Challenges in the Formal Verification of Attested TLS

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[4]Linaro, Lausanne, Switzerland

May 16, 2024

Agenda

Don't be scared of maths![1]

- Writing is nature's way of letting you know how sloppy your thinking is. (Guindon)

[1] https://www.microsoft.com/en-us/research/publication/2018/05/book-02-08-08.pdf

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- Formal mathematics is nature's way of letting you know how sloppy your mathematics is. (Leslie Lamport)

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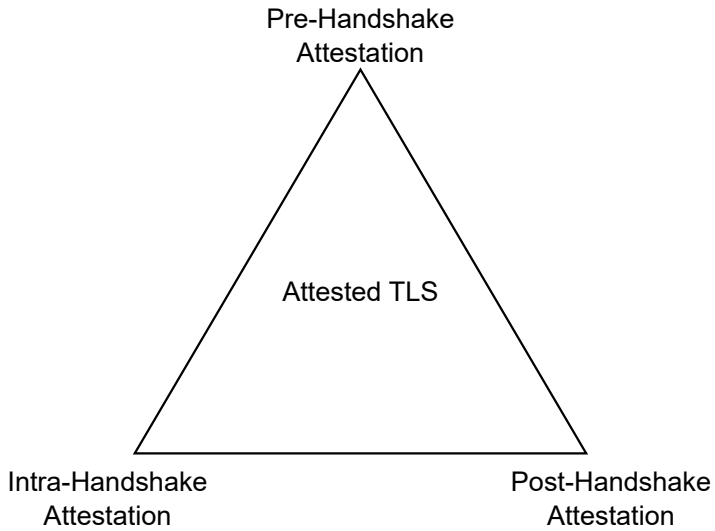
Outline

Attested TLS



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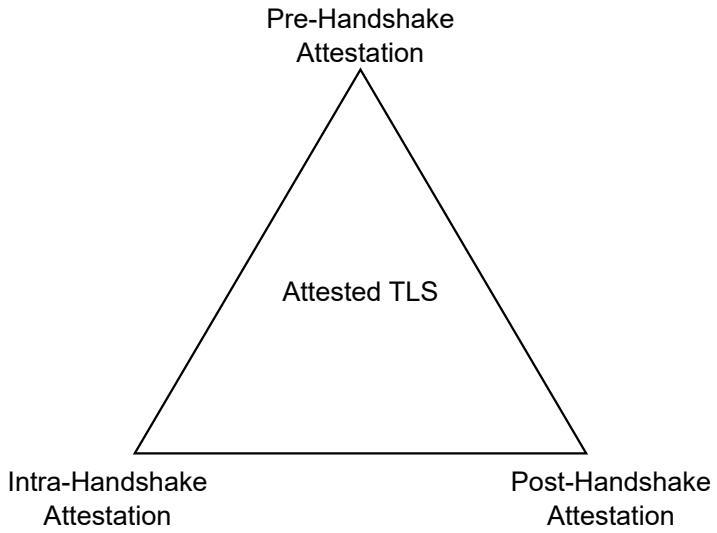

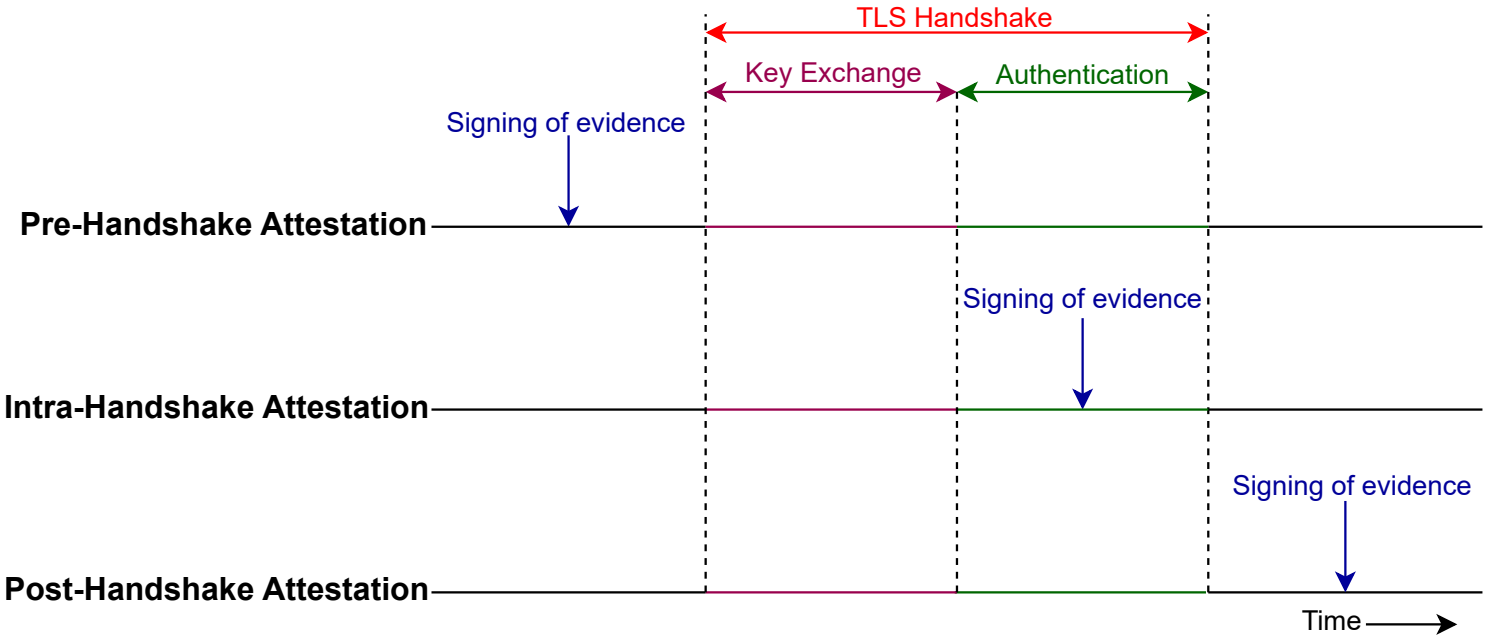

Intel's RA-TLS[2]

- Widely used pre-HS attestation protocol, e.g., in

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Goal

- Formally analyze the security of Intel's RA-TLS

Contributions

- First formal analysis of attested TLS for TEEs (happy to discuss in Hackathon)

[3] https://github.com/Inria-Prosecco/reftls

Contributions

- First formal analysis of attested TLS for TEEs (happy to discuss in Hackathon)
- Validation of formal model[3] of TLS 1.3 Key Schedule, revealing 3 major issues

[3] `https://github.com/Inria-Prosecco/reftls`

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Analysis Approach and Tool

- Approach: Symbolic[4]

[4] Barbosa, Barthe, Karthik Bhargavan, Blanchet, Cremers, Liao, and Parno, "SoK : Computer-Aided Cryptography", 2021.

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Analysis Approach and Tool

- Approach: Symbolic[4]
- Tool used: ProVerif[5]

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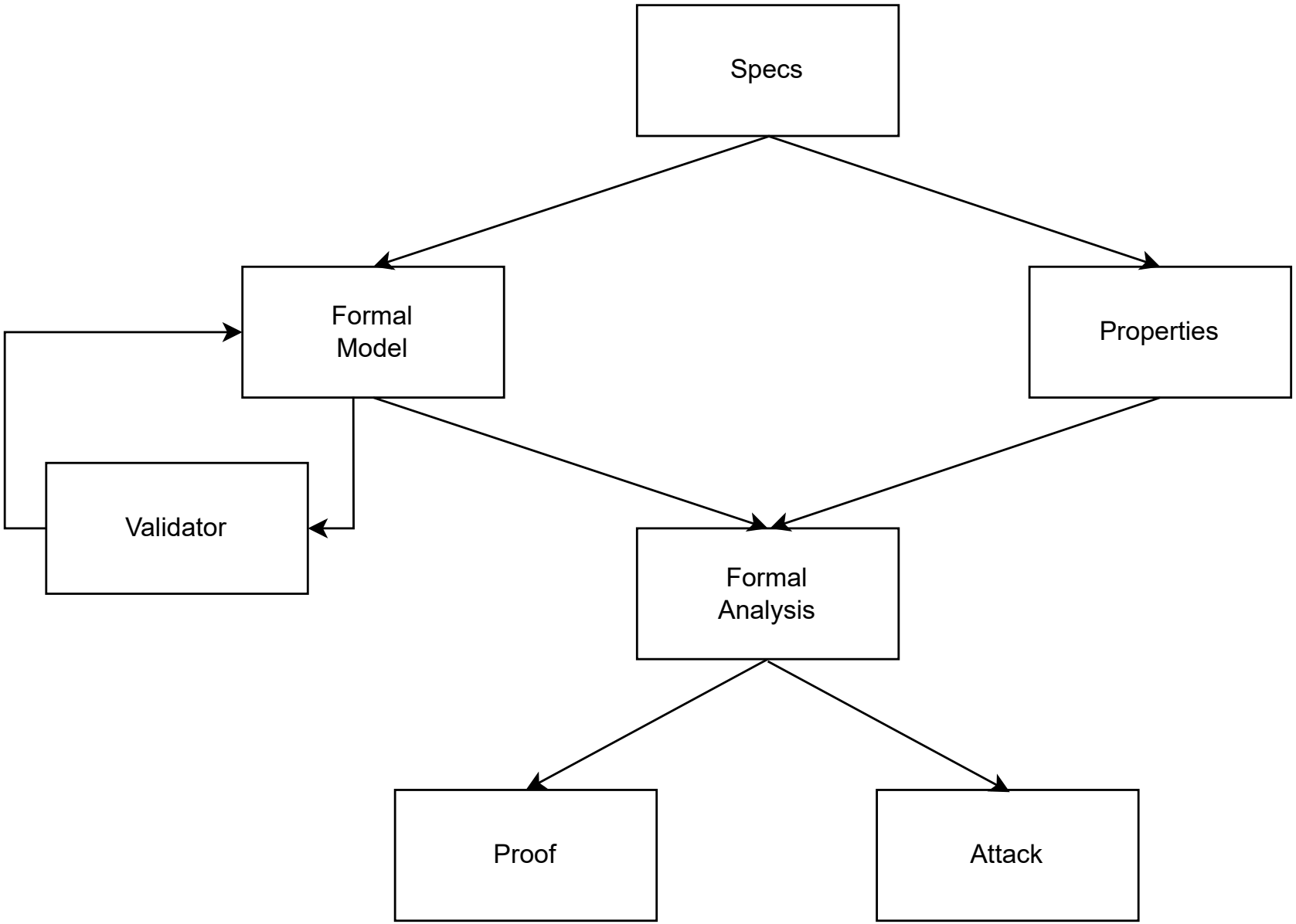
Approach - Simplified



Challenge in Specification of Intel's RA-TLS[6]

- Incomplete and outdated specs for RA-TLS
  - Specs based on TLS 1.2 (TLS 1.3 is RFC since Aug 2018)
  - Fix: Used implementation and community input for formal model

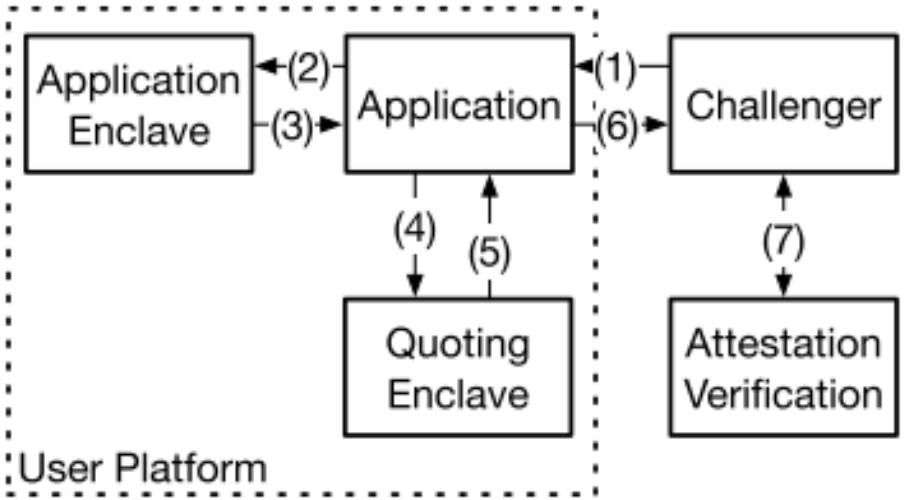


Figure 1: Remote Attestation Example. The challenger is off-platform with respect to the attester.

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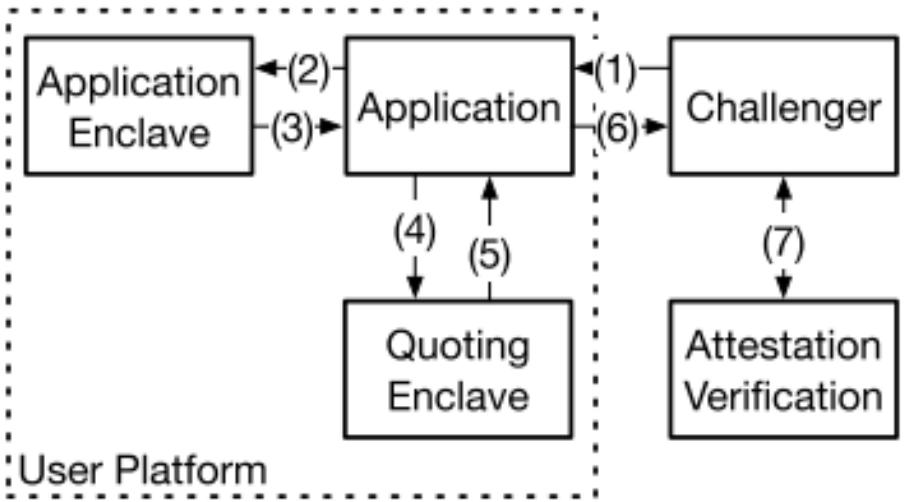

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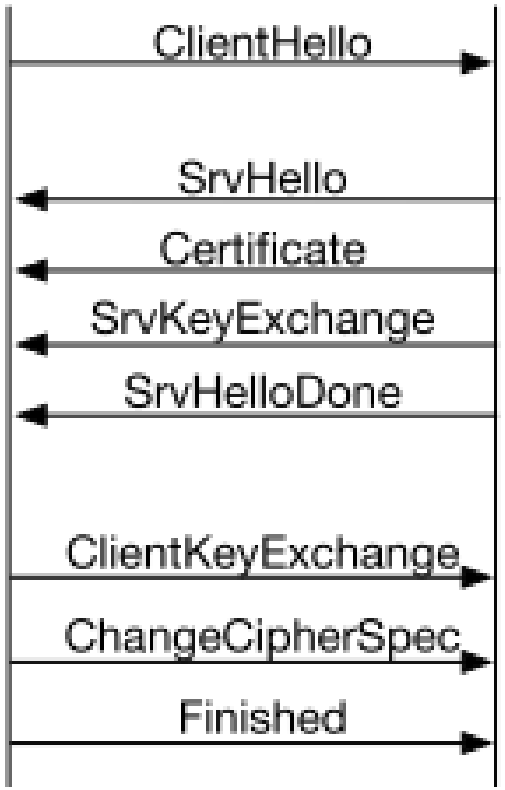

Figure 2: TLS 1.2 Handshake Messages.

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Challenges from Formal Perspective

- Very few comments in Inria's TLS formal model[7]

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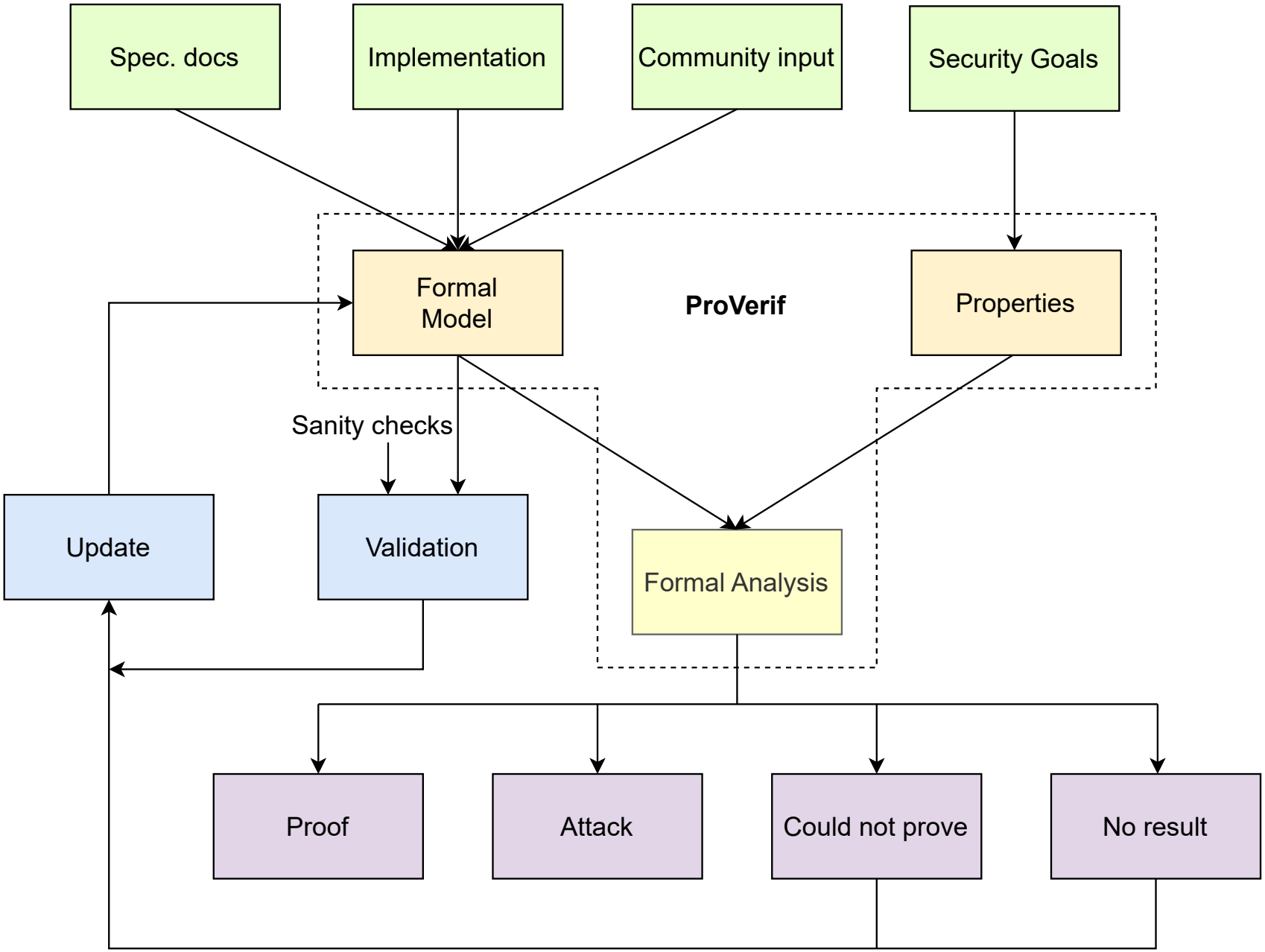
Approach

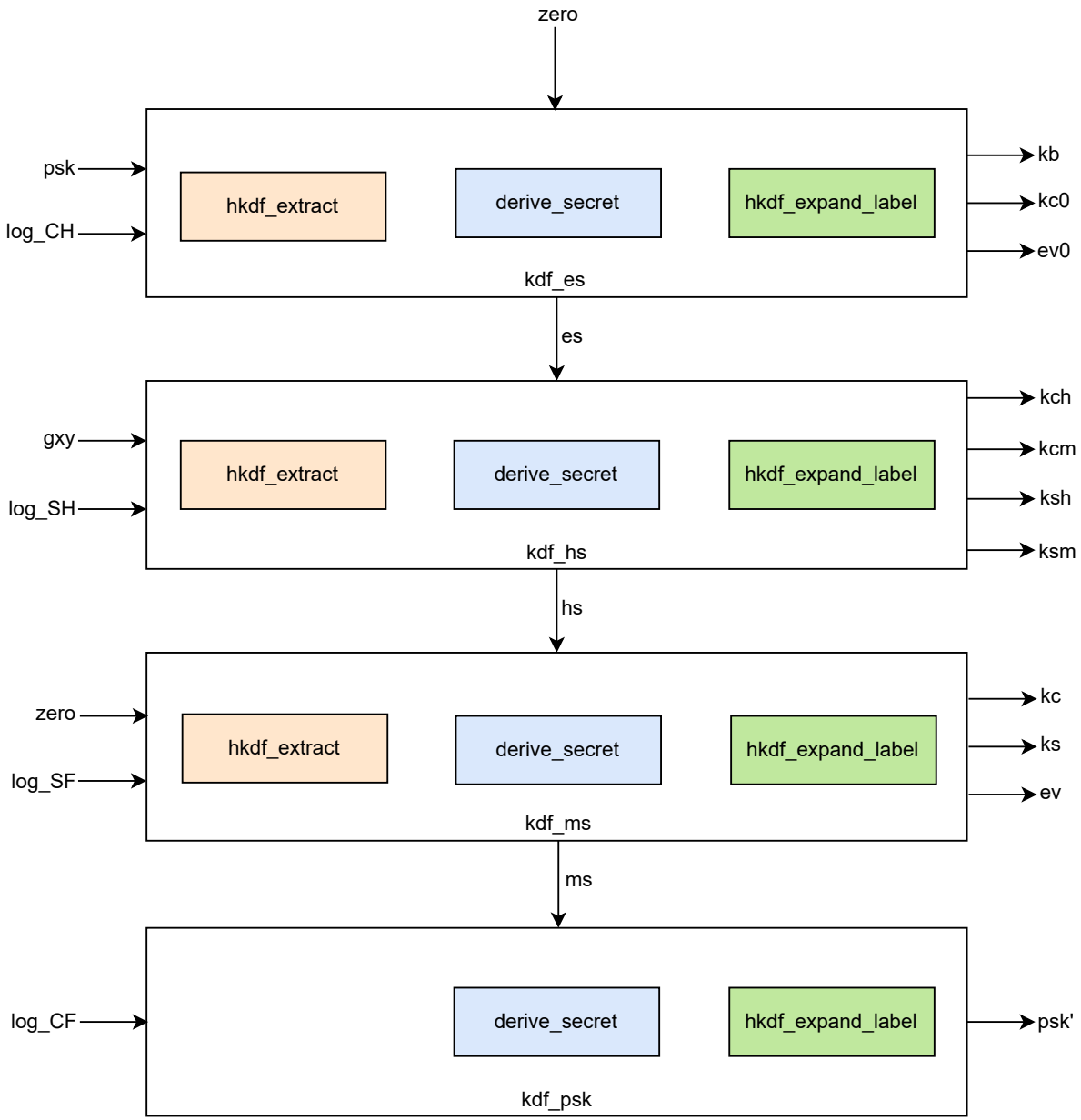

Spec. docs
Implementation
Community input
Security Goals
Formal Model
ProVerif
Properties
Sanity checks
Update
Validation
Formal Analysis
Proof
Attack
Could not prove
No result

Outline

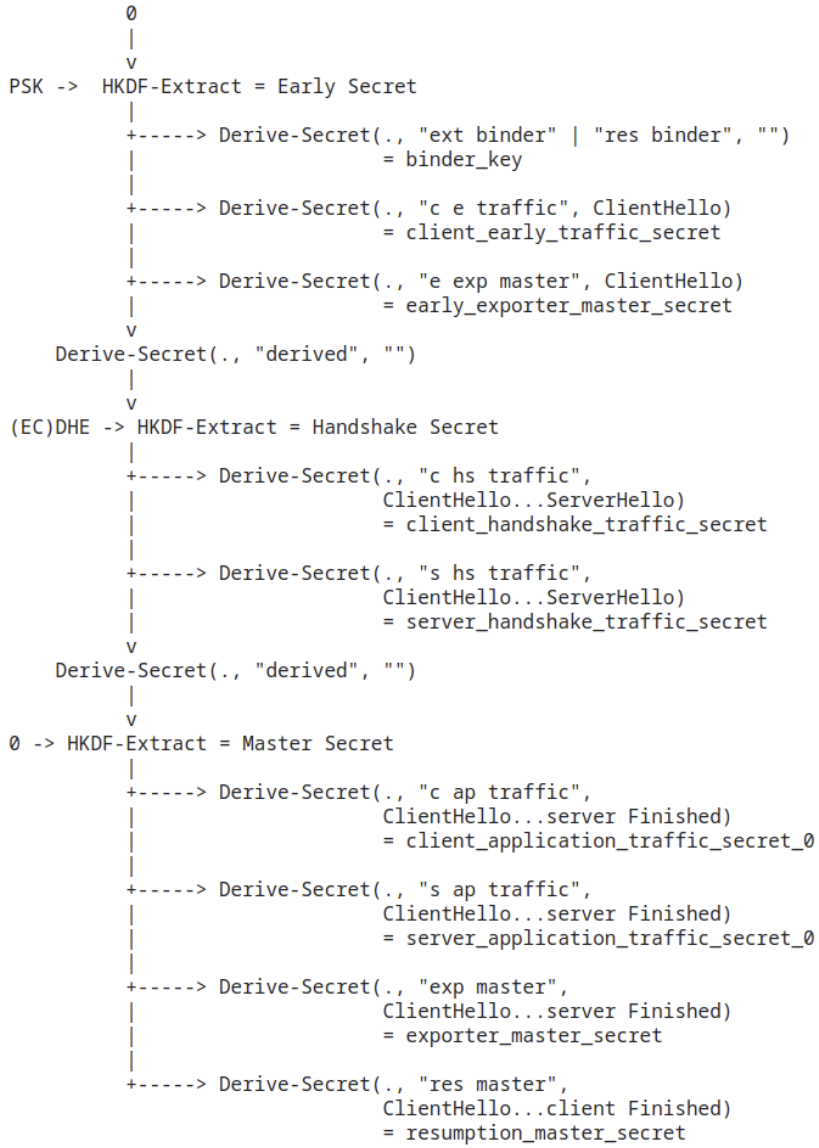
Agenda

5. Validation of TLS 1.3 (Quick overview)
   - Key Schedule
   - Validation of Key Schedule

Key Schedule - Overview

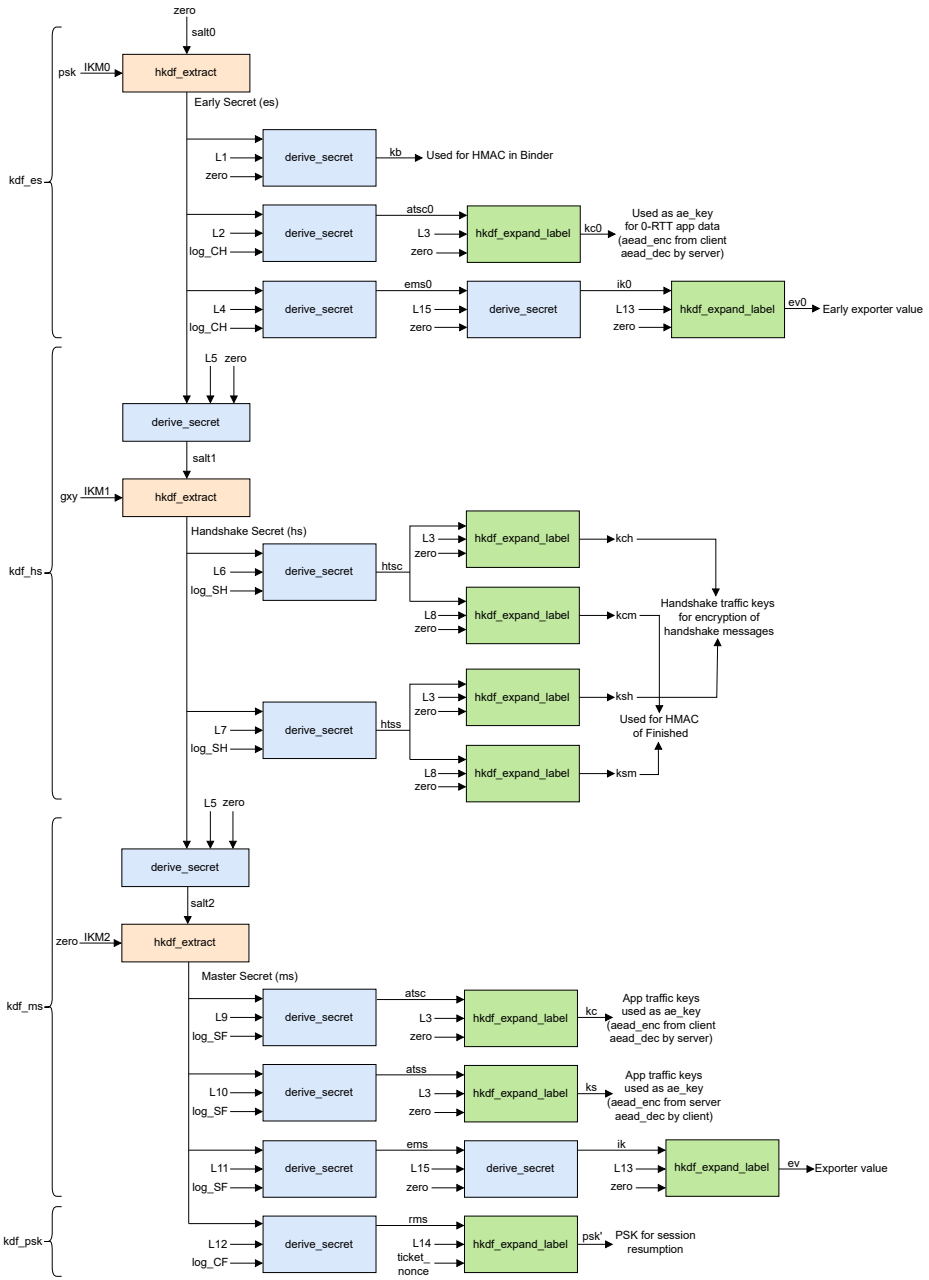


Key Schedule[9]



[9] https://datatracker.ietf.org/doc/html/rfc8446#section-7.1

Key Schedule with 2nd Stage



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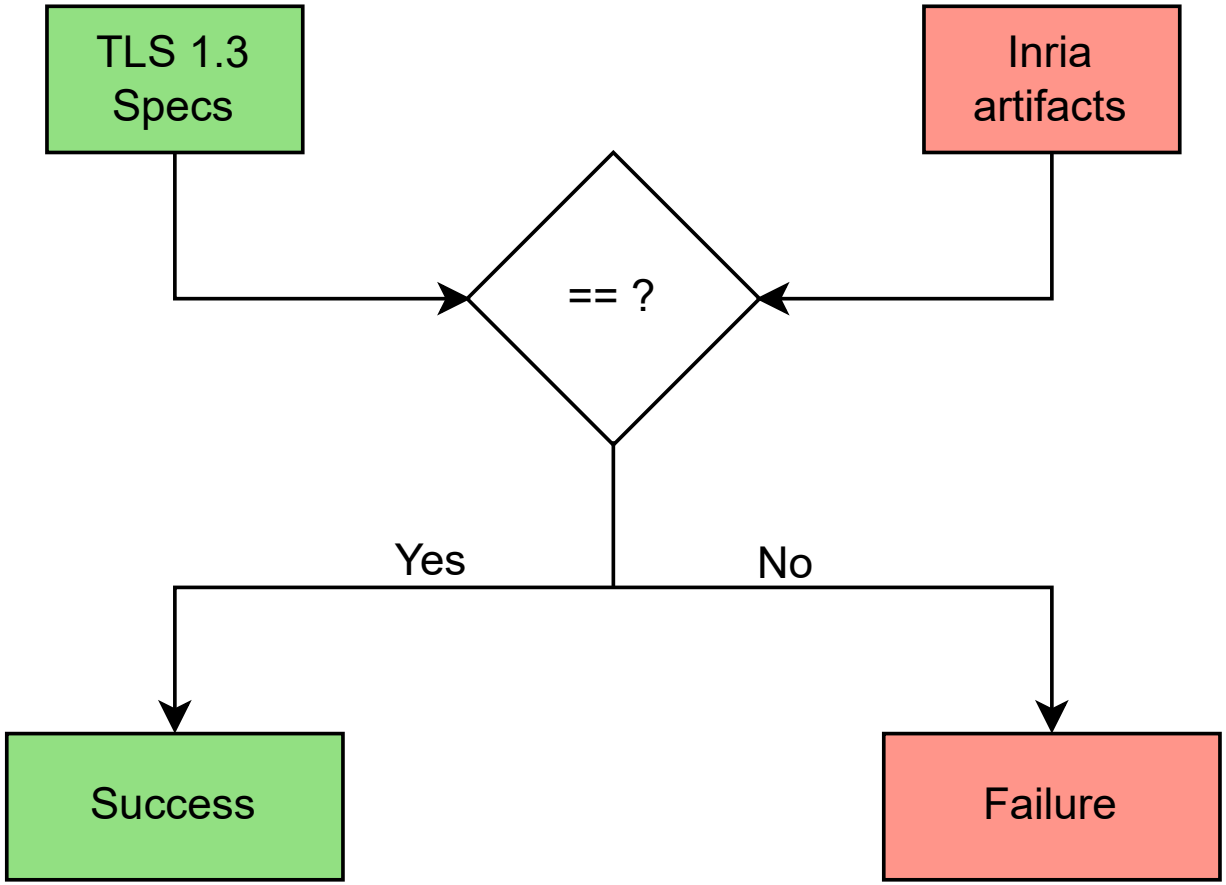
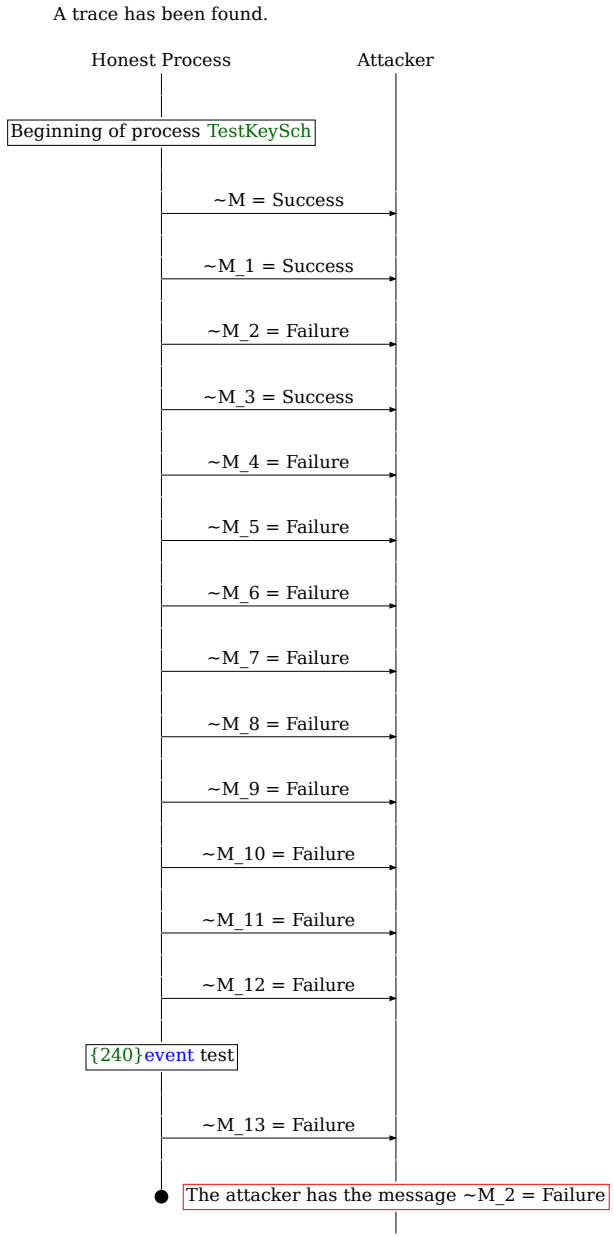
Validation Framework



Validation Result



Example Issue: Master Secret[10]

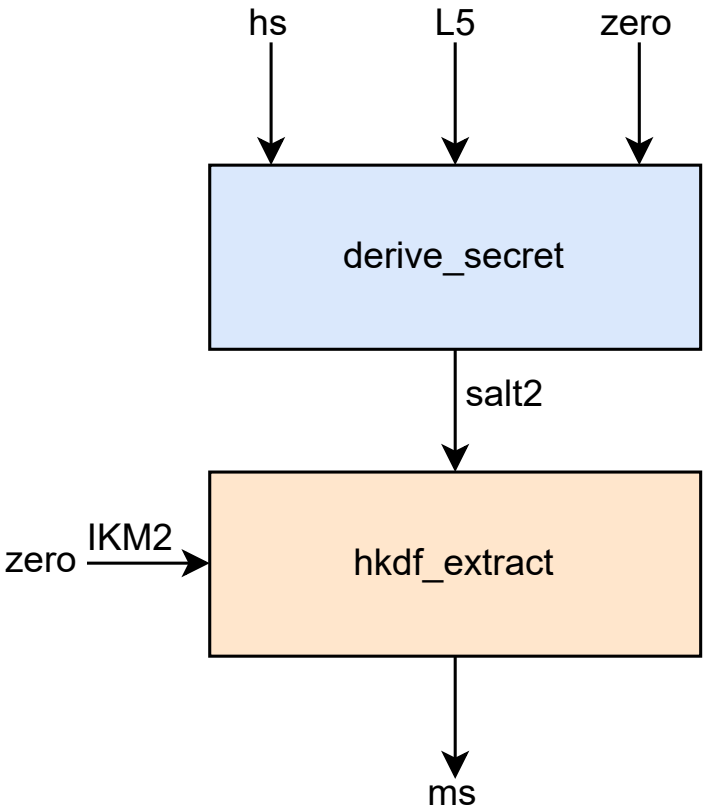


Figure: TLS 1.3 Specs

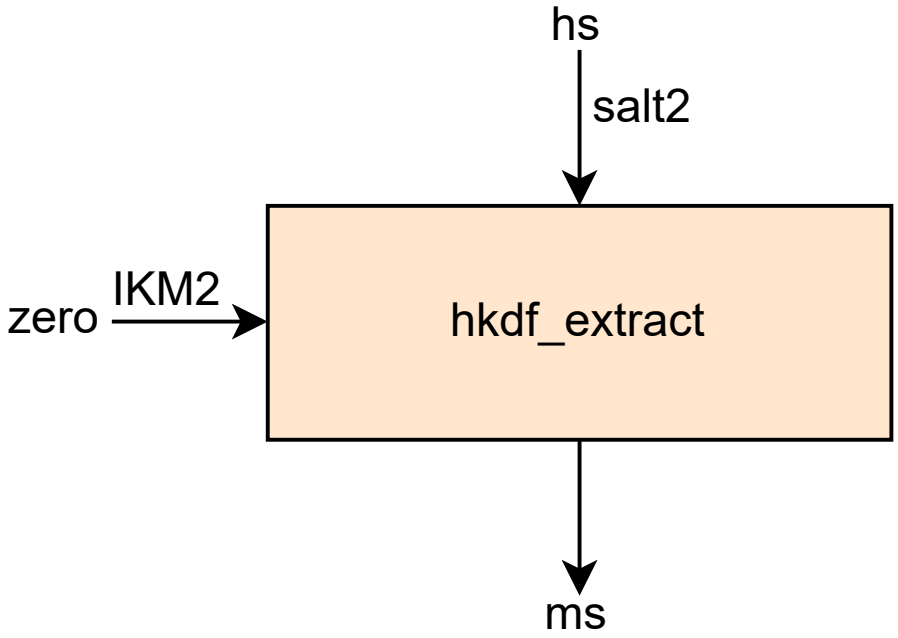


Figure: Inria artifacts

[10] https://github.com/Inria-Prosecco/reftls/issues/6

Ruling out Abstractions

- Ubuntu 20.04 LTS on an Intel Core i7-11800H processor with 64 GB of RAM

Code	**ProVerif 2.04**	**ProVerif 2.05**
Original	6 min 06.634 s	6 min 02.256 s
With issue 1 fixed	5 min 51.682 s	6 min 03.335 s
With issue 2 fixed	7 min 04.472 s	6 min 14.954 s
With issue 3 fixed	7 min 11.434 s	6 min 41.872 s
With all 3 issues fixed	6 min 40.010 s	6 min 31.887 s

A "Tale" of Community input

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[13] `https://mailarchive.ietf.org/arch/msg/tls/ZGmyHwTYh2iPwPrirj_rkSTYhDo/`

[14] `https://github.com/CCC-Attestation/meetings/blob/main/materials/MuhammadUsamaSardar_Formal_RA-TLS.pdf`

[15] `https://wiki.ietf.org/meeting/119/hackathon`

[16] `https://datatracker.ietf.org/meeting/119/materials/slides-119-cfrg-formal-analysis-of-ra-tls-00`

A "Tale" of Community input

- Paper authors[11]
  - Bruno Blanchet
  - Karthikeyan Bhargavan
  - Nadim Kobeissi
- LURK authors[12]
- IETF TLS WG[13]
- IRTF UFMRG chairs
- CCC attestation SIG[14]
- ...
- IETF 119 Hackathon[15]
- IRTF Crypto Forum RG @ IETF 119[16]
- Tool session @ GT MFS'24

[11] Karthikeyan Bhargavan, Blanchet, and Kobeissi, "Verified Models and Reference Implementations for the TLS 1.3 Standard Candidate", 2017.

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Summary

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  - Security of IETF draft[17]

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Key References

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ACK

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