Generic Anamorphic Encryption, Revisited: New Limitations and Constructions

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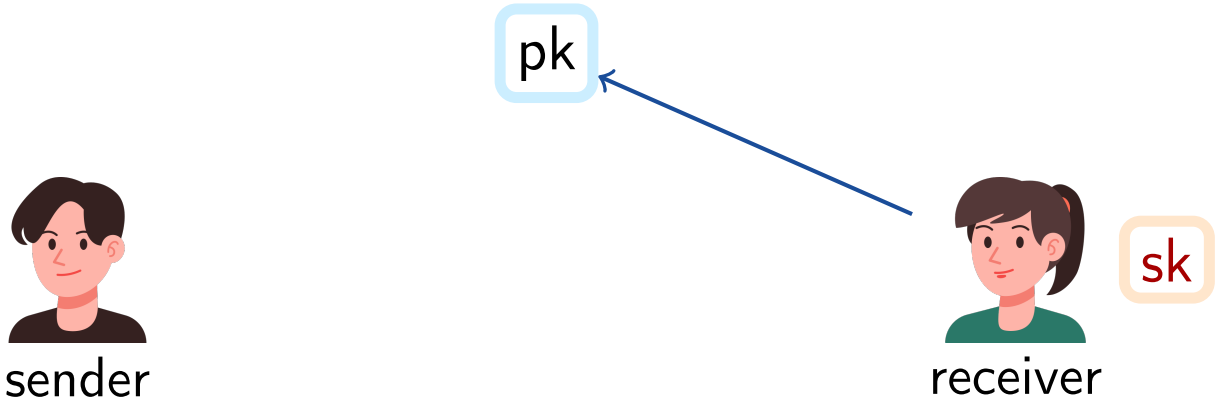
[3]Universidad Politecnica de Madrid, Spain.

Introduction

sender

receiver

Introduction



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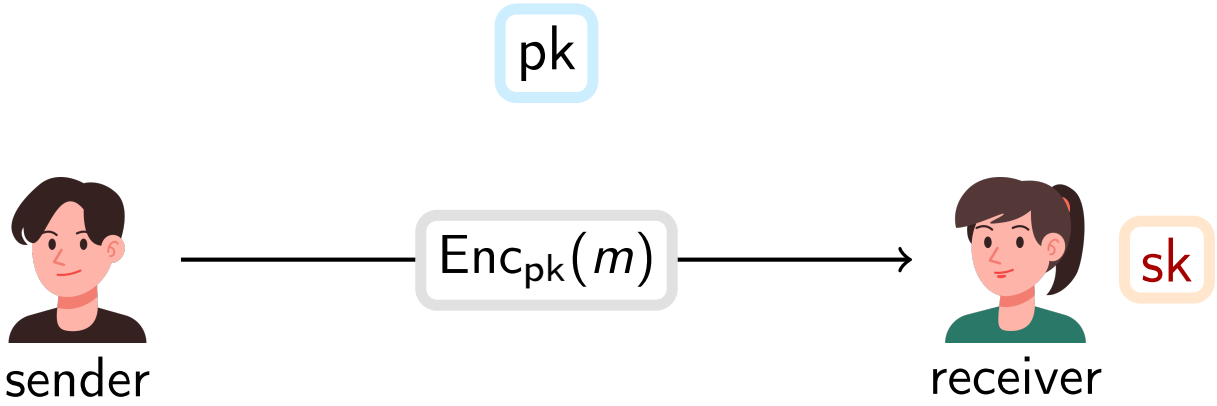

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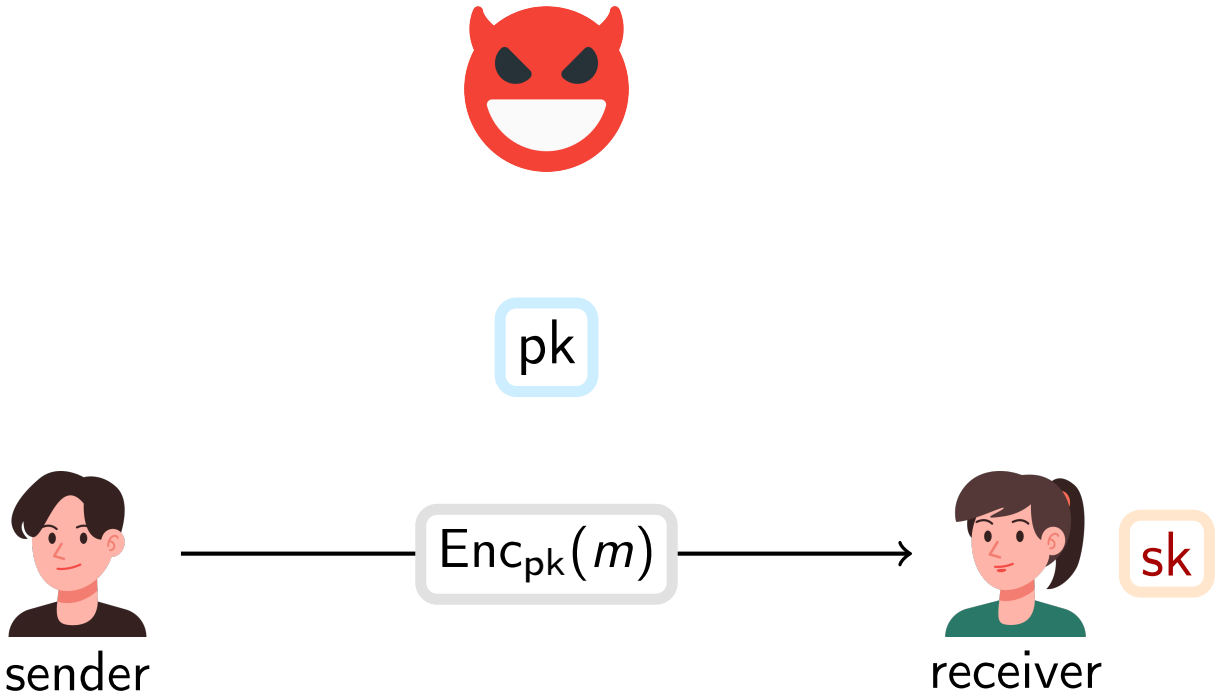

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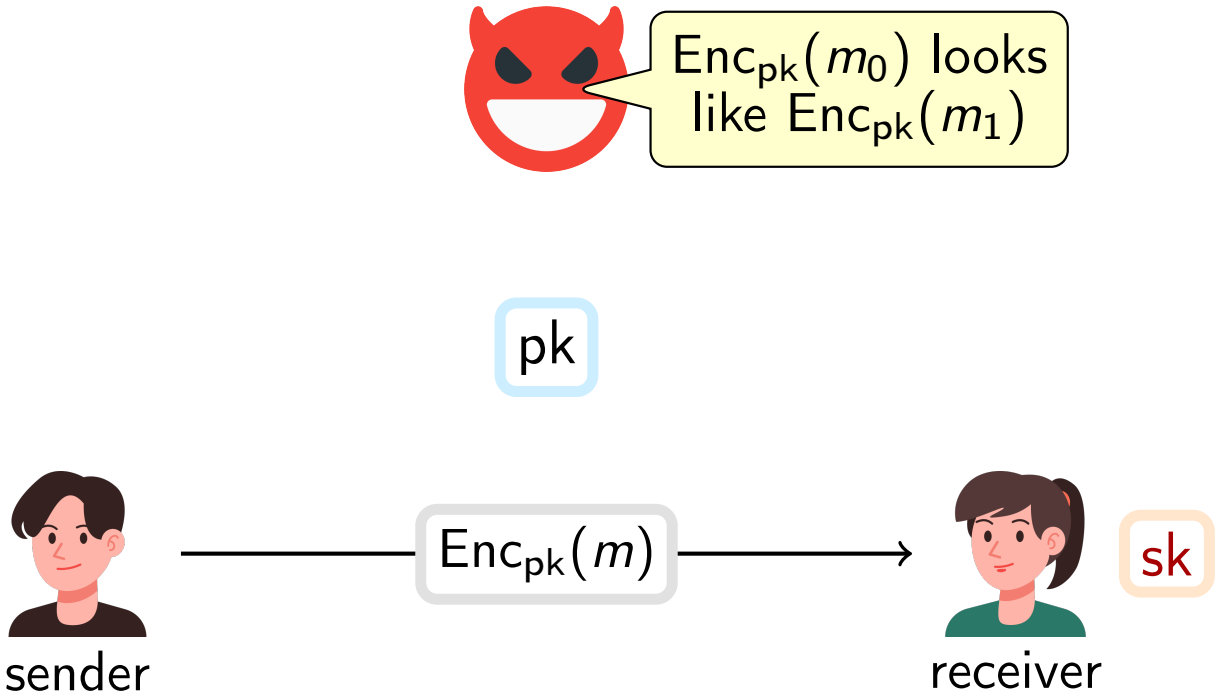

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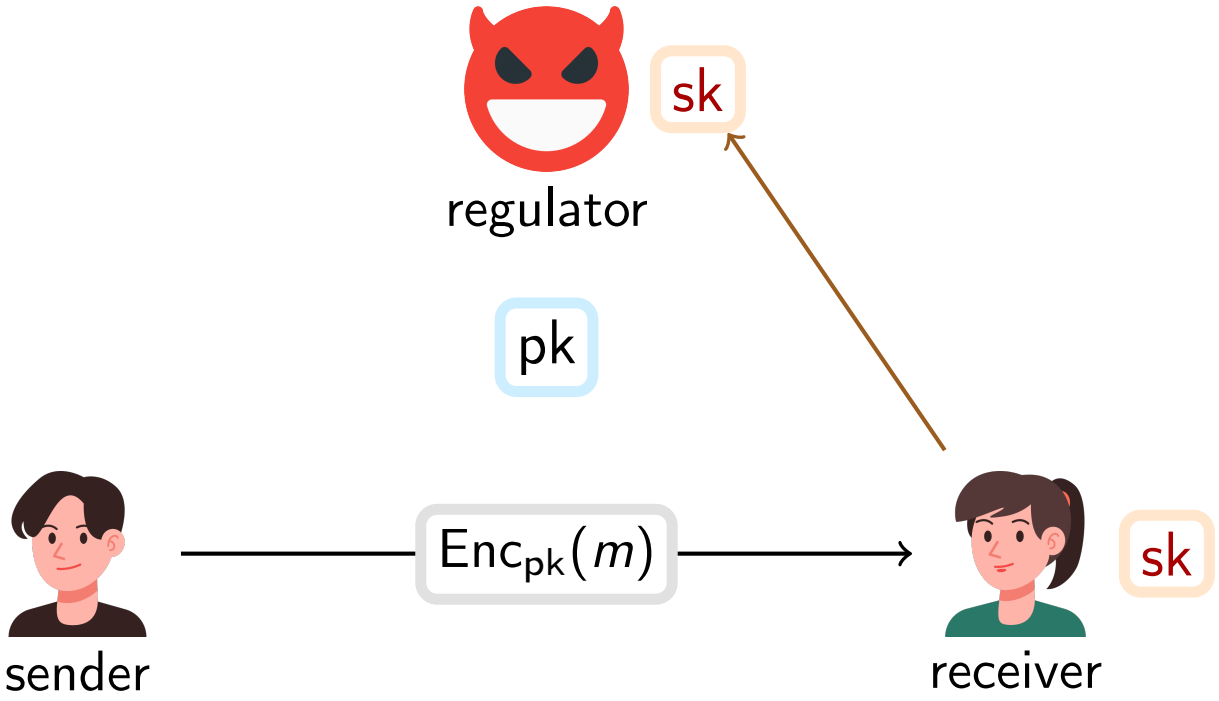

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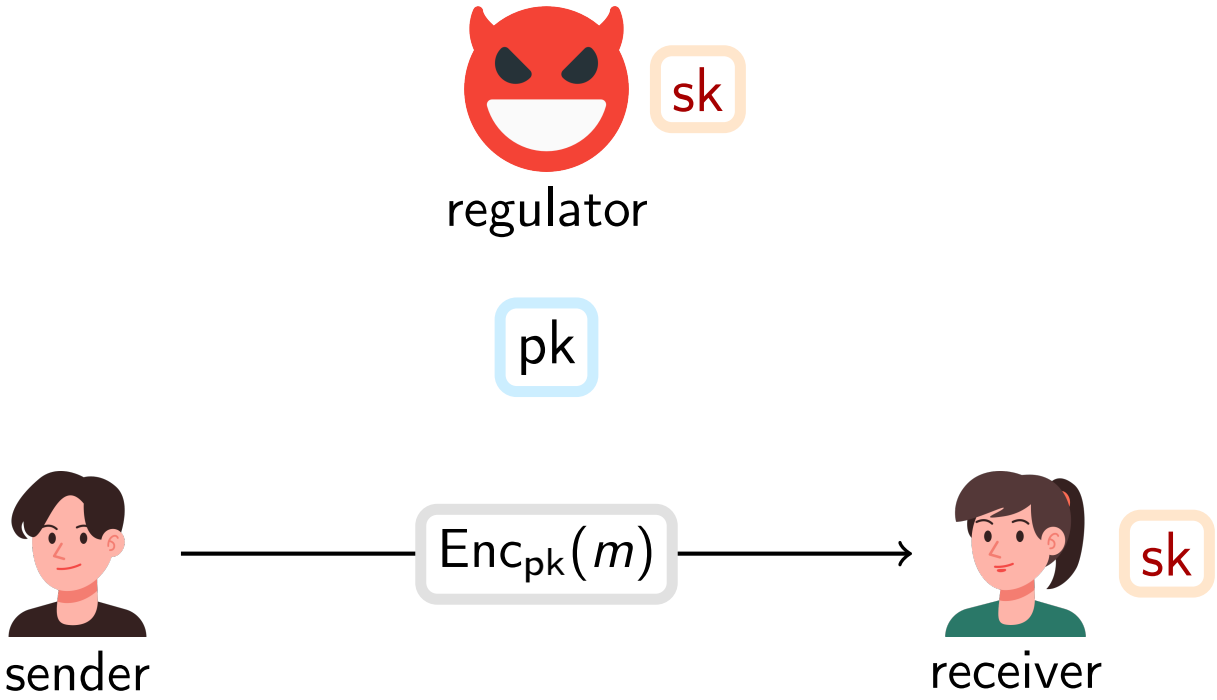

Q. Can we obtain privacy from the regulator?

Implicit assumption

Receiver privacy assumption

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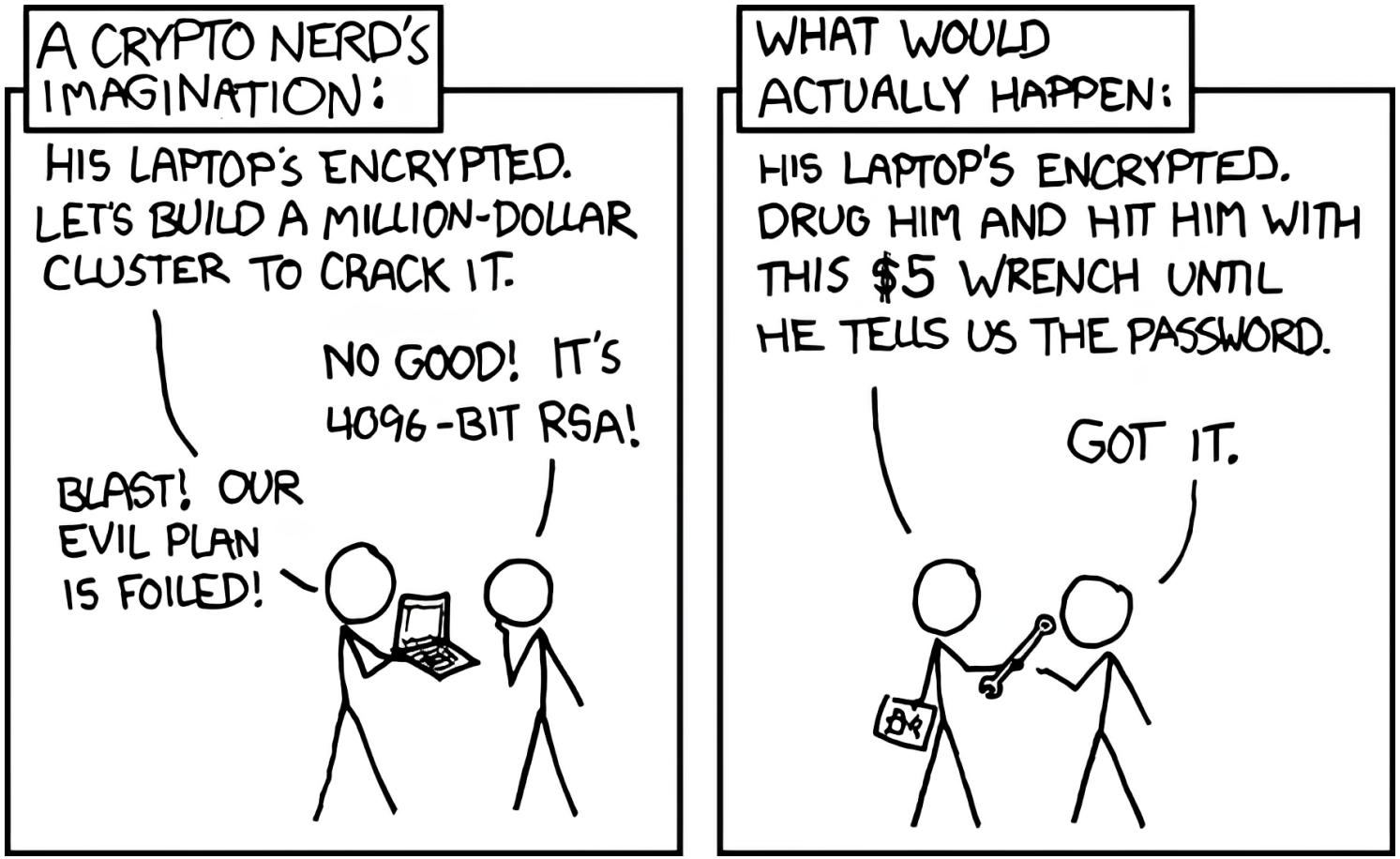
Receiver privacy assumption



xkcd.com/538/

Anamorphic Encryption Definition [PPY22]

AT.Gen AT.Enc AT.Dec

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AT.Gen AT.Enc AT.Dec

sender

receiver

regulator

Anamorphic Encryption Definition [PPY22]

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apk

dk

sender

ask
dk

receiver

ask

regulator

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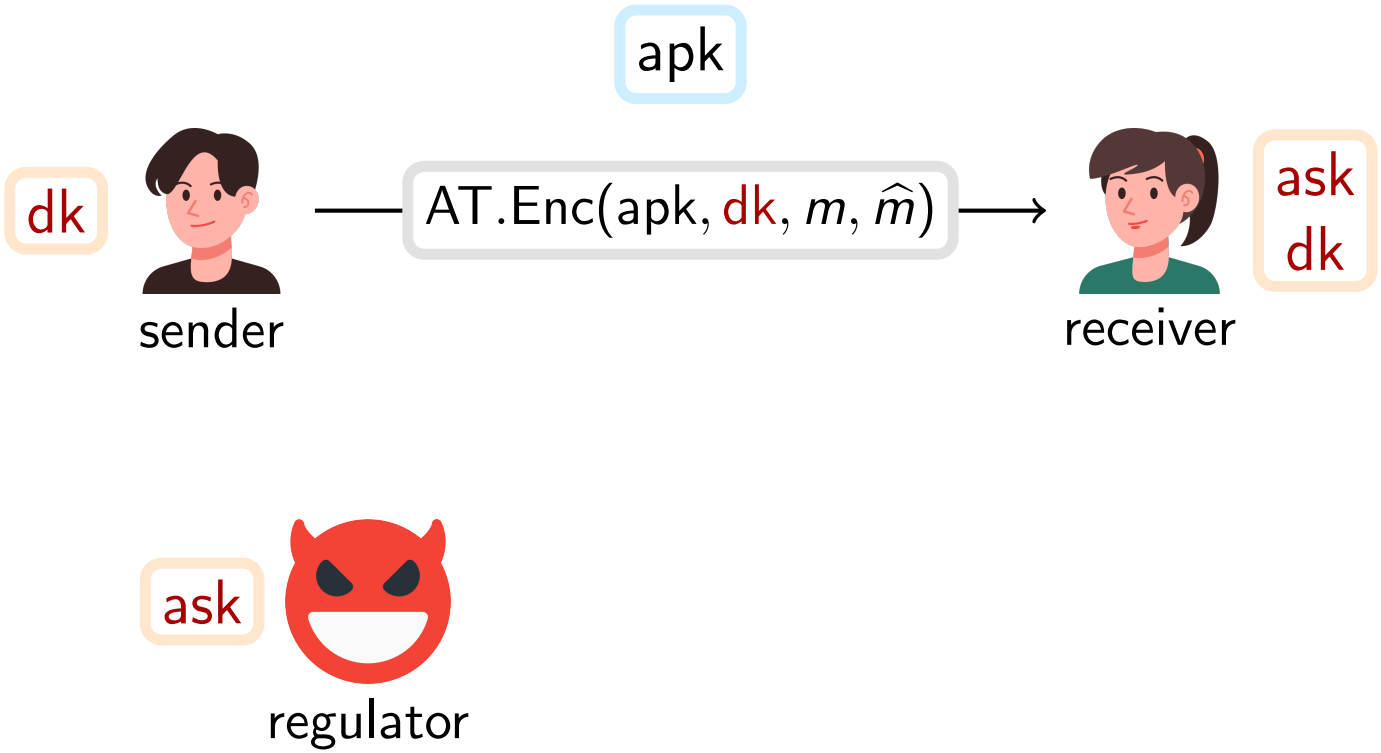

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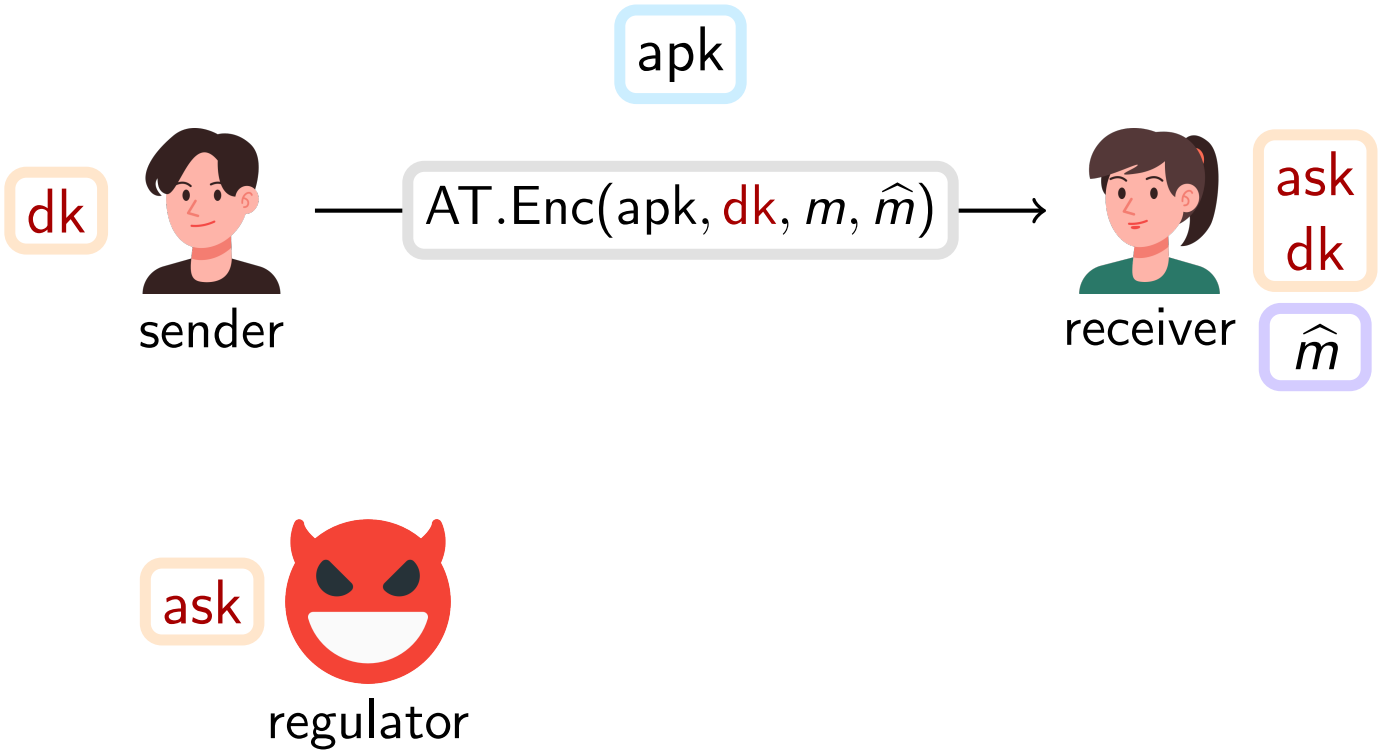

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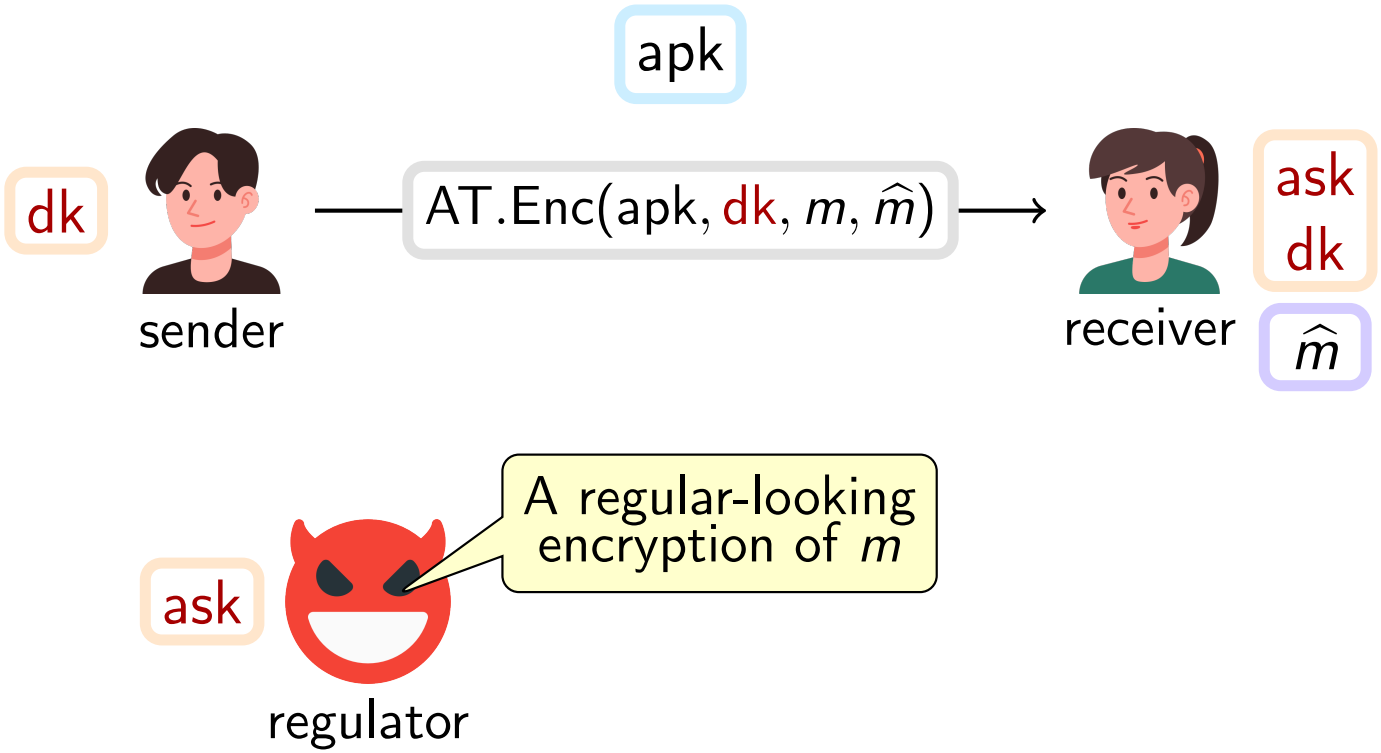

Anamorphic Encryption Definition [PPY22]

Security of an Anamorphic Triplet $(\mathsf{AT.Gen}, \mathsf{AT.Enc}, \mathsf{AT.Dec})$ is defined with respect to a PKE $(\mathsf{E.Gen}, \mathsf{E.Enc}, \mathsf{E.Dec})$.

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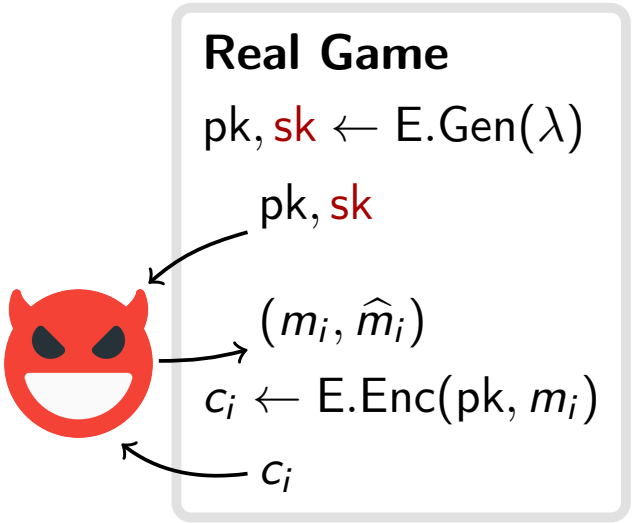

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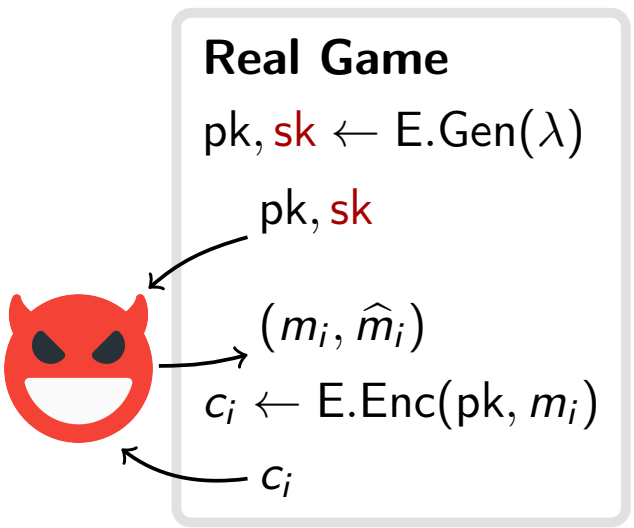

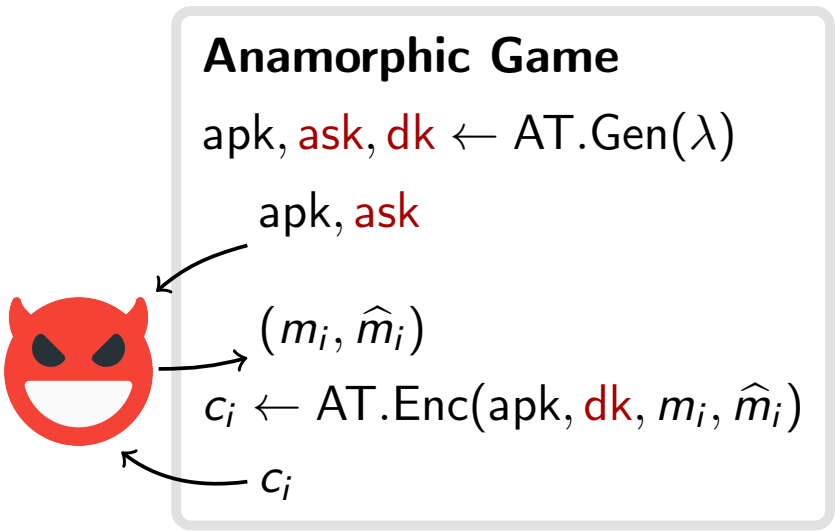

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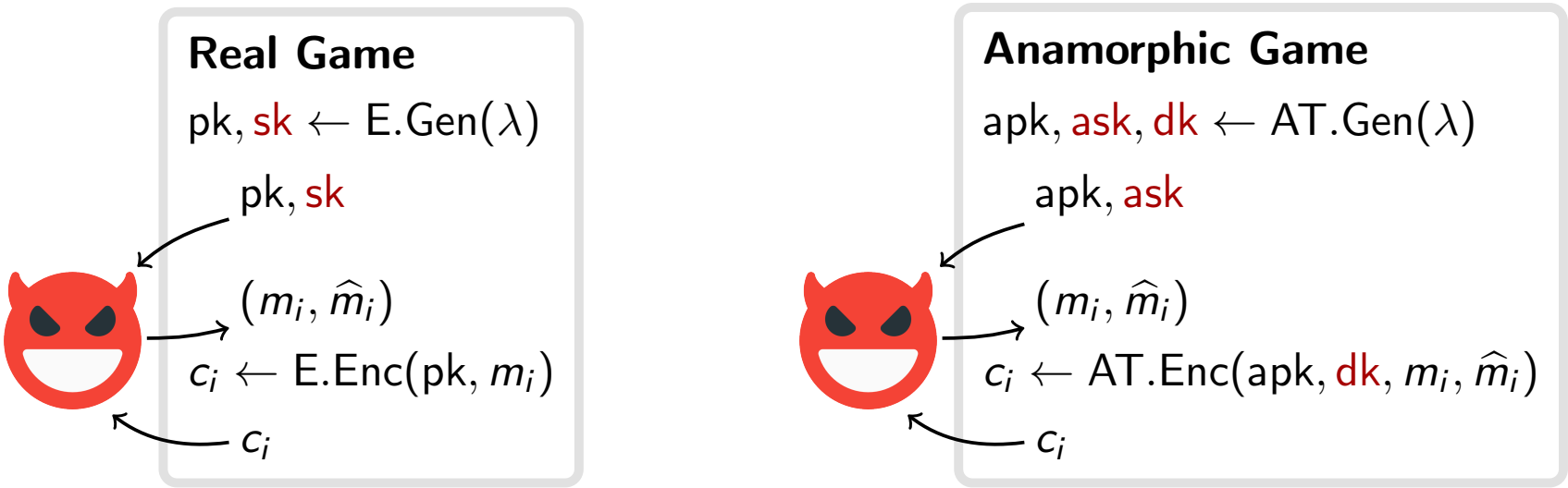

Real Game $\overset{c}{\approx}$ Anamorphic Game

Constructions

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Specific:

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- Naor-Yung transform [PPY22]

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Generic:

- Rejection Sampling (RS) [PPY22]

Rejection Sampling Scheme [PPY22]

$\mathsf{AT.Gen}(\lambda)$:

1. $(\mathsf{apk}, \mathsf{ask}) \leftarrow^{\$} \mathsf{E.Gen}(\lambda)$
2. $\mathsf{dk} \leftarrow^{\$} \mathcal{K}$
3. **return** $\mathsf{apk}, \mathsf{ask}, \mathsf{dk}$

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AT.Enc($\mathsf{apk}, \mathsf{dk}, m, \widehat{m}$) :

1. $c \leftarrow \mathsf{E.Enc}(\mathsf{pk}, m)$
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3. **else**: **return** c

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- Only supports $O(\log \lambda)$ bits long messages.

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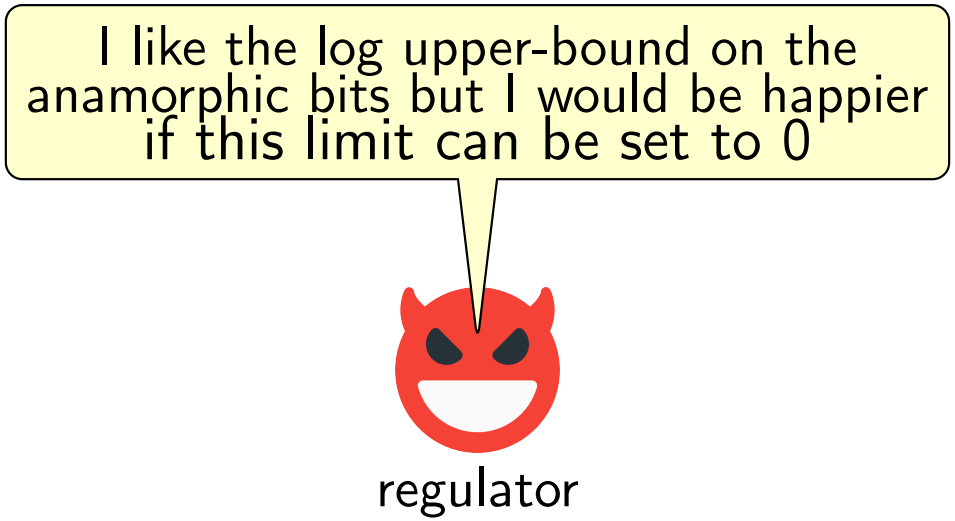
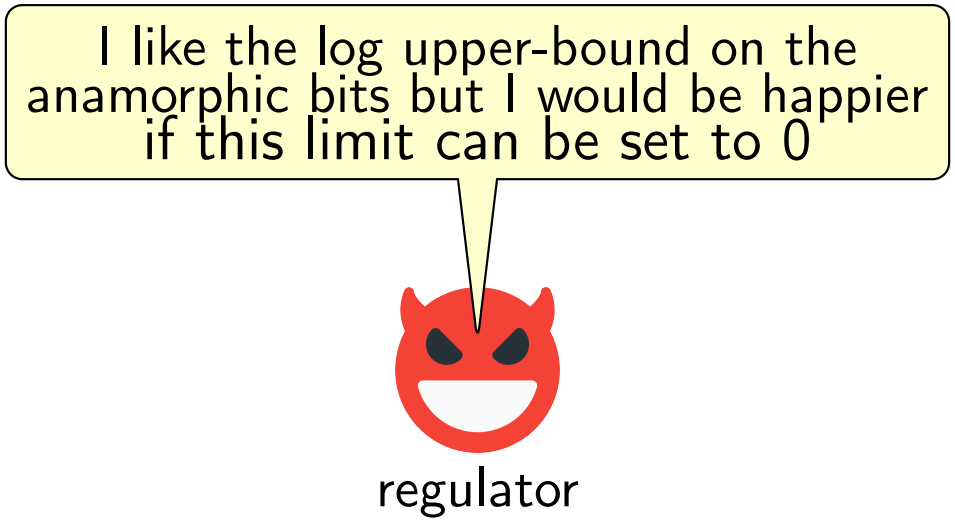
- Supports $O(\log \lambda)$ bits long messages. [CGM24b]

Question


I like the log upper-bound on the anamorphic bits but I would be happier if this limit can be set to 0
regulator

Question



Q. There exists an Anamorphic Triplet for any PKE?

Weak PKE - example

Weak PKE - example

- Injective OWF F
- A set B s.t. $|B| = \text{poly}(\lambda)$ disjoint from C

Weak PKE - example

$\mathsf{E.Gen}^*(\lambda)$:

1. $\mathsf{pk}, \mathsf{sk} \leftarrow^{\$} \mathsf{E.Gen}(\lambda)$
2. $m^* \leftarrow^{\$} M,\ y^* \leftarrow F(m^*)$
3. $\mathsf{pk}^* \leftarrow (\mathsf{pk}, y^*),\ \mathsf{sk}^* \leftarrow (\mathsf{sk}, m^*)$
4. **return** $(\mathsf{pk}^*, \mathsf{sk}^*)$

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$\mathsf{E.Enc}^*(\mathsf{pk}^*, m)$:

1. Parse $\mathsf{pk}^* = (\mathsf{pk}, y^*)$
2. **if** $F(m) = y^*$:
3. **return** $c \leftarrow^{\$} B$
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$\mathsf{E.Dec}^*(\mathsf{sk}^*, c)$:

1. Parse $\mathsf{sk}^* = (\mathsf{sk}, m^*)$
2. **if** $c \in B$: **return** m^*
3. **else**: **return** $\mathsf{E.Dec}(\mathsf{sk}, c)$

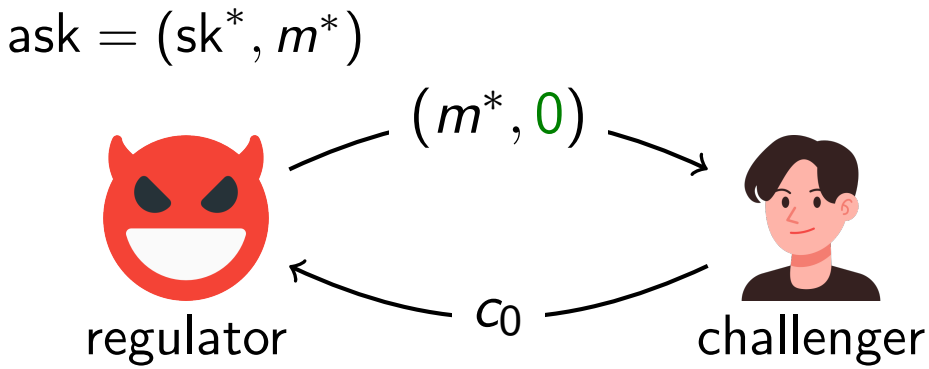
Weak PKE - example

$$\mathsf{ask} = (\mathsf{sk}^*, m^*)$$

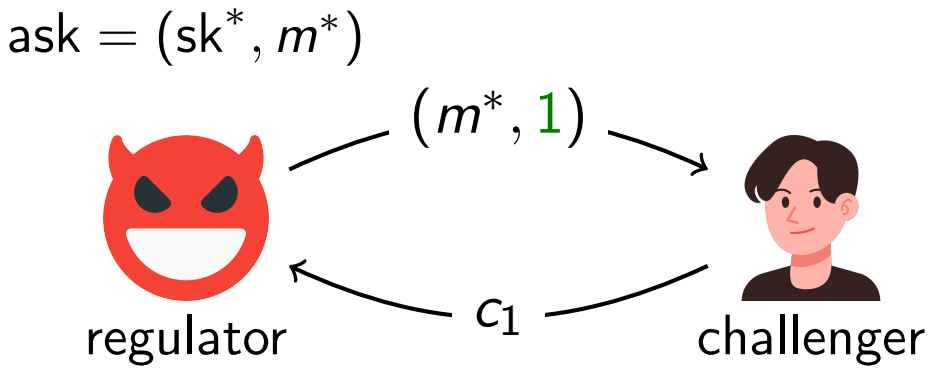
regulator

challenger

Weak PKE - example



Weak PKE - example



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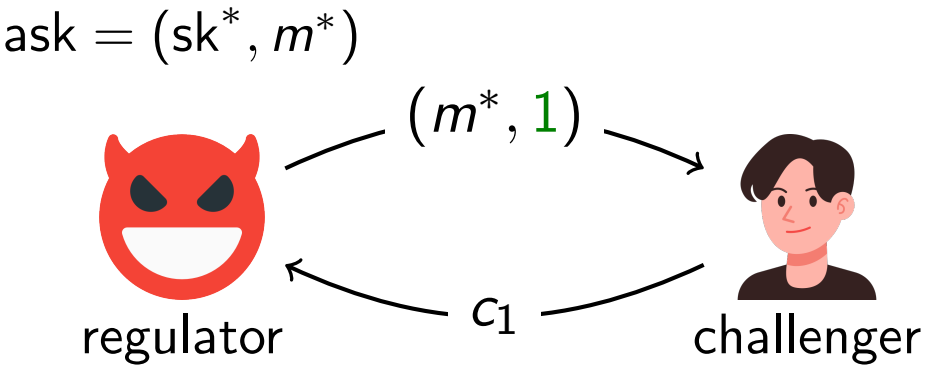
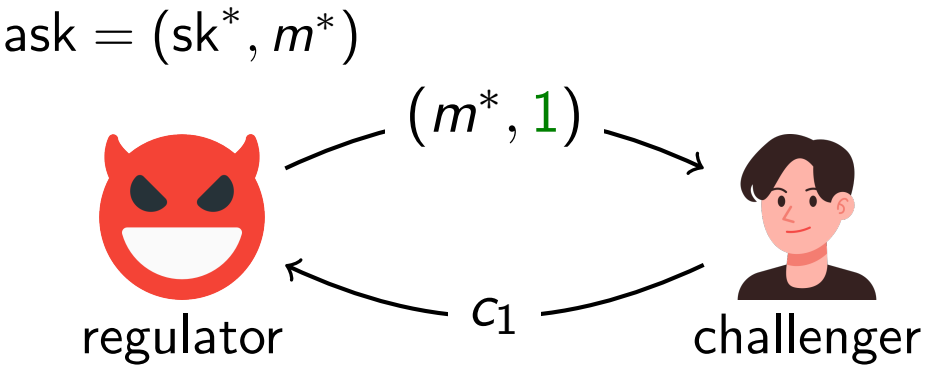


return $c_0 == c_1$

Weak PKE - example



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$$\Pr[c_0 = c_1 \mid \text{Real Game}] = 1/|B|$$

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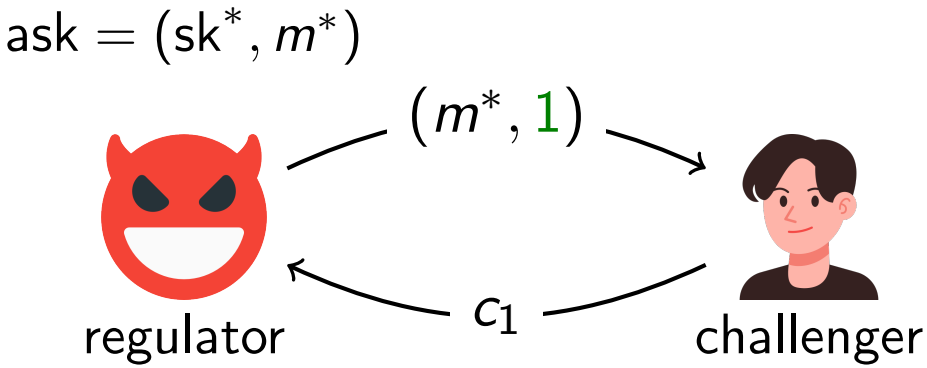

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$$\Pr[c_0 = c_1 \mid \text{Real Game}] = 1/|B|$$

$$\Pr[c_0 = c_1 \mid \text{Anamorphic Game}] = 1/|B|(1/2 + \text{negl}(\lambda))$$

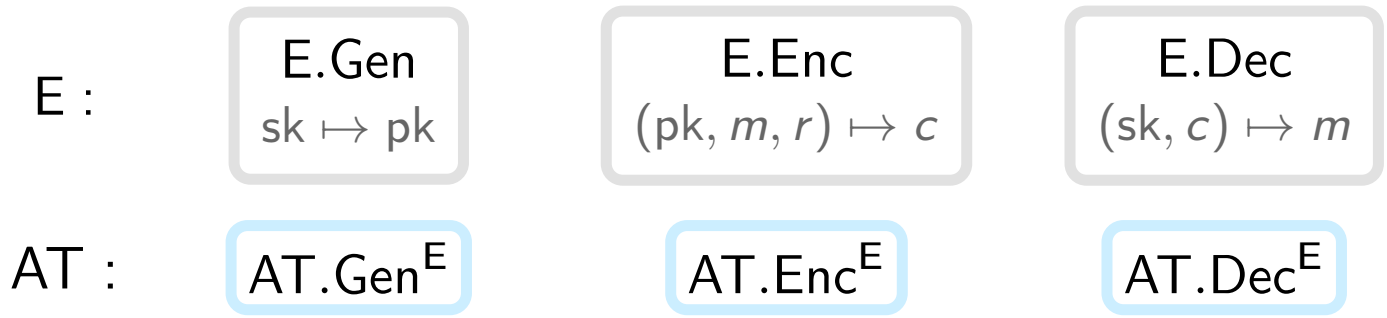
Black-Box Anamorphic Encryption

E : $\boxed{\text{E.Gen}\ \ \mathsf{sk} \mapsto \mathsf{pk}}$ $\boxed{\text{E.Enc}\ \ (\mathsf{pk}, m, r) \mapsto c}$ $\boxed{\text{E.Dec}\ \ (\mathsf{sk}, c) \mapsto m}$

Black-Box Anamorphic Encryption

E :	E.Gen $\mathsf{sk} \mapsto \mathsf{pk}$	E.Enc $(\mathsf{pk}, m, r) \mapsto c$	E.Dec $(\mathsf{sk}, c) \mapsto m$
AT :	$\mathsf{AT.Gen}^{\mathsf{E}}$	$\mathsf{AT.Enc}^{\mathsf{E}}$	$\mathsf{AT.Dec}^{\mathsf{E}}$

Black-Box Anamorphic Encryption



Assumption: If the oracles in E form a correct and secure encryption scheme then $(\mathsf{E}, \mathsf{AT}^{\mathsf{E}})$ is a secure AE.

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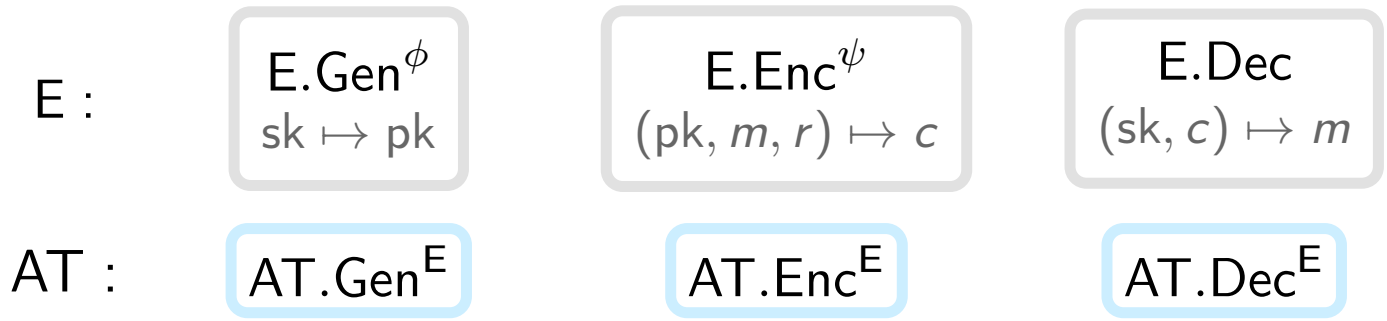

Assumption: If the oracles in E form a correct and secure encryption scheme then $(\mathsf{E}, \mathsf{AT}^{\mathsf{E}})$ is a secure AE.

Ideal PKE: Take E.Gen and E.Enc as truly random functions.

$$\phi : \mathsf{SK} \to \mathsf{PK} \qquad \psi : \mathsf{PK} \times M \times R \to C$$

Weak Messages

A message m^* is a weak one if:

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Weak Messages

A message m^* is a weak one if:

- Has only poly many valid ciphertexts
- $m^* \approx m$ for a random m
- m^* is hard to find given only pk

Weak PKE

$\mathsf{E.Gen}^{\phi}$
$\mathsf{sk} \mapsto \mathsf{pk}$

$\mathsf{E.Dec}$
$(\mathsf{sk}, c) \mapsto m$

$\mathsf{E.Enc}^{\psi,\tau}$
$(\mathsf{pk}, m, r) \mapsto c$

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$\mathsf{E.Find}$
$(\mathsf{sk}, i) \mapsto m_i^*(\mathsf{sk})$

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Ideal PKE: Take E.Gen, E.Enc and m_i^* as truly random functions.

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Ideal PKE: Take E.Gen, E.Enc and m_i^* as truly random functions.

τ is a randomness biasing function.
Acts as identity on *good* messages, compresses on *weak* messages.

IND-CPA proof idea

- sk is random $\implies$ sk is hard to find

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- if sk is unknown then $m_i^*(\mathsf{sk})$ is random $\implies$ m_b is not weak

IND-CPA proof idea

- sk is random $\implies$ sk is hard to find
- if sk is unknown then $m_i^*(\mathsf{sk})$ is random $\implies$ m_b is not weak
- if c^* is never decrypted and m_b is not weak $\implies$ $\mathcal{A}$ cannot query E.Enc with the same randomness as used to generate the challenge ciphertext

Weak PKE - adversary

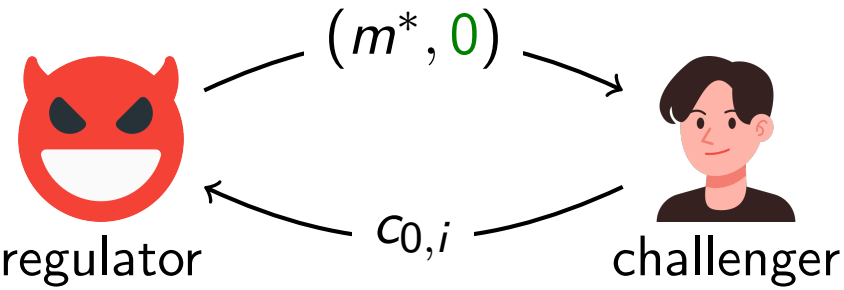
$m^* \leftarrow \mathsf{E.Find}(\mathsf{sk}, \log \nu)$

regulator

challenger

Weak PKE - adversary

$m^* \leftarrow \mathsf{E.Find}(\mathsf{sk}, \log \nu)$



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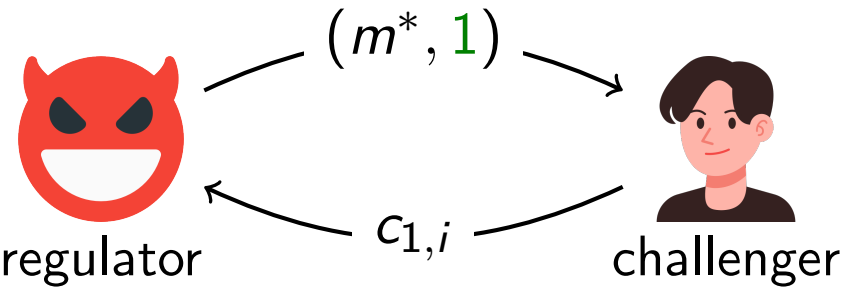
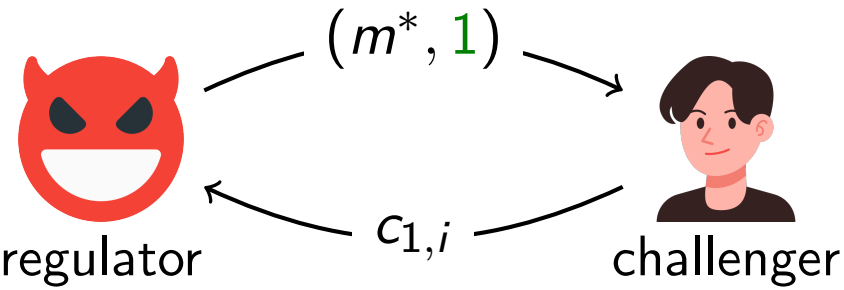


return 0 **if** $\nexists i, j$ s.t. $c_{0,i} = c_{1,j}$

Weak PKE - adversary

$m^* \leftarrow \mathsf{E.Find}(\mathsf{sk}, \log \nu)$



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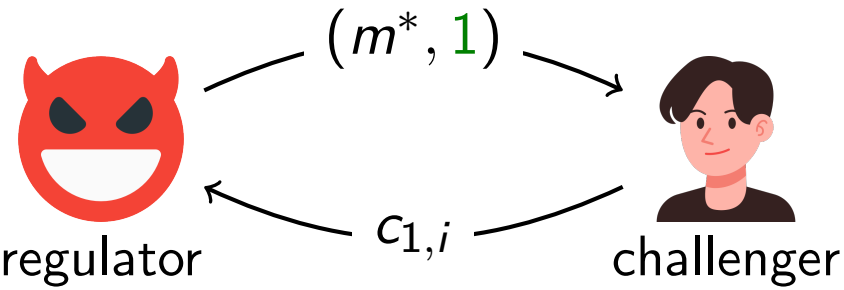

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$$\Pr[c_0 = c_1 \mid \text{Anamorphic Game}] \leq 1/(\lambda\sqrt{2})$$

Positive results

Semi-Adaptive security.

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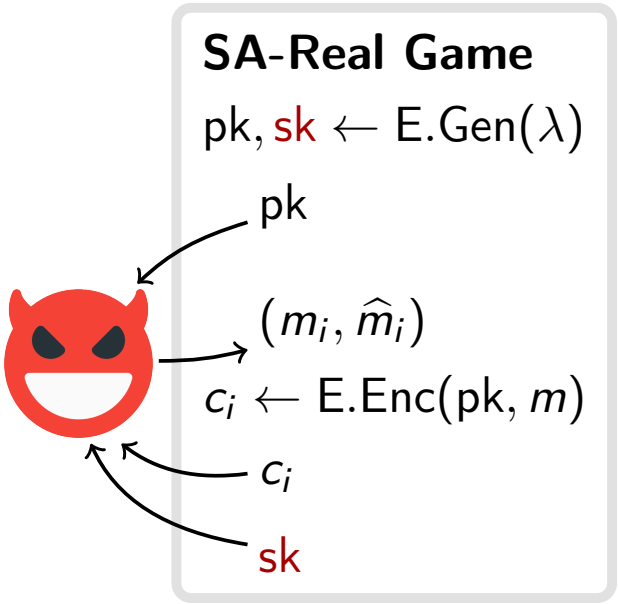

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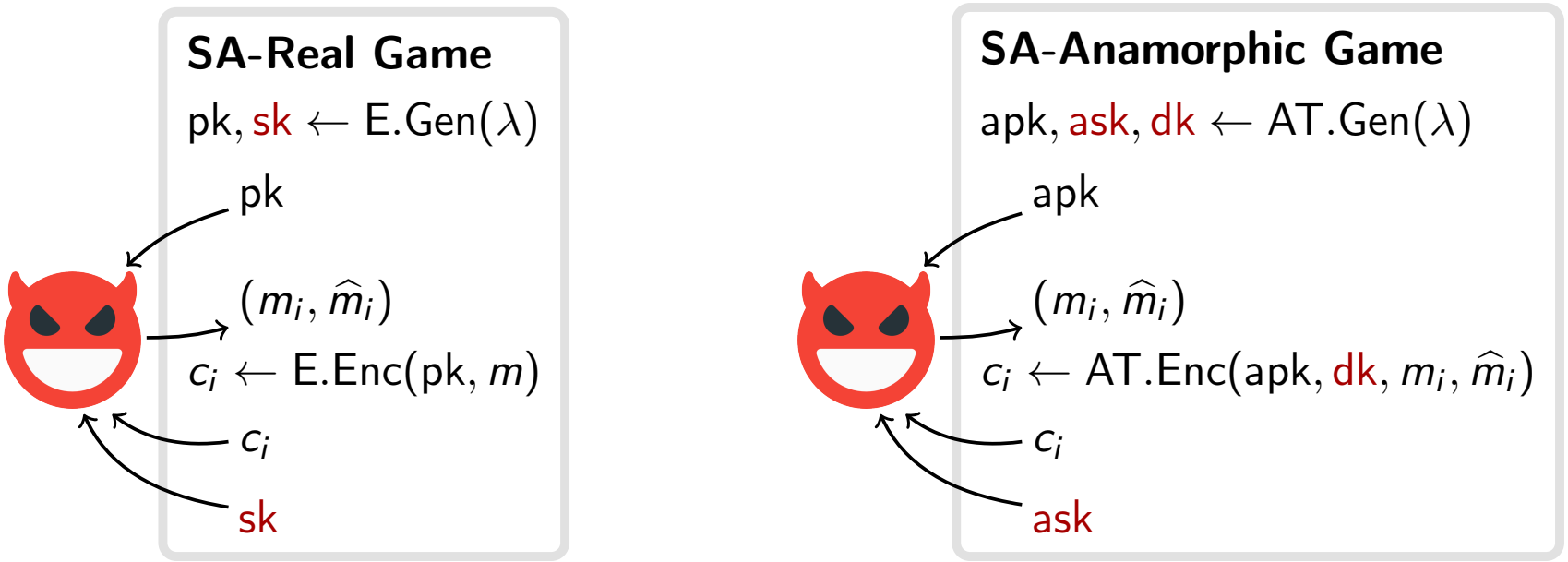

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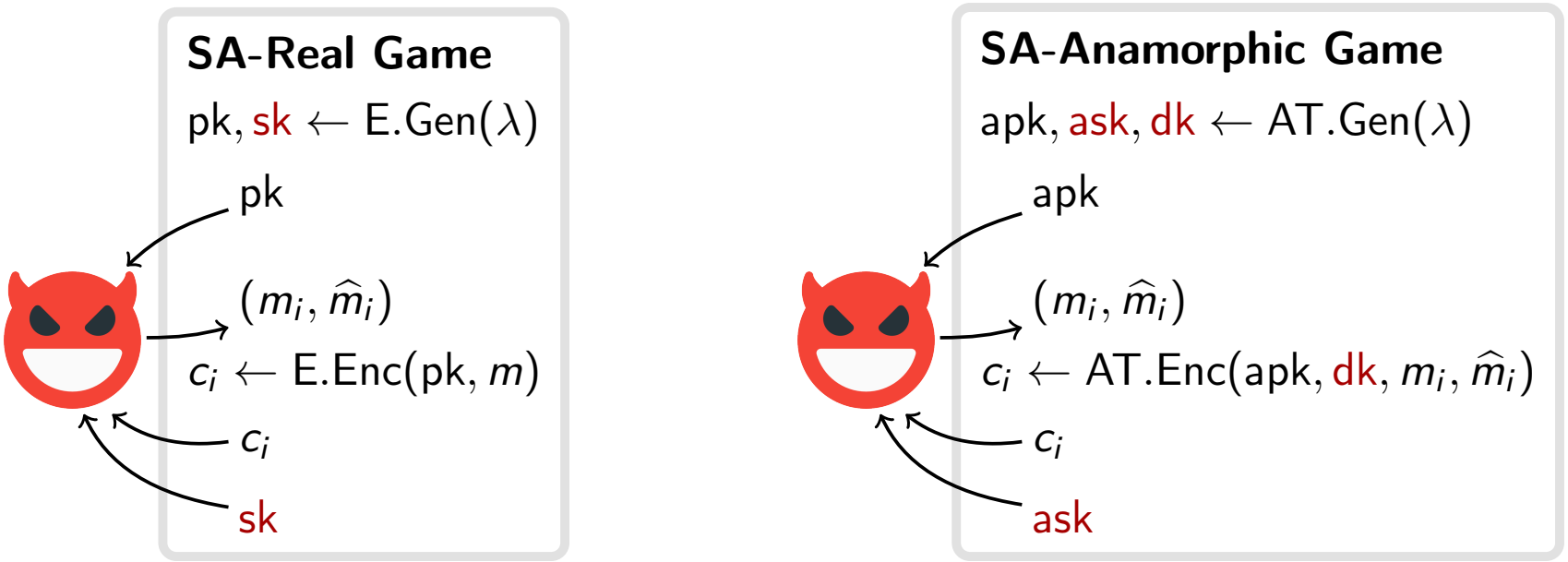

SA-Real Game $\overset{c}{\approx}$ SA-Anamorphic Game

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- Black-box Asymmetric SA-AE is impossible

Rejection Sampling Scheme [PPY22]

AT.Gen(λ) :

1. $(\mathsf{apk}, \mathsf{ask}) \leftarrow^{\$} \mathsf{E.Gen}(\lambda)$
2. $\mathsf{dk} \leftarrow^{\$} \mathcal{K}$
3. **return** $\mathsf{apk}, \mathsf{ask}, \mathsf{dk}$

AT.Enc($\mathsf{apk}, \mathsf{dk}, m, \widehat{m}$) :

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- Supports $O(\log \lambda)$ bits long messages.

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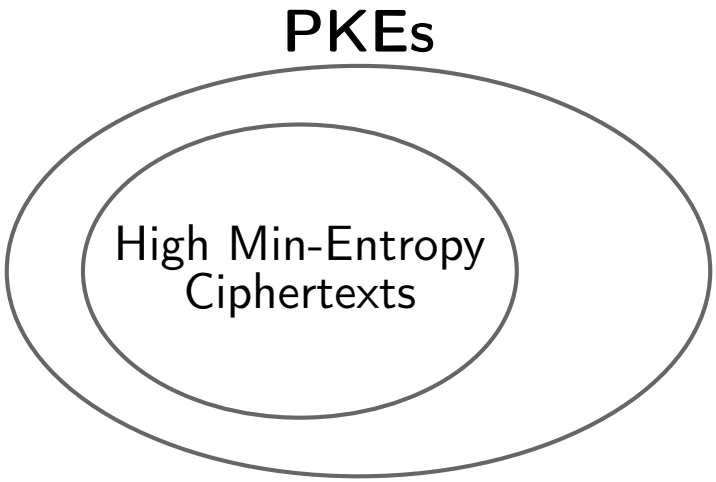

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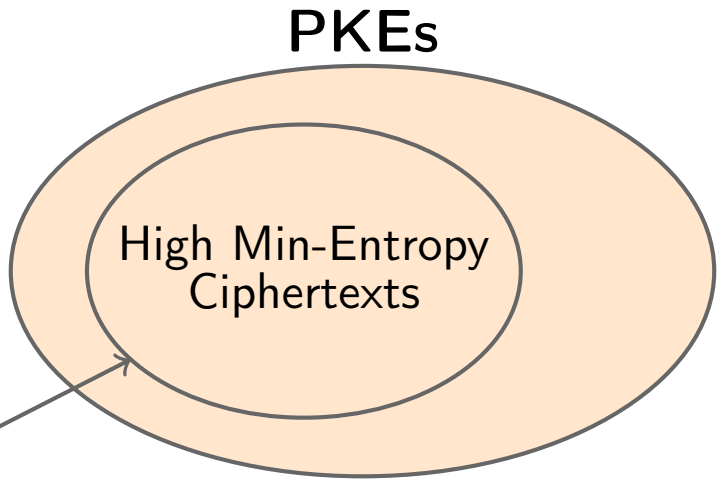

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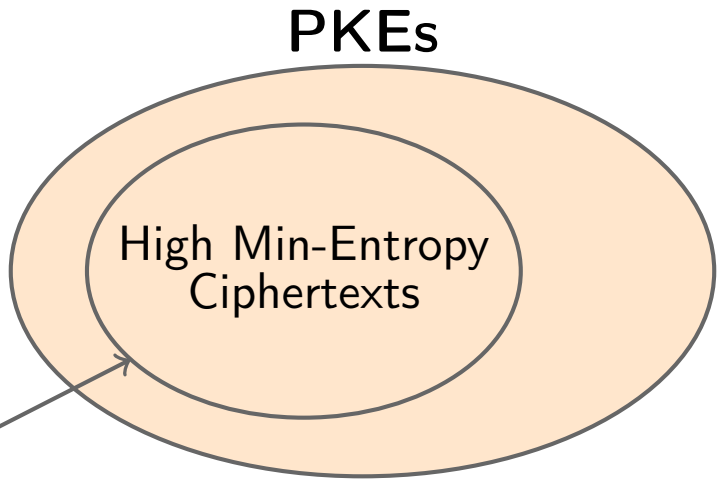

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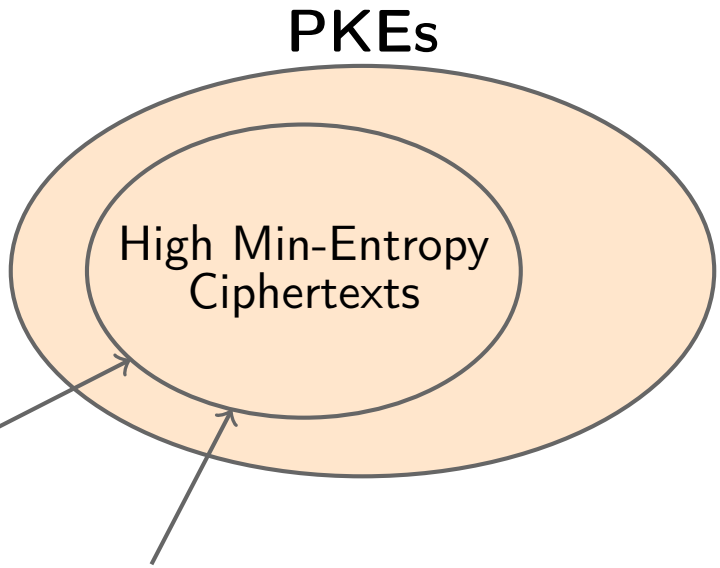

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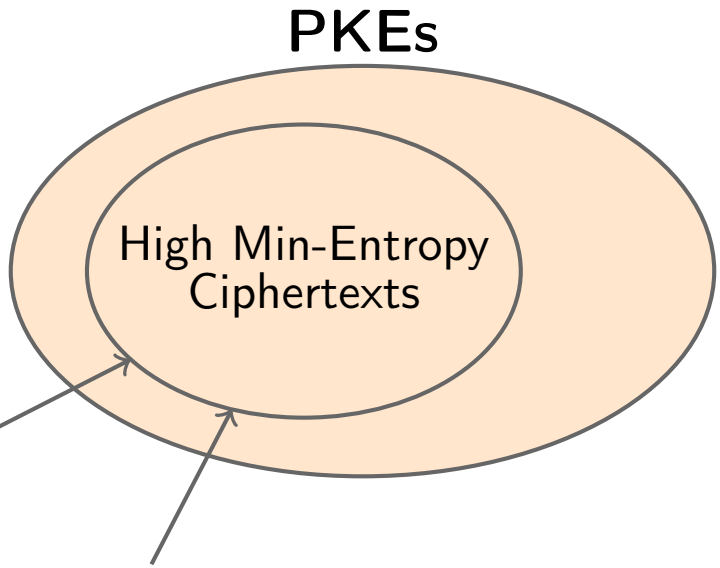

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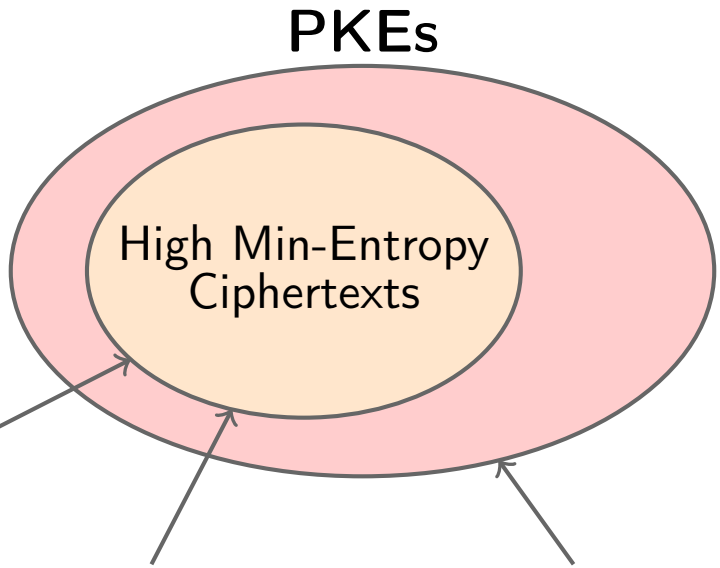

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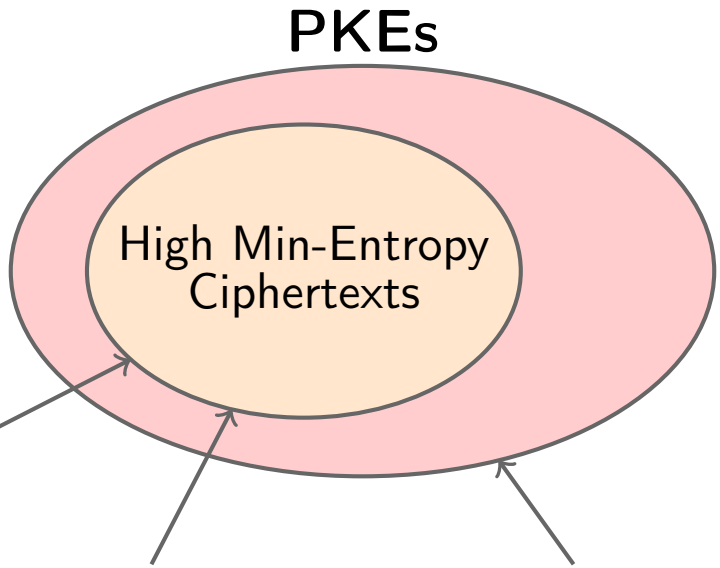

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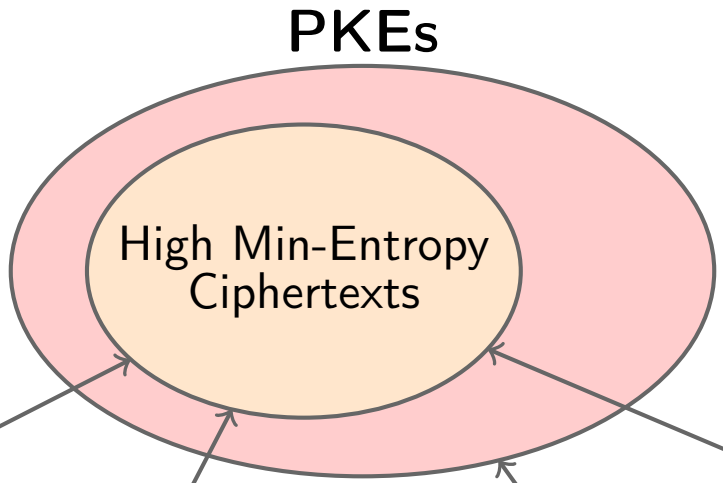

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Q & A

Thanks for your attention

Any questions?

ia.cr/2024/1119