Tools and Techniques for Symbolic Protocol Verification

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Outline

1. Introduction
2. Approach
3. Symbolic Security Analysis
4. Security Analysis
5. Summary

Relevance for PV community

- Program $\rightarrow$ Product/service

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- Infrastructure management issues $\rightarrow$ Deployed in cloud

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- Additional challenges
  - Identity code?
  - Identity of code?
  - Unspecified/not well-understood mechanisms

Confidential Computing

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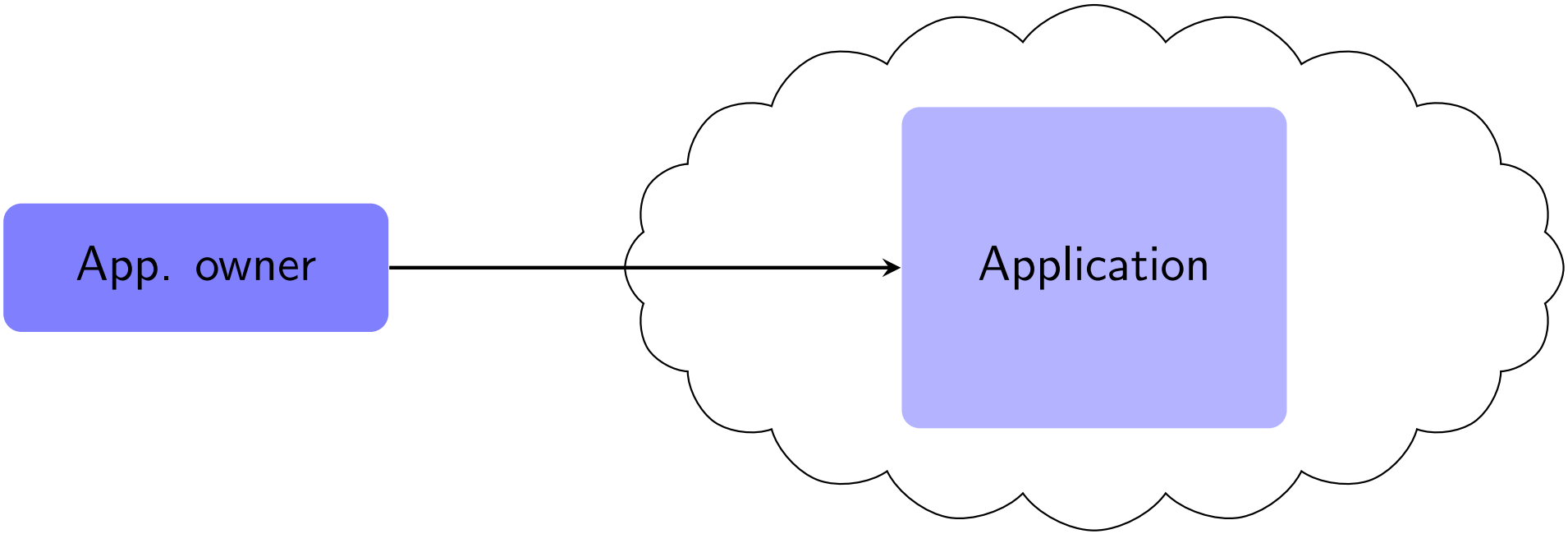
App. owner

Confidential Computing



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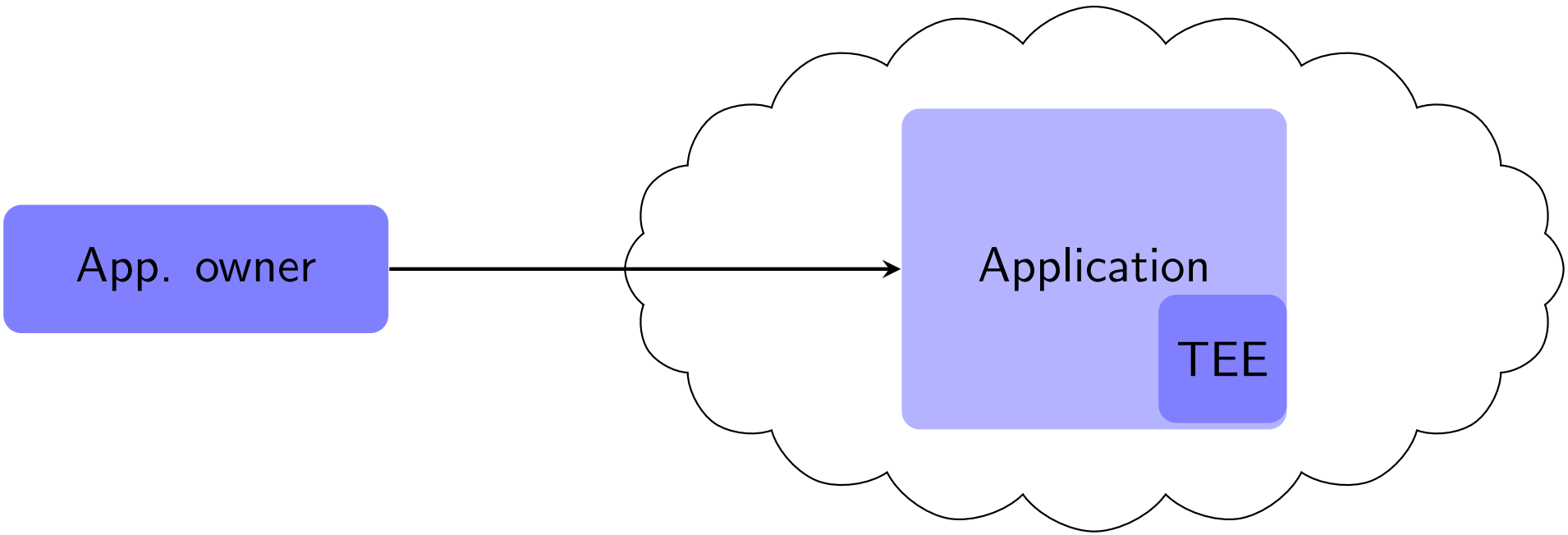
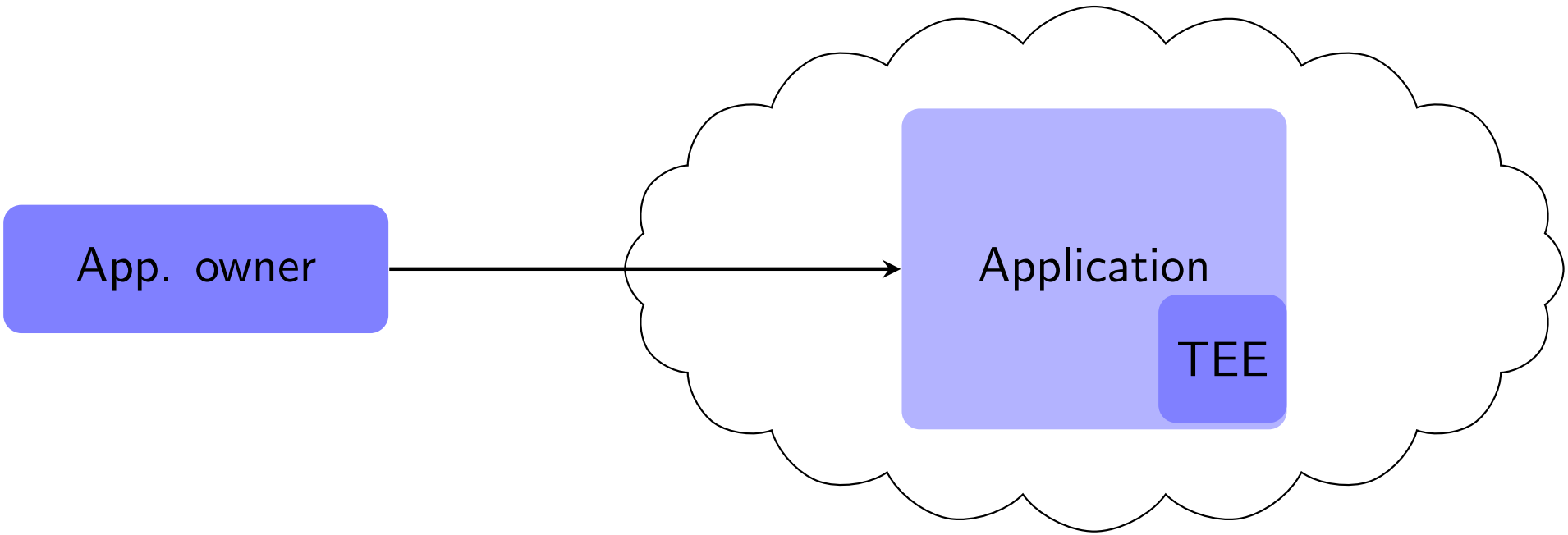


- Protection of data in use

Confidential Computing



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- Adversary: root access

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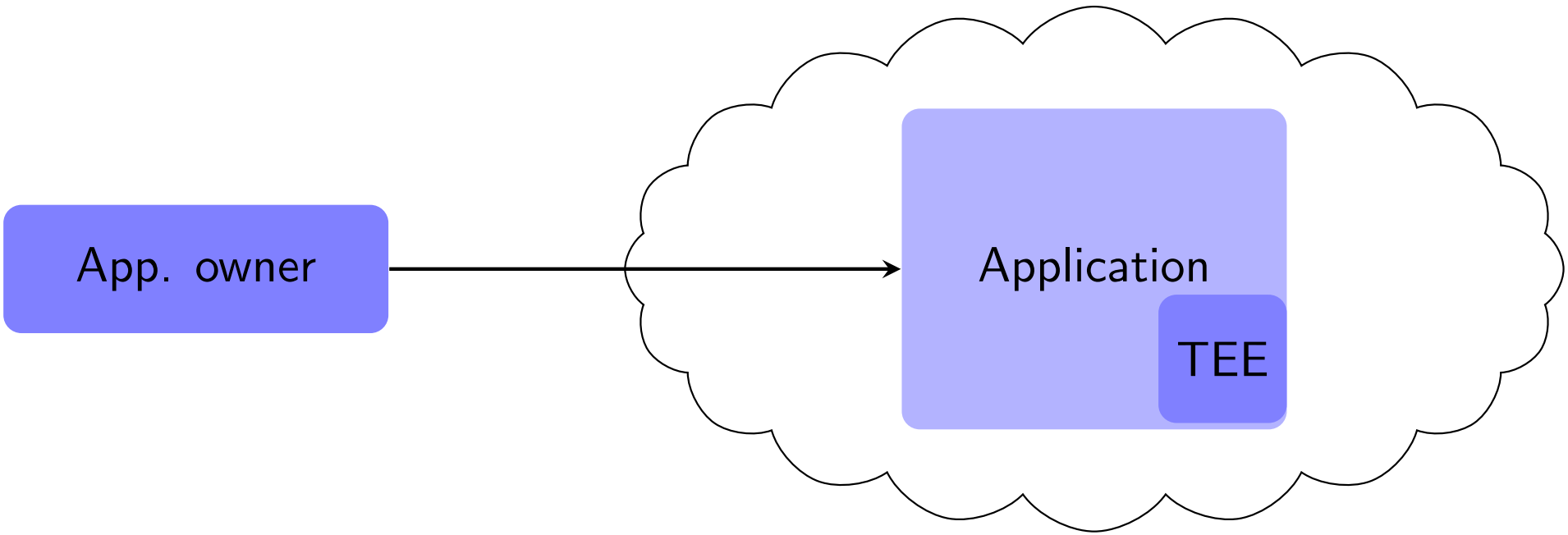

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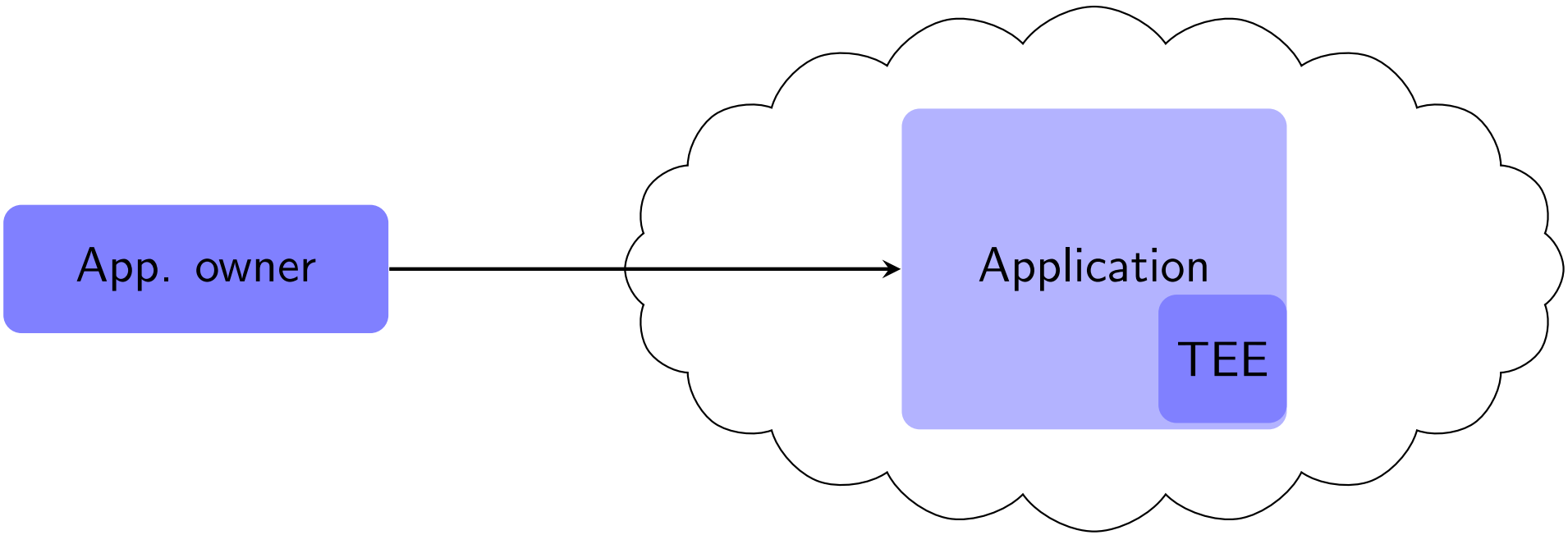

- Protection of data in use
- Adversary: root access
- Isolation and attestability
- Attestation: arguably the most critical but most misunderstood concept in CC

Attestation

- Trust to app owner: right app in right platform

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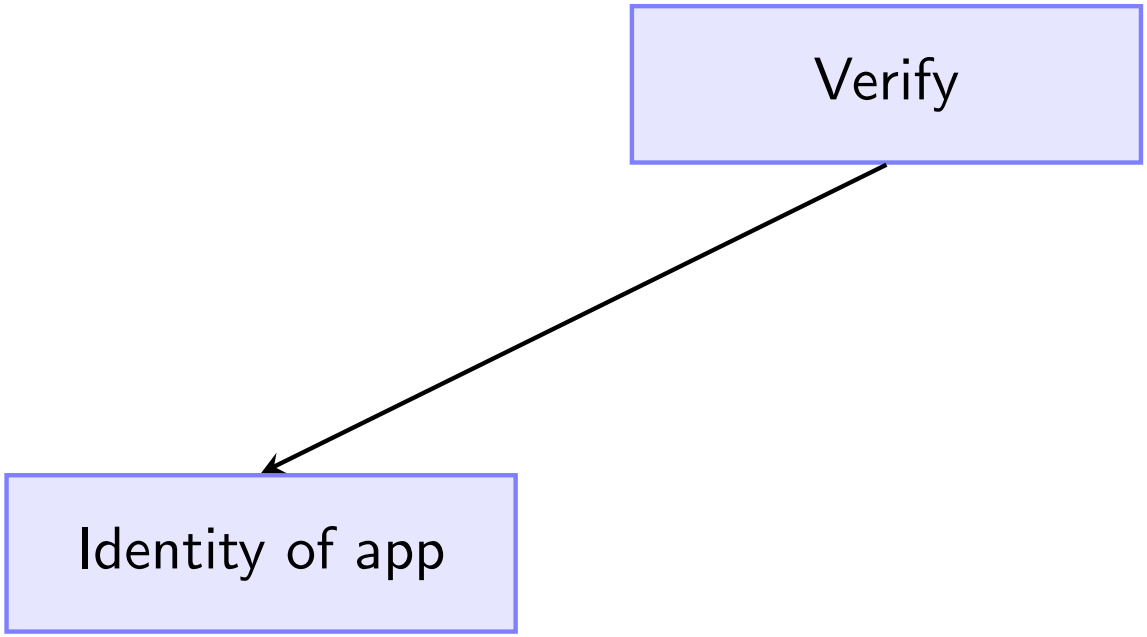

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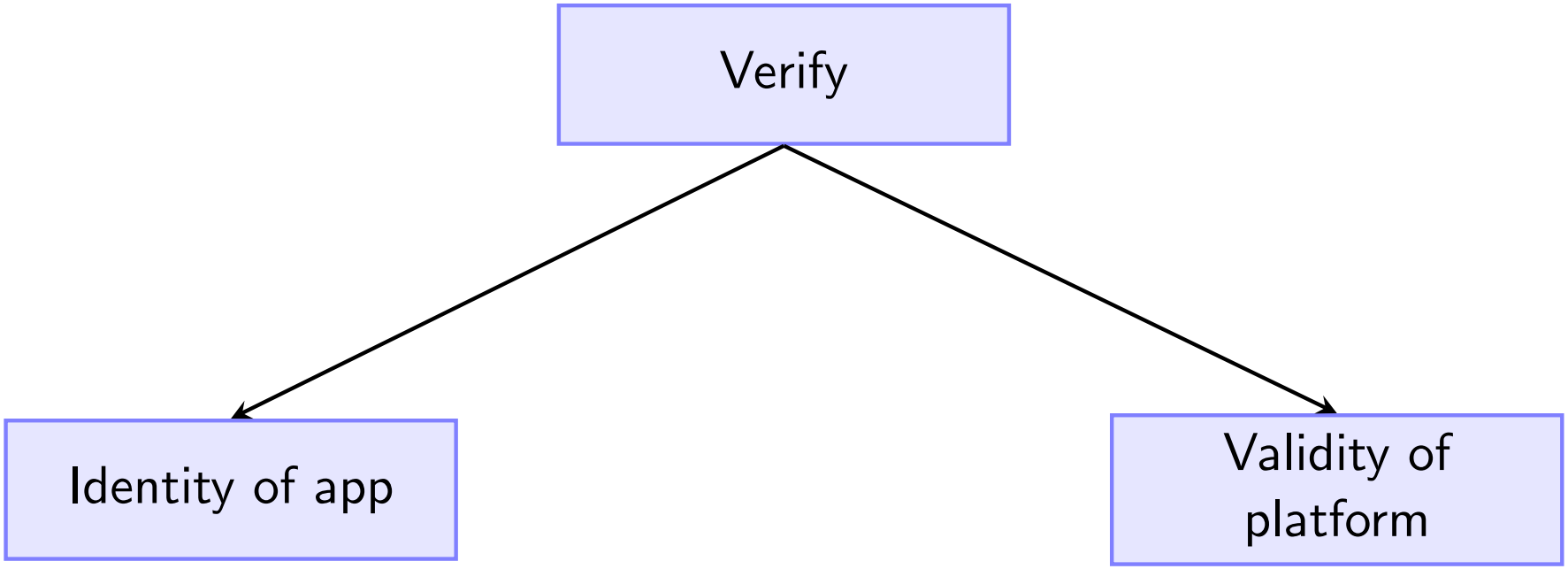

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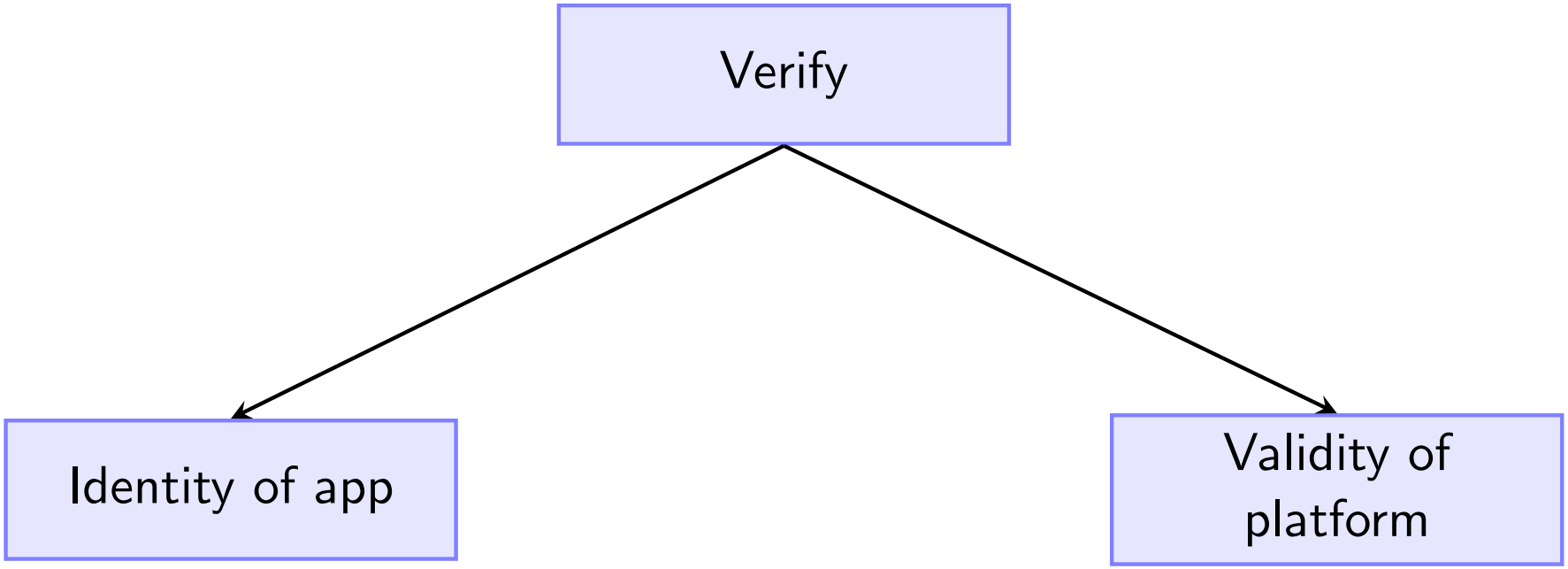

- Secure channel creation

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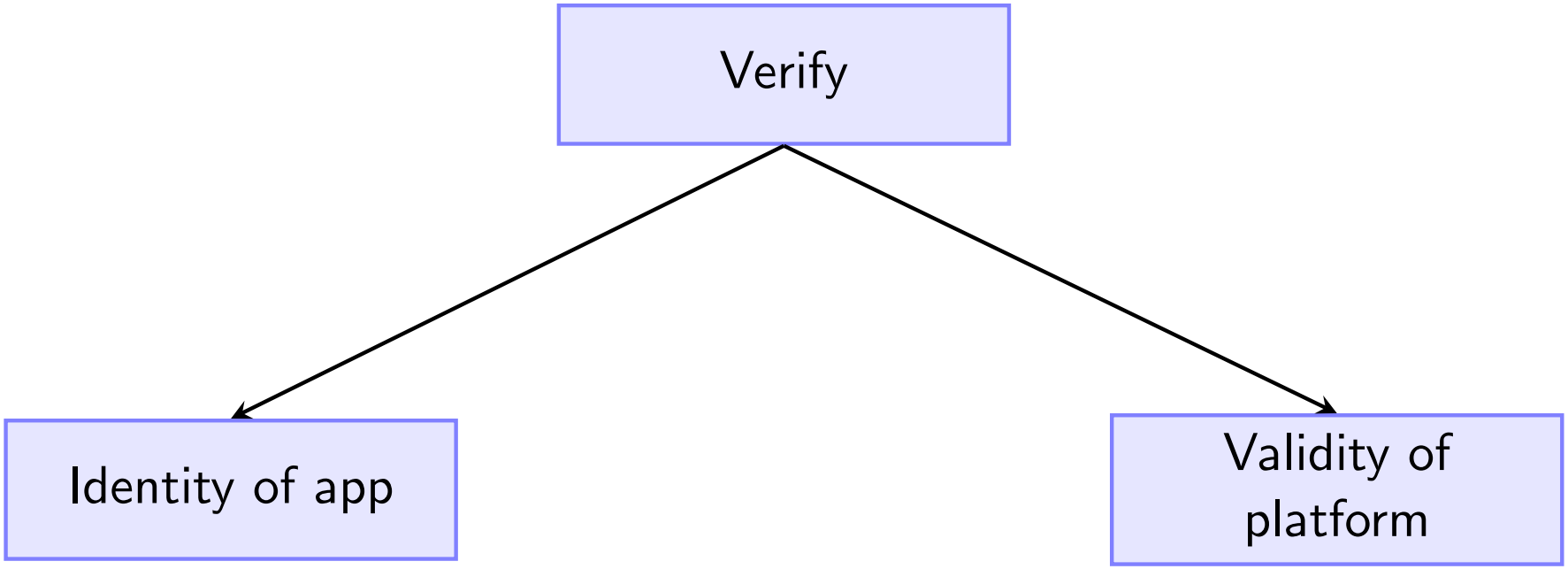

- Secure channel creation
- Provisioning of secrets and config.

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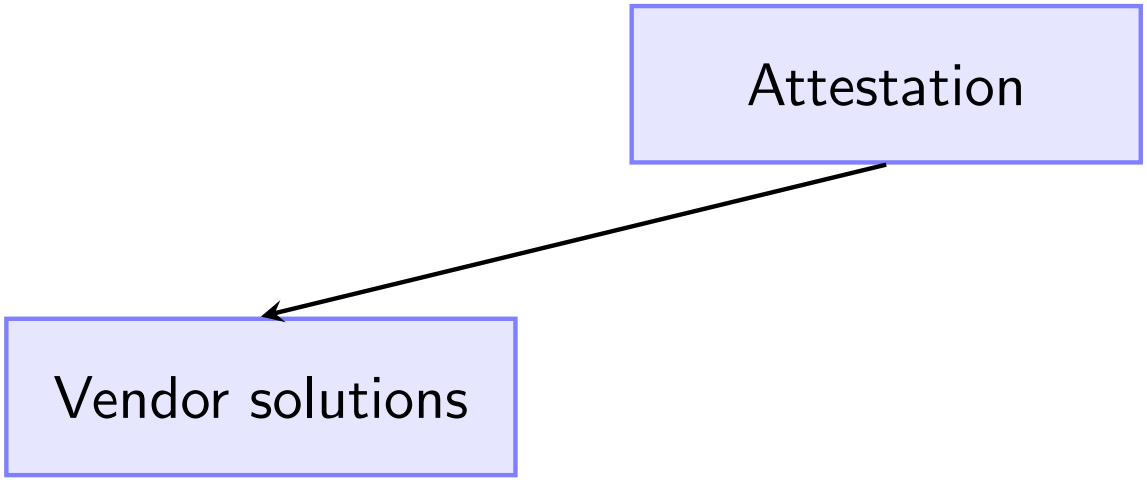
Systemization for Attestation Mechanisms



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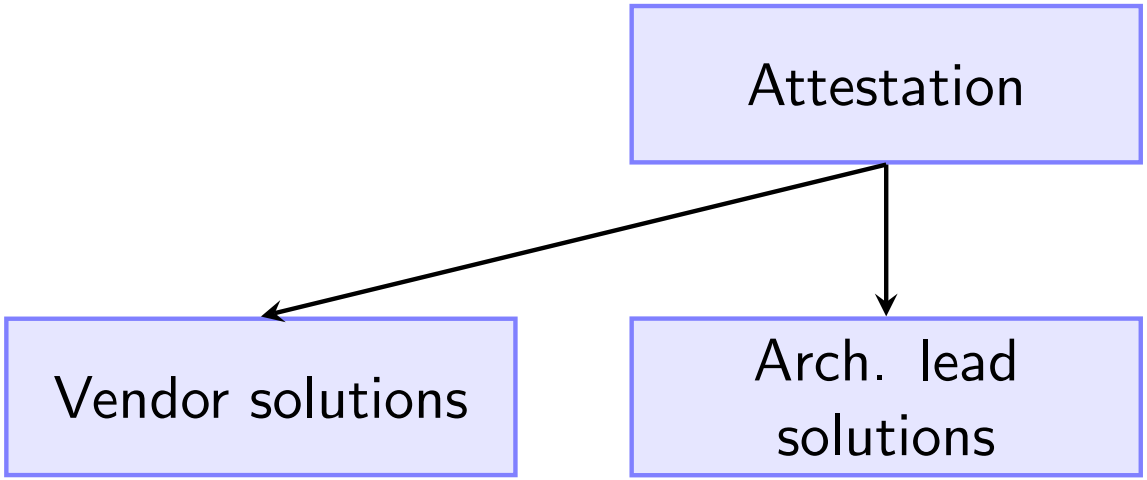

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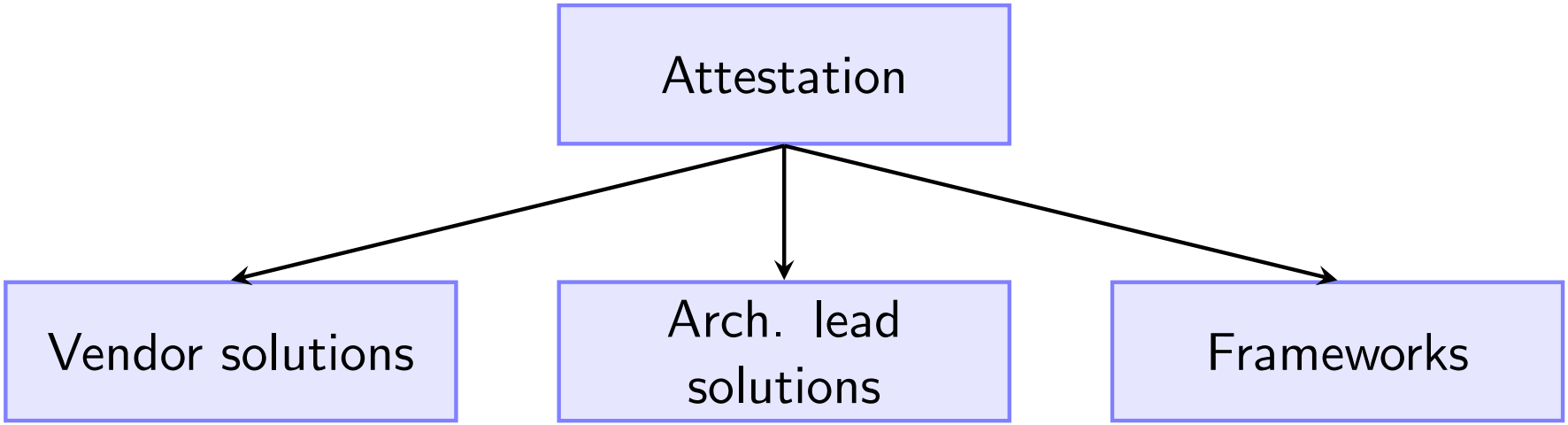

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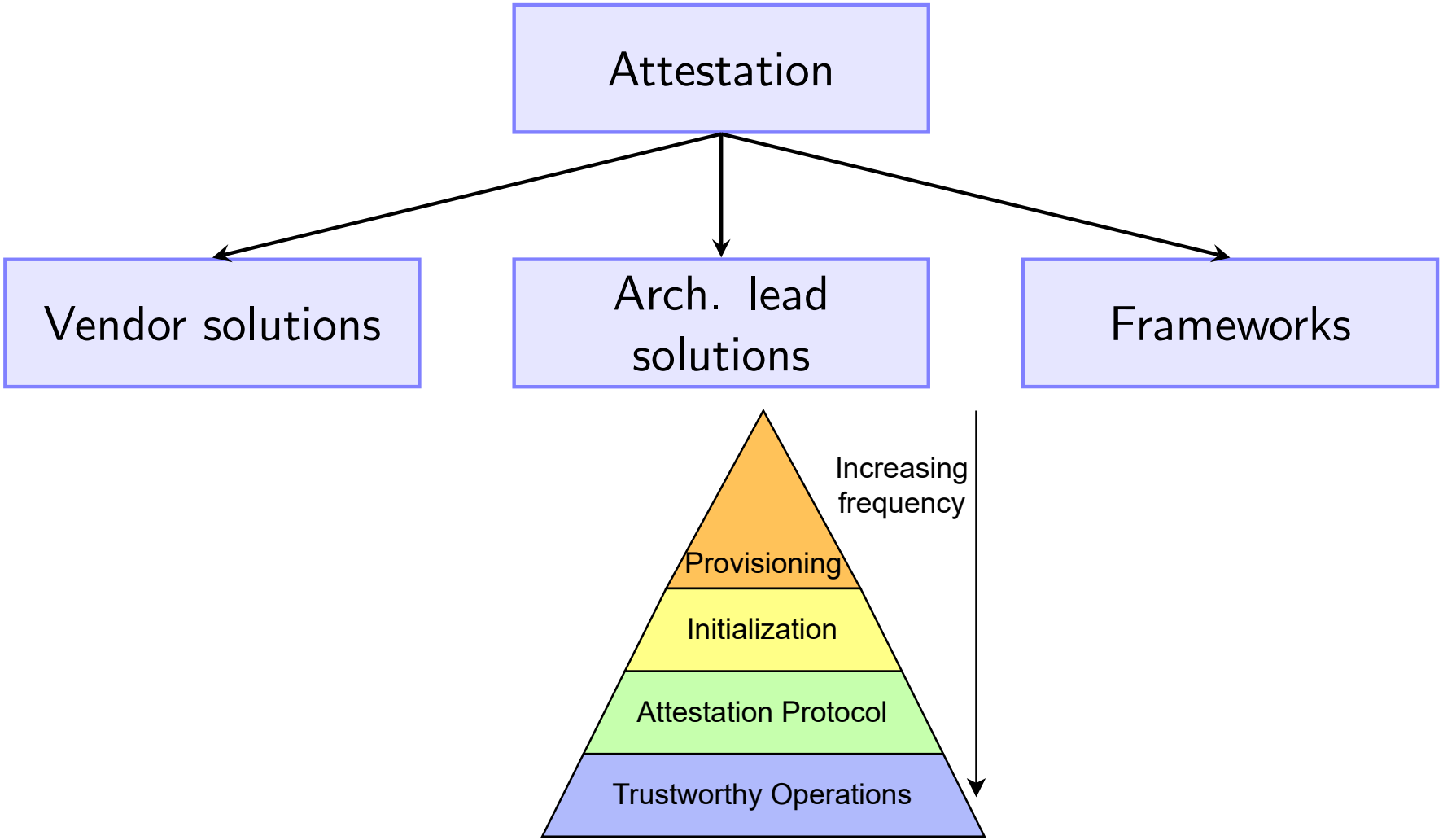

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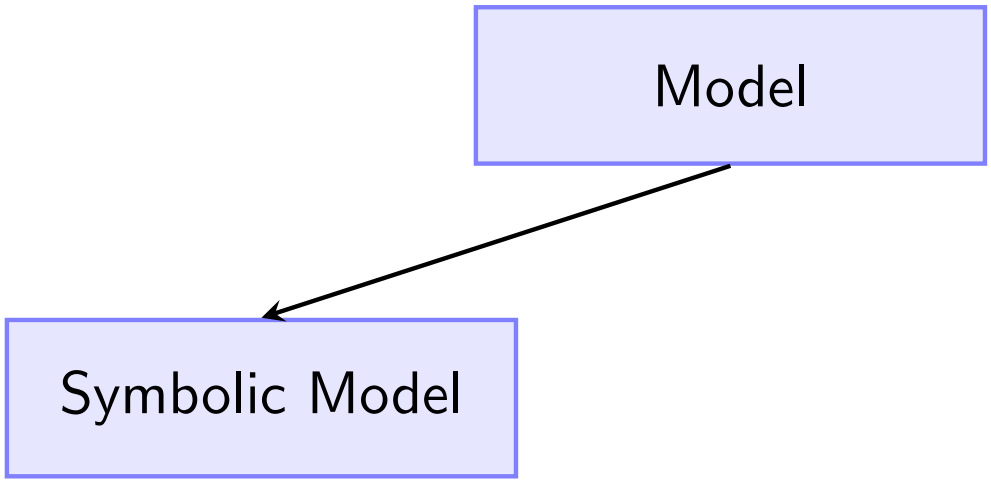
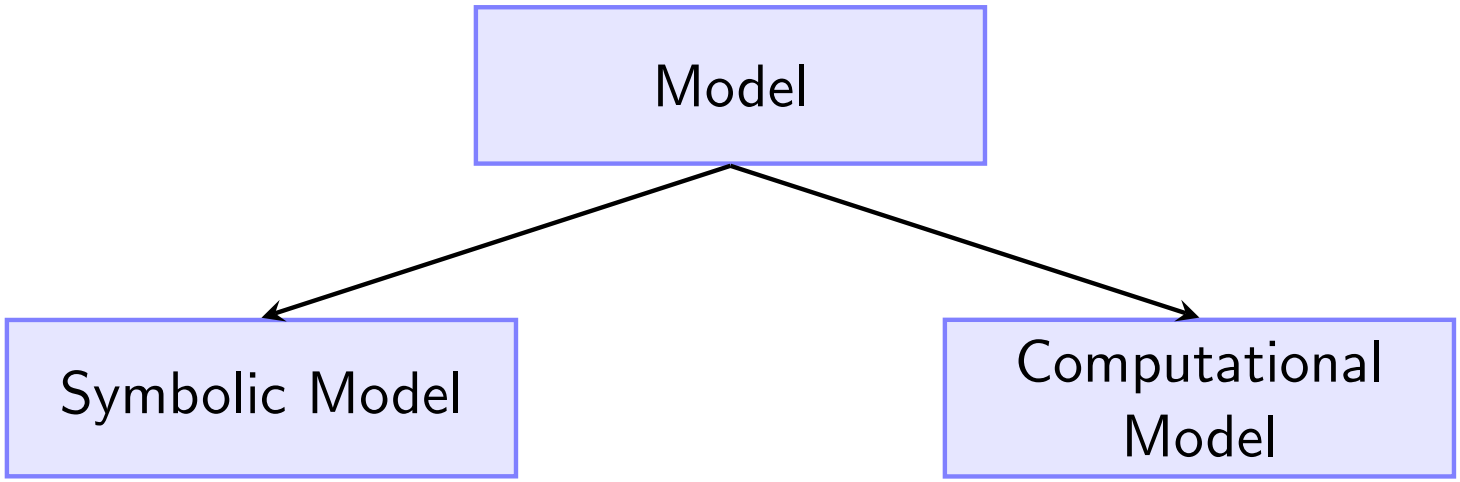


- Formal model
- Messages represented by "Terms"
- What attacker can do

[1] Barbosa et al., "SoK : Computer-Aided Cryptography", 2021

Model for Security Analysis[1]



- Used by cryptographers
- What attacker cannot do

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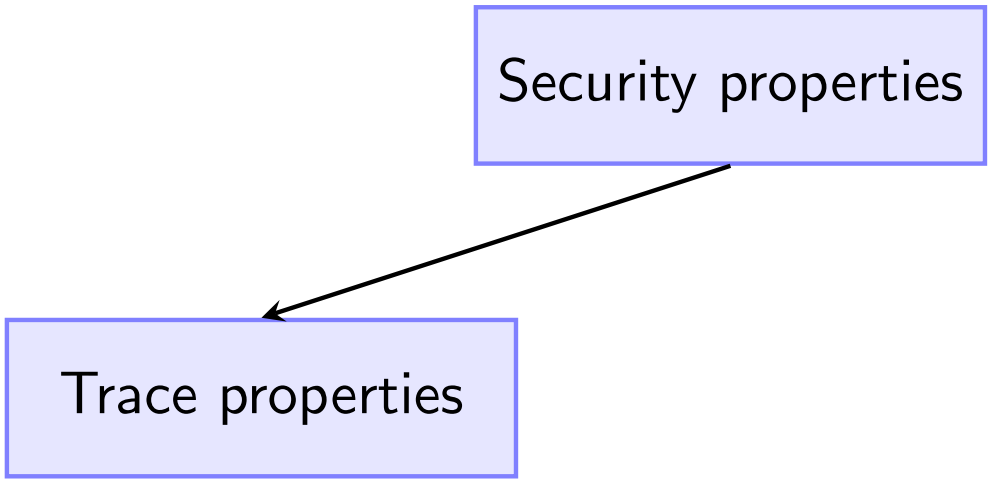
Threat Model for Symbolic Analysis

- "Dolev-Yao"[2] (symbolic) attacker
- Full control of communication network
- Unbounded number of sessions and messages
- Attacker behavior: Non-deterministic
- Assume cryptographic primitives are perfect

[2] Dolev and Yao, "On the security of public key protocols", 1983

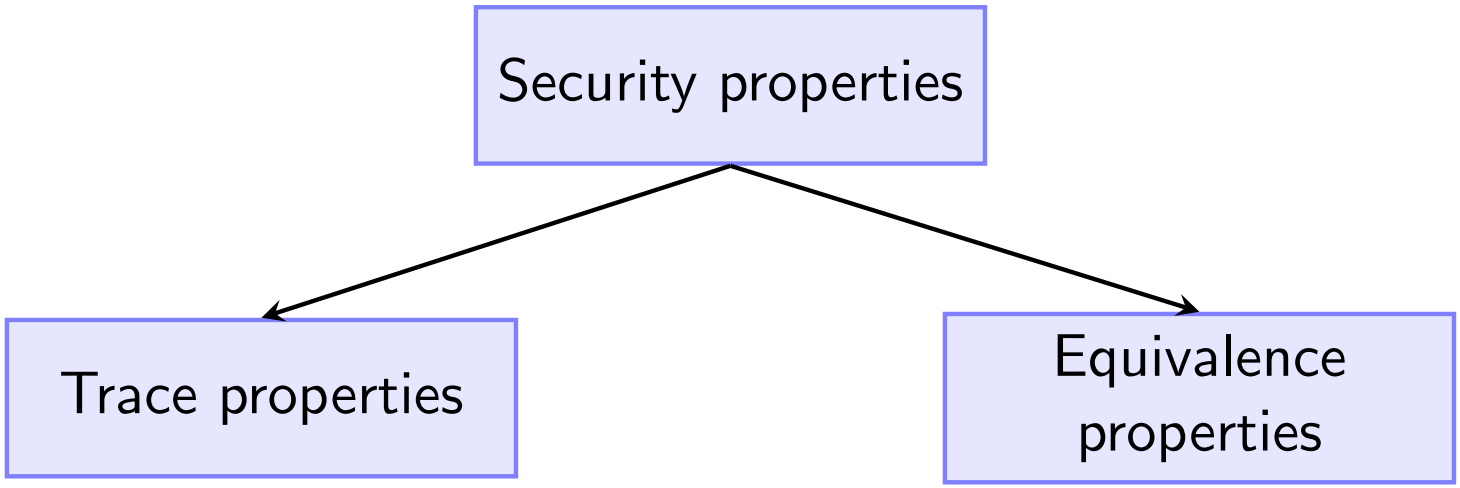
Security properties[3]



- Defined on each run of the protocol
  - Confidentiality/Secrecy
  - Authentication

[3] Blanchet, "Modeling and verifying security protocols with the applied pi calculus and ProVerif", 2016

Security properties[3]



- Adversary cannot distinguish 2 processes
- e.g., observational equivalence
- Tools: ProVerif, DeepSec (almost the same semantics)

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ProVerif[4] vs. Tamarin prover[5]

- More automation vs. user interaction

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- Computational security analysis on *same* model (CryptoVerif[4])

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- Faster[5]

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- Computational security analysis on *same* model (CryptoVerif[4])
- Faster[5]
  - esp. recent improvements[6]
- Supports equivalence properties

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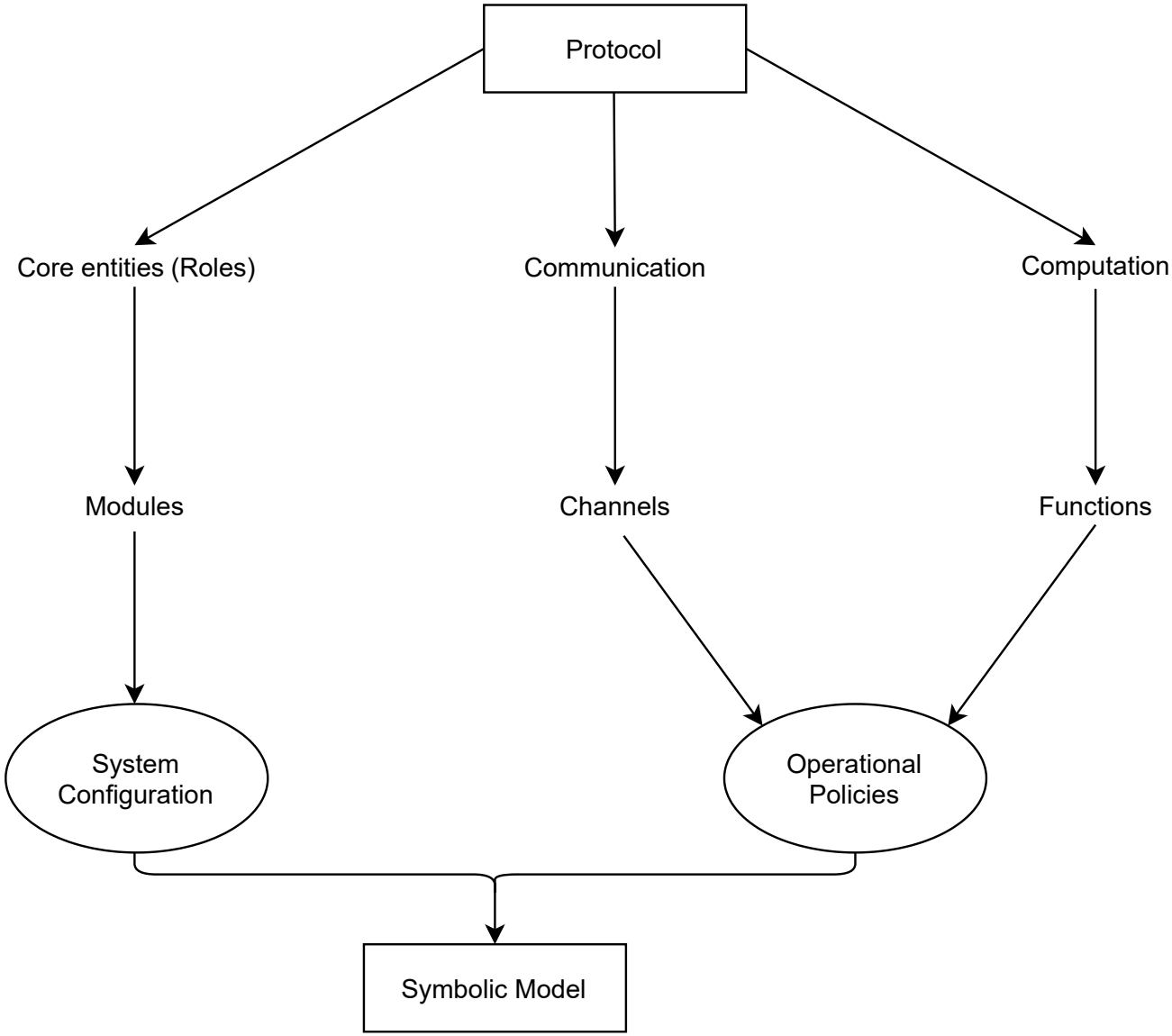
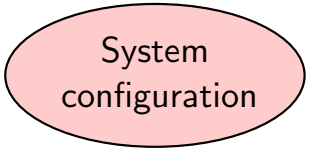
Overview of Approach



Workflow of the Analysis Approach



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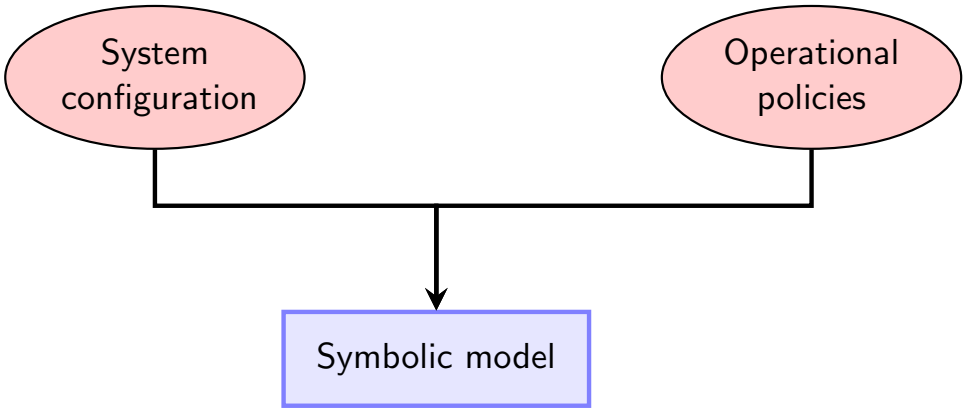

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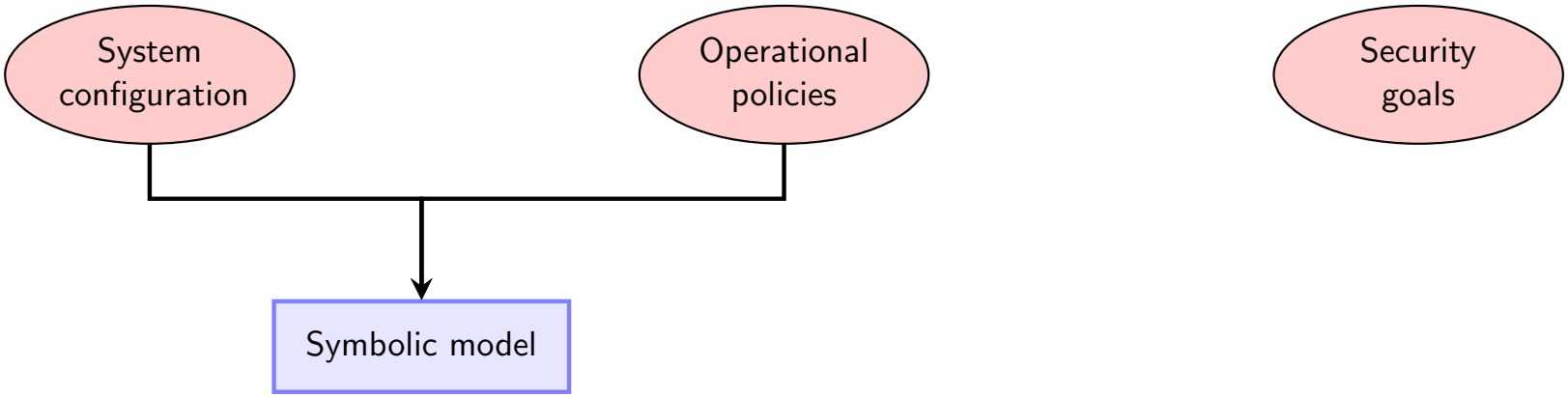

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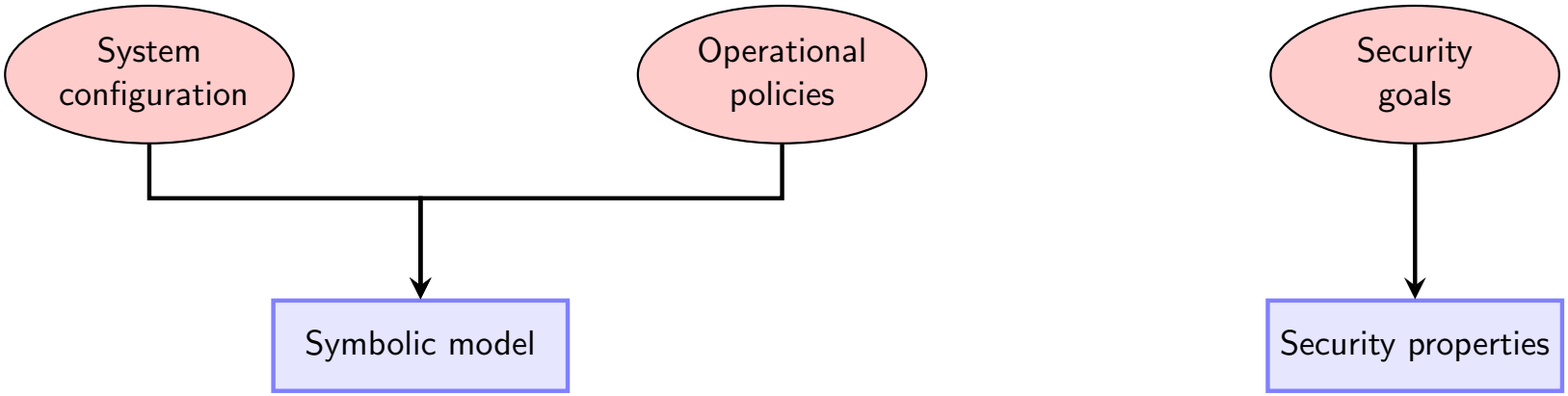

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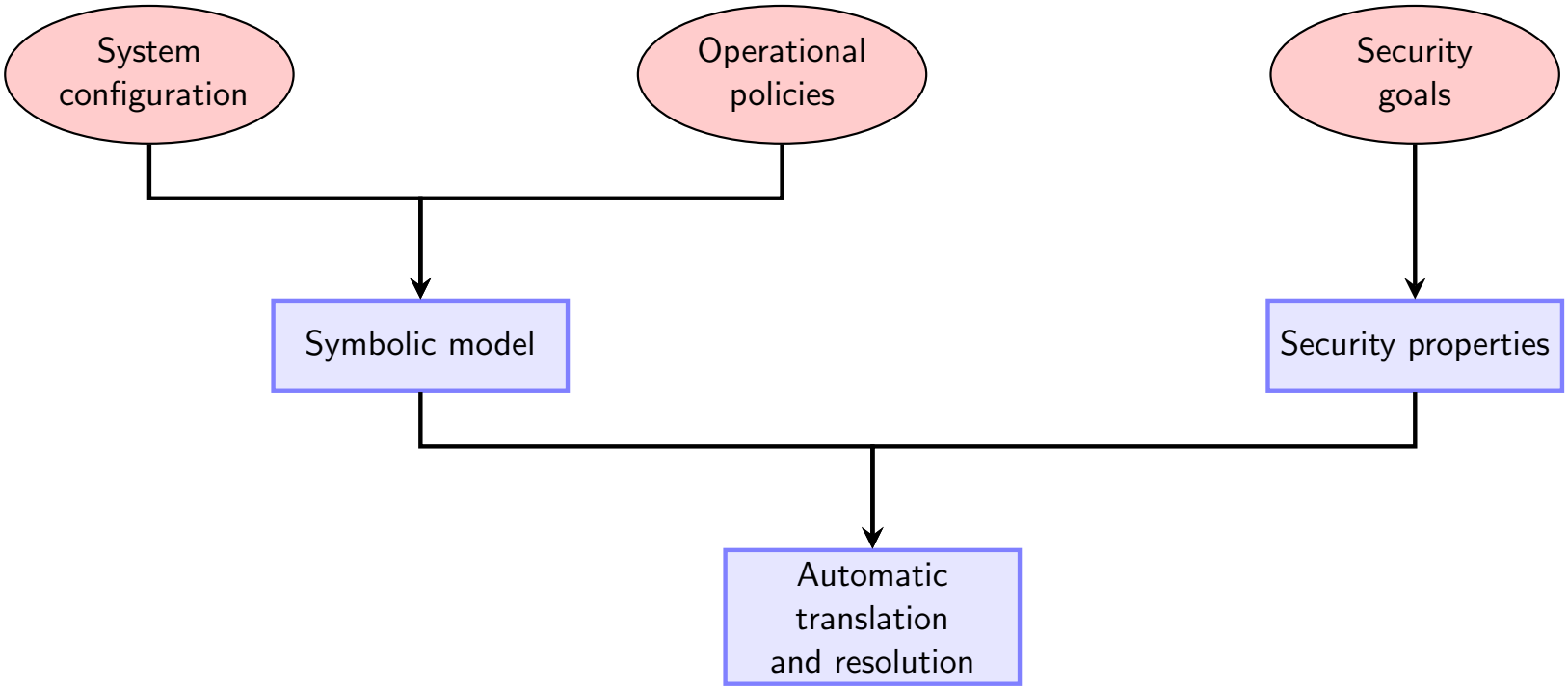

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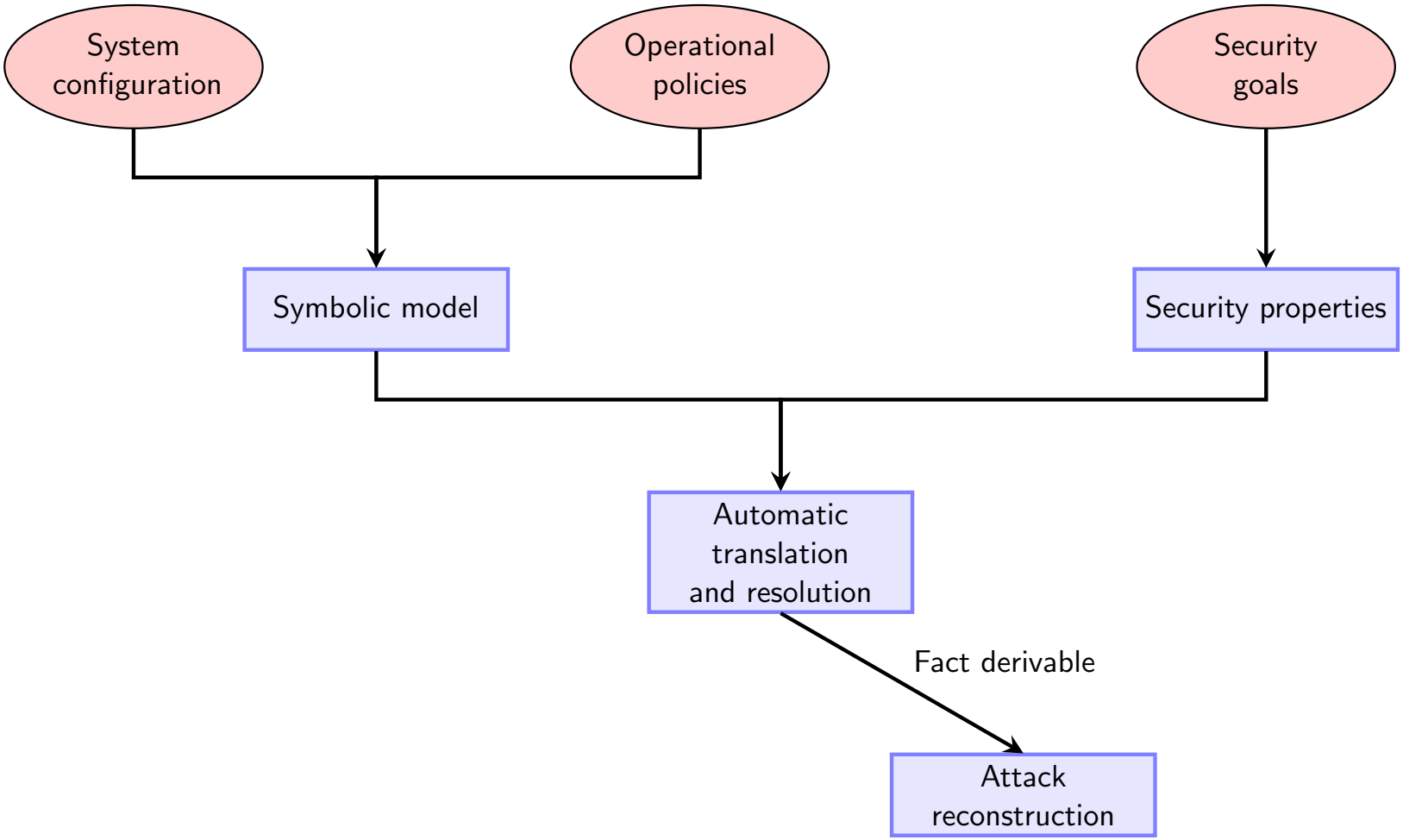

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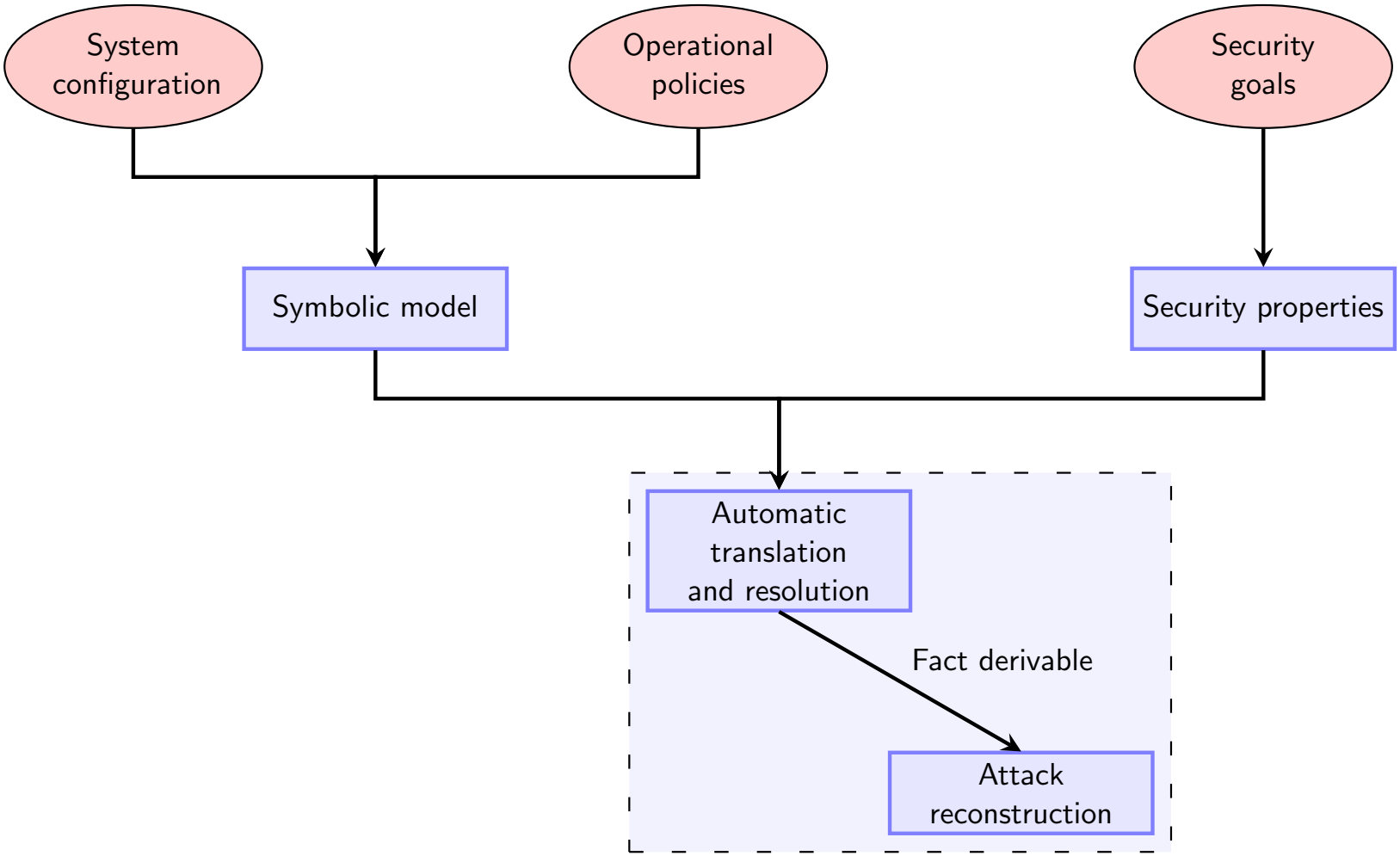

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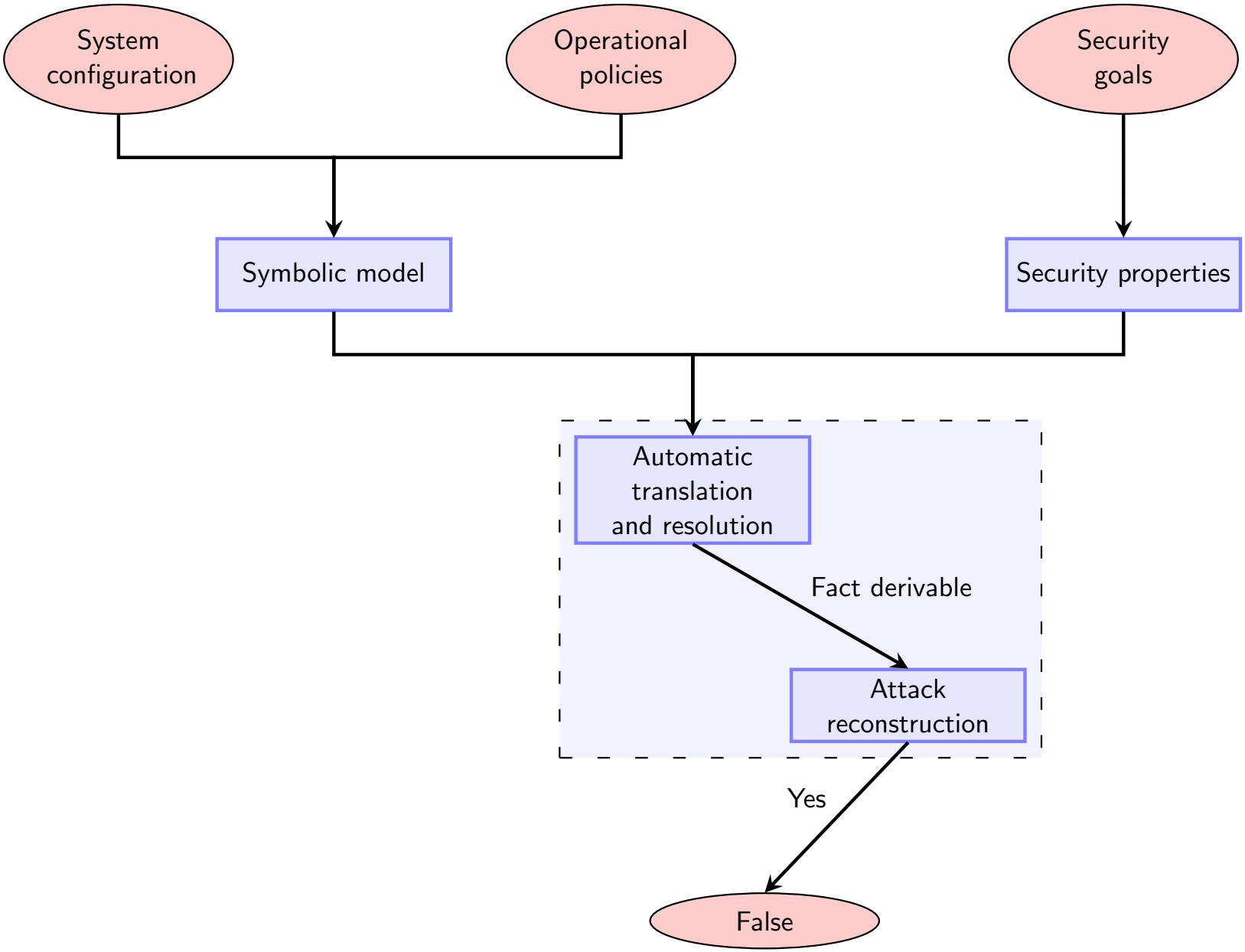

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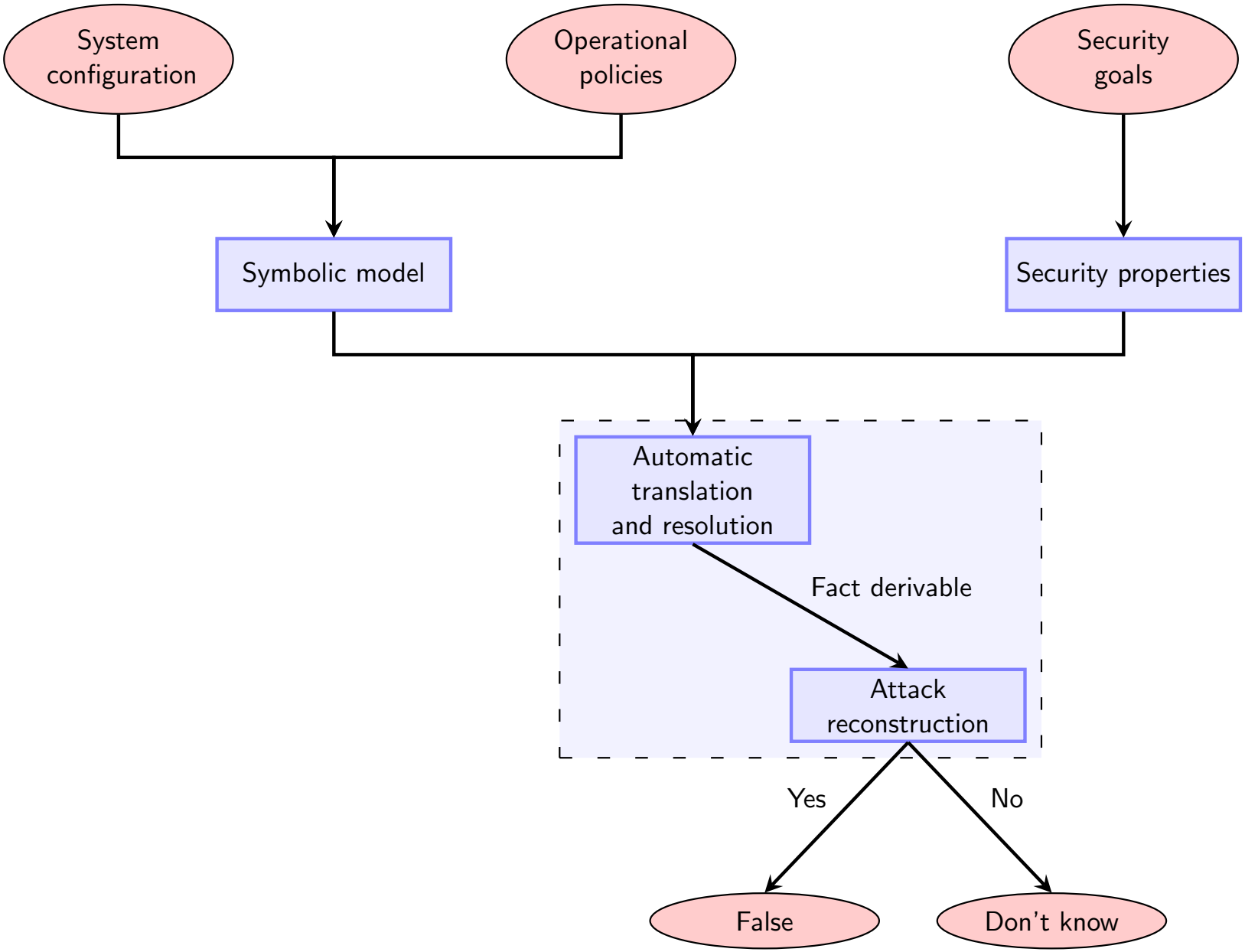

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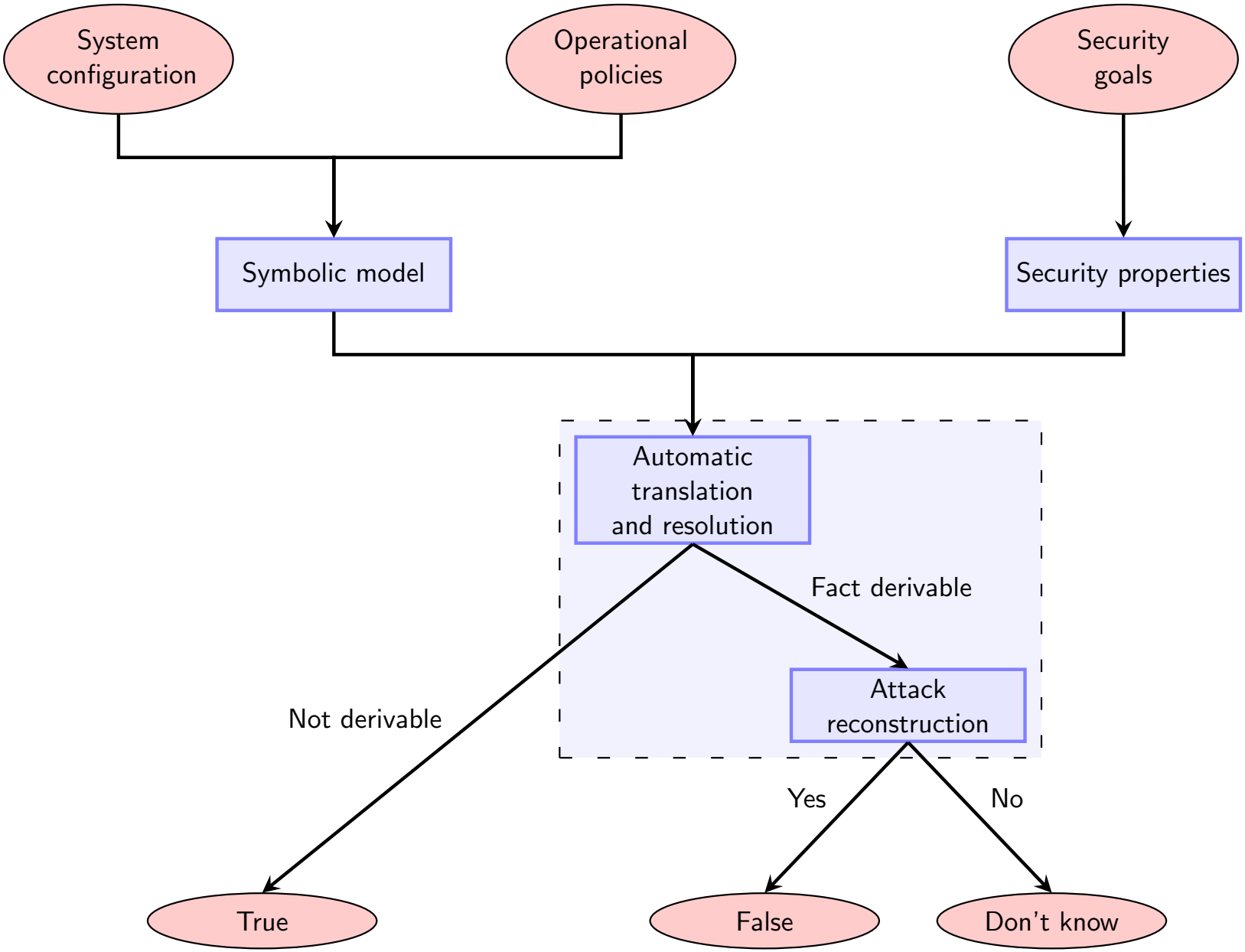

Specification of Security Goals

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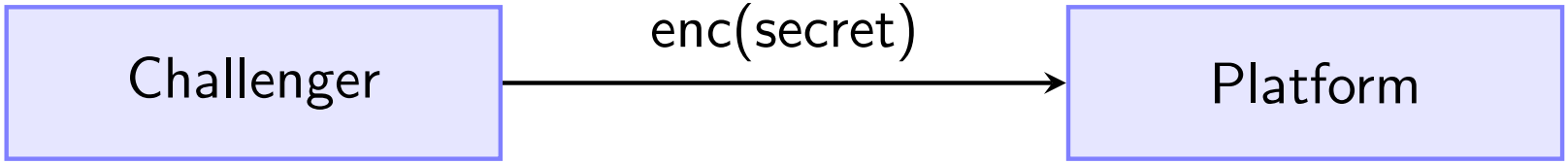

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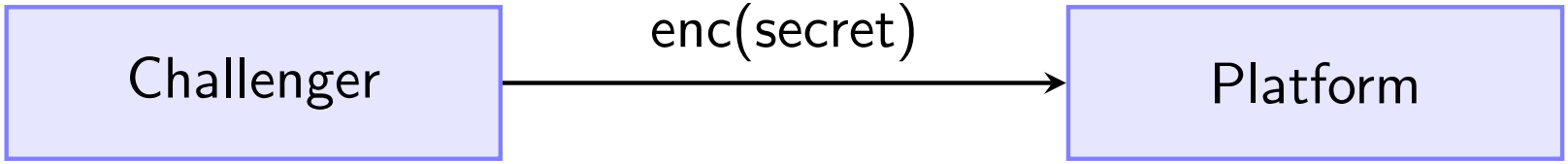

  - Formalized as a reachability property

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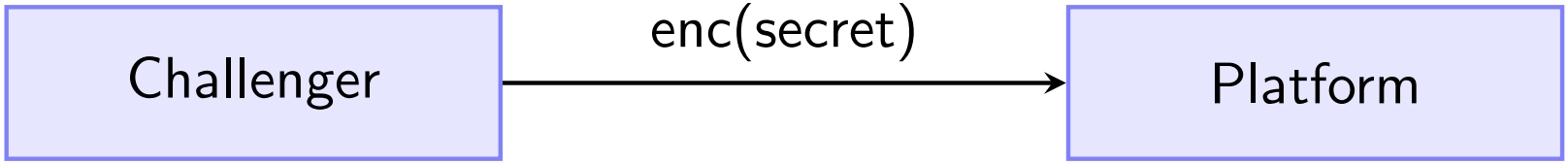

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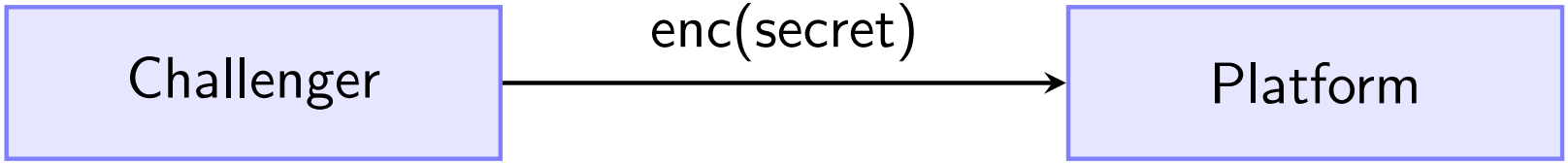

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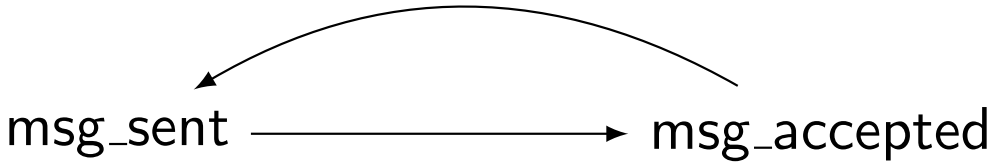

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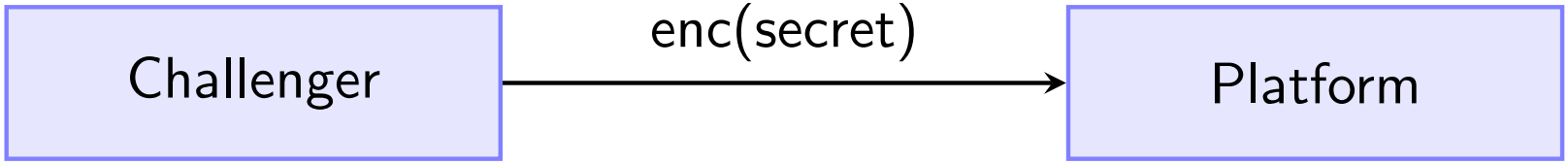

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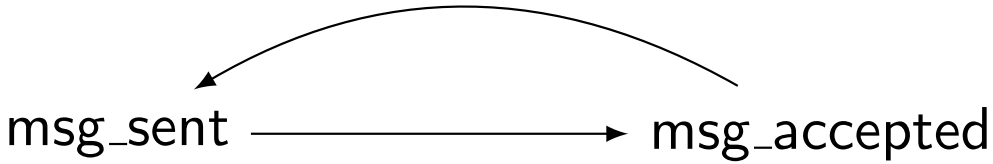

  - Correspondence assertions

query $x_1 : t_1, ..., x_n : t_n$;
event $(msg\_accepted(M_1, ..., M_j))$ ==> event $(msg\_sent(N_1, ..., N_k))$. (1)

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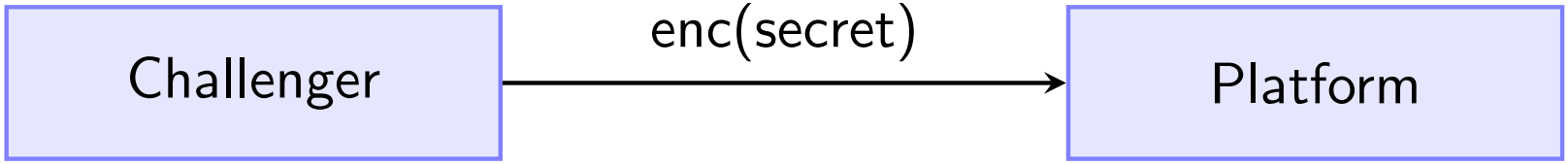

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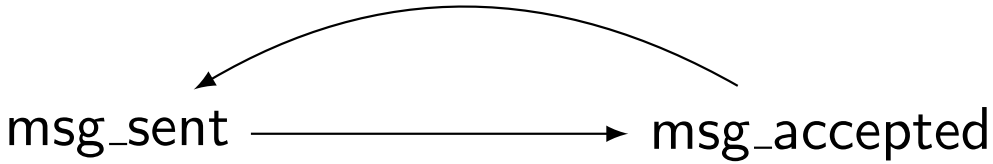

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  - Additional check: Reachability of `msg_accepted`

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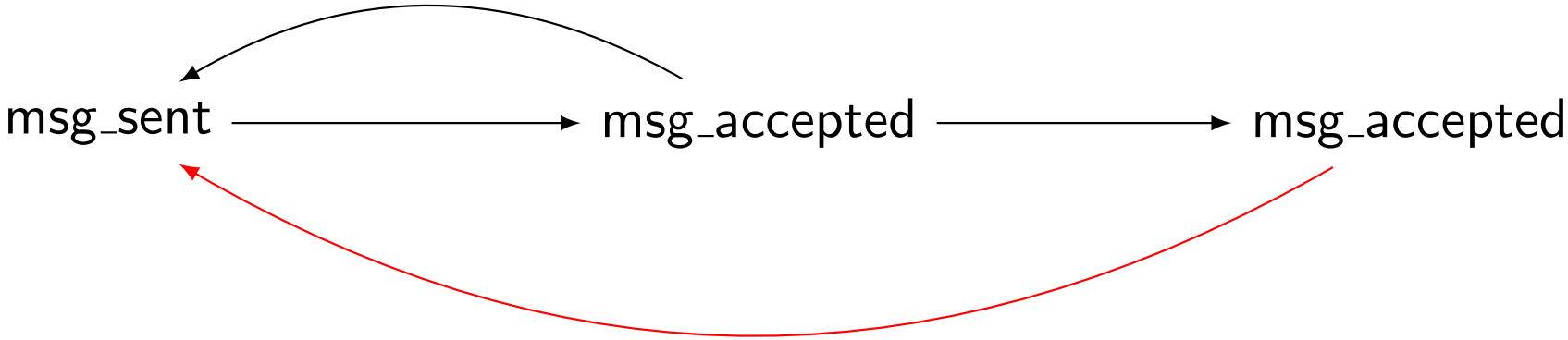

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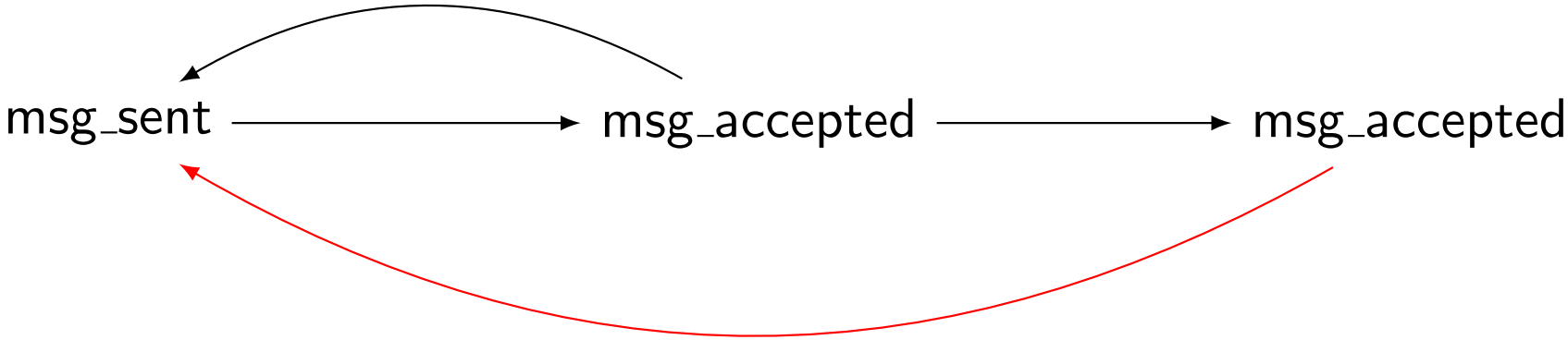

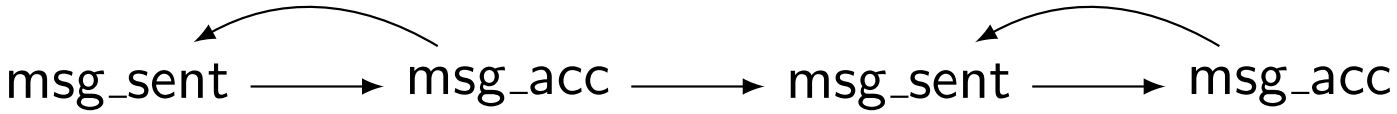

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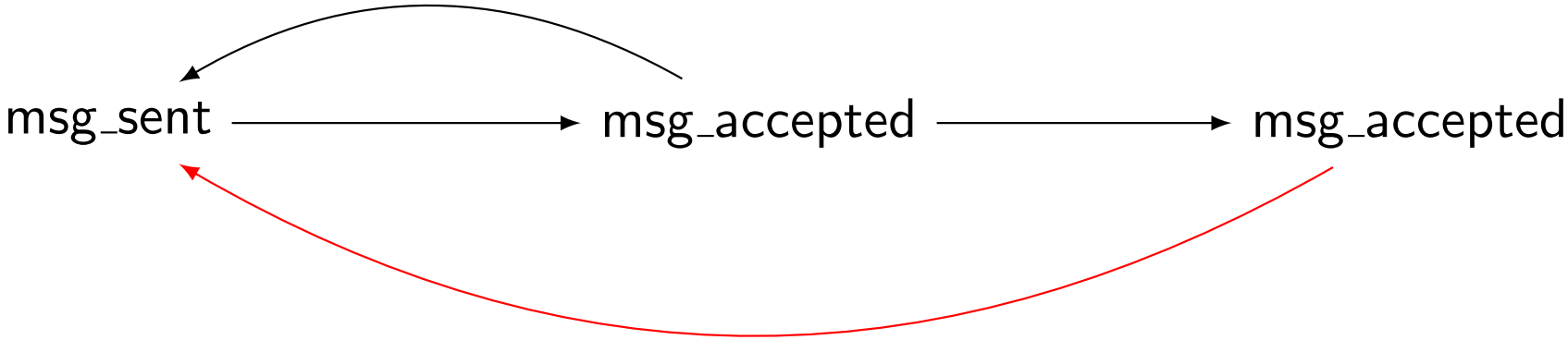

- Injective correspondence assertions

$$\texttt{query}\ x_1 : t_1, \ldots, x_n : t_n\,;$$
$$\texttt{event}\ (msg\_acc(M_1, \ldots, M_j))\ \texttt{==>}\ \texttt{inj-event}\ (msg\_sent(N_1, \ldots, N_k)). \quad (2)$$

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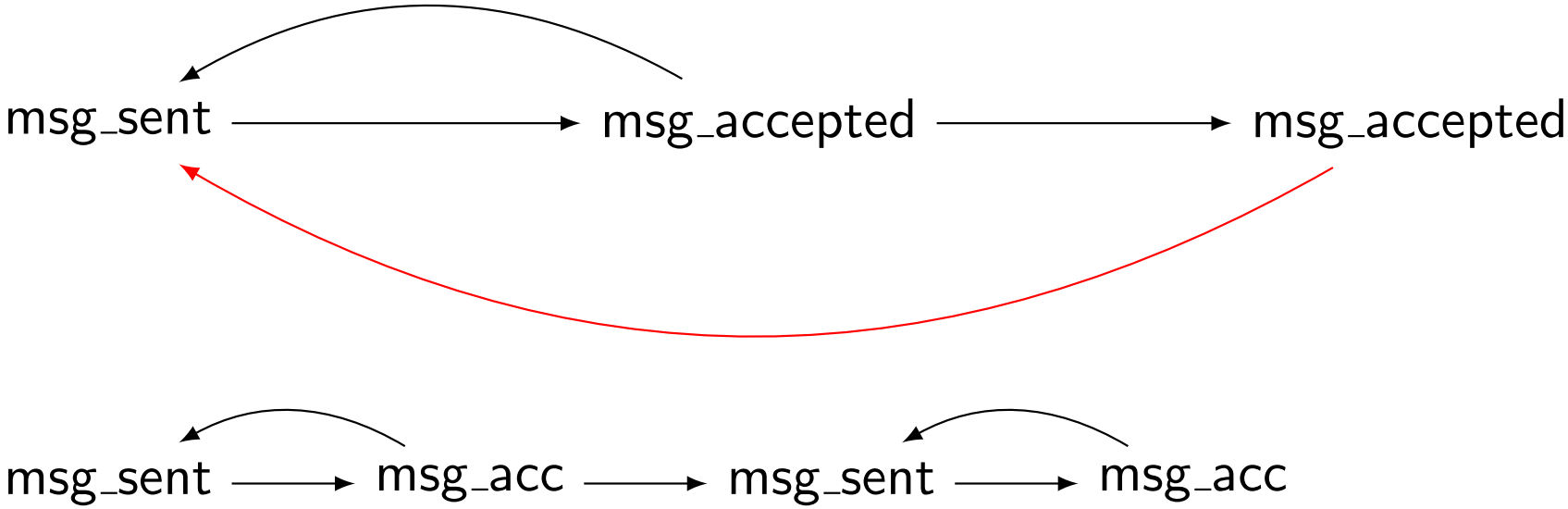

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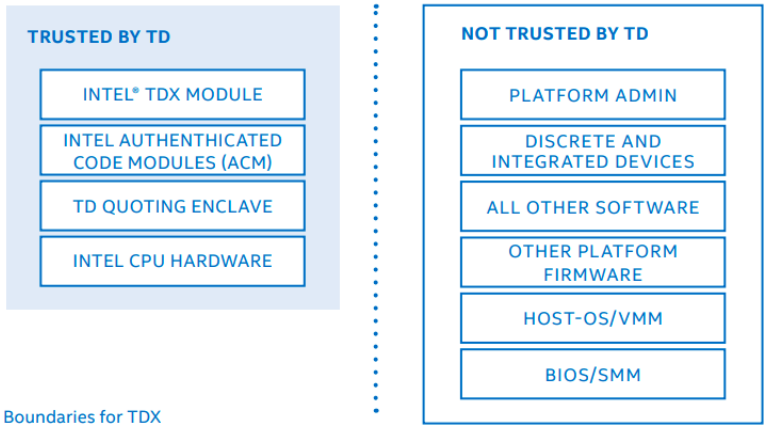

Figure 5.1. Trust Boundaries for TDX

Analysis

- Intel TDX: how do we precisely express trust boundaries?

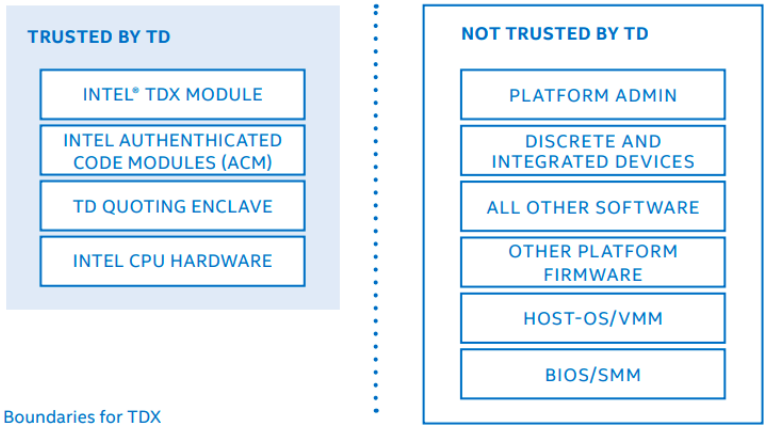

Figure 5.1. Trust Boundaries for TDX

- SCONE: when do we say that something is attested?

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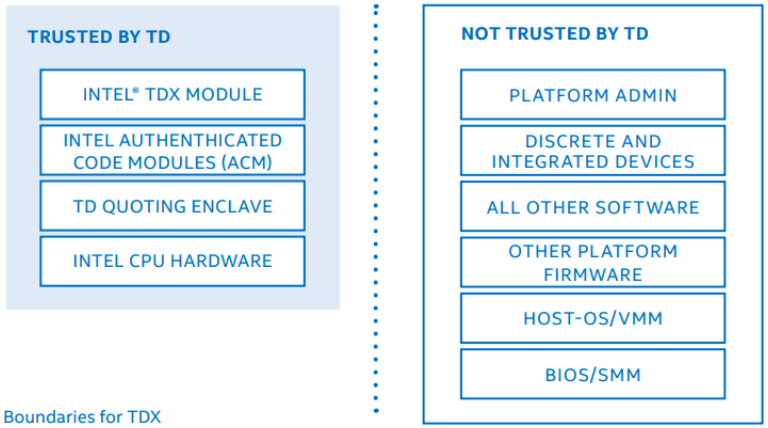

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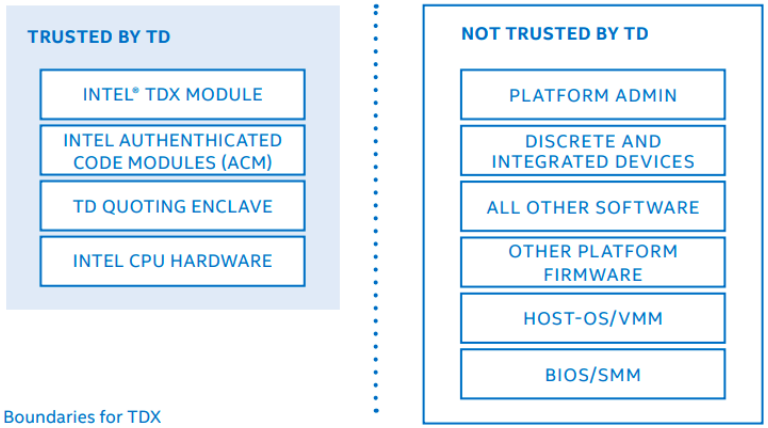

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- SCONE: when do we say that something is attested?
  - Challenge: closed-source nature of SCONE
- Arm CCA: authentication properties

```
query data : bitstring, sig : sign;
event (accepted(data, sig)) ==> inj-event (sent(data, sig)).
```
(3)

Outline

1. Introduction
   - Confidential Computing
   - Attestation
2. Approach
3. Symbolic Security Analysis
4. Security Analysis
5. Summary

Take-home

- Towards TEE-agnostic verification infrastructure for transparency and interoperability

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  - Provisioning protocols not well-understood
  - Analysis and categorization of Claims

Key References


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Contributions/collaborations welcome