Zappa for Correctly Implementing CPSA Analyzed Protocols

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Problem Statement

Given Security protocol specification that meets its goals

- Eg, verified using analysis tool

Want Protocol implementation meeting specification

- With assurance that it does

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Problem Statement

Given Security protocol specification that meets its goals

- Eg, verified using analysis tool
- CPSA, for instance

Want Protocol implementation meeting specification

- With assurance that it does
- Zappa compiles the spec
- Coq script validates source/target pairs for simplified core compiler

Same source file for both CPSA and Zappa

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How does Zappac work?

- CPSA uses the Dolev-Yao adversary model.
- Receptions are destructured using Dolev-Yao elimination rules.
  - Examples: projection from a tuple and decryption.
- Transmissions are synthesized using Dolev-Yao introduction rules.
  - Examples: Tuple construction and encryption.

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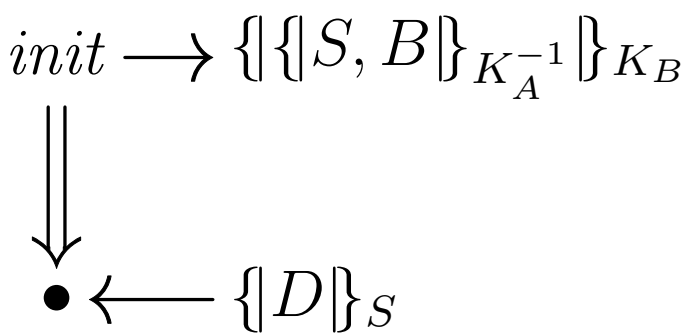
Corrected Blanchet Simple Example Protocol

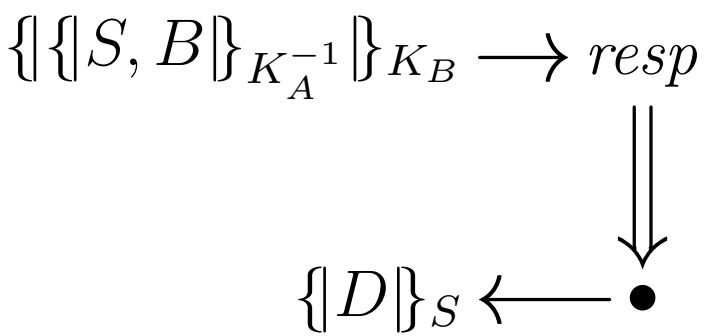
$$A \to B\colon \{|\{|S, B|\}_{K_A^{-1}}|\}_{K_B} \quad [S \text{ generated}]$$
$$B \to A\colon \{|D|\}_S \quad [D \text{ generated}]$$

CPSA Style Roles

Initiator (*init* role)



Responder (*resp* role)



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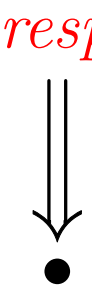
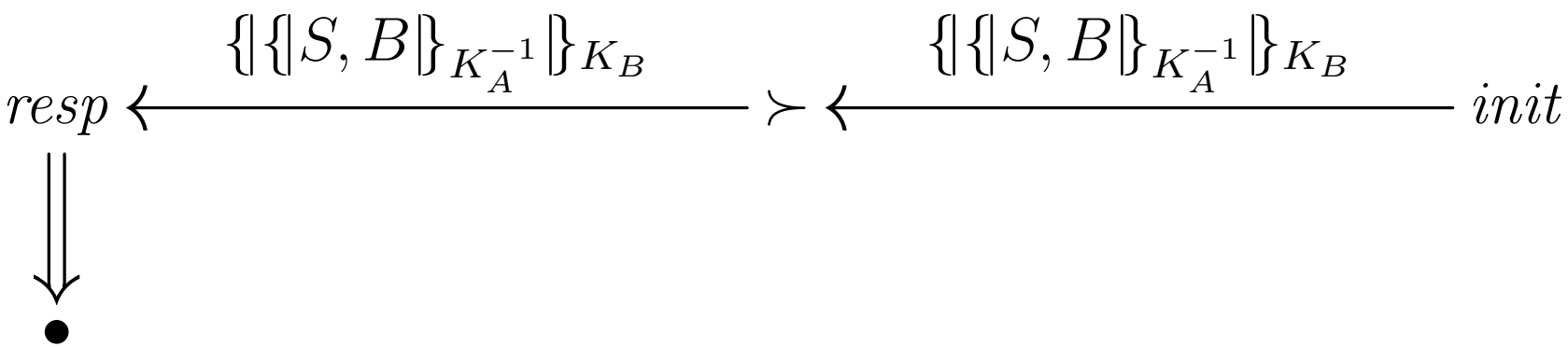
CPSA Analysis From the Responder Point-of-View

Query



Analysis



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CPSA Summary

Cryptographic Protocol Shapes Analyzer

- Query is a protocol and points-of-views.
- Analysis is concise descriptions of allowed behaviors.
- Deduce the goals achieved from the allowed behaviors.

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Modifications to CPSA to Support Code Generation

Channels: Specify an endpoint for message reception and transmission.

- Channels, as added to CPSA, have a distinct sort.
- Channels cannot be included in messages.

Proc Info: Specify generated procedure parameters and return values.

- All channels must be included in the parameters.

resp:

1. Parameters C, B, K_A, and K_B^{-1}.
2. Receive on C: $\{|\{|S, B|\}_{K_A^{-1}}|\}_{K_B}$.
3. Generate D.
4. Send on C: $\{|D|\}_S$.
5. Return D and S.

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Zappac Output for the Responder Role

Parameters

1. *Parameters* C, B, K_A, *and* K_B^{-1}.

```
/// Role: resp (blanchet.scm:16:3)
pub fn resp<M, C, Z: Zil<M, C>>(
    z: &Z, v0: &mut C, v1: &M, v2: &M, v3: &M
    ) -> Result<(M, M)> {
  z.chck(b"name", v1)?;
  z.chck(b"akey", v2)?;
  z.chck(b"~akey", v3)?;
```

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Zappac Output for the Responder Role

Reception

2. *Receive on* C: $\{|\{|S, B|\}_{K_A^{-1}}|\}_{K_B}$.

```
// Recv (blanchet.scm:19:6)
let v4 = z.recv(b"enc", v0)?;
let v5 = z.adec(b"enc", &v4, v3)?;
let v6 = z.vrfy(b"enc", &v5, v2)?;
let v7 = z.proj(b"cat", 2, &v6, 0)?;
z.chck(b"skey", &v7)?;
let v8 = z.proj(b"cat", 2, &v6, 1)?;
z.chck(b"name", &v8)?;
z.same(&v8, v1)?;
```

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Zappac Output for the Responder Role

Transmission and Return Values

3. *Generate D.*
4. *Send on C: $\{\!|D|\!\}_S$.*
5. *Return D and S.*

```
    // Send (blanchet.scm:20:6)
    let v9 = z.frsh(b"data")?;
    let v10 = z.senc(b"enc", &v9, &v7)?;
    z.send(v0, &v10)?;
    Ok((v9, v7))
}
```

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Zappa Summary

- Source is a CPSA query.
- Target contains a procedure for each role in the protocol.
- Implement the Zil trait to create an executable.
  - Use the extensive Zappa libraries.
  - Provide your own implementation of the Zil trait.

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Why is Zappac Output Correct?

- Zappac implements the Roletran algorithm.
  - Roletran's source file is a simplification of Zappac's.
  - Roletran's target file is easily translated into Zappac's.
- A Coq scrip automatically proves Roletran source/target pairs have the same semantics, and therefore achieve the same goals.
  - Script proves:
    - ★ A run of the protocol, implies an execution for its procedure (Liveness).
    - ★ An execution of the proceduce, implies a run of the protocol (Safety).
  - The procedure semantics is specified using a small step semantics.
  - Zil method implementations must honor the small step semantics.

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Zappa Runtime Systems

- Two distinct runtime system libraries are provided.
- Tools automatically generate parts of a runtime system.
- ASN.1 specified communication formats are supported.
- Zappa system supports protocols with state.

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Conclusion

Assured Protocol Implementation Scheme

- Use CPSA to ensure your protocol achieves desired goals.
- Use Zappa to ensure the generated code achieves the same goals.
- CPSA and Roletran are available here.
  Roletran paper is here.

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