Access Control Encryption for General Policies from Standard Assumptions

Sam Kim David J. Wu

Stanford University

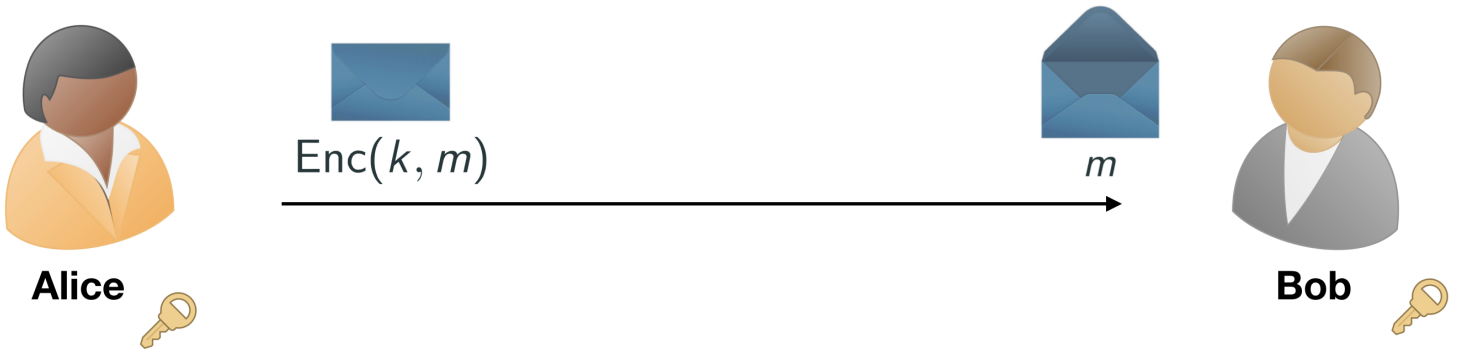
Symmetric Encryption

Alice

Bob

Symmetric Encryption

Symmetric Encryption



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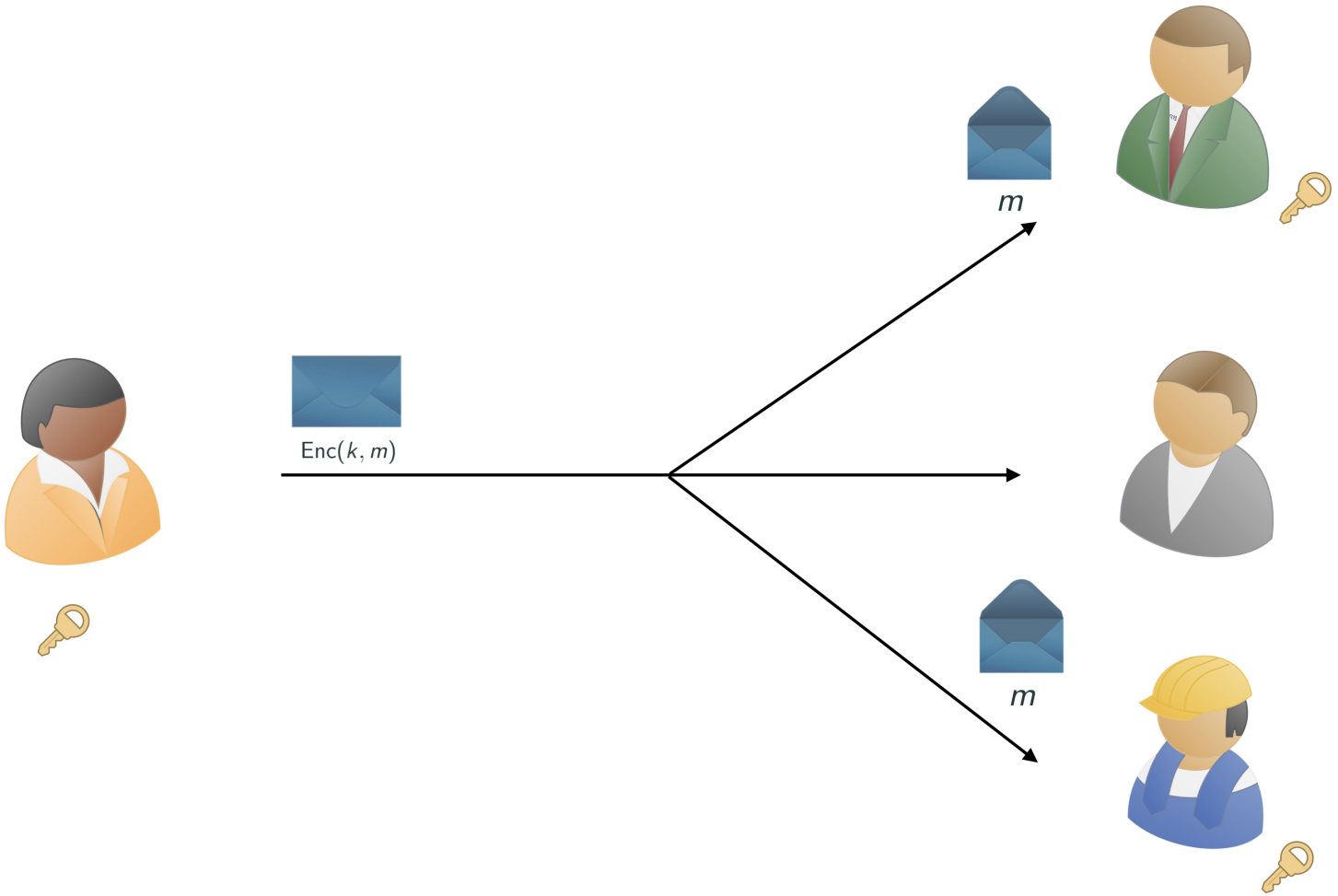

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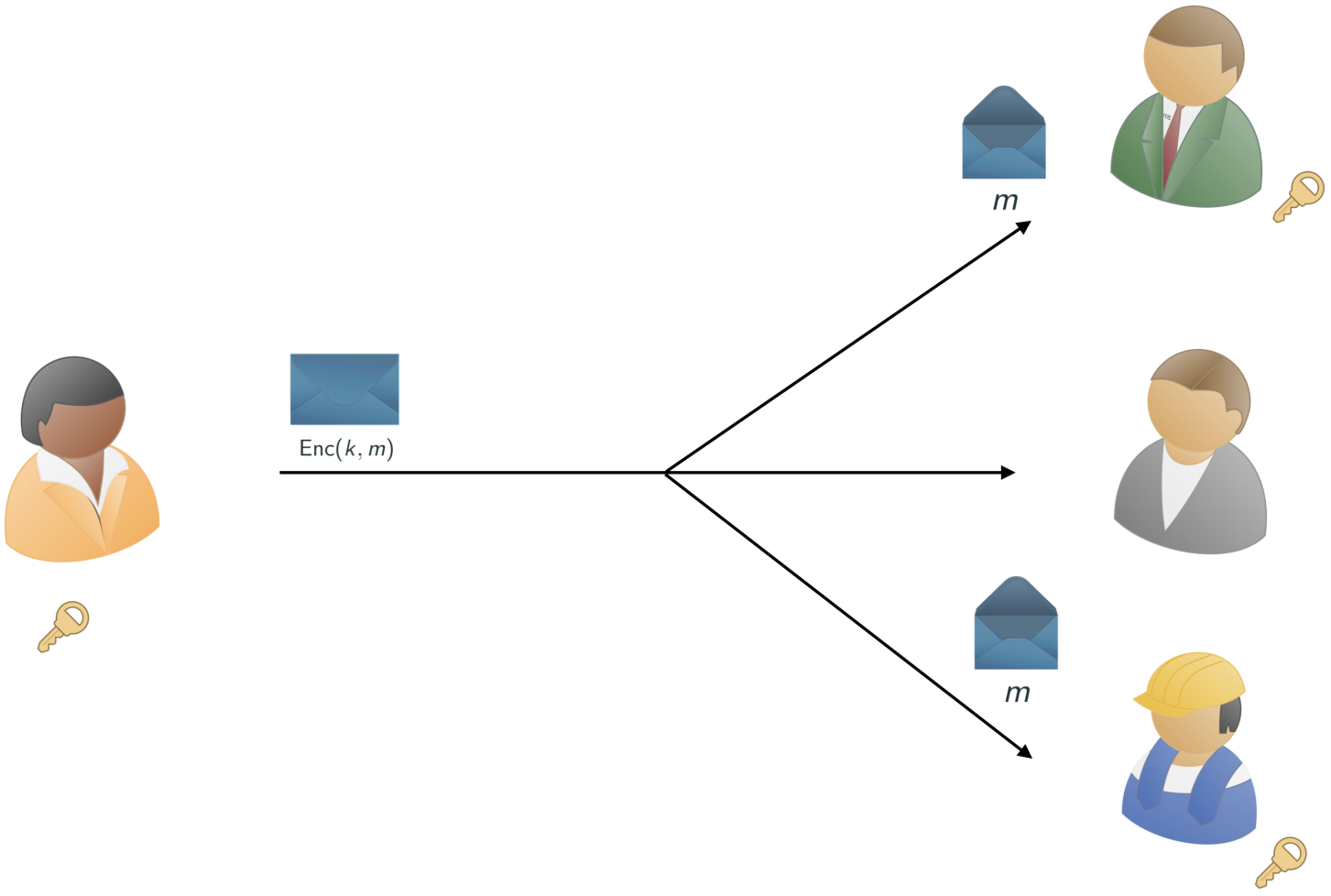

Must have many shared keys!

Functional Encryption [BSW11]

f_1

f_2

f_3

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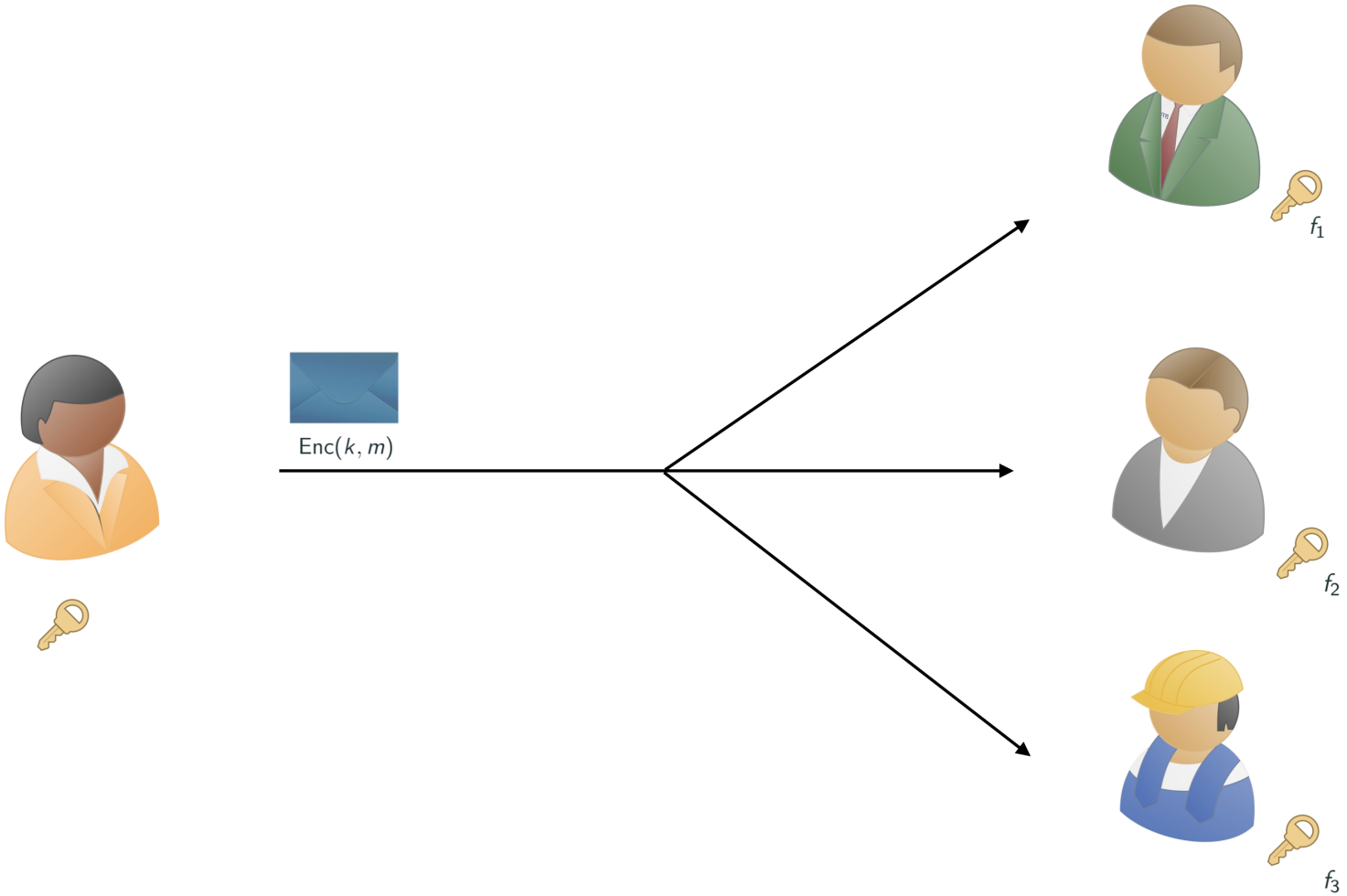

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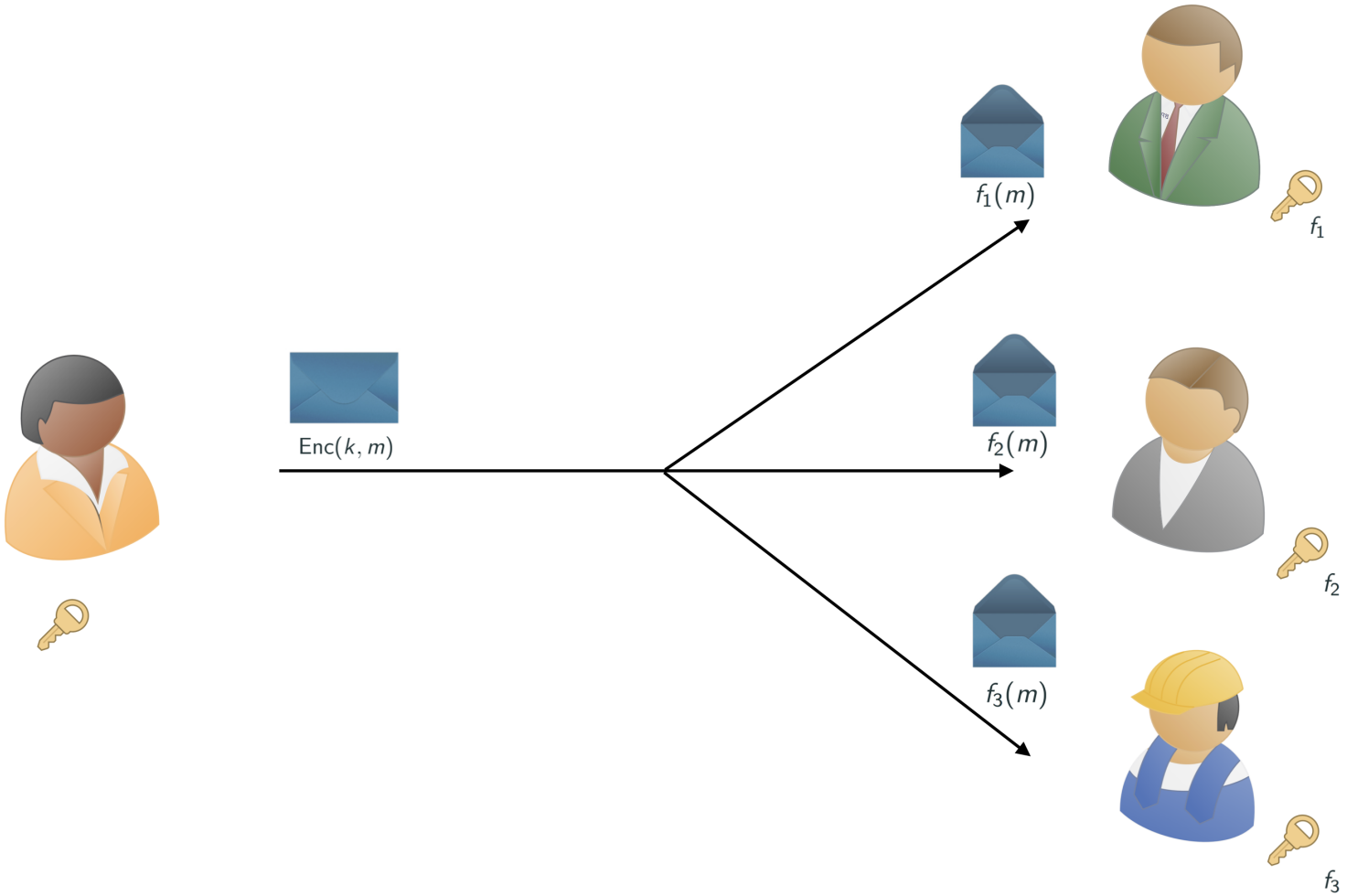

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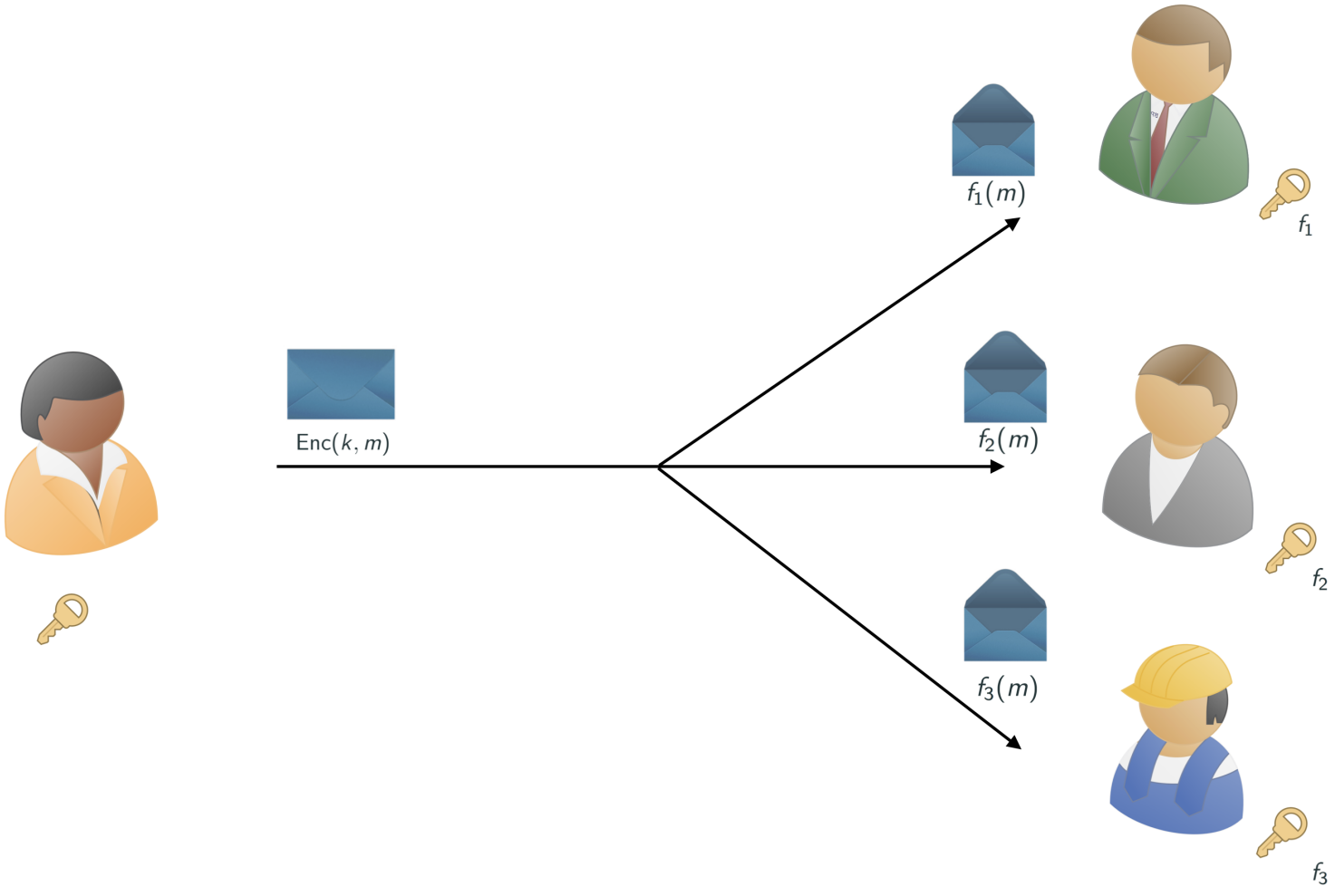

Functional Encryption: Fine-Grained Control of Decryptors

Access Control Encryption [DHO16]

Can we also have fine-grained control of encryptors?

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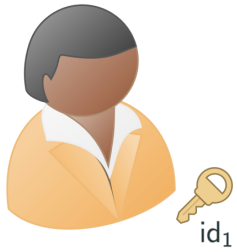
[DHO16]: Access Control Encryption (ACE)

Each ciphertext is processed by a Sanitizer

Access Control Encryption [DHO16]

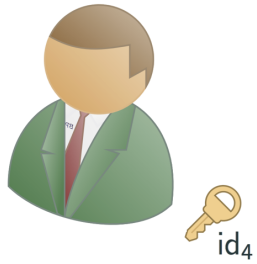
Encryptors

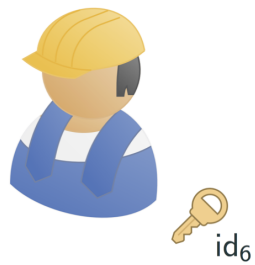


Fixed Predicate: $\pi(\mathrm{id}_i, \mathrm{id}_j) \to \{0, 1\}$

Sanitizer

Decryptors





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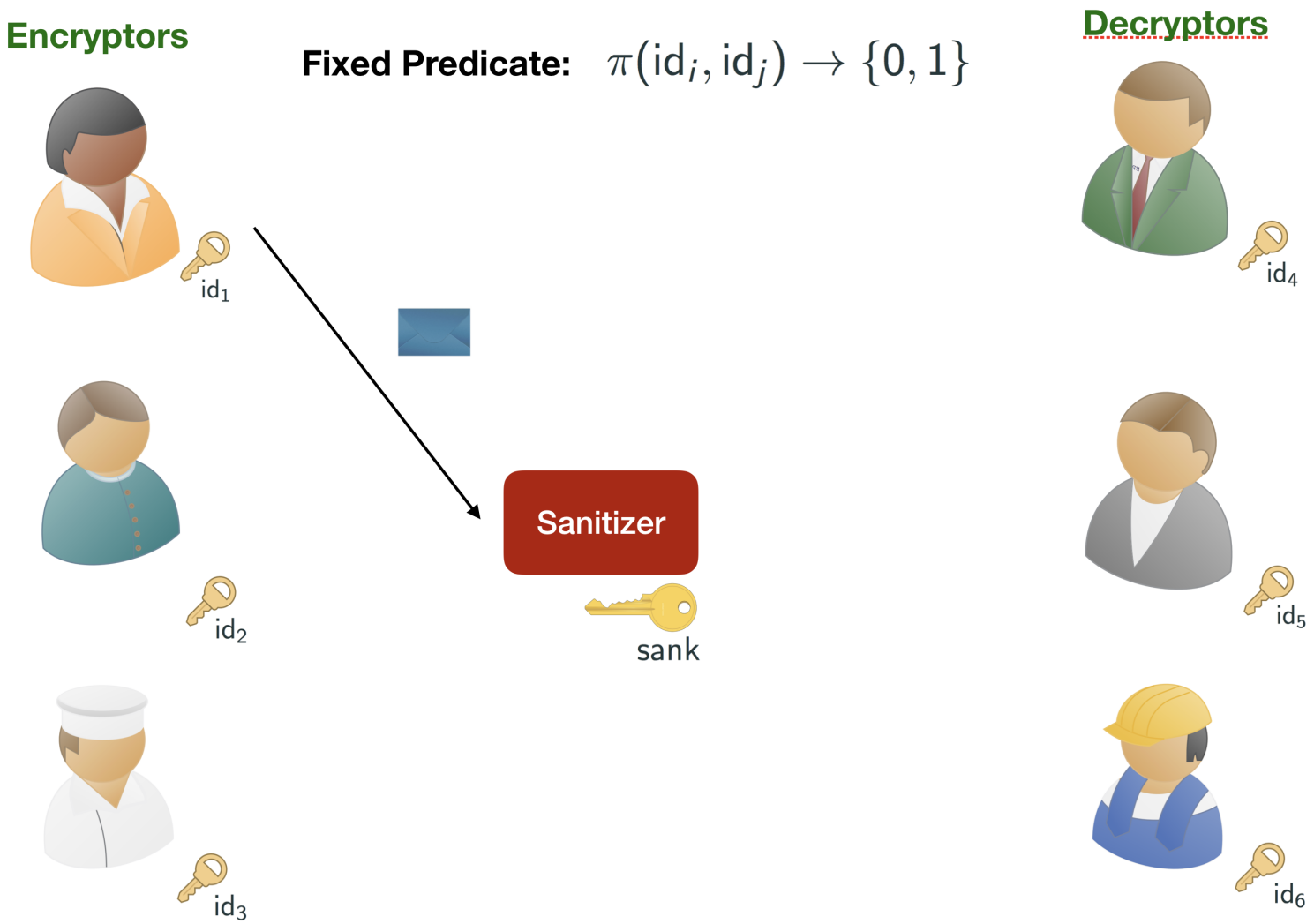

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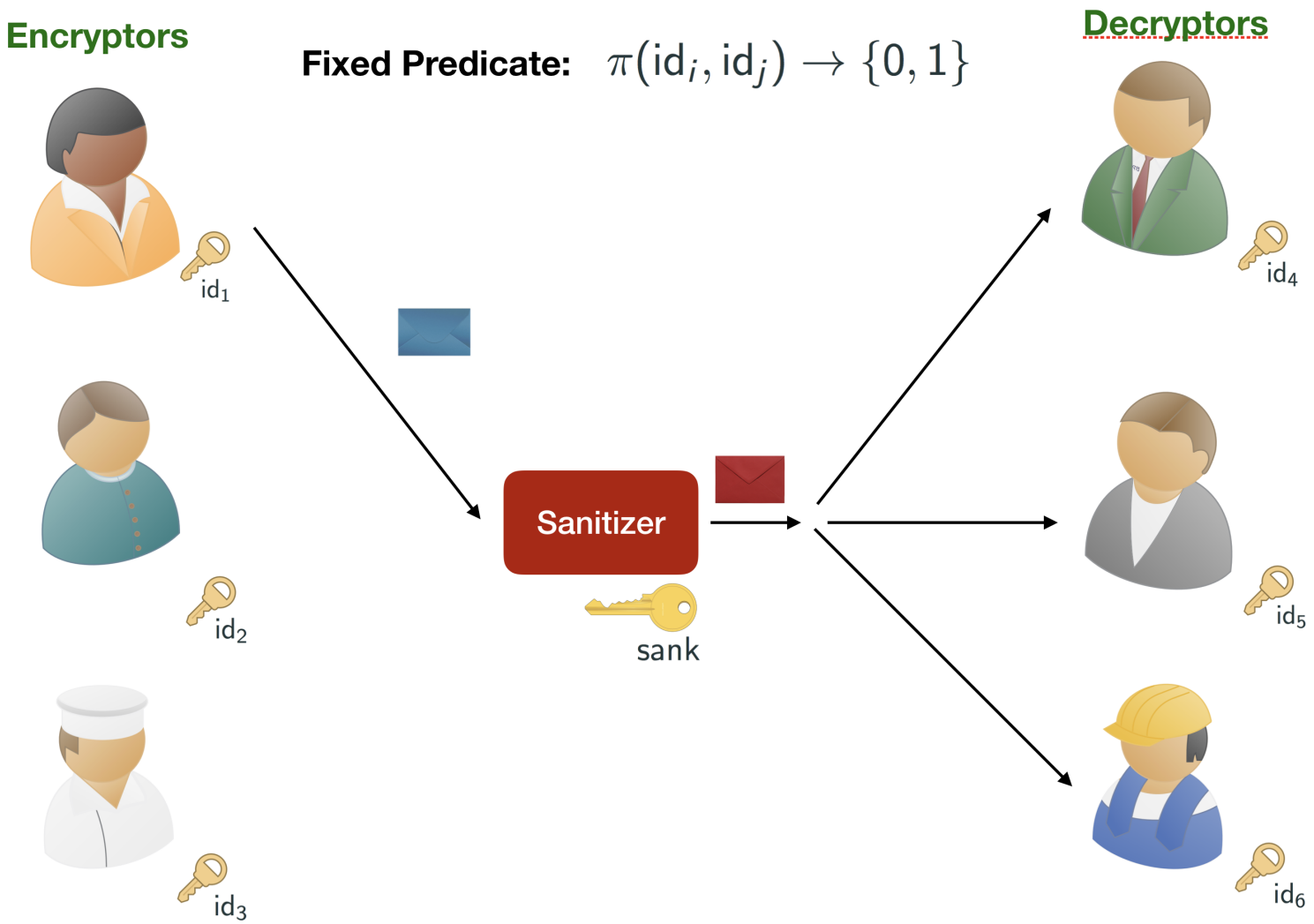

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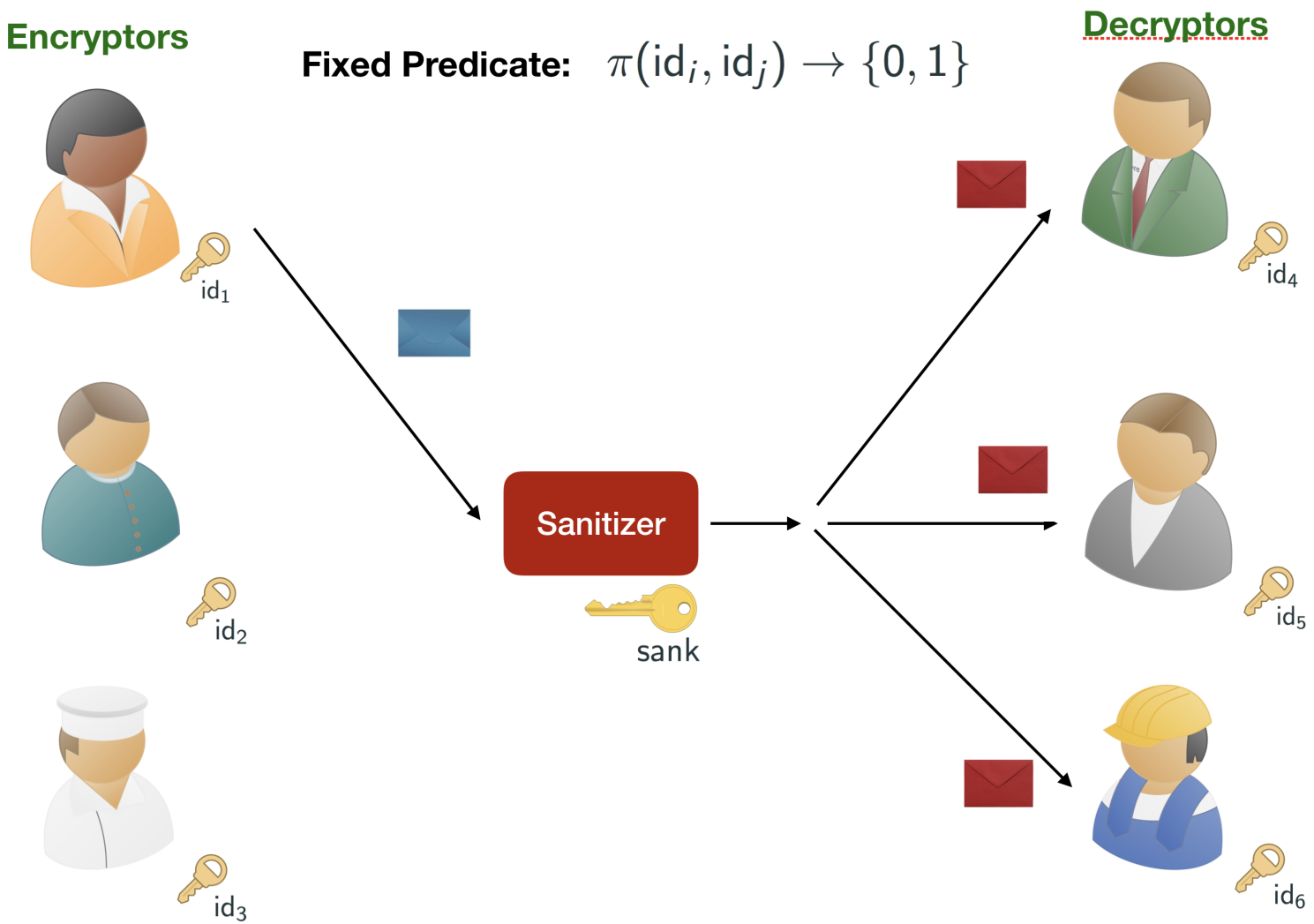

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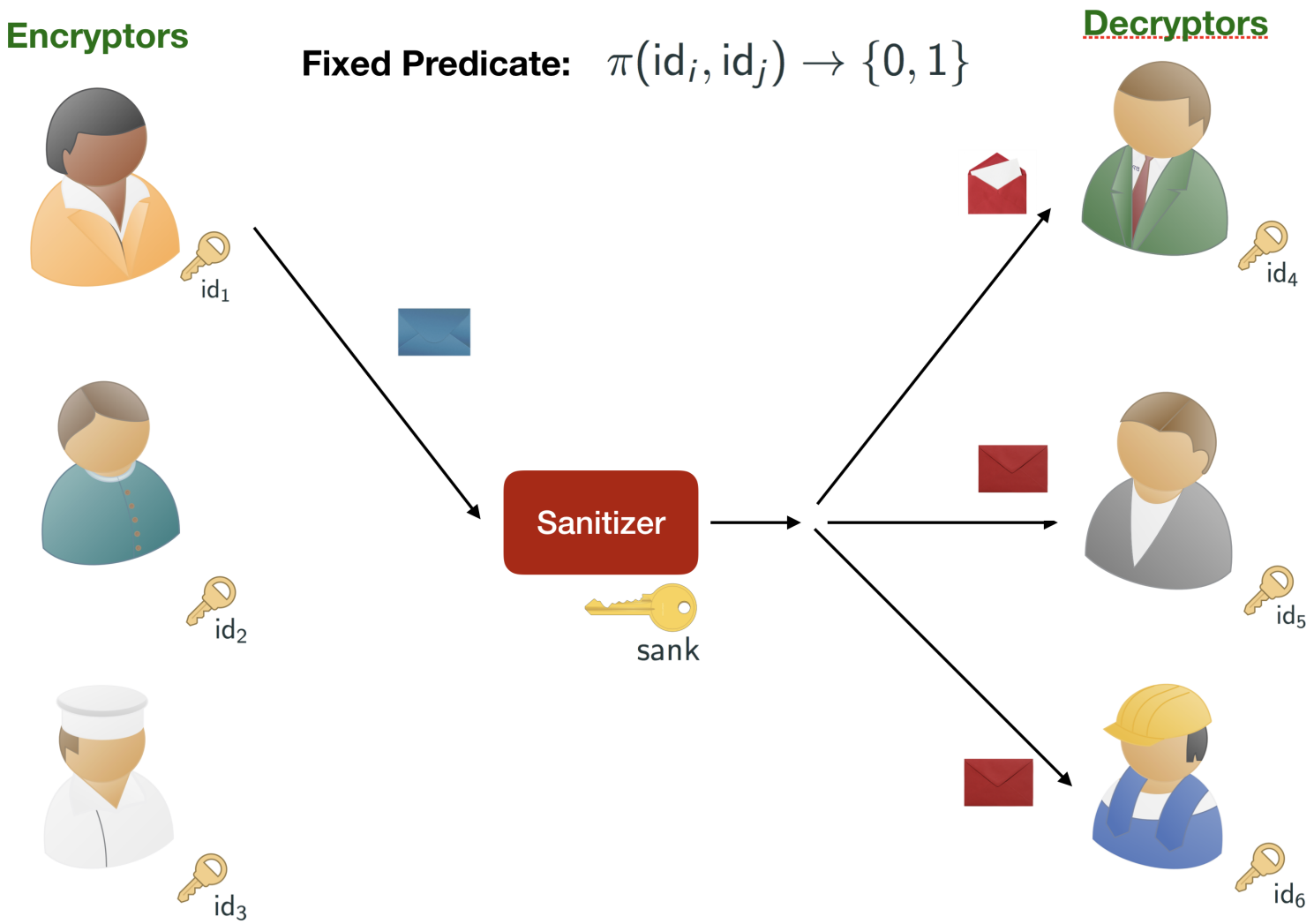
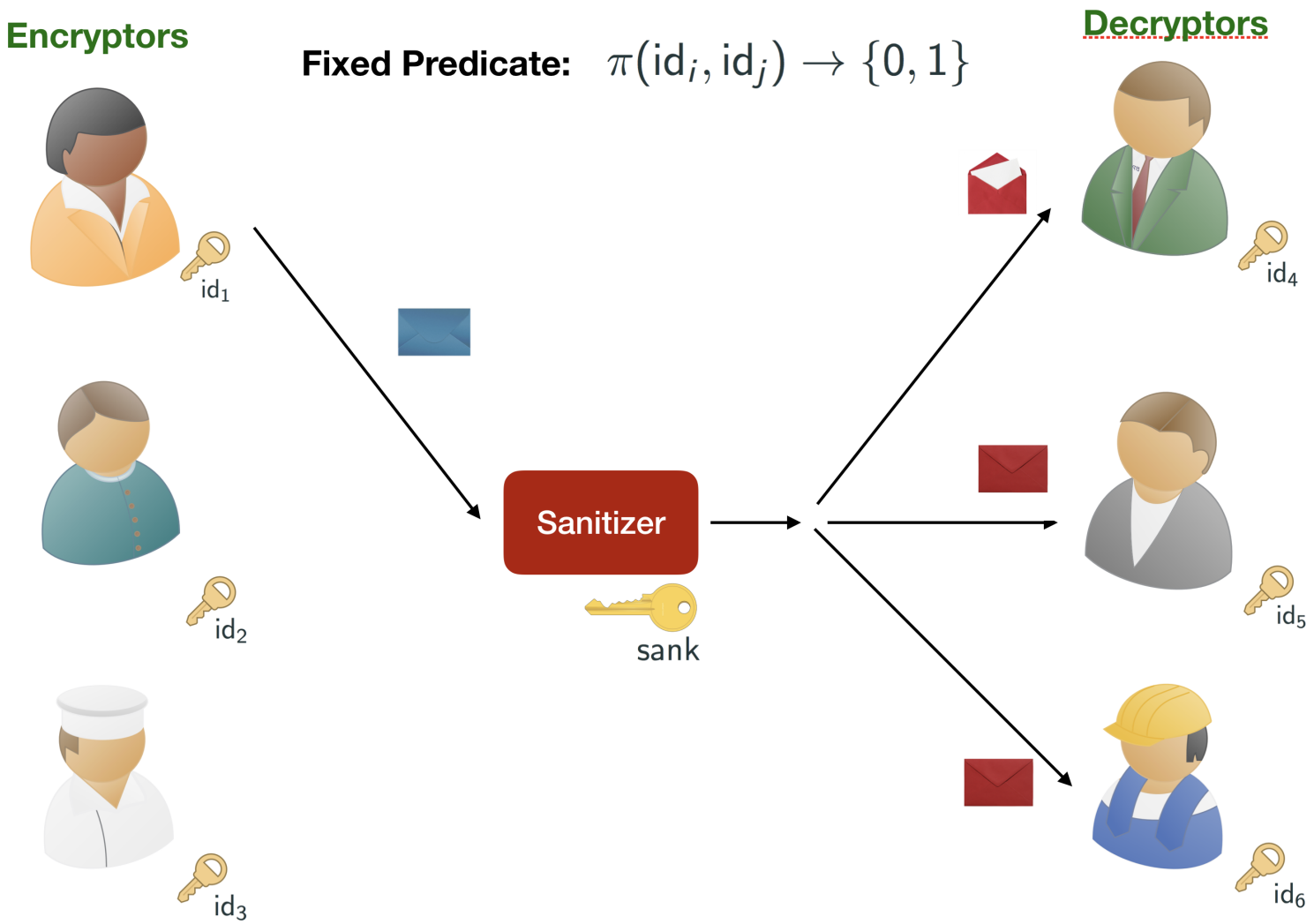


Correctness: User id_i's ciphertext decryptable by user id_j iff $\pi(\mathrm{id}_i, \mathrm{id}_j) = 1$.

Access Control Encryption [DHO16]



General Goal: Minimize what Sanitizer learns!

No-Read Security

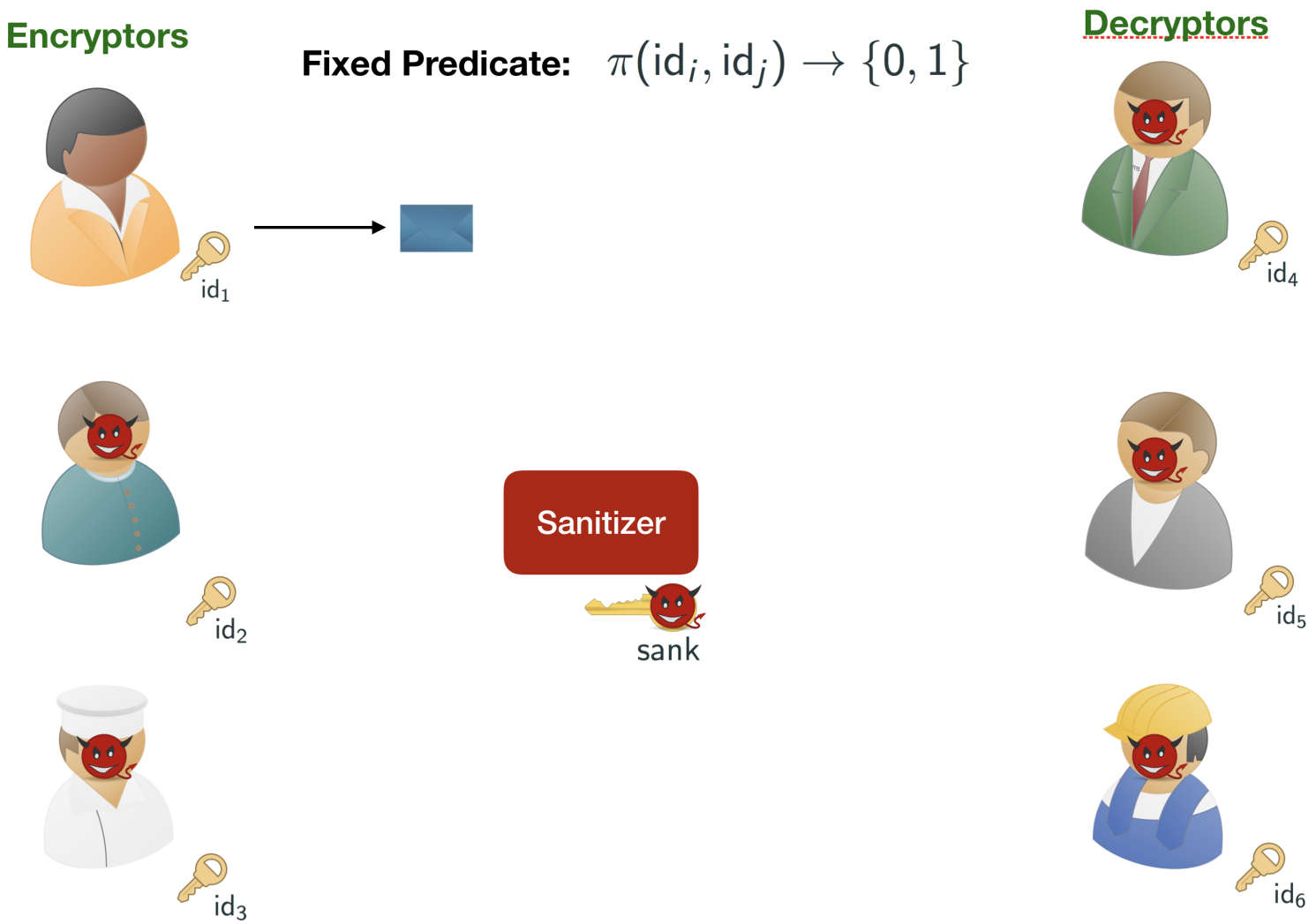
Encryptors

Fixed Predicate: $\pi(\mathrm{id}_i, \mathrm{id}_j) \rightarrow \{0, 1\}$

Sanitizer

Decryptors

No-Read Security



Requirement: Without a predicate-satisfying key, adversary learns no information.

No-Write Security

Encryptors

id_1

id_2

id_3

Fixed Predicate: $\pi(id_i, id_j) \rightarrow \{0, 1\}$

Sanitizer

sank

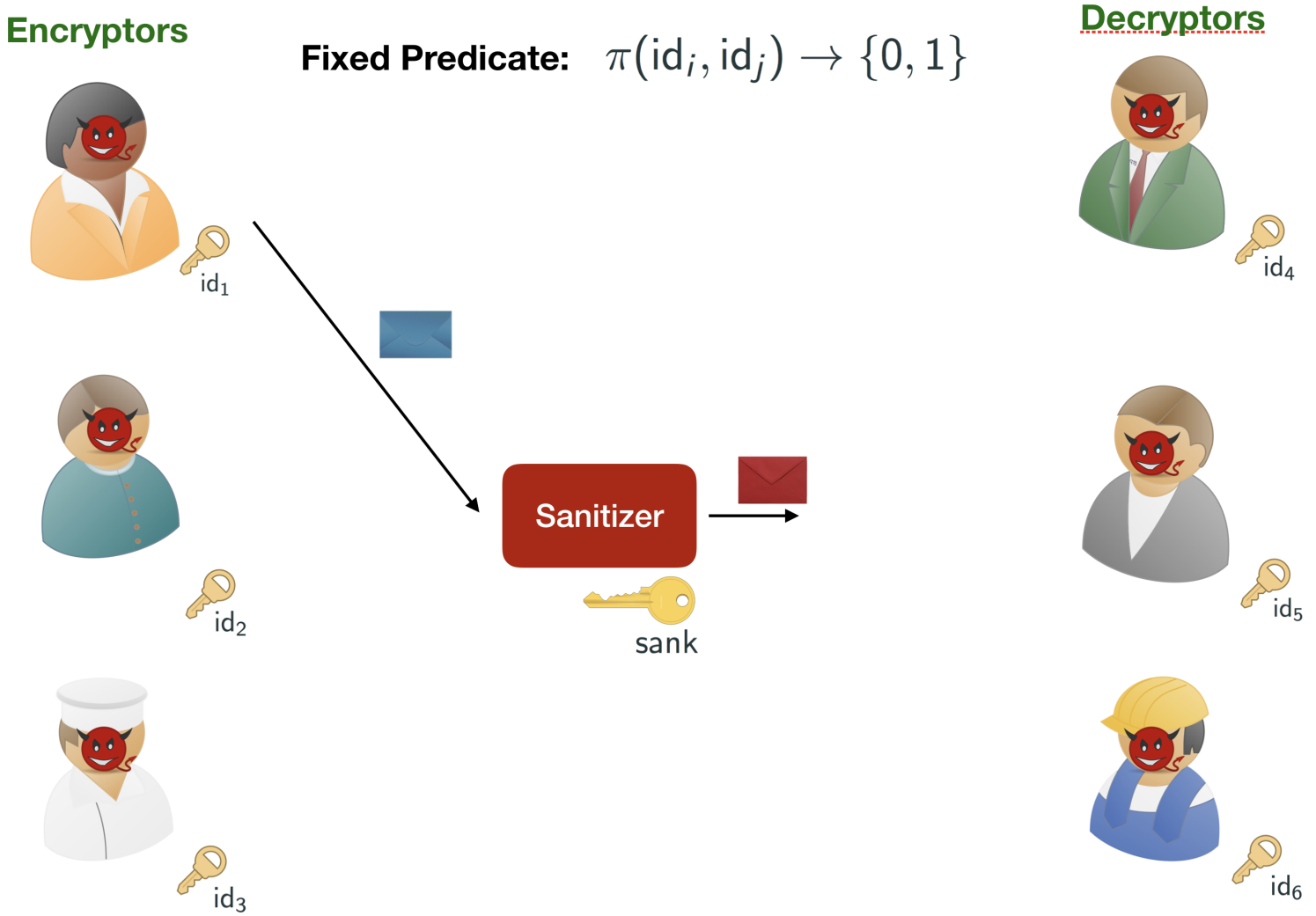
Decryptors

id_4

id_5

id_6

No-Write Security



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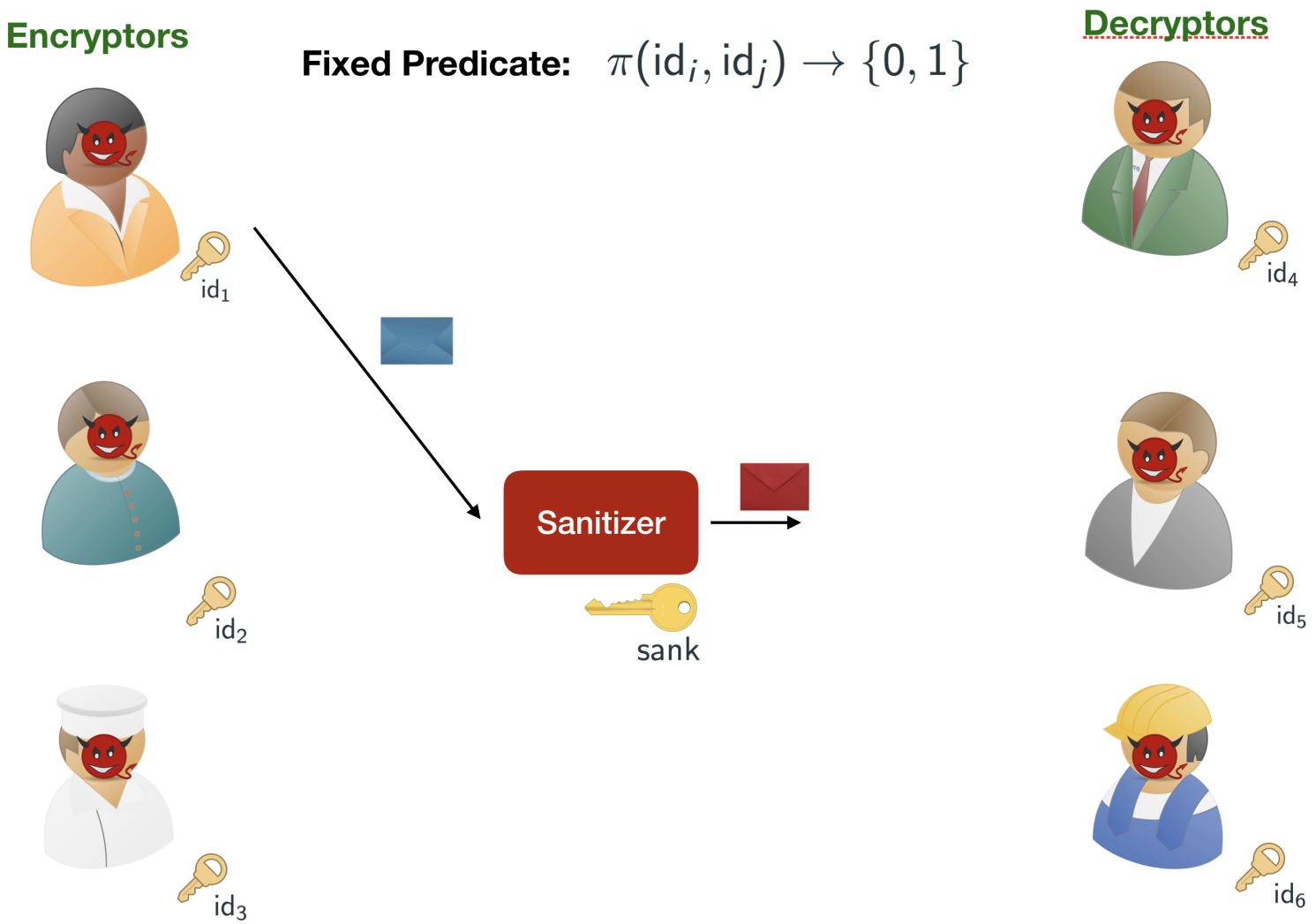

Requirement: Without a predicate-satisfying pair of keys, adversary cannot distinguish: honestly sanitized ctxt vs. randomly generated ctxt

Previous Works

Construction	Predicate	Ciphertext Size	Assumption
DHO16	arbitrary	$O(2^n)$	DDH or DCR
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Our Results

Construction	Predicate	Ciphertext Size	Assumption
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This Work:	arbitrary	poly(n)	DDH, RSA, LWE

Starting Point: Basic Cert

Let's first achieve: No-Write Security

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Simple Idea: Provide cert σ_{id} of id as encryption key

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Encryptor can attach $(\mathsf{id}_i, \sigma_{\mathsf{id}_i})$ to message.

Sanitizer verifies $(\mathsf{id}_i, \sigma_{\mathsf{id}_i})$ and encrypt to all identities id_j for which

$$\pi(\mathsf{id}_i, \mathsf{id}_j) = 1$$

Starting Point: Basic Cert

Encryptors

id_1
σ_{id_1}

id_2
σ_{id_2}

id_3
σ_{id_3}

Fixed Predicate: $\pi(\mathsf{id}_i, \mathsf{id}_j) \rightarrow \{0, 1\}$

Sanitizer

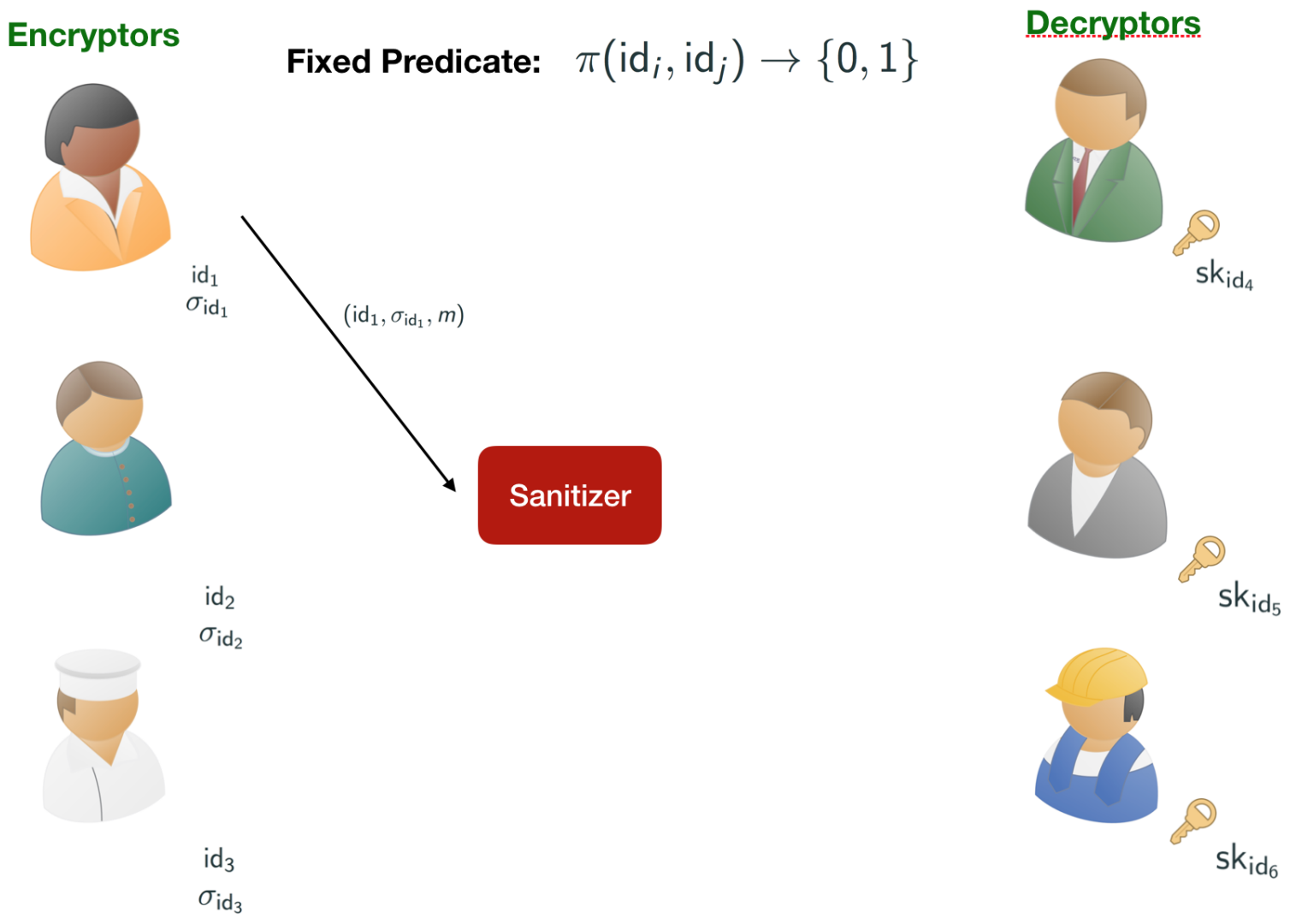
Decryptors

$\mathsf{sk}_{\mathsf{id}_4}$

$\mathsf{sk}_{\mathsf{id}_5}$

$\mathsf{sk}_{\mathsf{id}_6}$

Starting Point: Basic Cert



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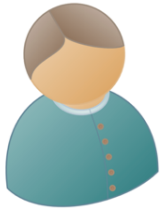

id_2
σ_{id_2}

id_3
σ_{id_3}

Sanitizer

$\mathsf{Enc}(\mathsf{sk}_{\mathsf{id}_4}, m) \| \mathsf{Enc}(\mathsf{sk}_{\mathsf{id}_6}, m)$

$\mathsf{sk}_{\mathsf{id}_4}$

$\mathsf{sk}_{\mathsf{id}_5}$

$\mathsf{sk}_{\mathsf{id}_6}$

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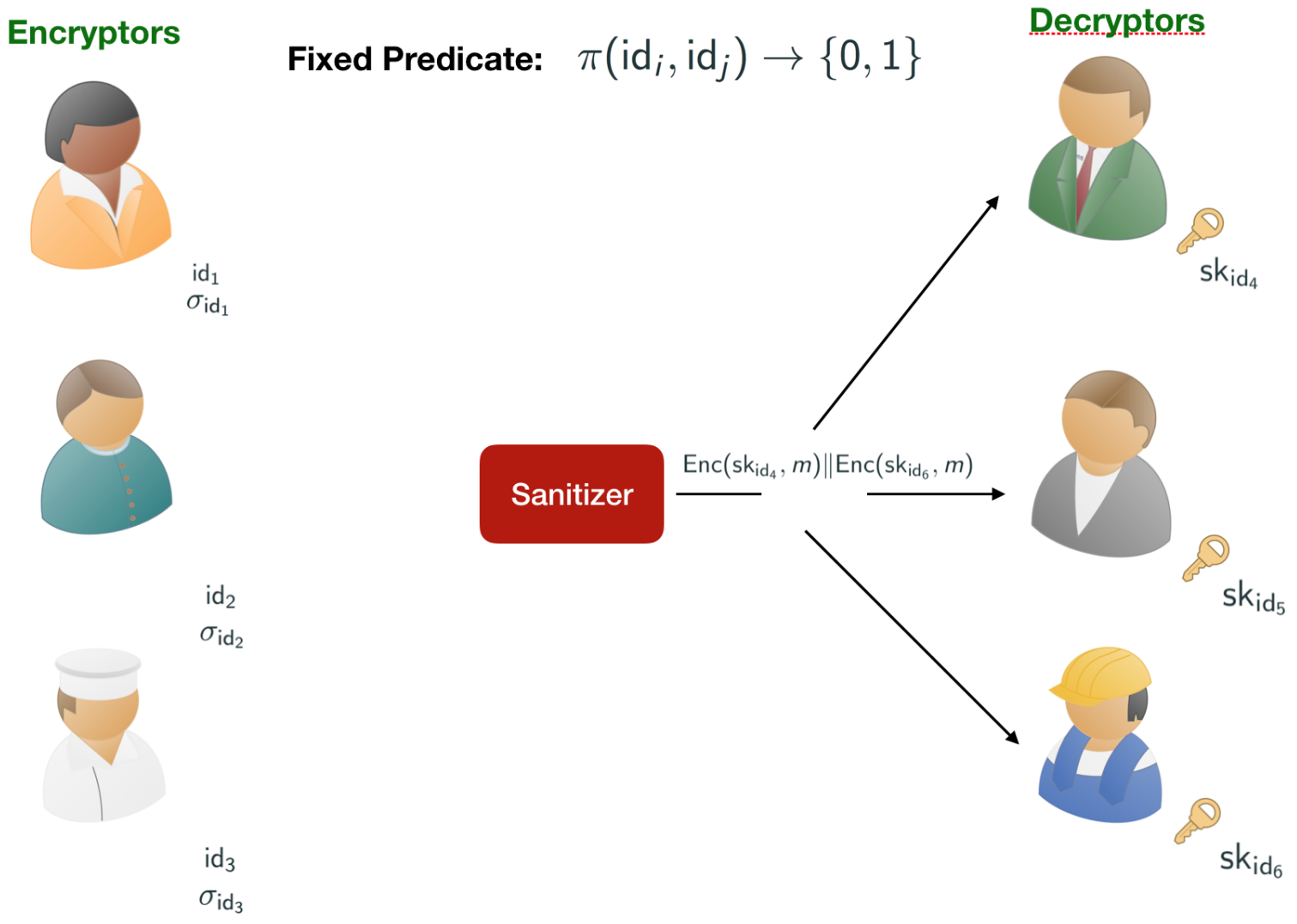

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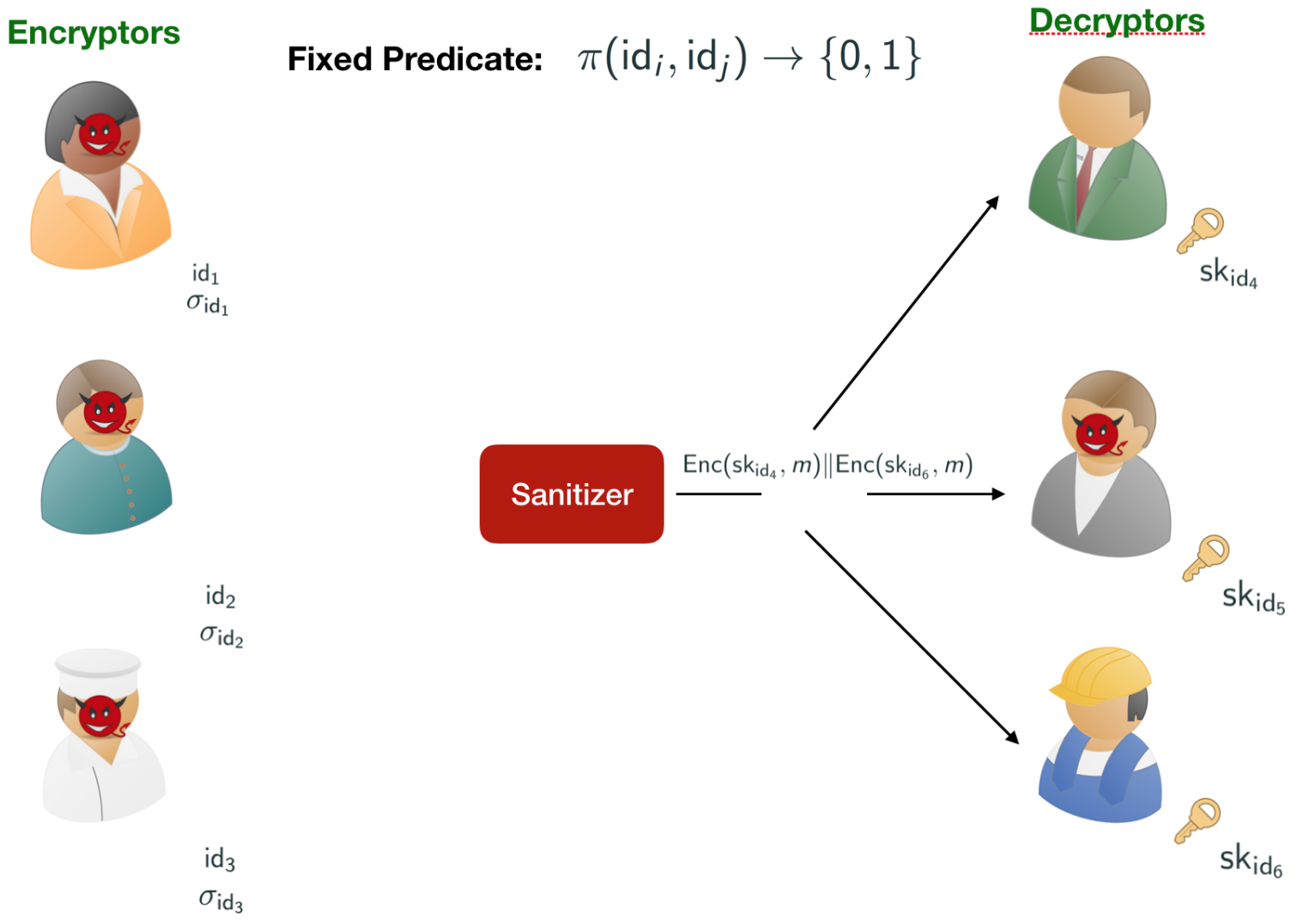

Compact Ciphertext: Predicate Encryption

Next Goal: Compact Ciphertext

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Useful Tool: Predicate Encryption [BW07,KSW08]

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Useful Tool: Predicate Encryption [BW07,KSW08]

Encryption algorithm takes in (attribute, message) pair

$$\mathsf{Enc}(x, m) \to \mathsf{ct}_{x,m}.$$

Decryption keys associated with function f: sk_f

$$\mathsf{Dec}(\mathsf{sk}_f, \mathsf{ct}_{x,m}) = \begin{cases} m & f(x) = 1 \\ \perp & f(x) = 0 \end{cases}.$$

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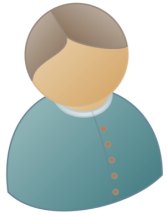
Idea:

- Sanitizer when given $(\mathsf{id}_i, \sigma_{\mathsf{id}_i}, m)$ encrypts $\mathsf{Enc}(\mathsf{id}_i, m)$
- Decryptor with id_j given $\mathsf{sk}_{\pi(\cdot,\mathsf{id}_j)}$

Compact Ciphertext: Predicate Encryption

Encryptors

id_1
σ_{id_1}



id_2
σ_{id_2}

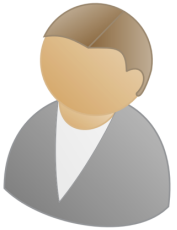
id_3
σ_{id_3}

Fixed Predicate: $\pi(\mathsf{id}_i, \mathsf{id}_j) \to \{0, 1\}$

Sanitizer

Decryptors

$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_4)}$



$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_5)}$

$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_6)}$

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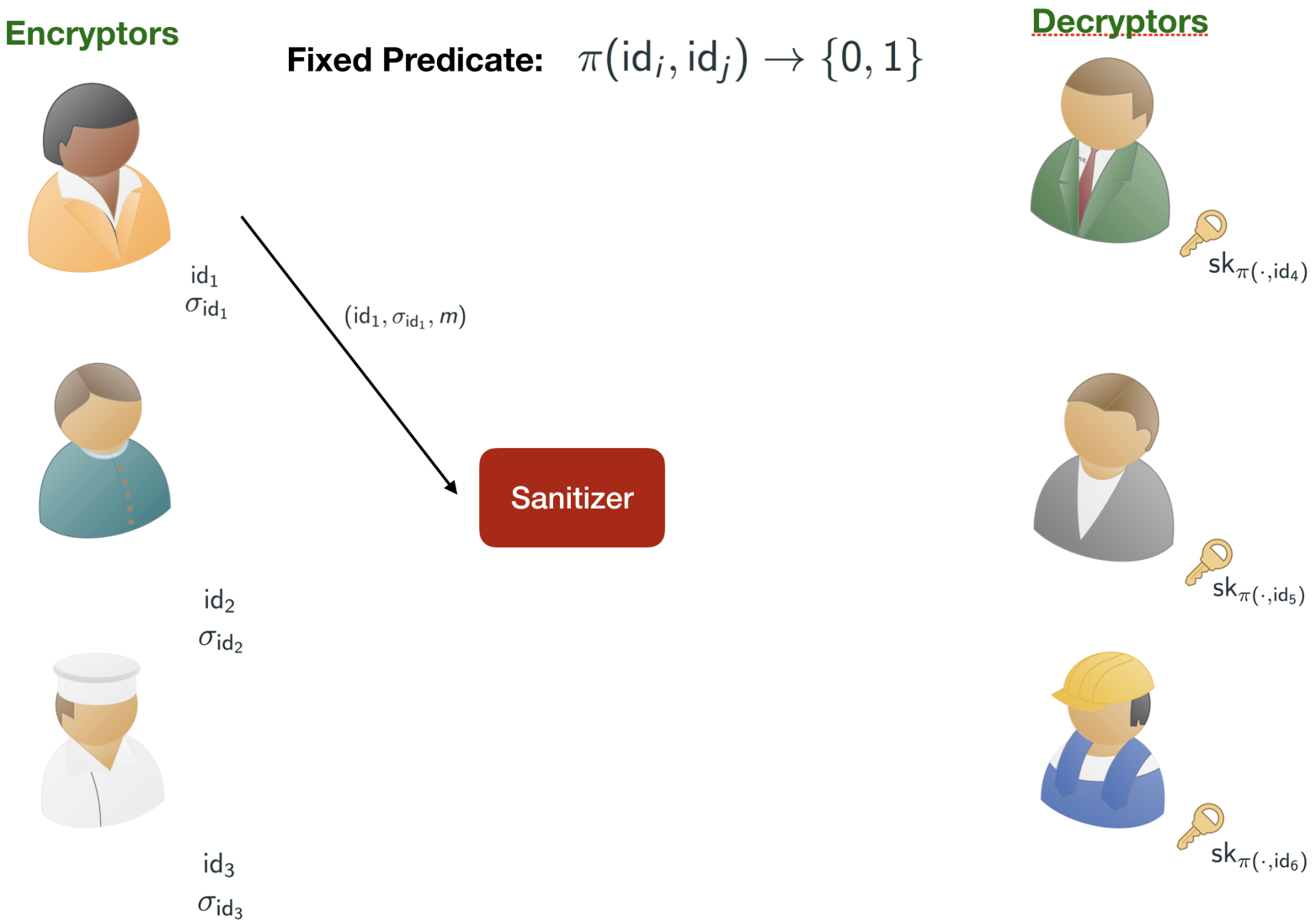

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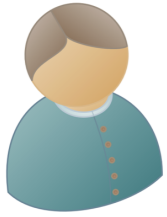
σ_{id_1}



id_2
σ_{id_2}

id_3
σ_{id_3}

Fixed Predicate: $\pi(\mathsf{id}_i, \mathsf{id}_j) \to \{0, 1\}$

$\mathsf{Enc}(\mathsf{id}_1, m)$

Sanitizer

Decryptors

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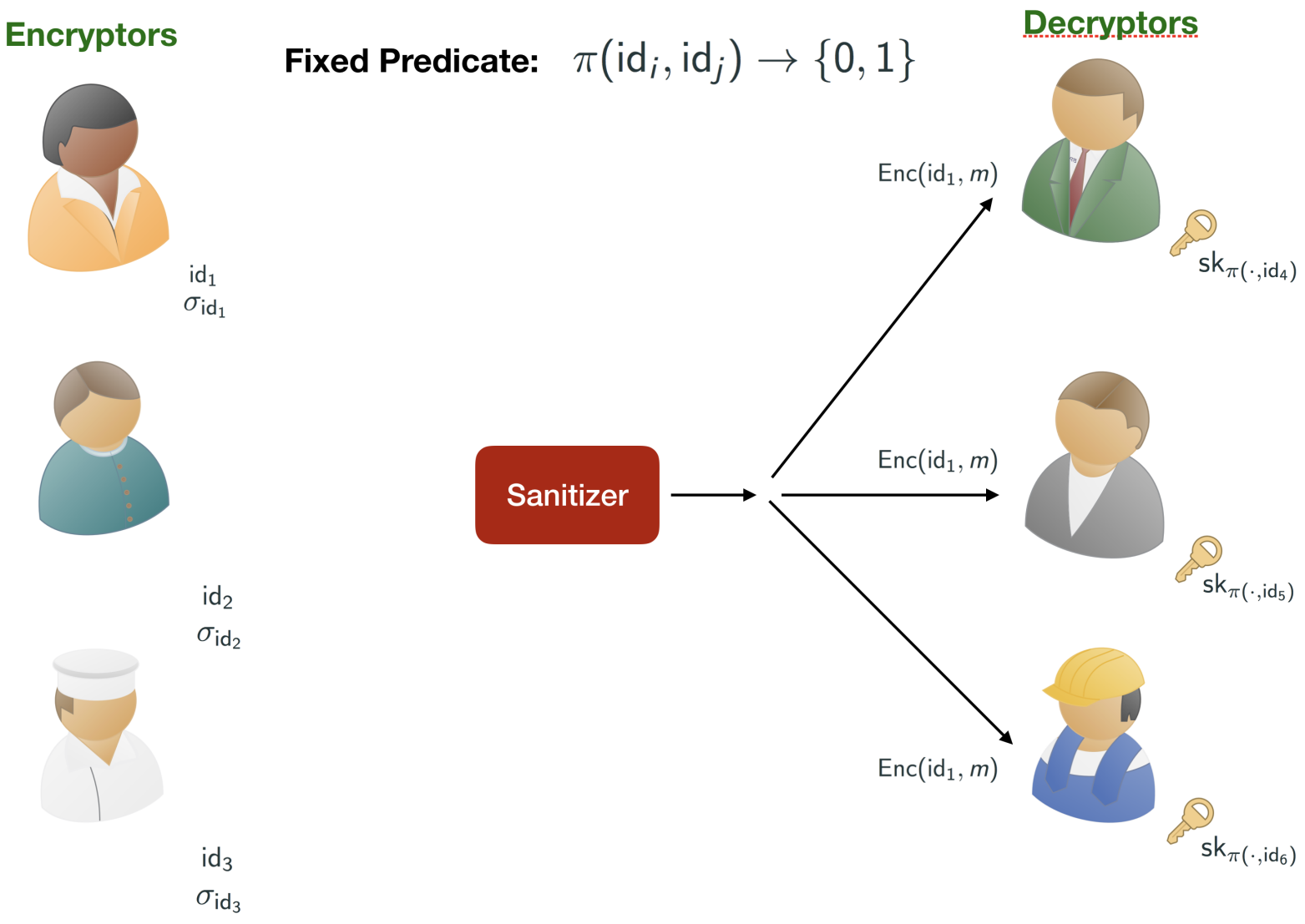

Hiding Information from Sanitizer

Next Goal: No-Read Security

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Problem: Sanitizer learns too much information!

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Current task:

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2. Encrypt $\mathsf{Enc}(\mathsf{id}, m)$

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Current task:

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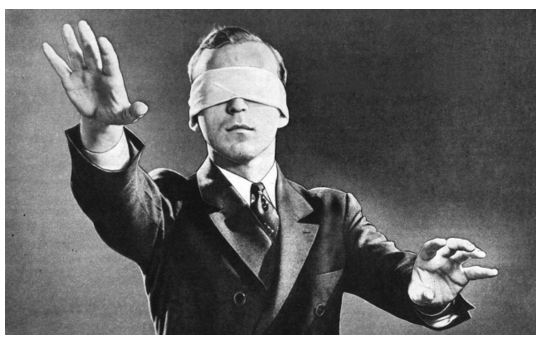
2. Encrypt $\mathsf{Enc}(\mathsf{id}, m)$

Can the sanitizer perform its task blind-folded?



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Idea: Provide FE secret key sk_F where F defined as follows:

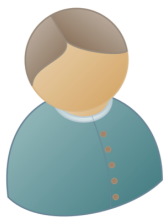
$F(\mathsf{id}, \sigma, m)$:

1. Check (id, σ)
2. If valid, then return $\mathsf{Enc}(\mathsf{id}, m)$

Hiding Information from Sanitizer

Encryptors

id_1
σ_{id_1}



id_2
σ_{id_2}

id_3
σ_{id_3}

Fixed Predicate: $\pi(\mathsf{id}_i, \mathsf{id}_j) \rightarrow \{0, 1\}$

Sanitizer

sk_F

Decryptors

$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_4)}$

$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_5)}$

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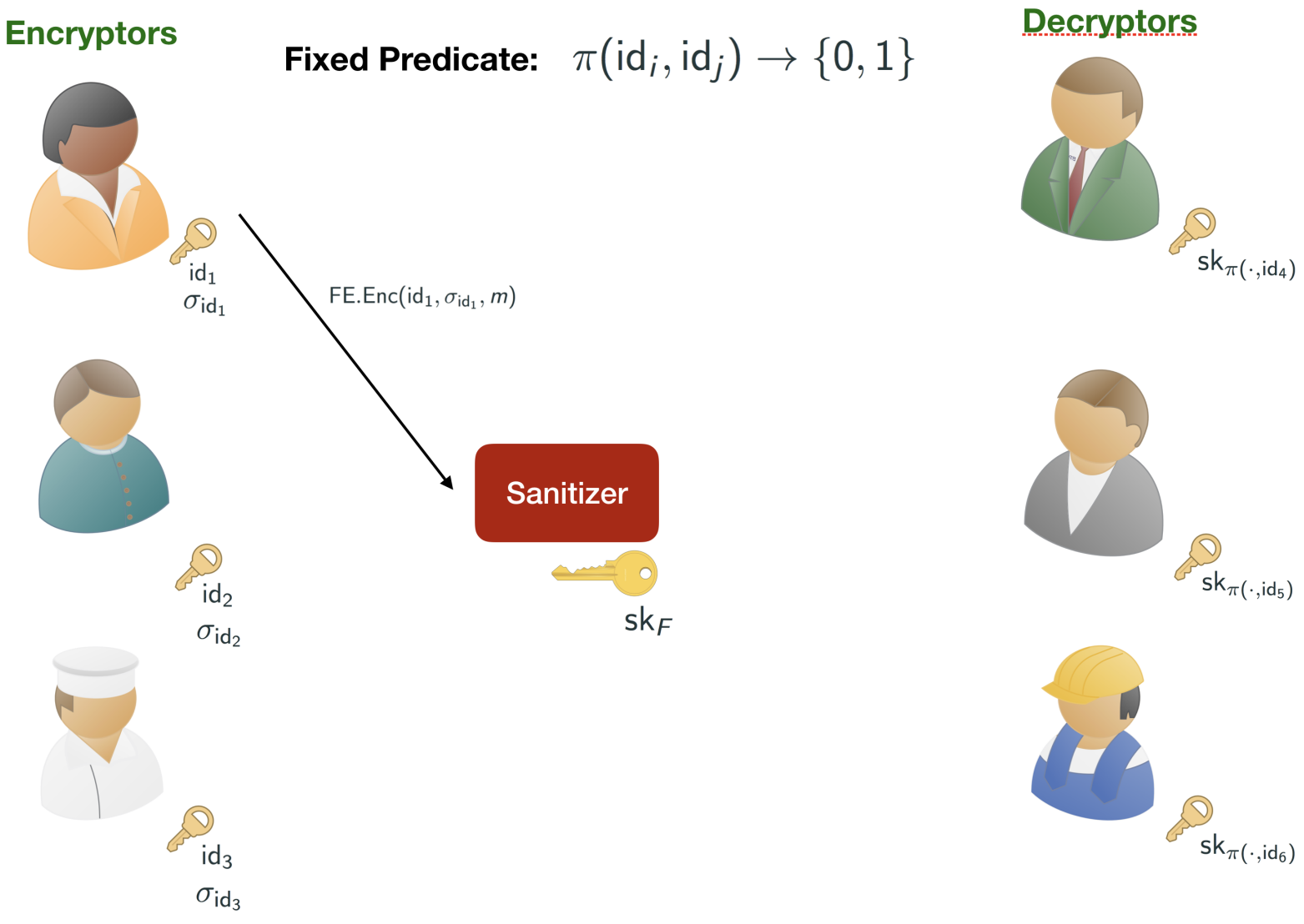
Hiding Information from Sanitizer



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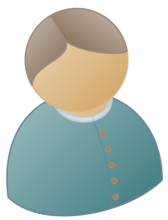
σ_{id_1}



id_2
σ_{id_2}

id_3
σ_{id_3}

Fixed Predicate: $\pi(\mathsf{id}_i, \mathsf{id}_j) \to \{0, 1\}$

Sanitizer

$\mathsf{PE.Enc}(\mathsf{id}_1, m)$

sk_F

Decryptors

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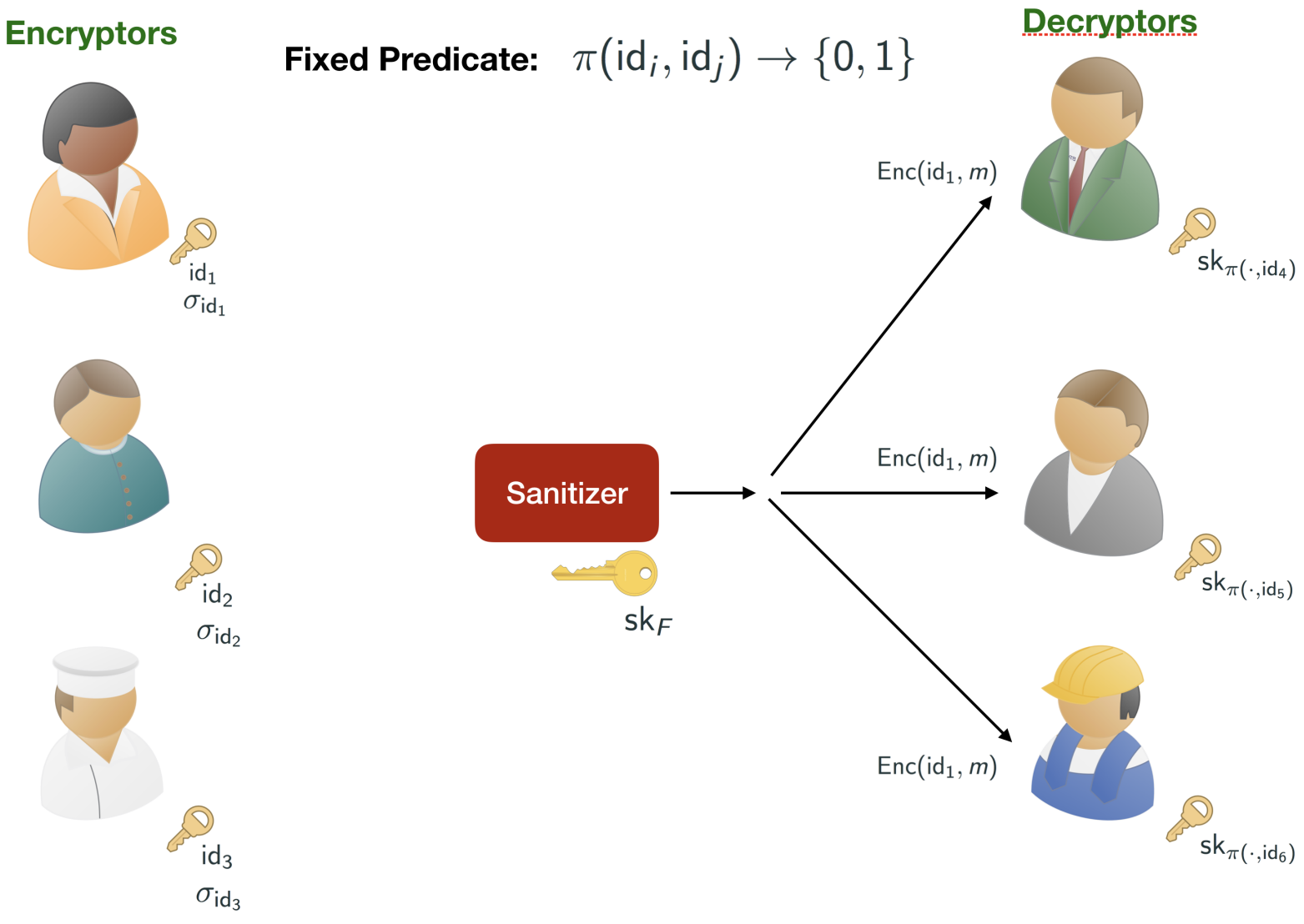
$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_5)}$

$\mathsf{sk}_{\pi(\cdot,\mathsf{id}_6)}$

Hiding Information from Sanitizer



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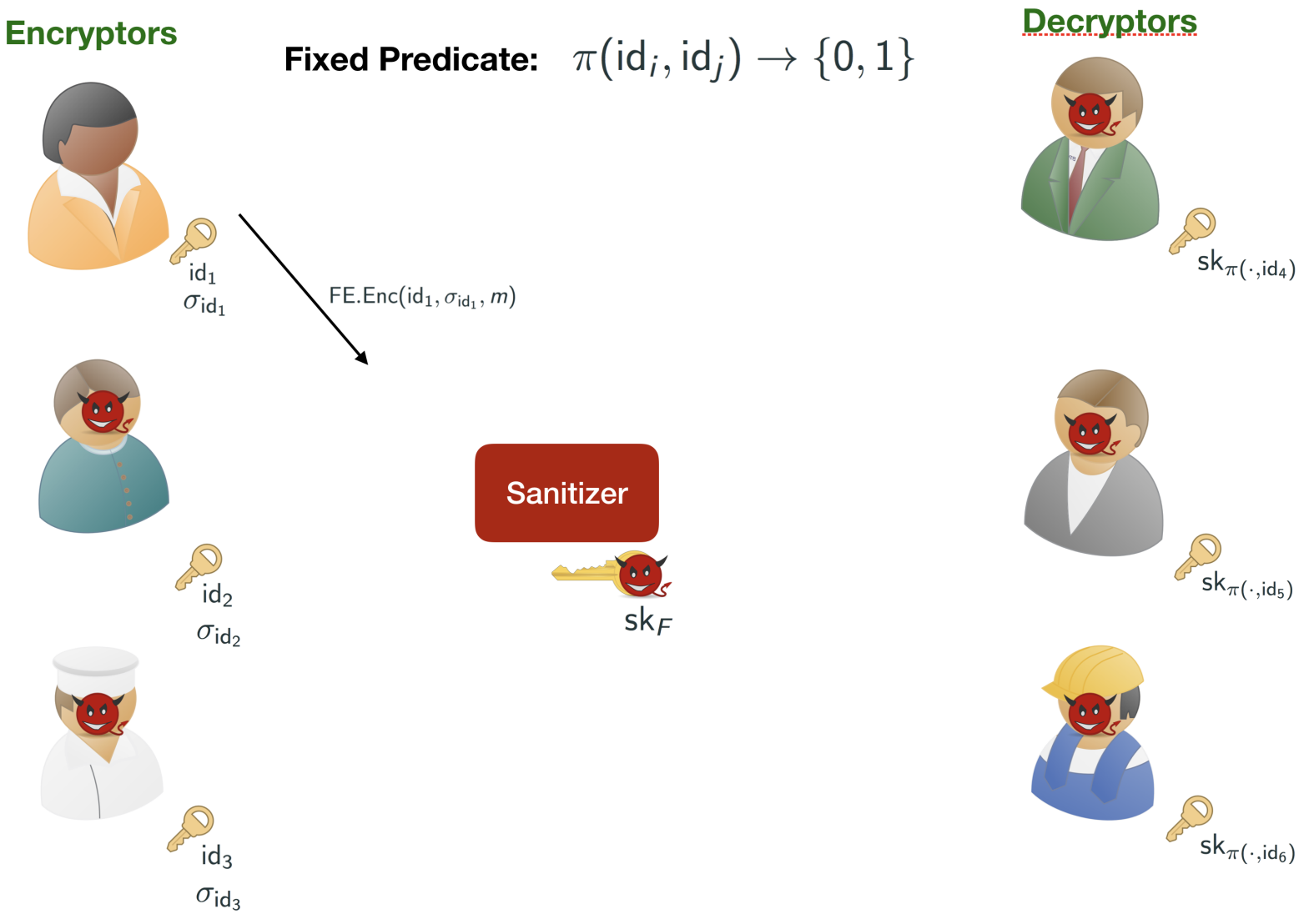

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Rely on FE for randomized functionalities [GJKS15, AW17]

Construction can be based on DDH + RSA.

Extensions

Additional extensions to ACE definition:

1. Dynamic policies

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2. Fine-grained sender policies

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Provide modifications of our constructions can achieve these extended definition.

Conclusion

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Thanks!