Formal Abstractions for Attested Execution Secure Processors

Eurocrypt

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CORNELL TECH

Trusted hardware:
Different communities, different world views

Crypto

- "Minimal" trusted hardware to circumvent theoretical impossibilities
- Little concern about practical performance

Architecture + **Systems & Security**

- Trusted execution of "general-purpose" user-defined progs
- Cost-effectiveness, reusability, expressivity

Architecture community converged on "attested execution"

Bastion

GhostRider

Iso-X

Ascend

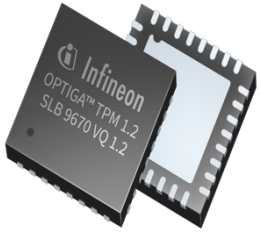
Sanctum

Aegis

Phantom

XOM

Academia



TPM

Intel® SGX

TrustZone®
Security Foundation by ARM®

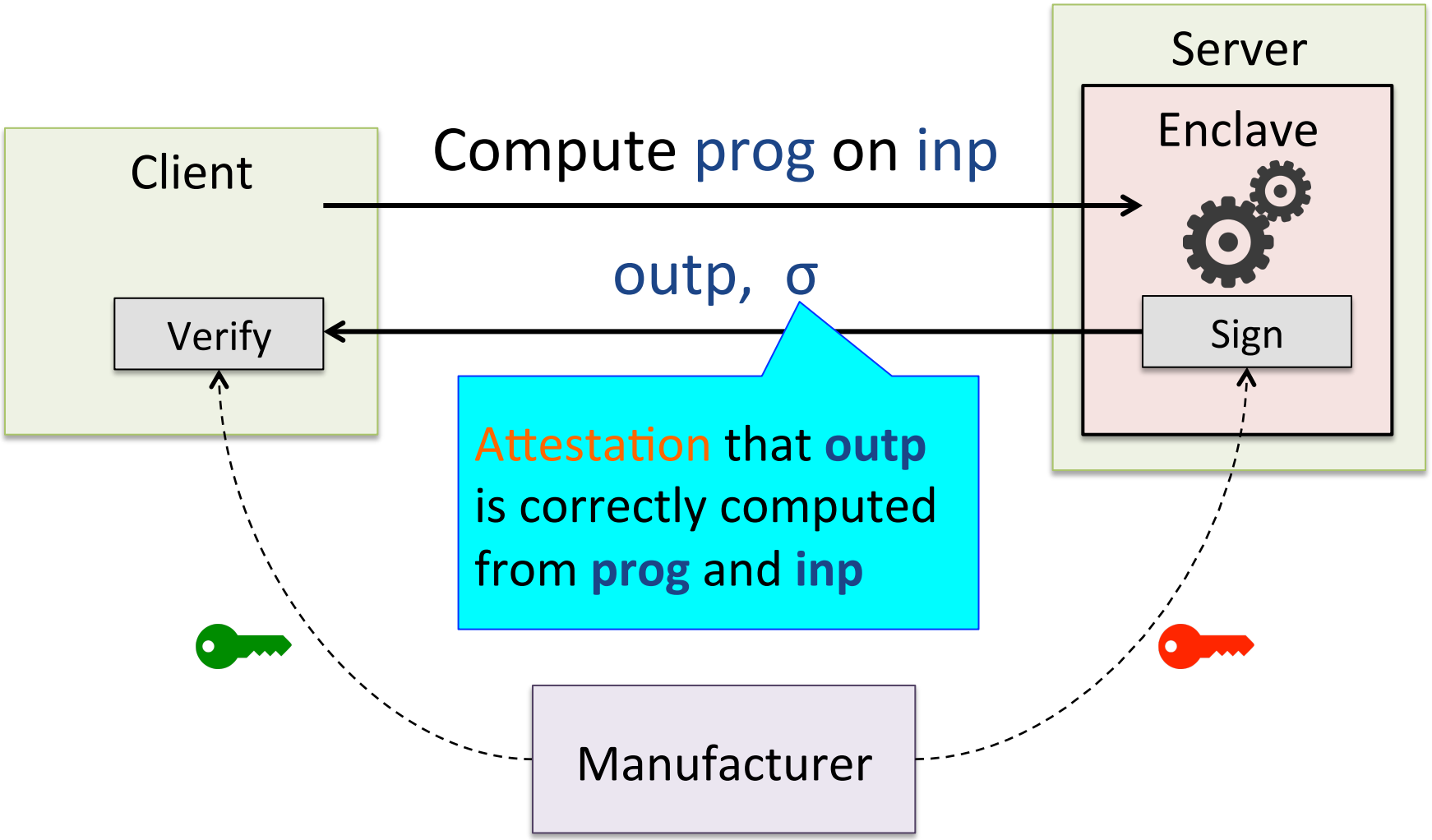
Industry

Architecture community converged on "attested execution"

What is "attested execution" ?

What can it (not) express?

Attested Execution



Why Ideal Abstractions?

- Formal security proofs for implementations from precise abstractions and security models

- **Ultimate Goal:** Formally verified processor implementing this formal abstraction

Formal Model

Signature scheme

Registry of all platforms with trusted hardware

$\mathcal{G}_{att}[\Sigma, reg]$

`init()`:  ,  ⟵ Σ.KeyGen(1^λ)

`getpk()` from P: send  to P

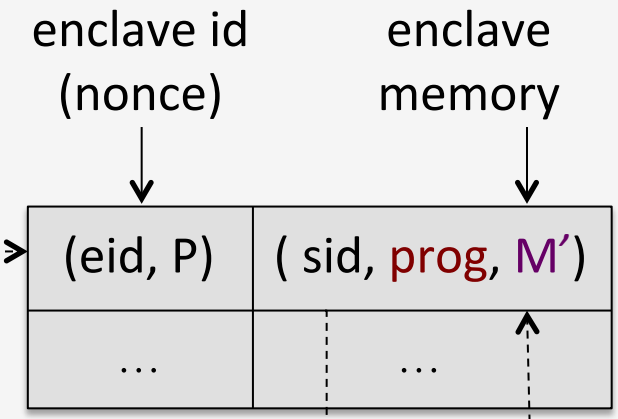
`install`(prog, sid) from P ∈ reg:

`resume`(eid, inp) from P ∈ reg:

(out, M') = prog(inp, M)

σ = Σ.Sign( , eid, sid, prog, out)

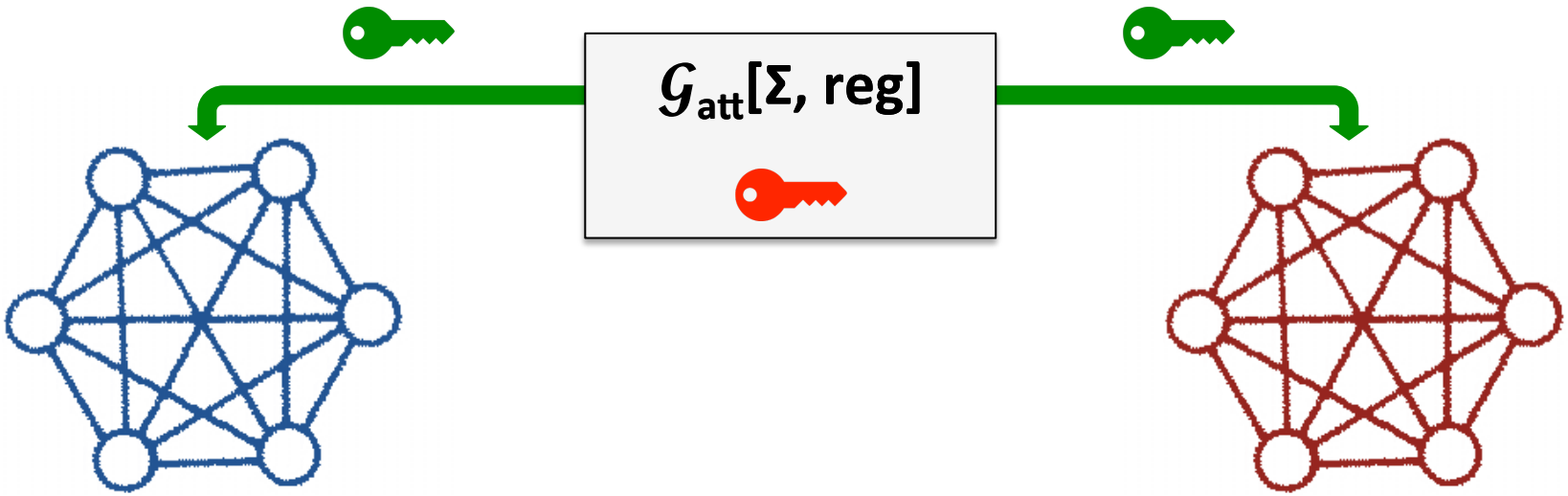
send (out, σ) *to P*



Composability with Global State

Model $\mathcal{G}_{\text{att}}$ as *global* ideal functionality [CDPW'07]

Attestation key is ***shared*** across protocols

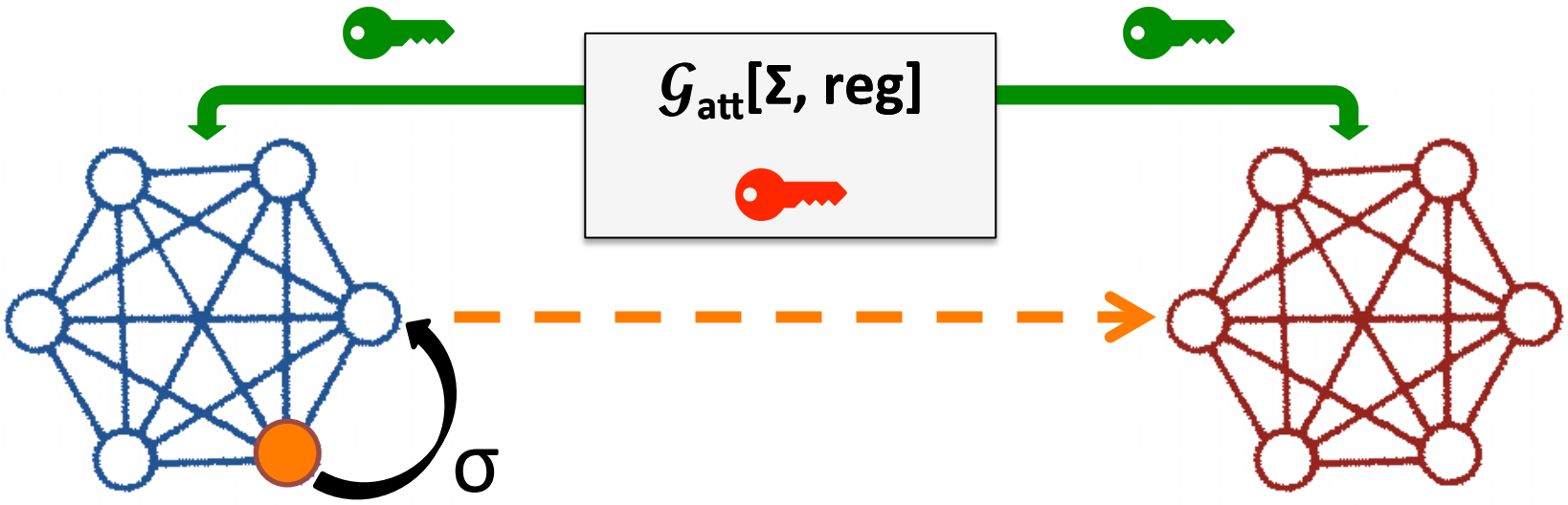


Composability with Global State

Model $\mathcal{G}_{\text{att}}$ as *global* ideal functionality [CDPW'07]

Example of concrete security issue:

Non-deniability for parties in **reg**



The more interesting question

What is “attested execution” ?

What can it **(not)** express?

The good

Powerful Abstraction!

$\mathcal{G}_{att}$ → **"Stateful Obfuscation"**

Impossible even with stateless tokens and cryptographic obfuscation

The surprise

UC-Secure MPC?

☑ It's Complicated

The good

Powerful Abstraction!

G_{att} → **"Stateful Obfuscation"**

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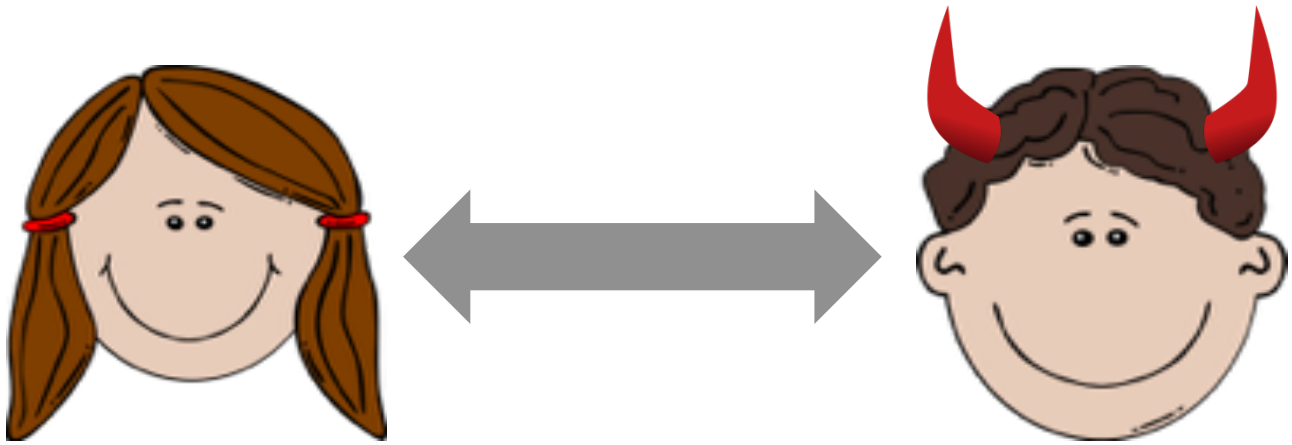
The surprise

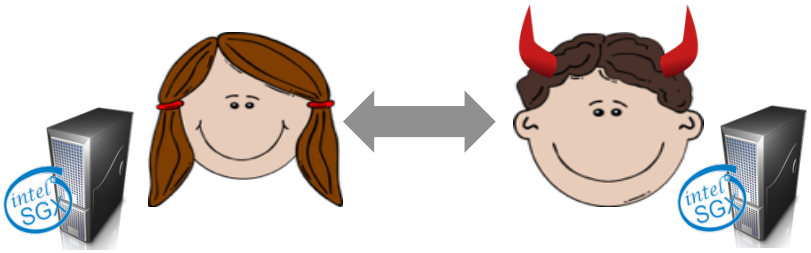
UC-Secure MPC?

☑ It's Complicated

Consider 2PC



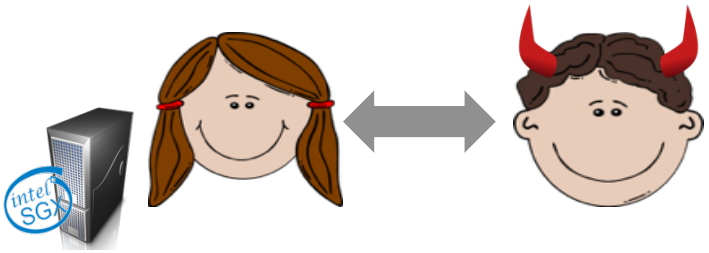
Consider 2PC



UC-secure 2PC possible if both parties have trusted hardware

Impossible if only one party has trusted hardware!

Consider 2PC



This is counter-intuitive.

Impossible if only one party has trusted hardware!

Issue: non-deniability

Convinced that
some honest party in the registry
participated in the protocol

σ

σ under **global** **pk**

Non-issue if all nodes have trusted hardware or if pk isn't global

Convinced that
some honest party in the registry
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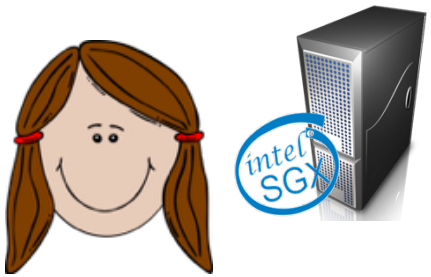
σ



σ under **global pk**

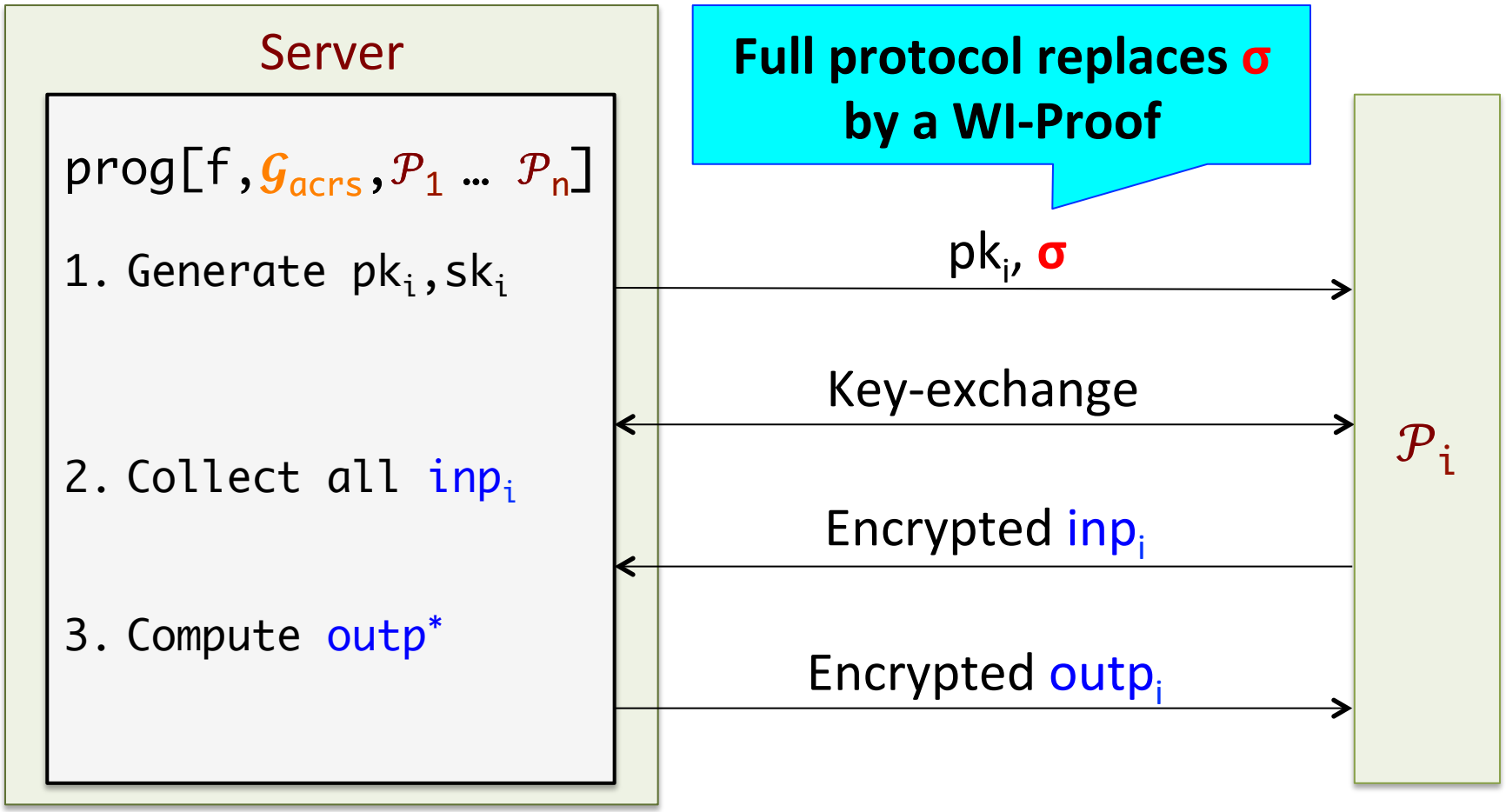
What if we **really really** want to use a single trusted processor?

Extra setup assumption: Augmented CRS

UC-Secure MPC with *O(1) crypto operations*

Backdoor enclave program: allow simulator to *extract inputs* and *program the outputs* for corrupt parties

What if we **really really** want to use a single trusted processor?



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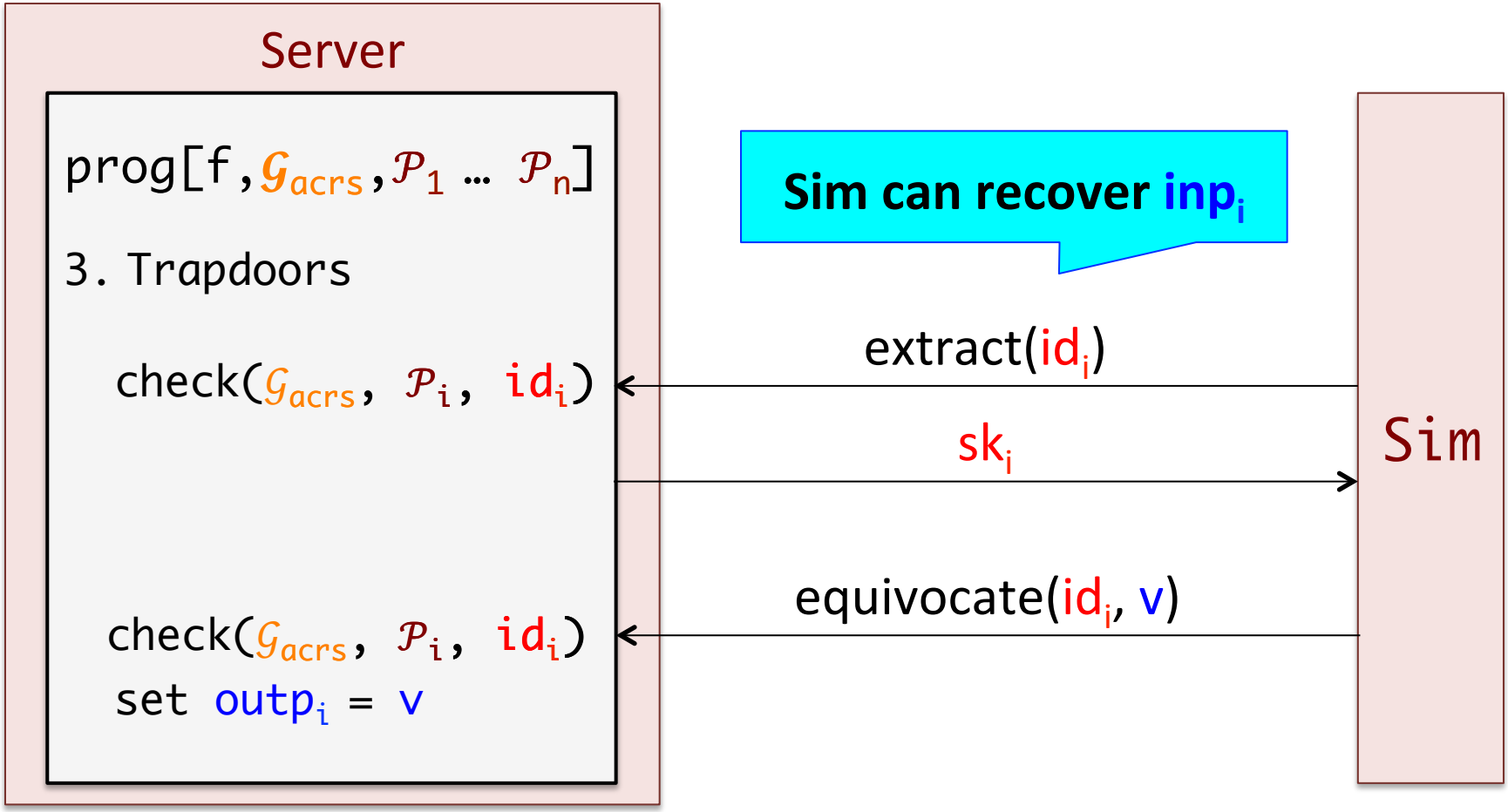


Can trusted hardware help with fairness?

- Fairness impossible for general functionalities in plain model [Cleve86]

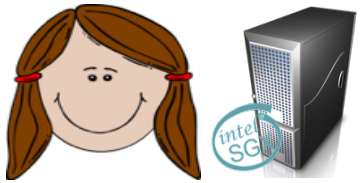
Fair 2PC

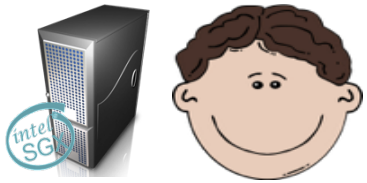
UC-Secure Fair 2PC

Enhanced model: Clock-aware secure processor

- Fair 2PC possible if both parties have clock-aware secure processors

- Fair coin-tossing possible if one party has clock-aware secure processors (+ ACRS)





Enclaves establish secure channel

Enclaves exchange inputs and compute outputs

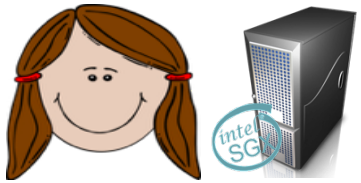
"Will release to Alice in 2^{λ} time"

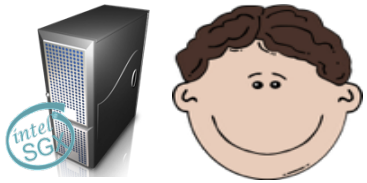
"Will release to Bob in 2^{λ} time"

"Will release to Alice in $2^{\lambda-1}$ time"

"Will release to Bob in $2^{\lambda-1}$ time"

...





Enclaves establish secure channel

If Alice learns result at time $t < 2^{\lambda}$,
Bob will learn it at the latest by time $2t$

+ no "wasted" computation!

"Will release to Alice in $2^{\lambda-1}$ time"

"Will release to Bob in $2^{\lambda-1}$ time"

…

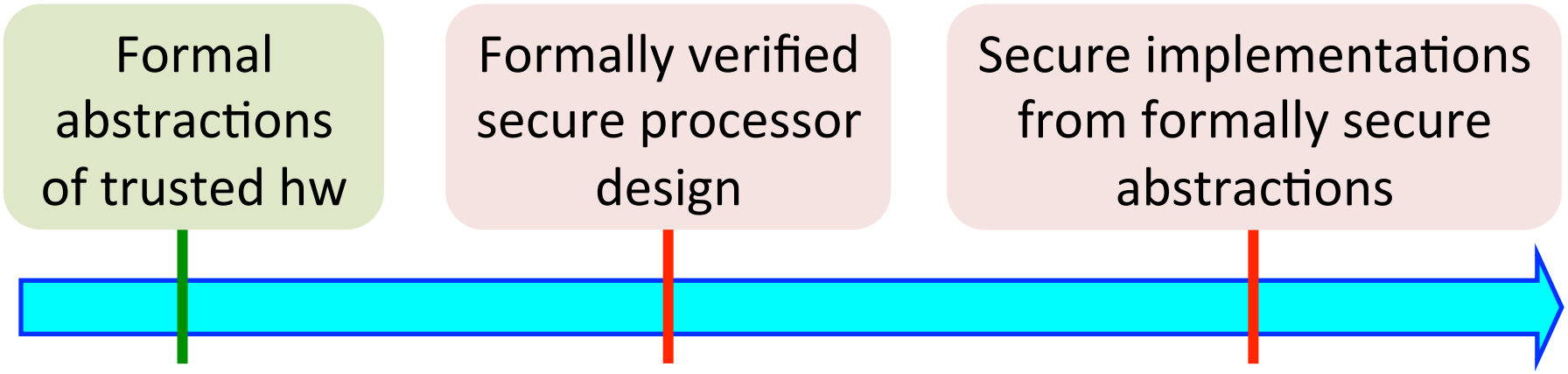
What next?

Attested execution is a powerful assumption

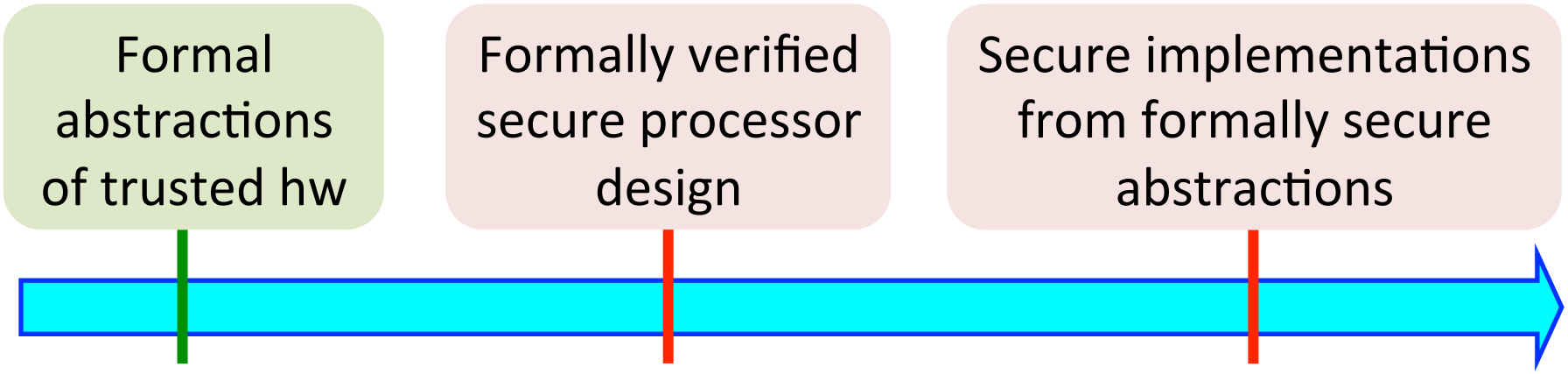
$\Longrightarrow$ Stateful Obfuscation, Efficient MPC, Fair 2PC

Subtle issues unless *all parties have trusted hardware*

$\Longrightarrow$ Non-deniability, Extra setup assumptions



Thank You


Formal abstractions of trusted hw
Formally verified secure processor design
Secure implementations from formally secure abstractions