Automated Analysis of TLS 1.3

0-RTT, Resumption and Delayed Authentication

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mozilla

New features of TLS 1.3

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?

Tamarin

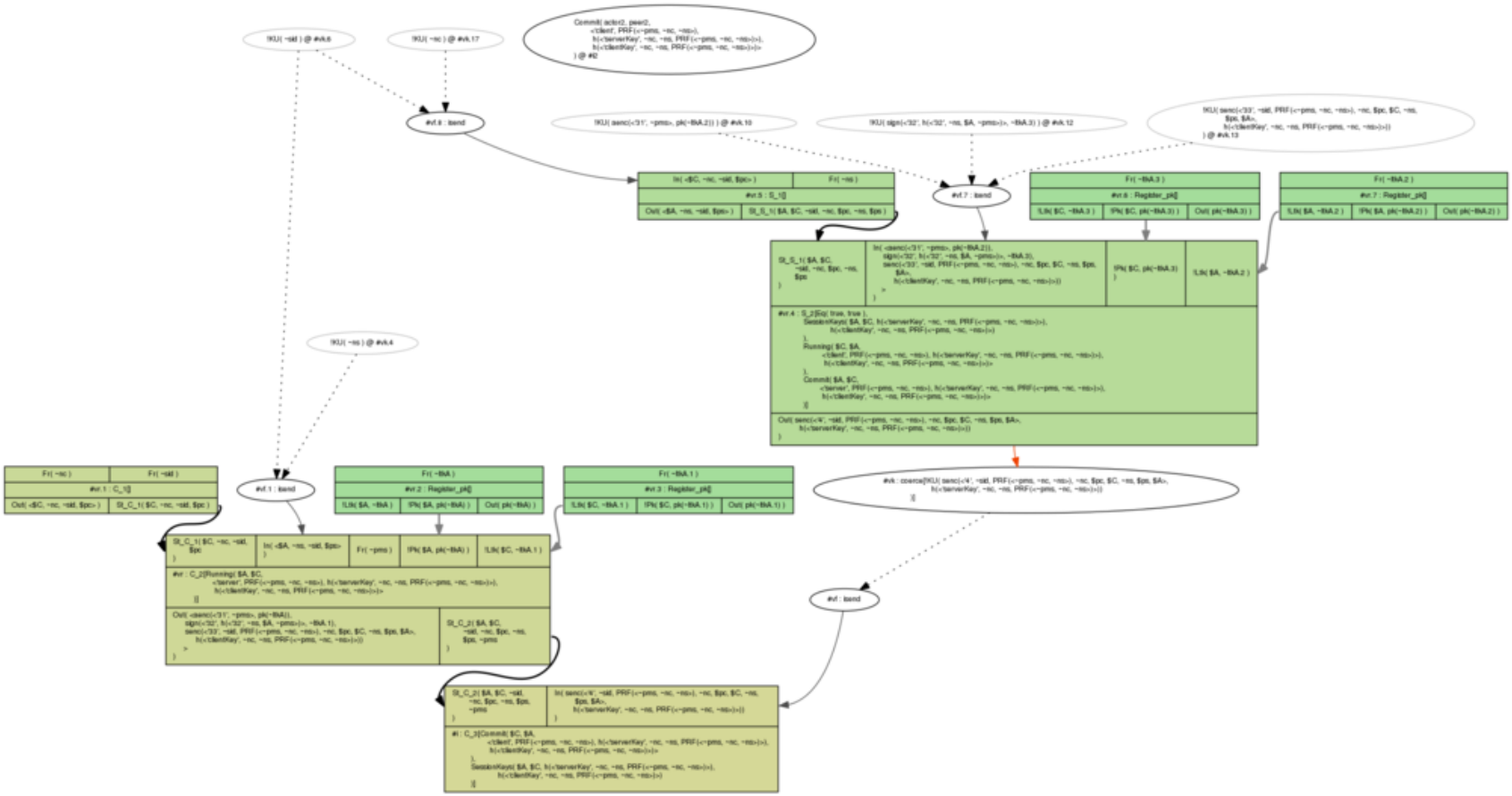
We built our model for use in the Tamarin prover.

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

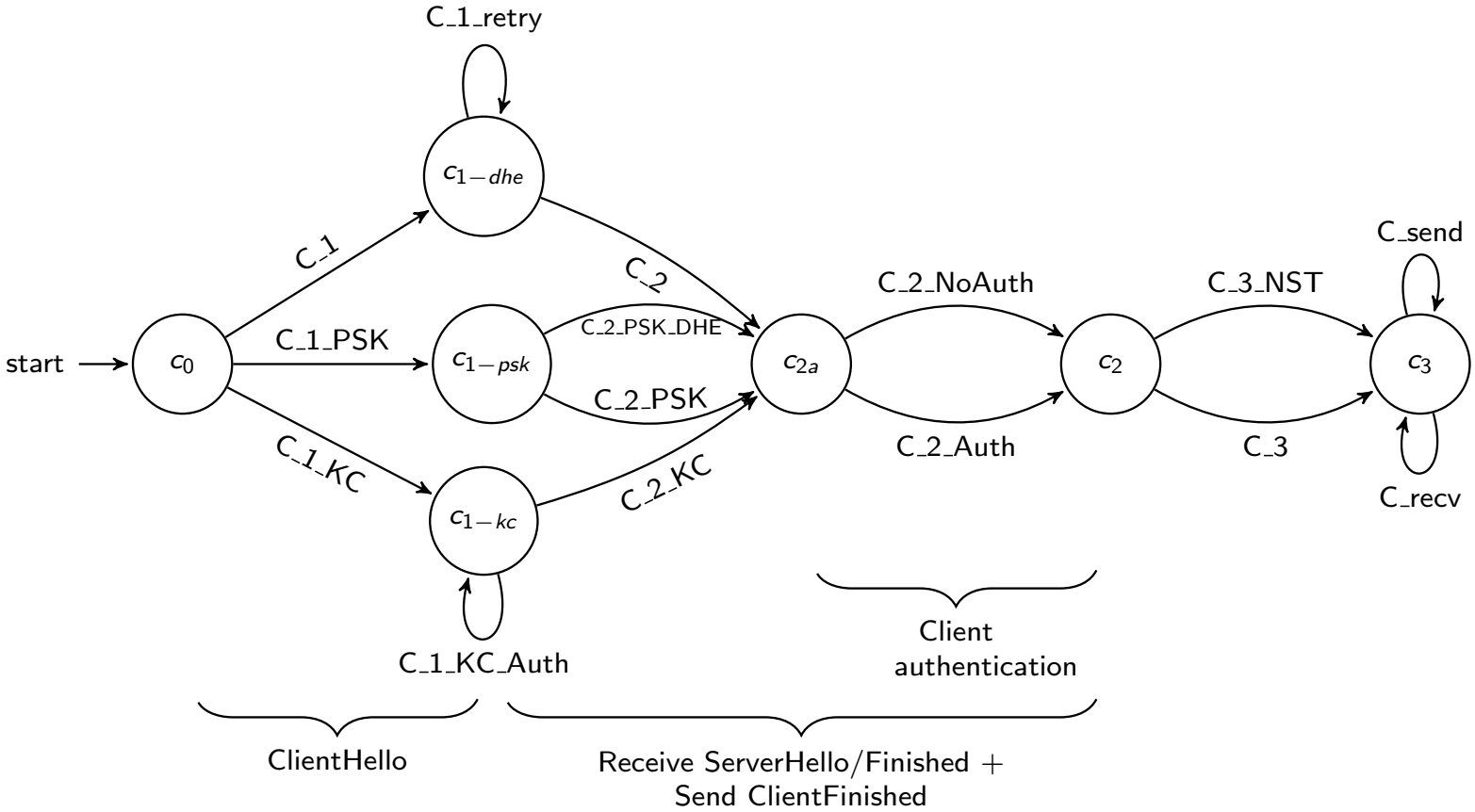
How does it work?

- 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.

Tamarin



Building a model



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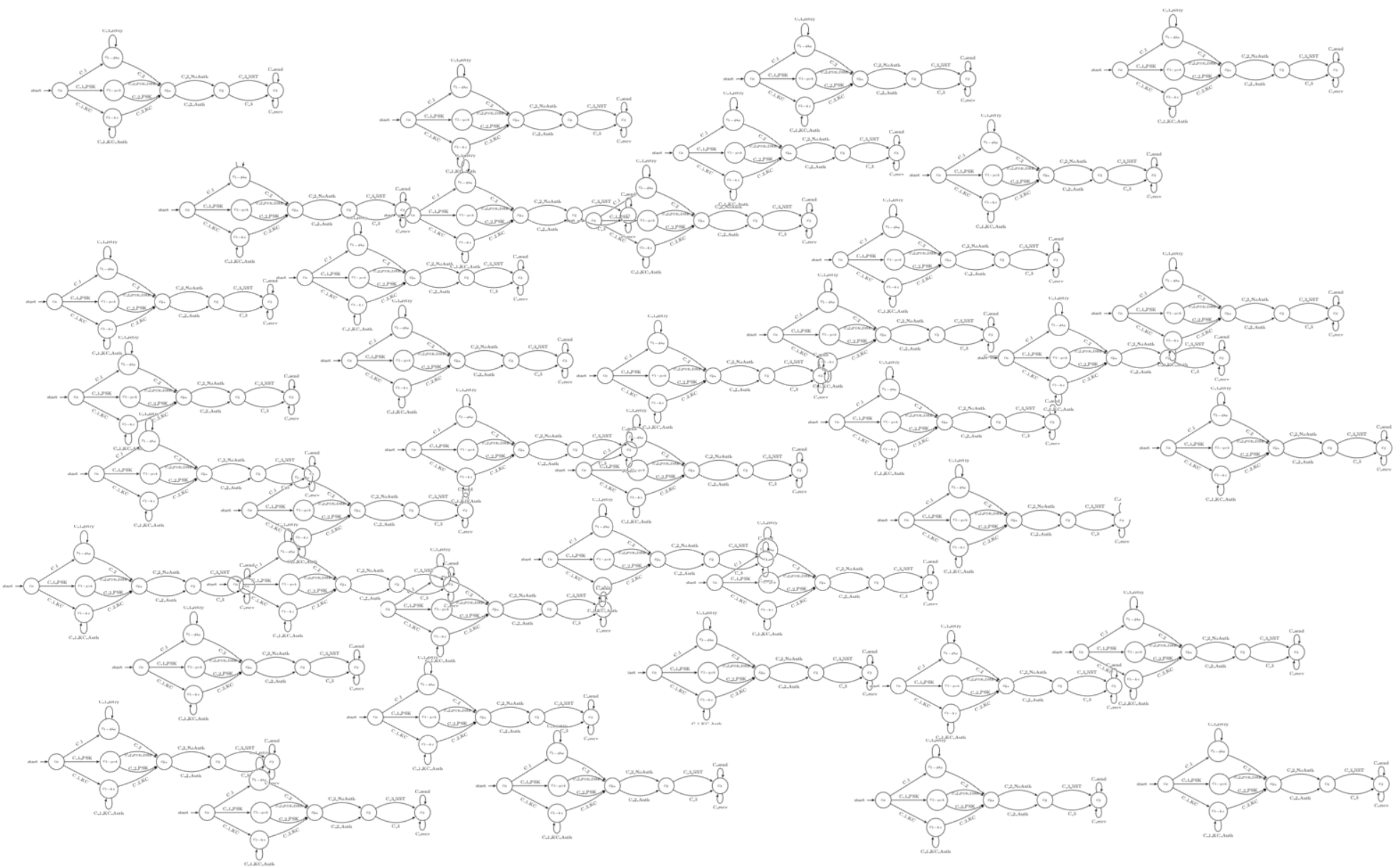
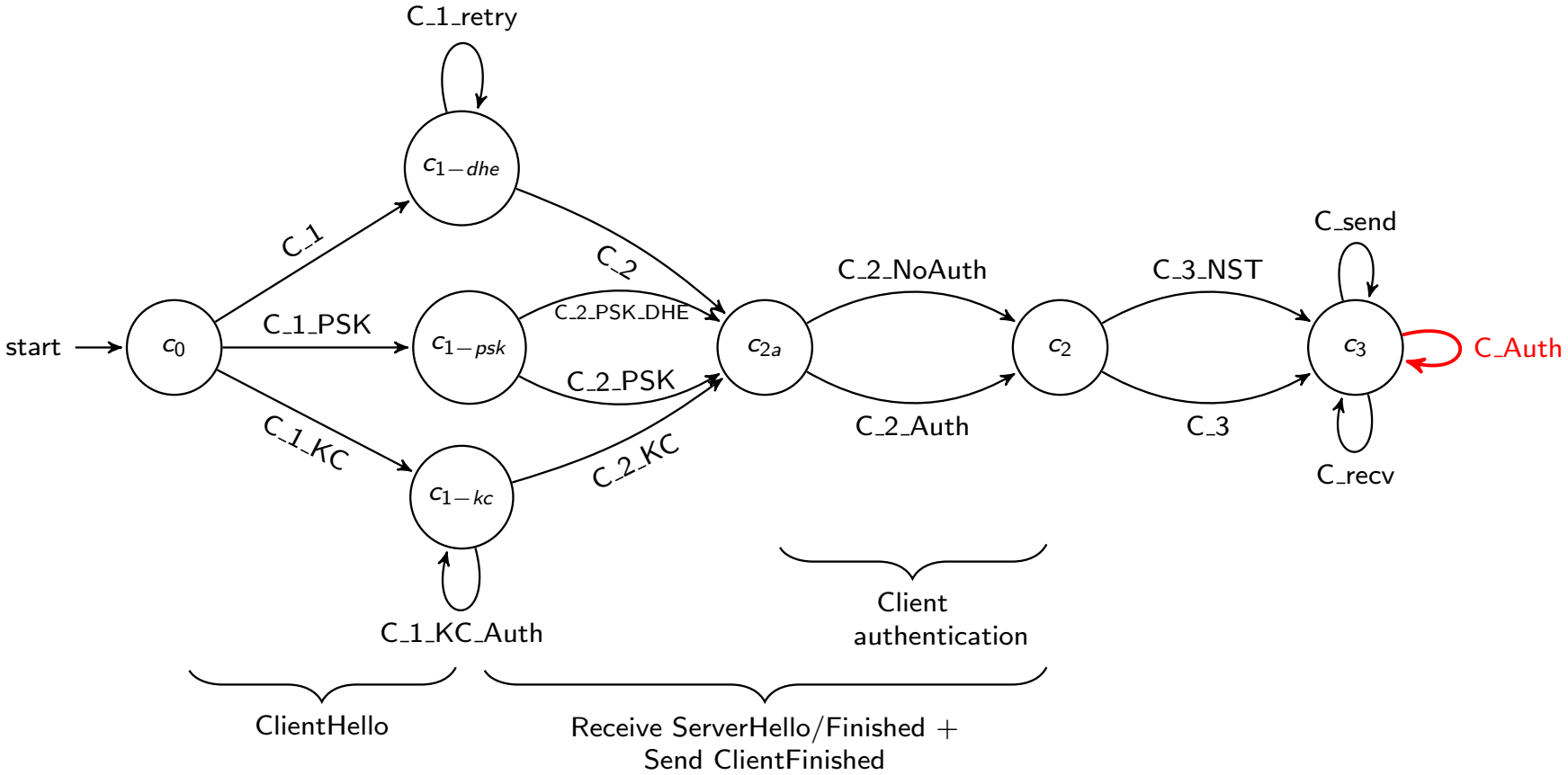


Verification

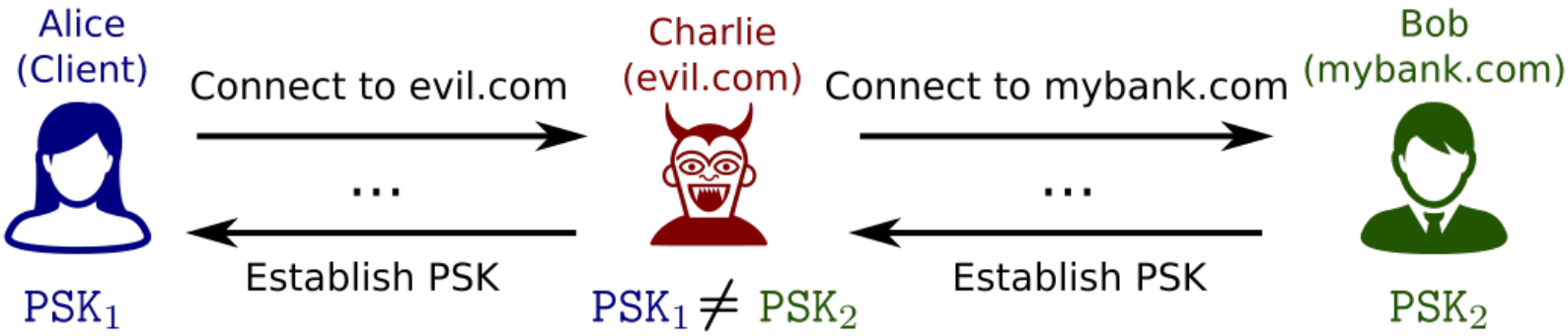
We verified the core properties of TLS 1.3 revision 10 as an authenticated key exchange protocol:

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

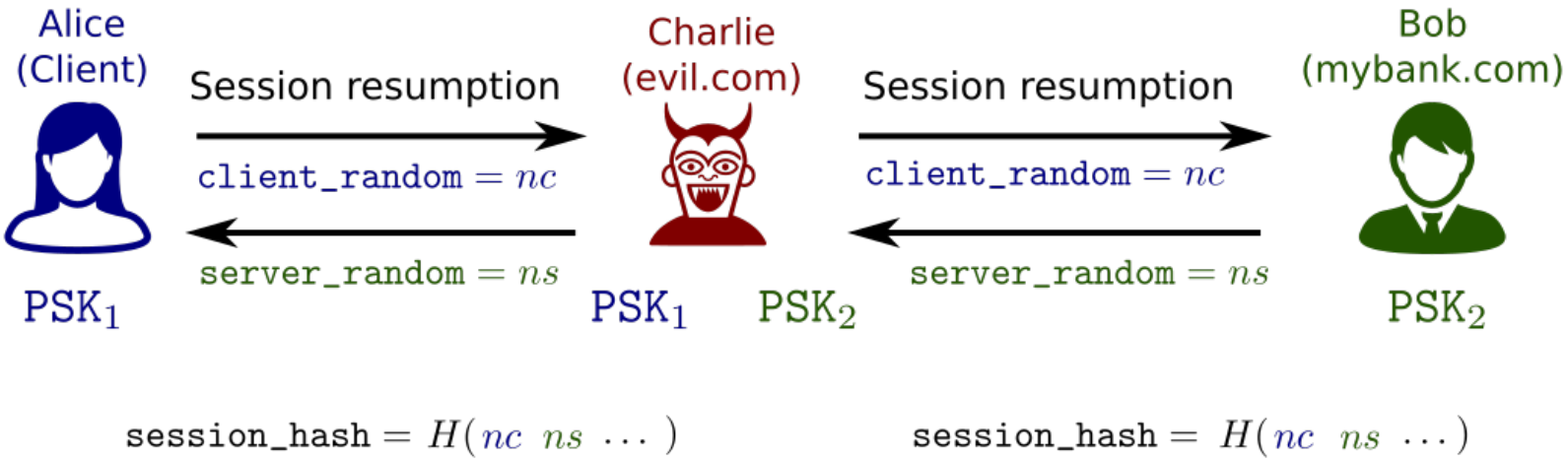
Attacking client authentication



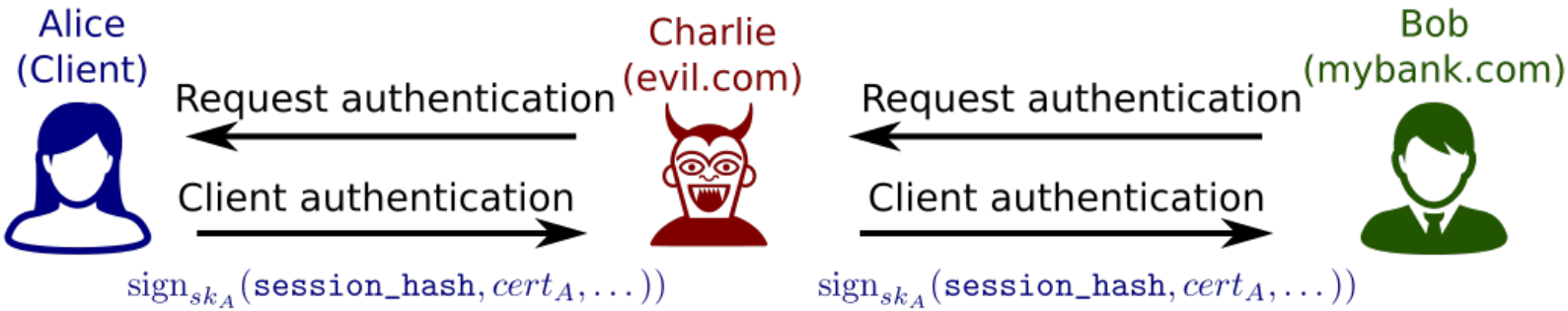
Attacking client authentication



Attacking client authentication



Attacking client authentication



$\texttt{session\_hash} = H(nc\ \ ns\ \ \ldots\ )$

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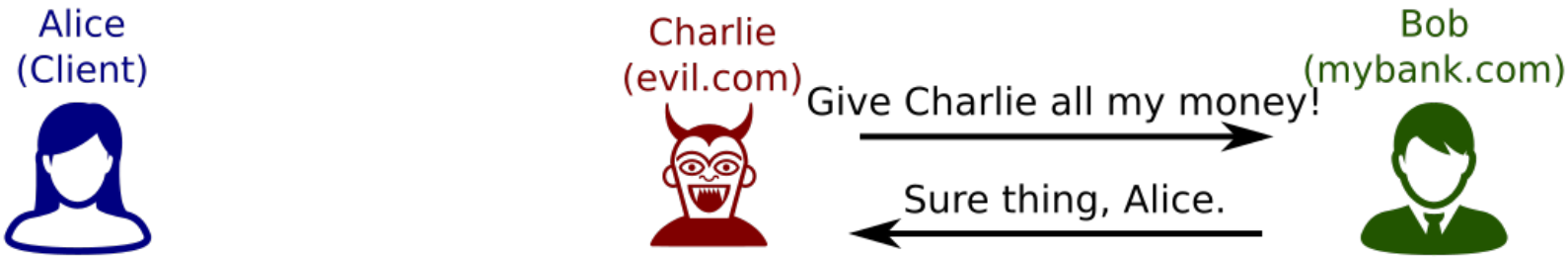

Conclusions

- 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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