Automated Analysis of TLS 1.3
0-RTT, Resumption and Delayed Authentication

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What’s new in TLS 1.3?

- 0-RTT handshake mode.
- Session resumption merged with PSK mode.
- Delayed client authentication mechanism.
- The full interaction of all the above components, as well as the regular modes.
Objectives

Our goal

Improve the security of TLS 1.3 by analysing the specification using state-of-the-art formal analysis methods.

Challenges:

- Complex protocol.
- Rapidly changing specification.

What class of attacks can we rule out?
We built our model for use in the Tamarin prover.

- Automated tool for protocol analysis.
- Supports loops and branches.
- Good symbolic Diffie-Hellman support.
- Considers an unbounded number of parties/handshakes.

How does it work?

- For simple models/properties, can prove automatically.
- Complex models require more user interaction.
- A proof shows that a property holds in all possible combinations of client, server, and adversary behaviours.
Automated Analysis of TLS 1.3
Building a model

ClientHello

Receive ServerHello/Finished + Send ClientFinished

Client authentication

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Verification

We verified the core properties of TLS 1.3 revision 10 as an authenticated key exchange protocol:

- Secrecy of session keys.
  - Holds for both client and server.
  - Forward secrecy.
- Mutual authentication.
Attacking client authentication

ClientHello

Receive ServerHello/Finished + Send ClientFinished

Client authentication

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Attacking client authentication

Alice (Client)
Connect to evil.com
Establish PSK
PSK₁ ≠ PSK₂

Charlie (evil.com)
Connect to mybank.com
Establish PSK

Bob (mybank.com)
Attacking client authentication

Alice (Client)  

PSK₁

client_random = nc
server_random = ns

Charlie (evil.com)

PSK₁  PSK₂

client_random = nc
server_random = ns

Bob (mybank.com)

PSK₂

session_hash = H(nc ns ...)  session_hash = H(nc ns ...)

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Attacking client authentication

Alice (Client)

Request authentication

Client authentication

sign_{sk_A}(session_hash, cert_A, ...)

Bob (mybank.com)

Request authentication

Client authentication

sign_{sk_A}(session_hash, cert_A, ...)

session_hash = H(nc ns ...)

session_hash = H(nc ns ...)
Attacking client authentication

Alice (Client)

Charlie (evil.com)

Give Charlie all my money!

Sure thing, Alice.

Bob (mybank.com)
Conclusions

- This story has a happy ending: revision 10 was proved secure, and the changes in revision 11 appear to address the attack.

- First comprehensive analysis of the new TLS 1.3 modes and their interaction.
  - We confirmed the base design is solid.
  - Prevented a potential weakness.

- Our state machines and models provide insight into the structure of TLS implementations.

- Future work: improve and build upon this model.

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