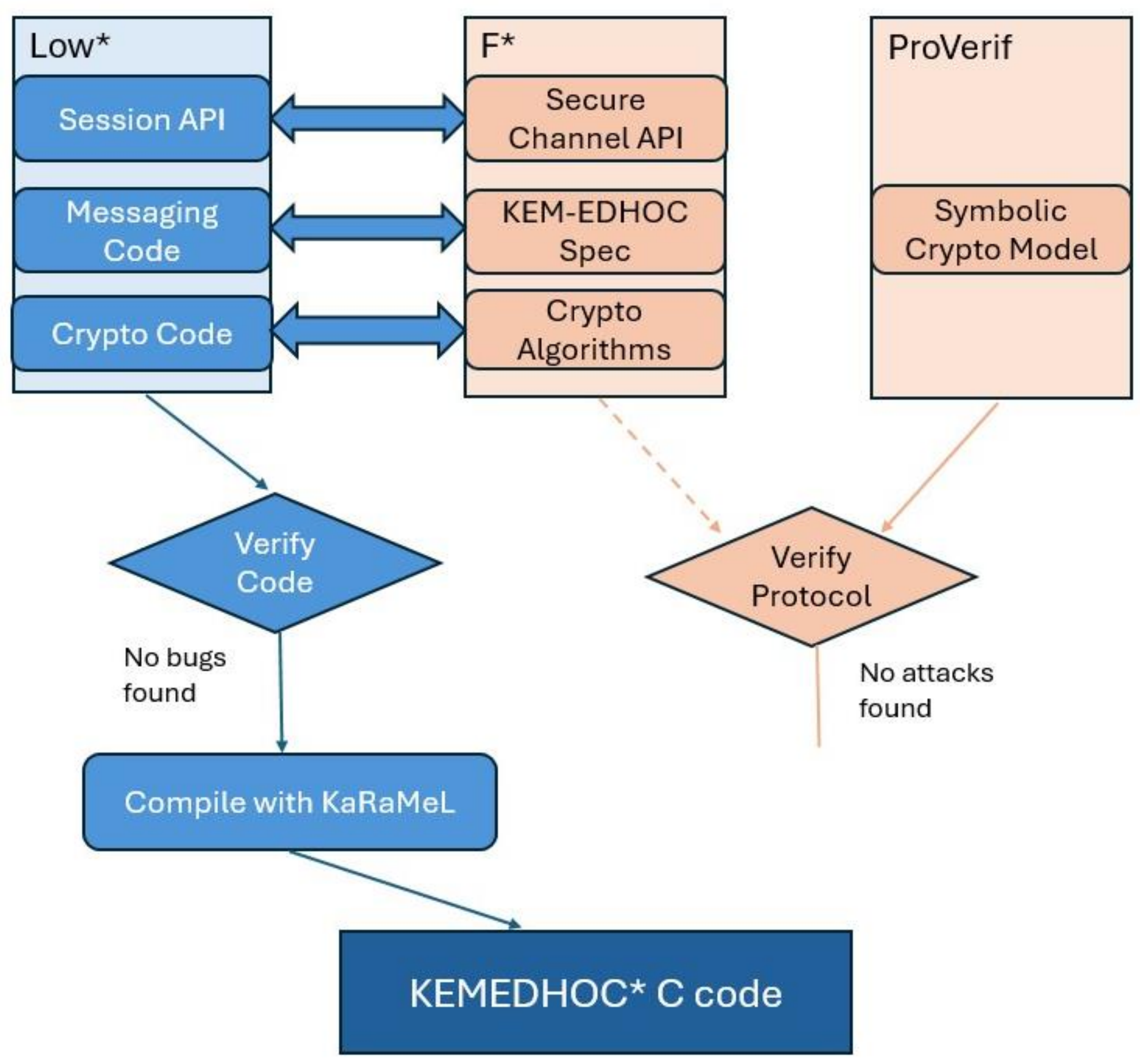


Problems:

- The standardized EDHOC protocol [RFC 9528] is **not quantum-safe**.
- Reference implementations of EDHOC are not formally verified (existing security analysis works only verify at the design level) -> **lack of end-to-end verification.**

Why ML-KEM is selected?

- ML-KEM is officially standardized by NIST (FIPS 203)
- ML-KEM introduces reasonable overheads and lower memory footprint compared to other standardized post-quantum schemes -> more constrained-device friendly.



Security Goals

Design level:

- Confidentiality
- Mutual key authentication
- Session key uniqueness
- Identity protection
- Downgrade protection
- *Quantum-proof*

Implementation level:

- Functional correctness
- Memory safety
- Side-channel resistance
- API-misuse resilience

Future work:

- Double-test with static analysis tools.
- Do benchmarking and compare to unverified implementations, e.g. uEDHOC.

Approach

Design level:

- Design a new KEM-based, signature-free authentication method which uses static and ephemeral KEM keys for authentication and shared key derivation respectively.
- Formally verify the symbolic model of new design using ProVerif.

Implementation level:

- Write and formally verify the high-level computational model (F*) of KEMEDHOC.
- Write the machine-level model (Low*) that correctly links to the F* model, guarantees memory safety and resistance to classes of side-channel attacks.
- Extract to C code using KaRaMel.

Helsinki System Security Lab (HSSL)

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