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Selective Opening Security from Simulatable Data Encapsulation

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Horst Görtz Institute for IT Security
Ruhr University Bochum

hgi
Horst Görtz Institut
für IT-Sicherheit

Selective Opening Attacks

Receiver

Senders

Selective Opening Attacks

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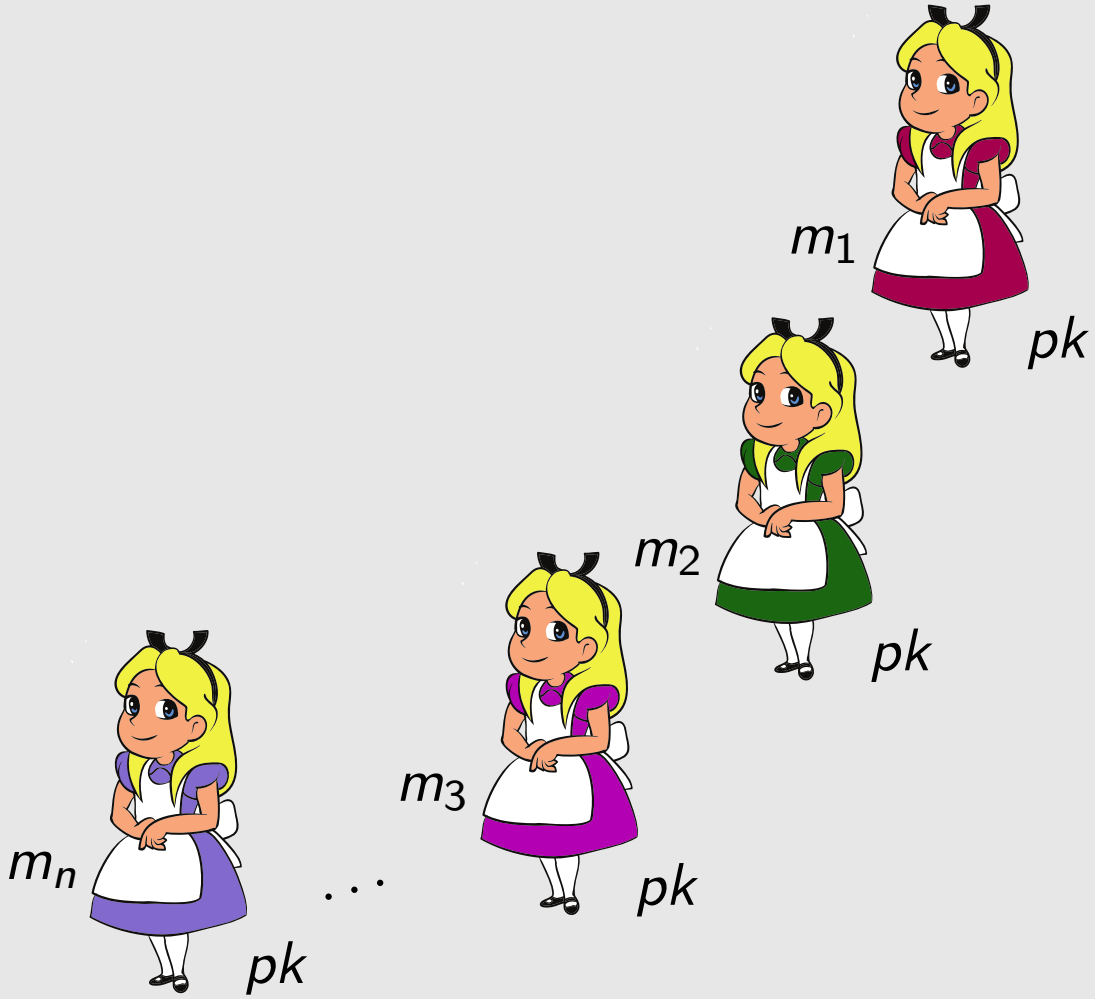
Senders



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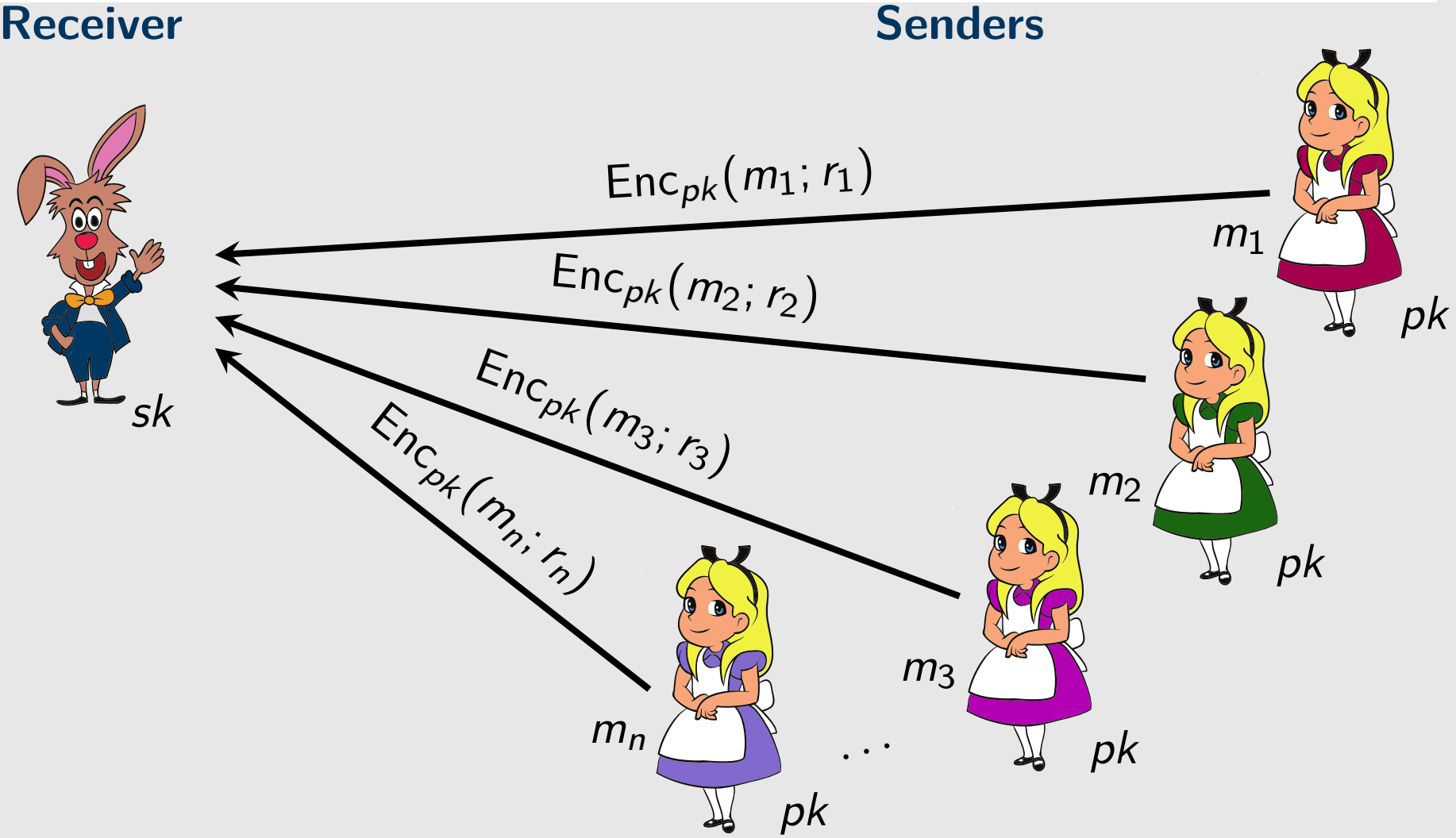

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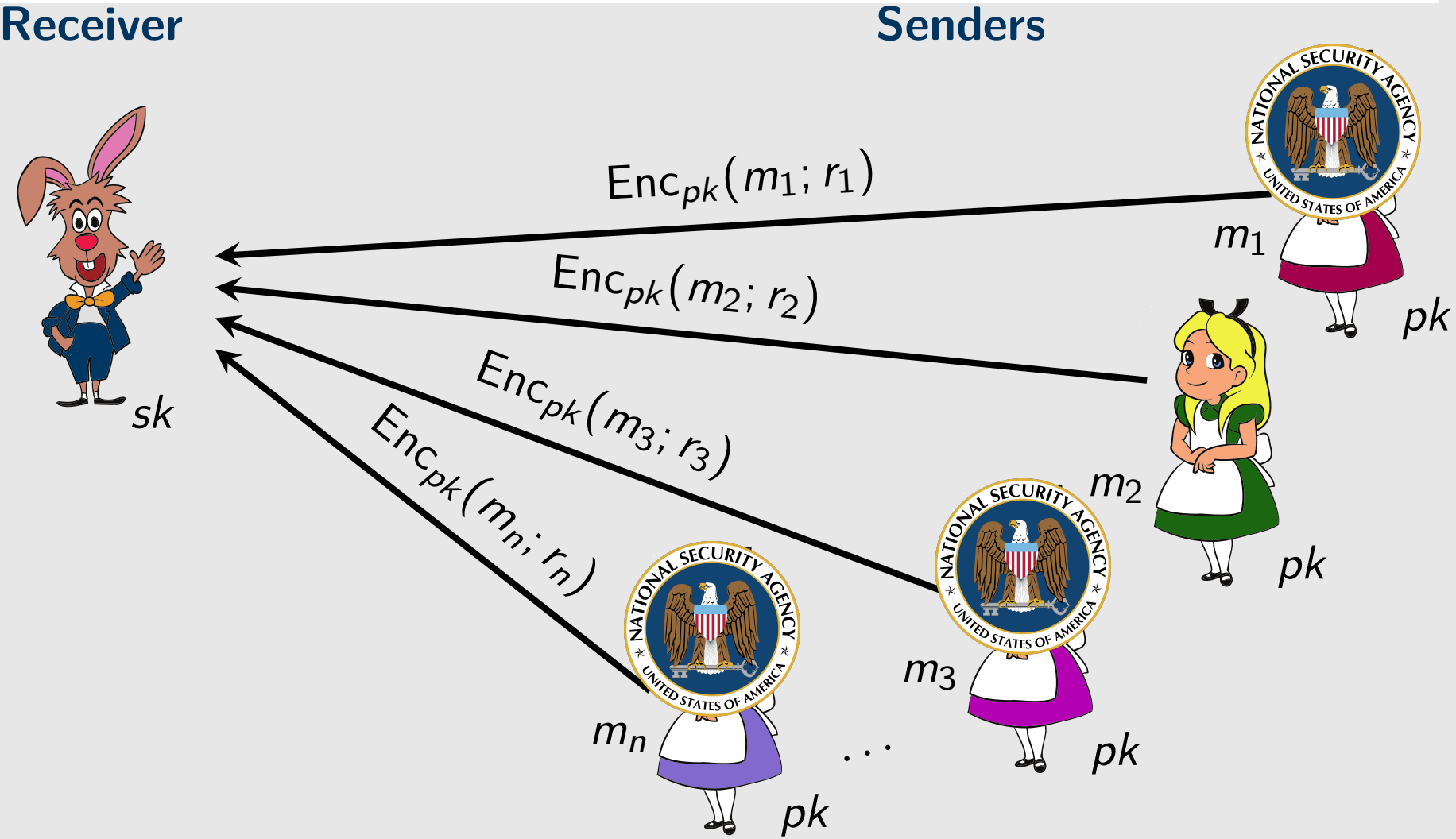
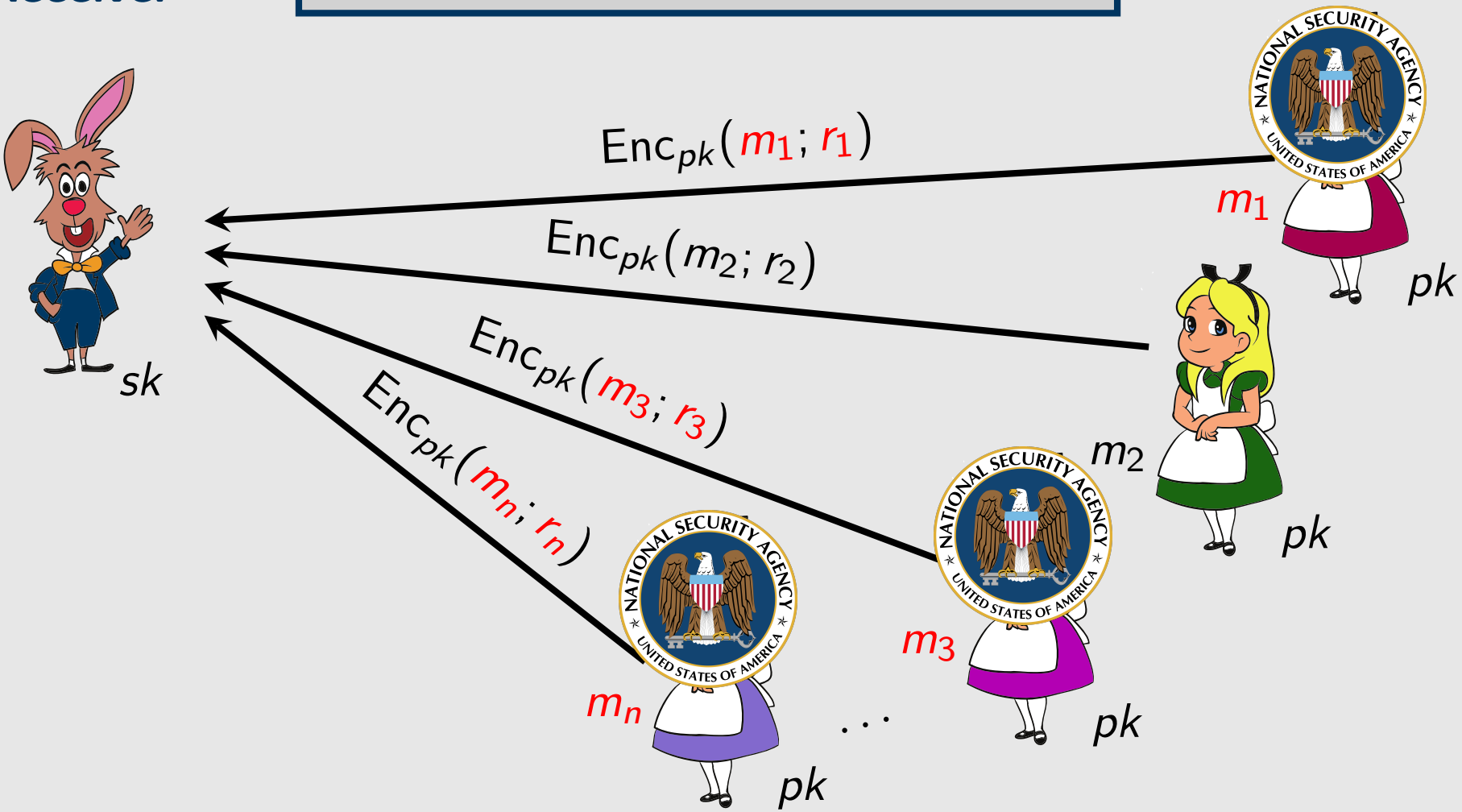


Selective Opening Attacks

Receiver

Corrupting senders reveals m and r.



Selective Opening Attacks

Corrupting senders reveals m and r.

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$\mathrm{Enc}_{pk}(m_1; r_1)$

$\mathrm{Enc}_{pk}(m_2; r_2)$

$\mathrm{Enc}_{pk}(m_3; r_3)$

$\mathrm{Enc}_{pk}(m_n; r_n)$

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m_2 pk

m_3 pk

m_n pk

$\ldots$

Do messages of uncorrupted parties remain confidential?

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- Dates back to [DNRS99]

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m_2

pk

m_3

pk

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m_1

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- Dates back to [DNRS99]
- Messages may depend on another
- SO security strictly stronger than standard security [HR14,HRW15]

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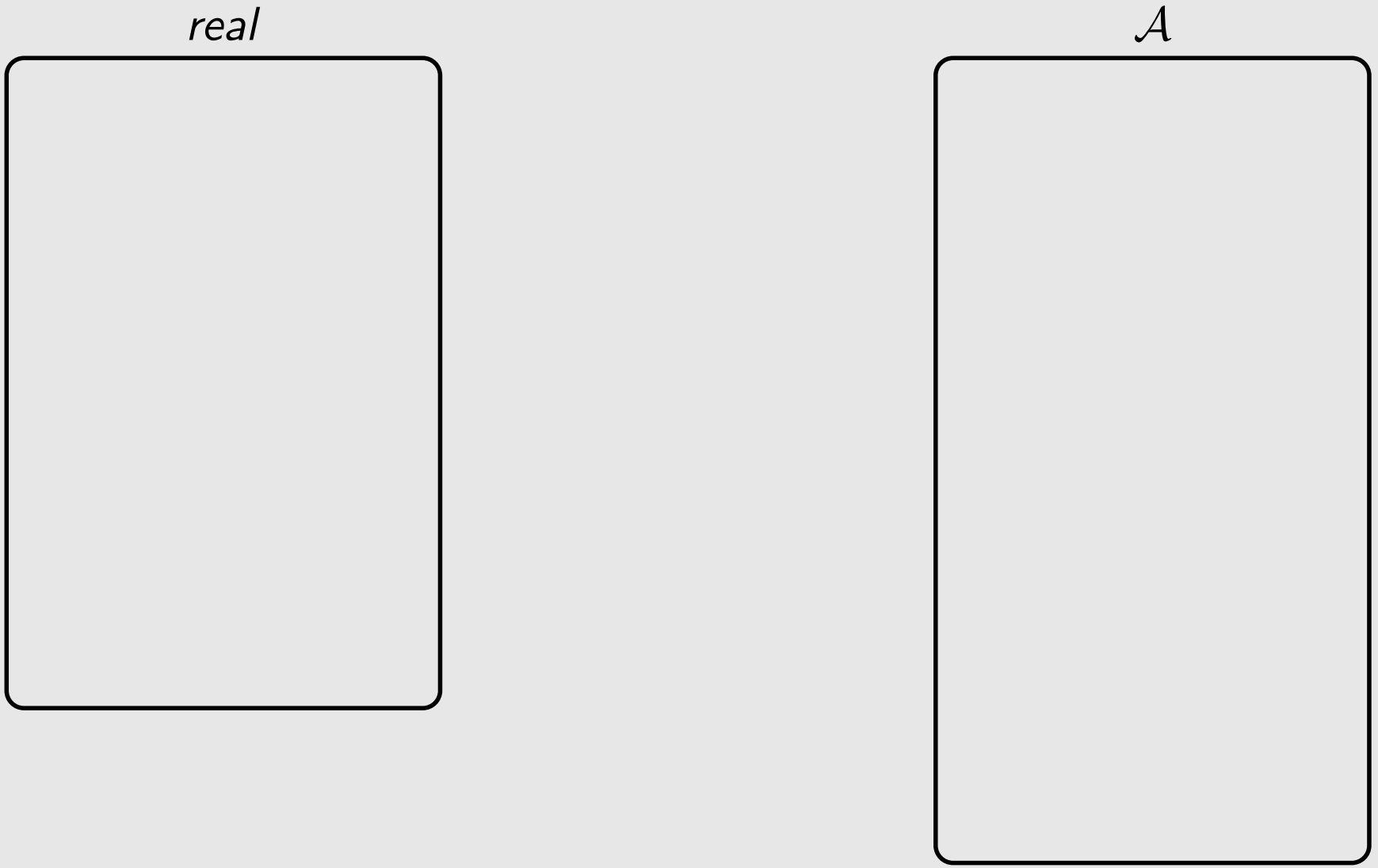
Defining SIM-SO-CCA Security [BHK12]



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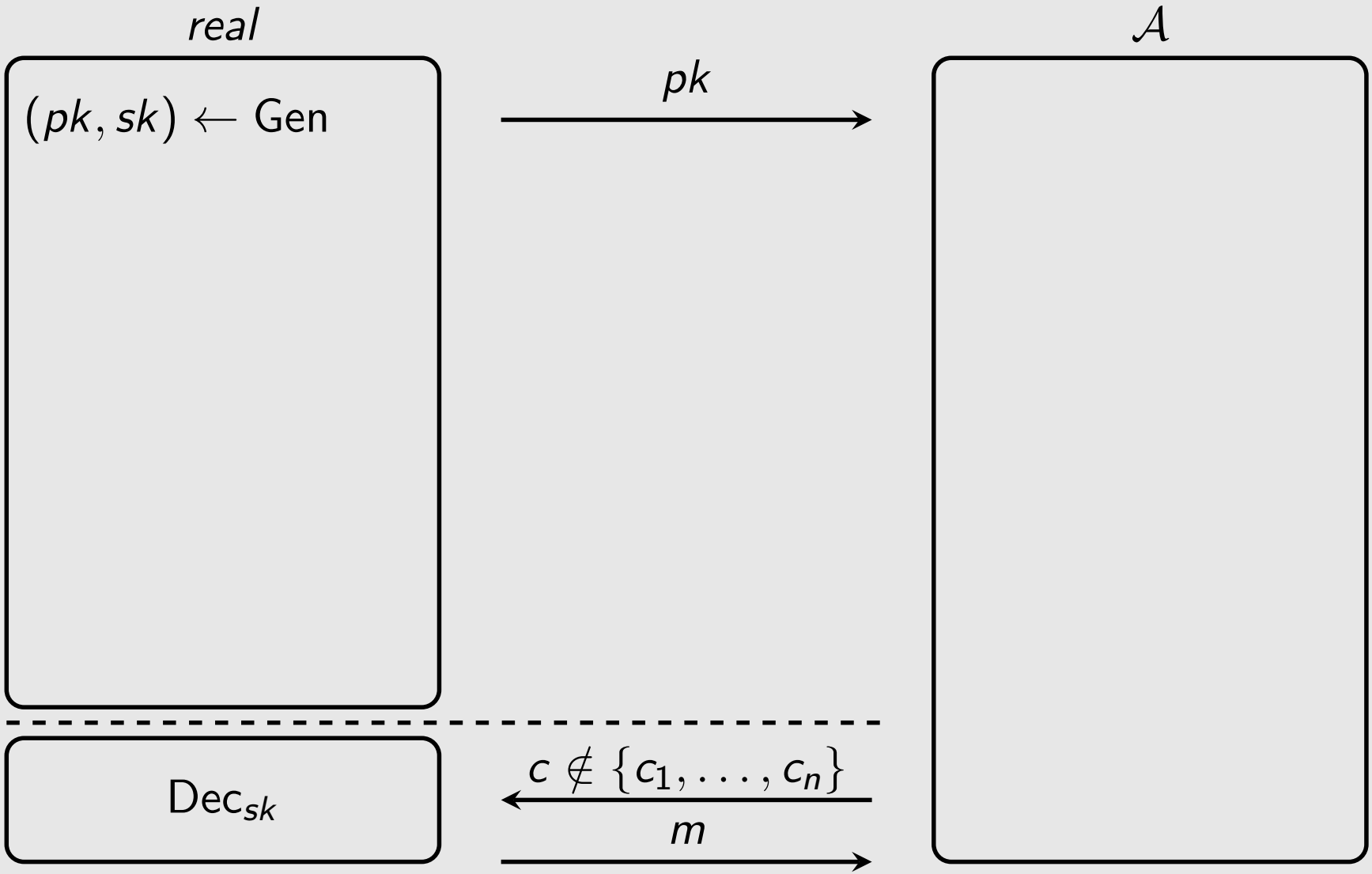

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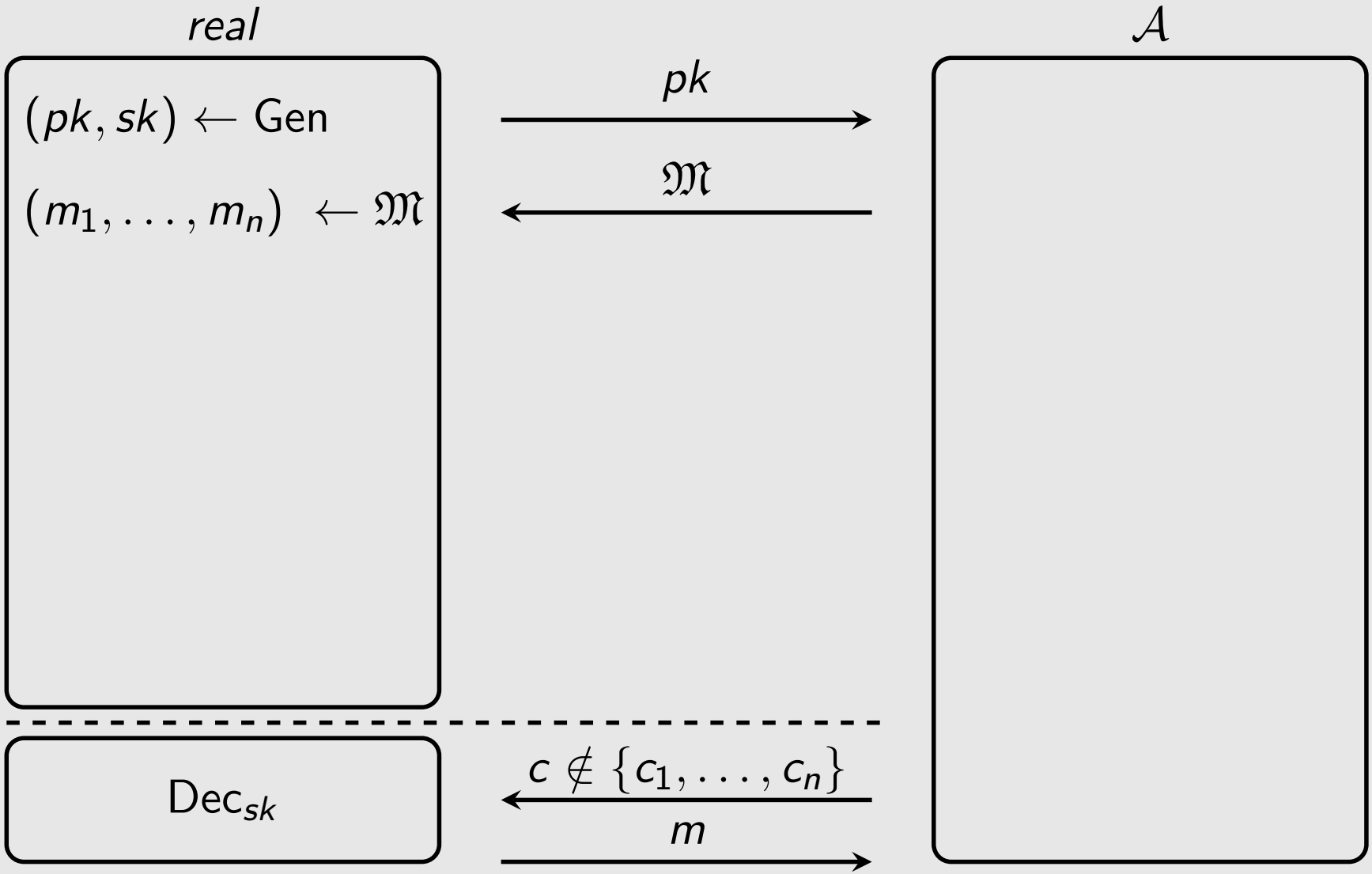

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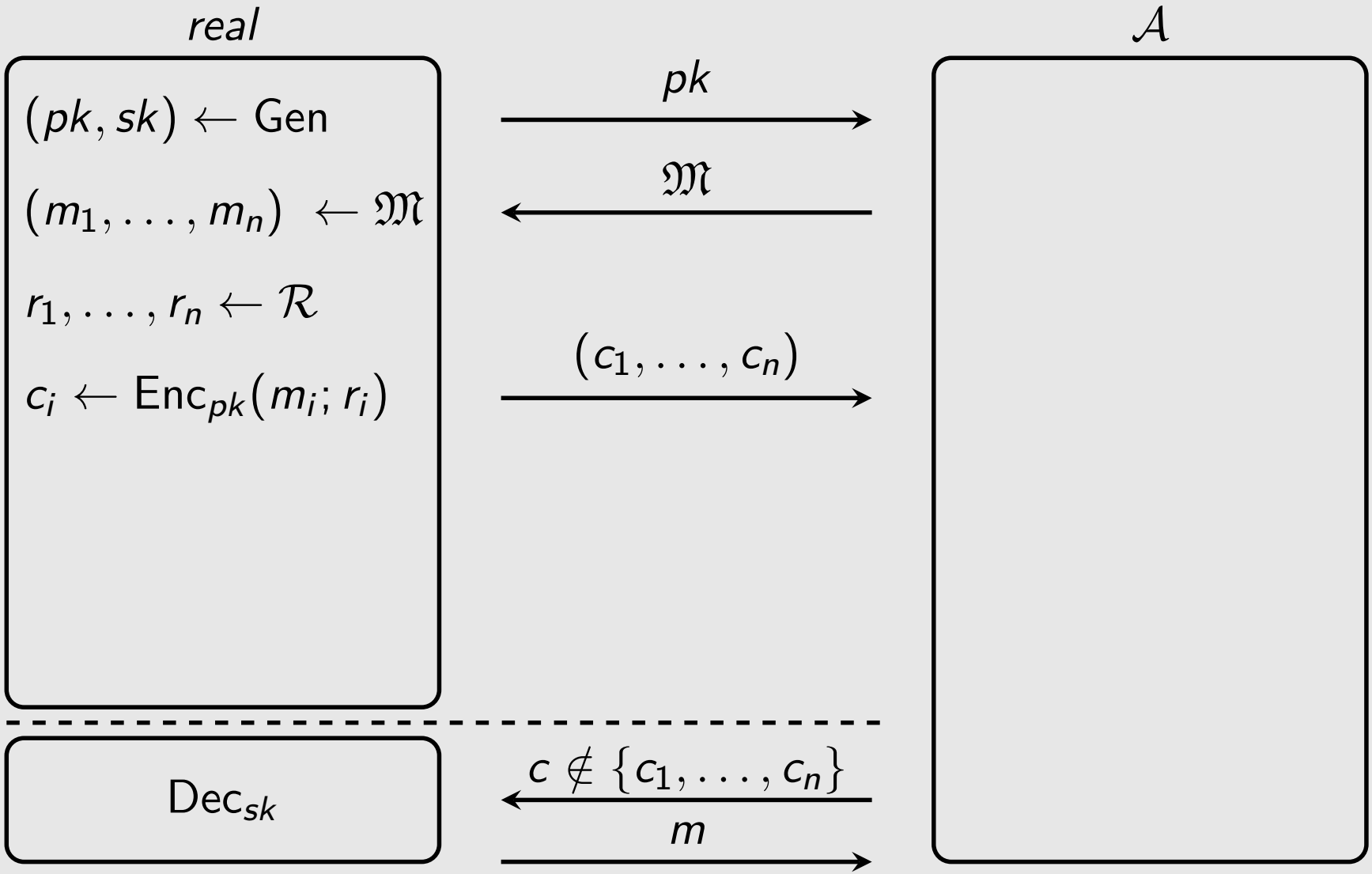

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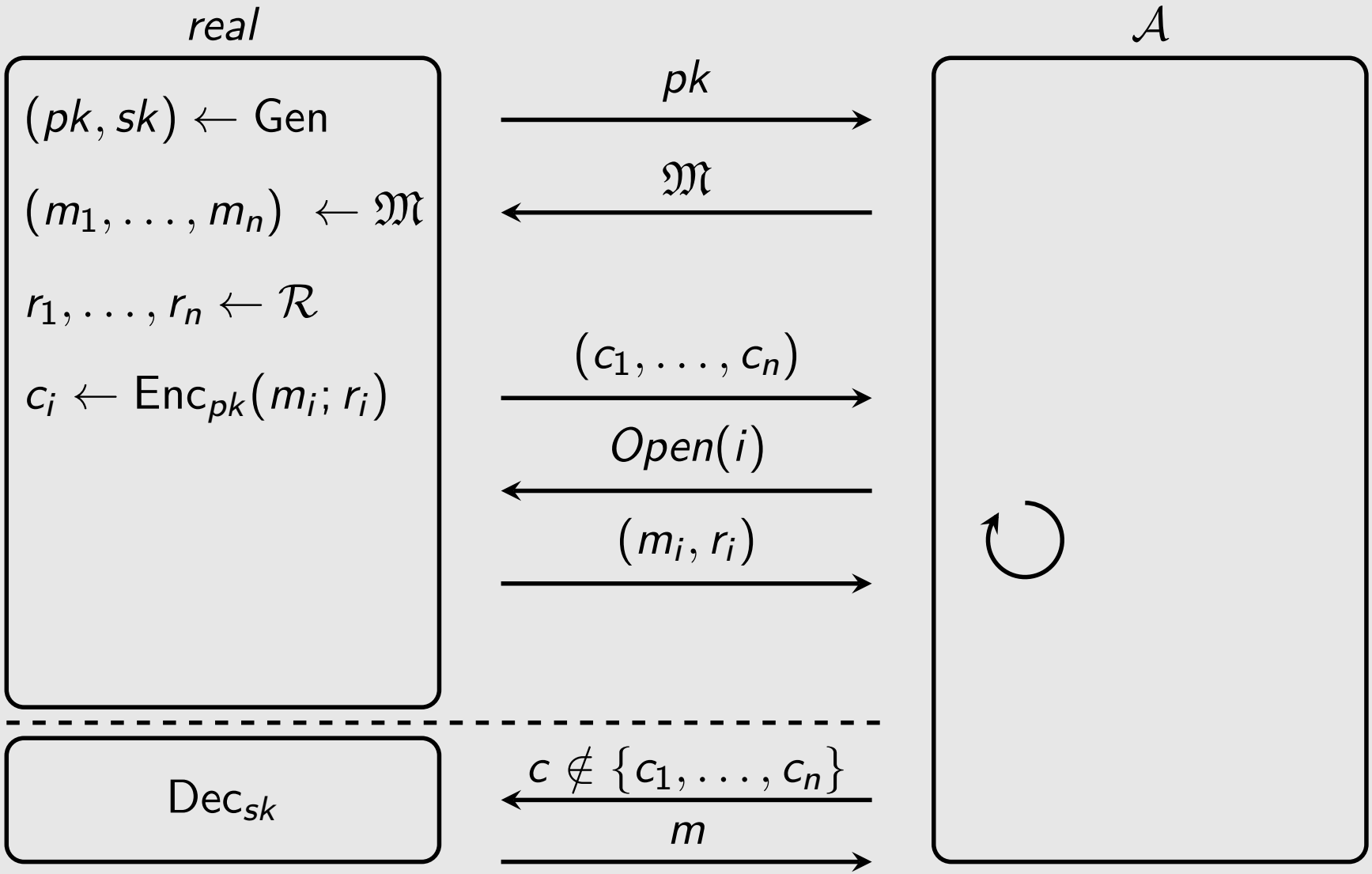

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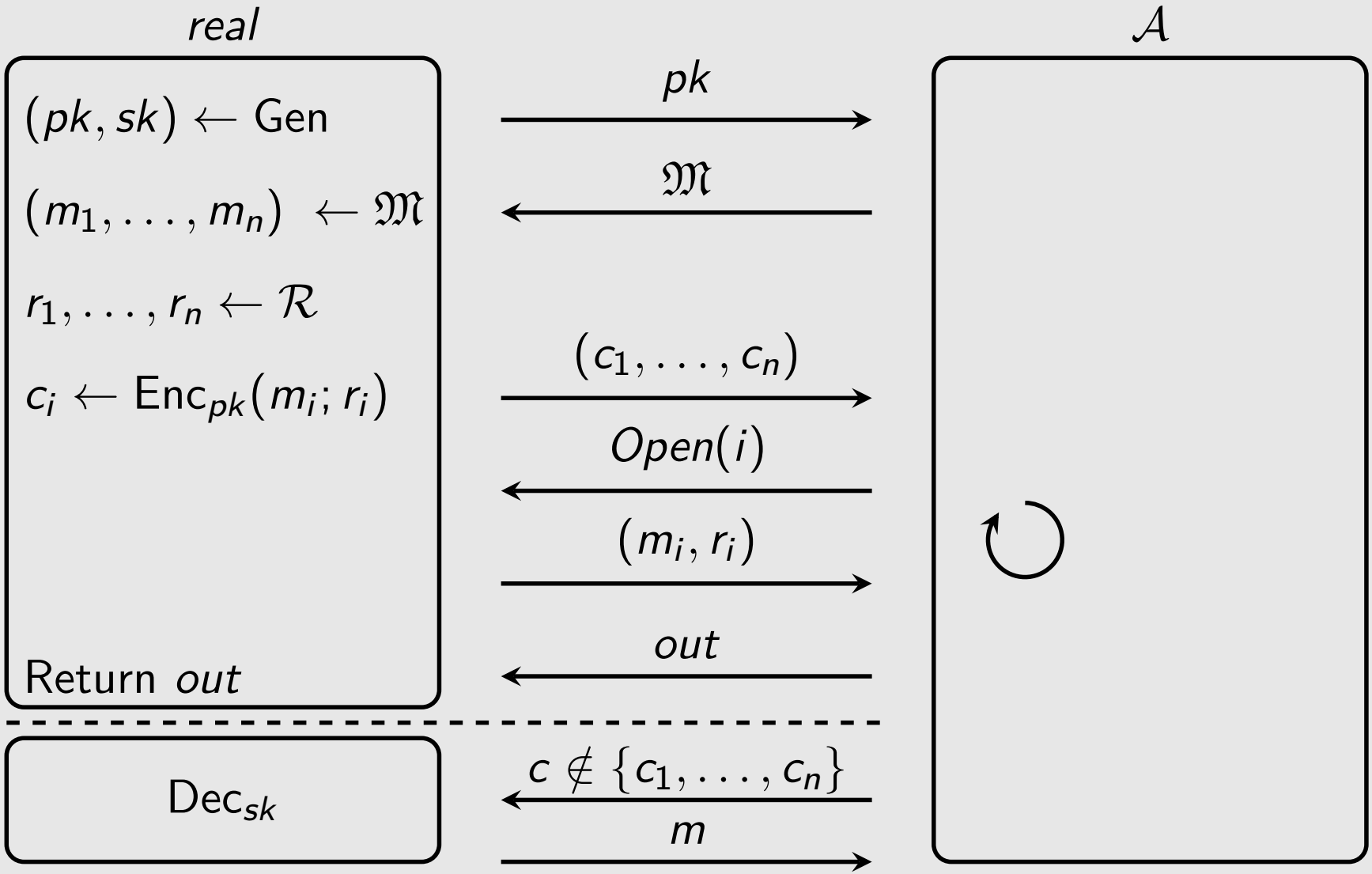

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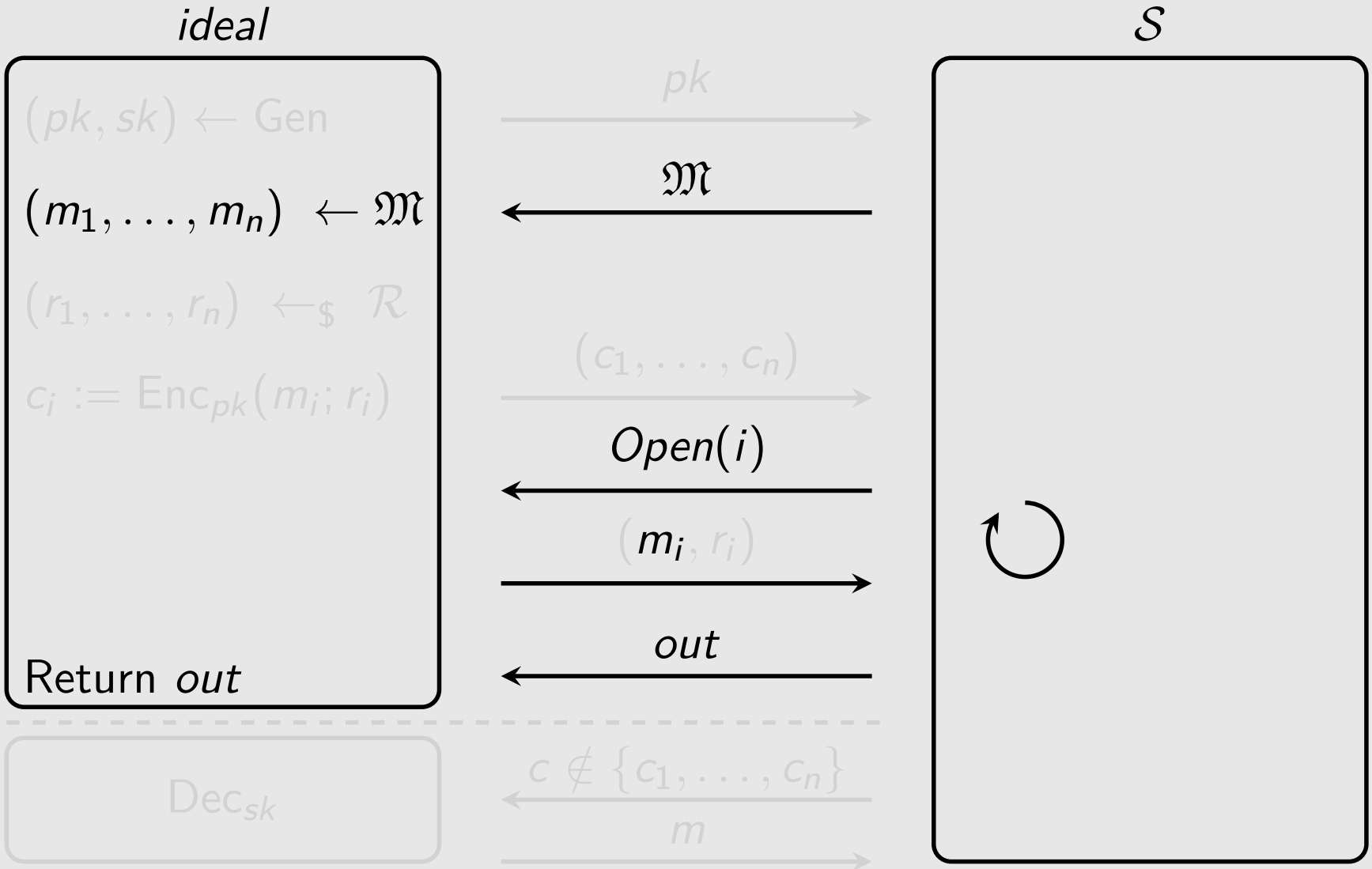

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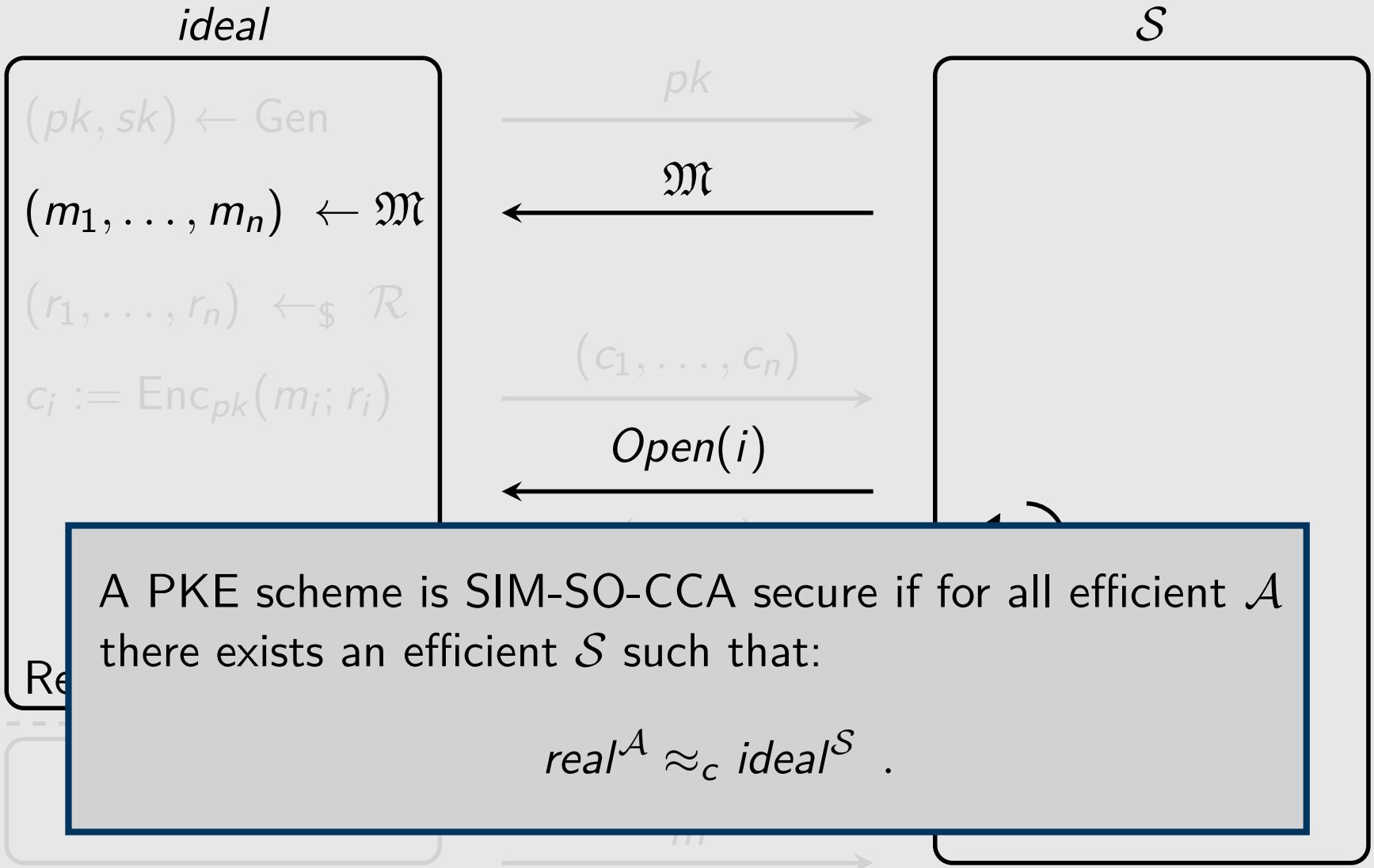

A PKE scheme is SIM-SO-CCA secure if for all efficient $\mathcal{A}$ there exists an efficient $\mathcal{S}$ such that:

$$real^{\mathcal{A}} \approx_c ideal^{\mathcal{S}} \ .$$

PKE in Practice and Previous Results

Hybrid Encryption – KEM/DEM paradigm

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- Asymmetric primitive to establish key (KEM)

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PKE in Practice and Previous Results

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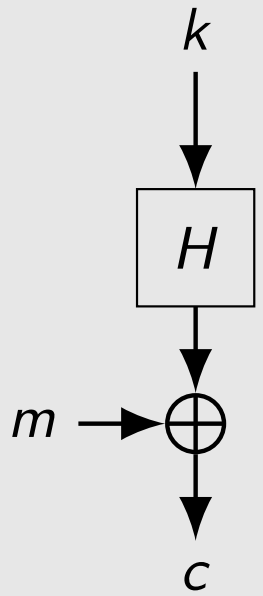
- Symmetric primitive to encrypt the message (DEM)
  e.g. CTR, CBC, CCM, GCM blockcipher modes

Previous Results

- DHIES, RSA-OAEP are SIM-SO-CCA secure [HJKS15]
- DEM: xor with the output of a random oracle



A Strategy for Proving SIM-SO-CCA Security

Given any adversary $\mathcal{A}$, construct a simulator $\mathcal{S}$.

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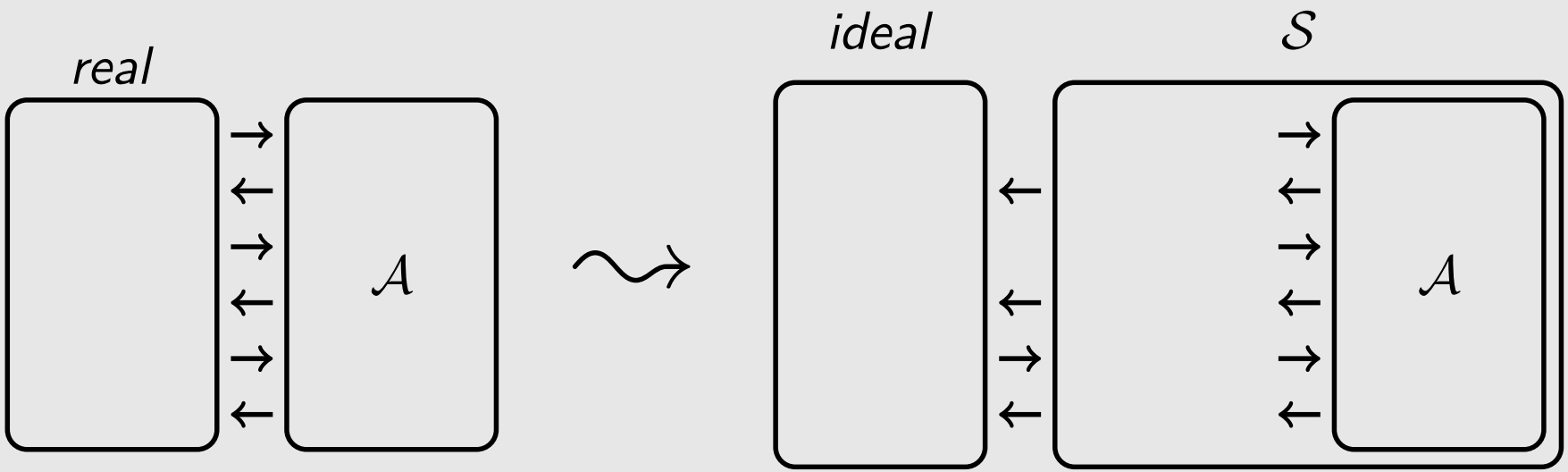
$\mathcal{S}$ (internally) runs $\mathcal{A}$ to draw the same conclusions as $\mathcal{A}$.



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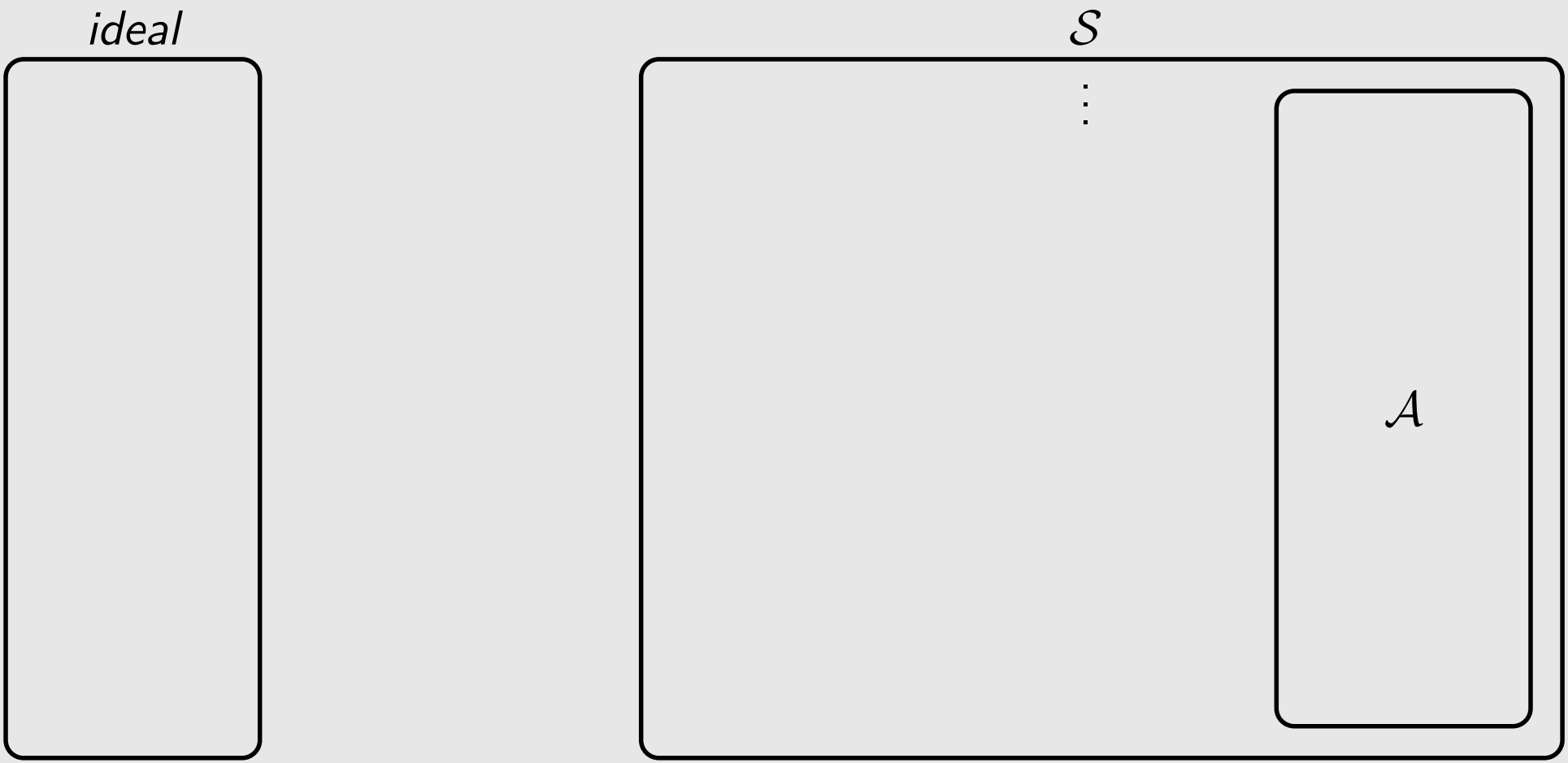

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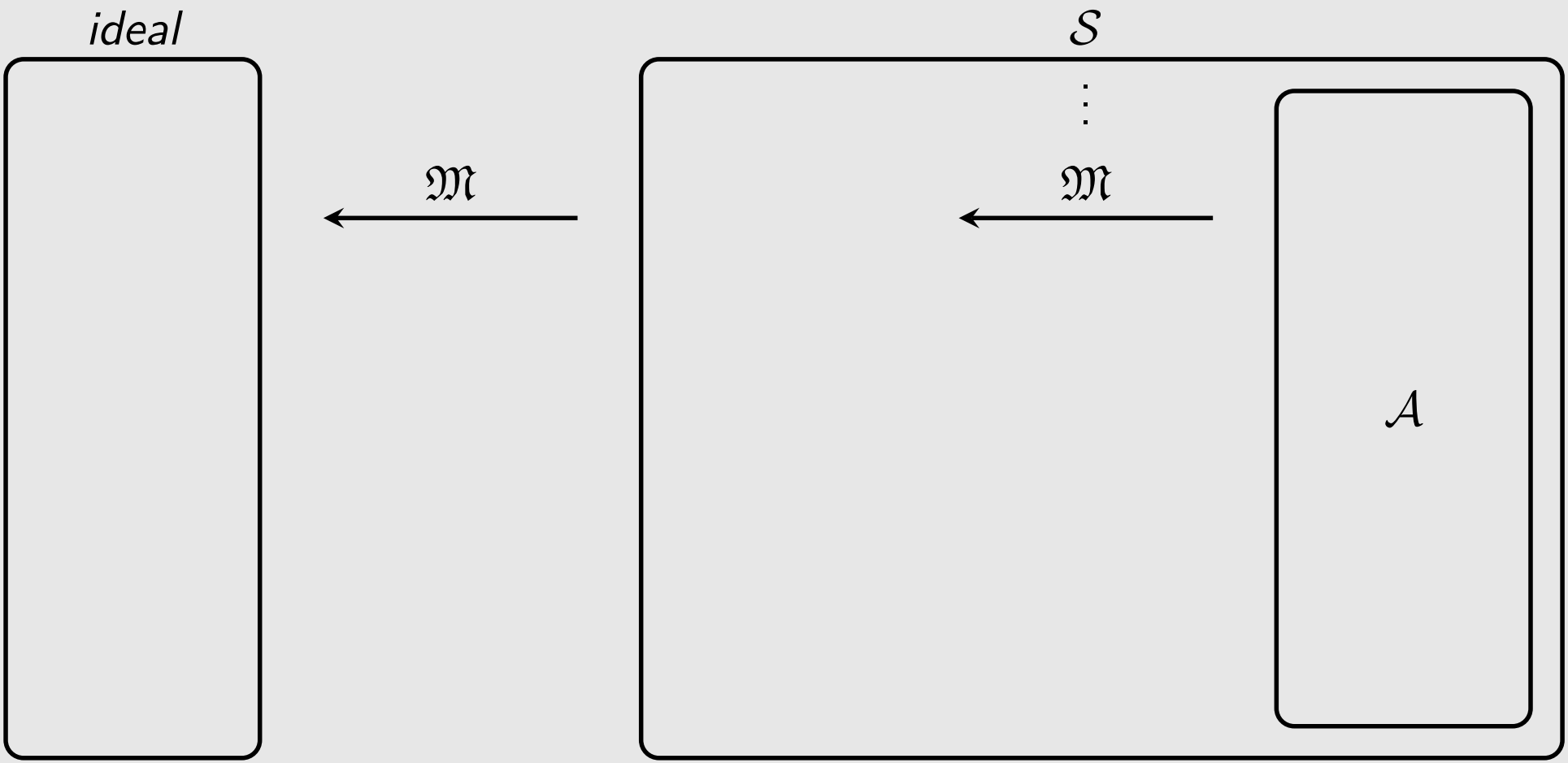

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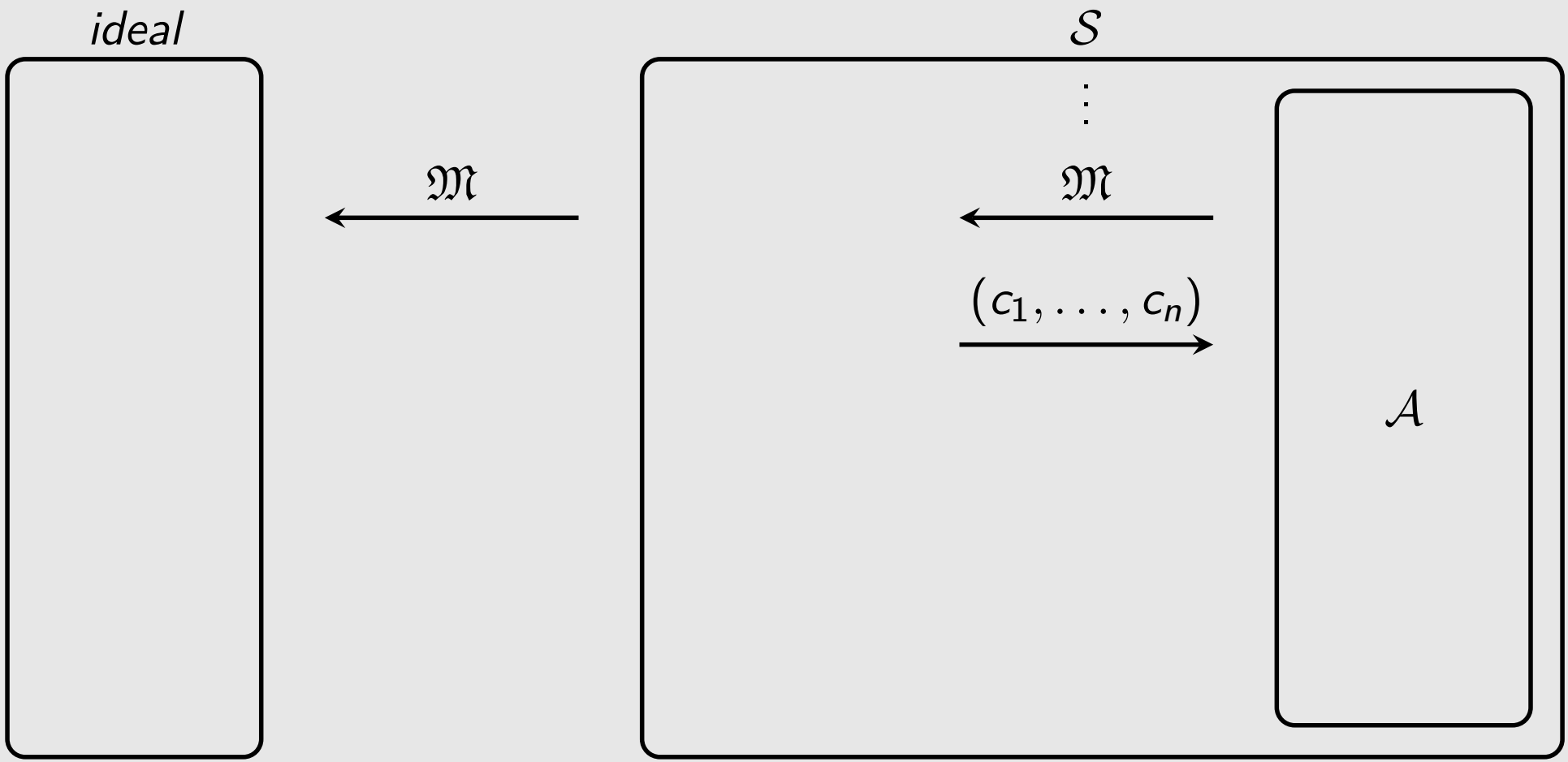

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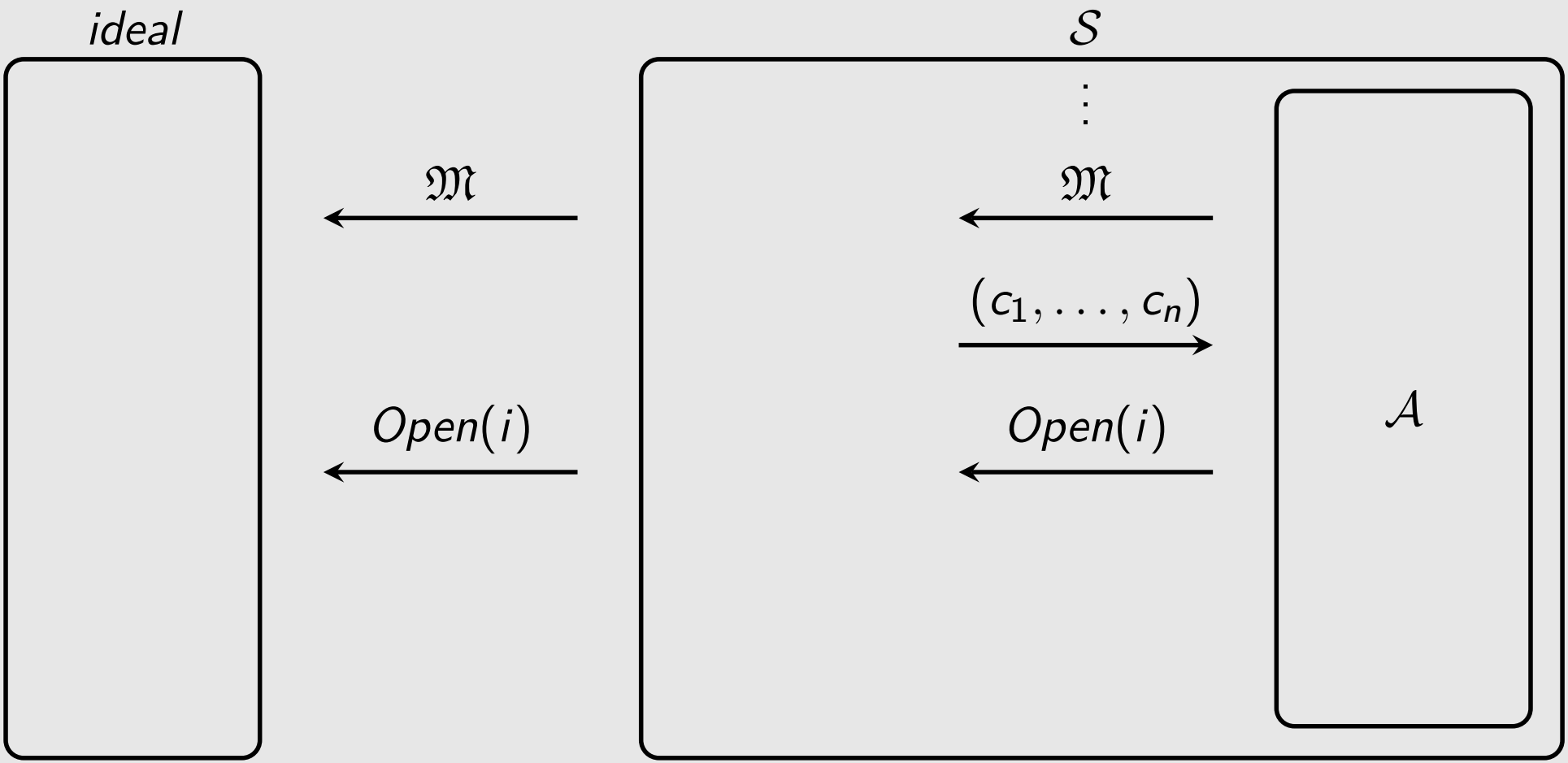

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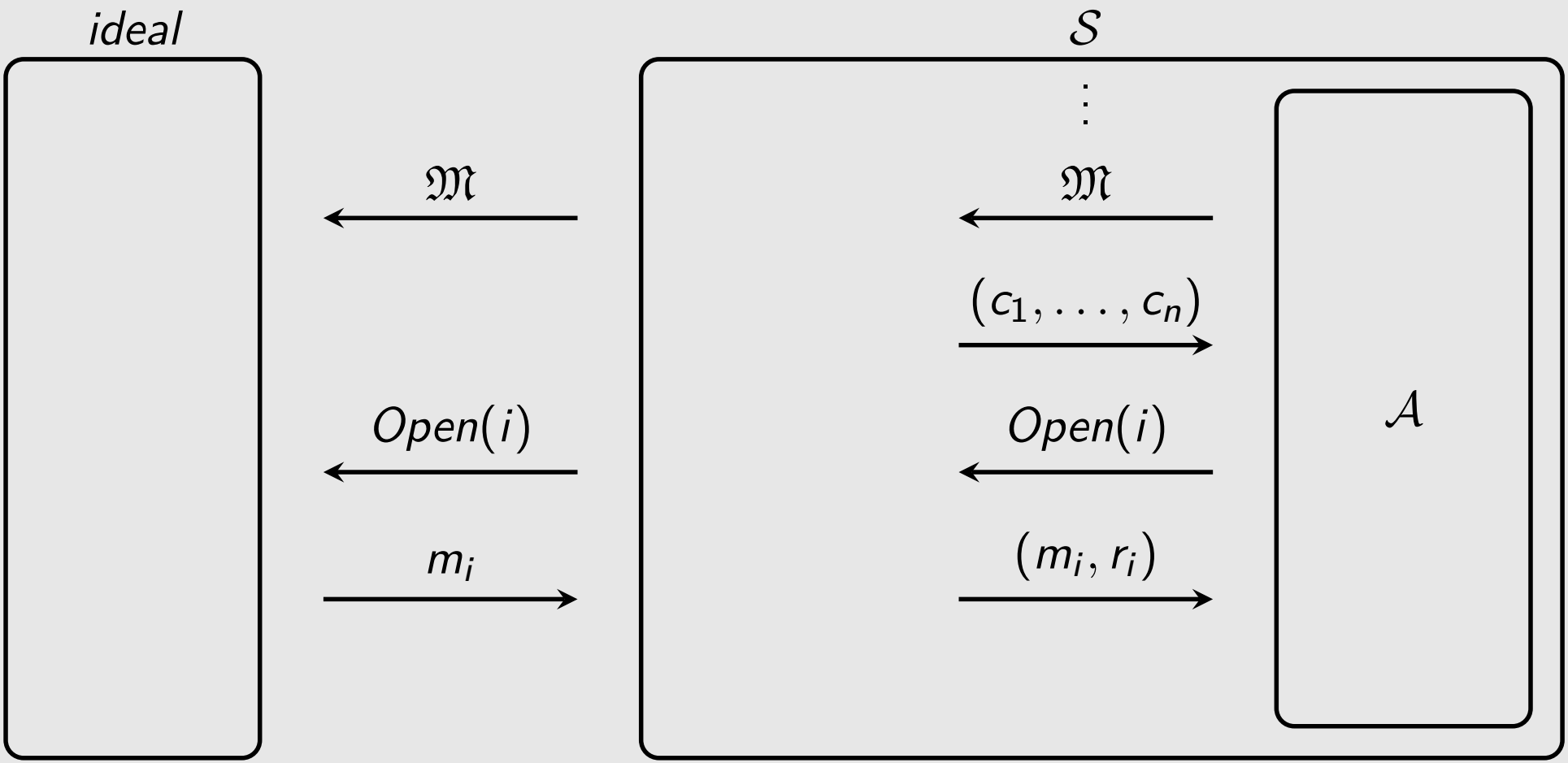

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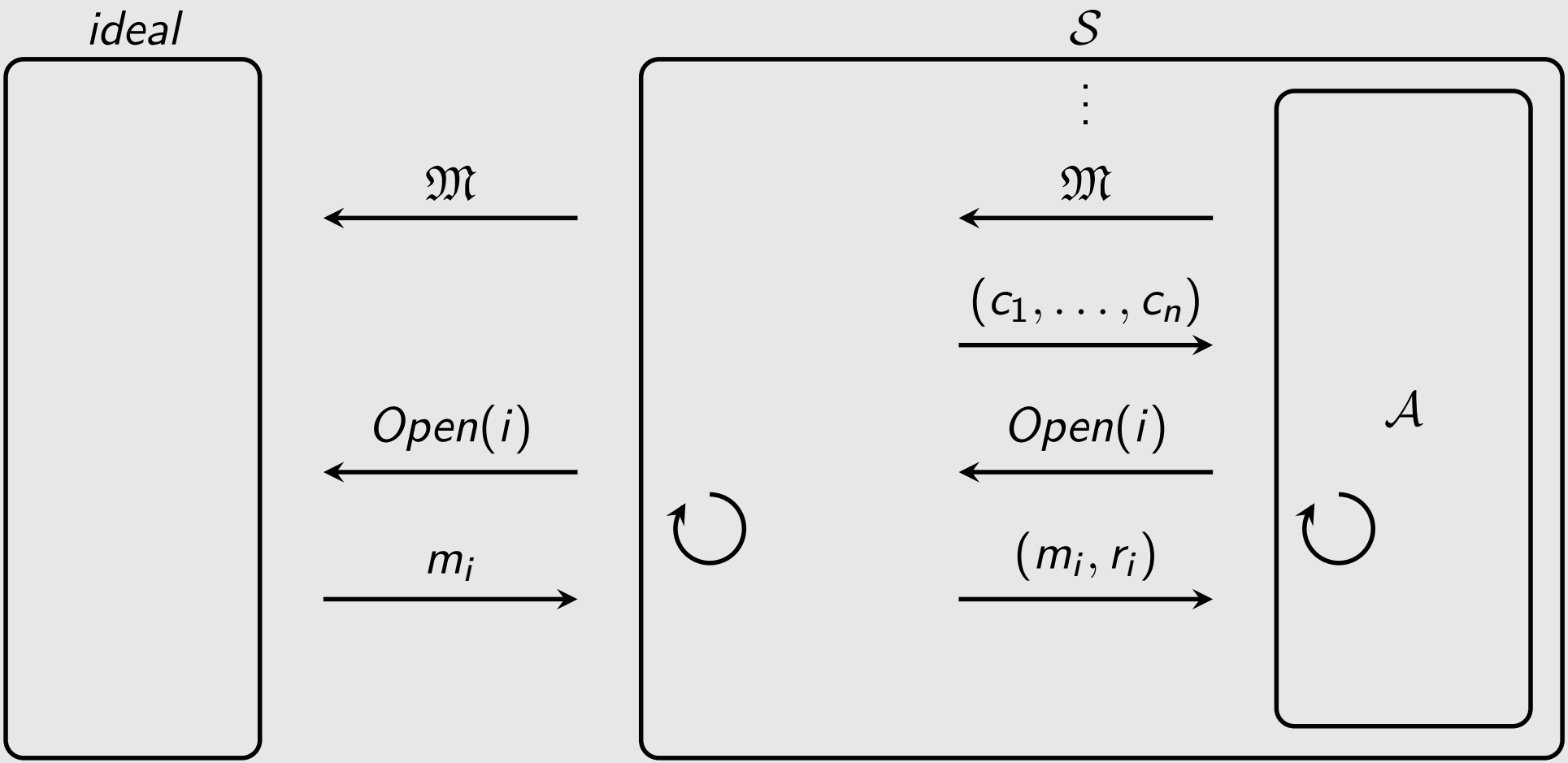

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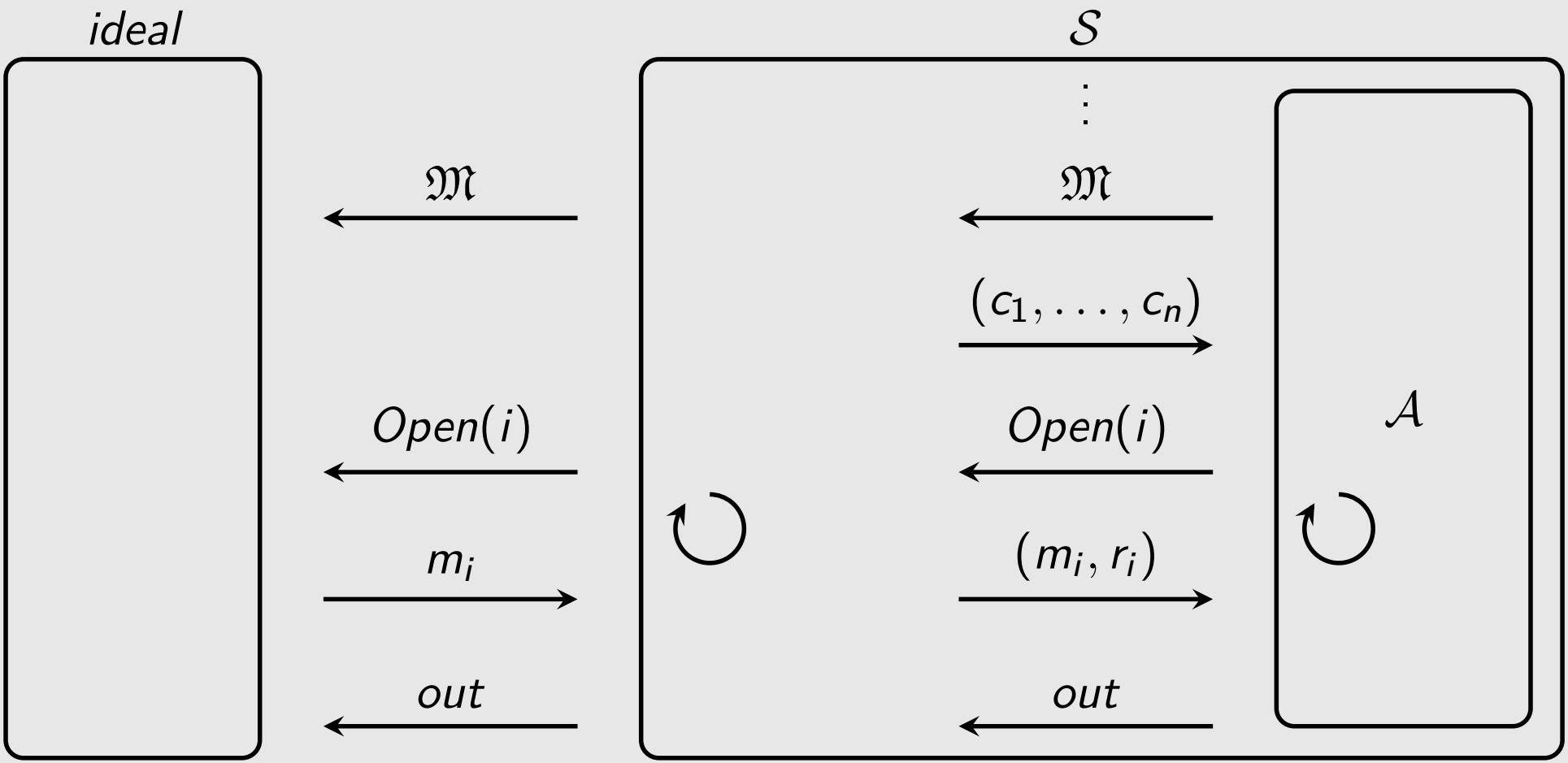

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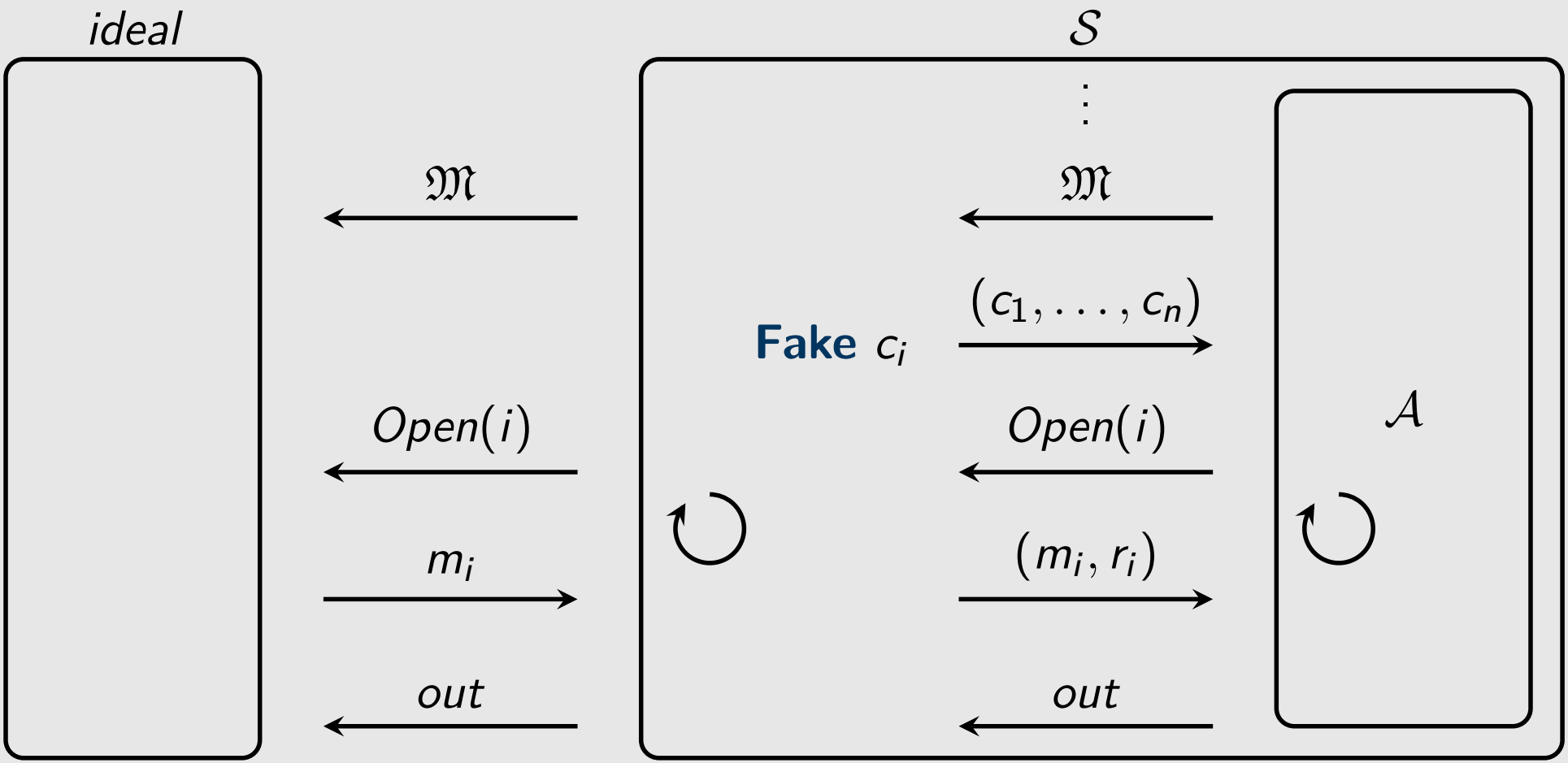

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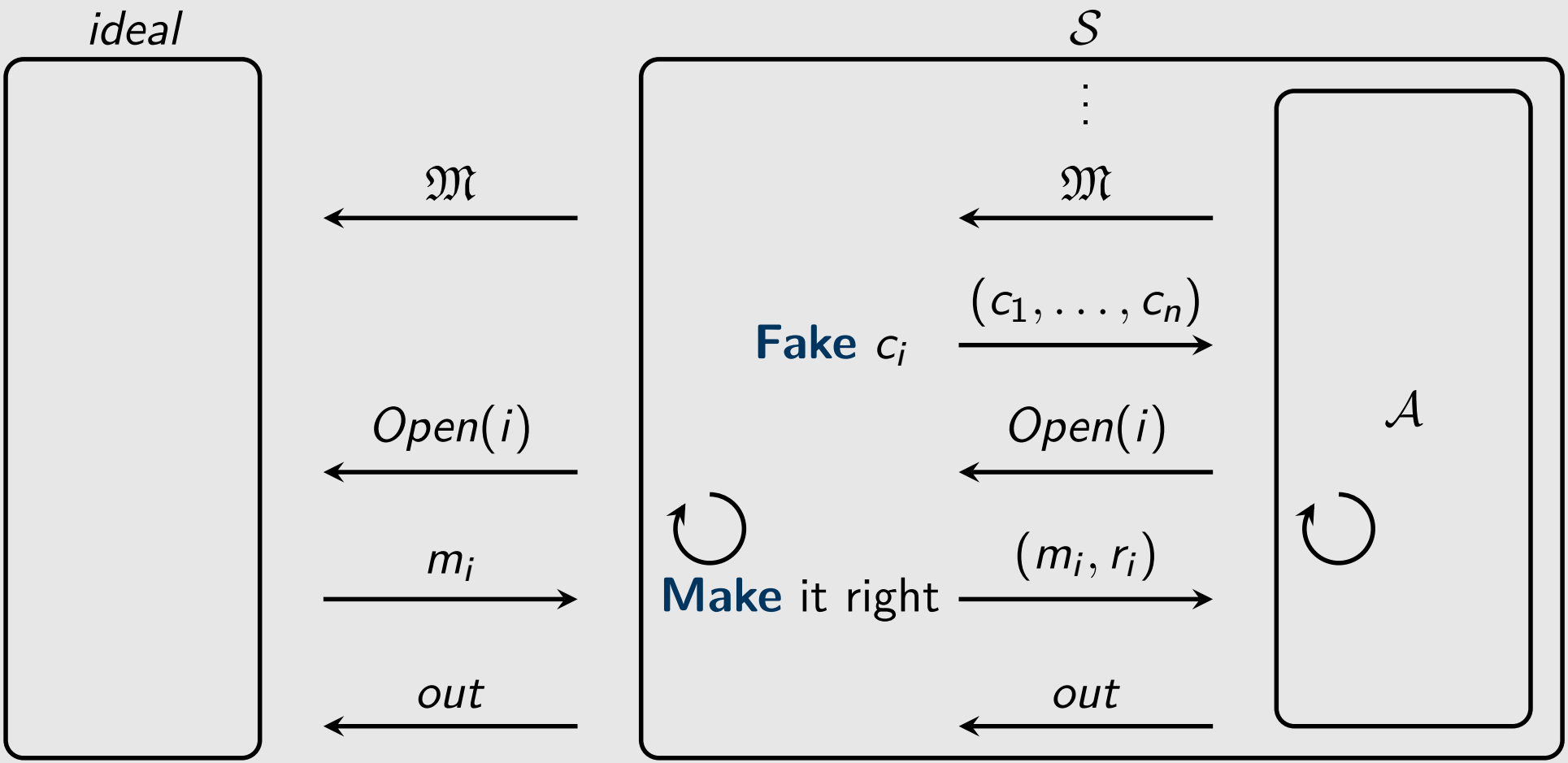
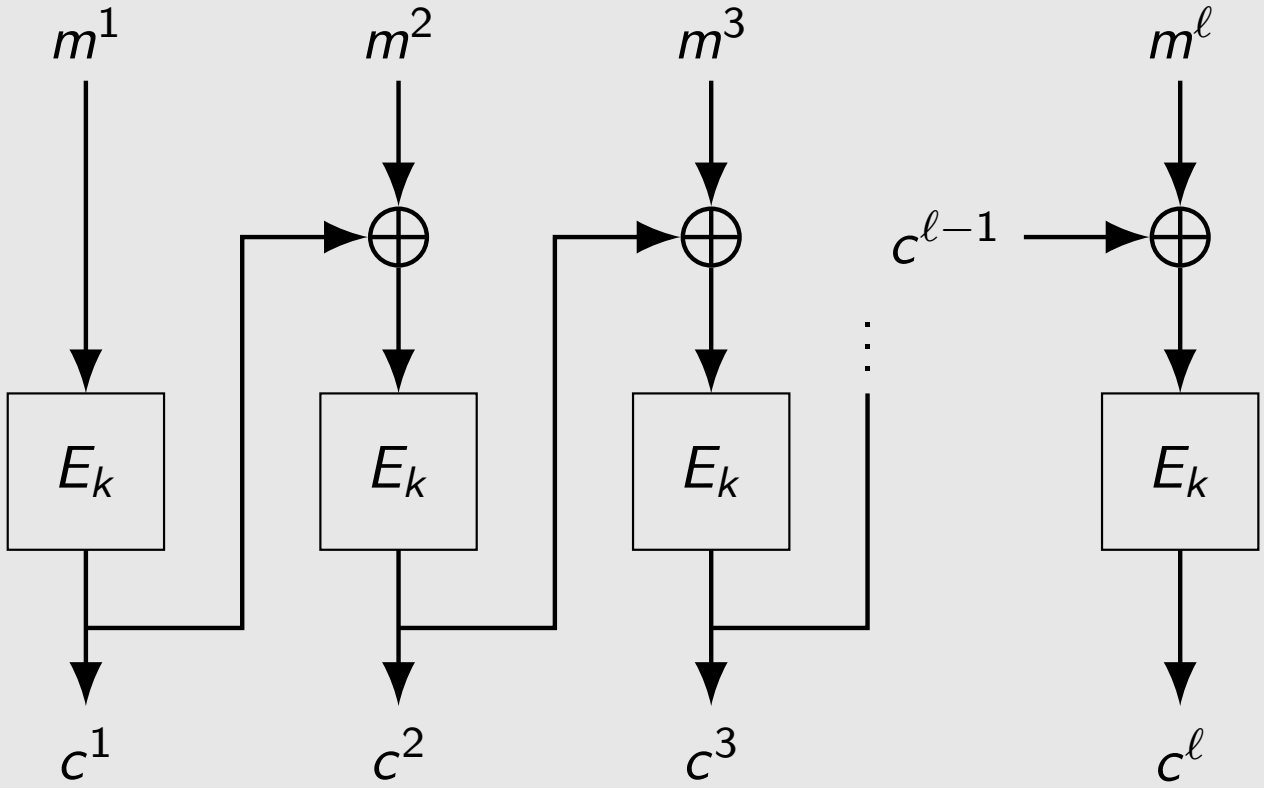


CBC Mode + MAC



k : **blockcipher key**
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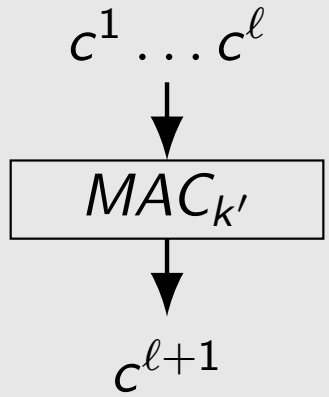

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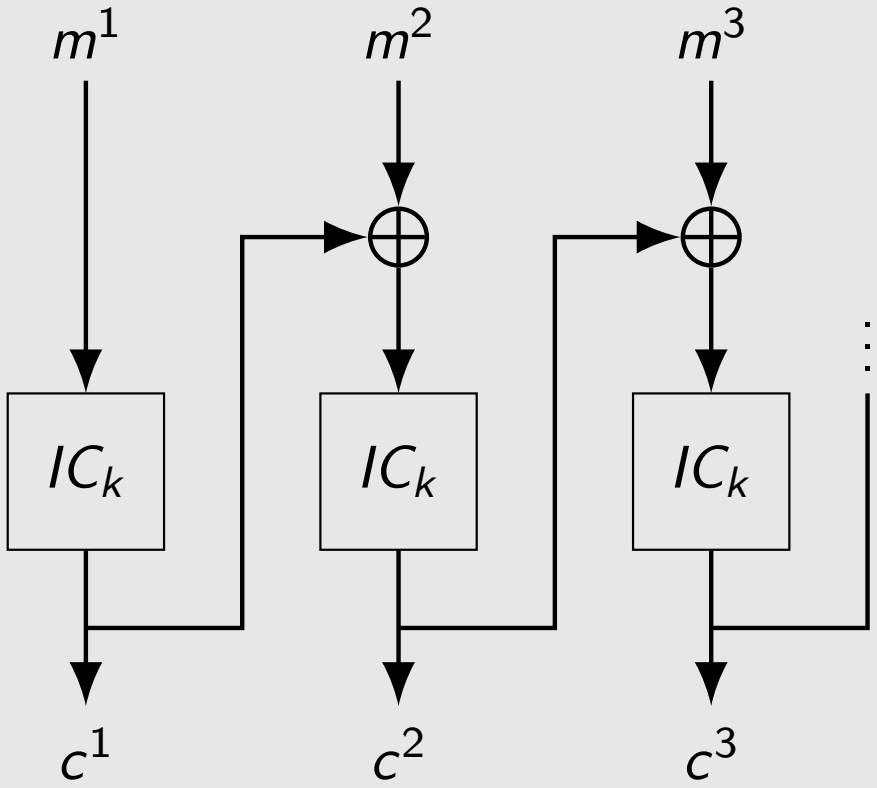

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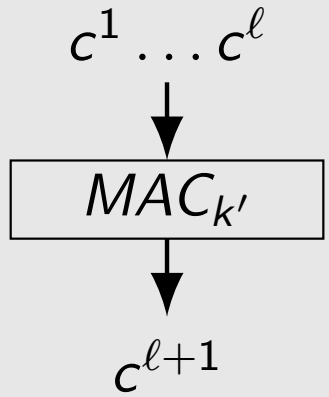

Simulatable oracle DEMs

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A 'DEM' $(\mathsf{Enc}, \mathsf{Dec})$ with oracle access to a permutation π where

$$\mathsf{Enc}^{\pi} : \mathcal{K}' \times \mathcal{M} \to \mathcal{C}$$

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such that:

1. If $(c \leftarrow \textbf{Fake}(k'); \tilde{\pi} \leftarrow \textbf{Make}(m))$ then $c = \mathsf{Enc}^{\tilde{\pi}}(k', m)$.
2. Running (**Fake**,**Make**) yields a uniform permutation.

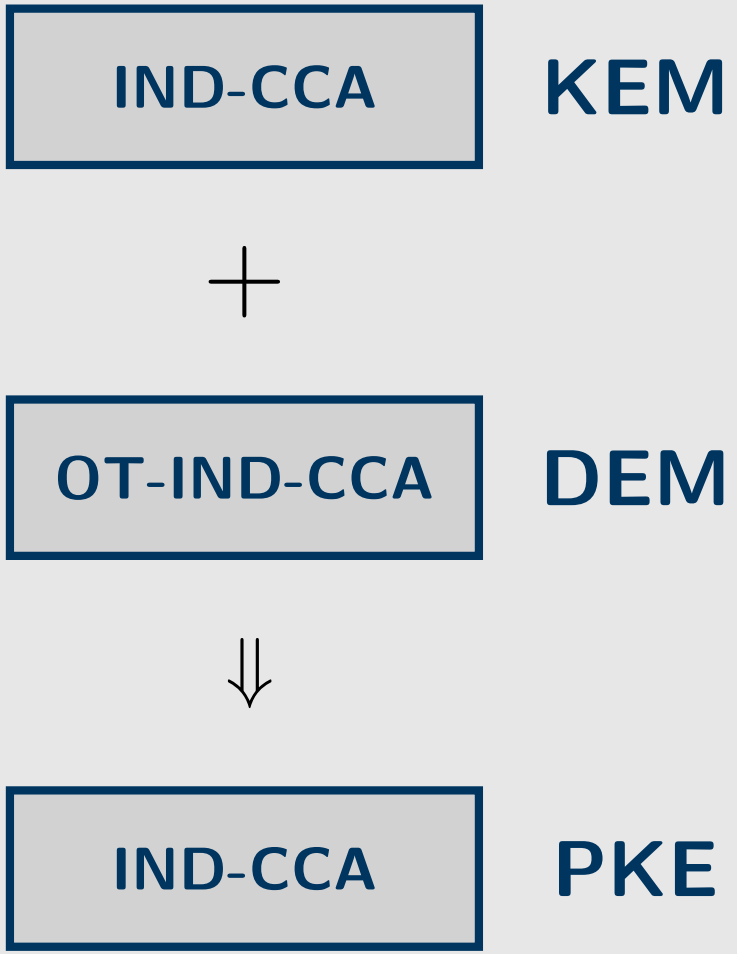
Security of Hybrid Encryption

KEM

DEM

PKE

Security of Hybrid Encryption



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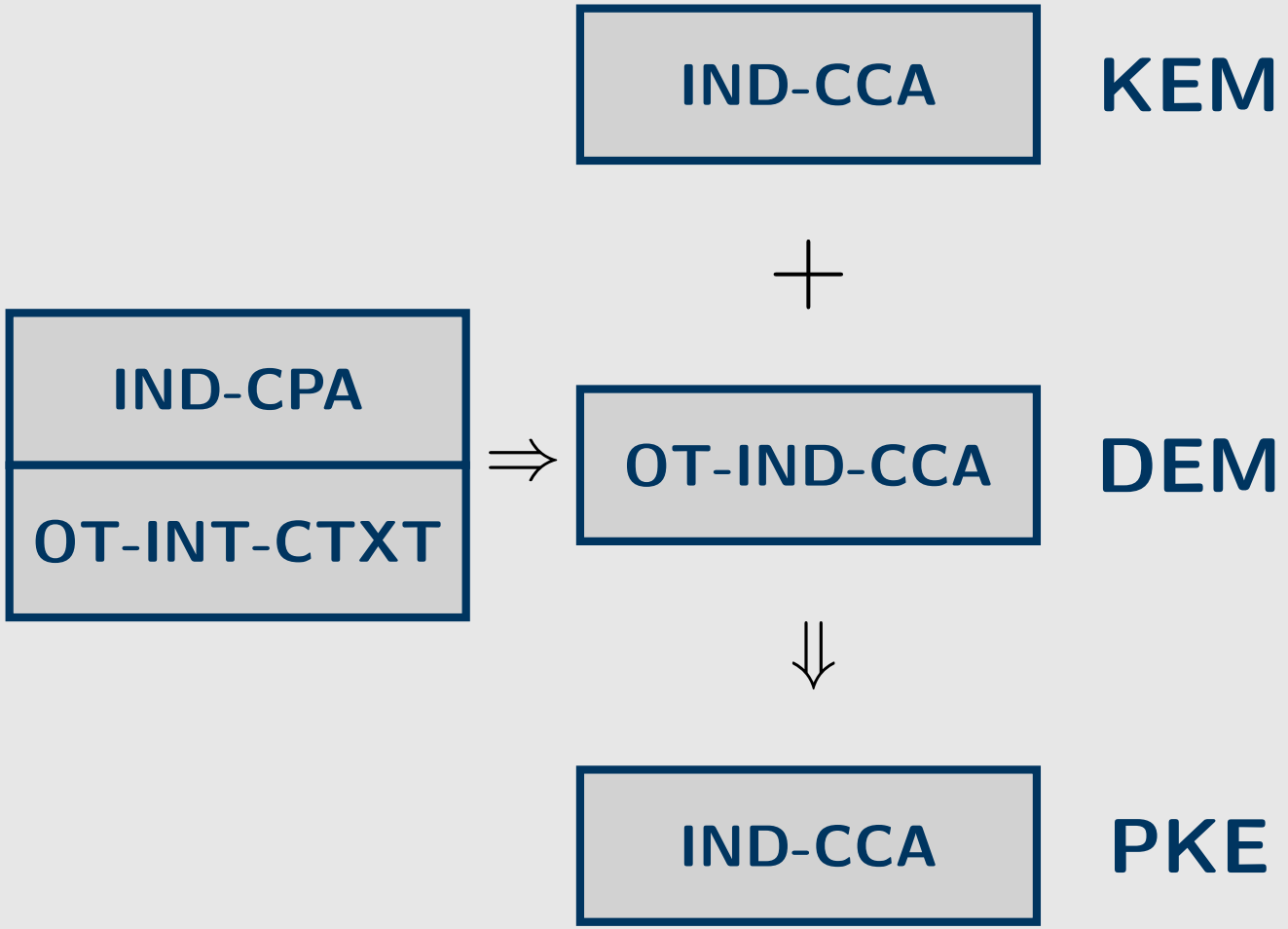

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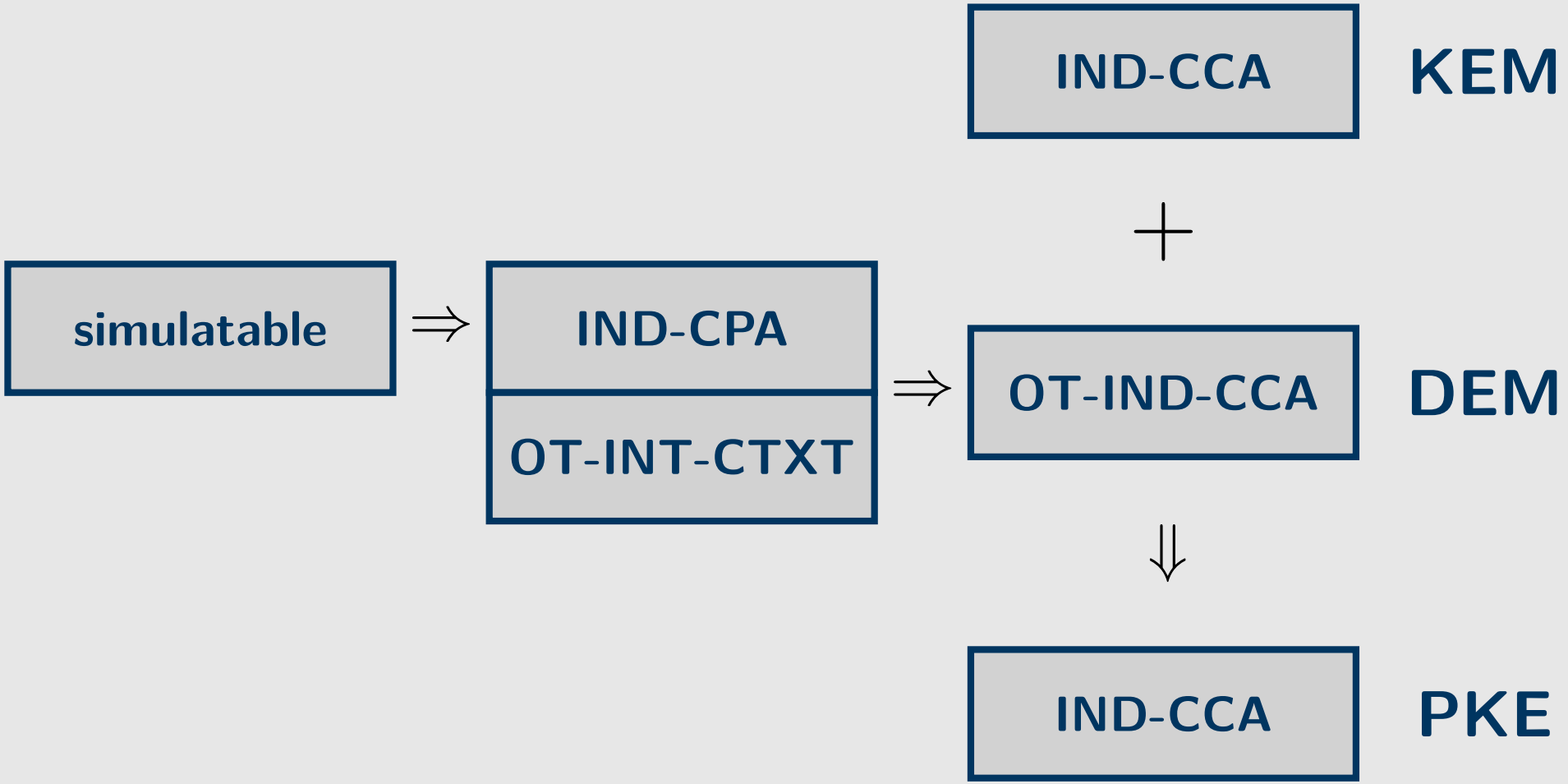

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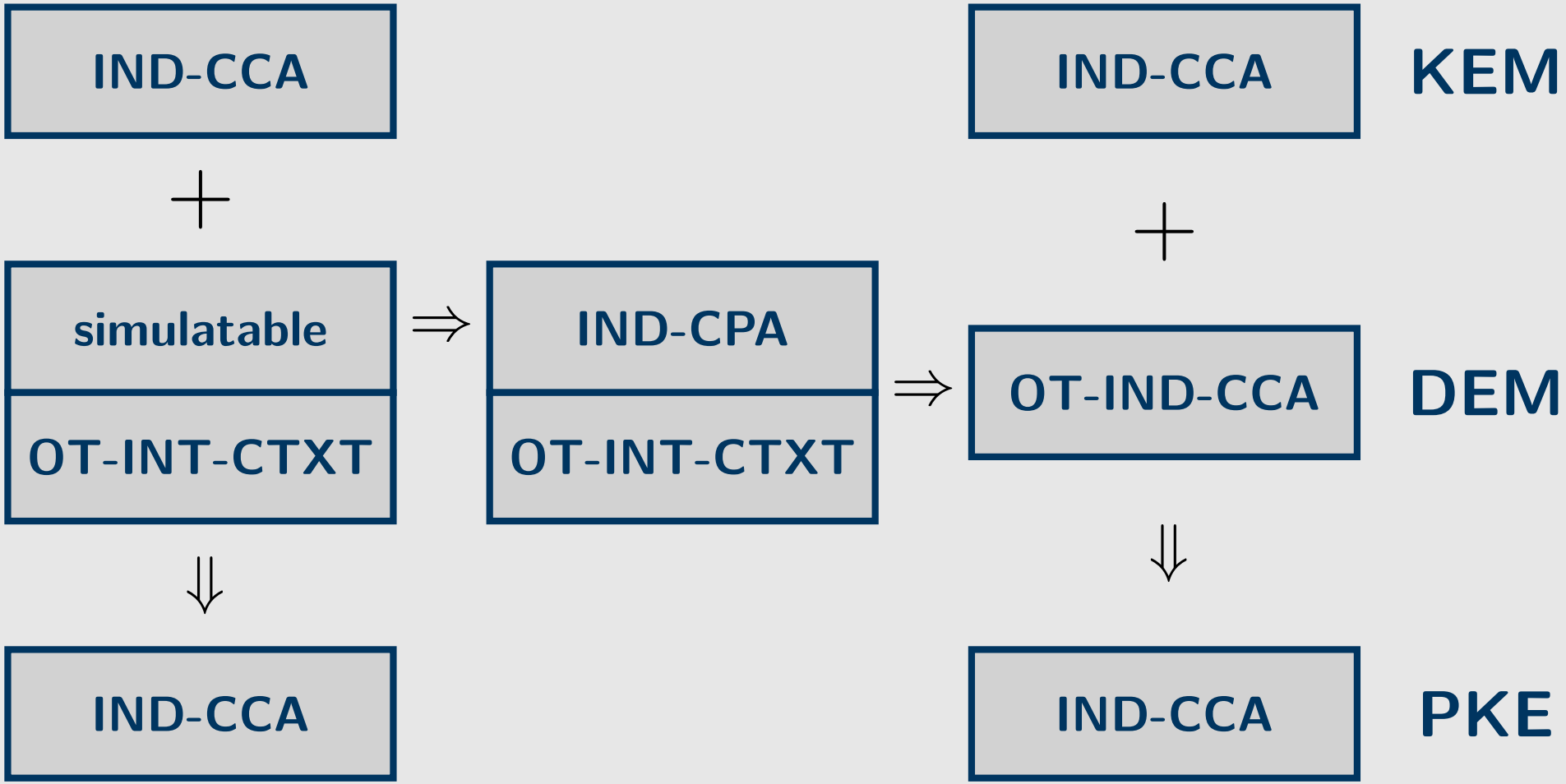

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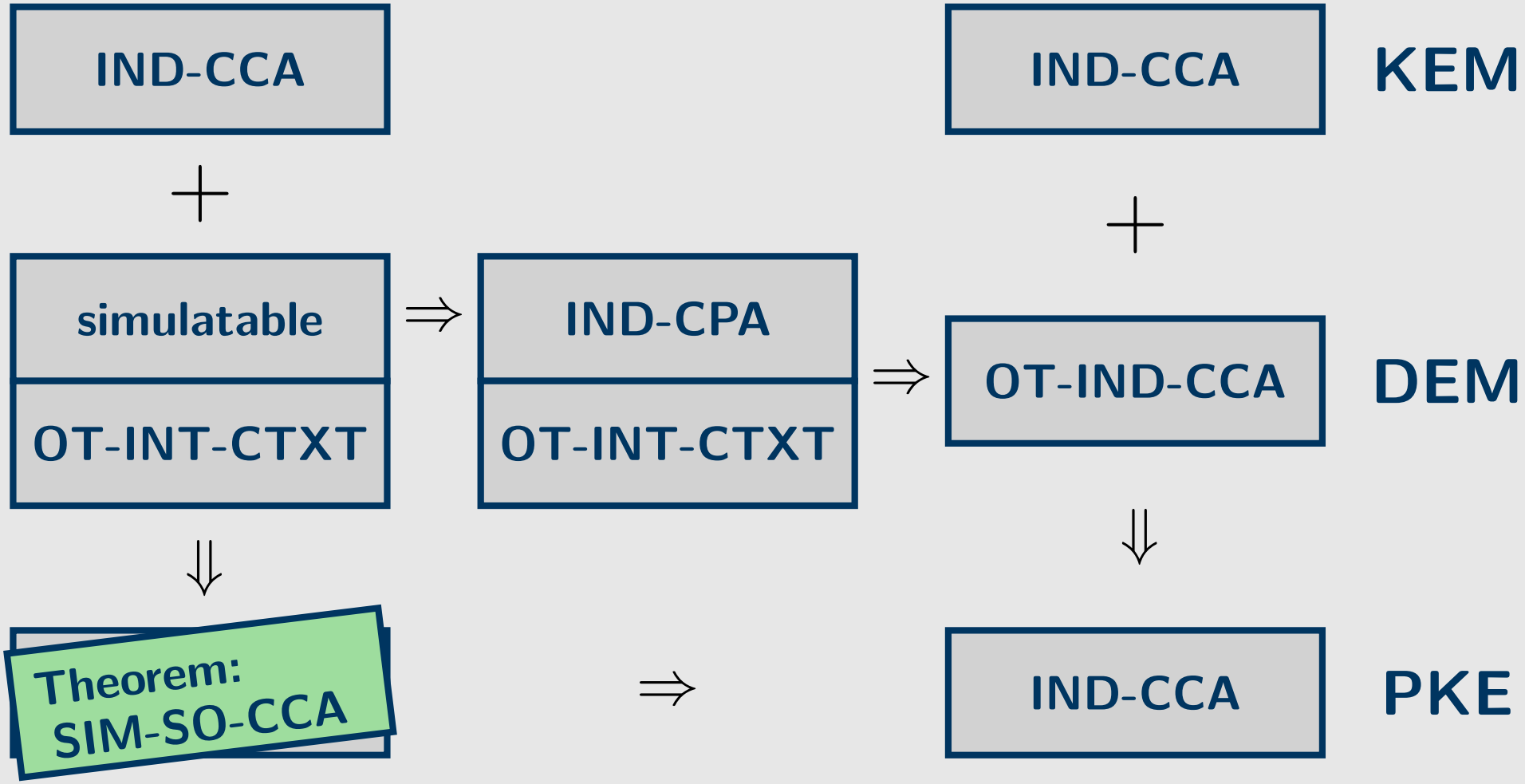

Security of Hybrid Encryption

Theorem:

IND-CCA

KEM

DEM

PKE

Security of Hybrid Encryption

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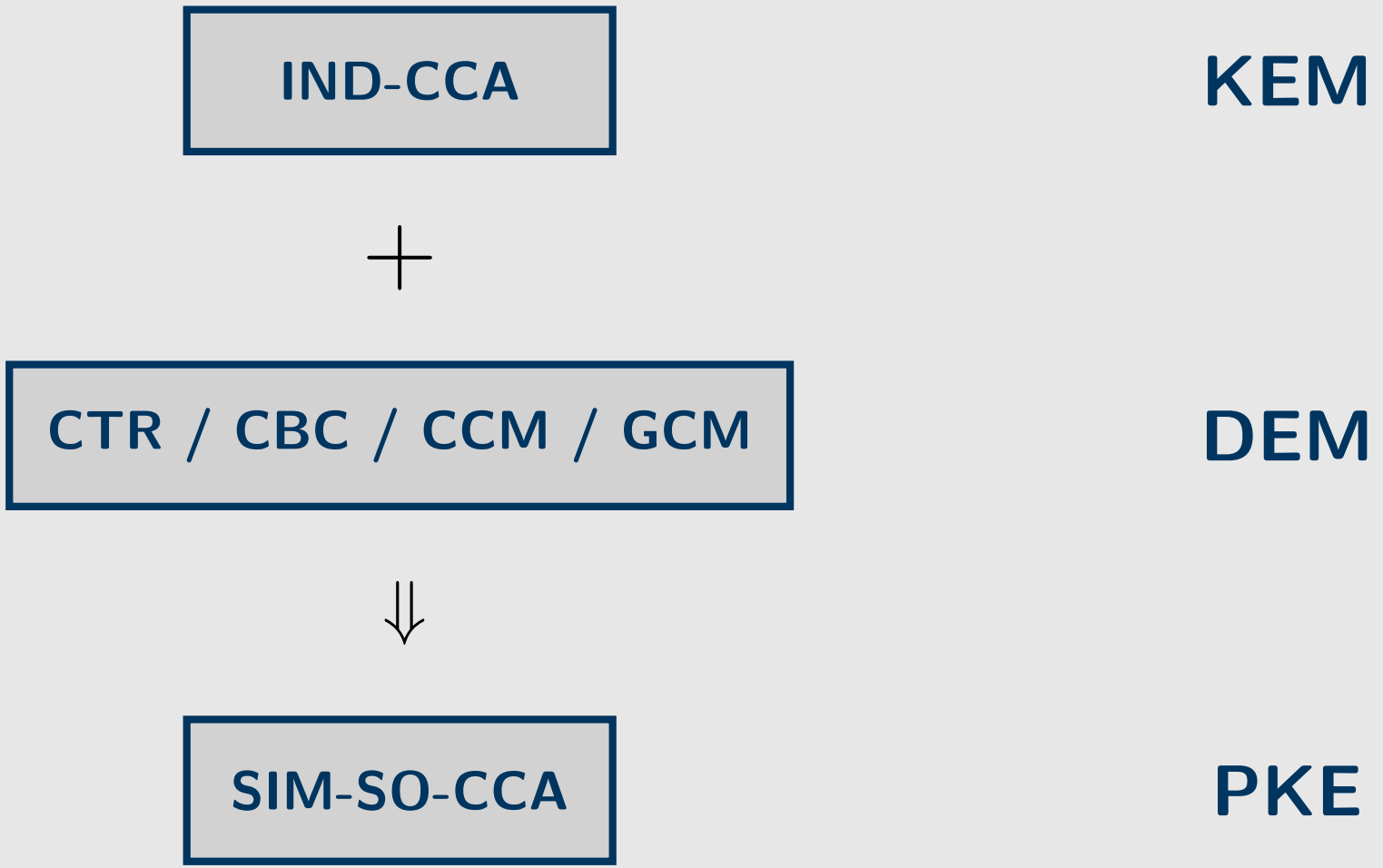
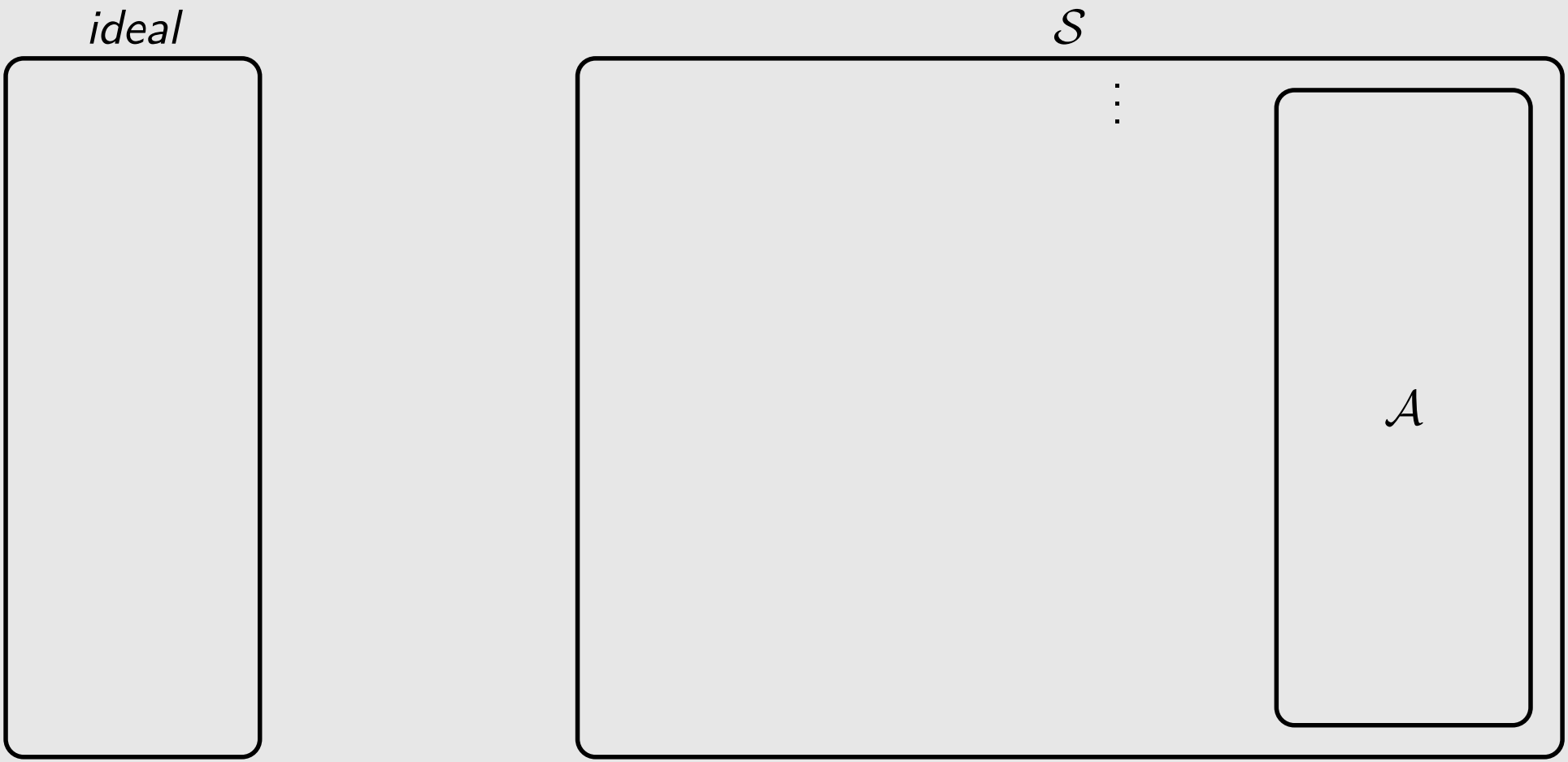


Intuition for the Proof



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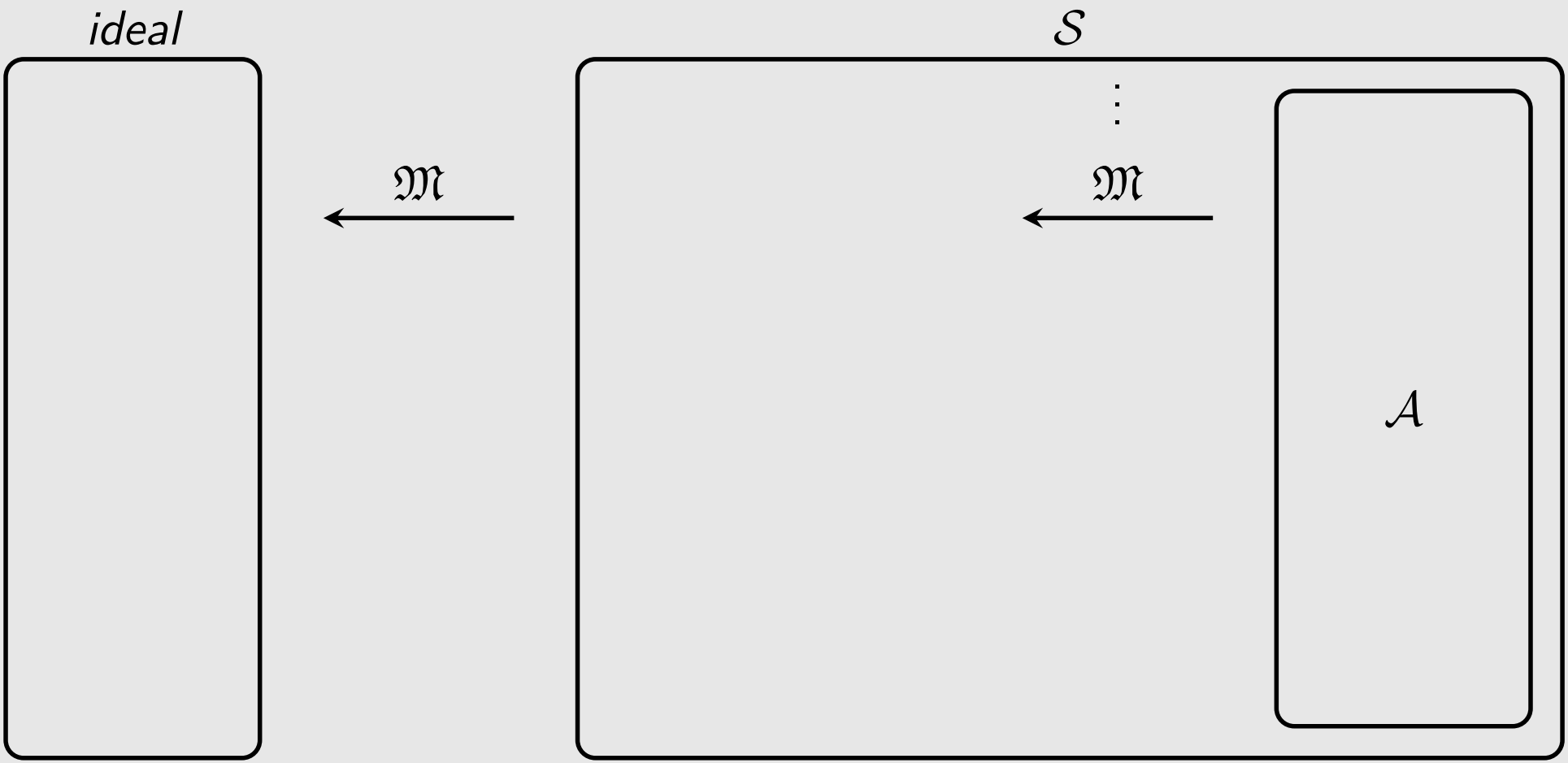

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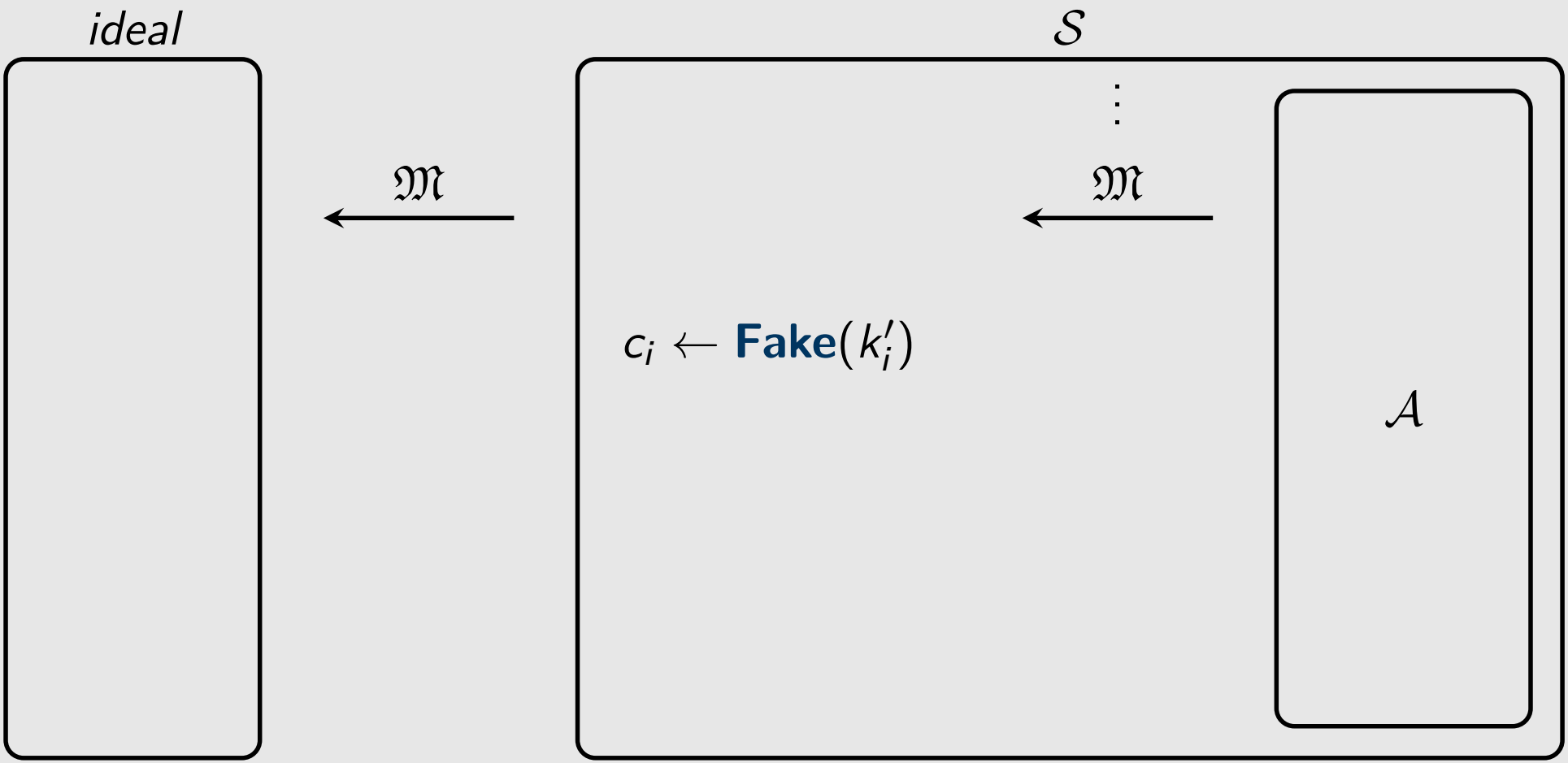

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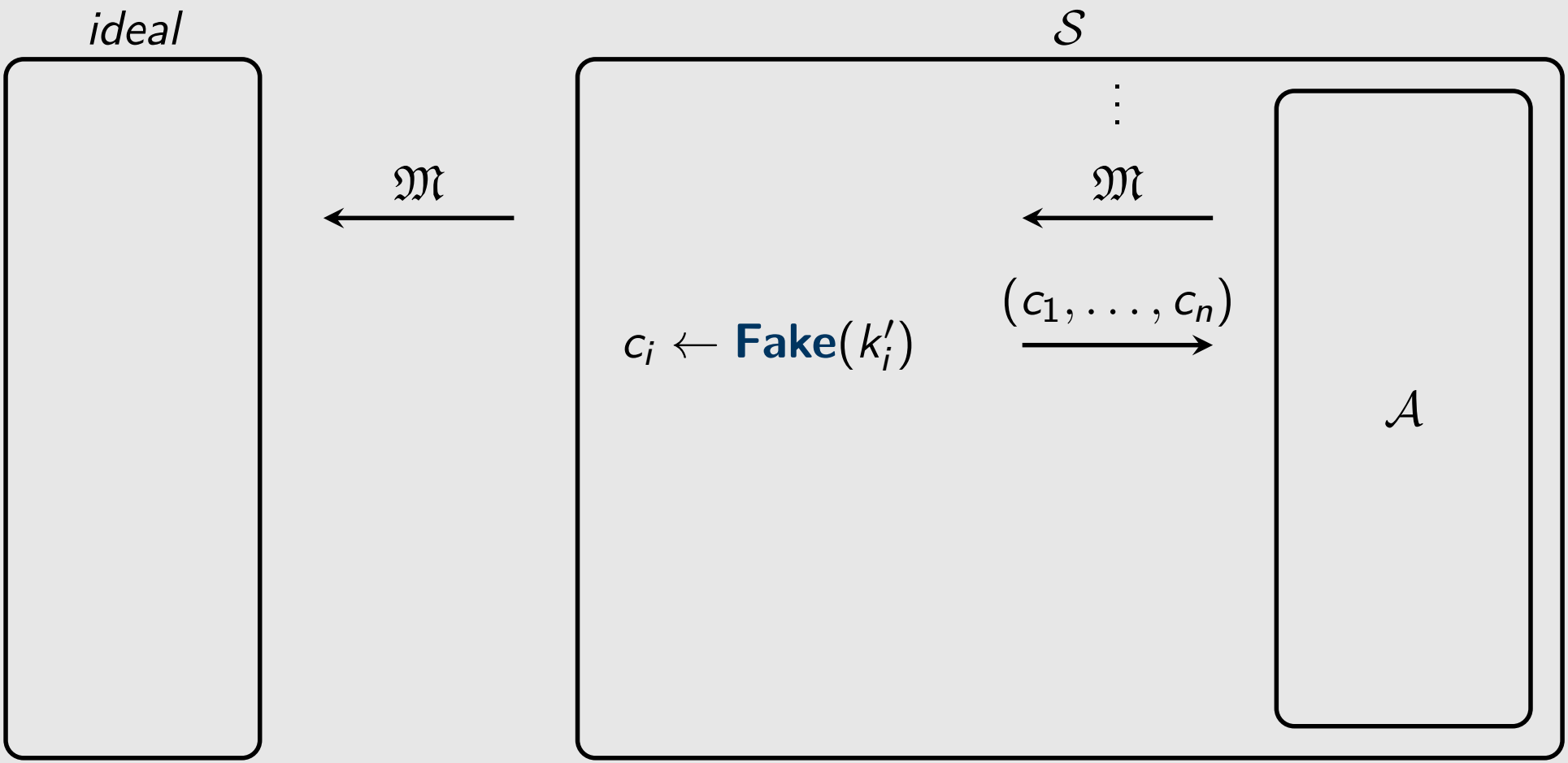

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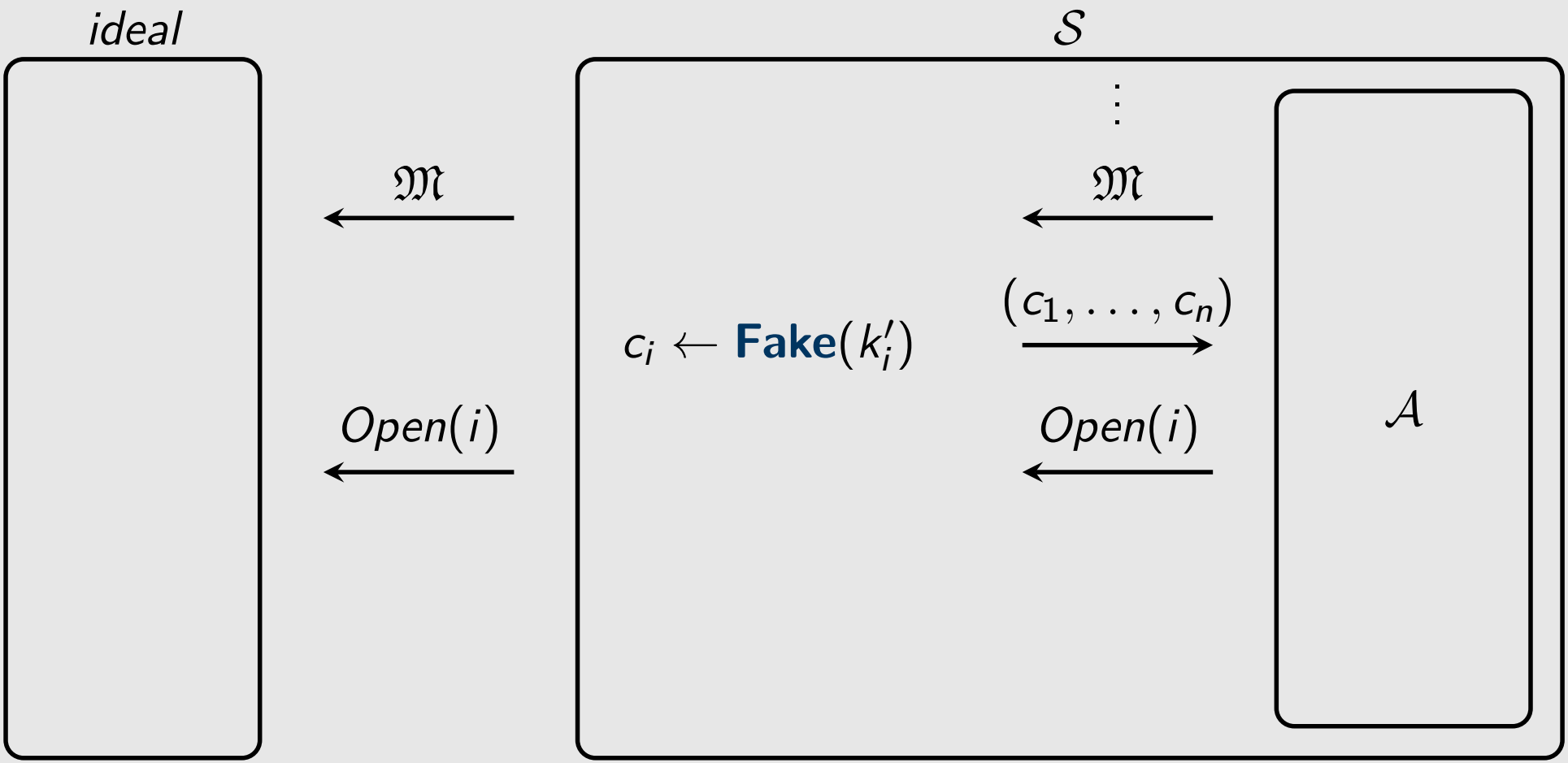

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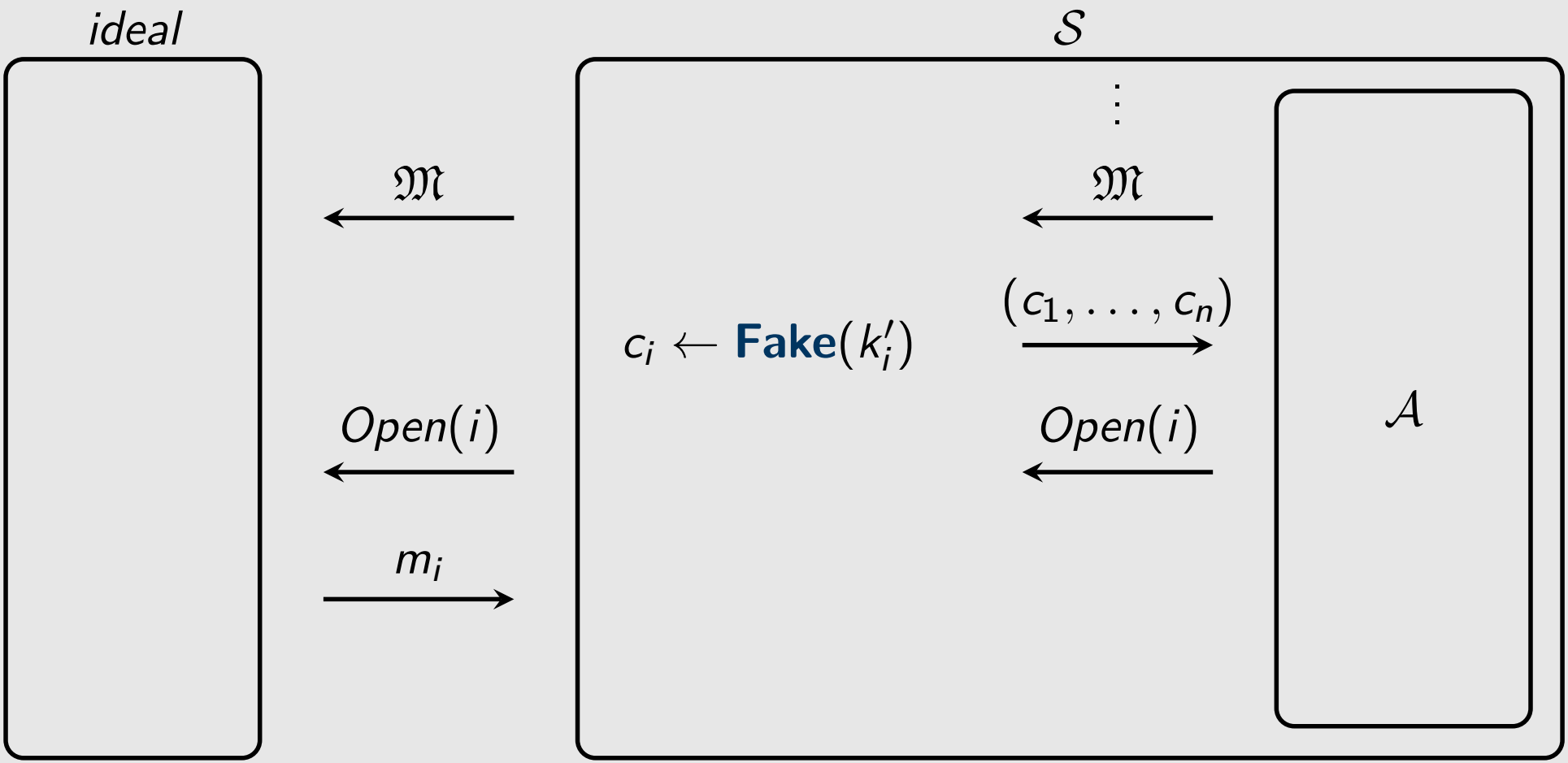

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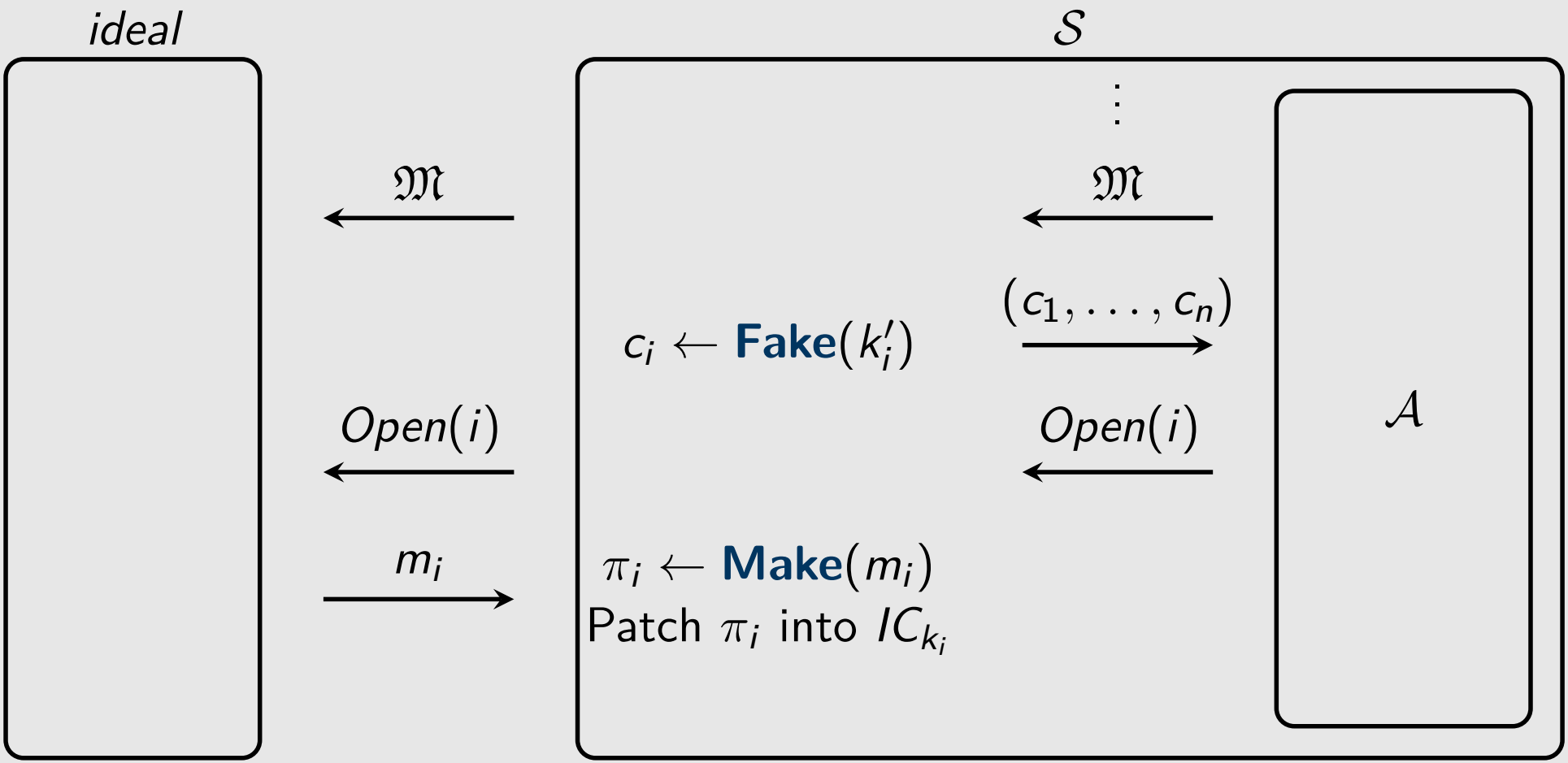

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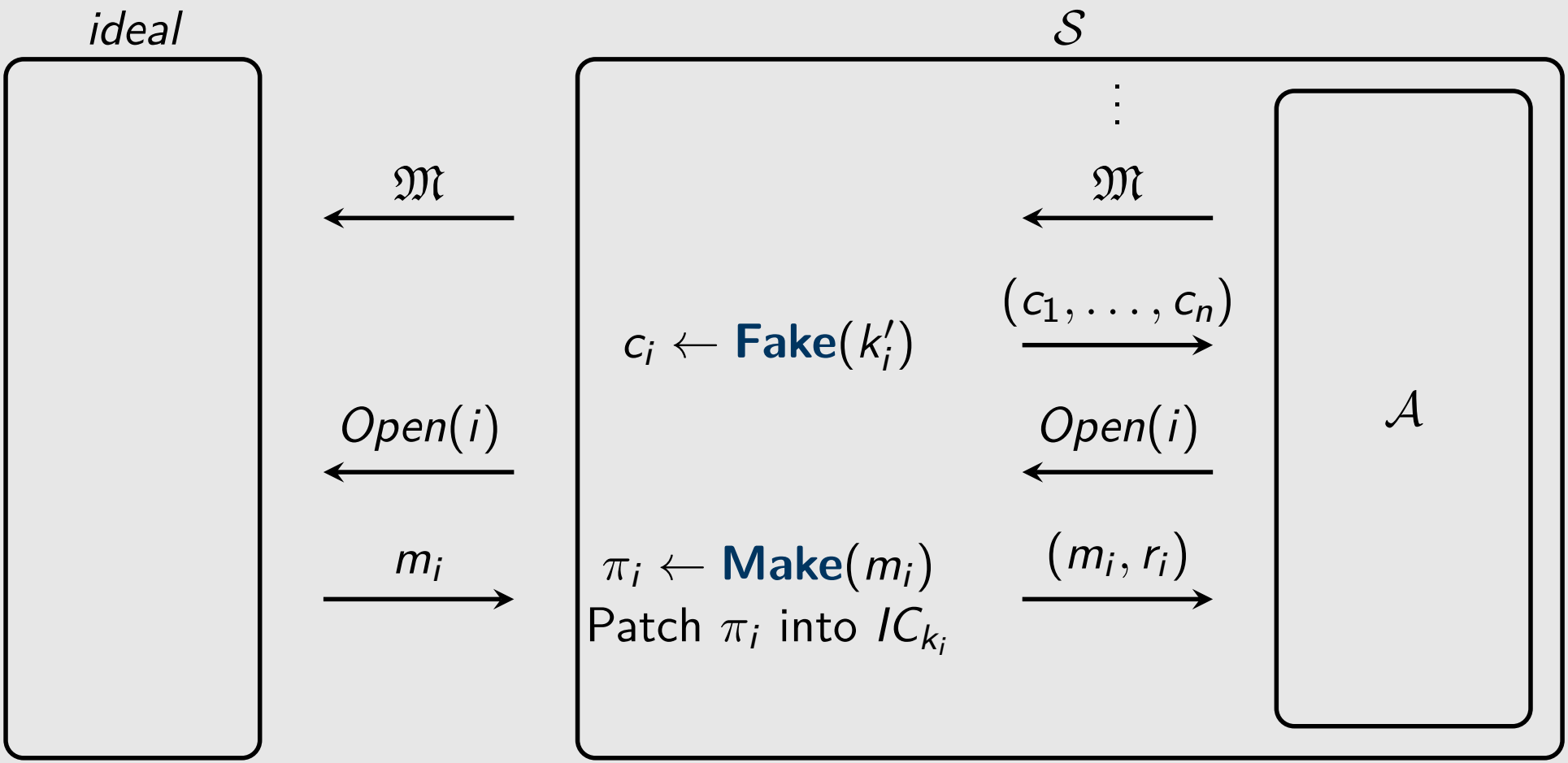

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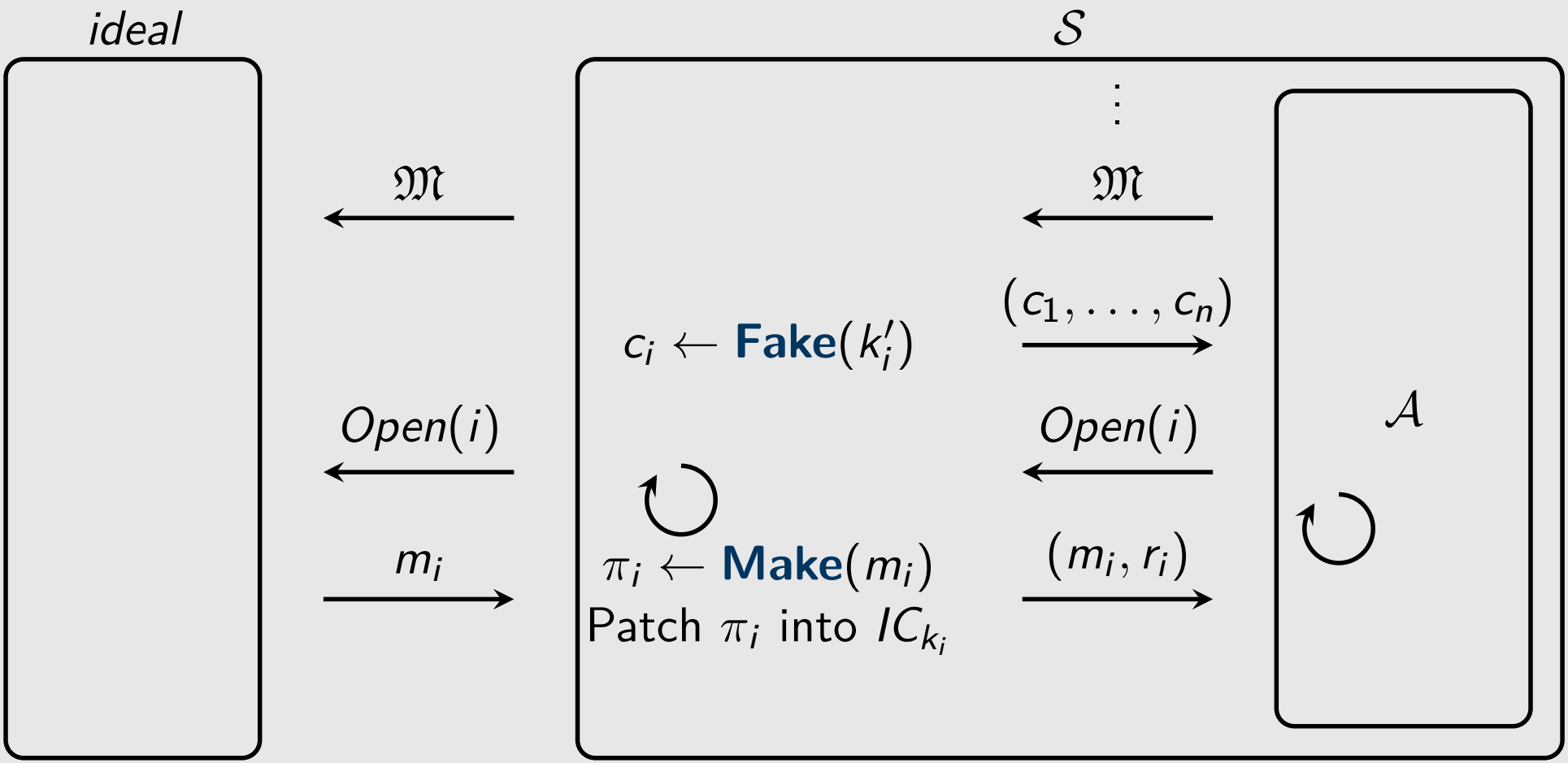

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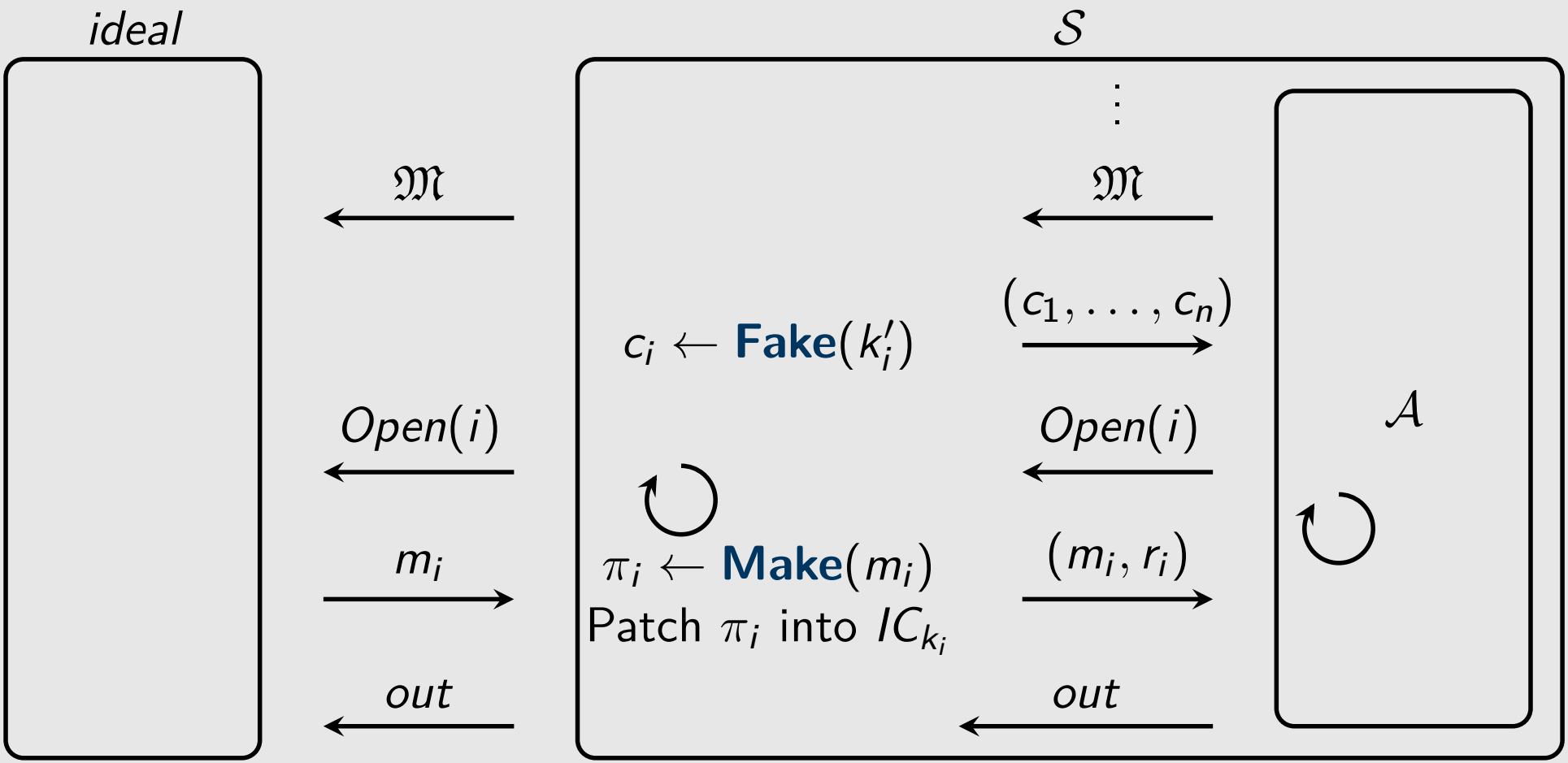

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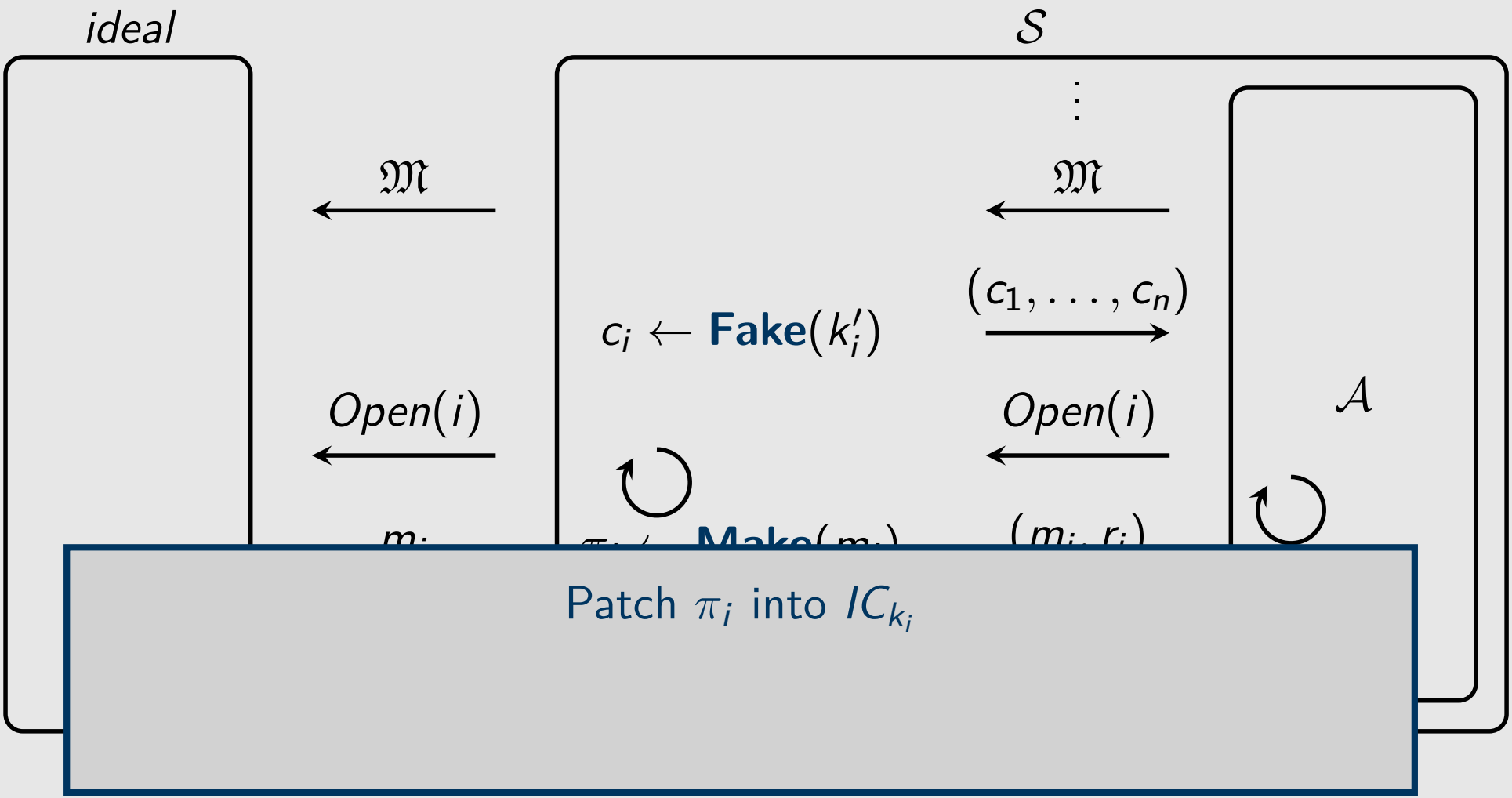

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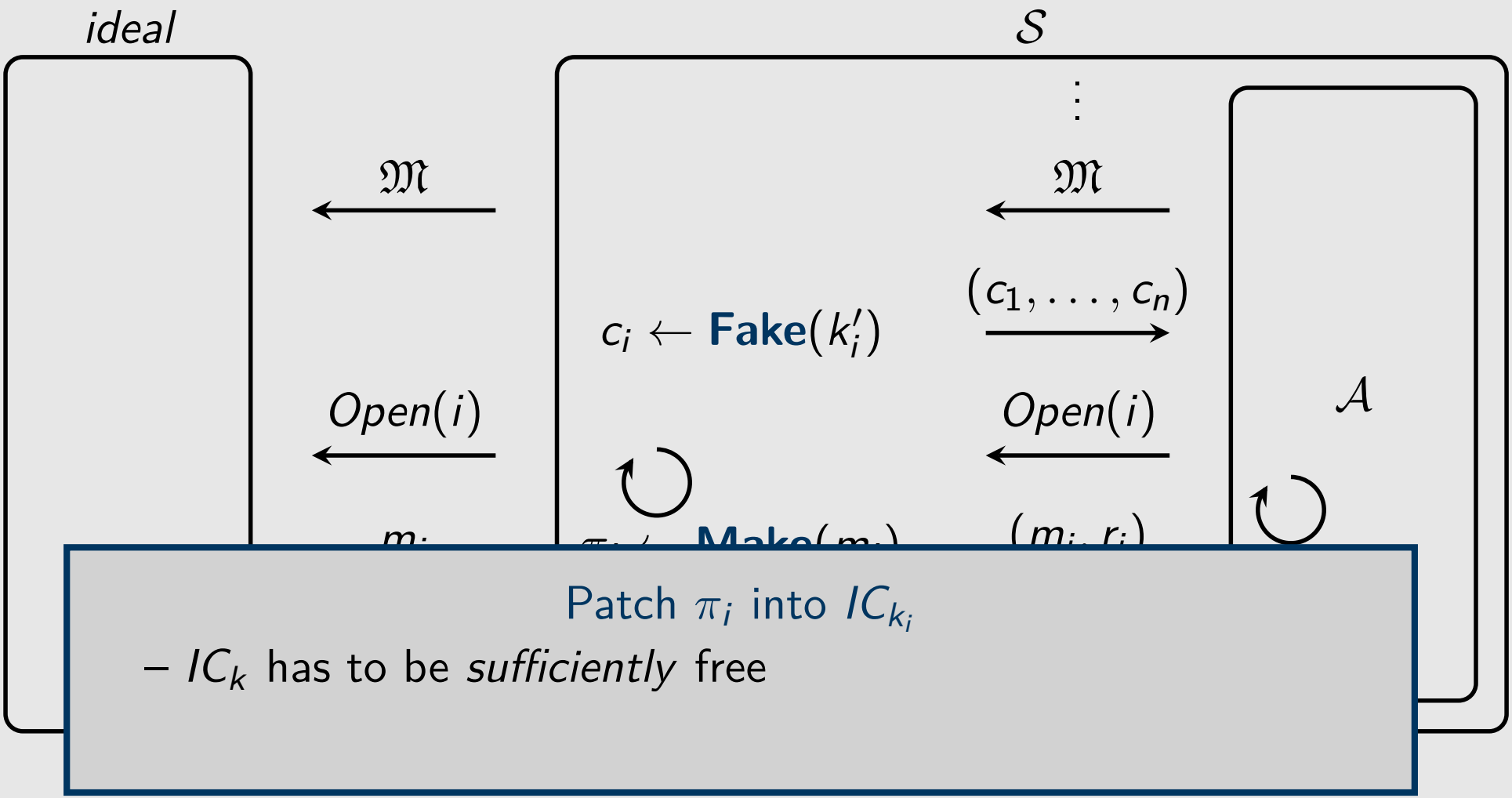
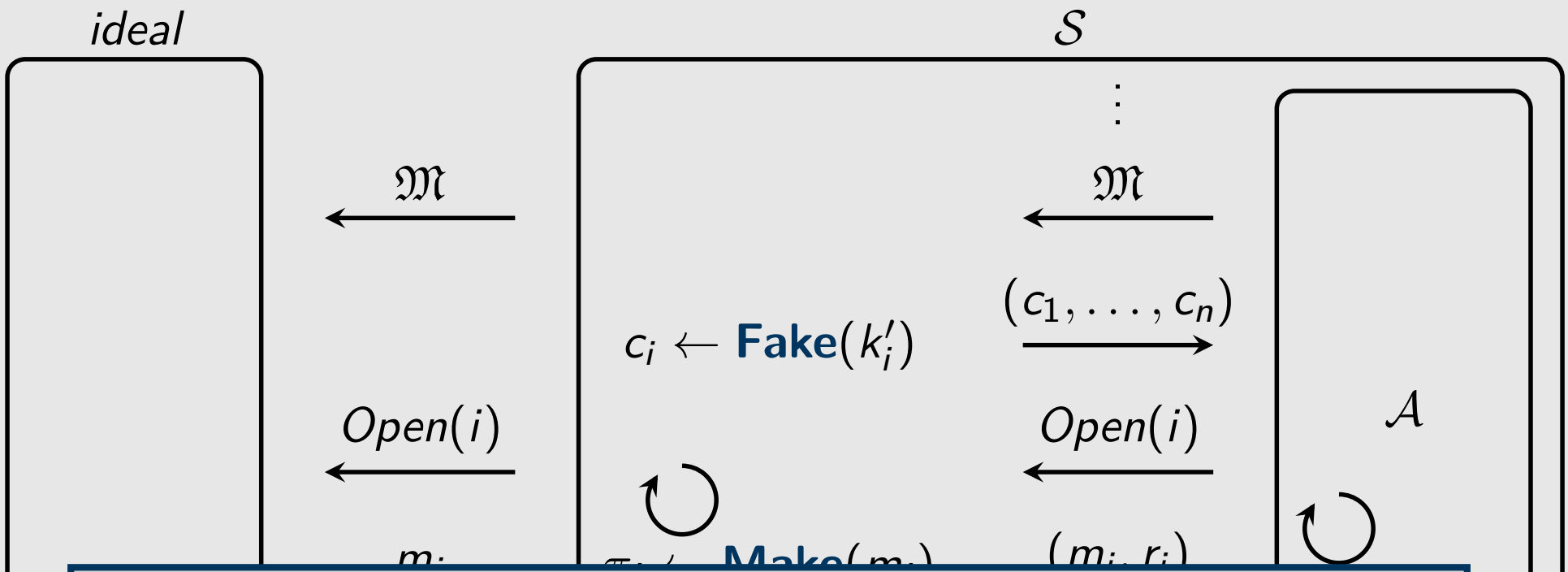


Intuition for the Proof



Patch π_i into IC_{k_i}

- IC_k has to be *sufficiently* free
- Ensured by standard security properties of KEM and DEM

In a nutshell

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- IND-CCA secure KEM: (k, k') computationally hidden.
- OT-INT-CTXT secure DEM: $\mathcal{A}$ cannot force an evaluation of IC_k by querying $\mathrm{Dec}(\boxed{k, k'}, \ldots)$.

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