Incompressible Cryptography beyond Public Key Encryption

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IIT Delhi

Ongoing work with Rishab Goyal, Venkata Koppula, Aman Verma

SECRET KEY ENCRYPTION (SKE)

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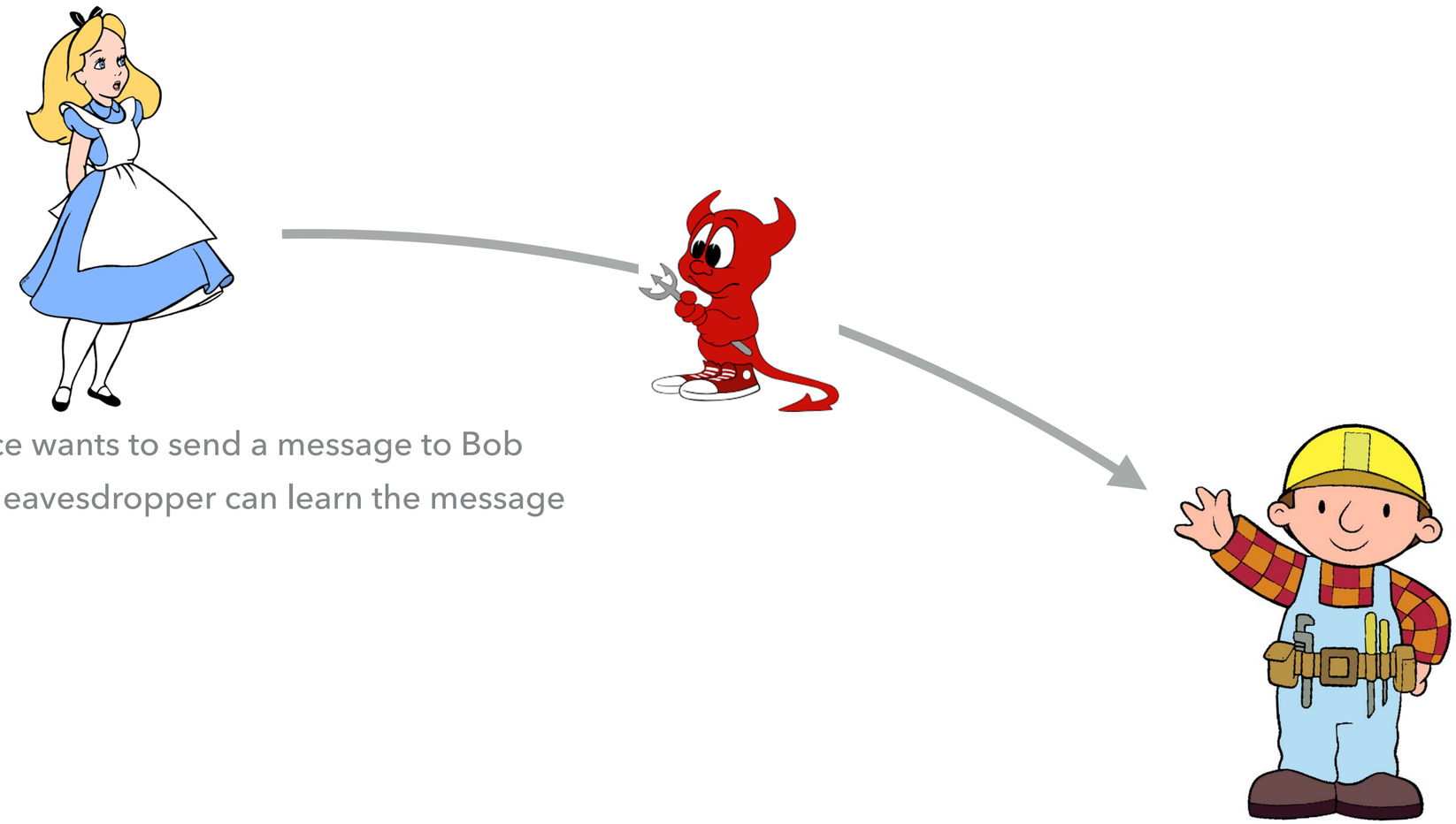
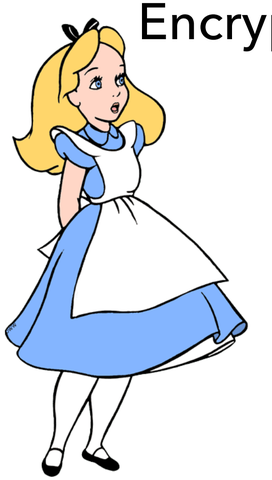


Alice wants to send a message to Bob
s.t. no eavesdropper can learn the message

SECRET KEY ENCRYPTION (SKE)

Encrypt m using key k



m

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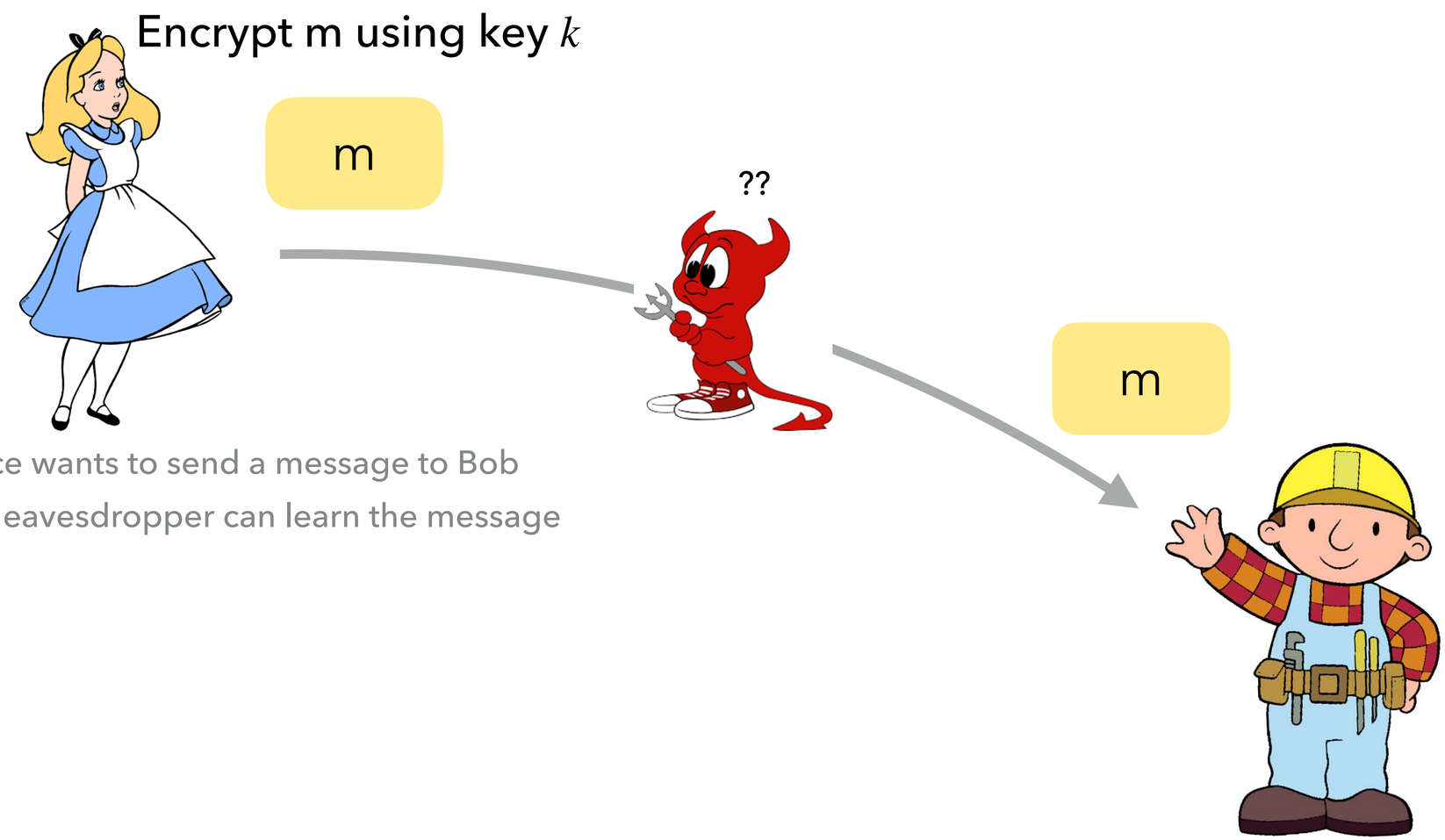

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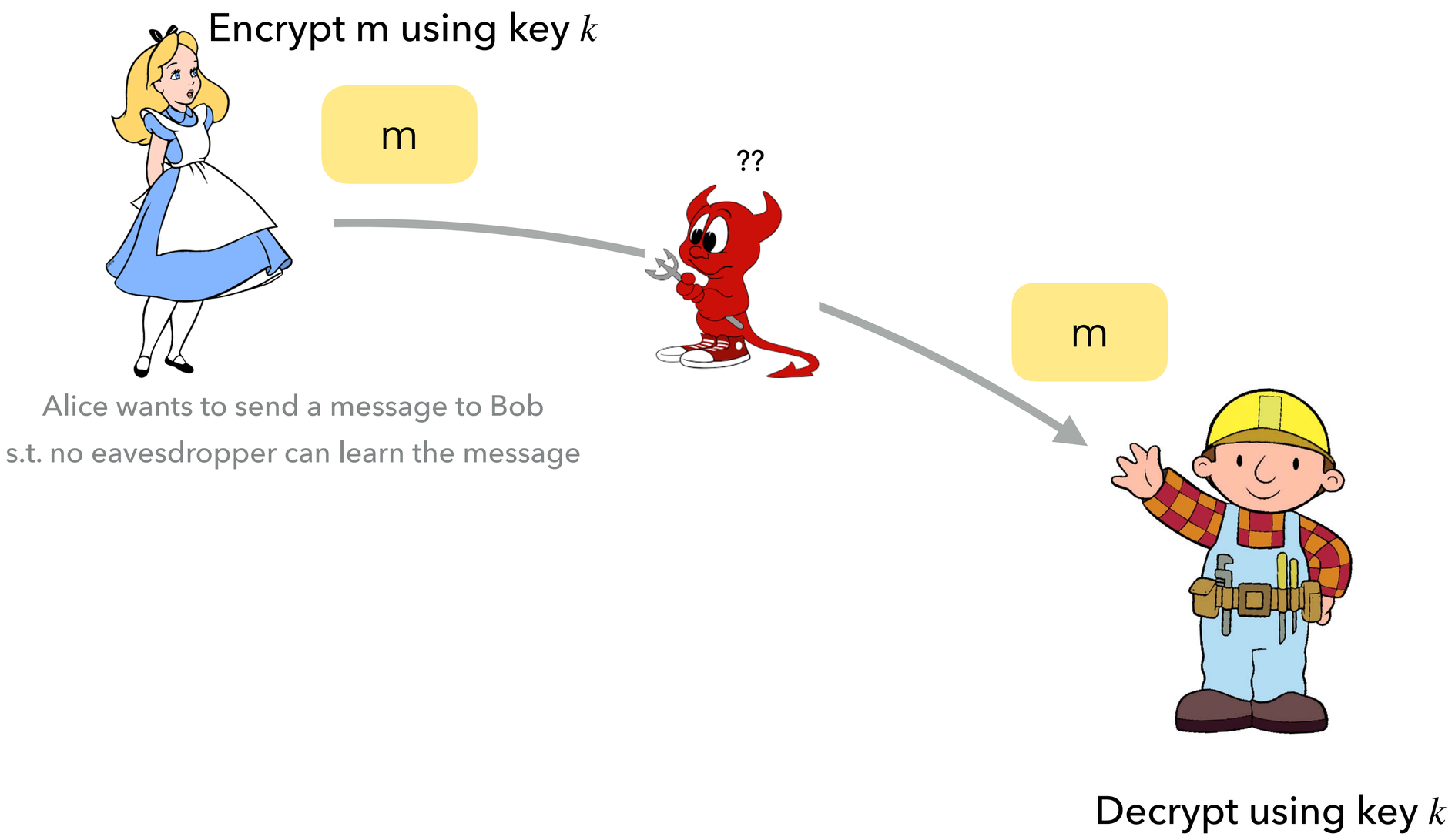

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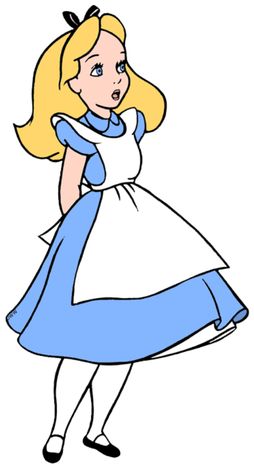
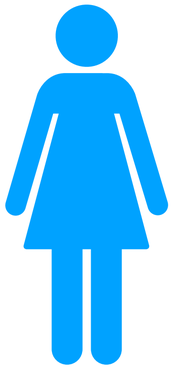
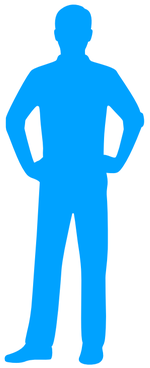
FUNCTIONAL ENCRYPTION (FE)

Alice wants to send m

Parties learn only function of m







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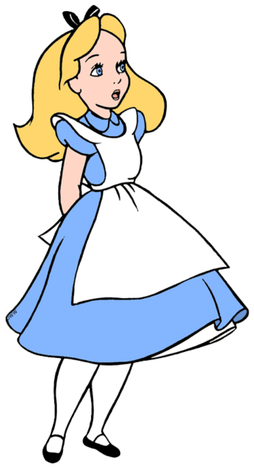
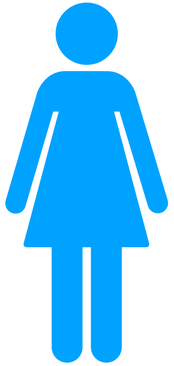


f_1



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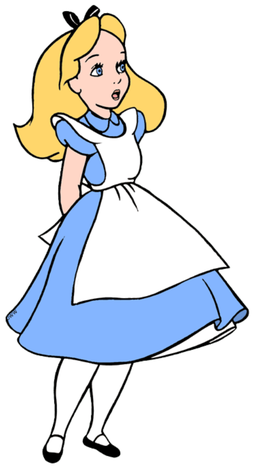

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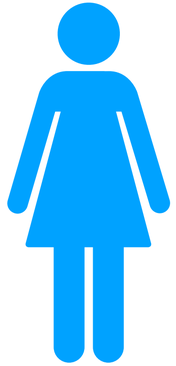

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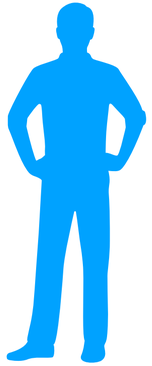

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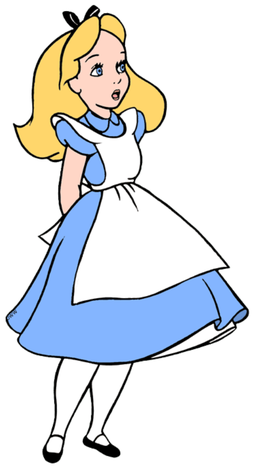

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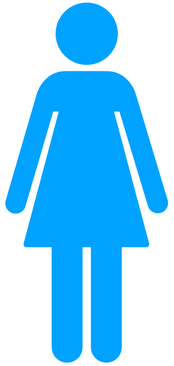

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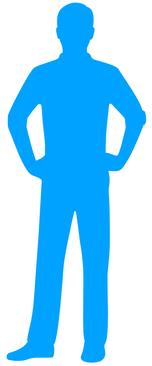

f_3

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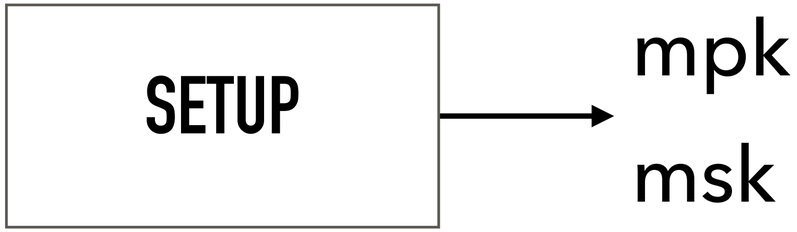

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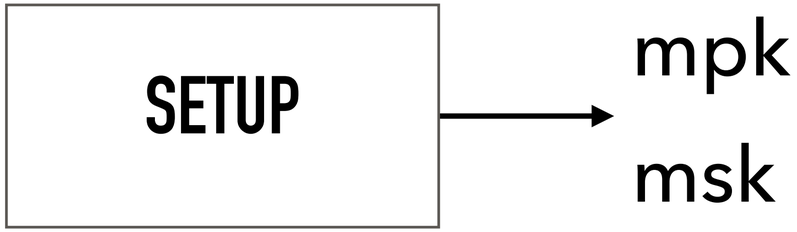

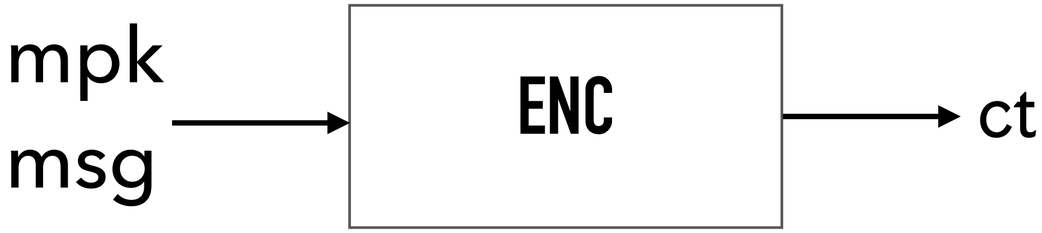

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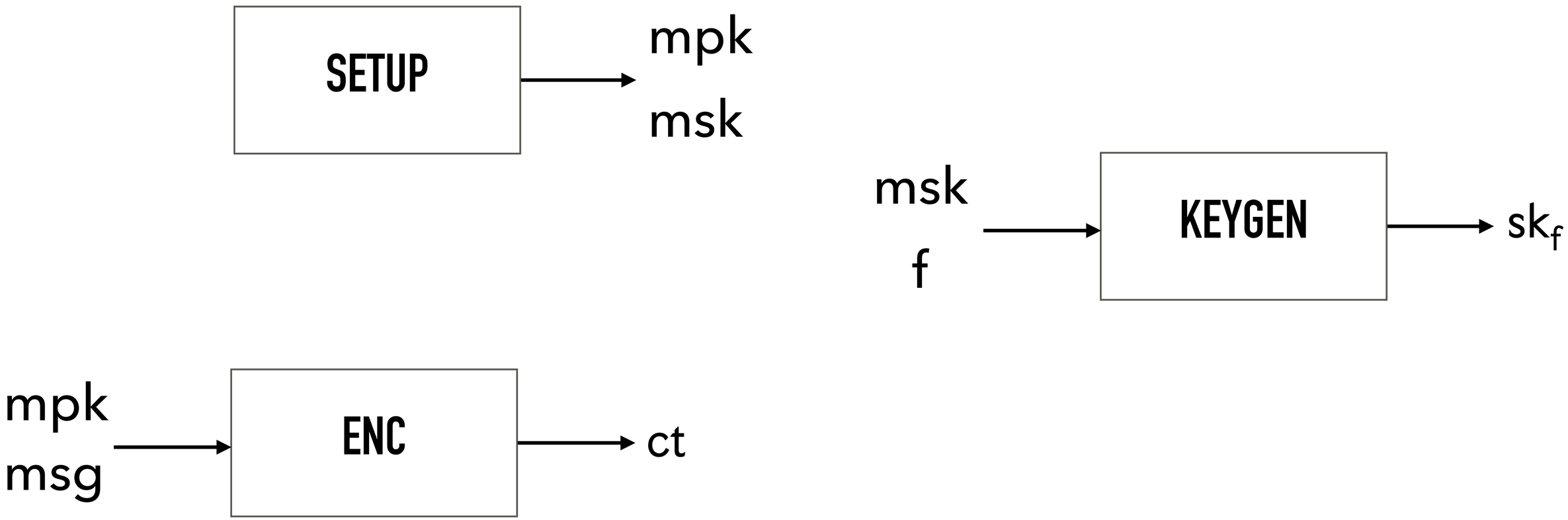

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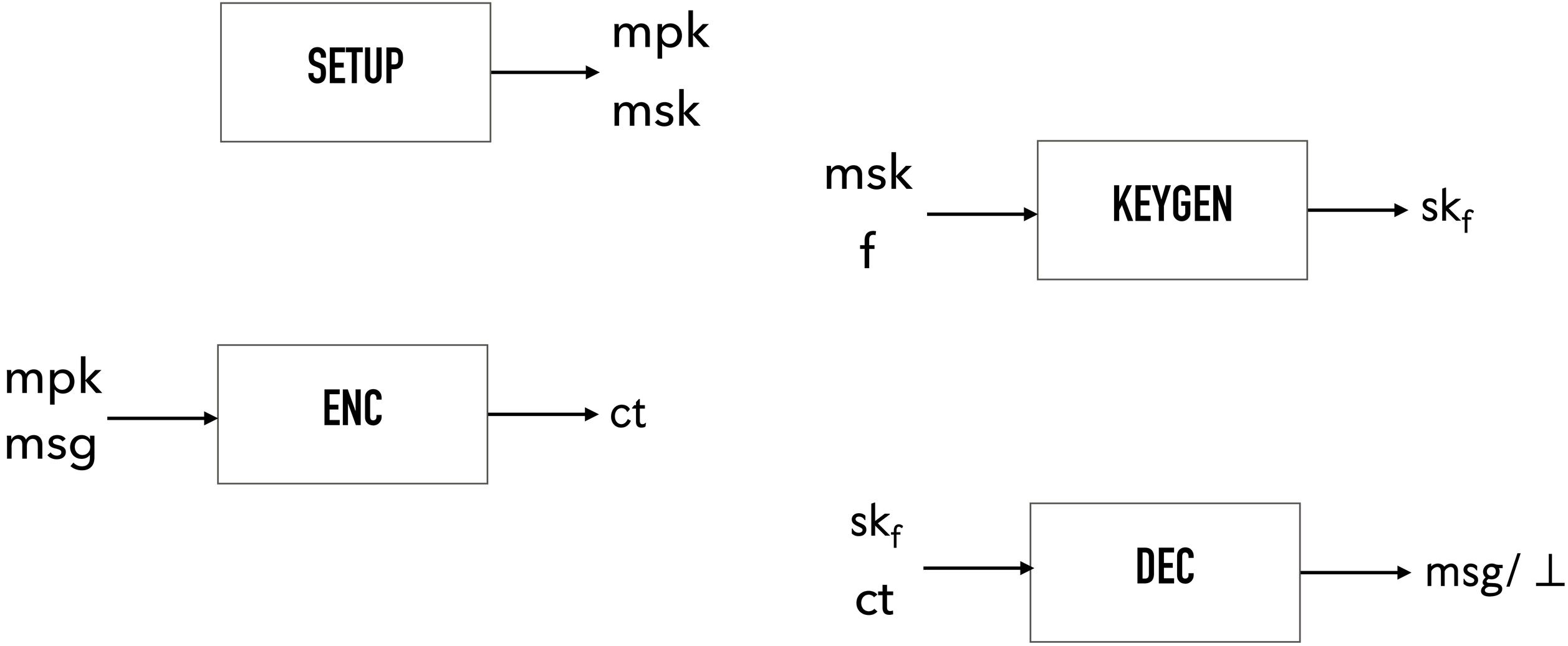

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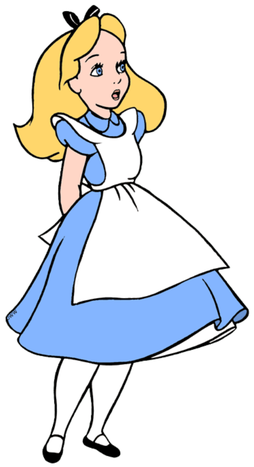

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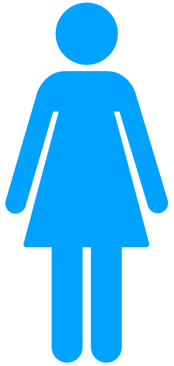

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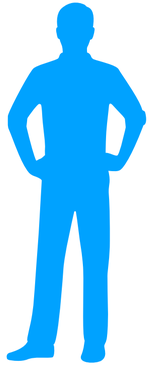

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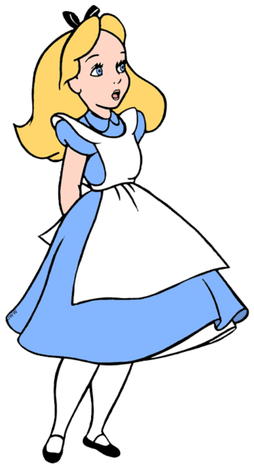

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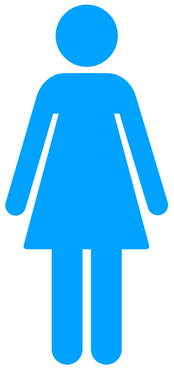

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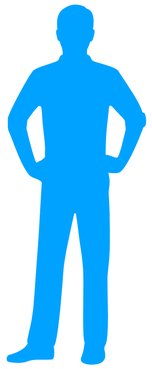

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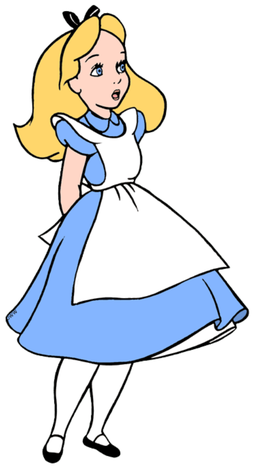

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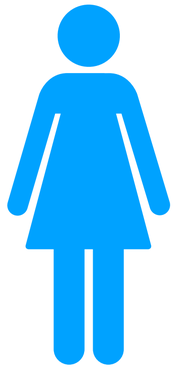

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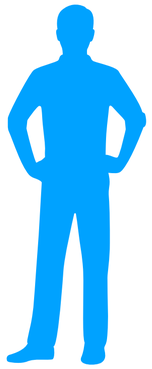

f_3

mpk

msk

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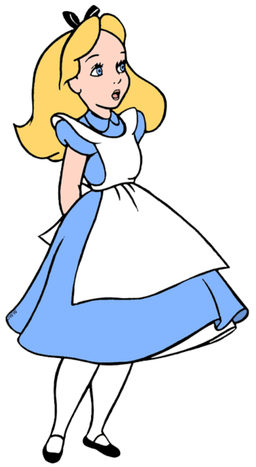

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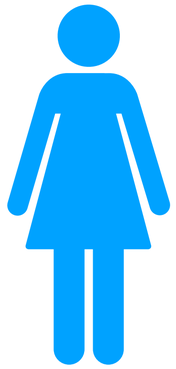

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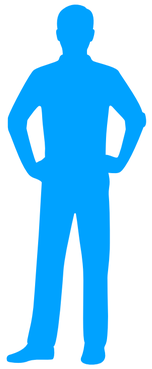

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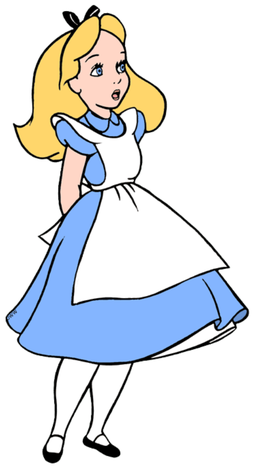
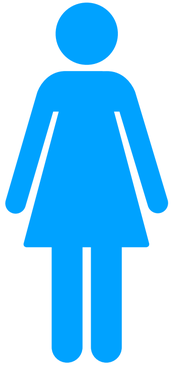


m

f_1

sk_{f_1}



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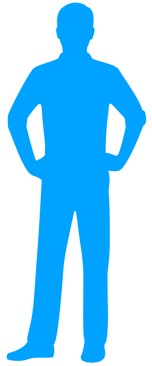

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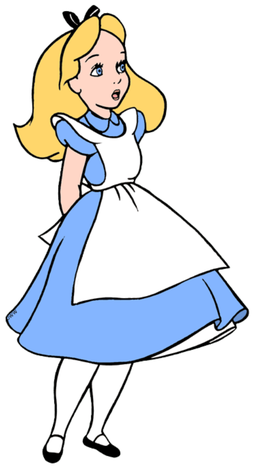

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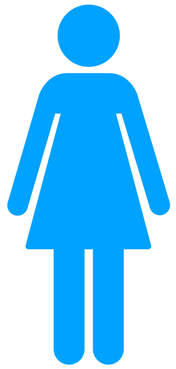
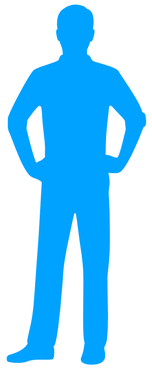


f_2

sk_{f_2}



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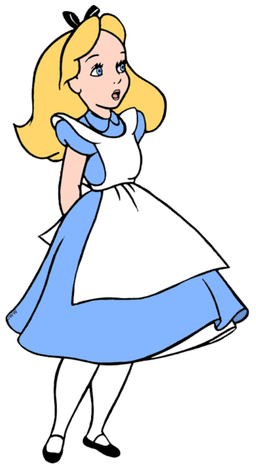
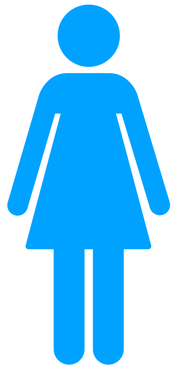


m

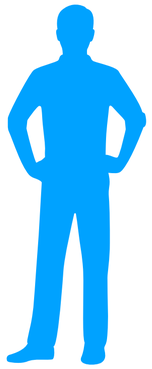
f_1

sk_{f_1}



f_2

sk_{f_2}



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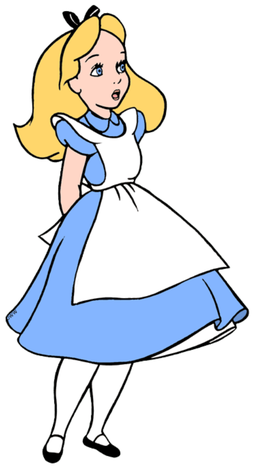


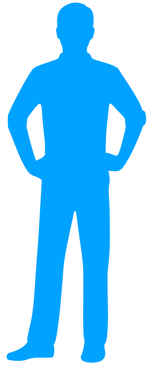
m

f_1

sk_{f_1}

f_2

sk_{f_2}



f_3

sk_{f_3}

Learns only

$f_1(m)$ and $f_2(m)$

ATTRIBUTE-BASED ENCRYPTION (ABE)

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<u>Example attribute:</u>

Student ✗

CSE Dept. ✓

Dean ✗

ATTRIBUTE-BASED ENCRYPTION (ABE)

Example attribute:

Student ✗

CSE Dept. ✓

Dean ✗

Example access policy:

((Student **AND** CSE Dept) **OR** Dean)

ATTRIBUTE-BASED ENCRYPTION (ABE)

Example attribute:

Student ✗

CSE Dept. ✓

Dean ✗

Example access policy:

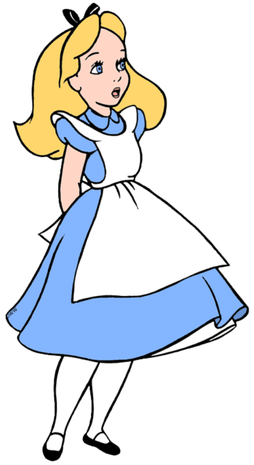
((Student **AND** CSE Dept) **OR** Dean)

Encrypt messages with 'access policy'

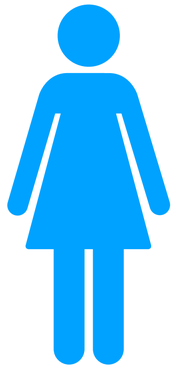
Only users having attribute satisfying access policy should learn message

ATTRIBUTE-BASED ENCRYPTION (ABE)

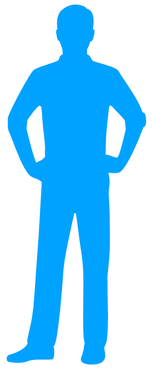
Alice wants to send m with policy f
s.t. only parties whose attributes satisfy
the policy can recover m



x_1



x_2



x_3

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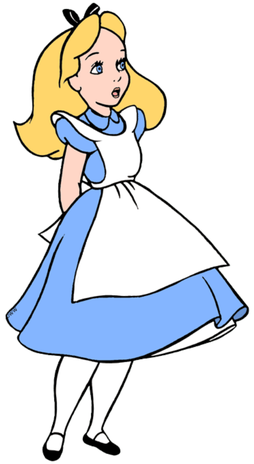
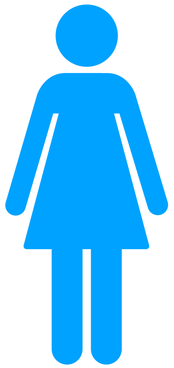
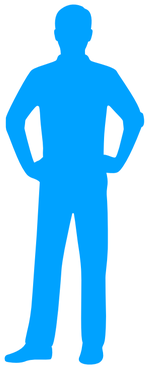


x_1



x_2



x_3

mpk

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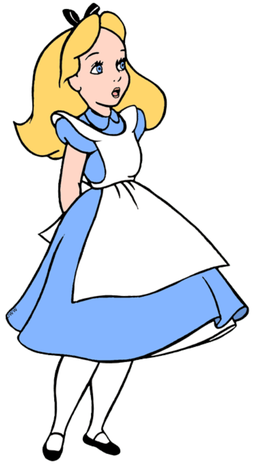
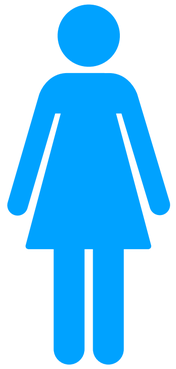


m; policy f

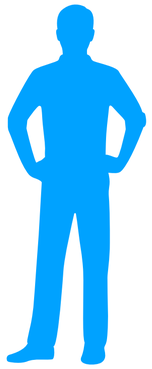
x_1

sk_{x_1}



x_2

sk_{x_2}



x_3

sk_{x_3}

mpk

msk

PROGRESS IN ABE / FE

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ABE

PROGRESS IN ABE / FE

ABE

- ABE for formulas [Goyal, Pandey, Sahai, Waters 07]

PROGRESS IN ABE / FE

ABE

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- ABE for bounded-depth circuits [Gorbunov, Vaikuntanathan, Wee 12]

PROGRESS IN ABE / FE

ABE

- ABE for formulas [Goyal, Pandey, Sahai, Waters 07]
- ABE for bounded-depth circuits [Gorbunov, Vaikuntanathan, Wee 12]
- ABE for bounded-depth circuits, succinct keys
  [Boneh, Gentry, Gorbunov, Halevi, Nikolaenko, Segev, Vaikuntanathan, Vinayagamurthy 13]

PROGRESS IN ABE / FE

ABE

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  [Jain, Lin, Sahai 20]

KEY ISSUE – KEY MANAGEMENT ISSUE

"Cryptography is a tool for turning
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What if decryption key is compromised?

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ED TARGETT

September 18, 2023 . 4:10 PM — 3 min read

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FORBES > INNOVATION > CYBERSECURITY

EDITORS' PICK

Zoom Gets Stuffed: Here's How Hackers Got Hold Of 500,000 Passwords

Davey Winder Senior Contributor

Co-founder, Straight Talking Cyber

Follow

Apr 28, 2020, 06:46am EDT

What if decryption key is compromised?

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- BIG KEY CRYPTOGRAPHY: make key so large that it is difficult for adversary to get the whole key

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- INCOMPRESSIBLE ENCRYPTION: this talk

INCOMPRESSIBLE ENCRYPTION

INCOMPRESSIBLE ENCRYPTION

Adi Shamir

I want that the secret of the Coco-Cola company to be kept not in a tiny file of one kilobyte, which can be exfiltrated easily by an APT (Advanced Persistent Threat). I want that file to be a terabyte, which cannot be [easily] exfiltrated.

(RSA 2013 conference)

INCOMPRESSIBLE ENCRYPTION

INCOMPRESSIBLE ENCRYPTION

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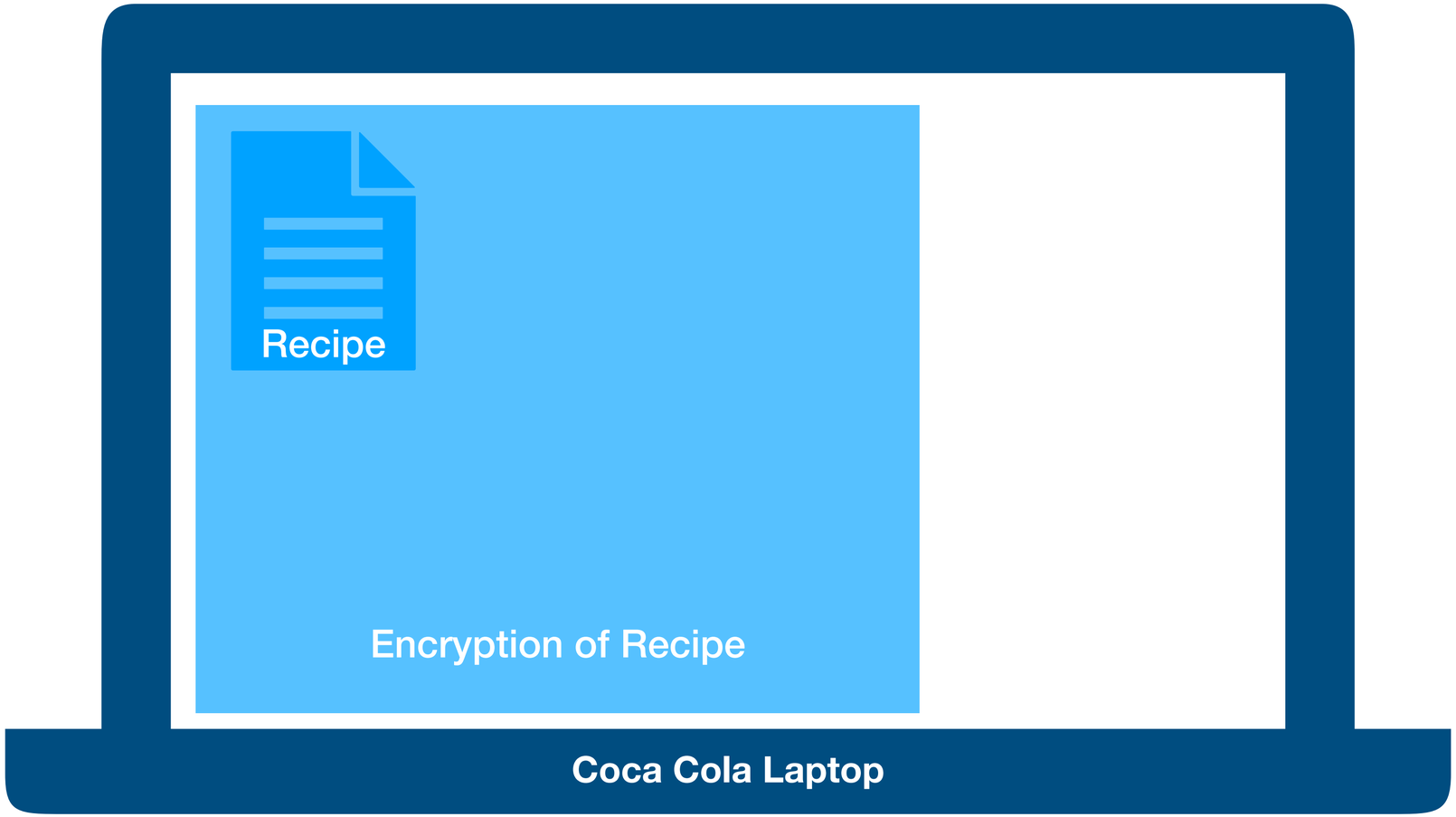

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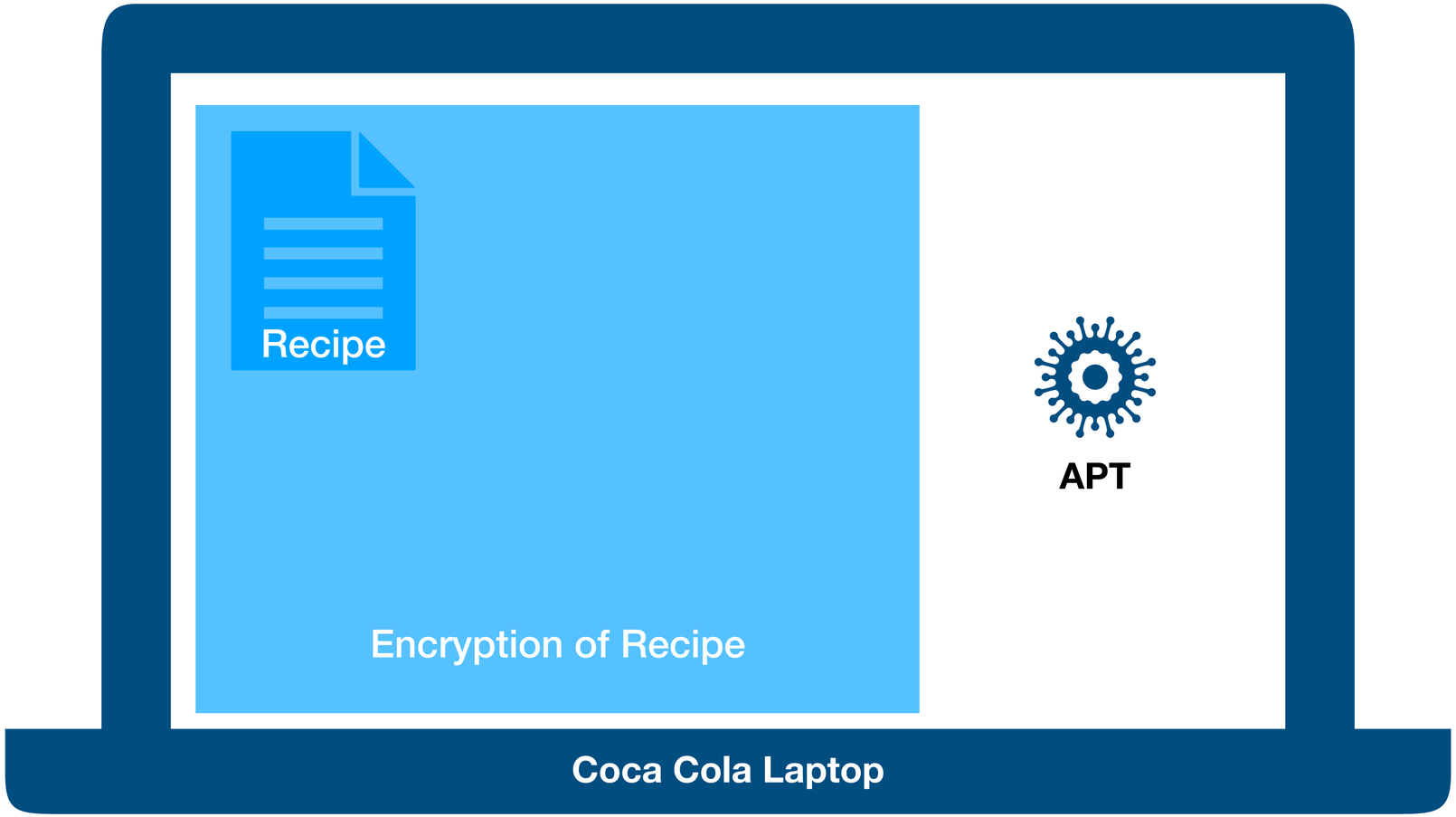
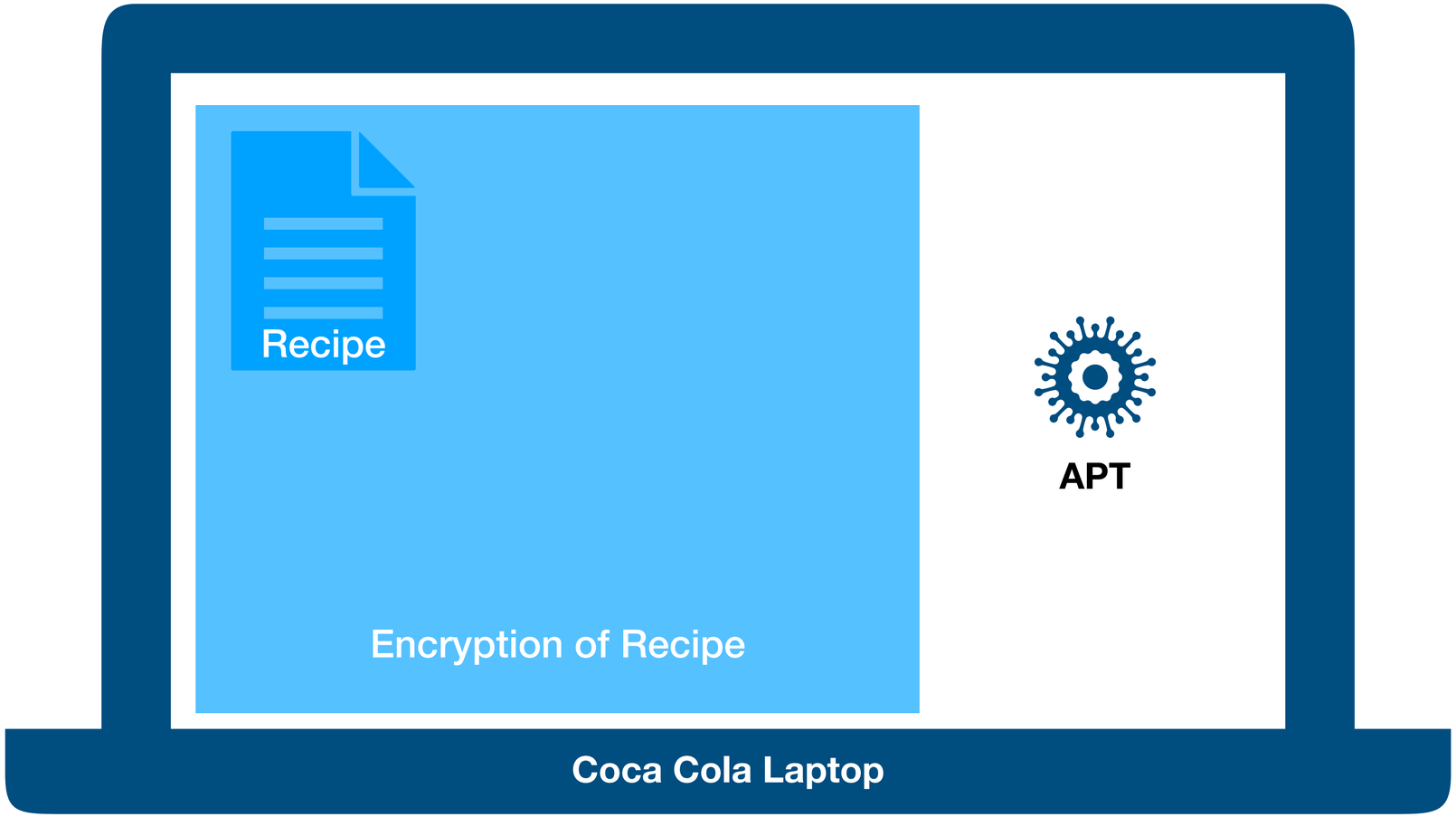


INCOMPRESSIBLE ENCRYPTION

APT can transmit a few MBs to adversary.



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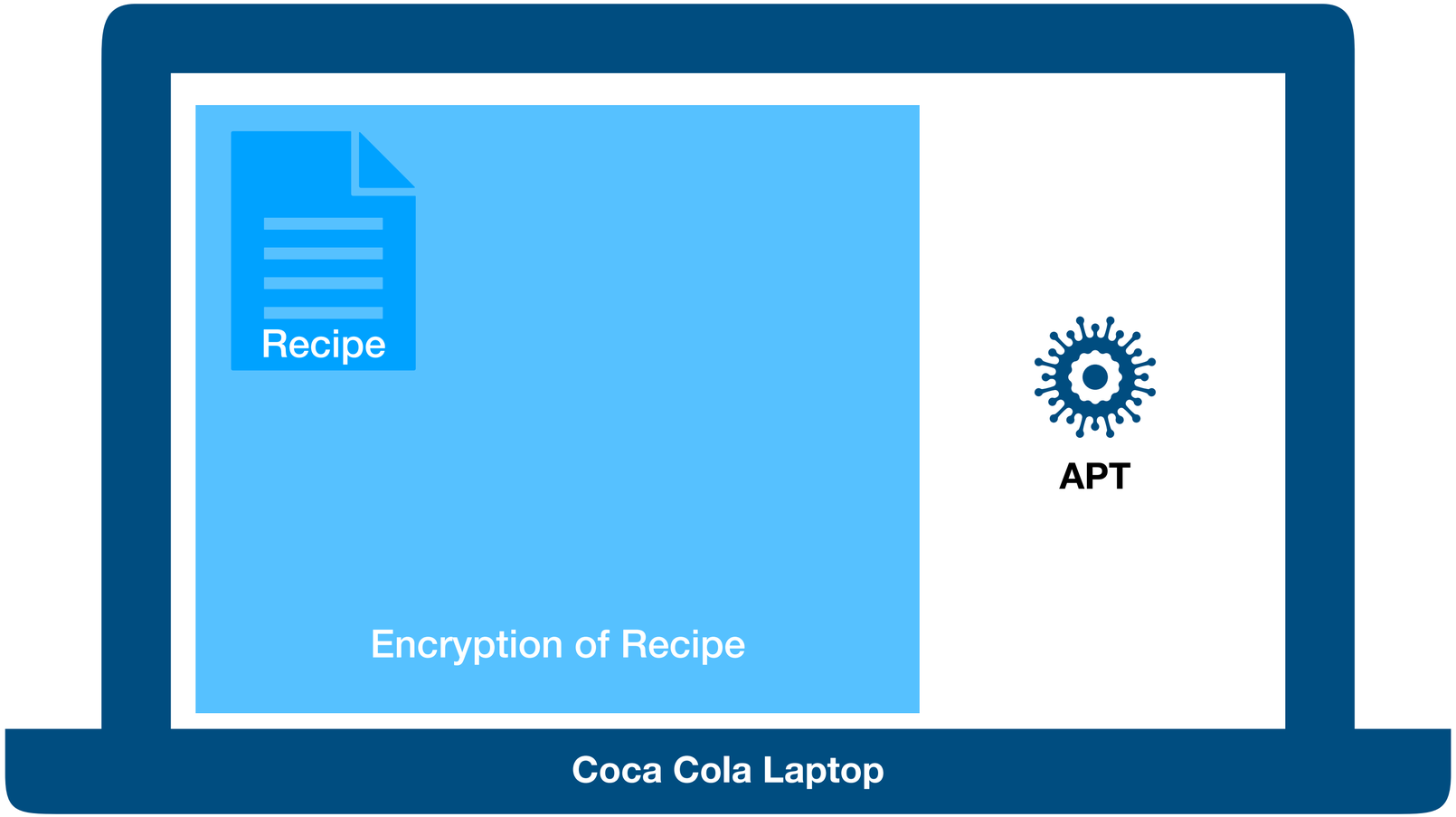

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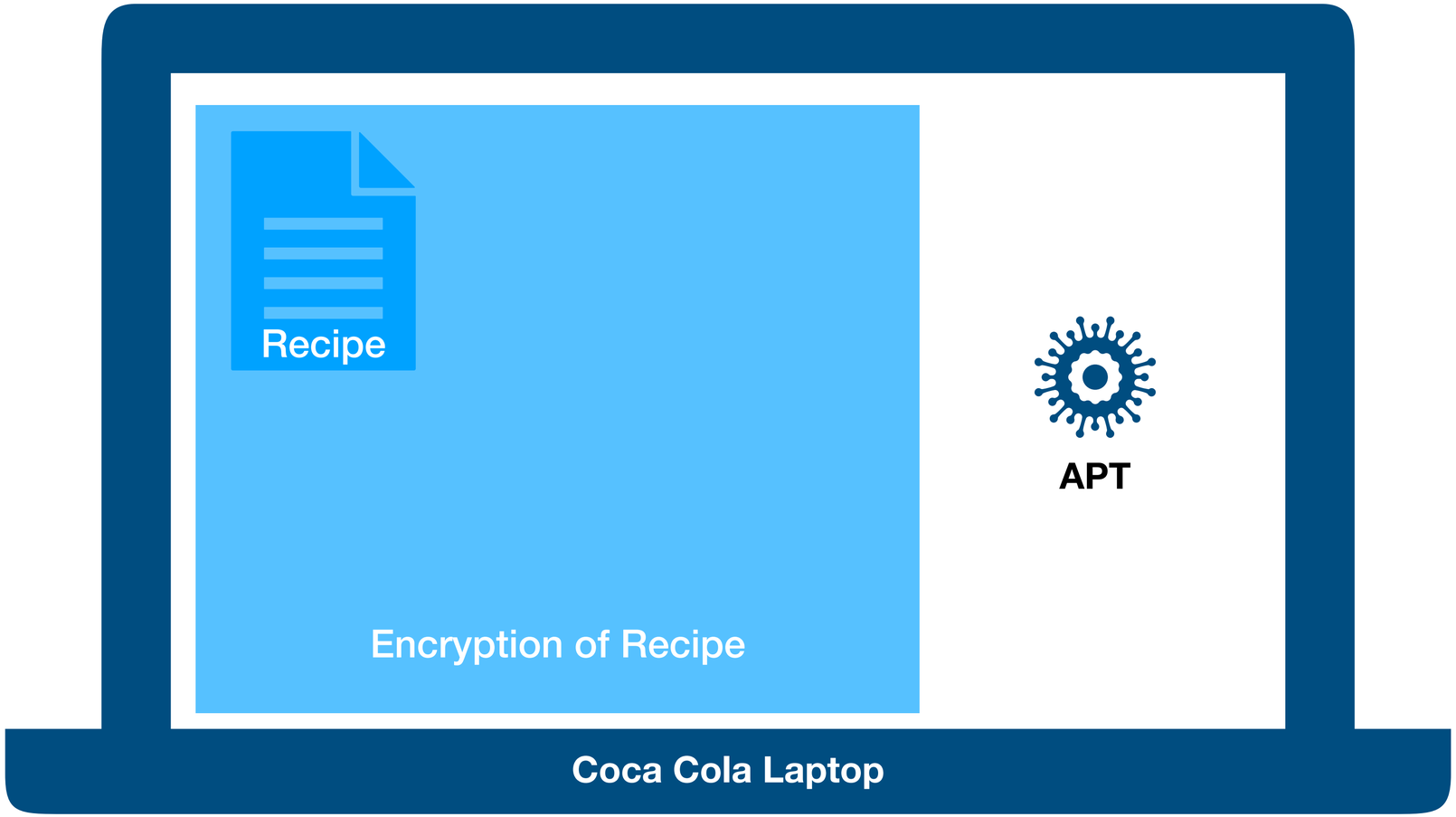

APT can transmit a few MBs to adversary.

- Can either try to learn recipe from the ciphertext, and send the recipe
- Can send a short summary of the ciphertext. **Later, adversary learns key**, and uses this summary to learn recipe.

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- INCOMPRESSIBLE CRYPTOGRAPHY [Guan, Wichs, Zhandry 22]
  Incompressible Public Key Encryption

- RATE-1 INCOMPRESSIBLE ENCRYPTION FROM STANDARD ASSUMPTIONS
  [Branco, Dottling, Dujmovic 22]
  Efficient incompressible PKE schemes from LWE/DDH

INCOMPRESSIBLE ENCRYPTION : OUR CONTRIBUTIONS

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- Constructions based on Minimal Assumptions
  Incompressible SKE + IBE/ABE/FE –> Incompressible IBE/ABE/FE

- Optimal* Rate Constructions from Standard Assumptions

***Optimality lies in the eyes of the beholder.**

PLAN FOR THE REMAINING TALK

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- Conclusion and Open Questions

Security Definitions

INCOMPRESSIBLE ENCRYPTION

INCOMPRESSIBLE ENCRYPTION

Challenger

Adversary

INCOMPRESSIBLE ENCRYPTION

Challenger

Adversary

$(sk, pk) \leftarrow Setup()$

pk →

INCOMPRESSIBLE ENCRYPTION

Challenger		Adversary
$(sk, pk) \leftarrow Setup()$		
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	$\xleftarrow{\quad m_0, m_1 \quad}$	
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INCOMPRESSIBLE ENCRYPTION

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wins if $b = b'$

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$|f(sk)| < S < |sk|$

← f

$f(sk)$ →

LEAKAGE RESILIENT SECURITY

Challenger		Adversary
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	$\xleftarrow{b' \in \{0,1\}}$	

Adversary wins if $b = b'$

Incompressible SKE

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- Only receiving sk, the second adversary returns $b' = state \oplus sk[0]$.

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Incompressible Security

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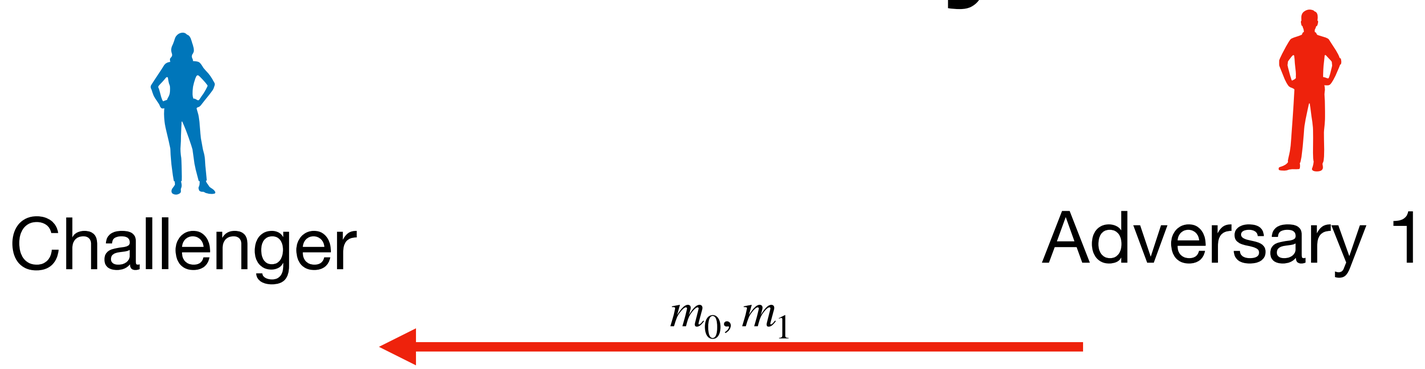
Adversary 1

Incompressible Security



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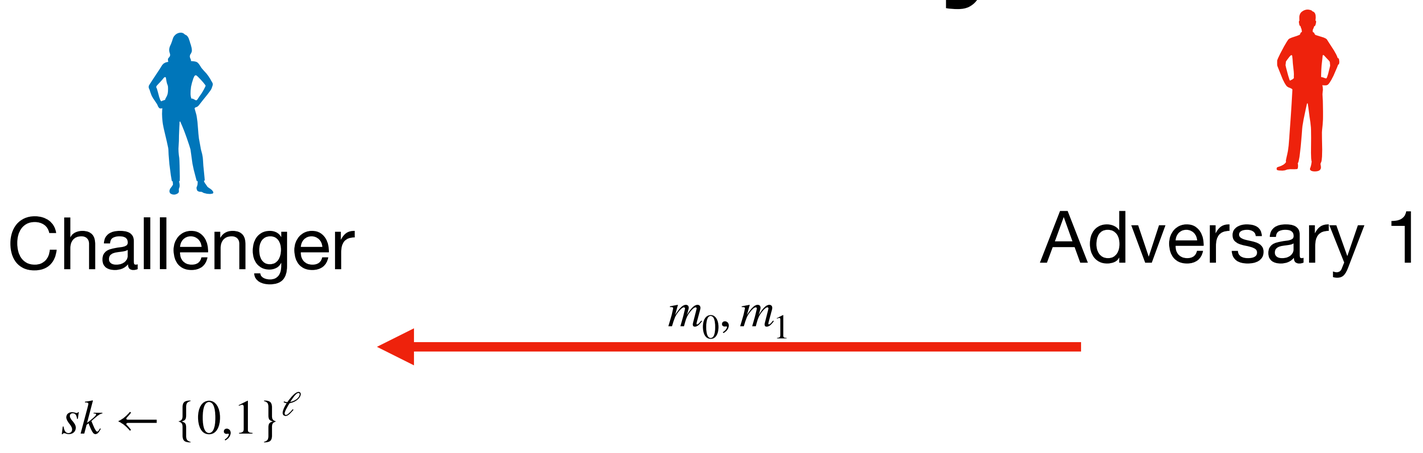

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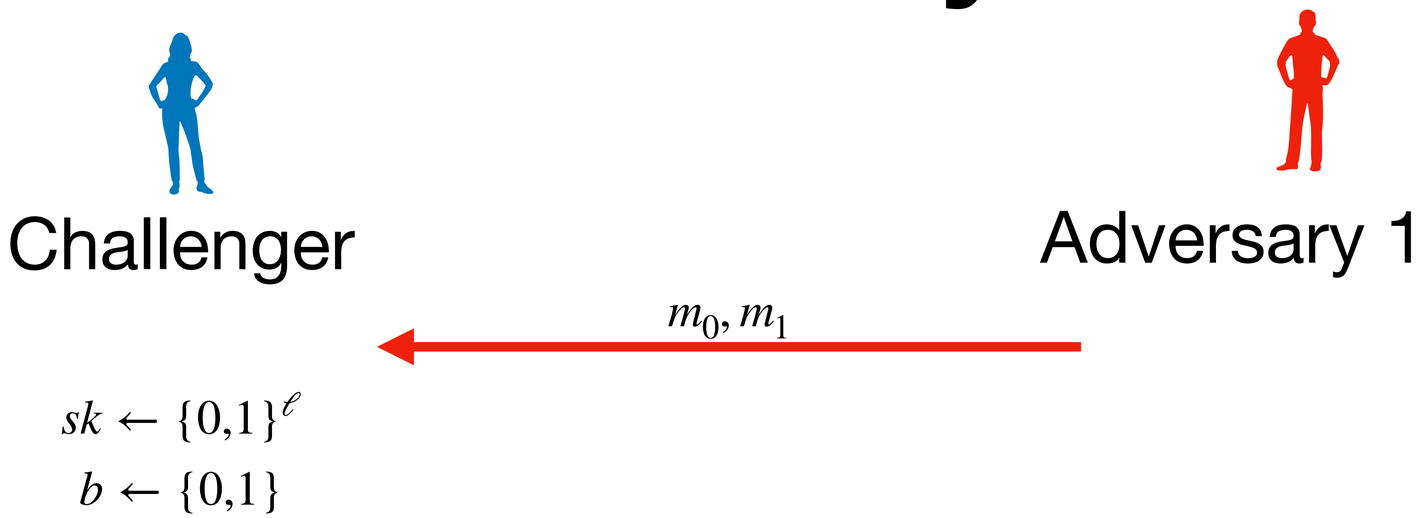

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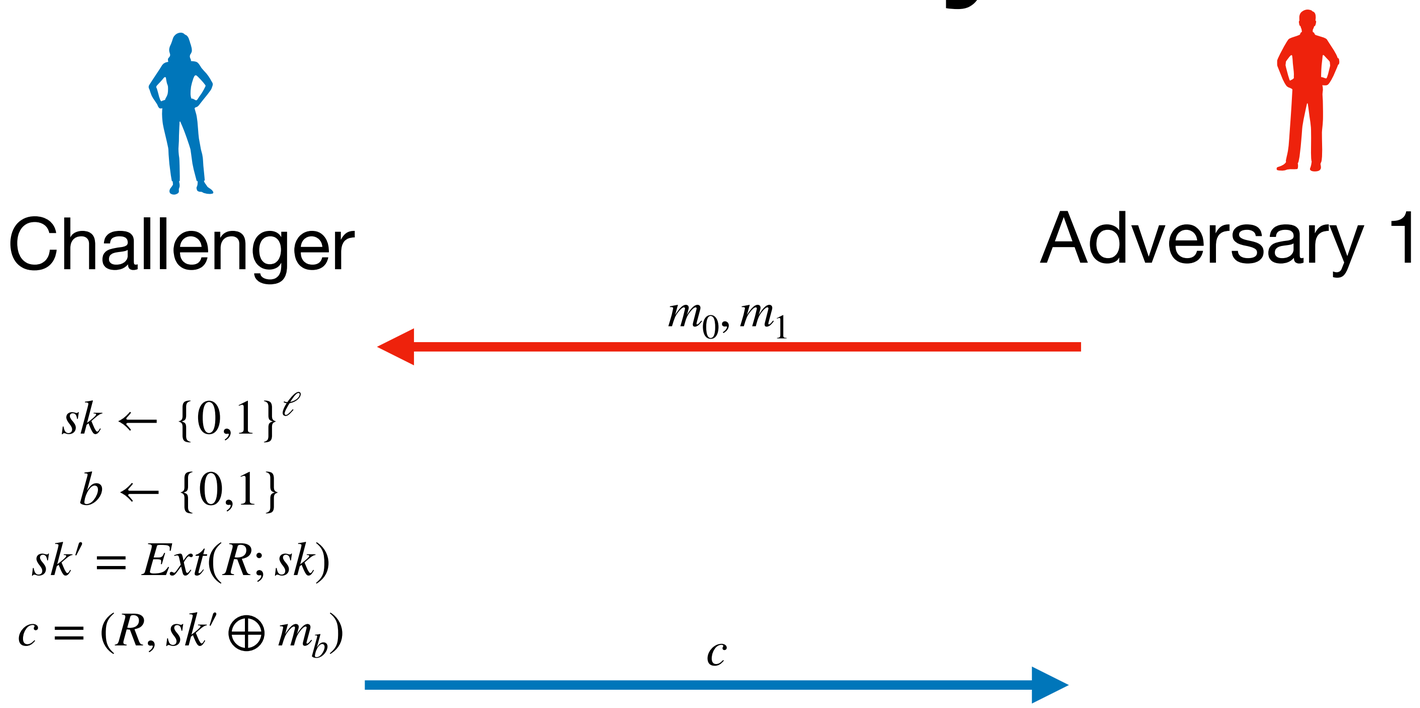

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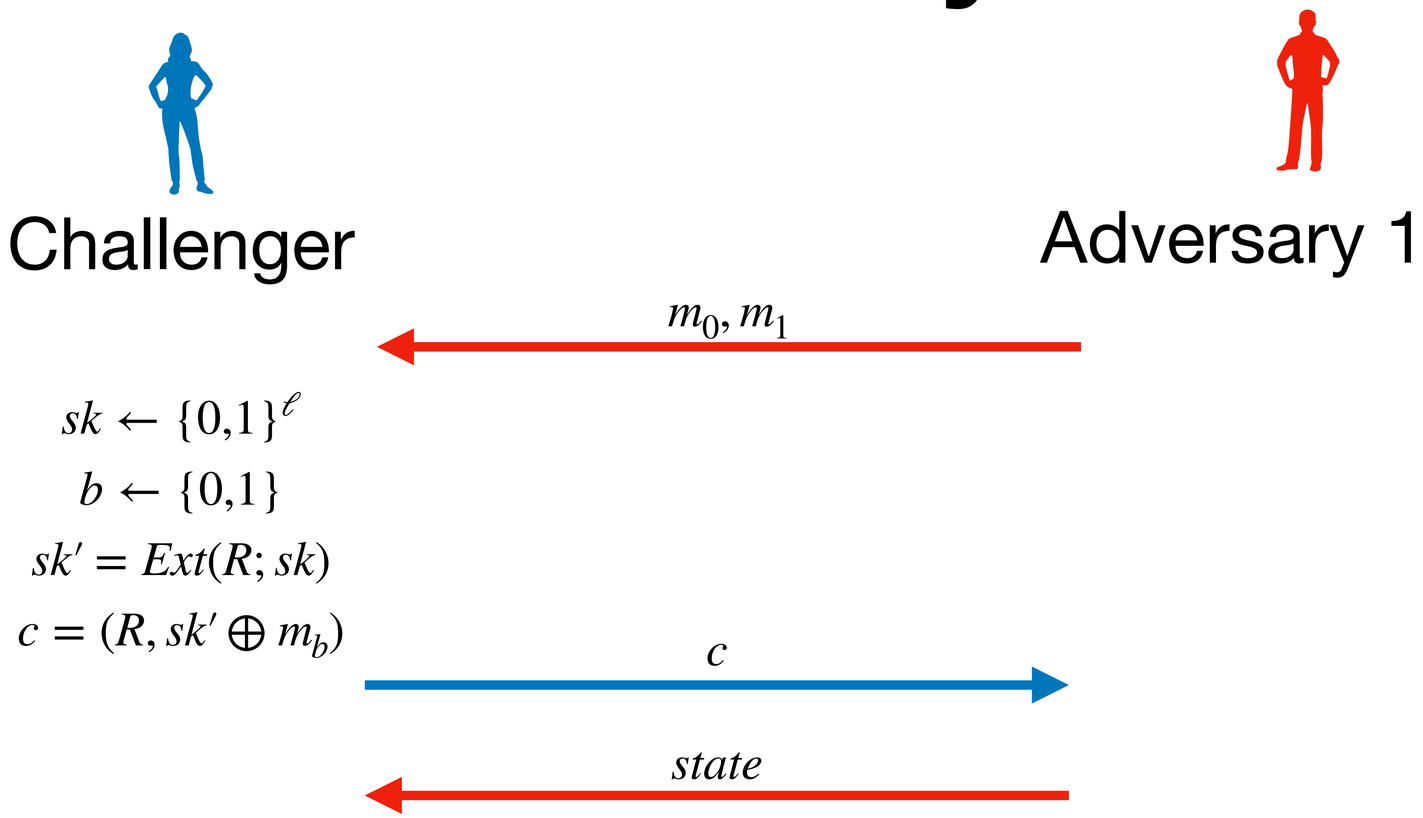

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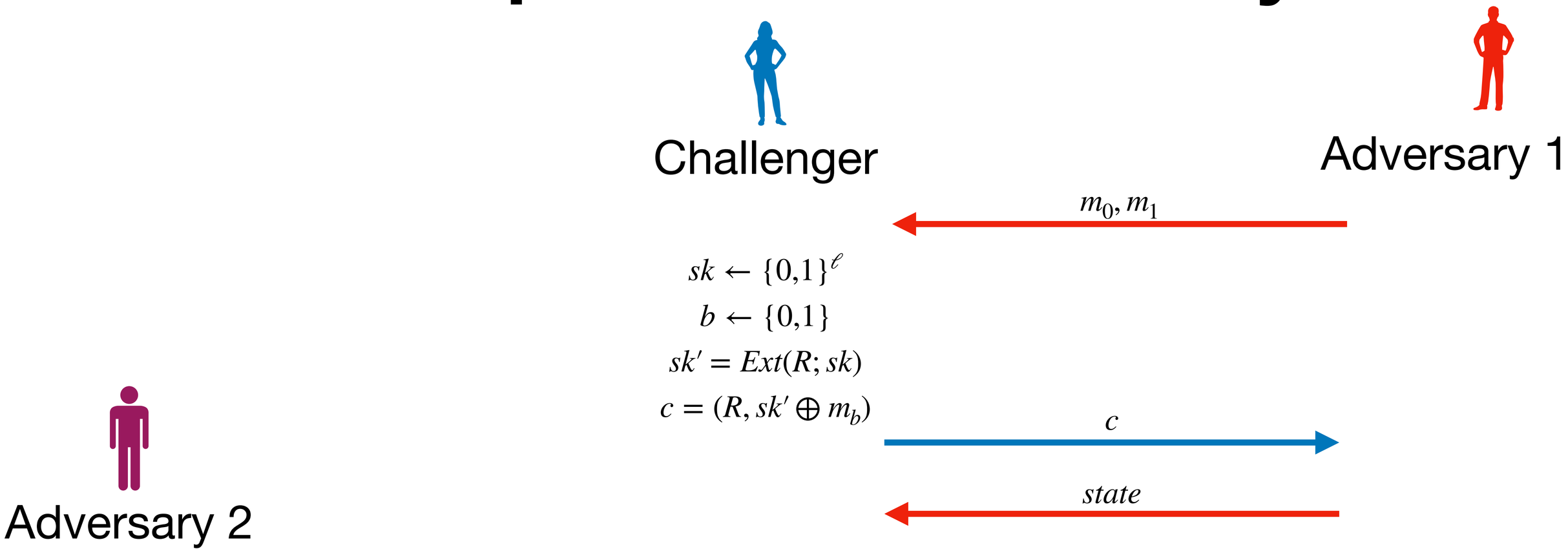

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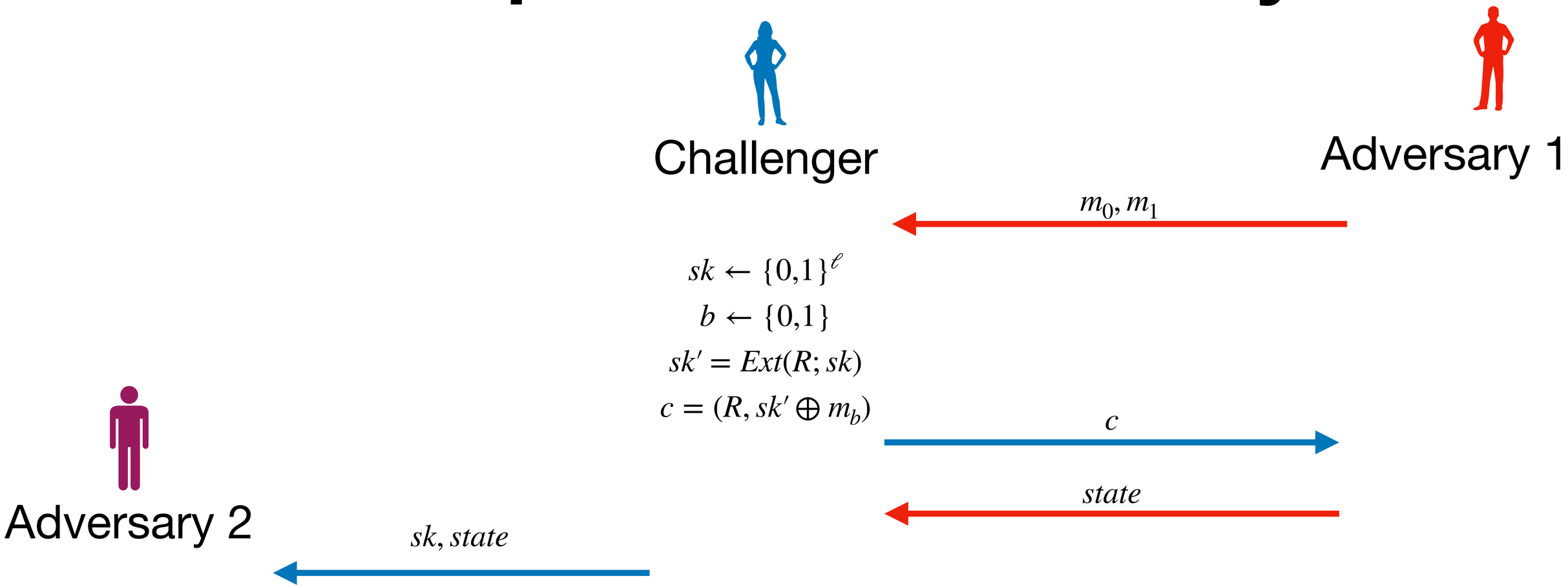

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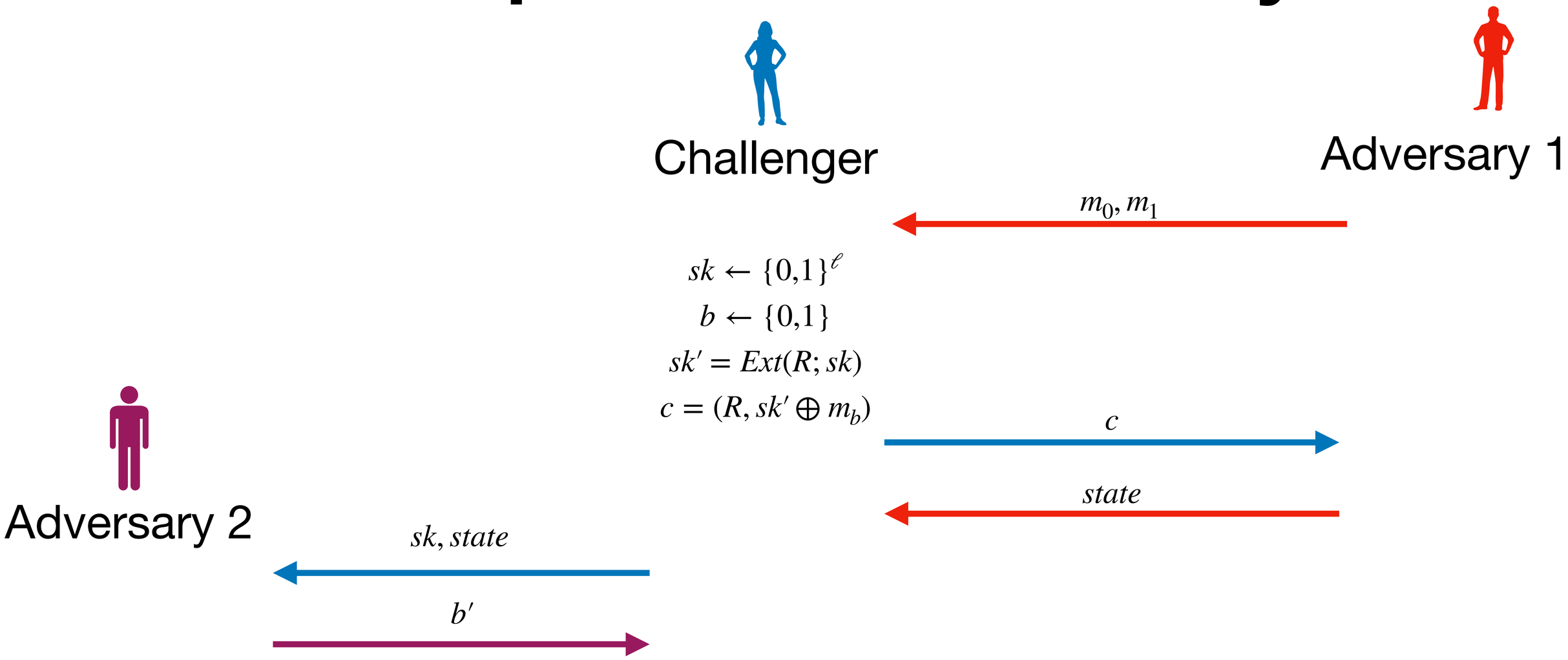

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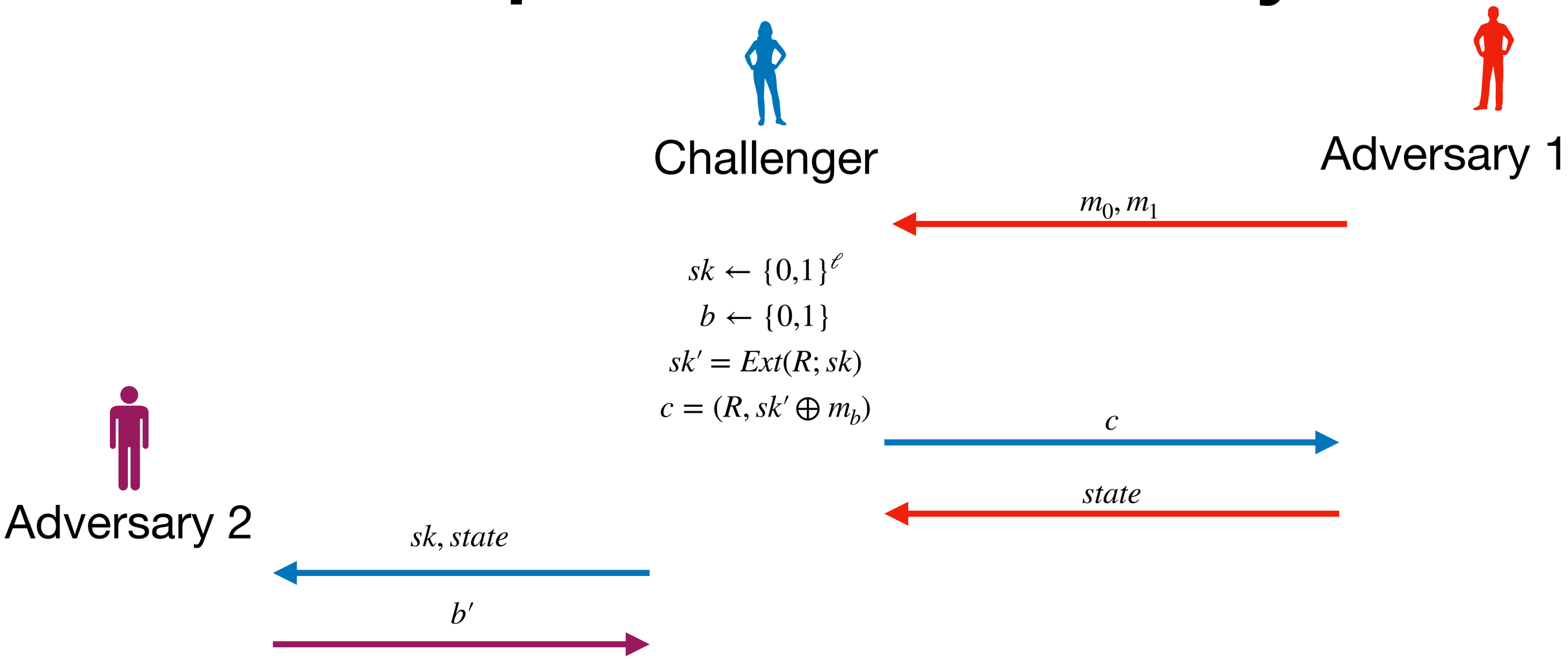

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$state$

$|state| \leq S \ll |R|$

Adversary 2

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b'

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Our Incompressible PKE Scheme

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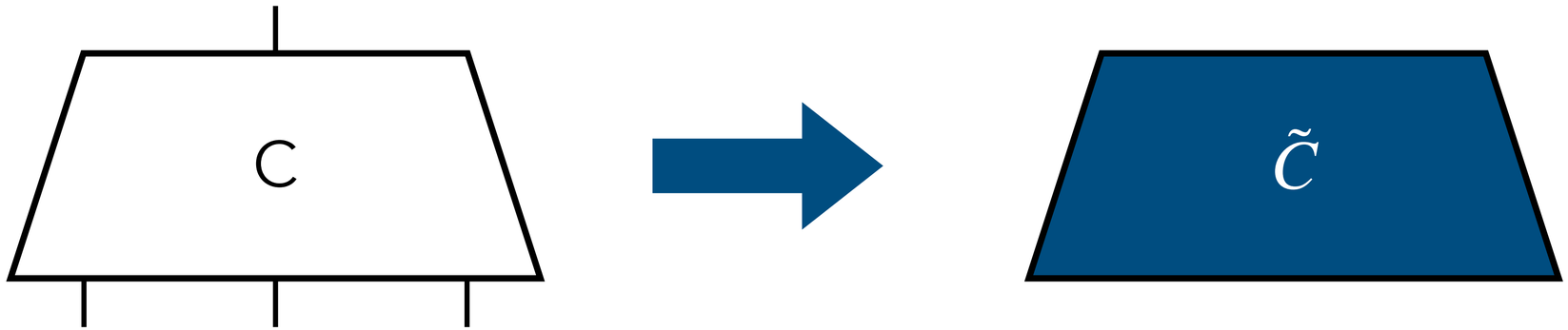
    - Decrypt the incompressible SKE ciphertext.

OUR INCOMPRESSIBLE PKE SCHEME

Circuit Garbling



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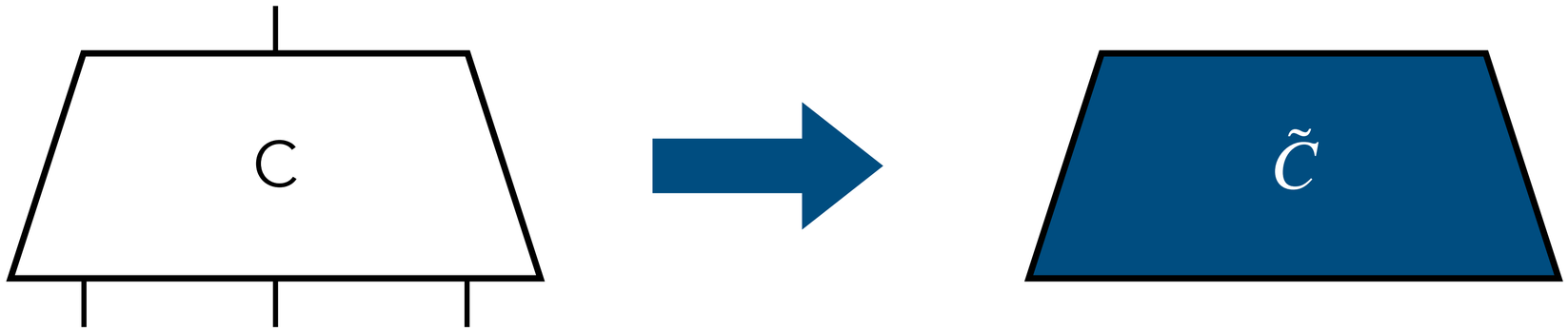

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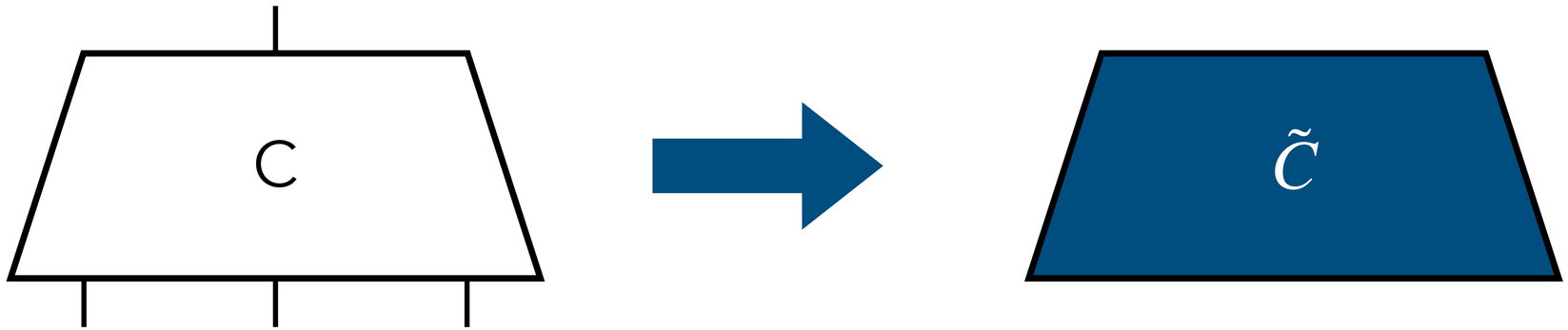
Correctness - For any x, $C(x) = \tilde{C}(\{lab_{i,x_i}\})$.

OUR INCOMPRESSIBLE PKE SCHEME

Circuit Garbling



$lab_{1,0}$ $lab_{2,0}$ $lab_{3,0}$

$lab_{1,1}$ $lab_{2,1}$ $lab_{3,1}$

Correctness - For any x, $C(x) = \tilde{C}(\{lab_{i,x_i}\})$.

Security - $\tilde{C}$ and $\{lab_{i,x_i}\}$ reveal $C(x)$, but nothing else.

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- $Setup()$:
  Generate $2n$ public/secret key,
  $$(pk_{i,b}, sk_{i,b}) \leftarrow PKE.Setup()$$
  Generate $k \leftarrow incSKE.Setup()$.
  $pk = \{pk_{i,b}\}$ and $sk = (k, \{sk_{i,k_i}\})$

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- $Enc(pk, m)$:
  $(\tilde{C}, lab_{i,b}) \leftarrow Garble(incSKE.Enc(\cdot, m))$
  $c_{i,b} \leftarrow PKE.Enc(pk_{i,b}, lab_{i,b})$
  Return $(\tilde{C}, \{c_{i,b}\})$

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- $Dec(sk, (\tilde{C}, \{c_{i,b}\}))$:
  $lab_{i,k_i} \leftarrow PKE.Dec(sk_{i,k_i}, c_{i,k_i})$
  $incSKE.ct = \tilde{C}(\{lab_{i,k_i}\})$
  $m \leftarrow incSKE.Dec(k, incSKE.ct)$
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Thank You!