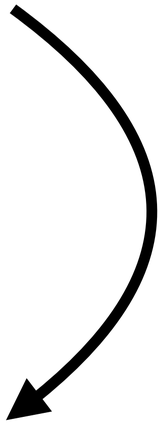
Let Attackers Program Ideal Models:
Modularity and Composability for Adaptive Compromise

Joseph Jaeger

Georgia Tech College of Computing
School of Cybersecurity and Privacy

2 Second Summary

SIM-AC definitions
[Jaeger, Tyagi C'20]



SIM*-AC definitions
[this work]

2 Second Summary

SIM-AC definitions
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Key Differences:

- Simulator **explicitly** program ideal model
- **Attacker** allowed to program ideal model
- Universal quantification of simulator

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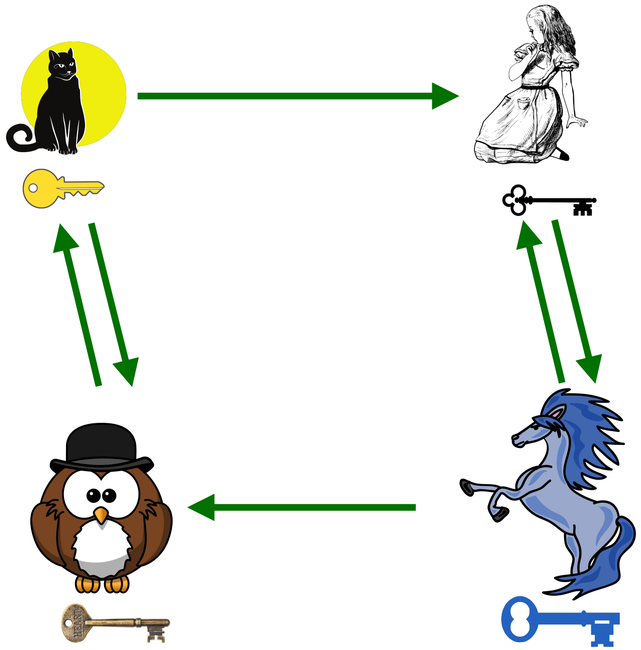
Adaptive Compromise Setting

(See also: Adaptive Corruptions/Security, Selective Opening Attacks, Non-committing encryption…)



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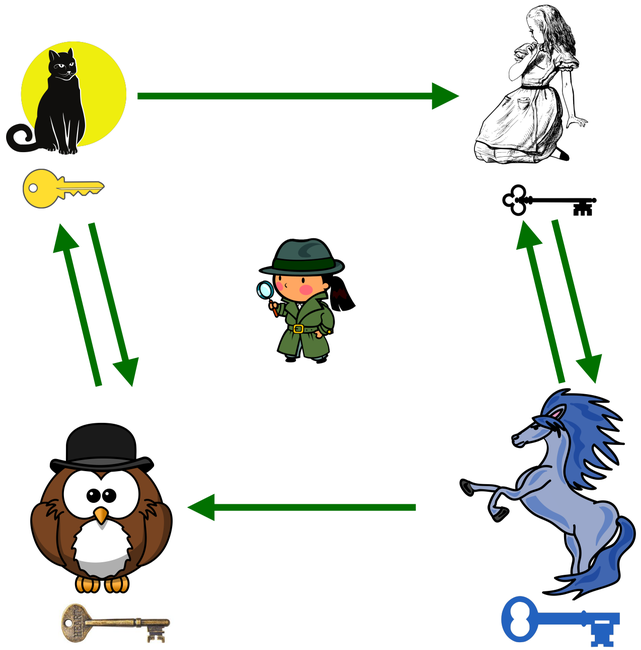

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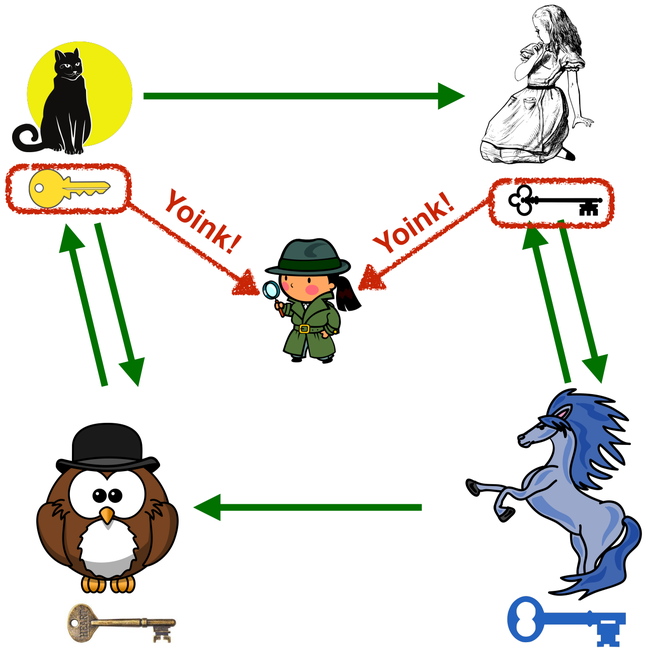

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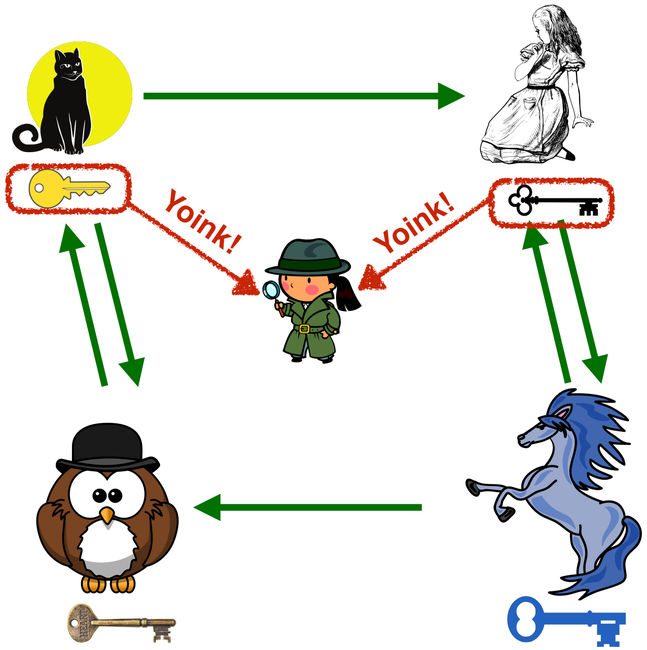

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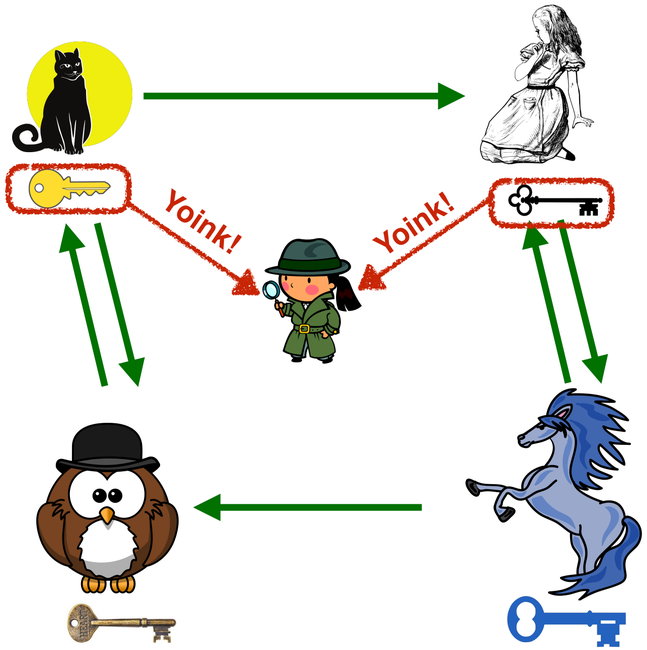

Arises in many settings

Primitives: Secure Computation, Commitment Schemes, Encryption, PRFs…

Definitional Frameworks: Game-based, Simulation-based (UC, CC, …)

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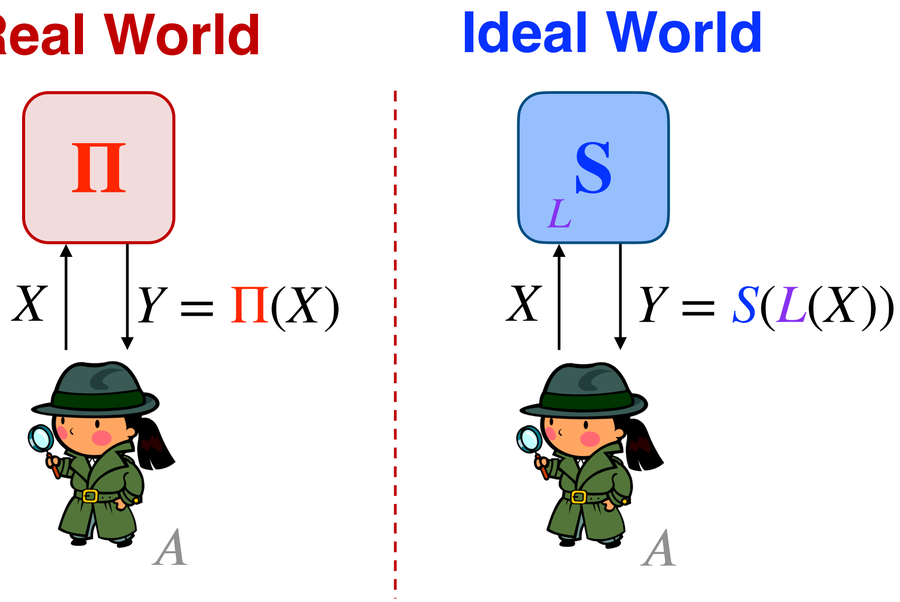
SIM-AC Definitions [Jaeger, Tyagi C'20]

Online Simulation Setting



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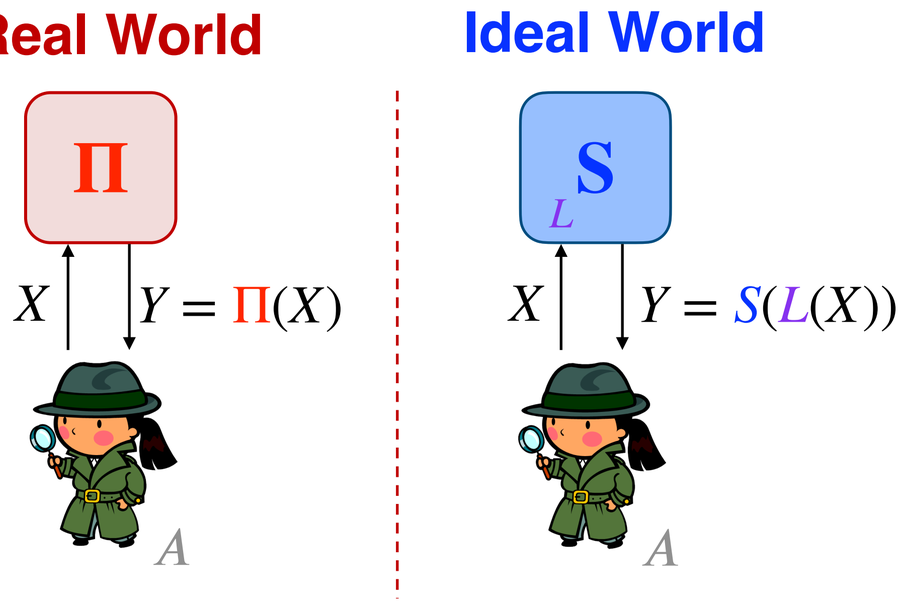

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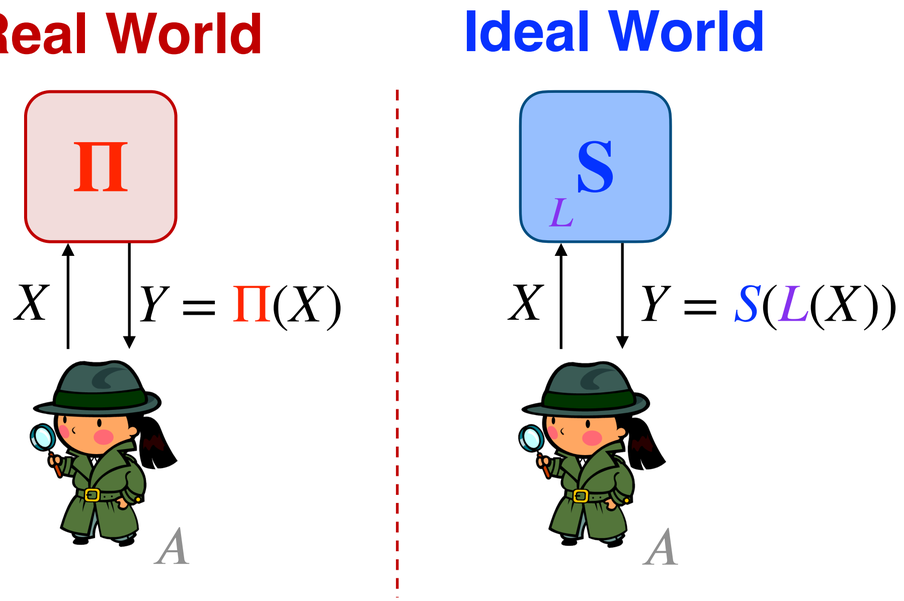

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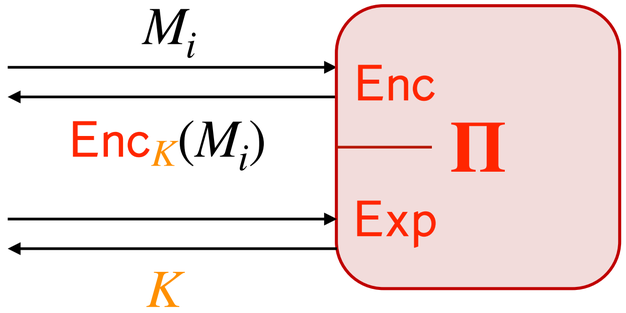
Symmetric Encryption (SIM-AC-CPA)

Real World



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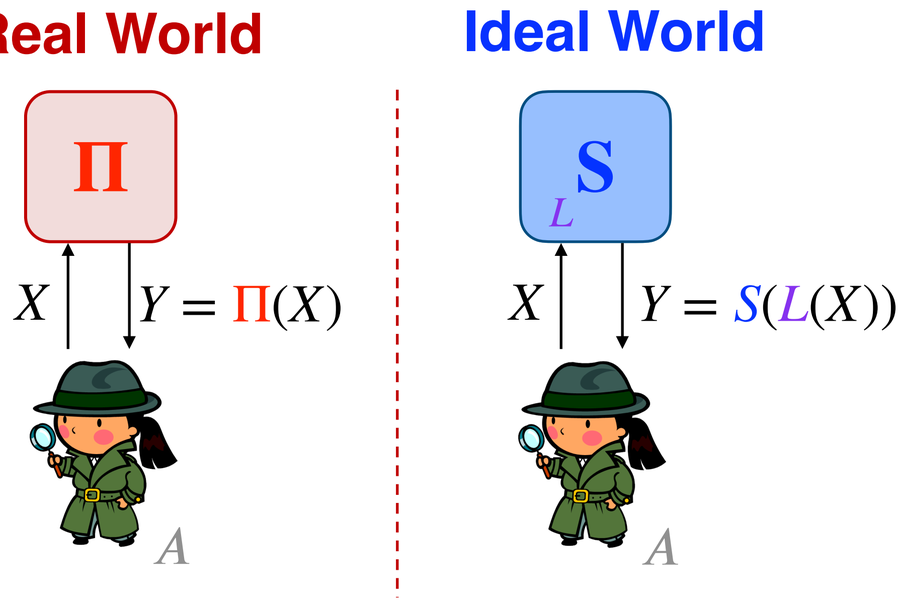

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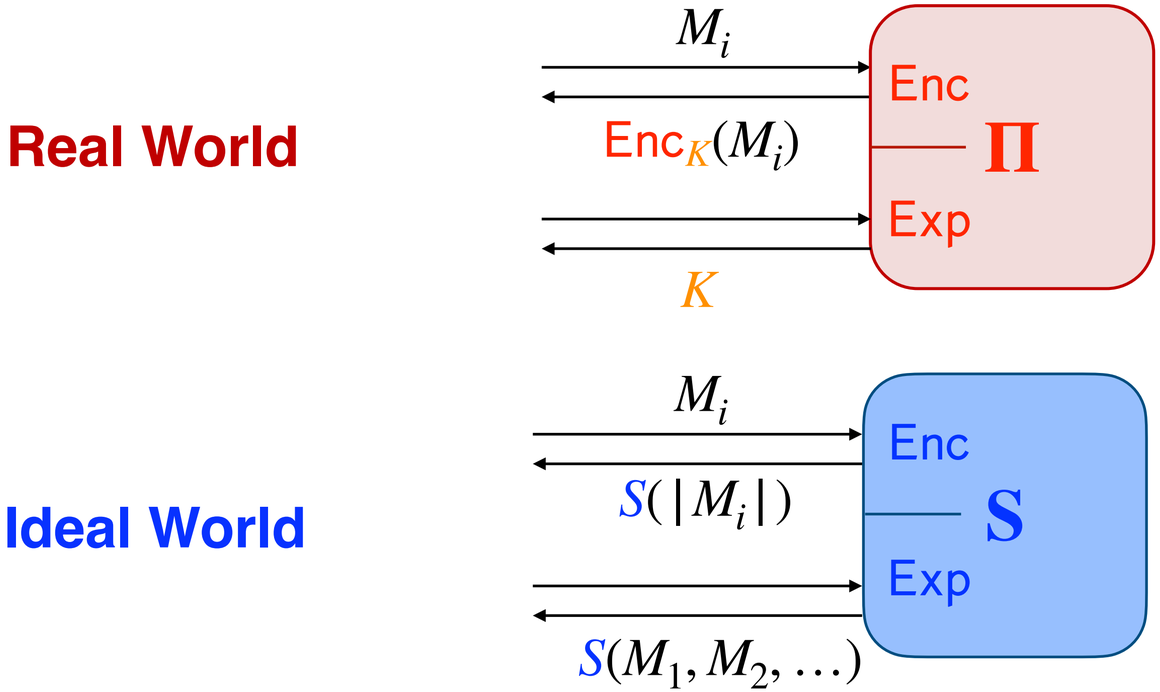

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Pseudorandom Function (SIM-AC-PRF)

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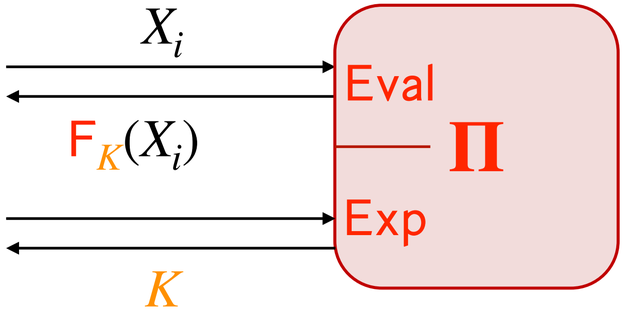

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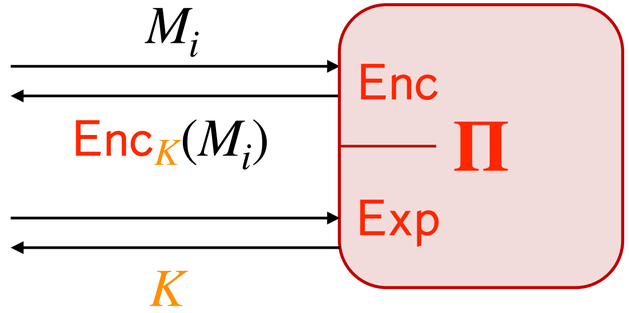

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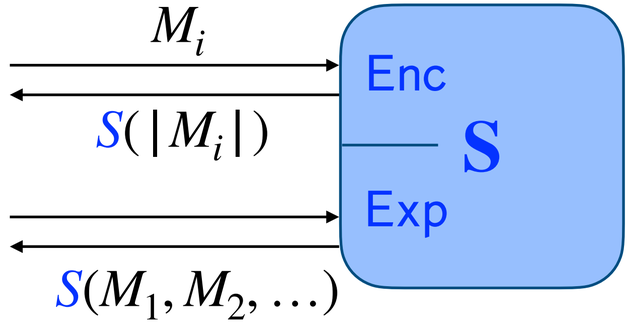

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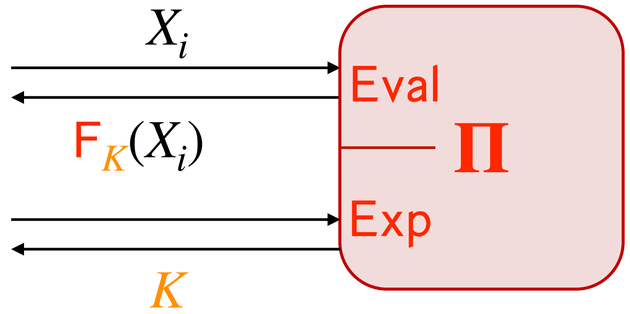

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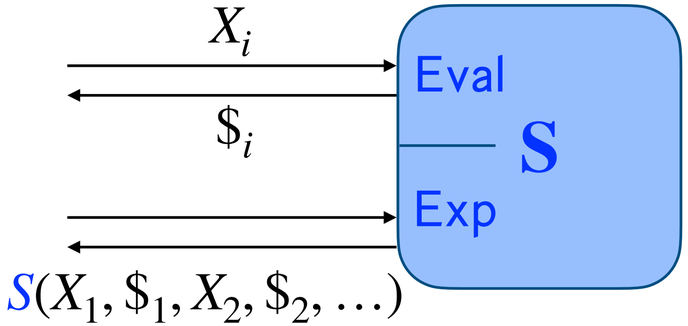

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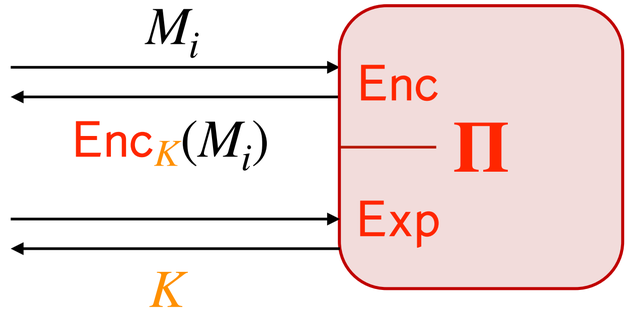

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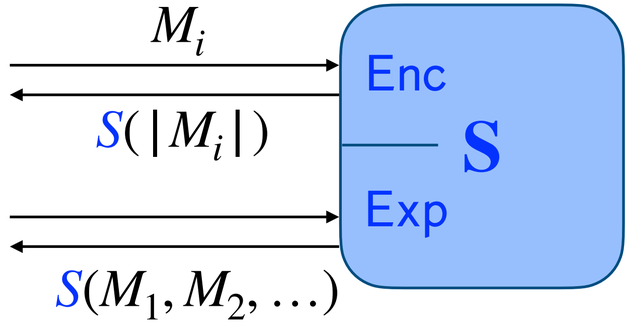

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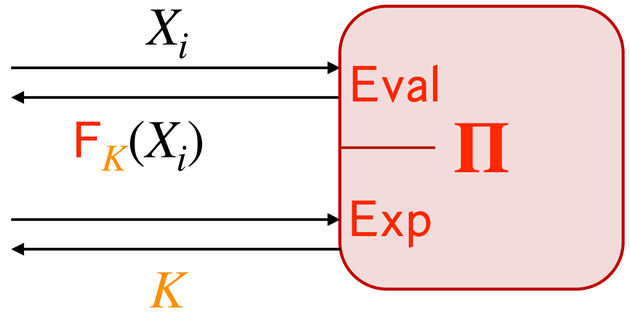

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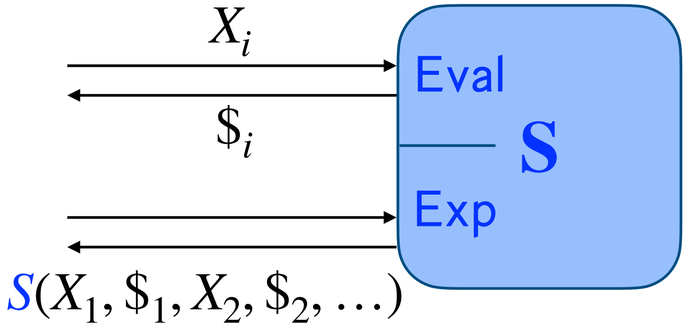

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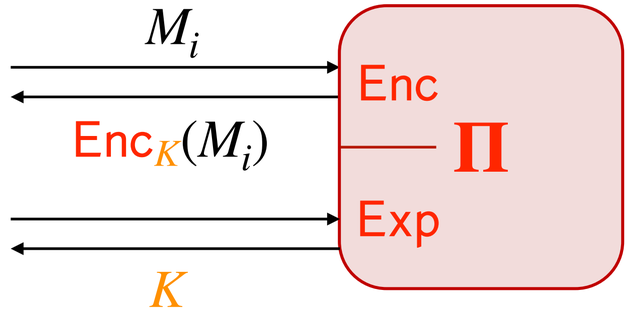

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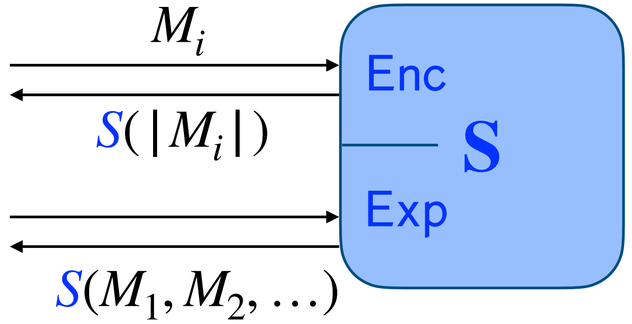

Not shown:

Requires ideal model. [Nielsen C'02]

Multi-user definitions.

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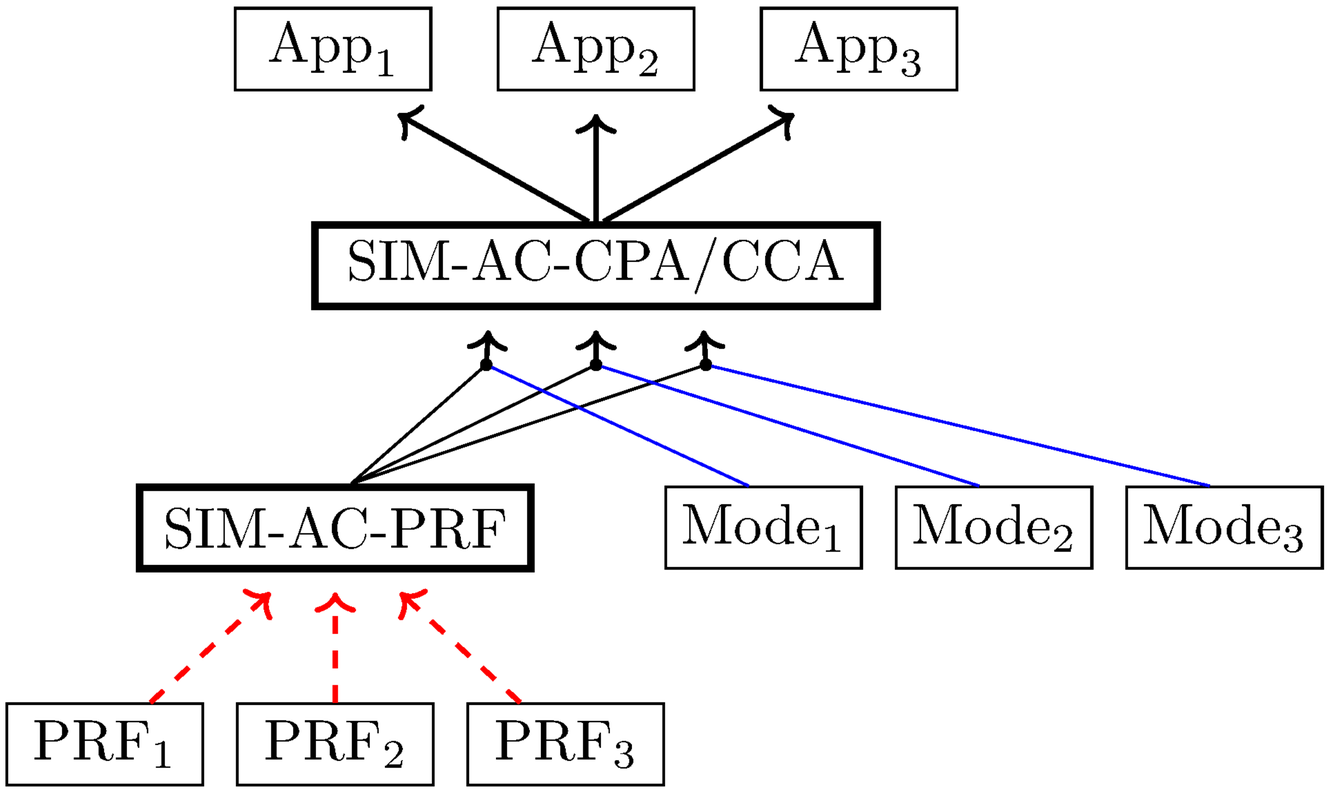
Benefits of SIM-AC [Jaeger, Tyagi C'20]



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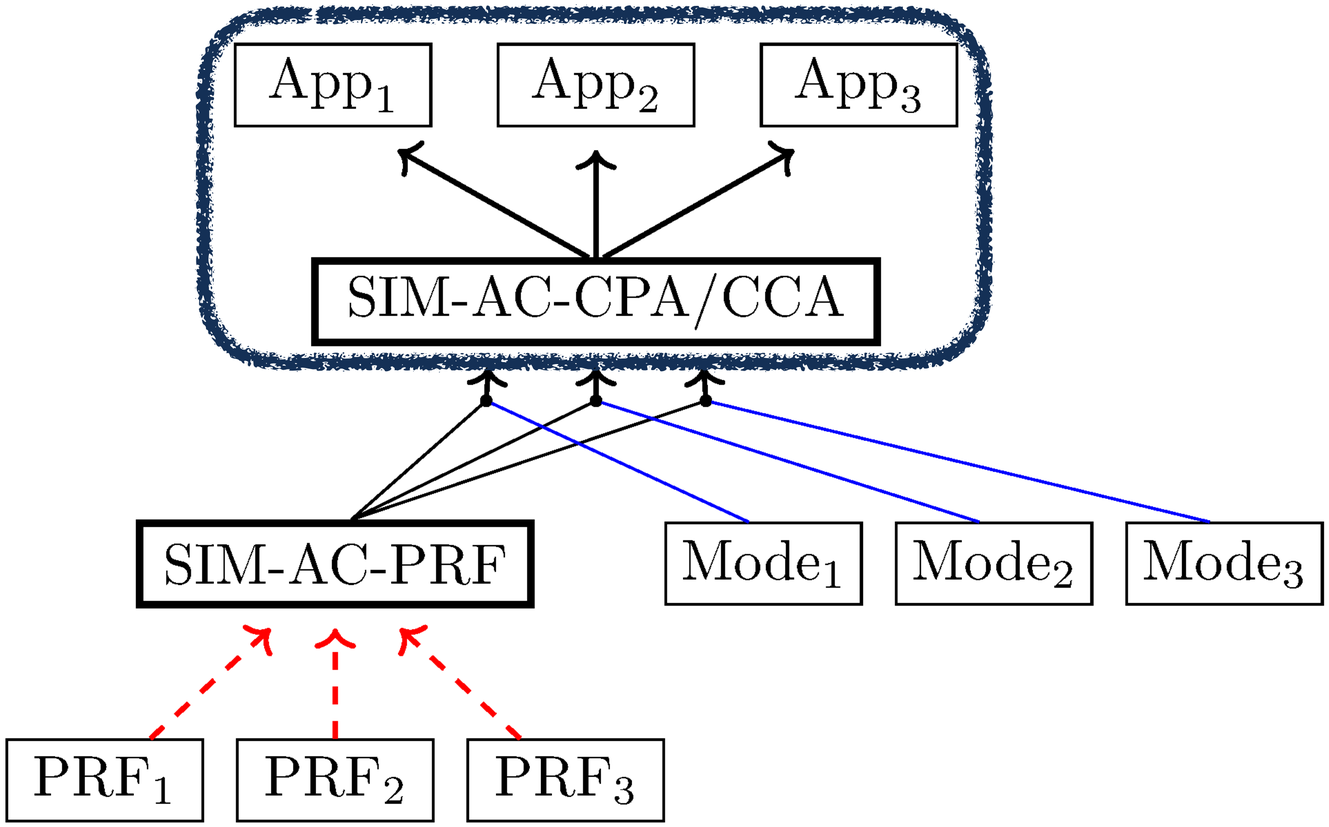

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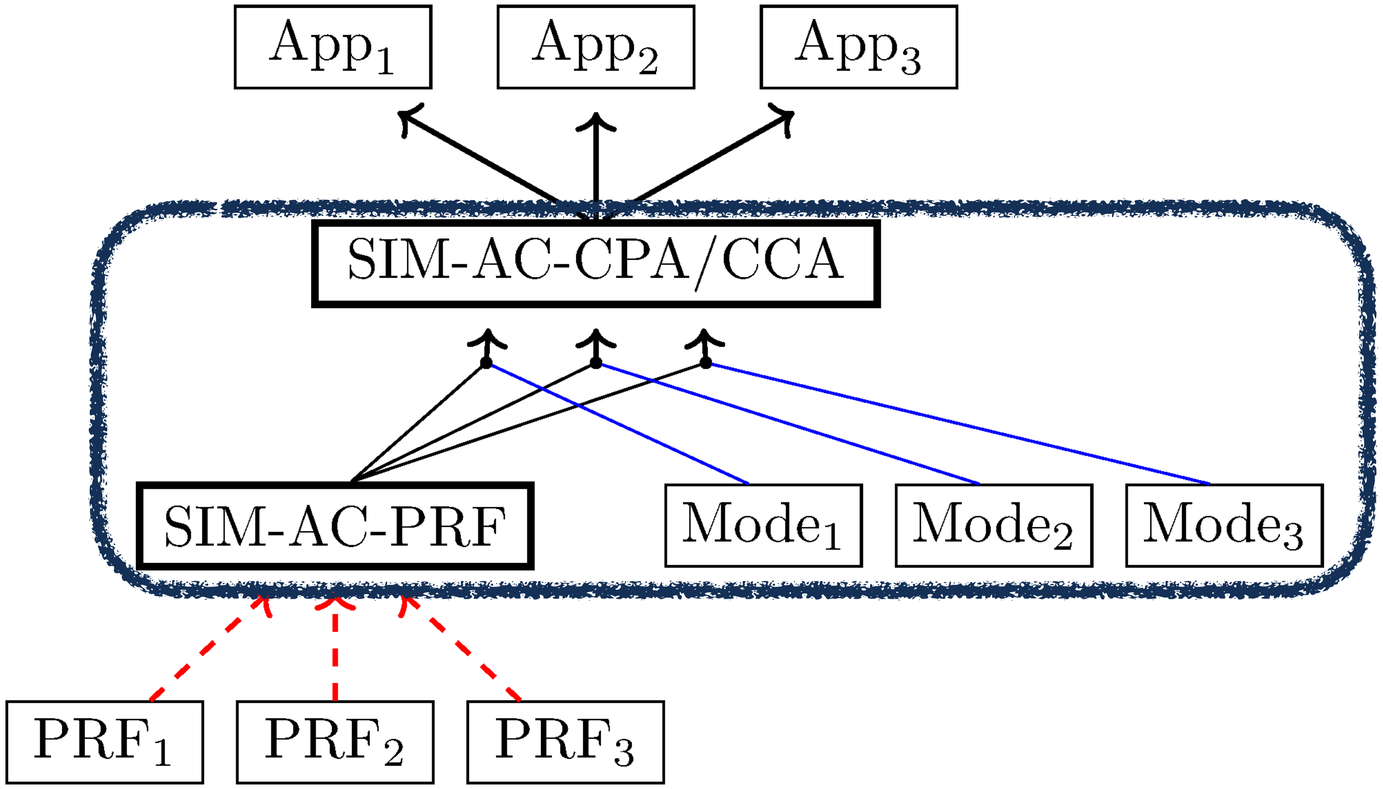

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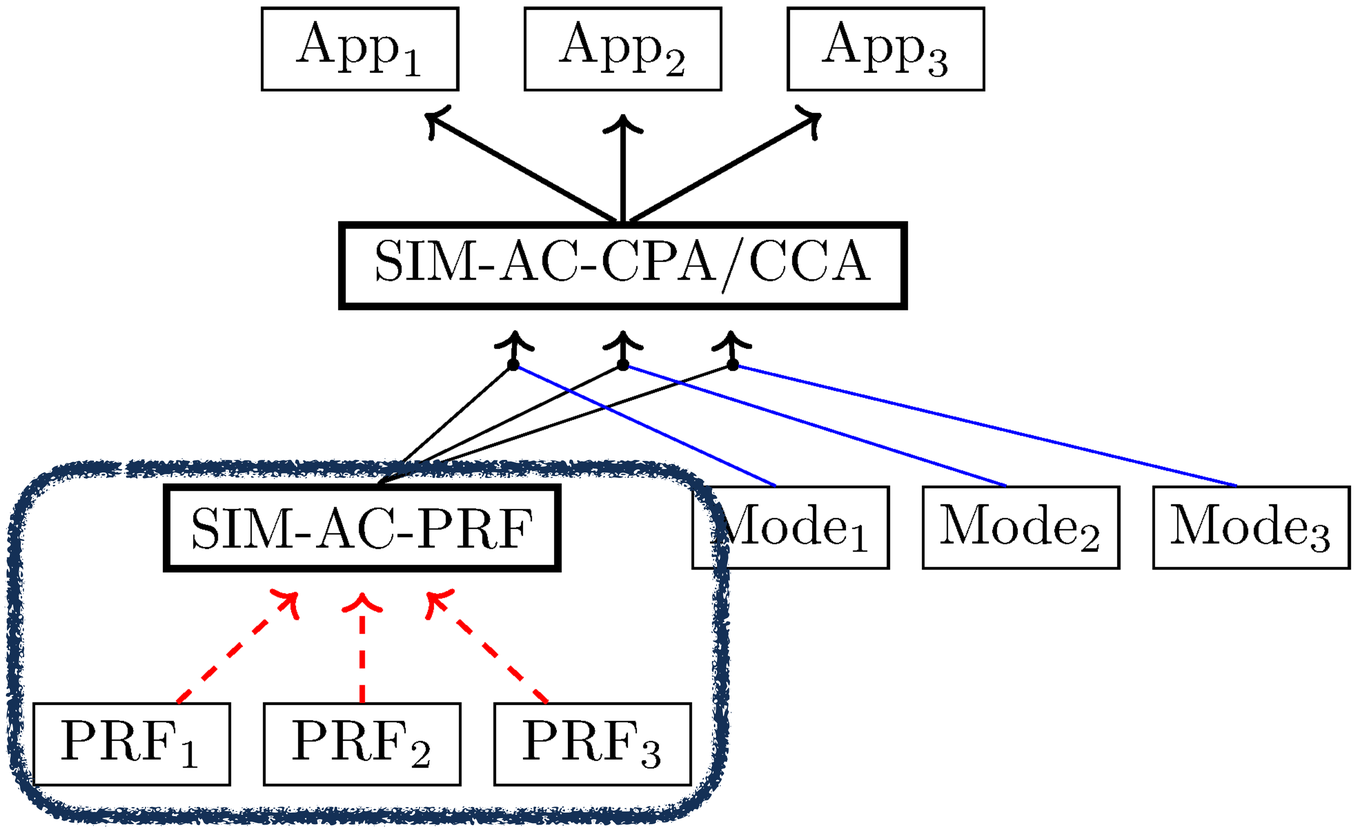

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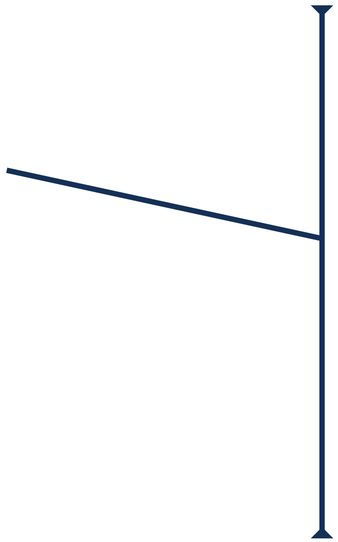

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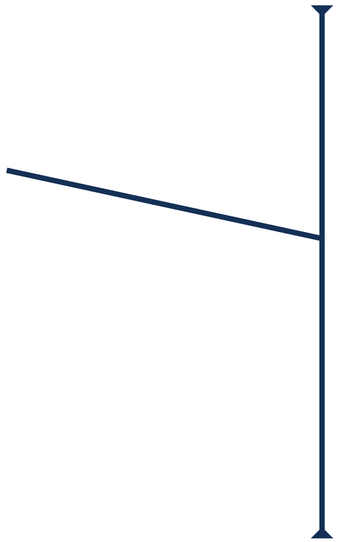

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4. SIM*-AC for **asymmetric encryption**.
   - Comparisons to prior definitions
   - KEM/DEM hybrid encryption
   - Fujisaki-Okamoto style transforms

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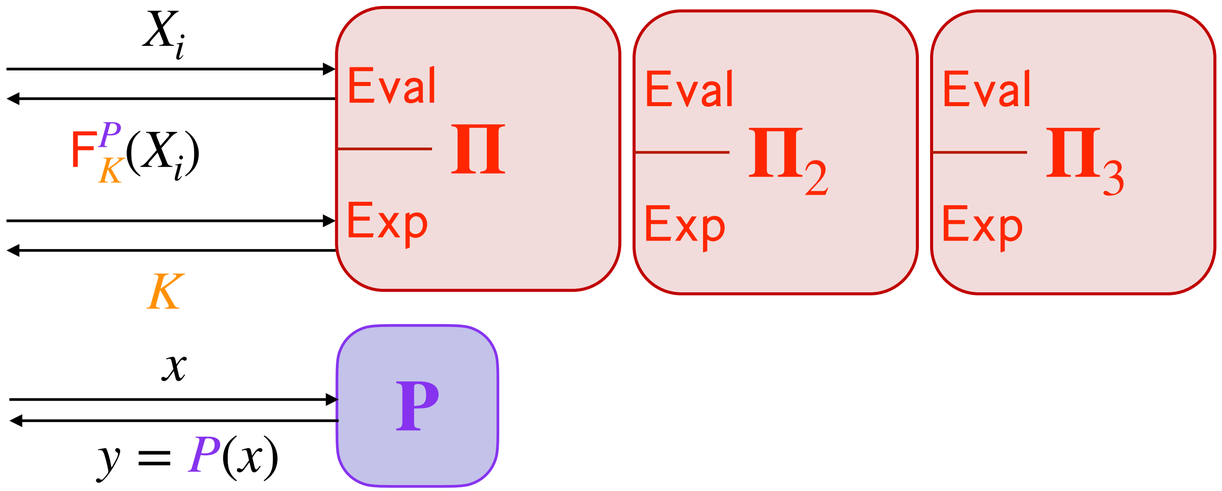

SIM-AC-PRF

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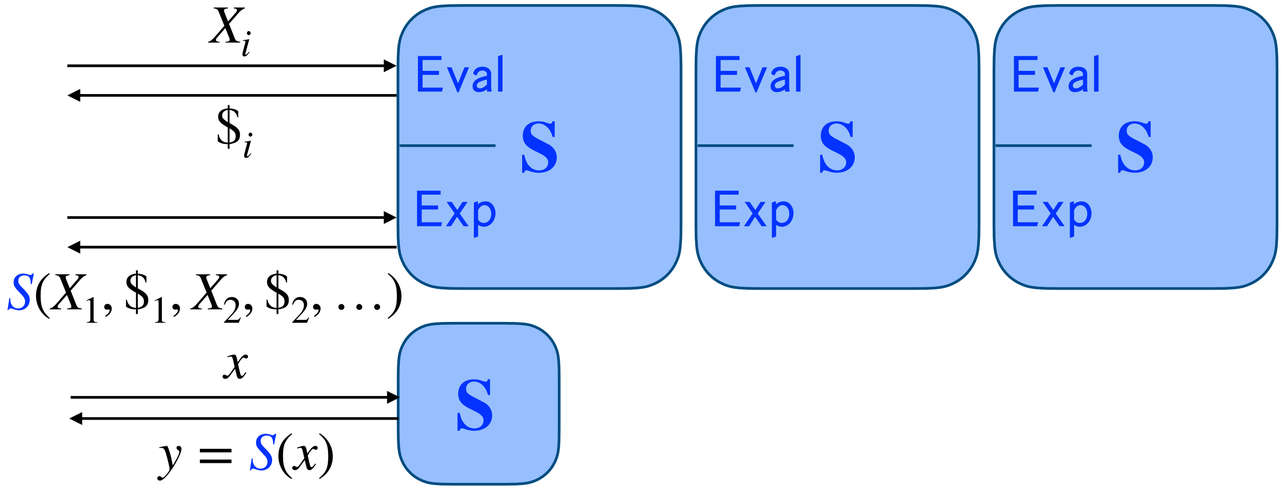

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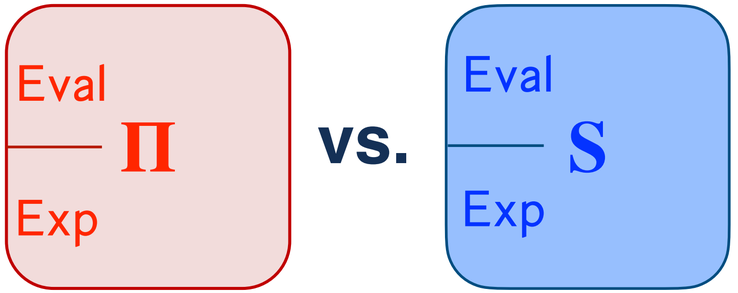

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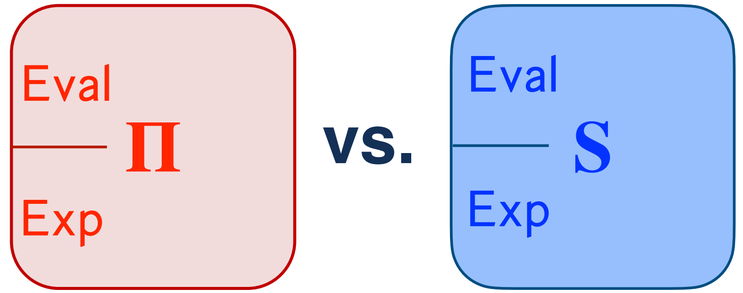

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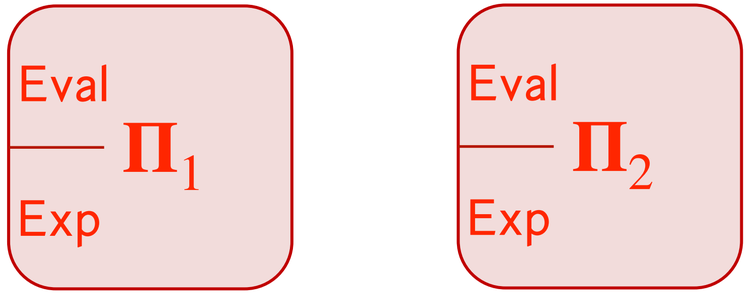

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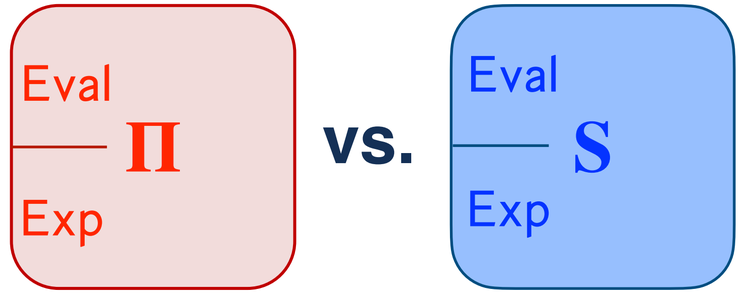

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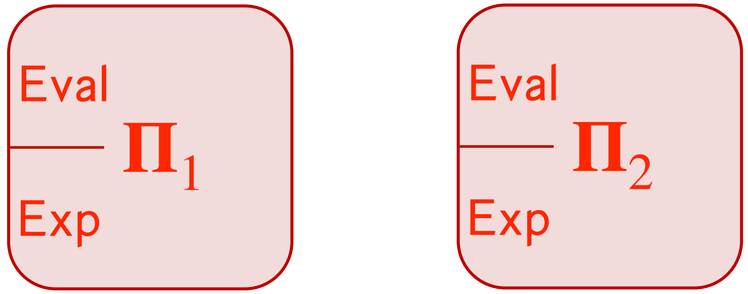

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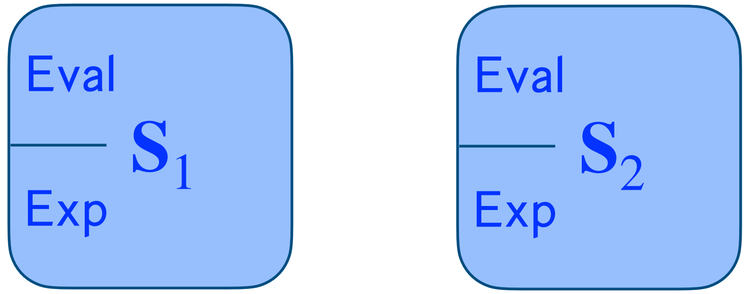

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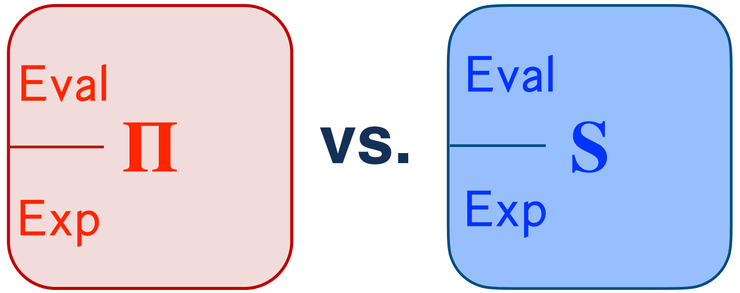

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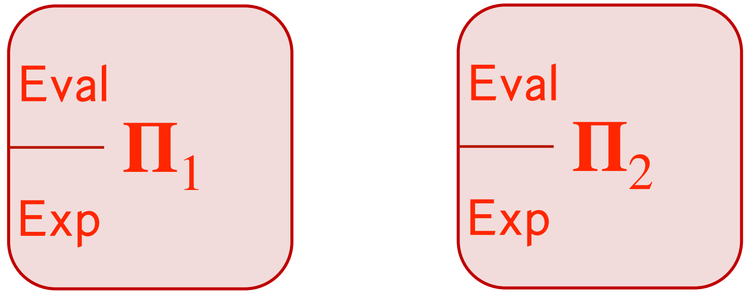

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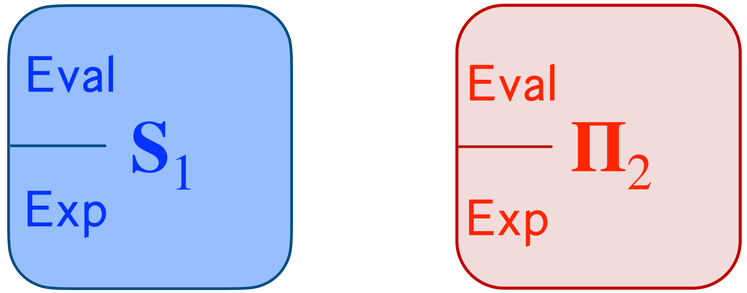

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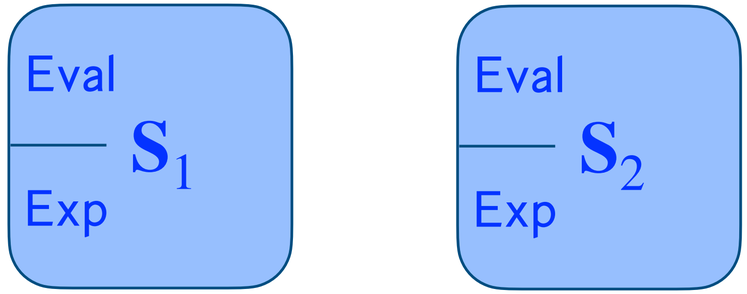

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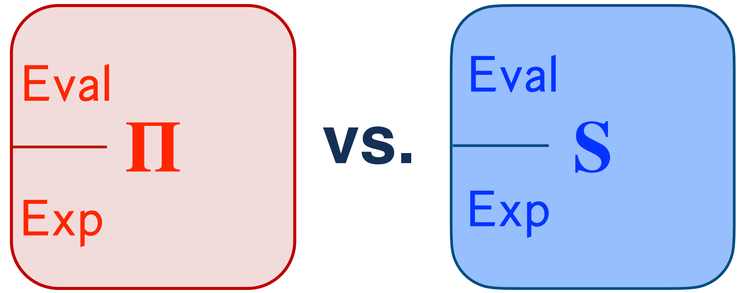

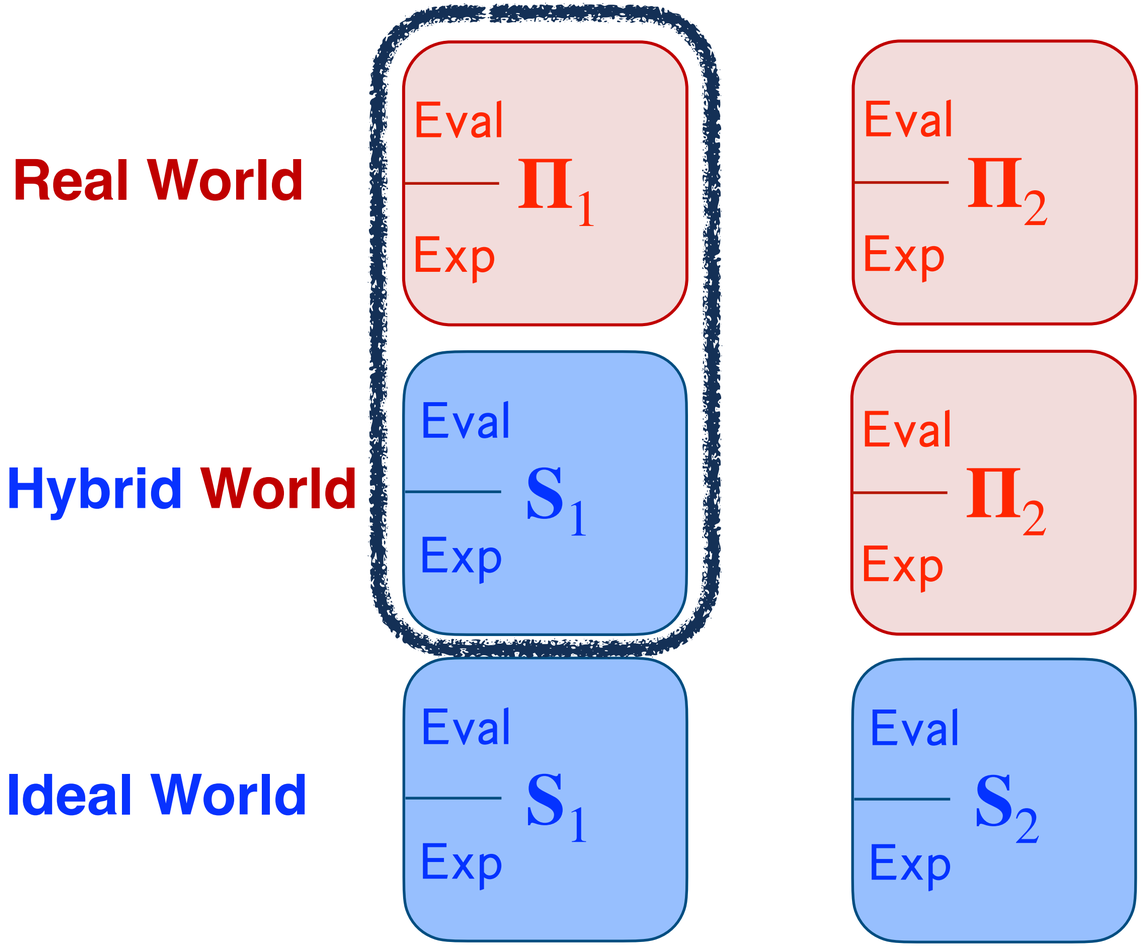

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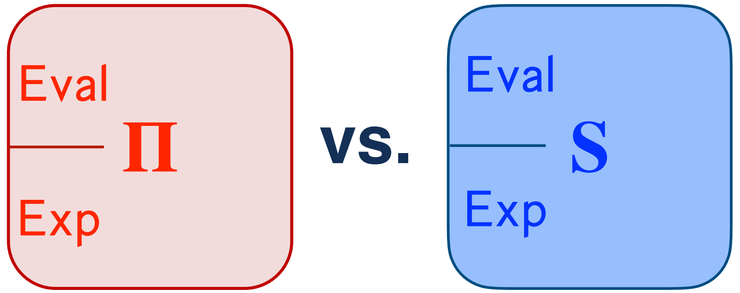

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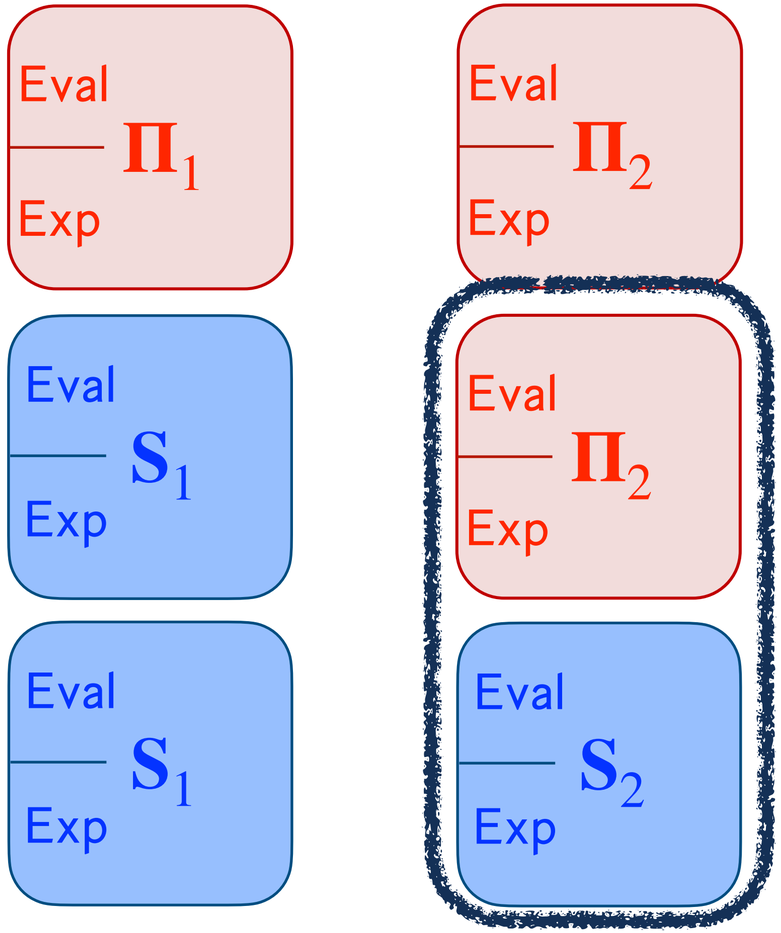

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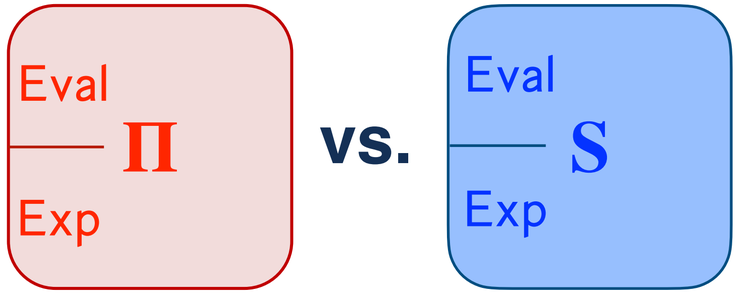

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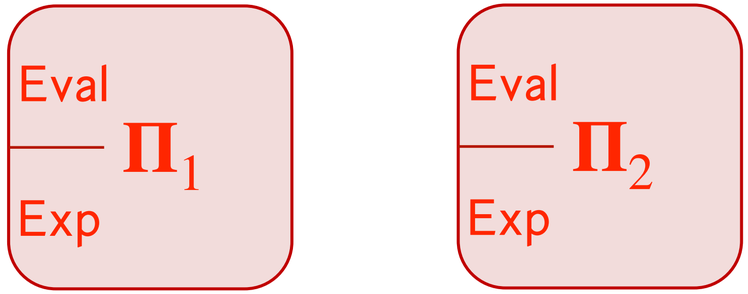

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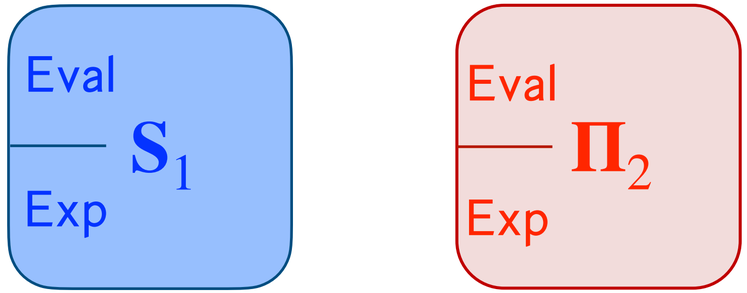

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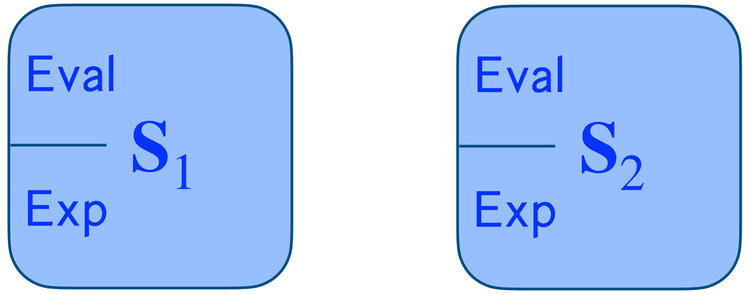

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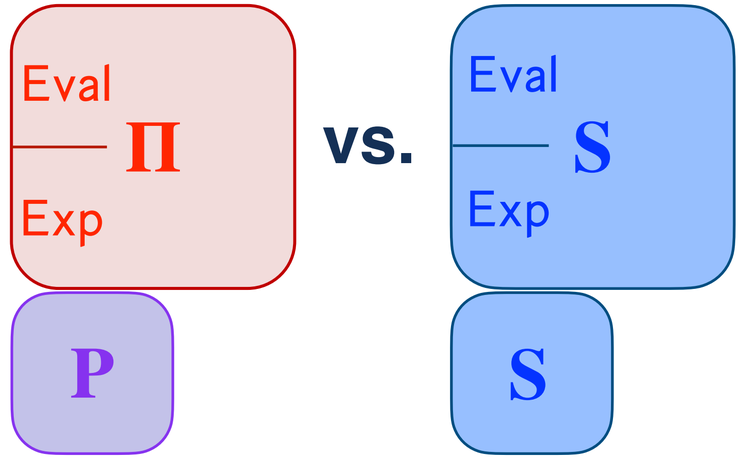
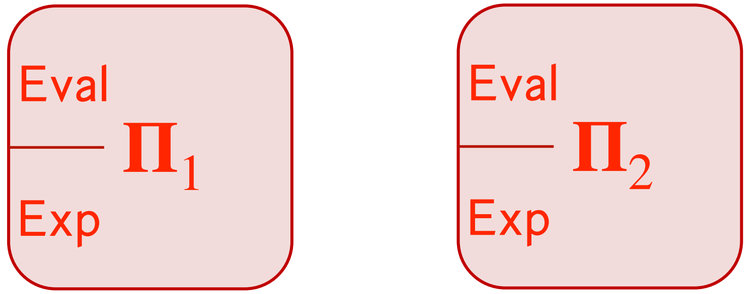
1. SIM-AC Shortcomings

Does single-user security → multi-user security?



Real World



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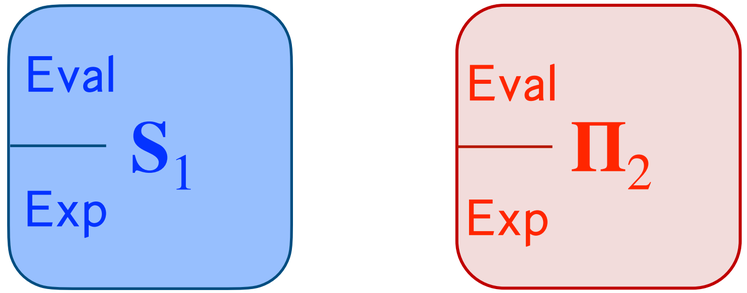

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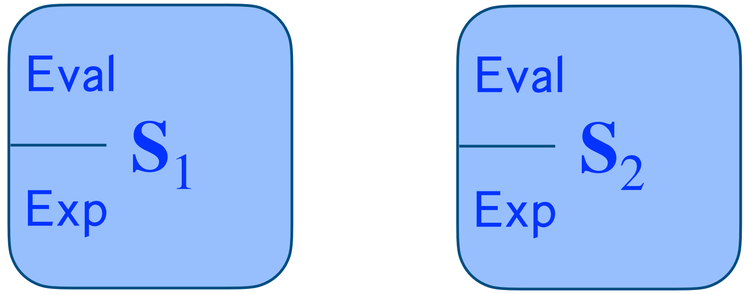

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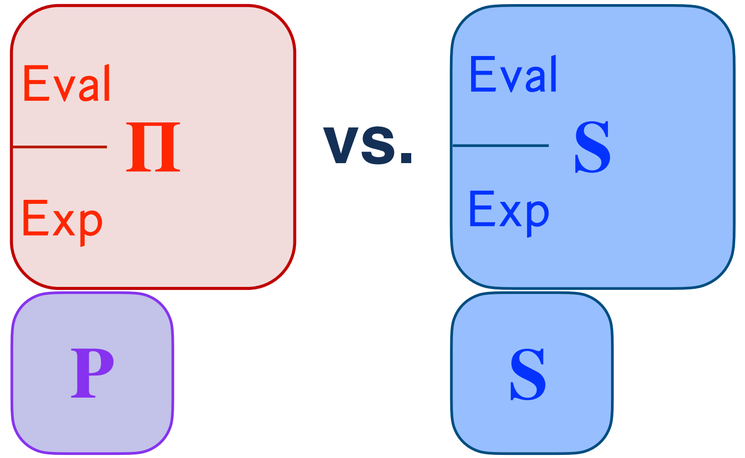

Real World

Hybrid World

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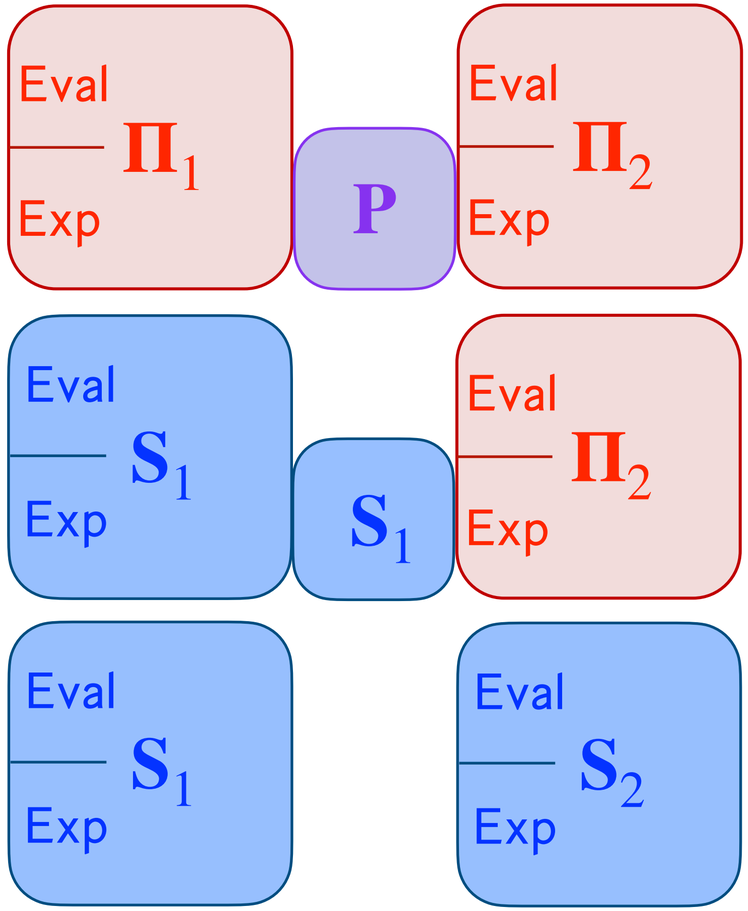

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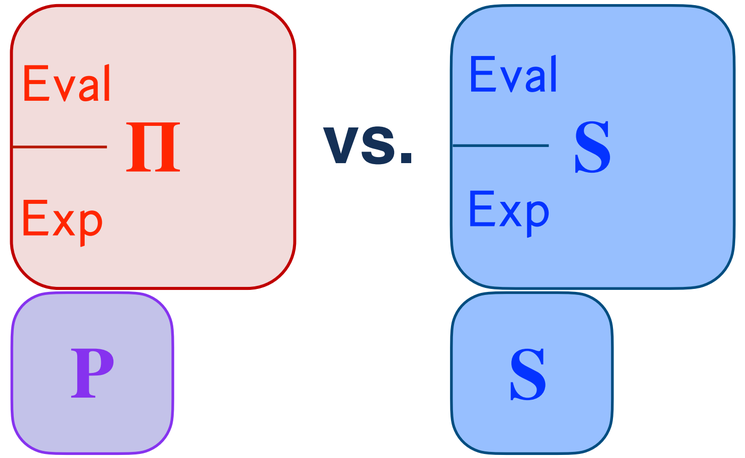

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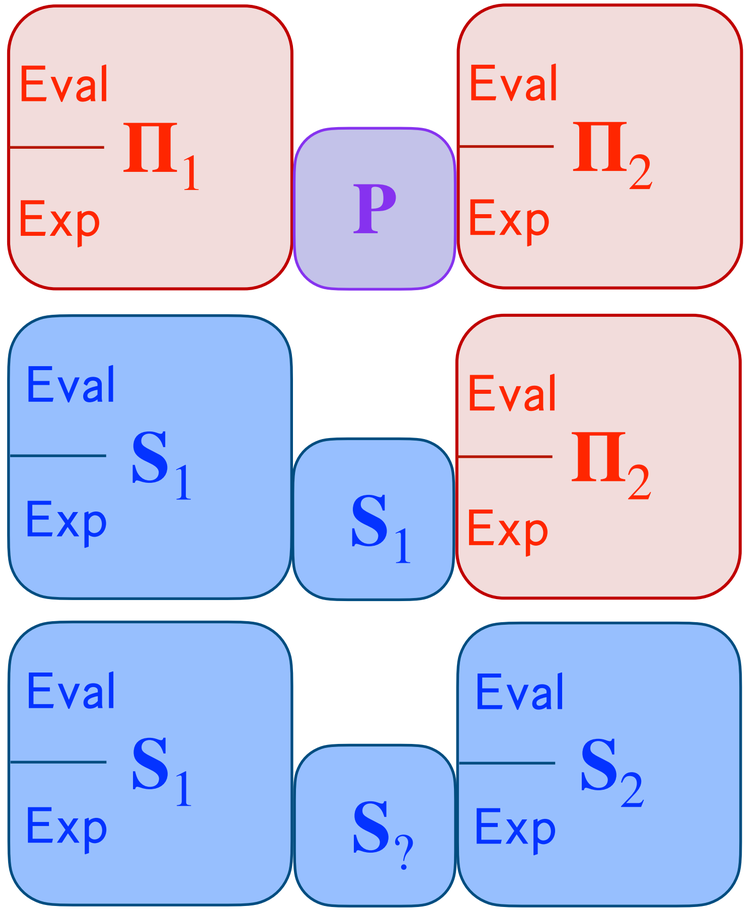

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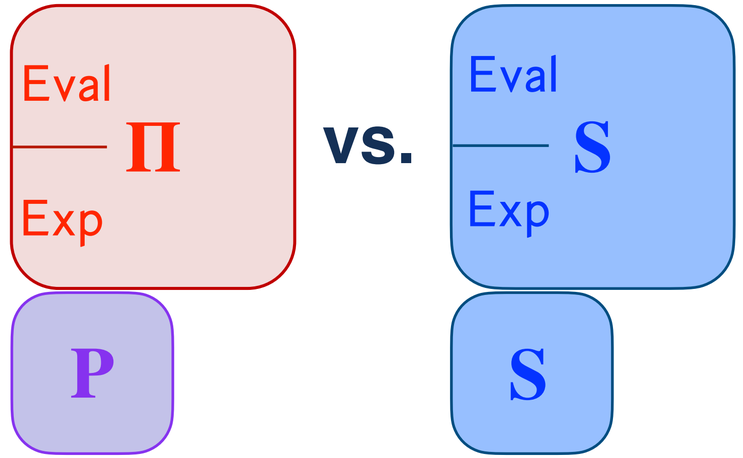

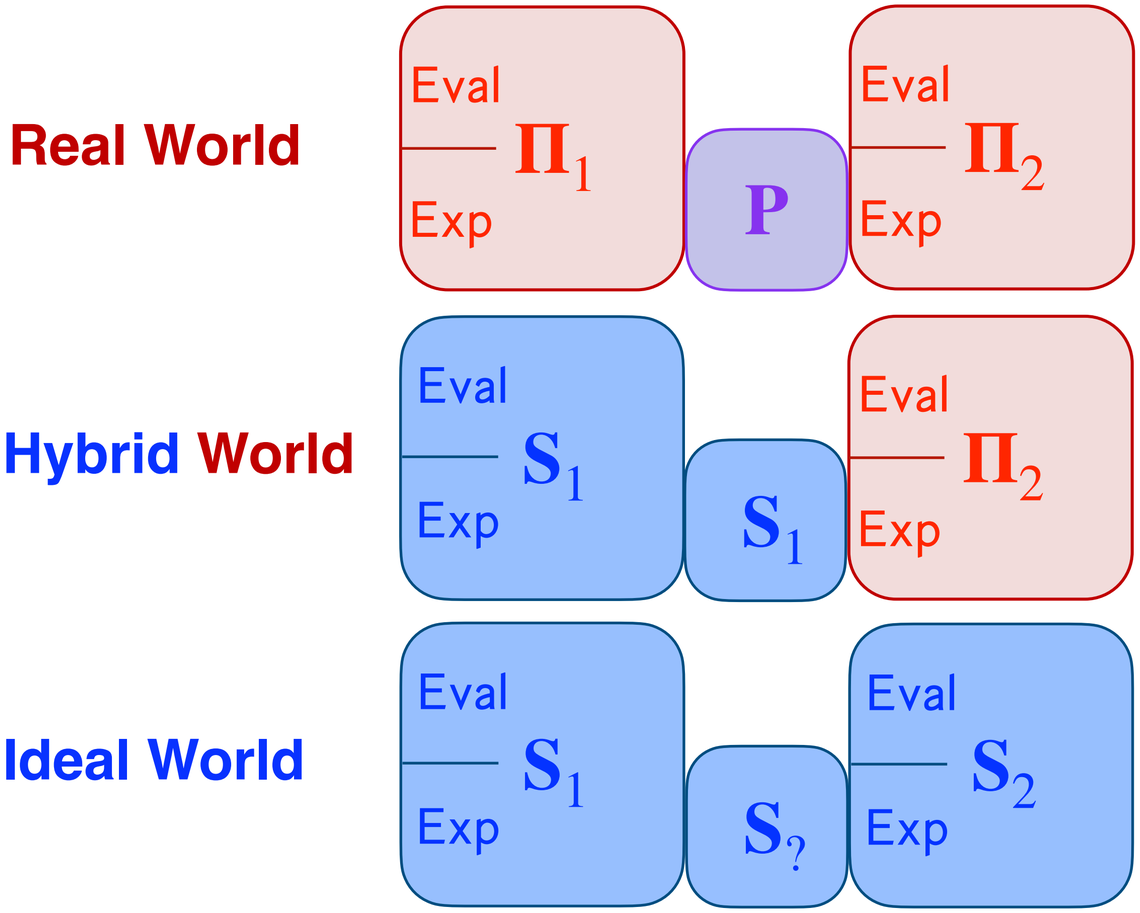

Simulator completely replacing P prevents reuse.

1. SIM-AC Shortcomings

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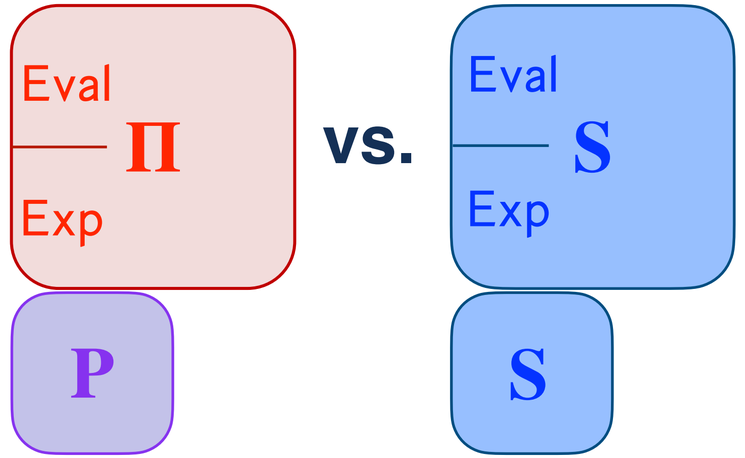

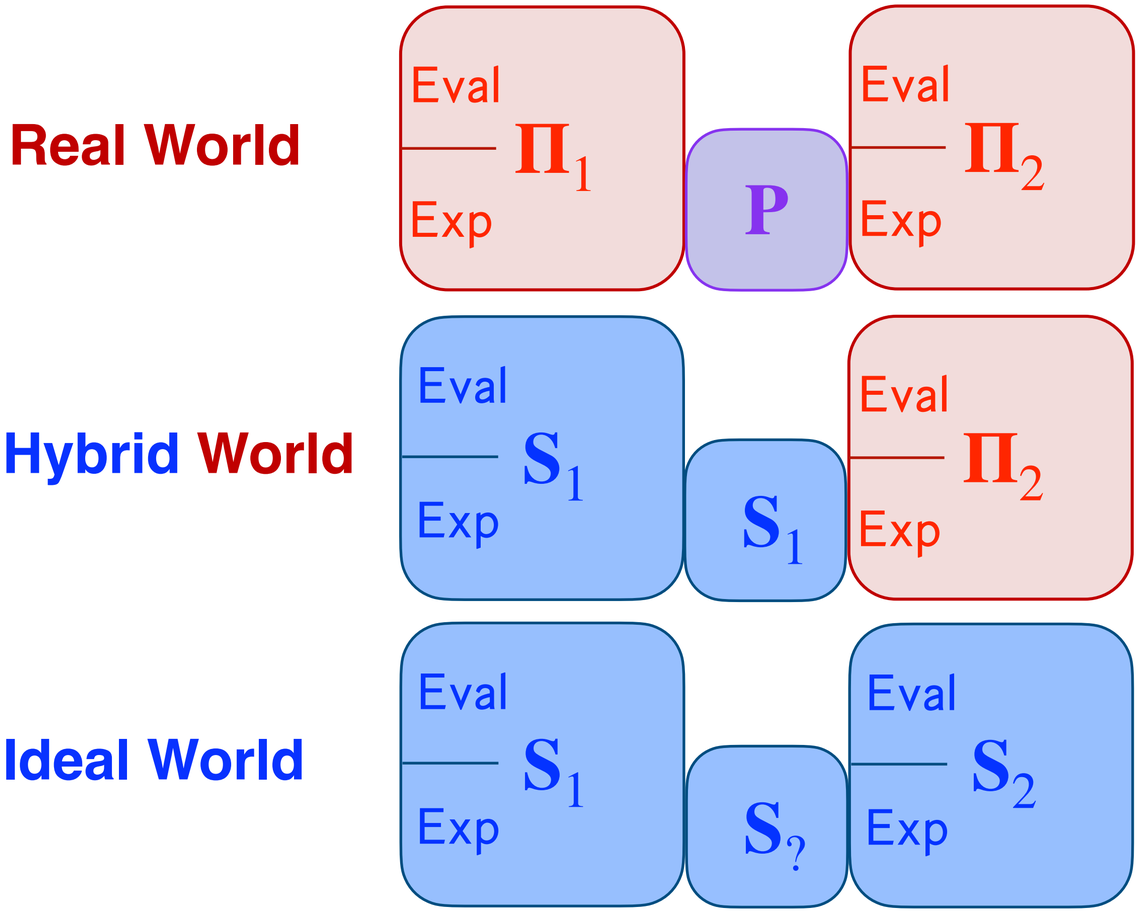

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- Searchable encryption*

Multiple schemes with the same primitive:

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- Enc-then-Mac*

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2. SIM*-AC Solution

One “solution”, don’t re-use P.

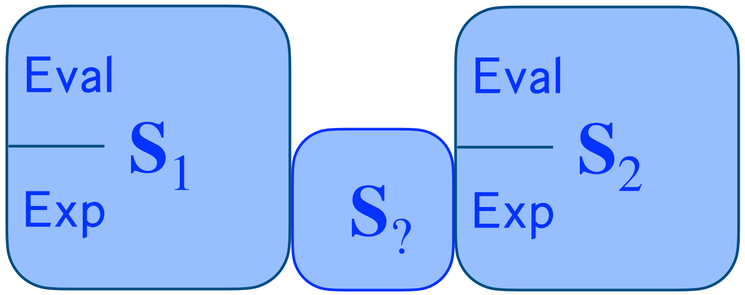
Paper 2020/241

Separate Your Domains: NIST PQC KEMs, Oracle Cloning and Read-Only Indifferentiability

Mihir Bellare, Hannah Davis, and Felix Günther

2. SIM*-AC Solution

Ideal World

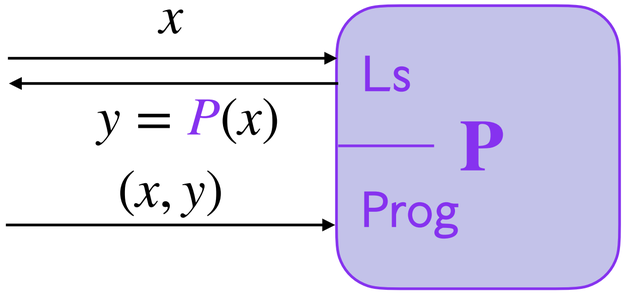


2. SIM*-AC Solution

Modify ideal primitive

Lazy sampling - Define P(x) when needed.

Programmable - Give (x,y) to define P(x)=y.



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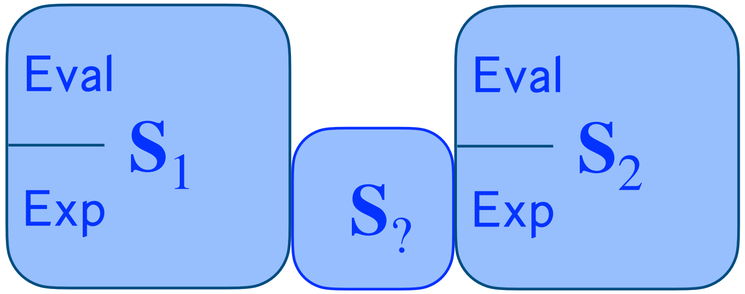

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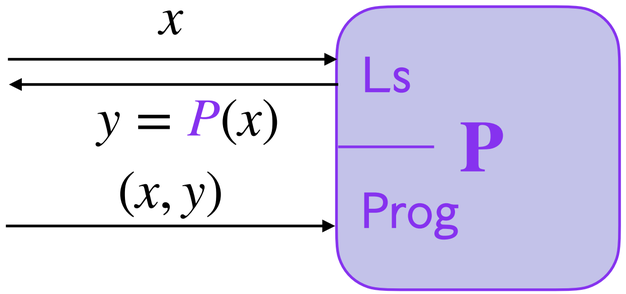
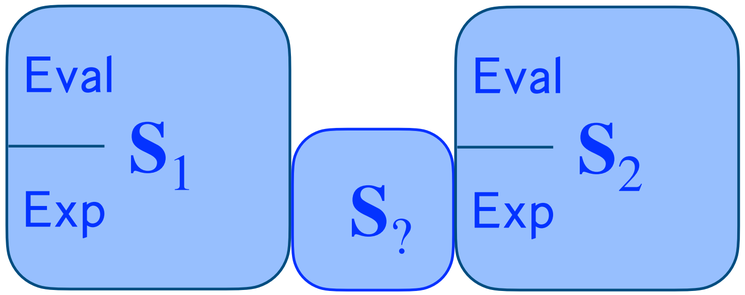
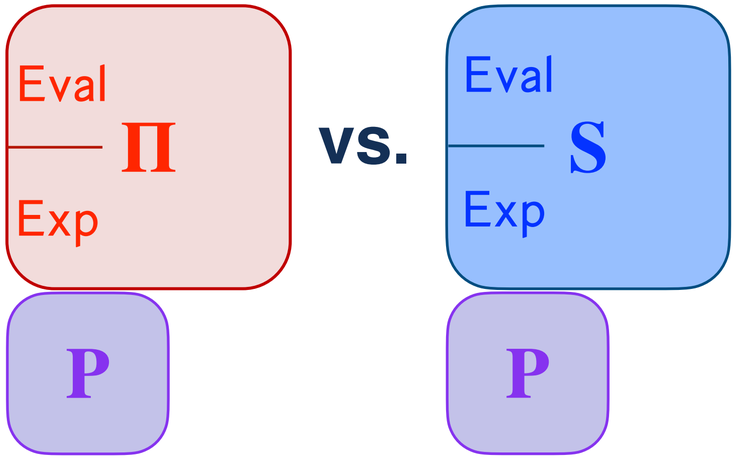


Have S explicitly program P.

Ideal World





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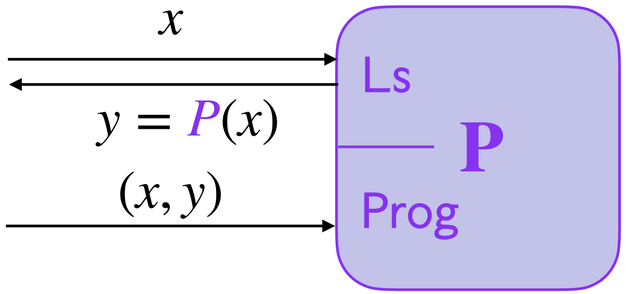

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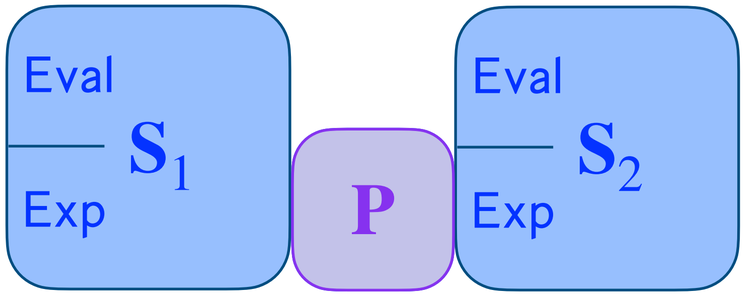

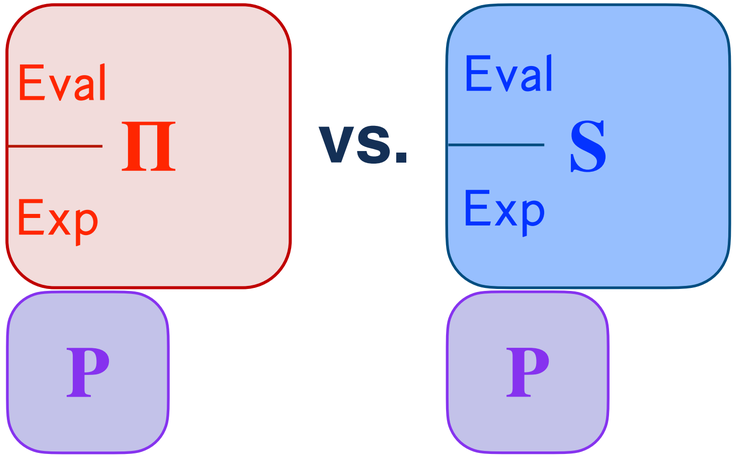

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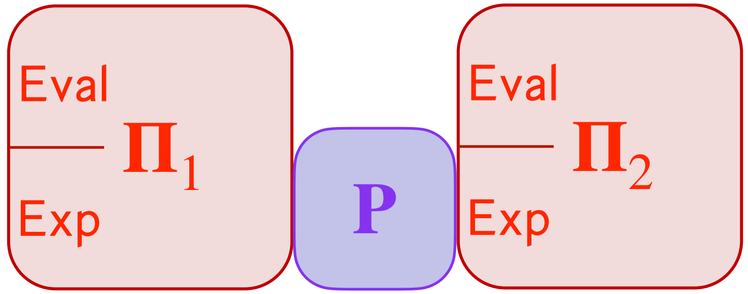
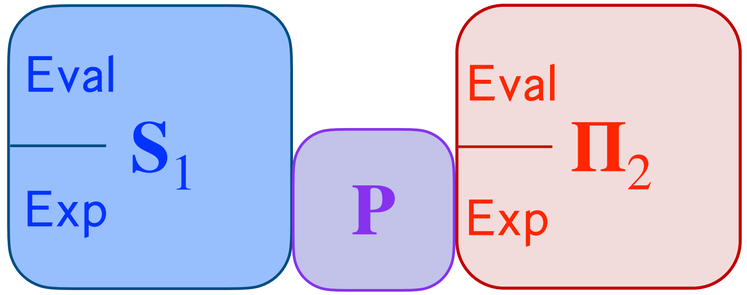
2. SIM*-AC Solution

Real World



Hybrid World



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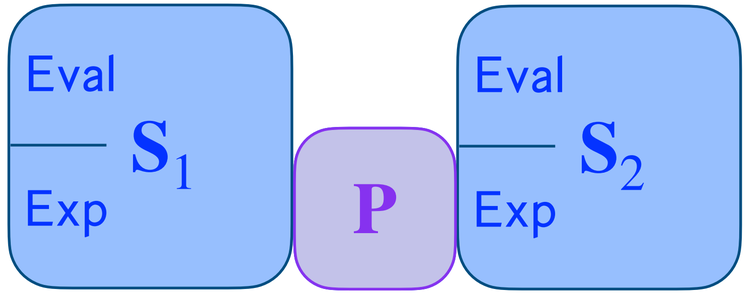

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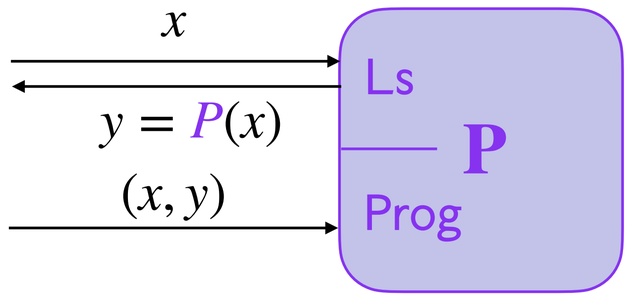

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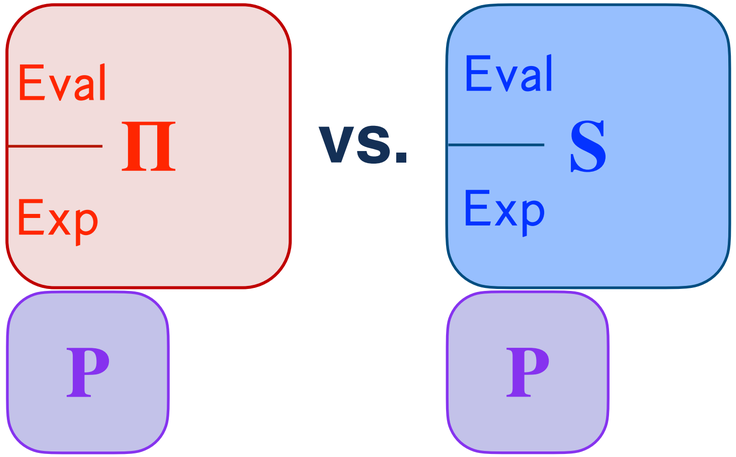
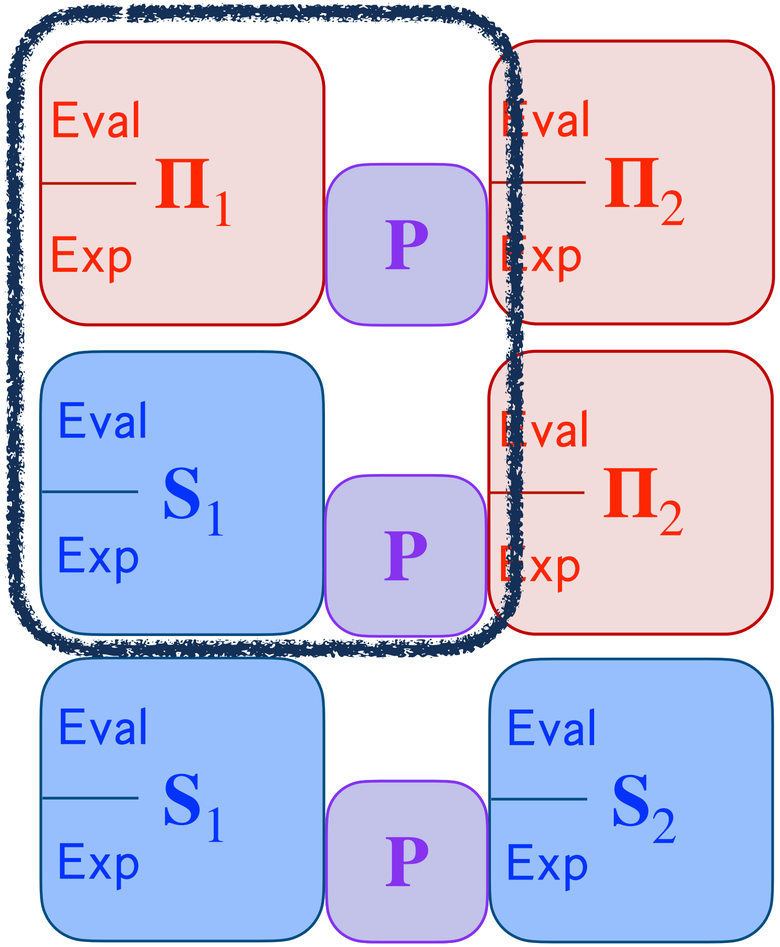


2. SIM*-AC Solution

Real World

Hybrid World

Ideal World



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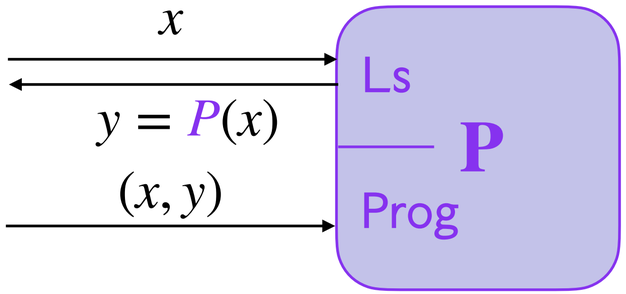

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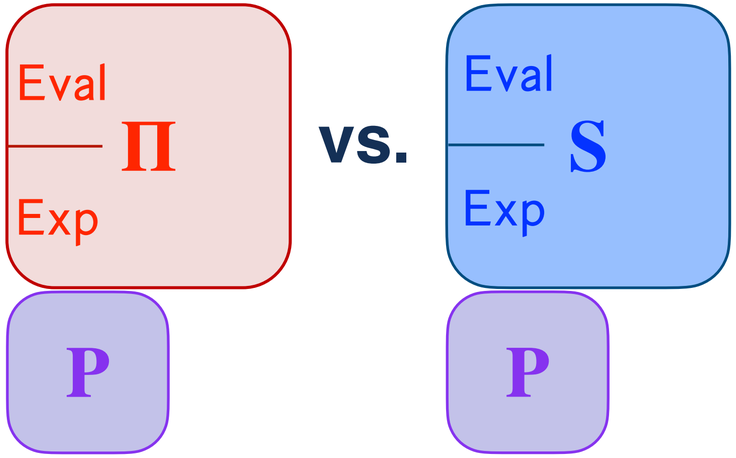

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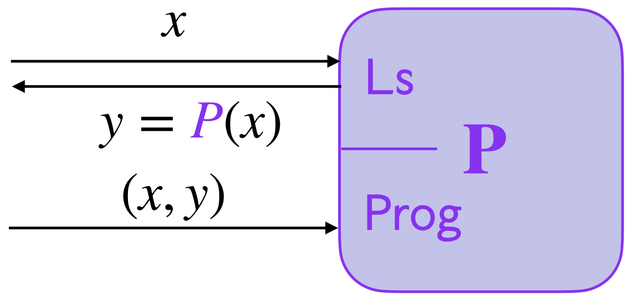

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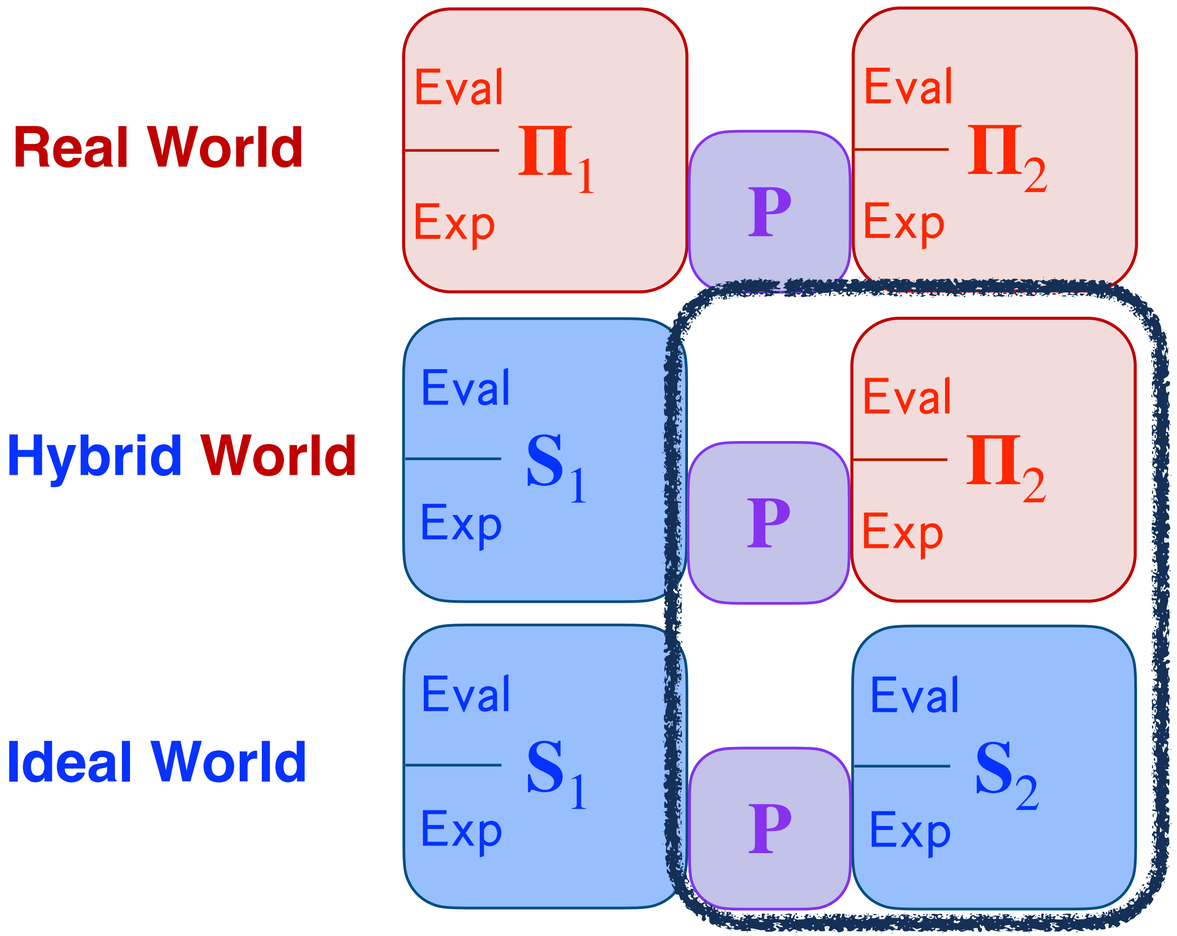

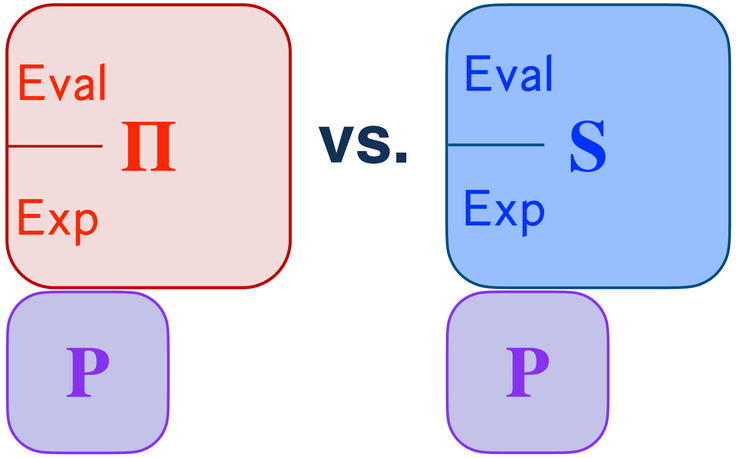

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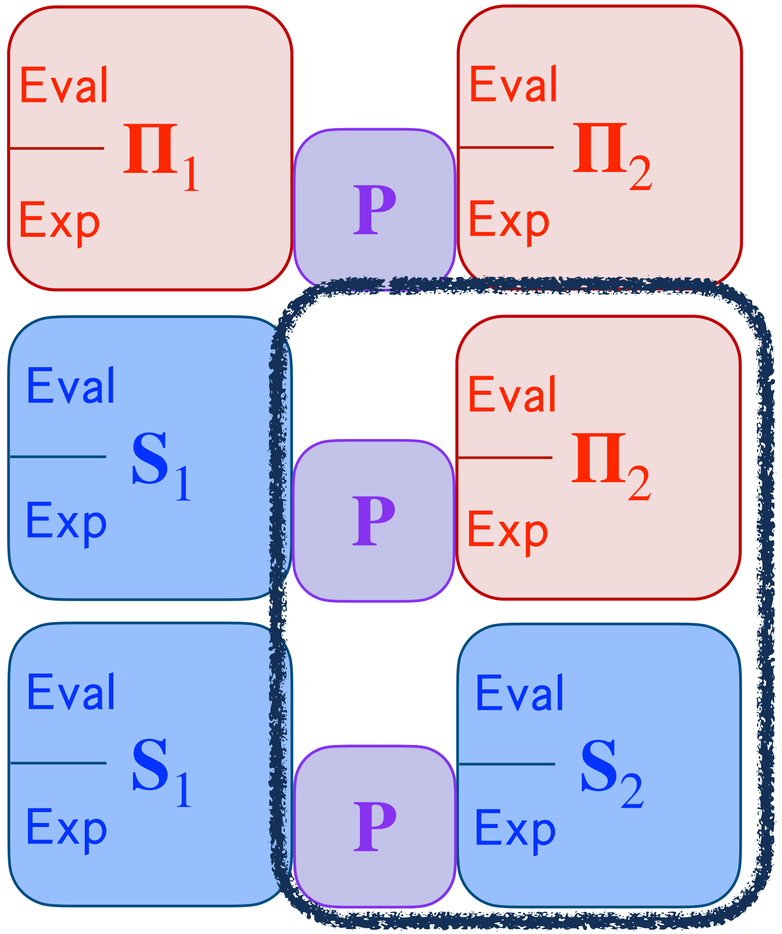
2. SIM*-AC Solution

Real World

Hybrid World

Ideal World



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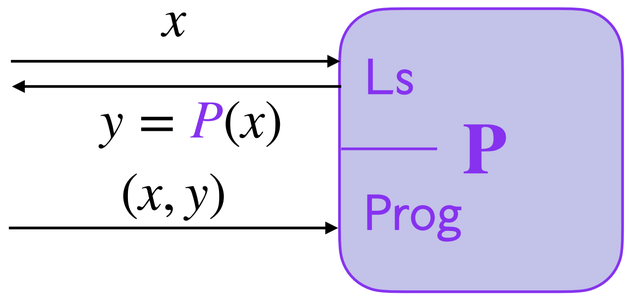

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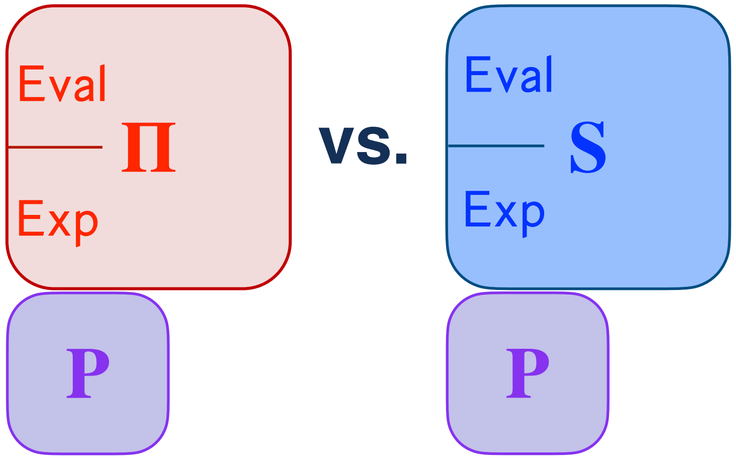

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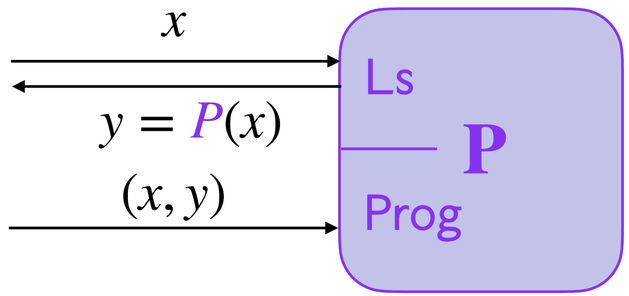

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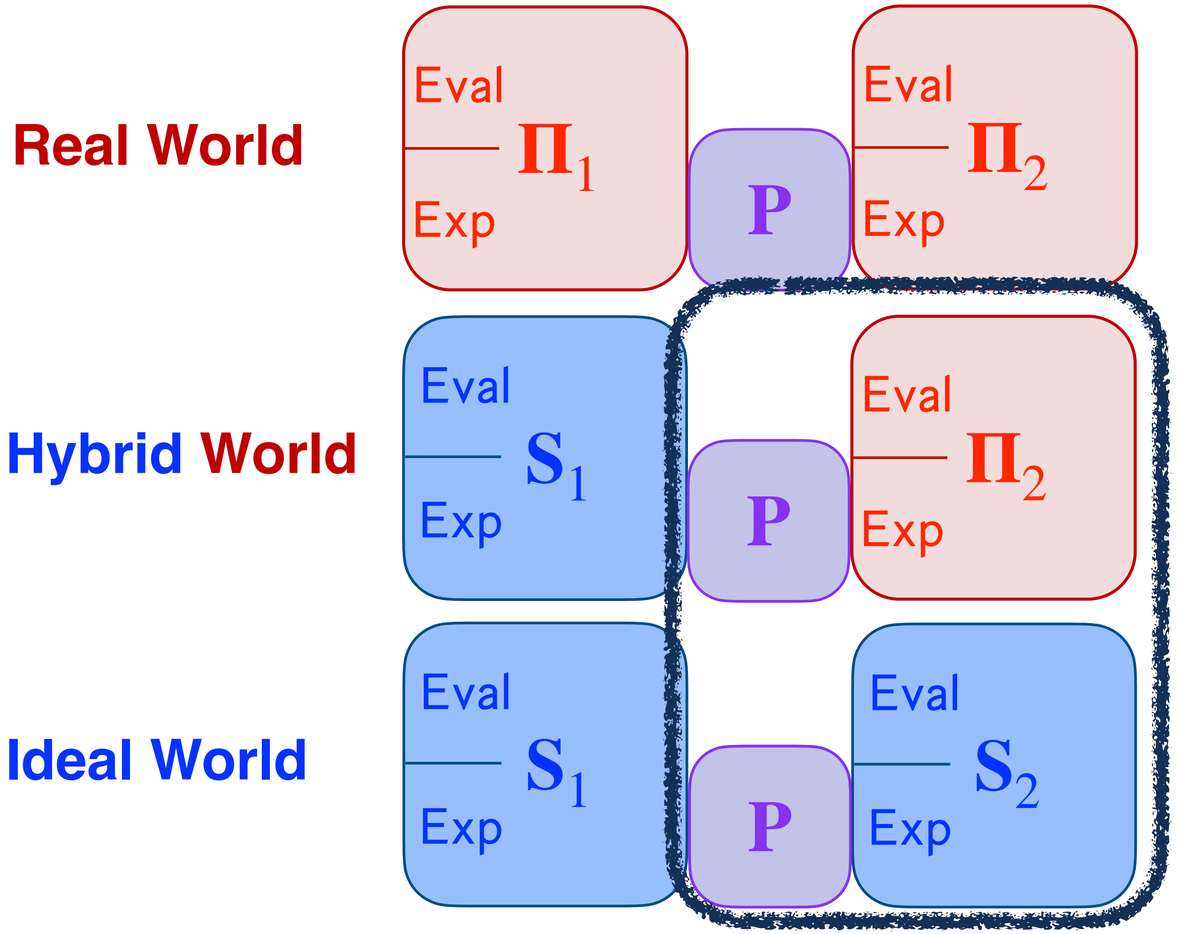
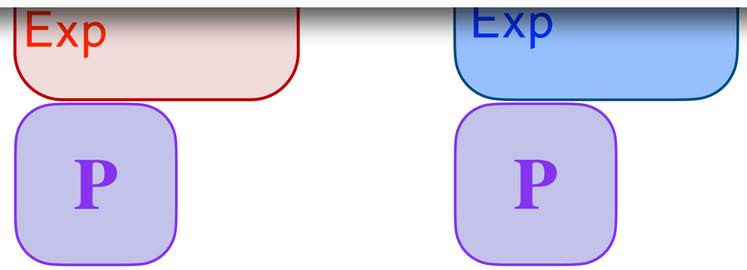


Paper 2018/165

The Wonderful World of Global Random Oracles

Jan Camenisch, Manu Drijvers, Tommaso Gagliardoni, Anja Lehmann, and Gregory Neven



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2. SIM*-AC Solution

Multiple uses of the same scheme:

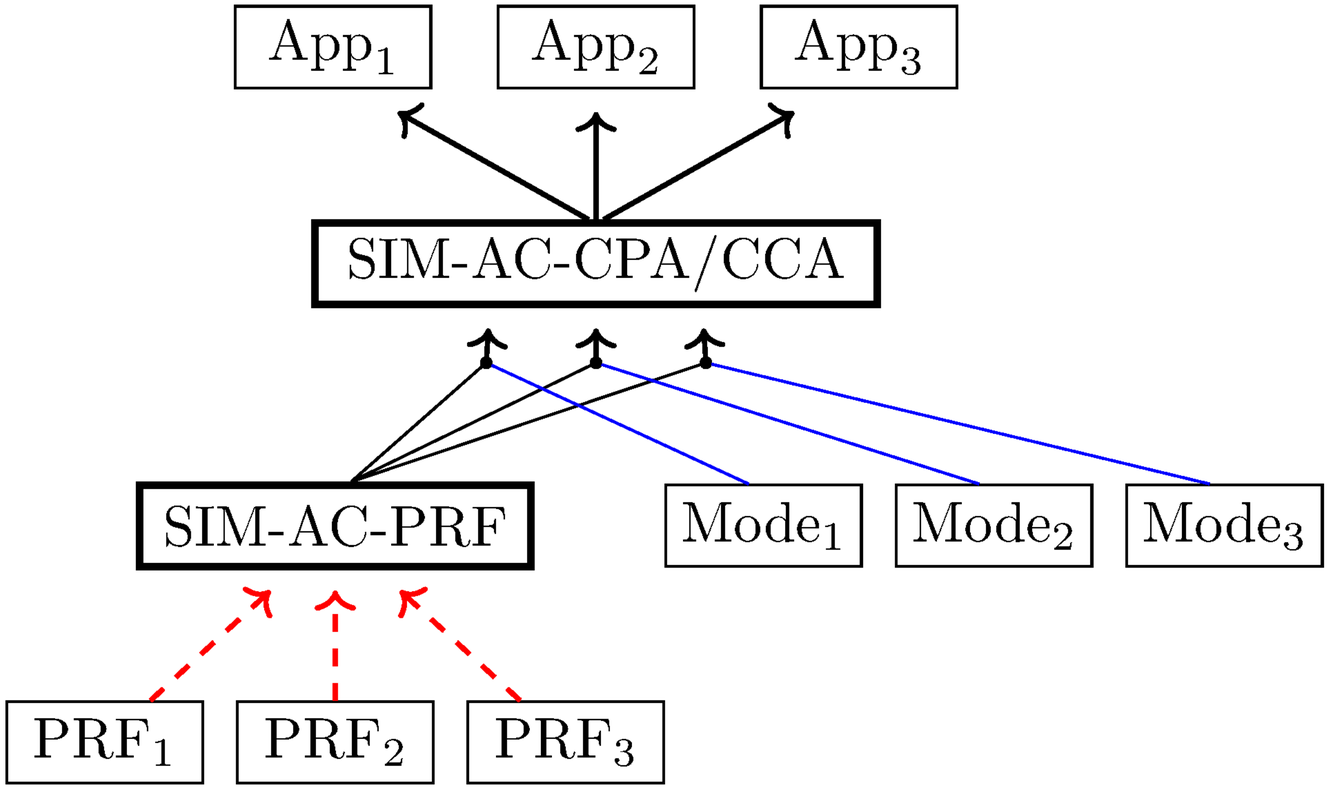
- Multi-user security
- Cascade PRF
- Searchable encryption*

New proofs for both of these.
Super-constant rounds/users needs universal simulator.

Multiple schemes with the same primitive:

- Searchable encryption*
- Revocable Cloud Storage*
- Enc-then-Mac*

3. Recovering Prior Results



High-level proofs:

Searchable encryption
Revocable Cloud Storage
OPAQUE

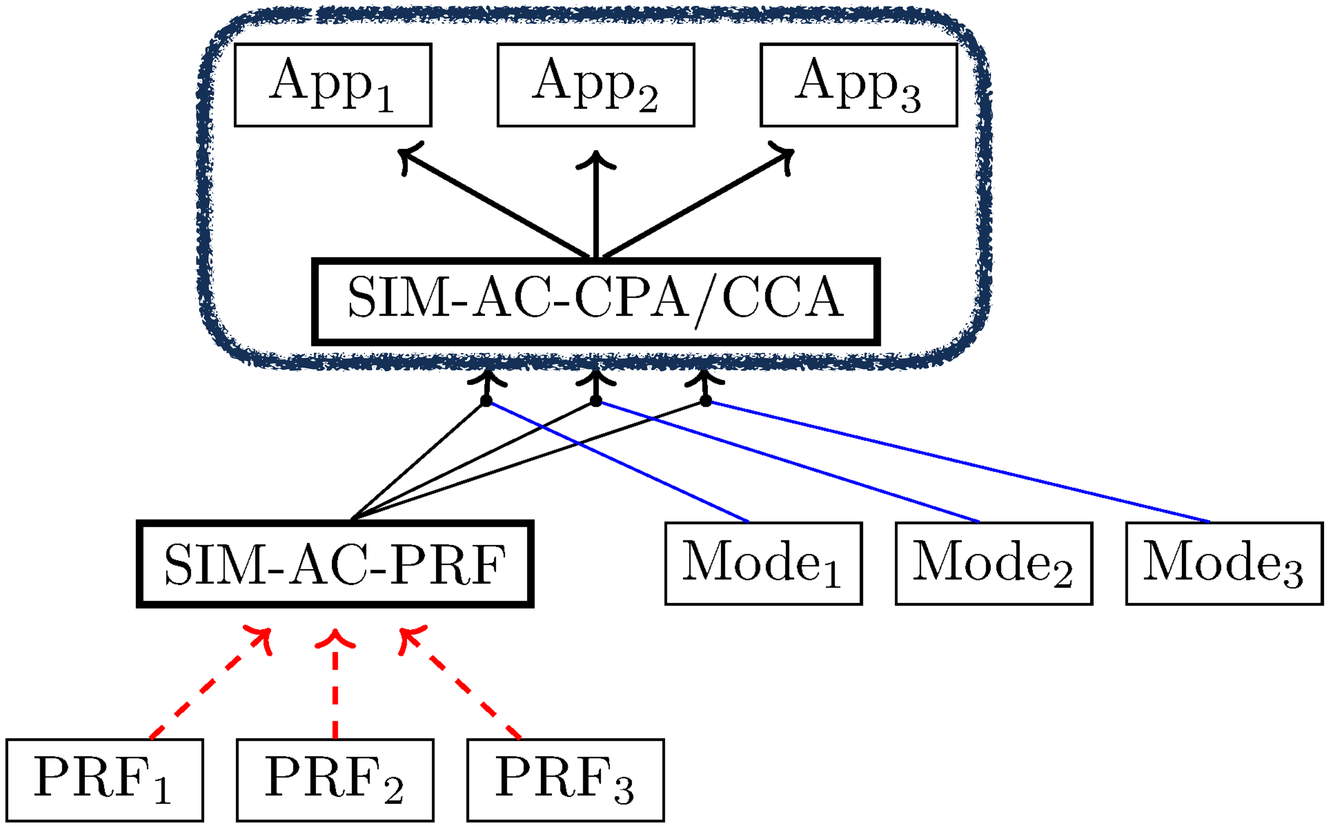
Intermediate-level proofs:

CTR, CBC, …
Enc-then-Mac

Low-level proofs:

Random oracle PRF
Ideal cipher PRF

3. Recovering Prior Results



High-level proofs:

Free!
SIM*-AC → SIM-AC

Intermediate-level proofs:

CTR, CBC, …
Enc-then-Mac

Low-level proofs:

Random oracle PRF
Ideal cipher PRF

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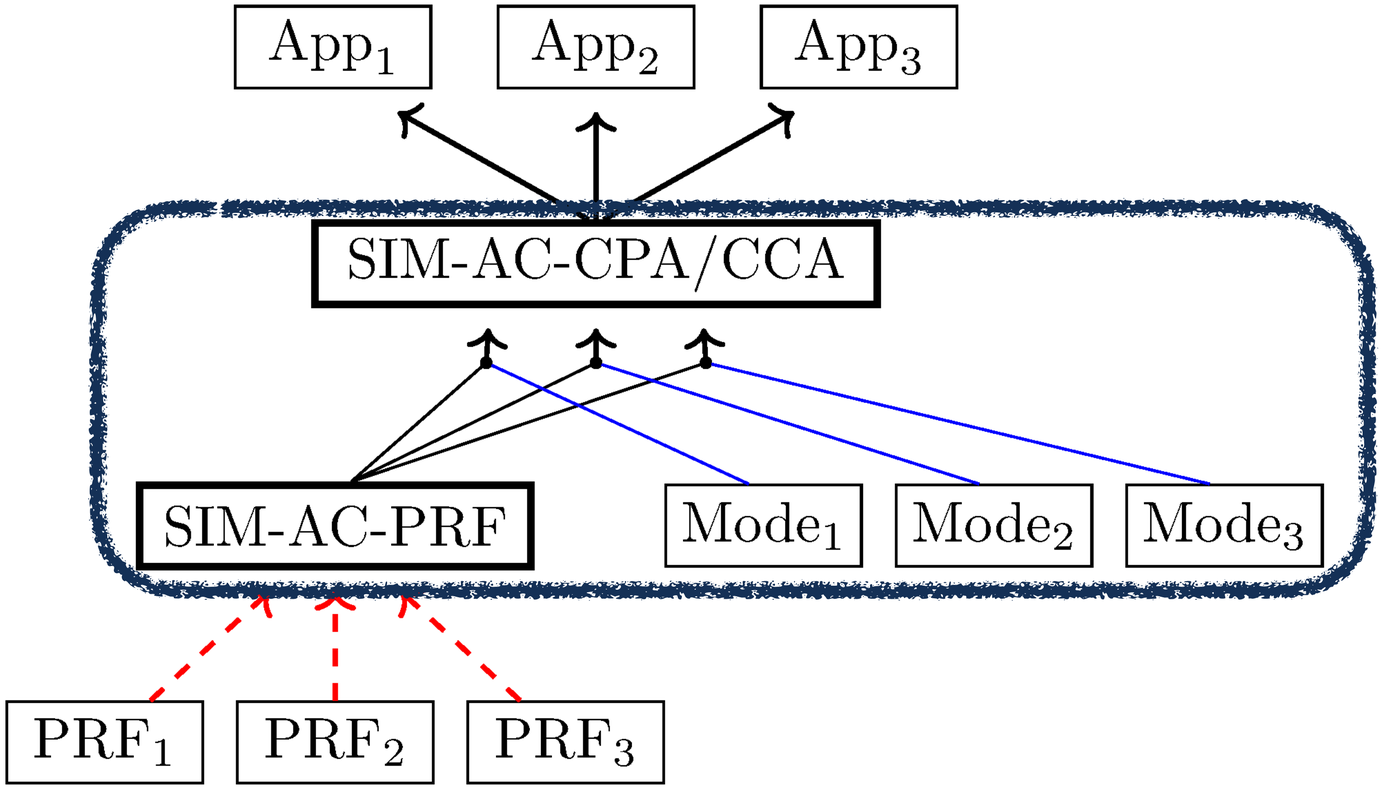

High-level proofs:

Free!

SIM*-AC → SIM-AC

Intermediate-level proofs:

“Free”

Sufficiently blackbox

Low-level proofs:

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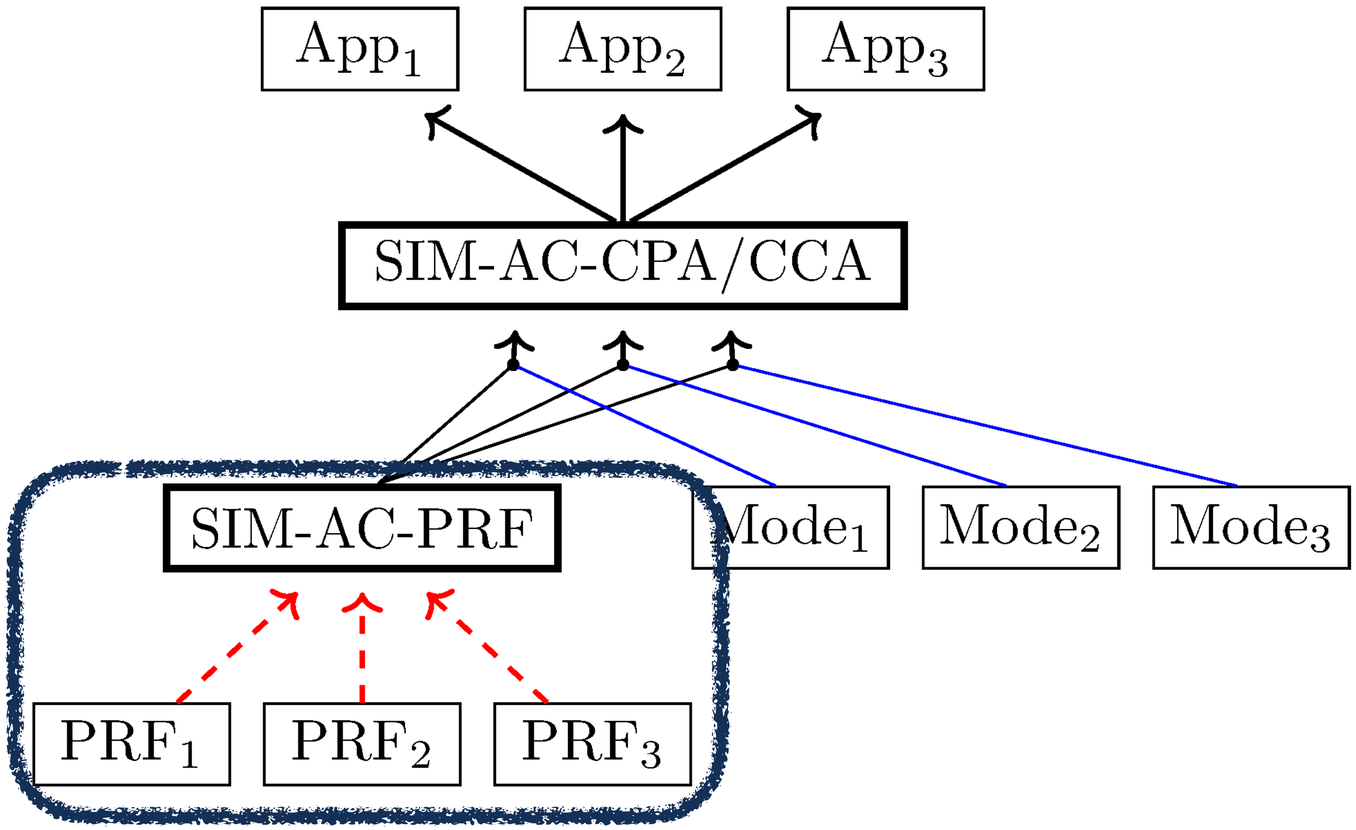

High-level proofs:

Free!

SIM*-AC → SIM-AC

Intermediate-level proofs:

“Free”

Sufficiently blackbox

Low-level proofs:

Not free, rewrite proofs

Basically same bounds

prim queries → # prim + prog

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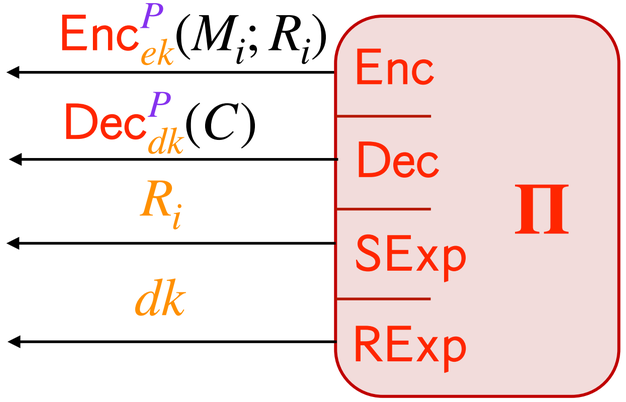
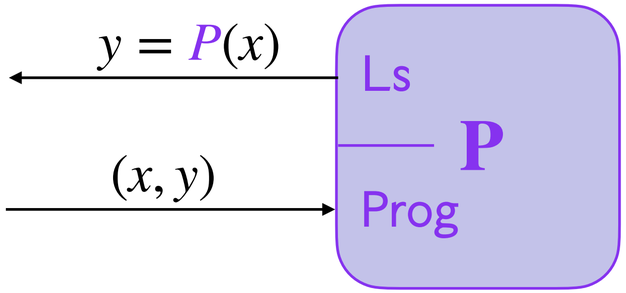
4. SIM*-AC For Asymmetric Encryption

Real World



Sender Exposure: Encryption randomness
Receiver Exposure: Decryption key

SIM*-AC-CCA



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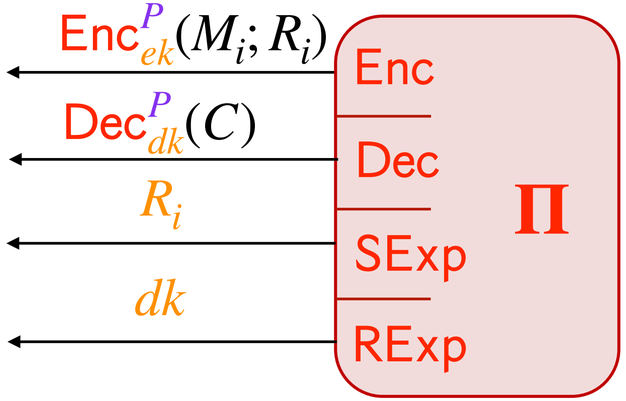
Real World



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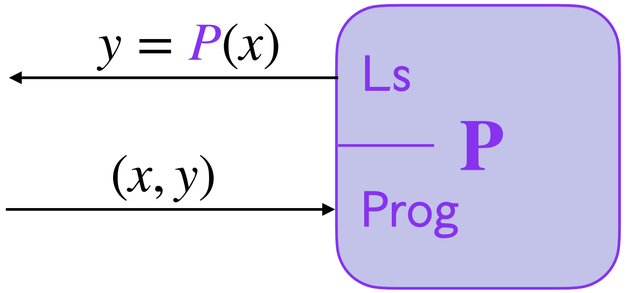
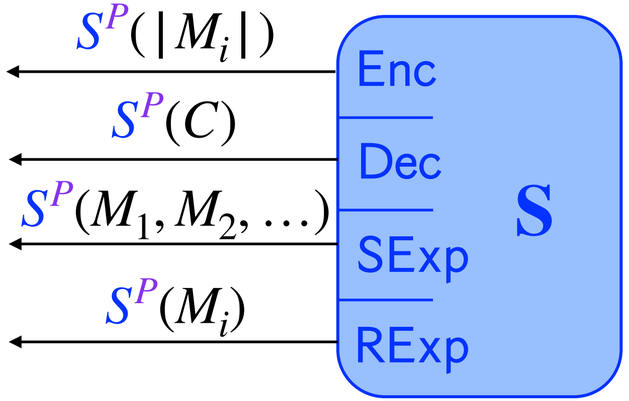
SIM*-AC-CCA



Ideal World



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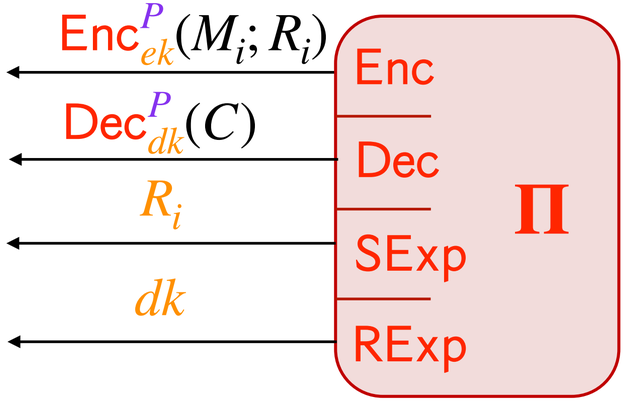
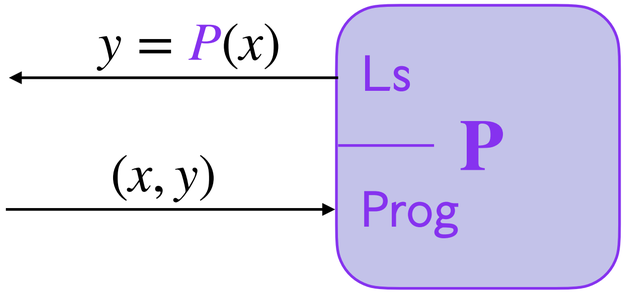
4. SIM*-AC For Asymmetric Encryption

Real World



Sender Exposure: Encryption randomness
Receiver Exposure: Decryption key

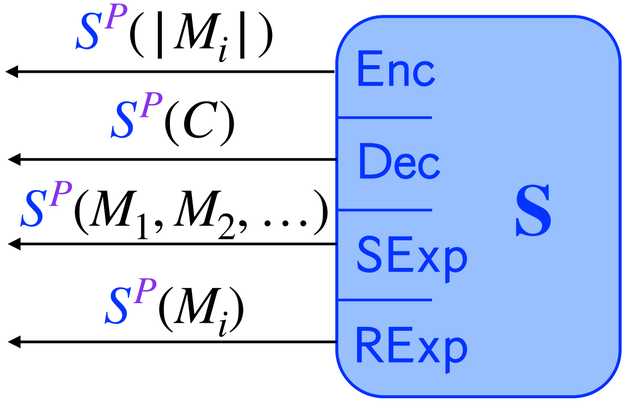
SIM*-AC-CCA



KEM definitions as well!

- Enc → Encaps
- Dec → Decaps
- Random key when ideal

Ideal World



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KEM/DEM: SIM*-AC-X **KEM** + SIM*-AC-X **DEM** → SIM*-AC-X **PKE** for X = CPA, CCA

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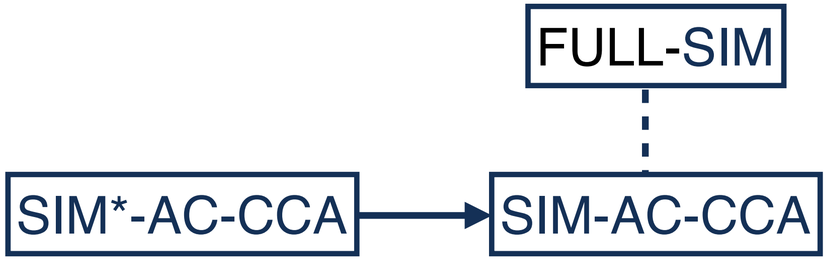

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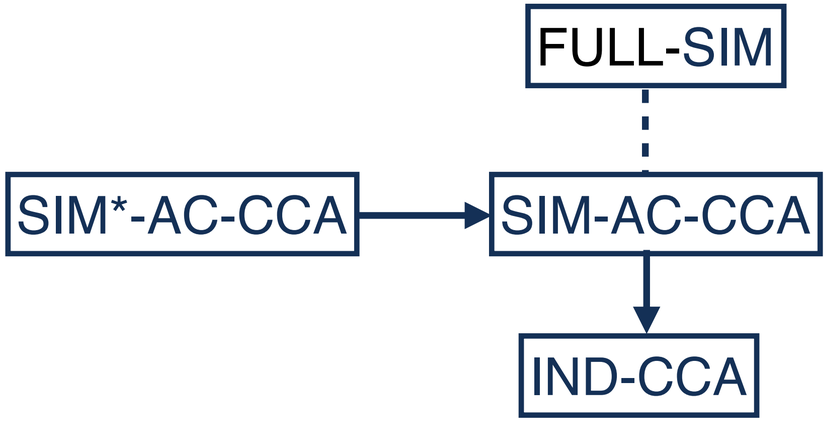

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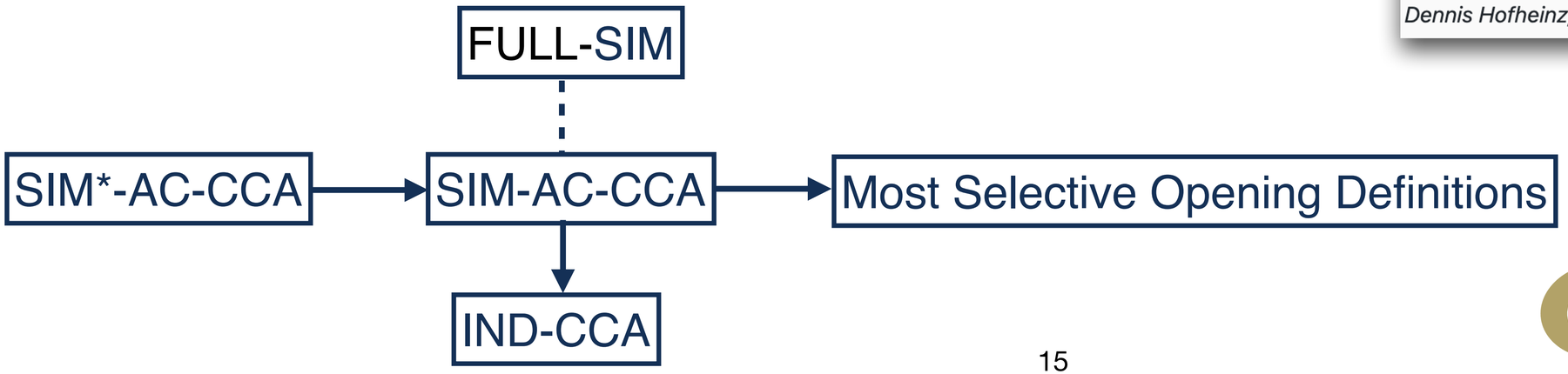

Let Attackers Program Ideal Models

Our Contributions

1. SIM-AC and it **shortcomings**.

2. SIM*-AC and it **solution** to shortcomings.
   - Multiple schemes with same primitive
   - Multiple uses of same scheme
   - Single-user security → Multi-user security

3. **Recovering prior results:** SIM-AC results hold with SIM*-AC.

4. SIM*-AC for **asymmetric encryption**.
   - Comparisons to prior definitions
   - KEM/DEM hybrid encryption
   - Fujisaki-Okamoto style transforms