Defining Encryption

Lecture 2

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Secrecy when Computationally Bounded

Roadmap

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- First, Symmetric Key Encryption

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  - We'll do it elaborately, so that it will be easy to see different levels of security

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  - In theory and in practice
- Today: defining symmetric-key encryption

Building the Model

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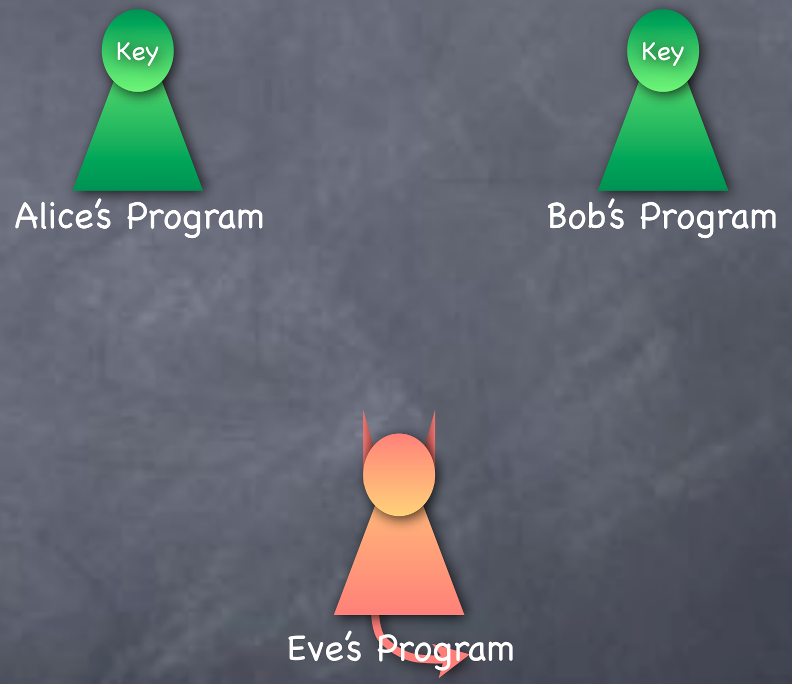
- Alice, Bob and Eve. Alice and Bob share a key (a bit string)



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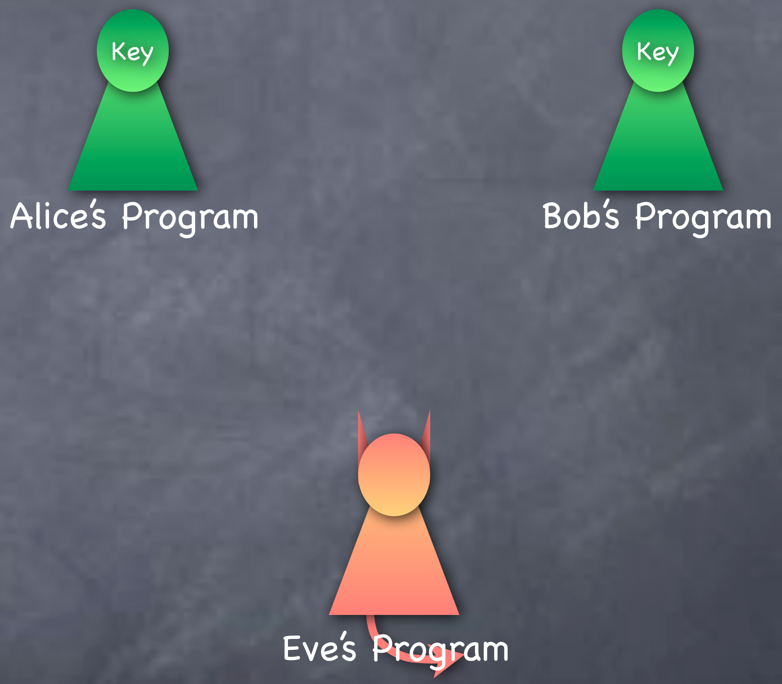

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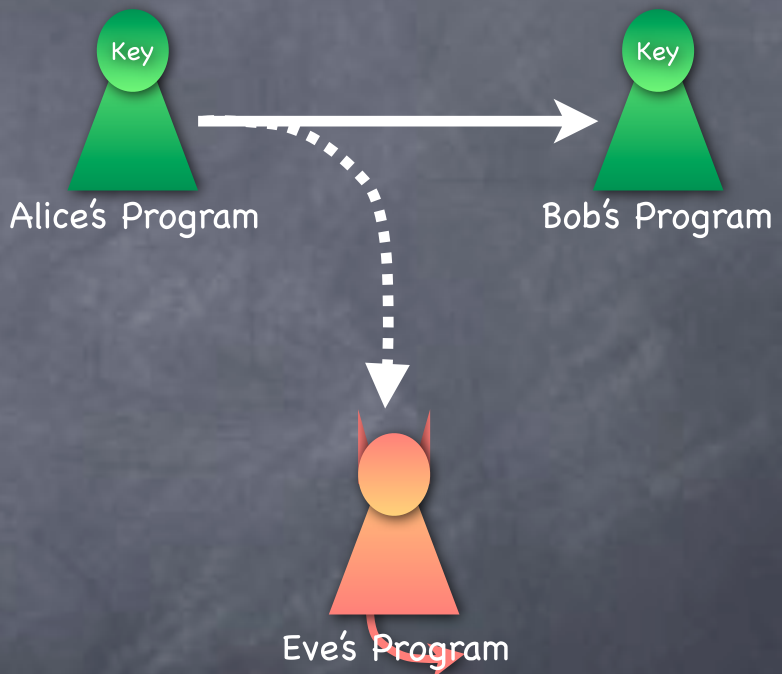
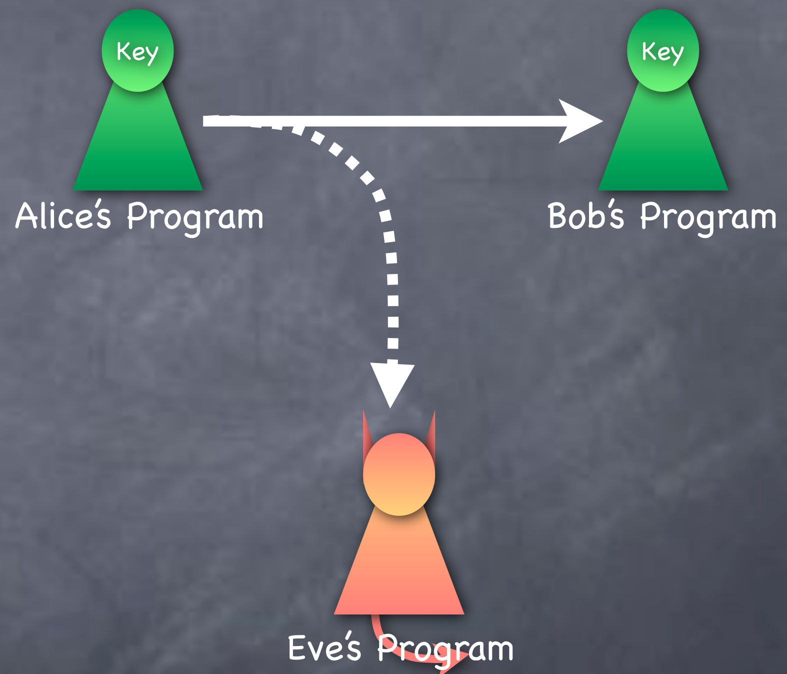
- Alice can send out a bit string on the channel. Bob and Eve both get it



Encryption: Syntax



Encryption: Syntax

- Three algorithms
  - Key Generation: What Alice and Bob do a priori, for creating the shared secret key
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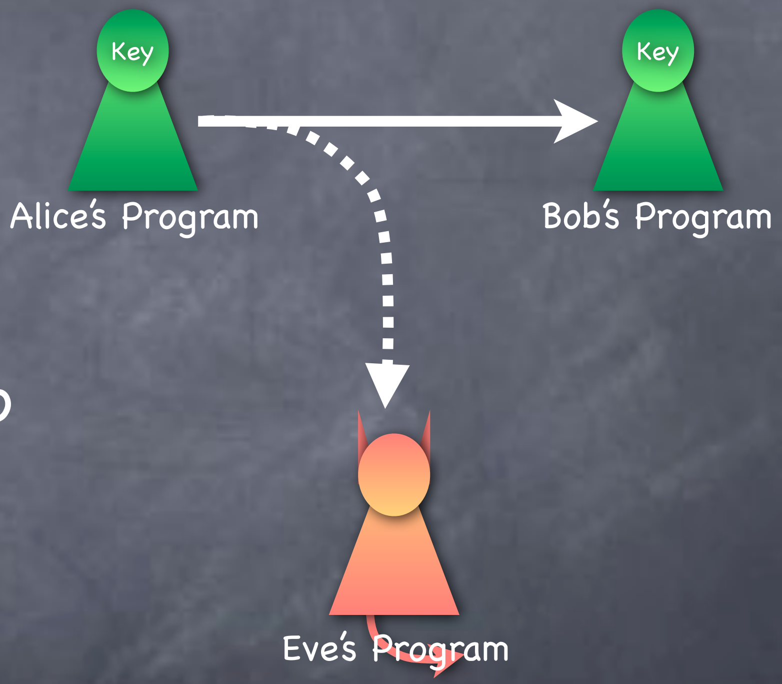

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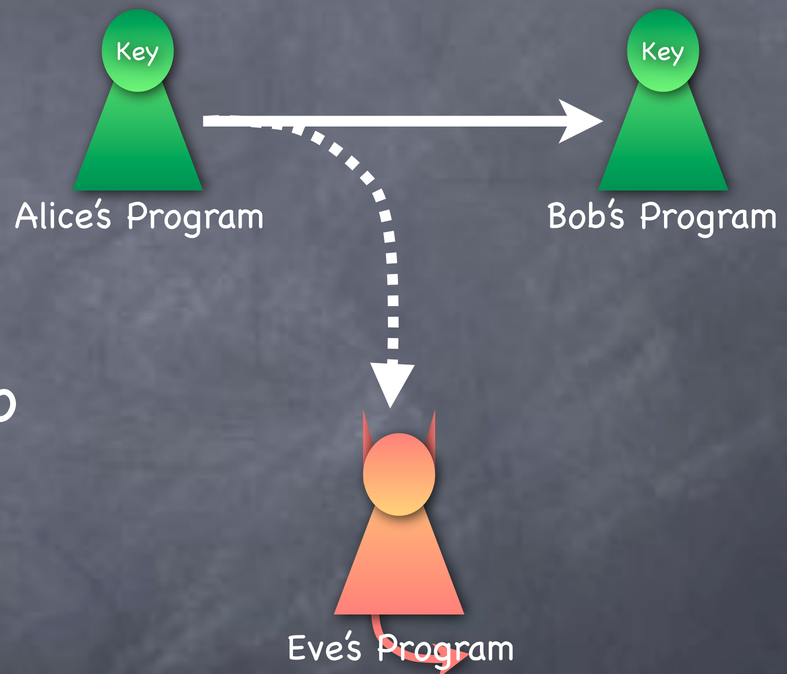
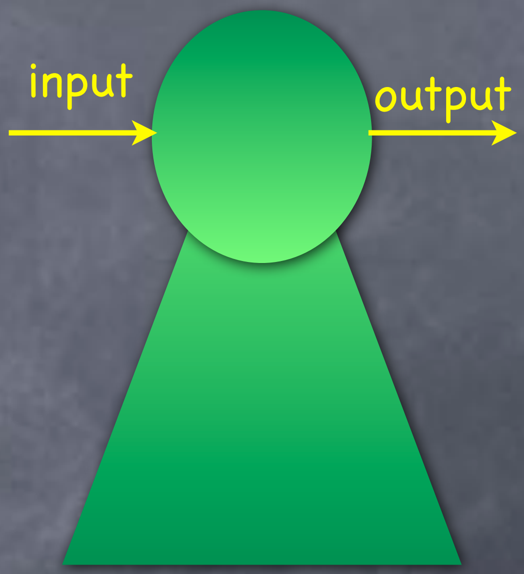
- All of these are (probabilistic) computations



Modeling Computation



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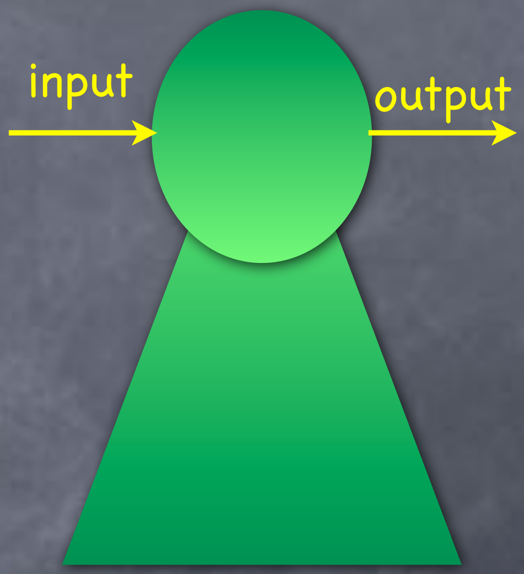

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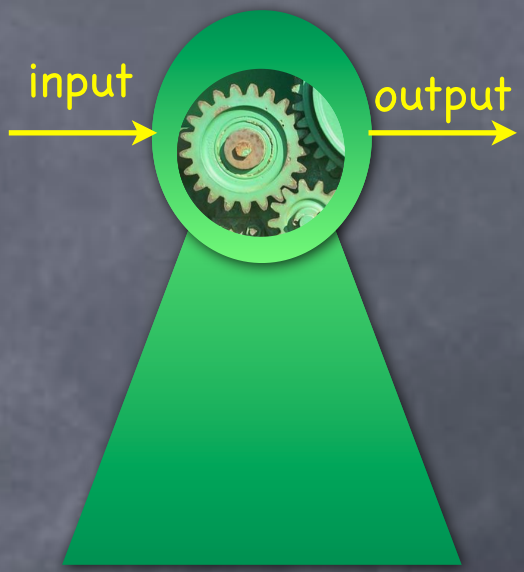

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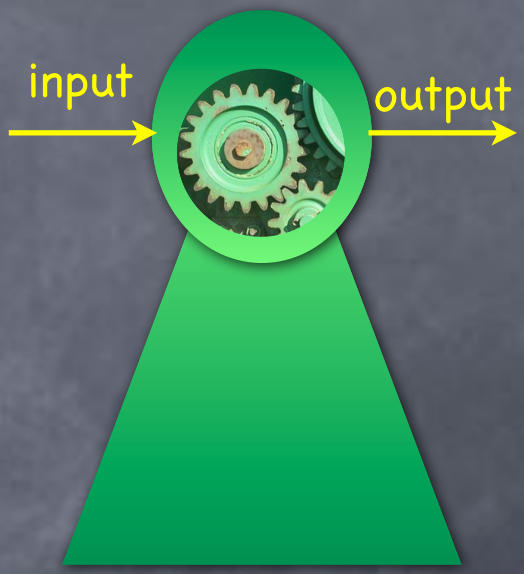

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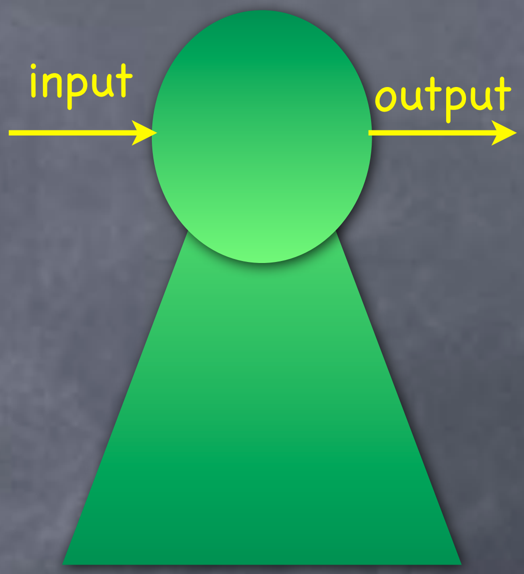

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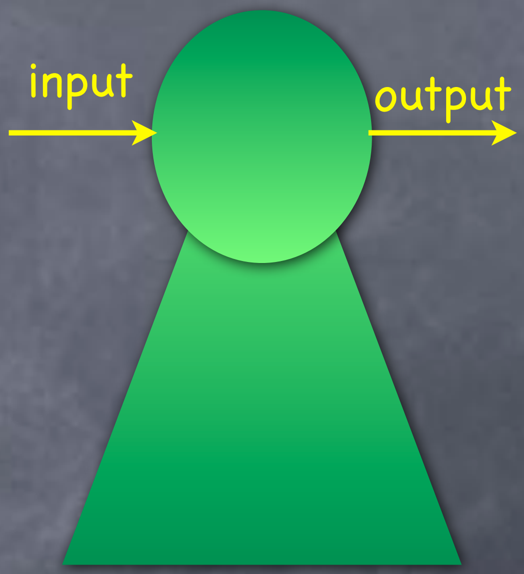

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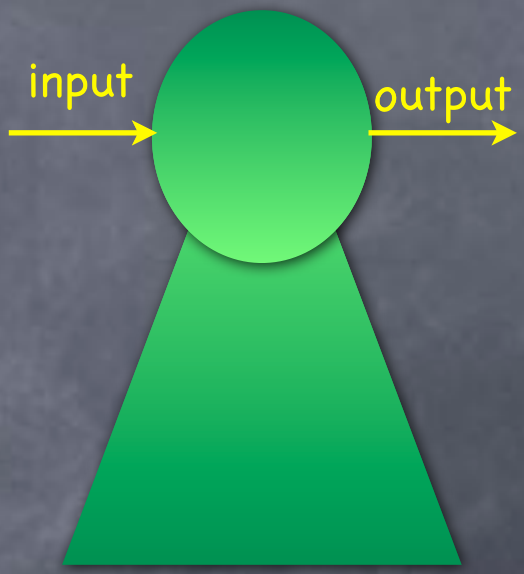

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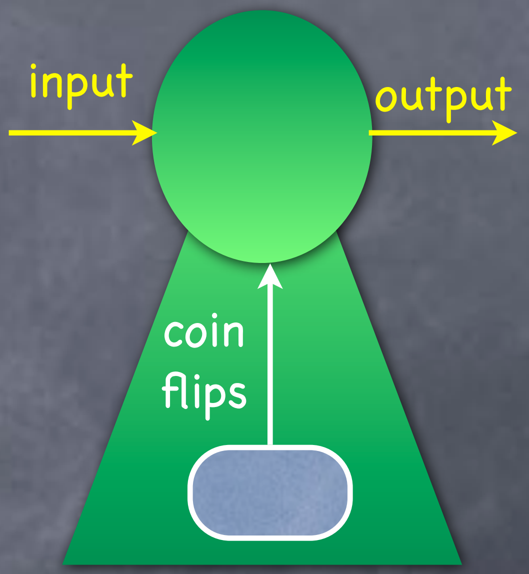

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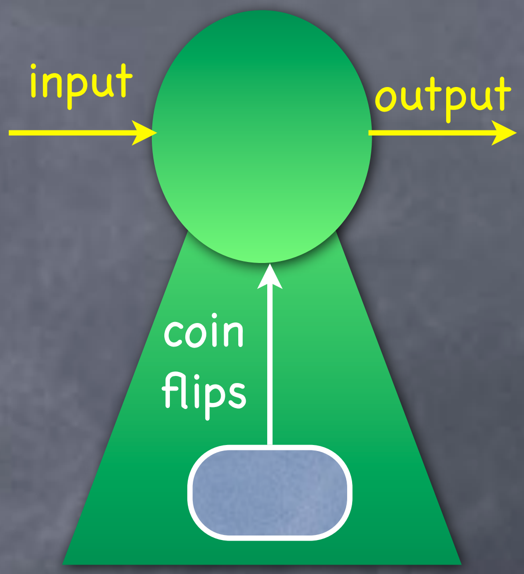

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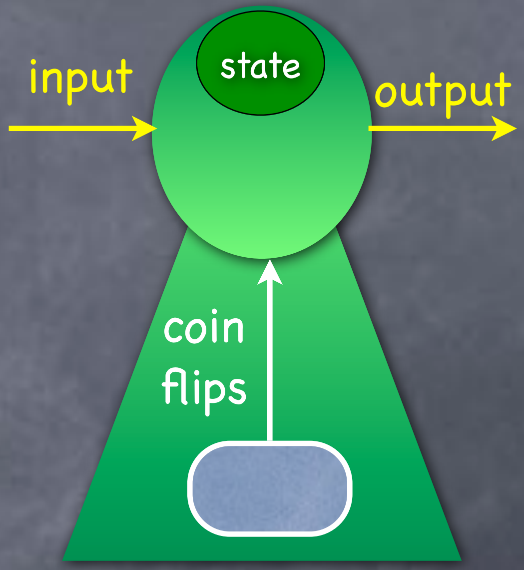

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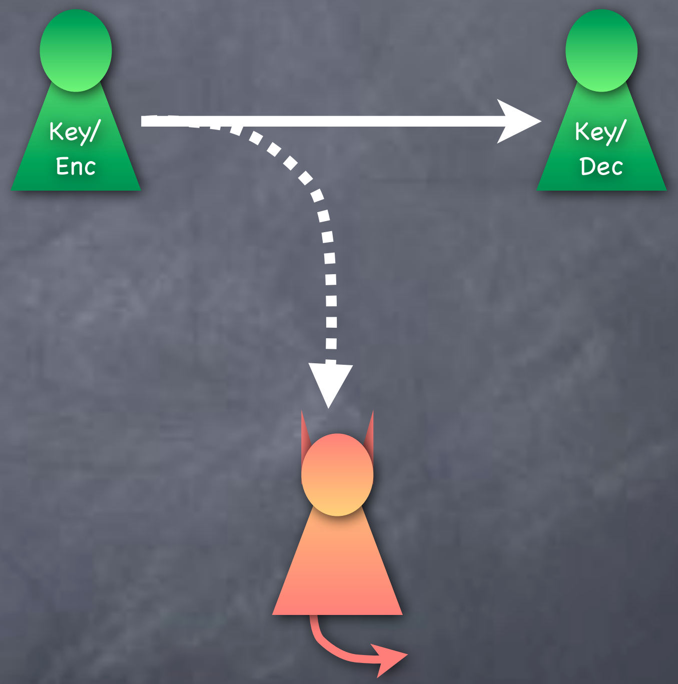
The Environment



The Environment

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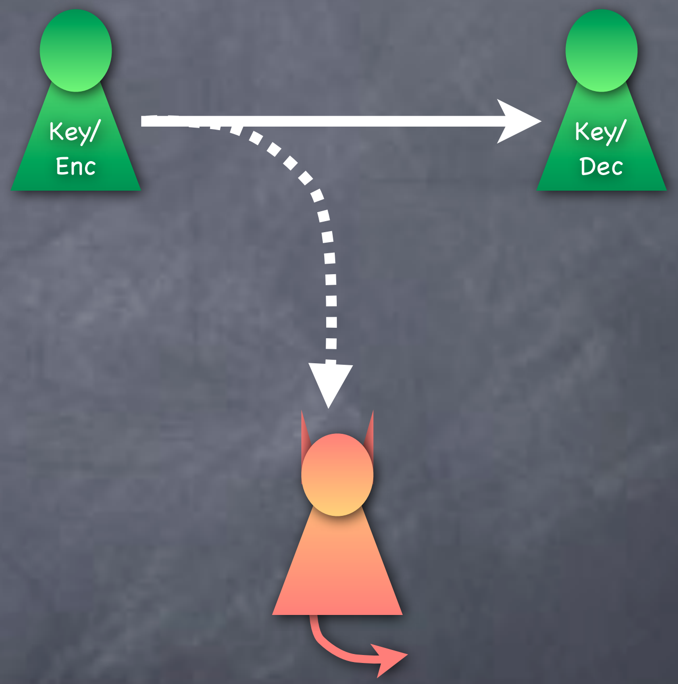

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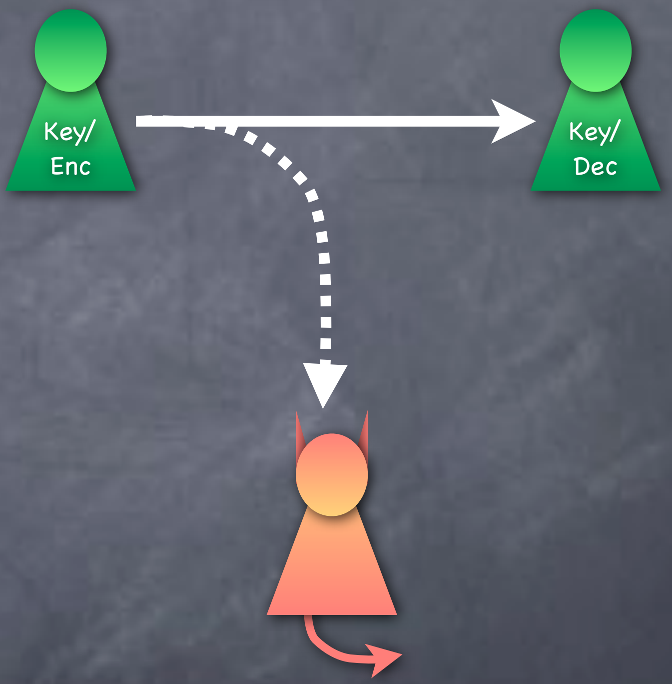

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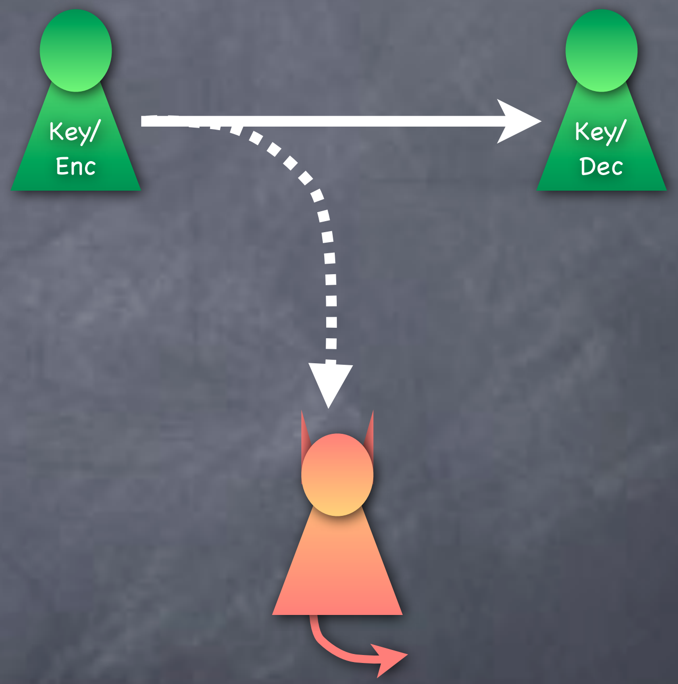

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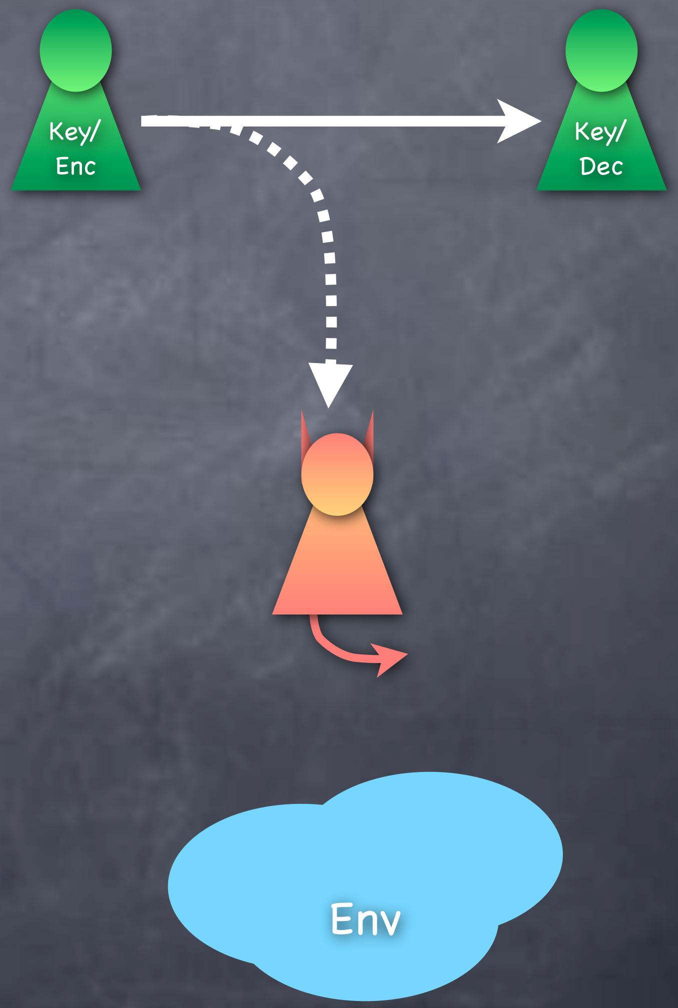

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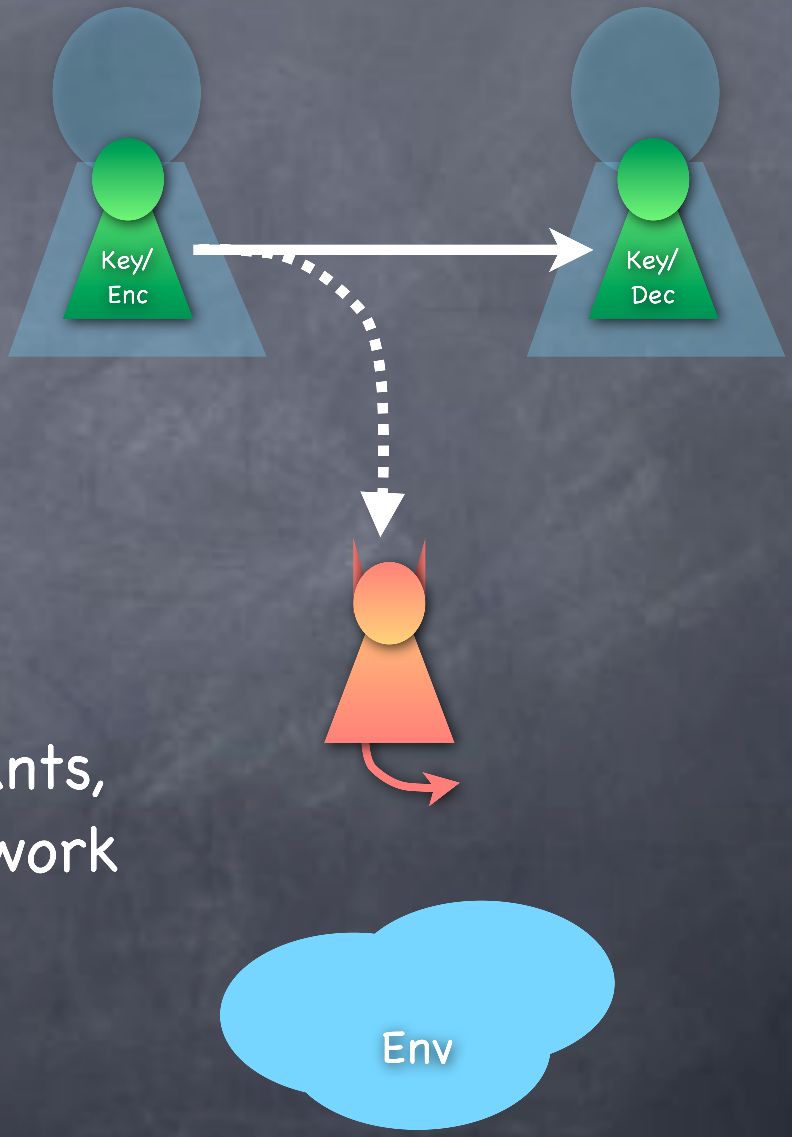

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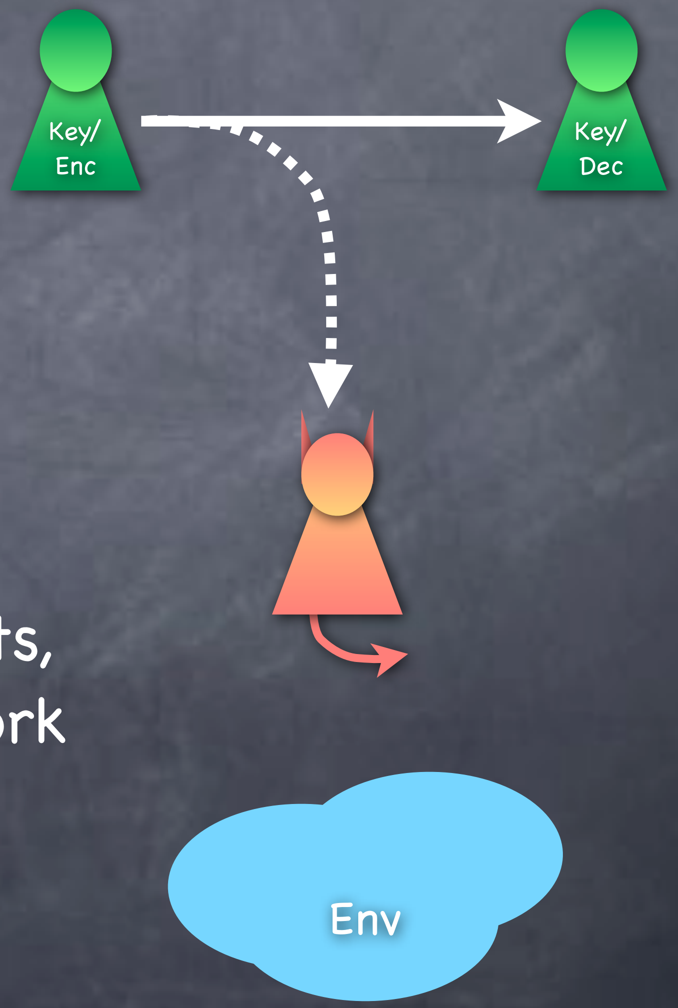

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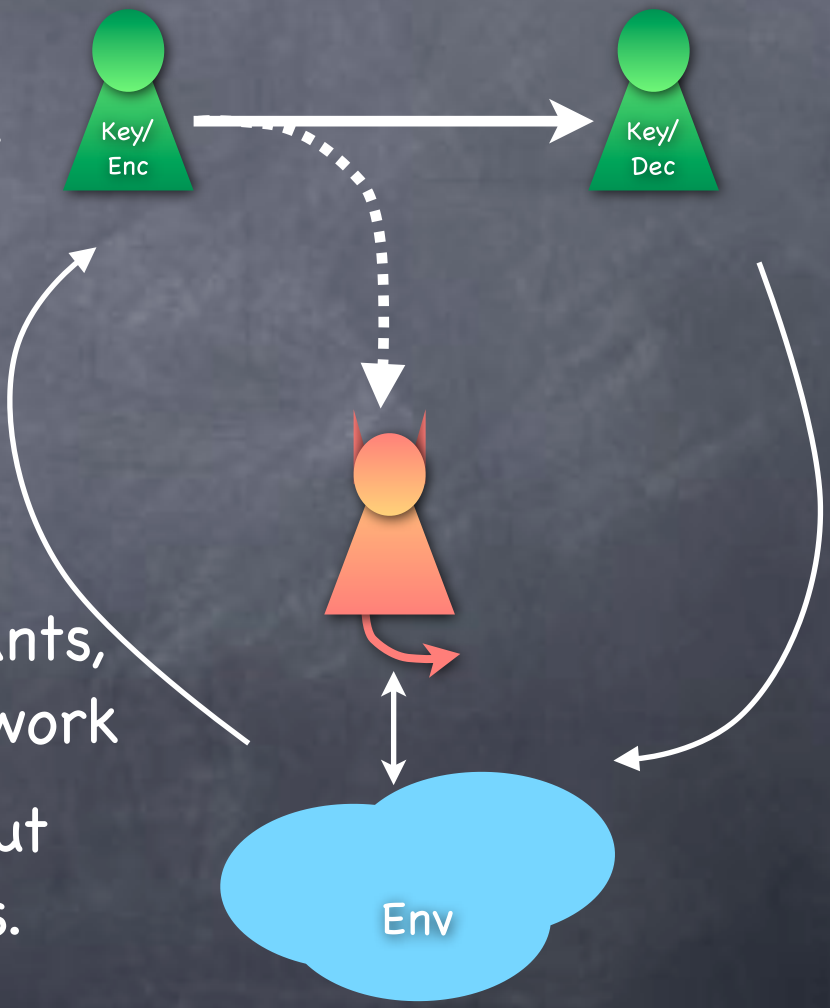
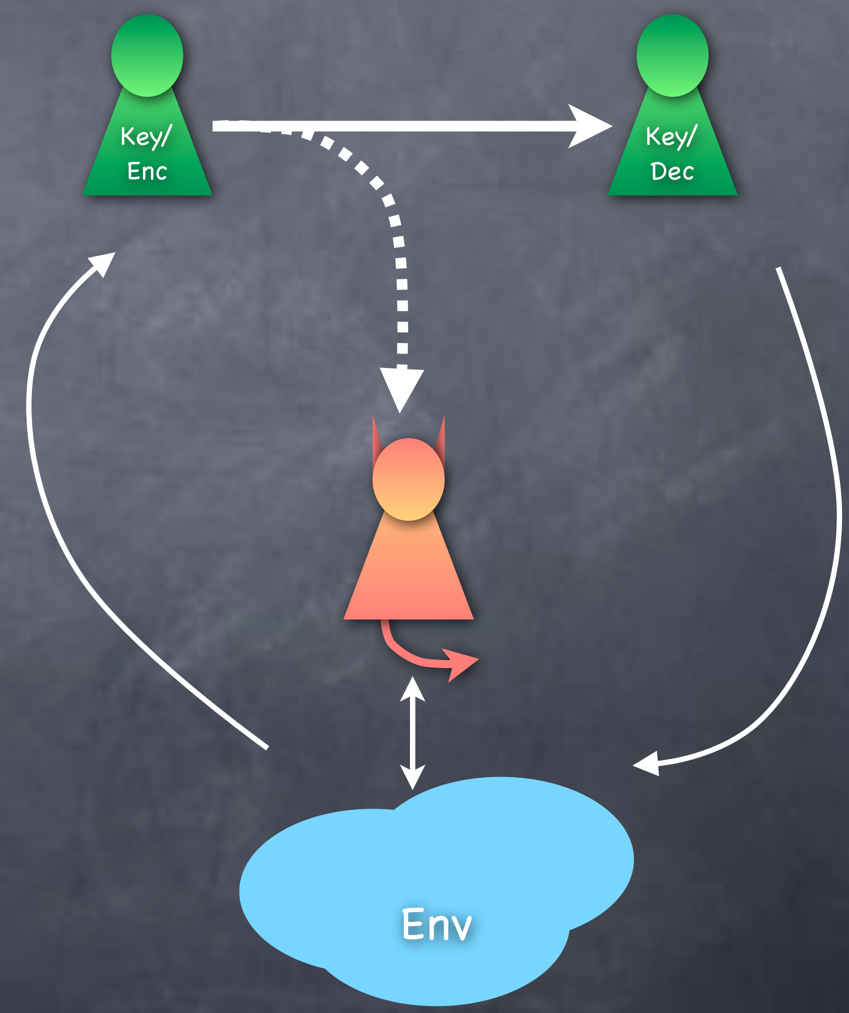
  - Abstract entity from which the input comes and to which the output goes. Arbitrarily influenced by Eve



Defining Security



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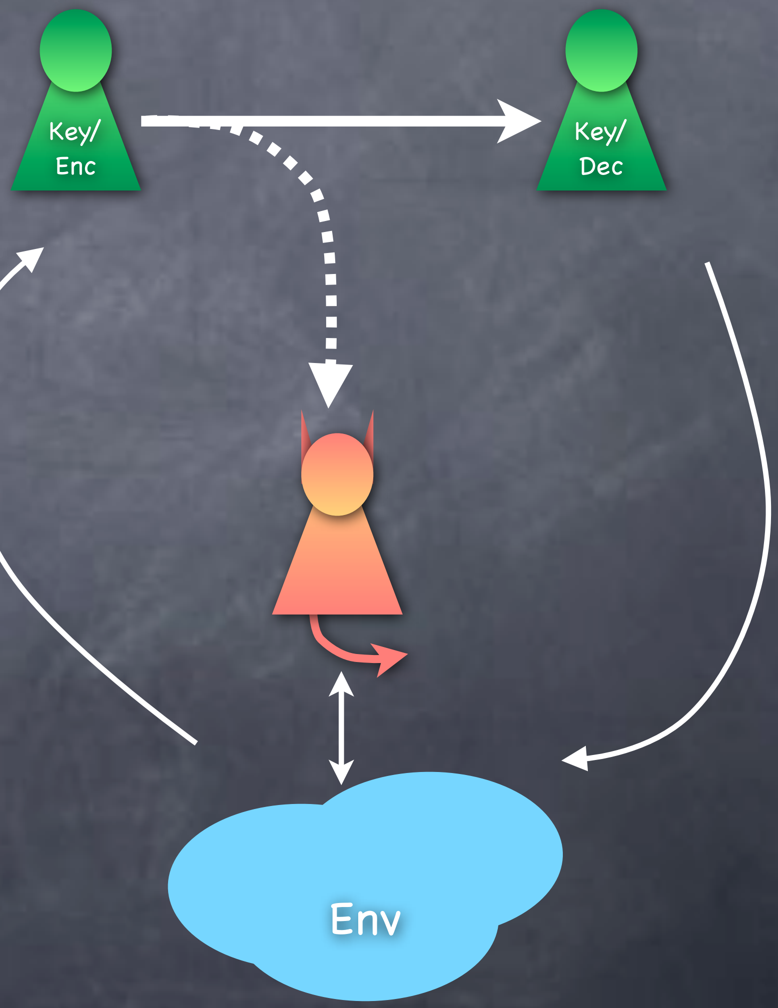

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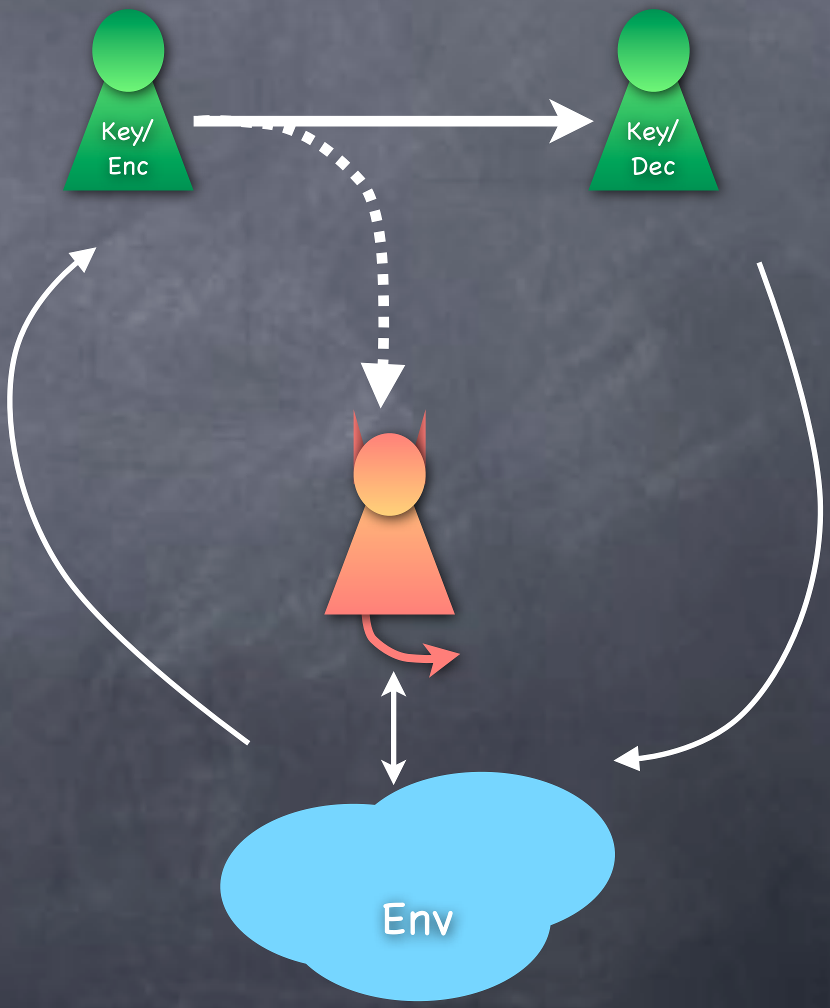

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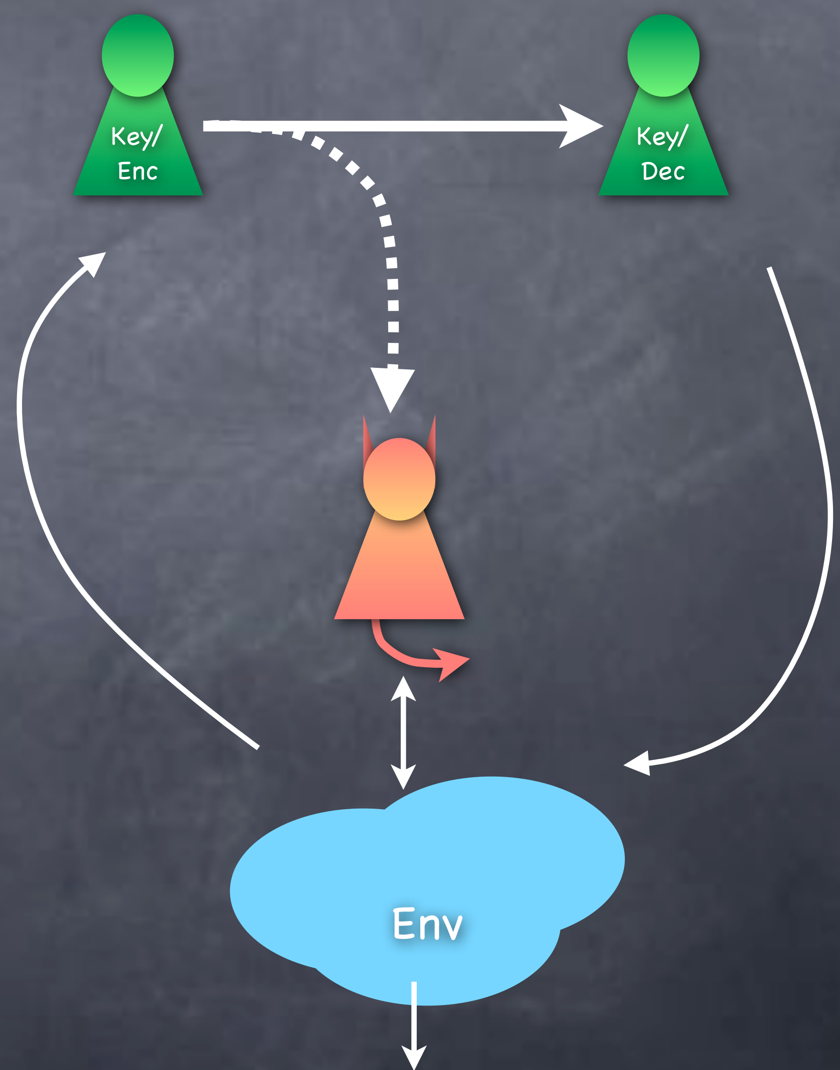

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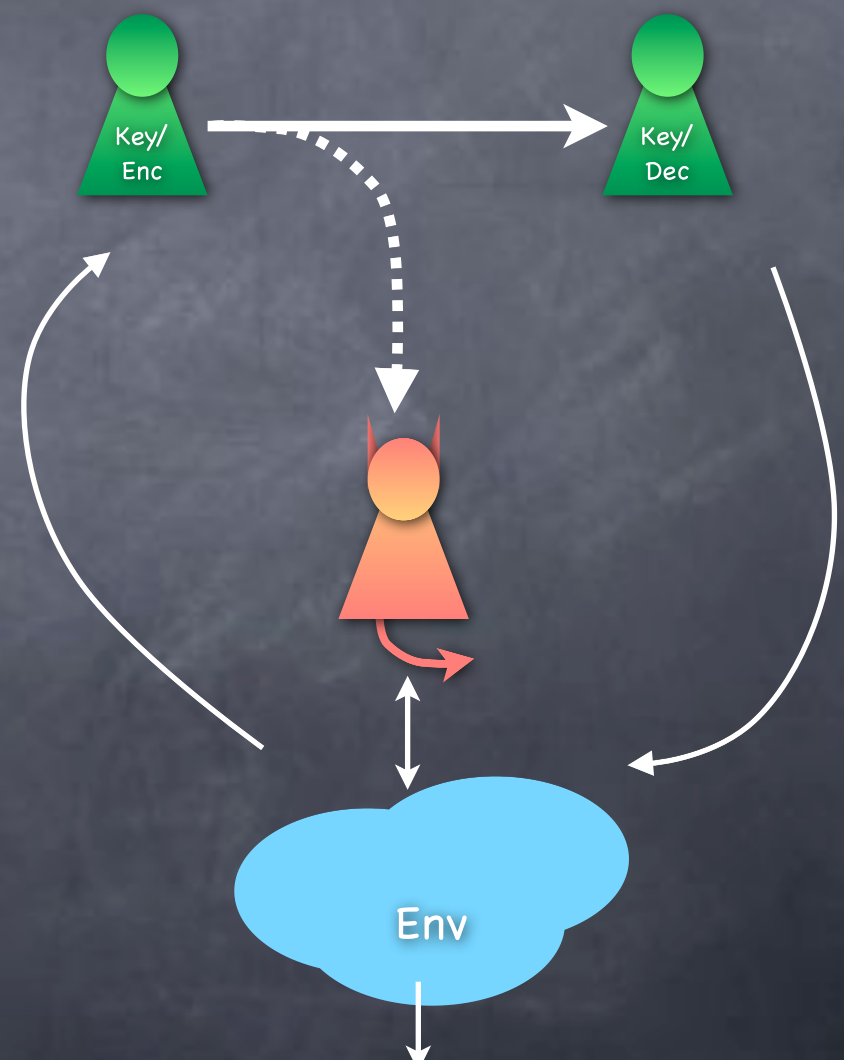

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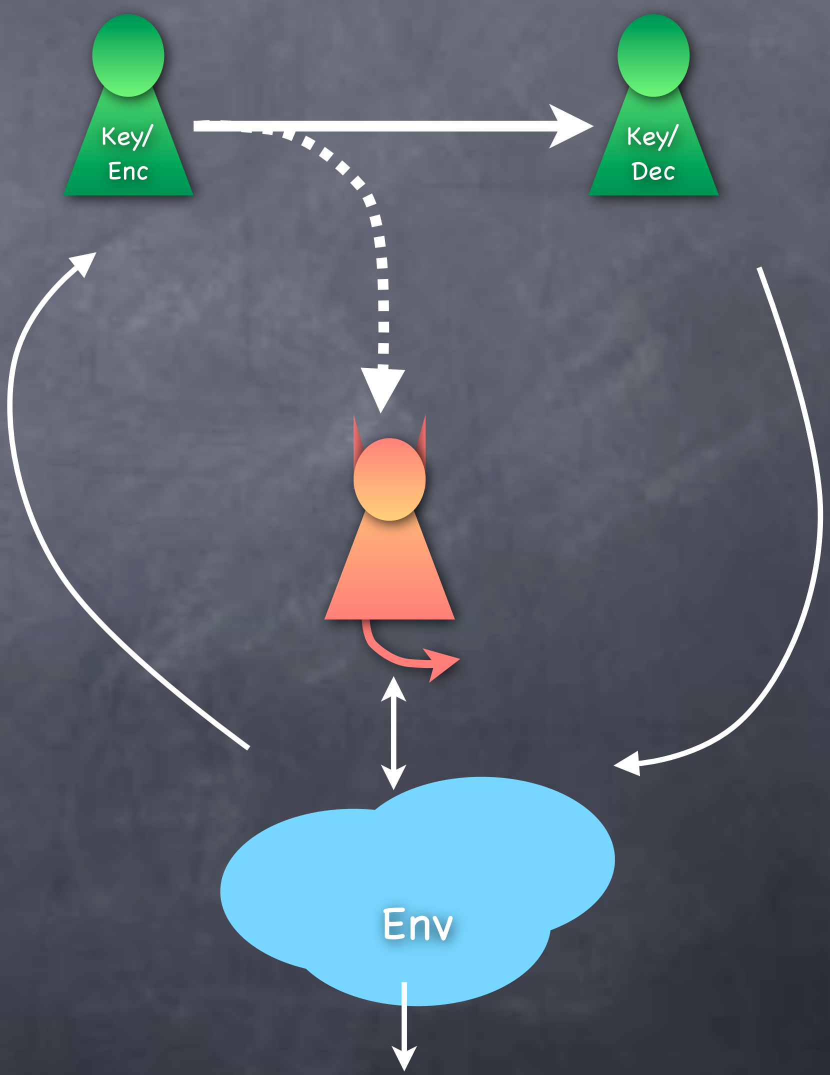
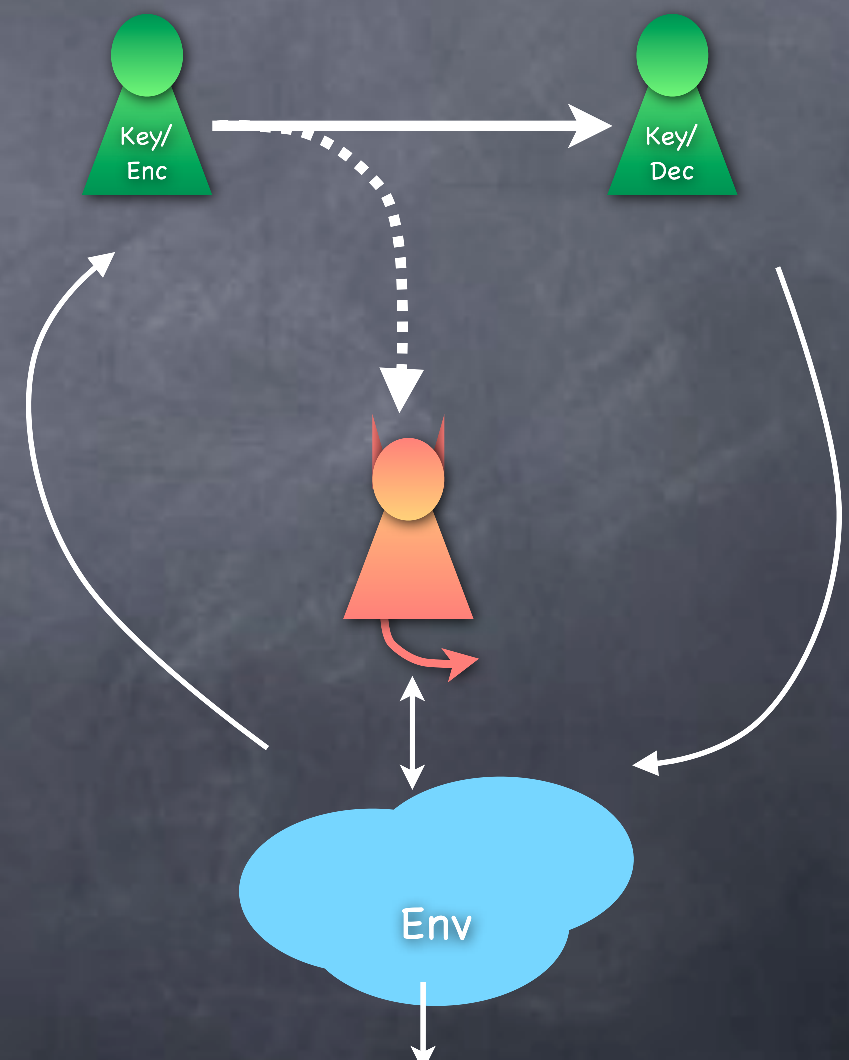
  - Anything that Eve couldn't have caused if an "ideal channel" was used



Defining Security

The REAL/IDEAL Paradigm



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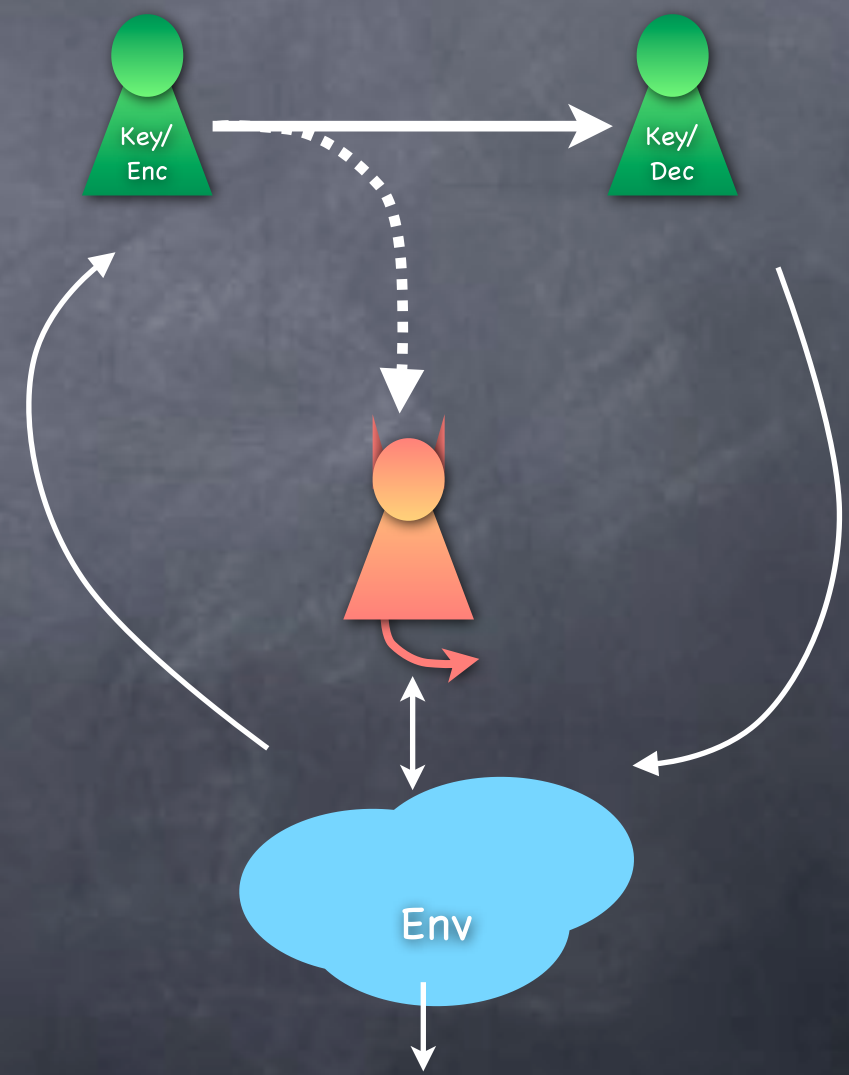

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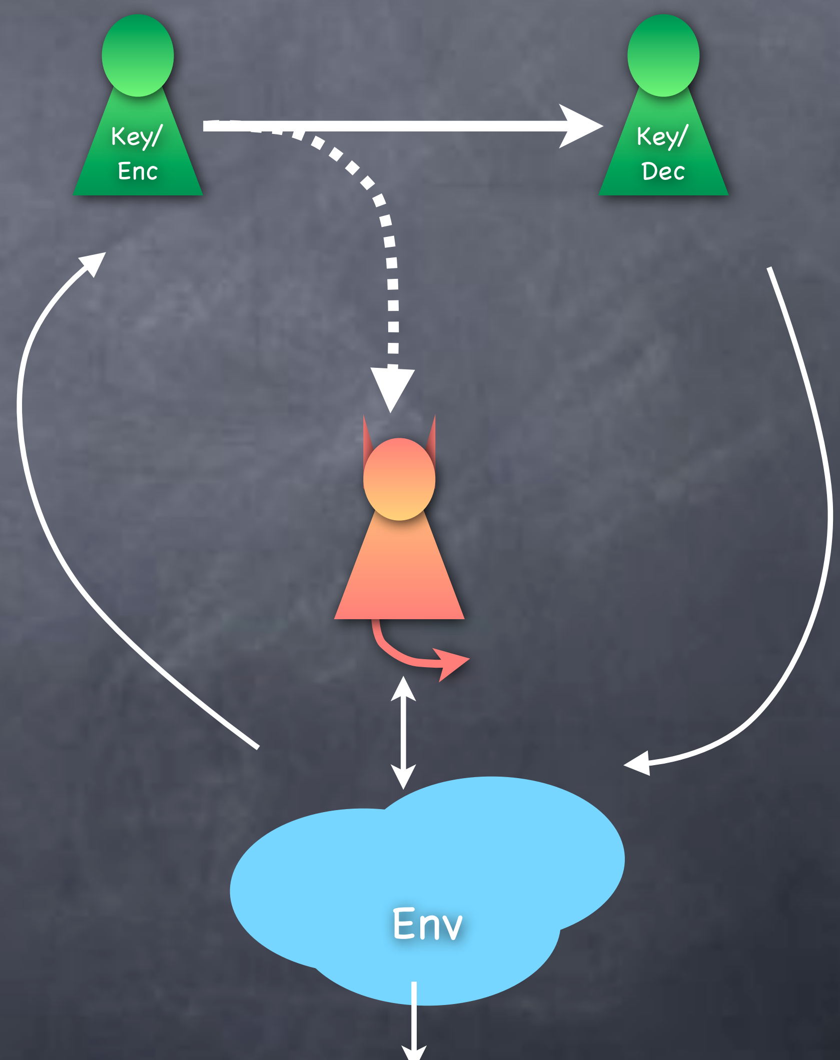

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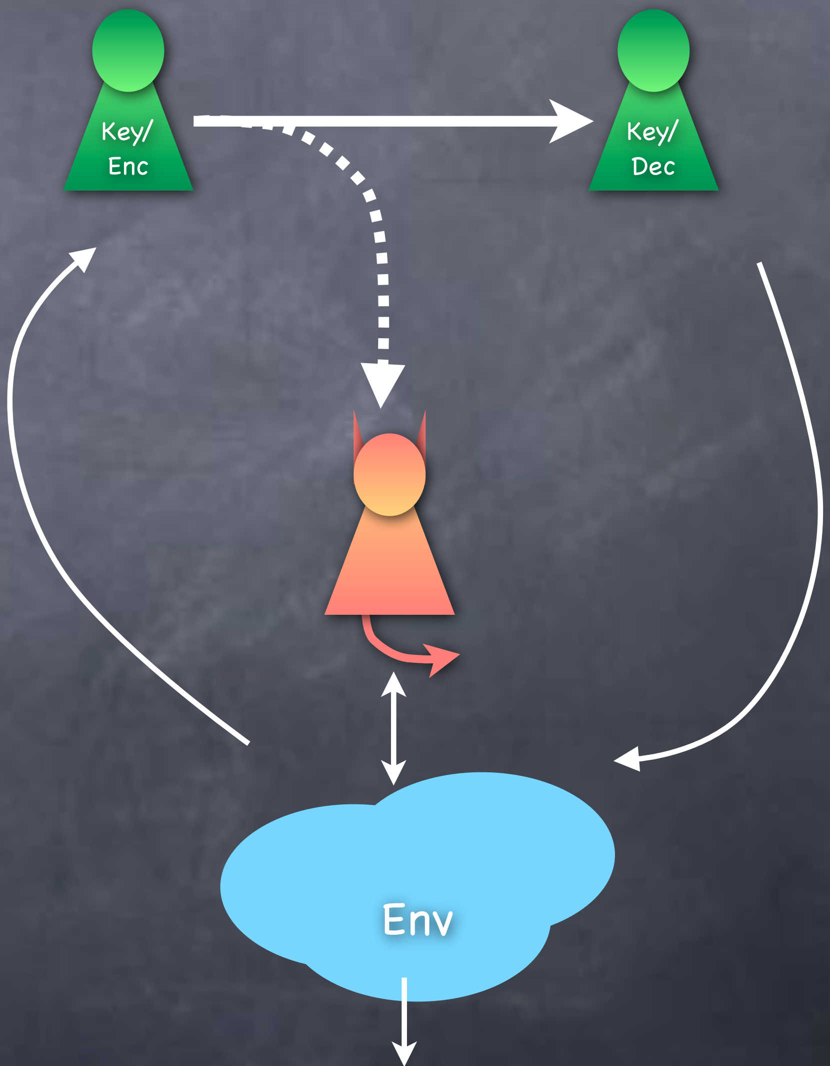

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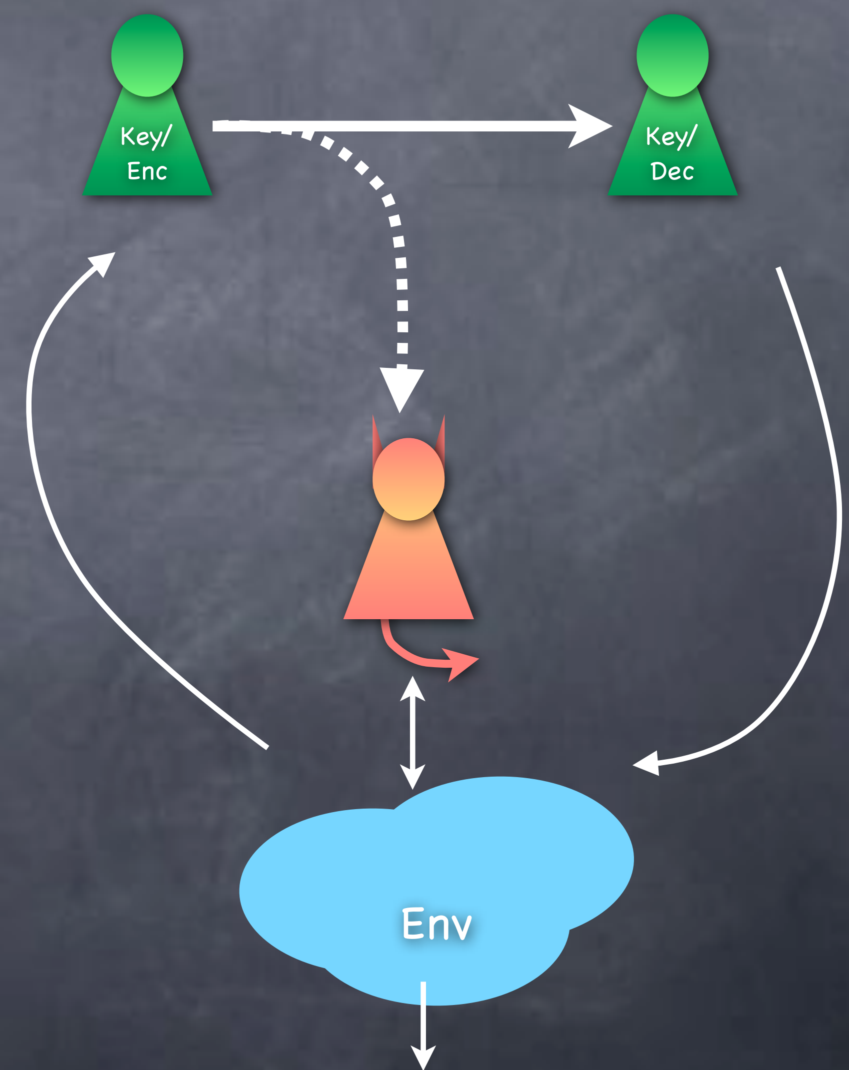
- Eve shouldn't produce any more effects than she could have in the ideal world
  - IDEAL world: Message sent over a (physically) secure channel. No encryption in this world.
  - REAL world: Using encryption
  - Encryption is secure if whatever Eve can do in the REAL world (using some strategy), she can do in the IDEAL world too (using an appropriate strategy)



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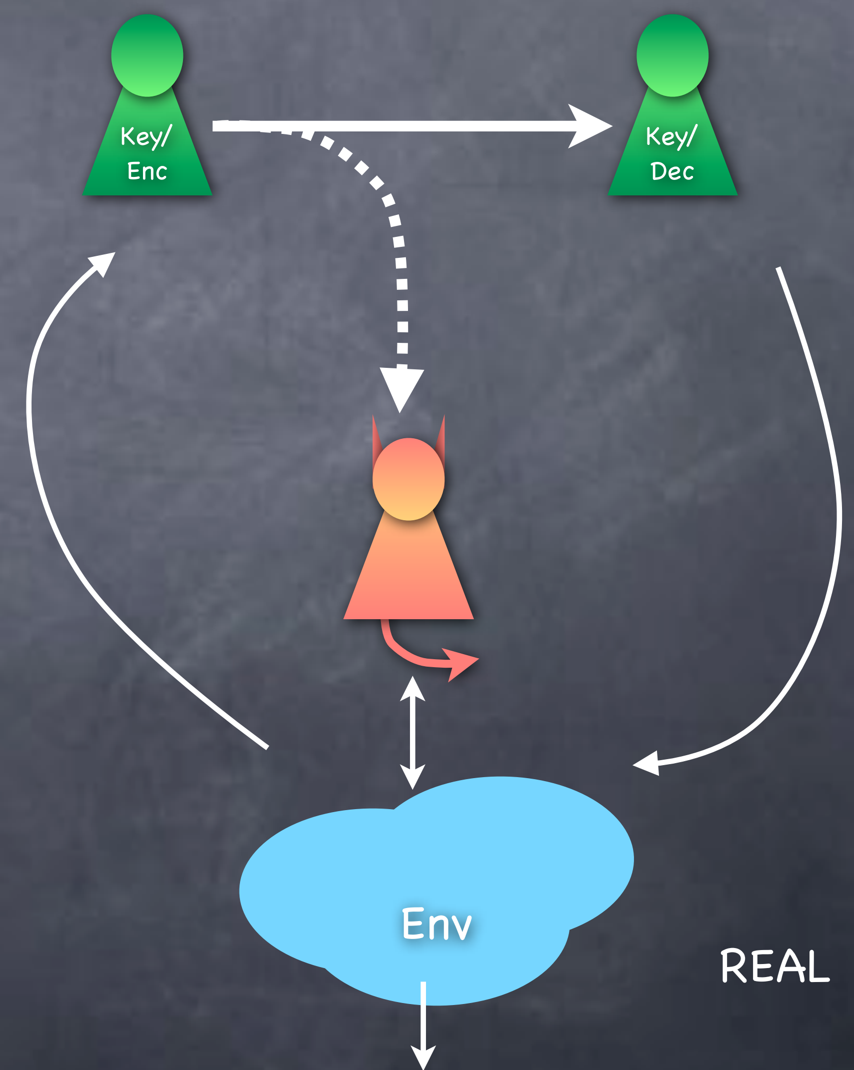

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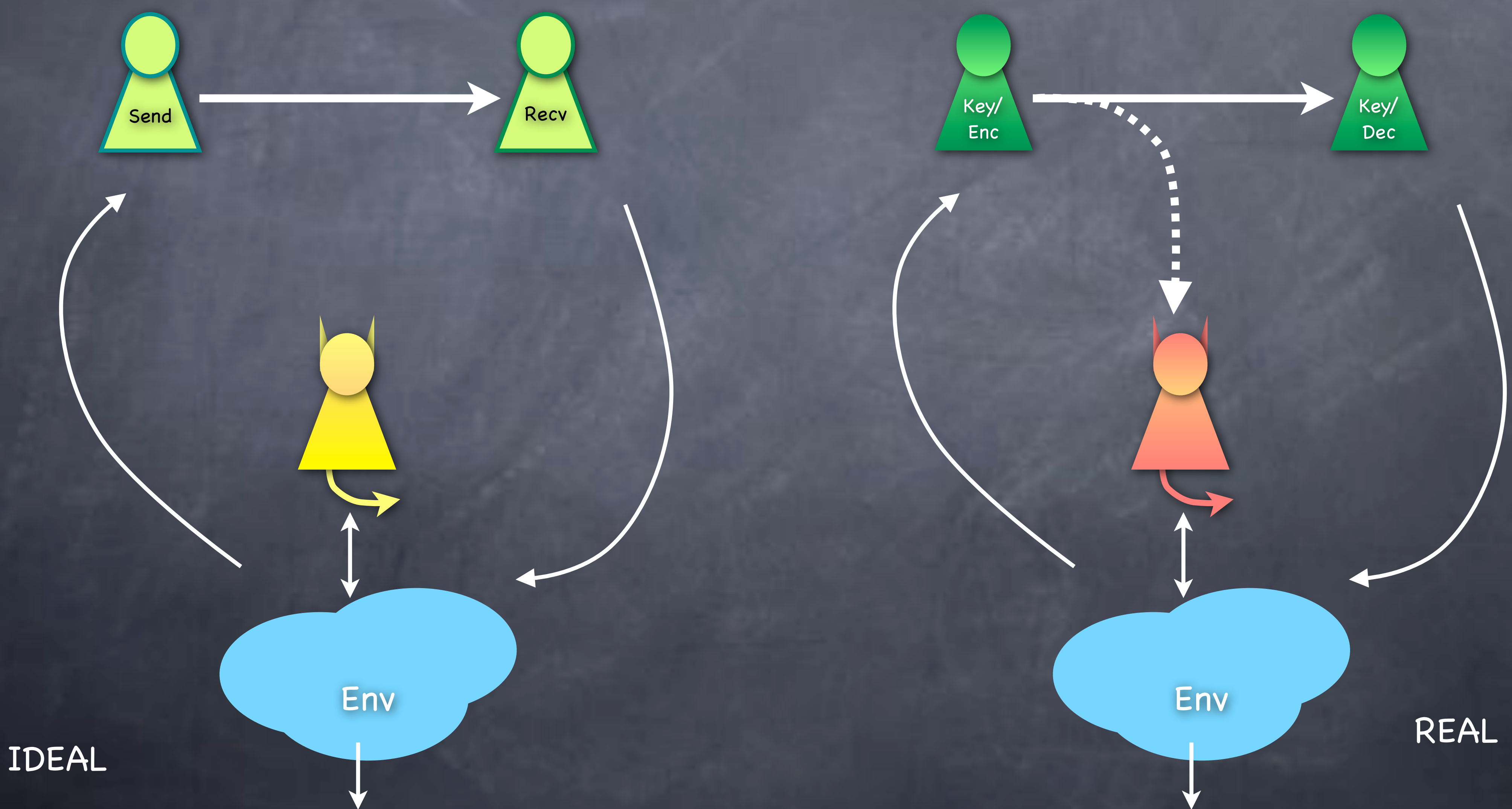

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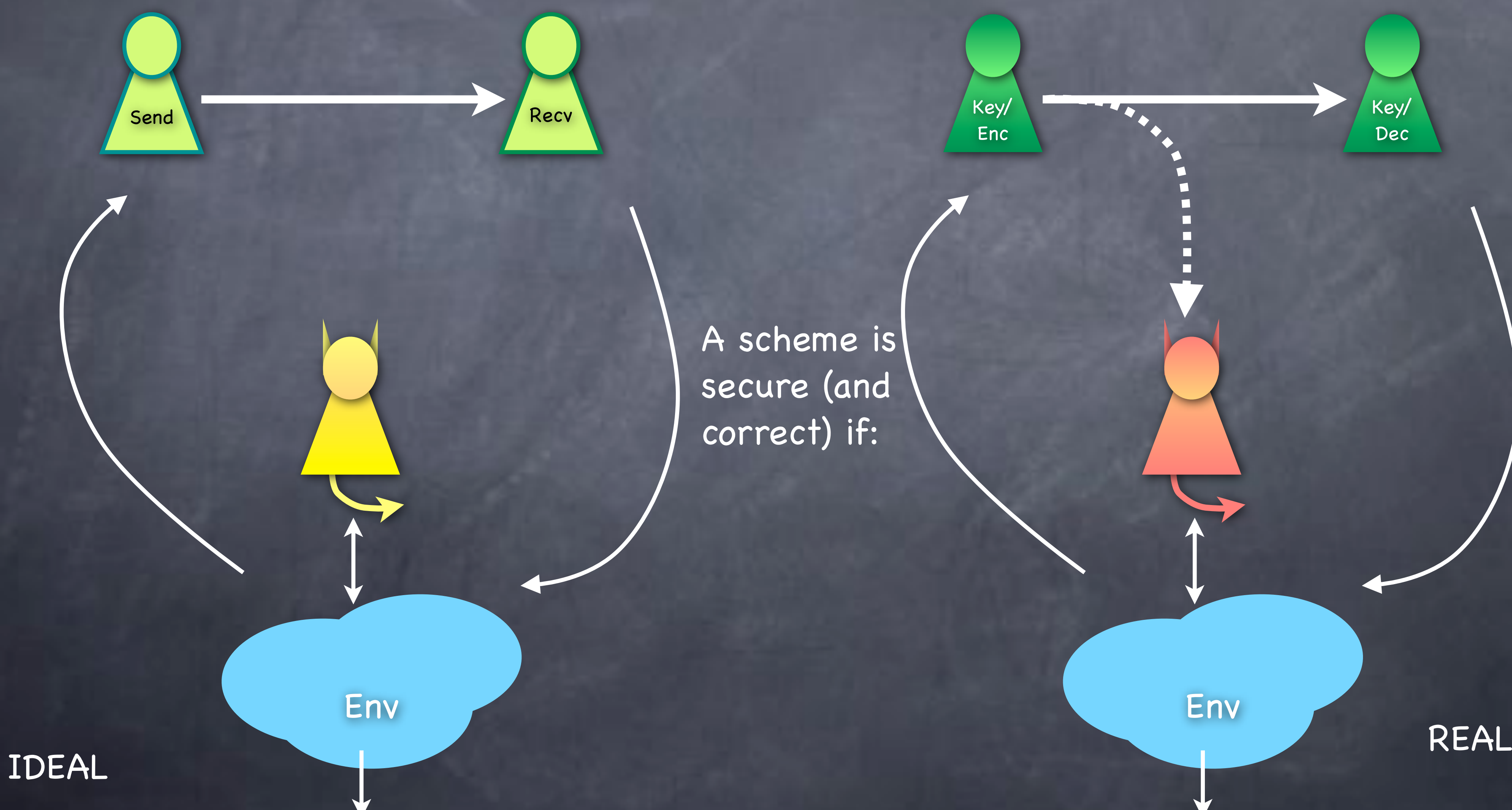

A scheme is secure (and correct) if:

Defining Security

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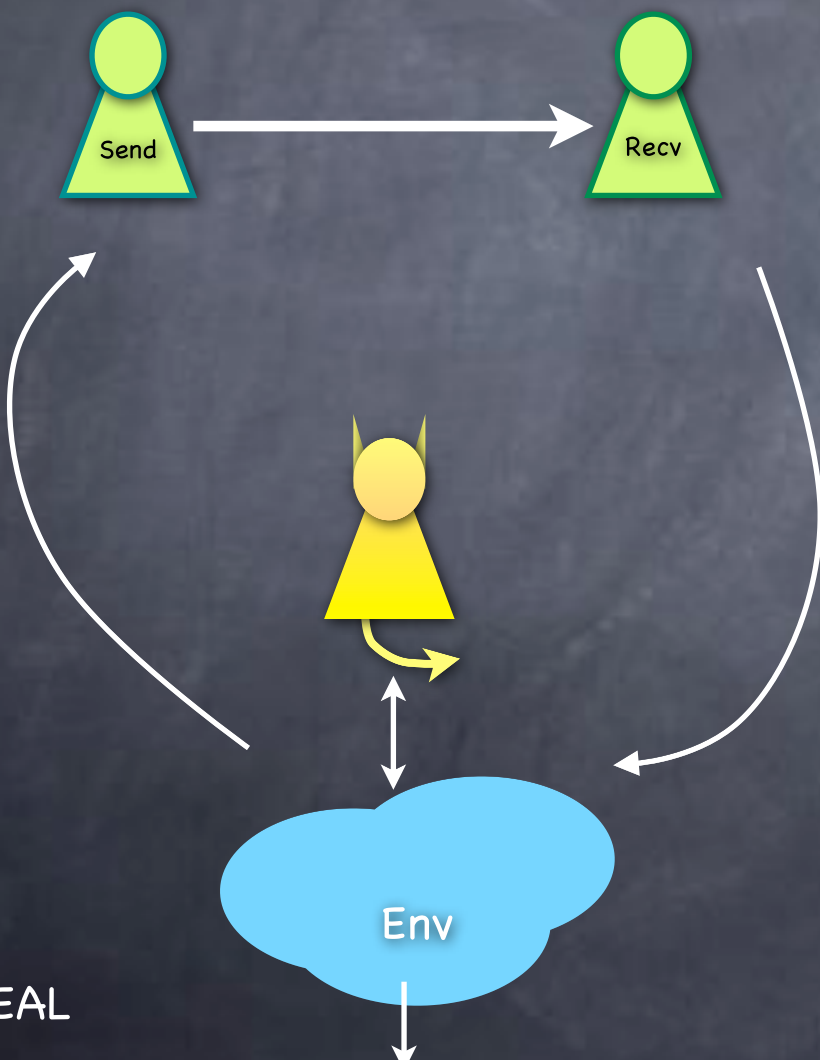

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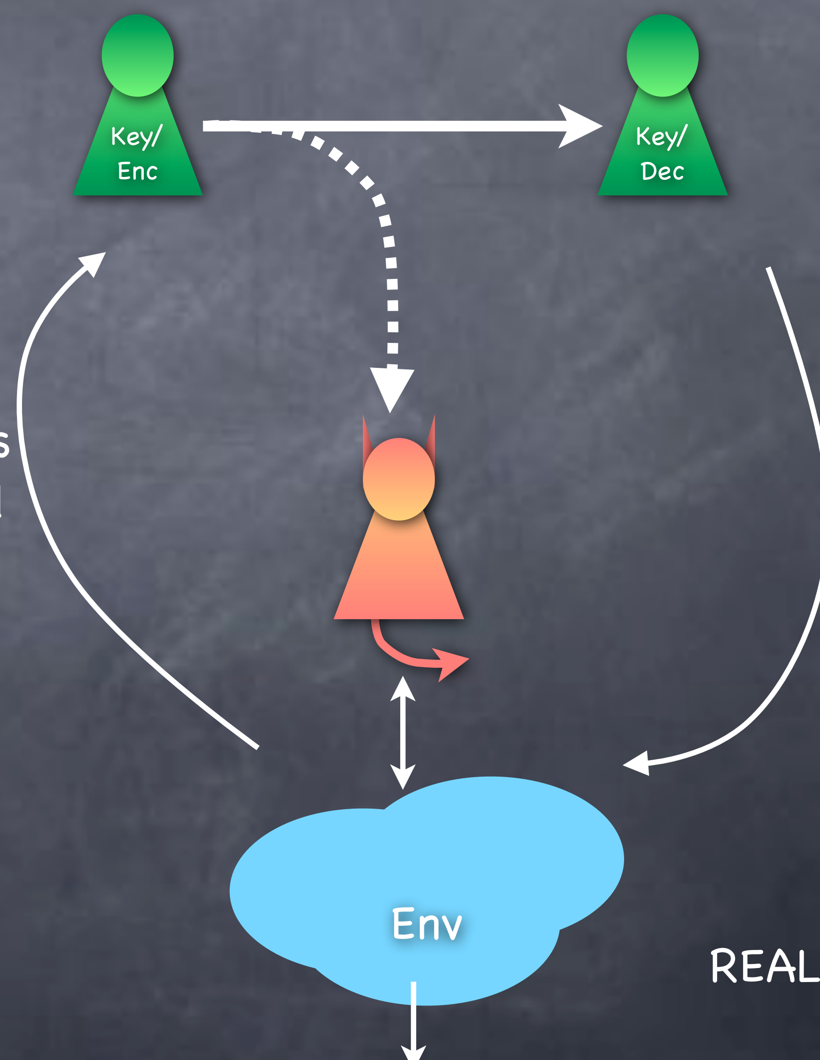

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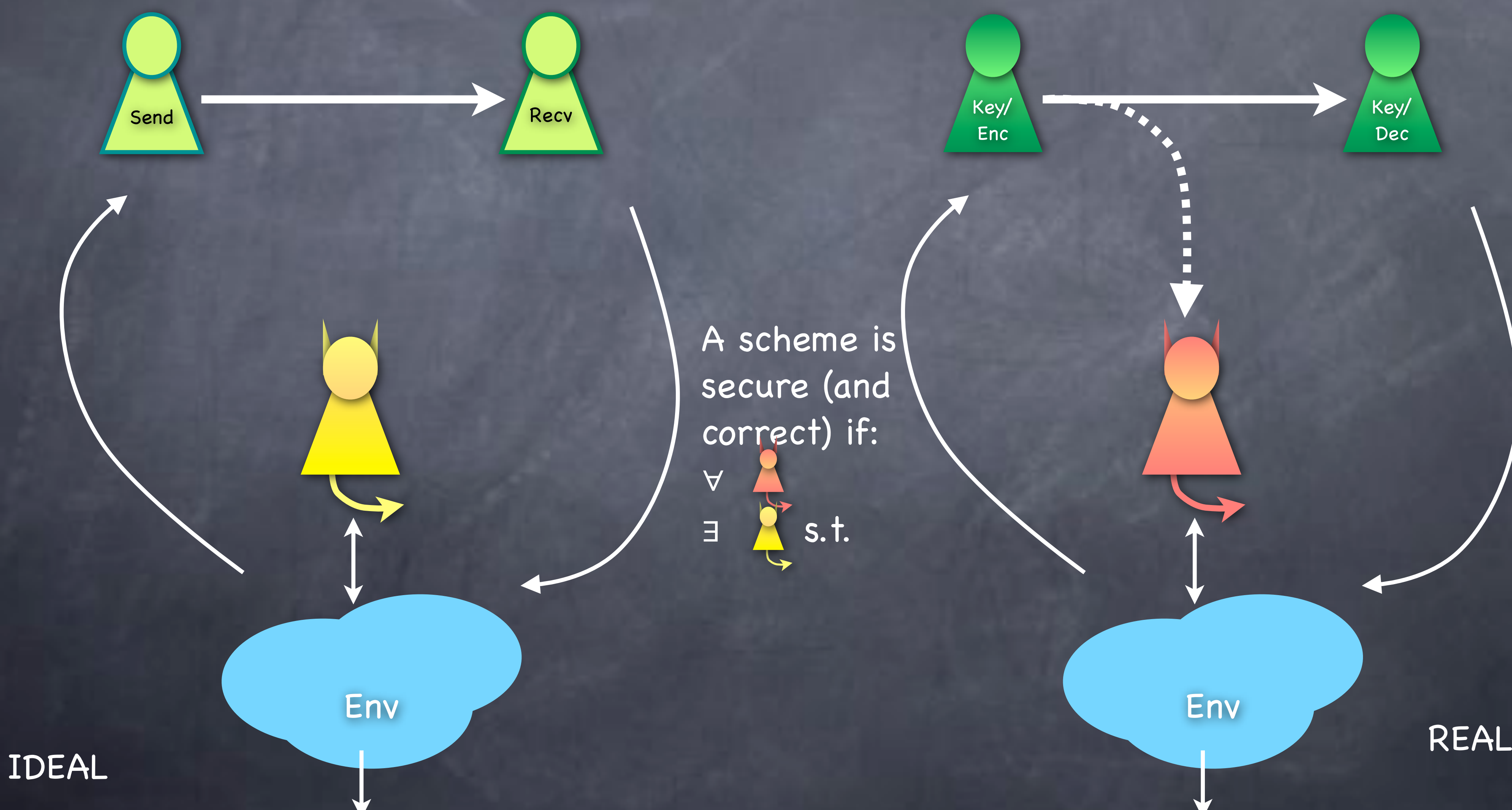

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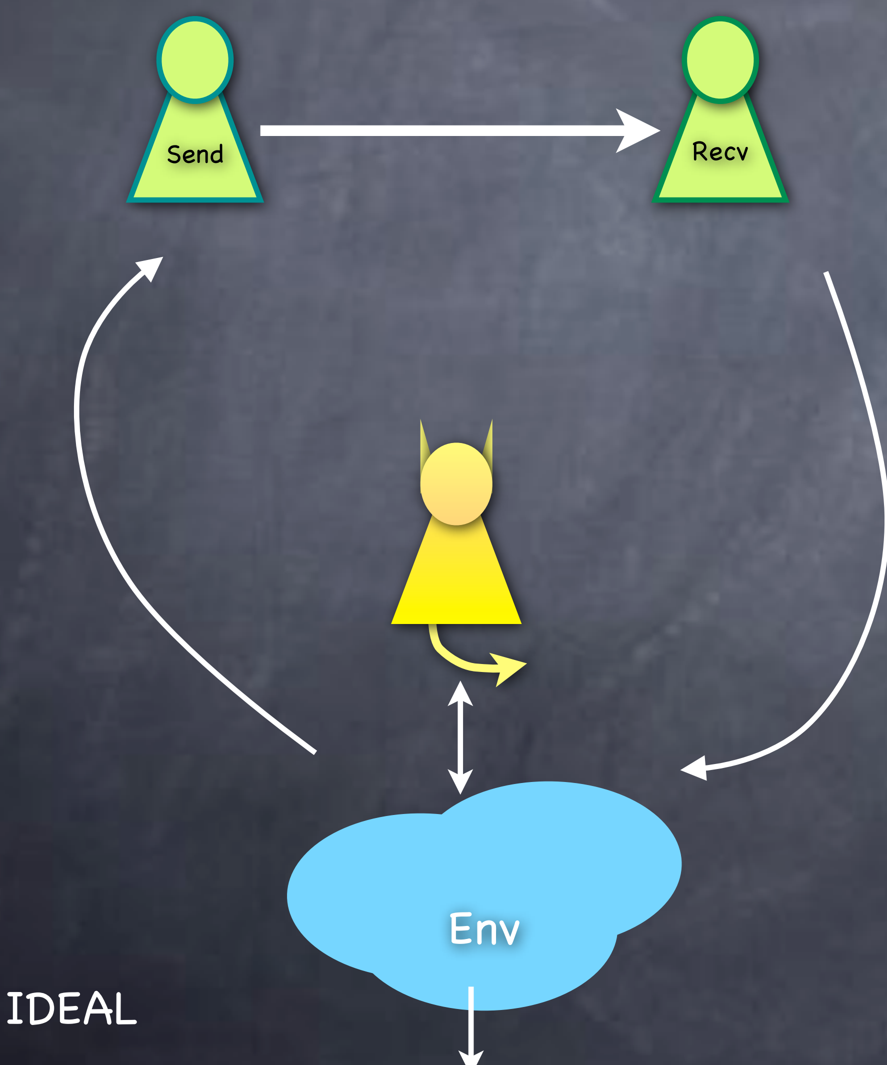

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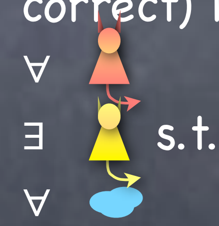

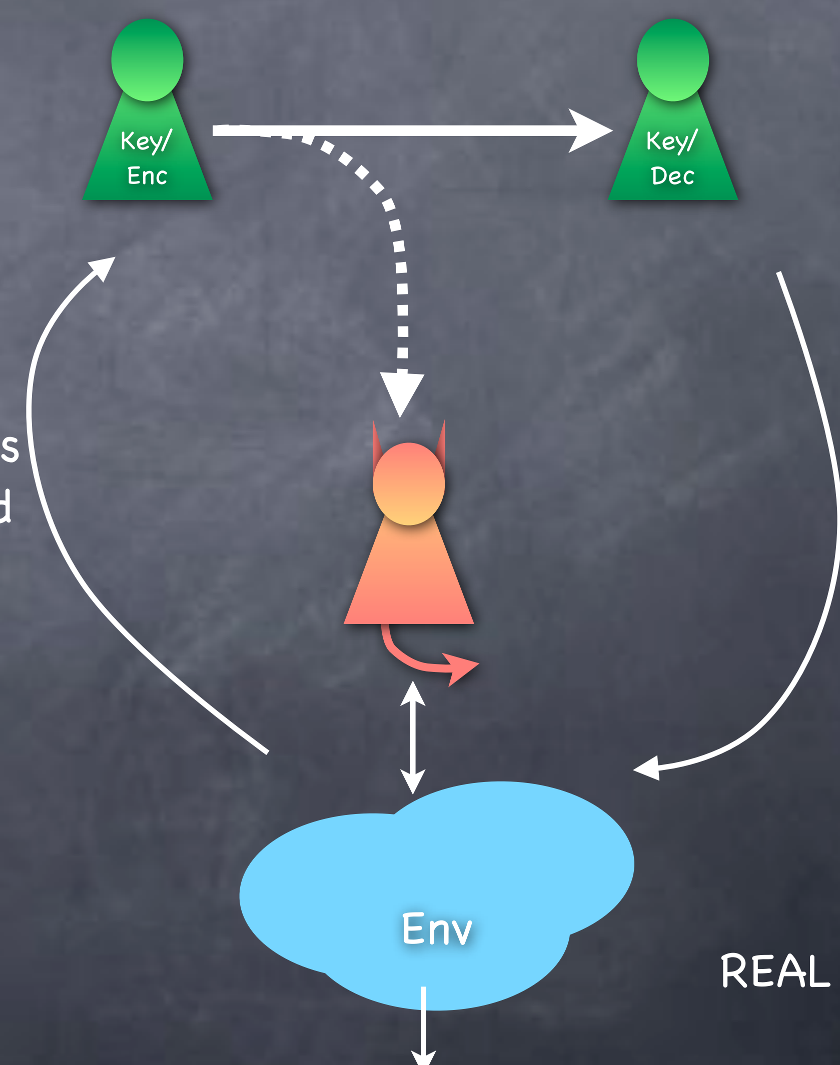

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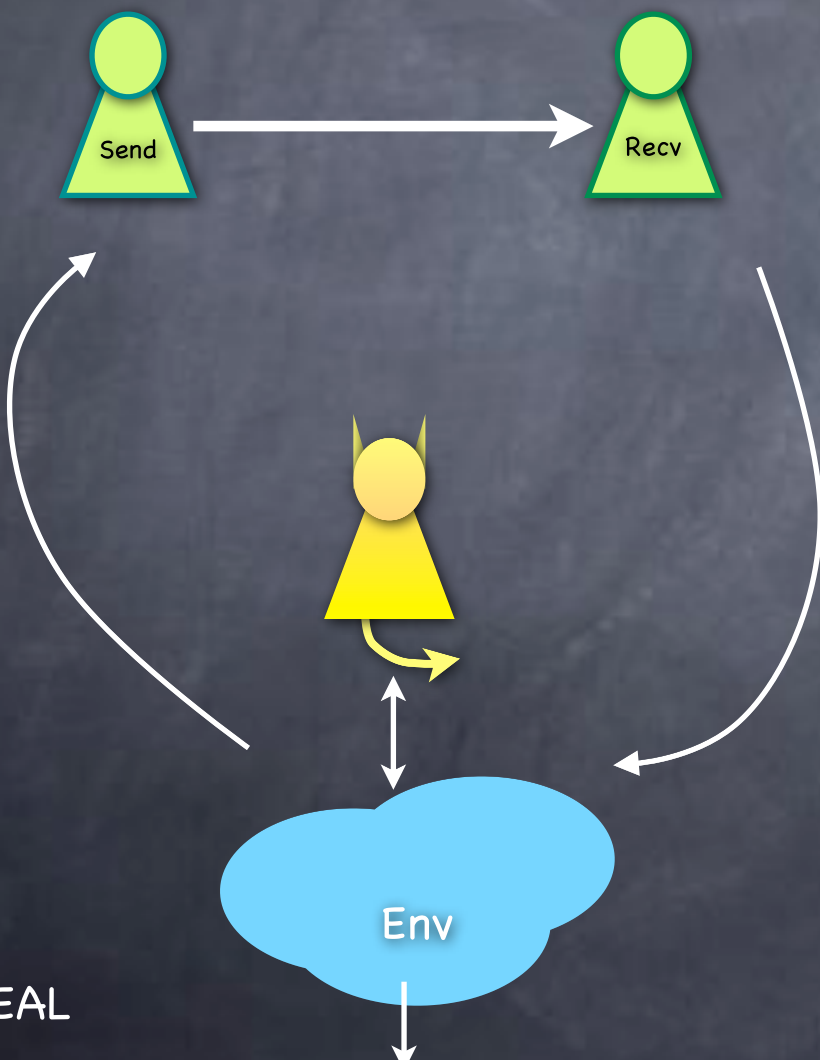

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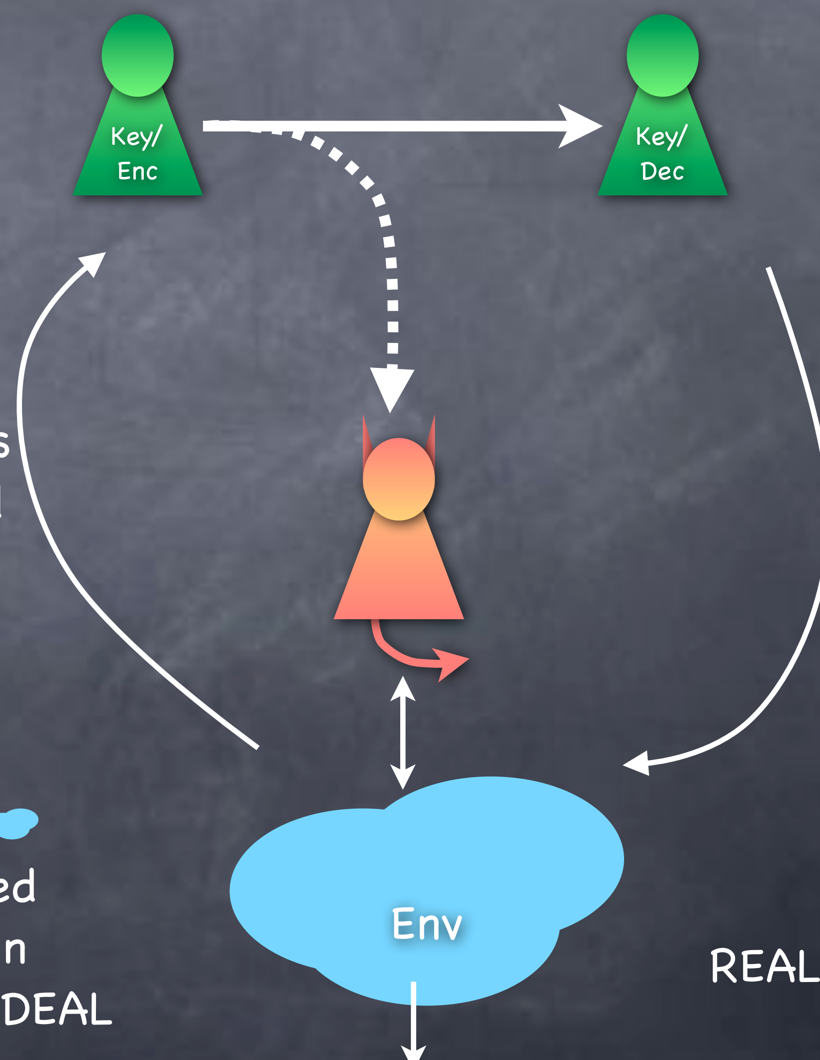
$\forall$

$\exists$ s.t.

$\forall$

output of is distributed identically in REAL and IDEAL



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- We will see three definitions of symmetric-key encryption
  - Security of “one-time encryption”
  - Security of (muti-message) encryption
  - Security against “active attacks”
- Will also see alternate (but essentially equivalent) security definitions

Onetime Encryption

Onetime Encryption
The Syntax

- Shared-key (Private-key) Encryption
  - Key Generation: Randomized
    - K ← $\mathcal{K}$, uniformly randomly drawn from the key-space (or according to a key-distribution)
  - Encryption: Deterministic
    - Enc: $\mathcal{M} \times \mathcal{K} \to \mathcal{C}$
  - Decryption: Deterministic
    - Dec: $\mathcal{C} \times \mathcal{K} \to \mathcal{M}$

Onetime Encryption

Perfect Secrecy

Onetime Encryption

Perfect Secrecy

- Perfect secrecy: $\forall$ m, m′ $\in \mathcal{M}$
  - $\{\mathrm{Enc}(m,K)\}_{K \leftarrow \mathrm{KeyGen}} = \{\mathrm{Enc}(m',K)\}_{K \leftarrow \mathrm{KeyGen}}$

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Onetime Encryption

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$\mathcal{M}$ \ $\mathcal{K}$	0	1	2	3
a	x	y	y	z
b	y	x	z	y

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Assuming K uniformly drawn from $\mathcal{K}$

Onetime Encryption

Perfect Secrecy

- Perfect secrecy: $\forall$ m, m' $\in \mathcal{M}$
  - $\{\text{Enc}(m,K)\}_{K\leftarrow\text{KeyGen}} = \{\text{Enc}(m',K)\}_{K\leftarrow\text{KeyGen}}$
- Distribution of the ciphertext is defined by the randomness in the key

$\mathcal{M}$ \ $\mathcal{K}$	0	1	2	3
a	x	y	y	z
b	y	x	z	y

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Pr[Enc(a,K)=x] = ¼,
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  - More generally $\mathcal{M} = \mathcal{K} = \mathcal{C} = \mathcal{G}$ (a finite group) and Enc(m,K) = m+K, Dec(c,K) = c-K

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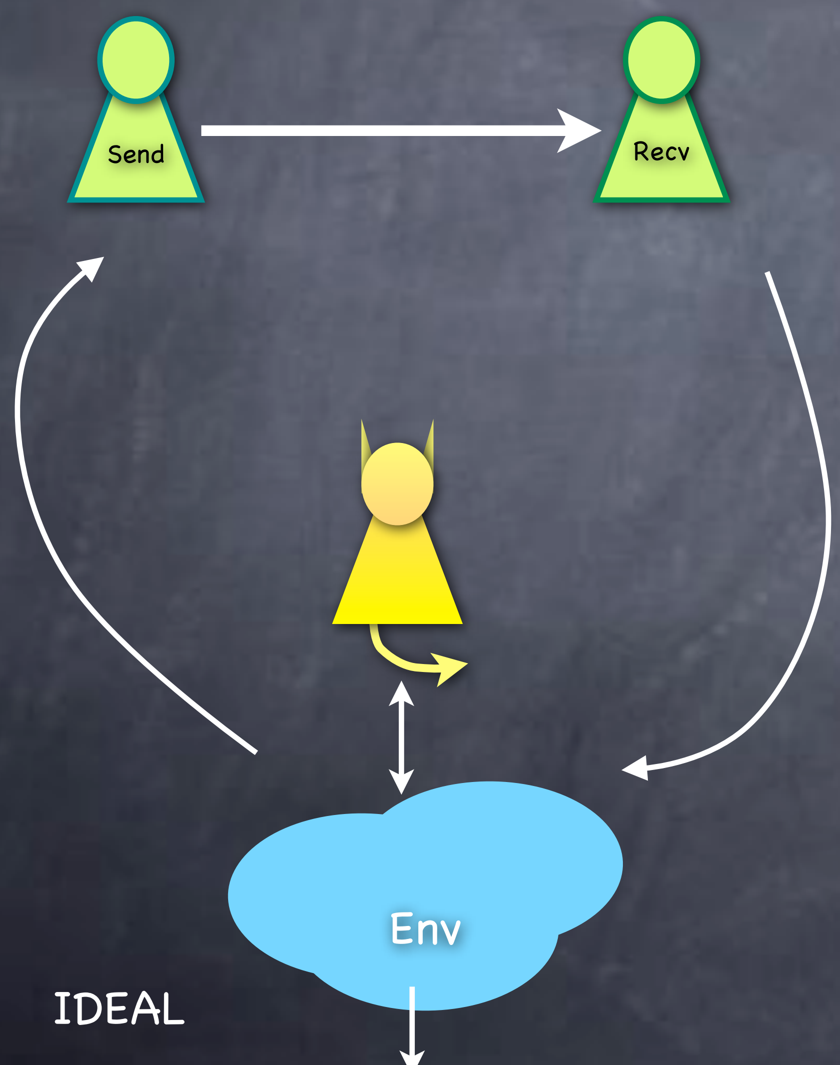
Onetime Encryption

SIM-Onetime Security



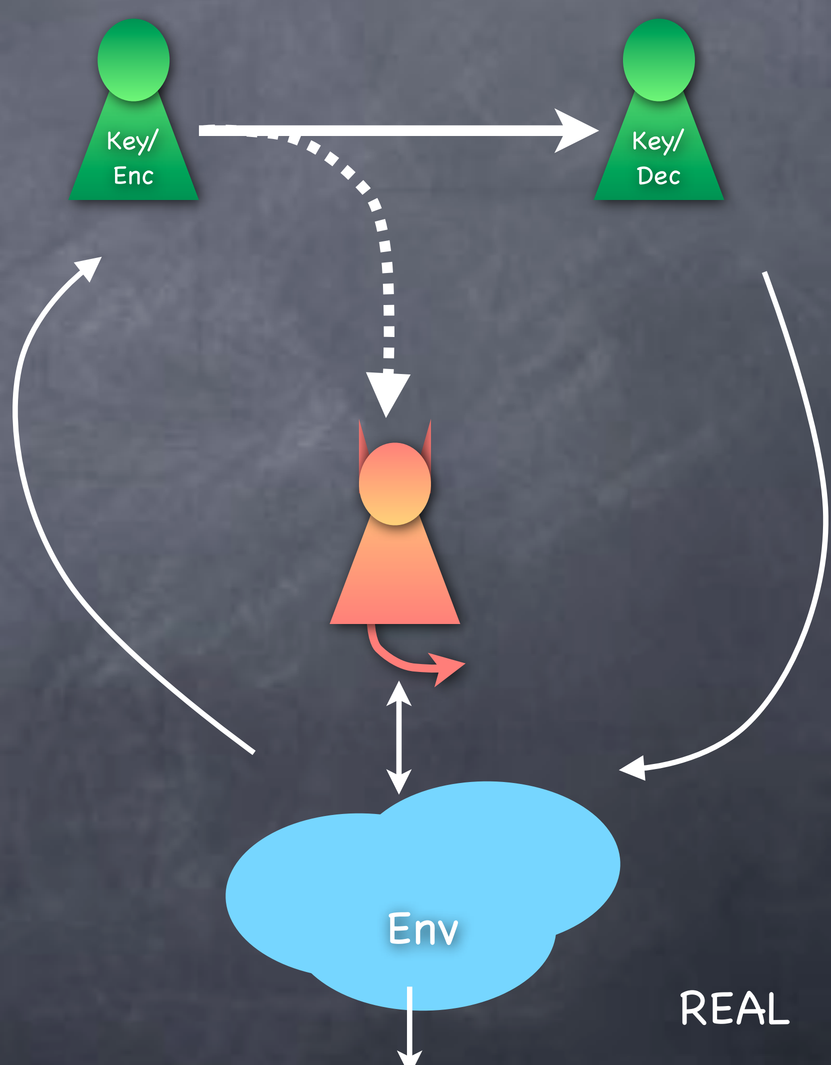
SIM-Onetime secure if:

∀ 

∃  s.t.

∀ 

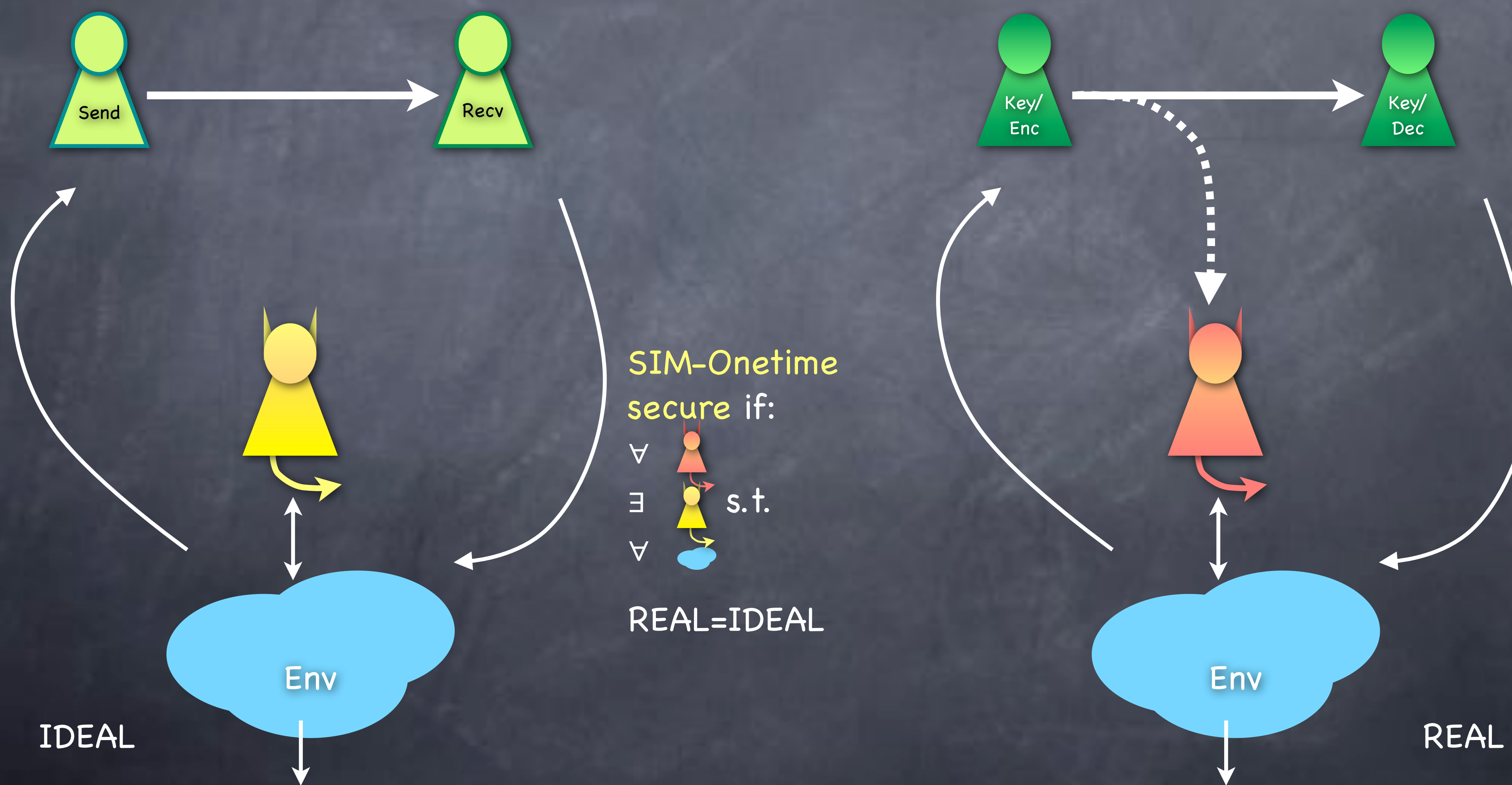
REAL=IDEAL



Onetime Encryption

SIM-Onetime Security

- Class of environments which send only one message



Onetime Encryption

SIM-Onetime Security

Equivalent to perfect secrecy + correctness

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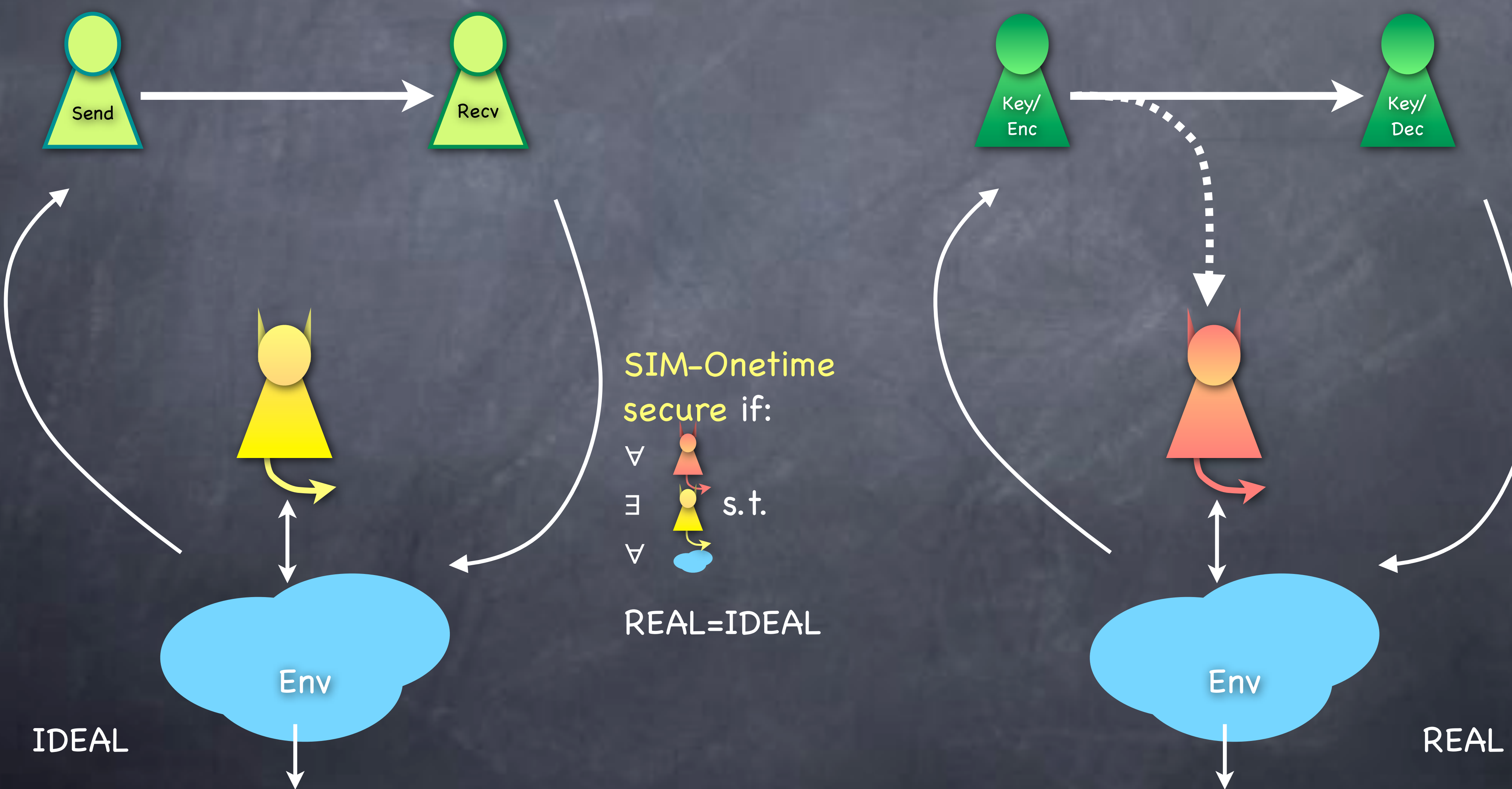
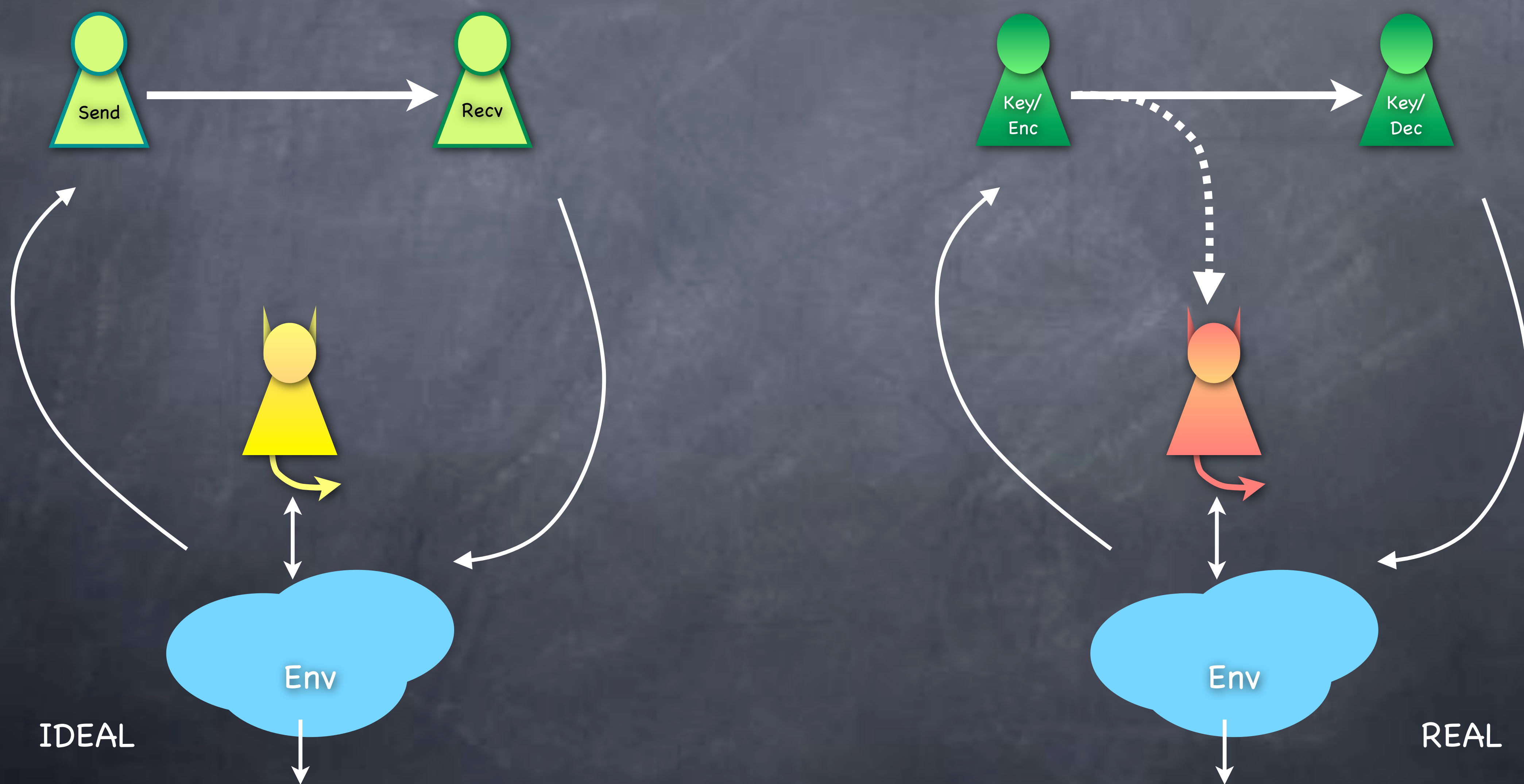


Perfect Secrecy + Correctness ⇒ SIM-Onetime Security



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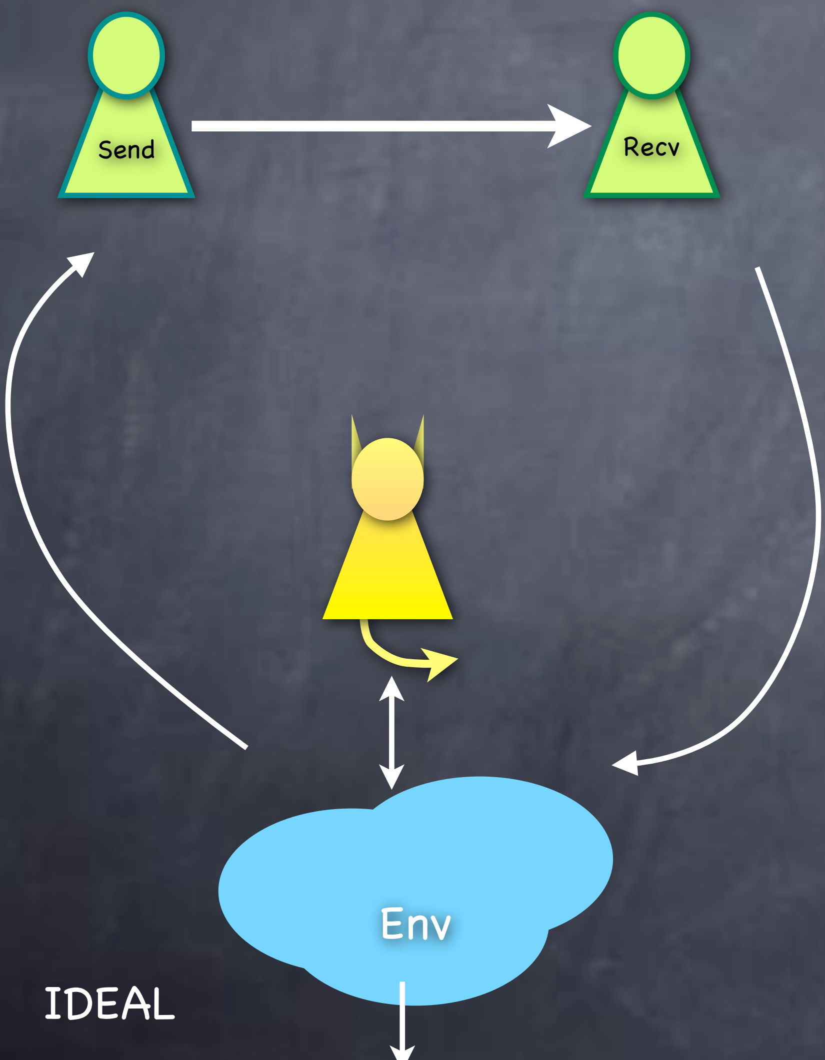
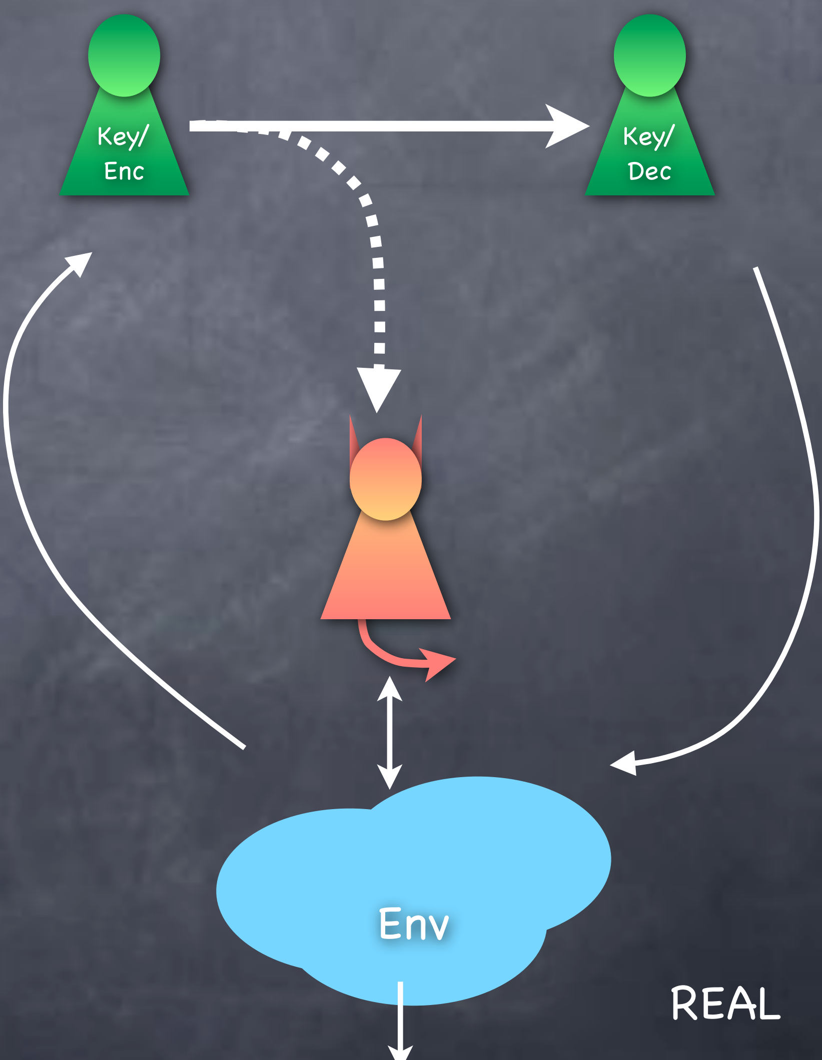


Consider this simulator: Runs adversary internally and lets it talk to the environment directly!



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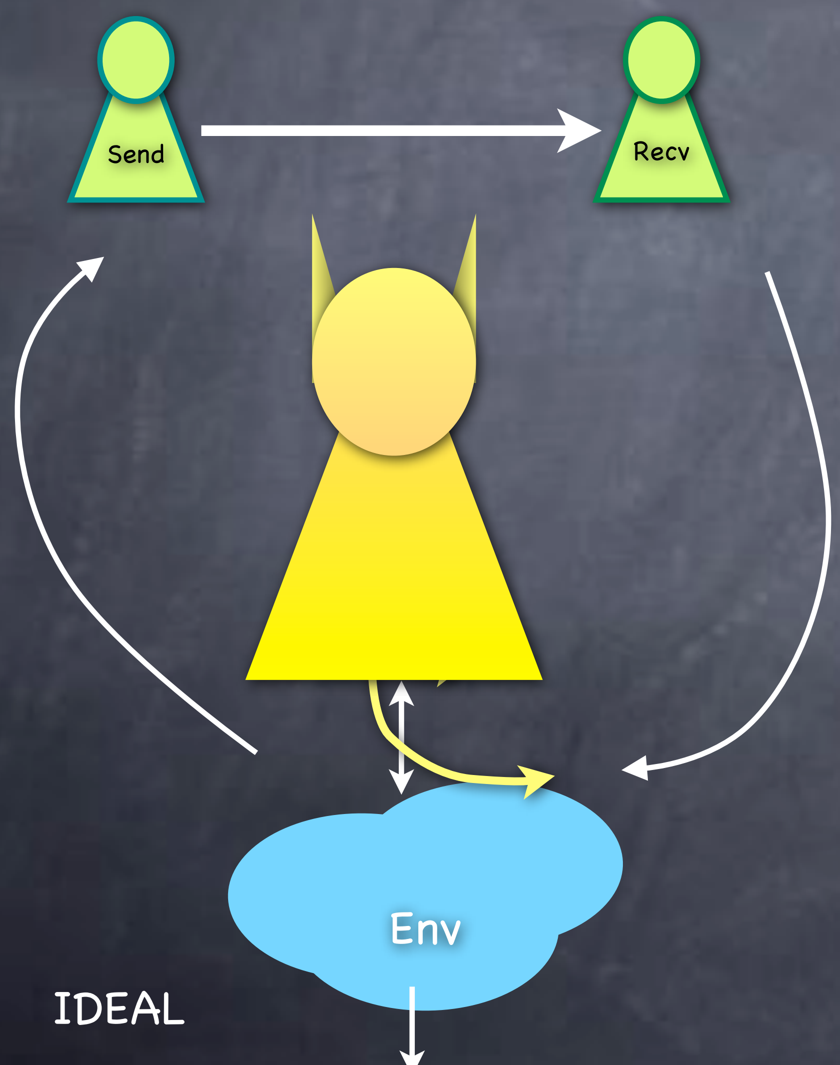

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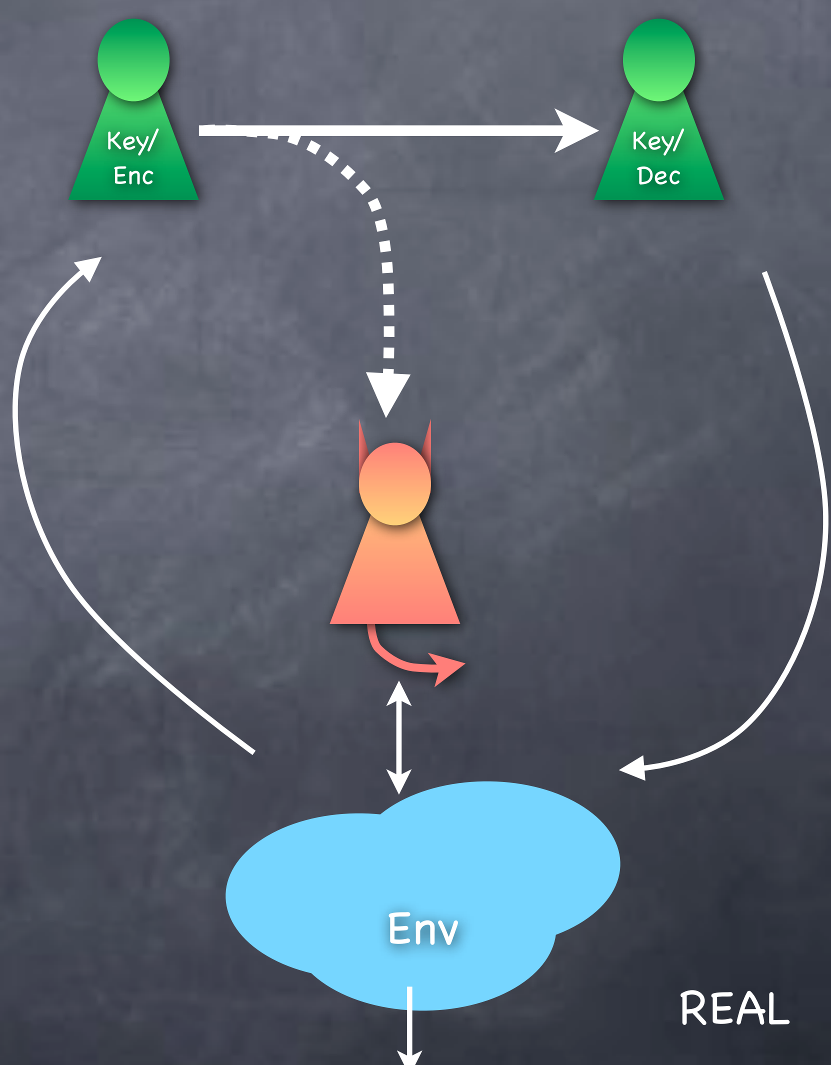

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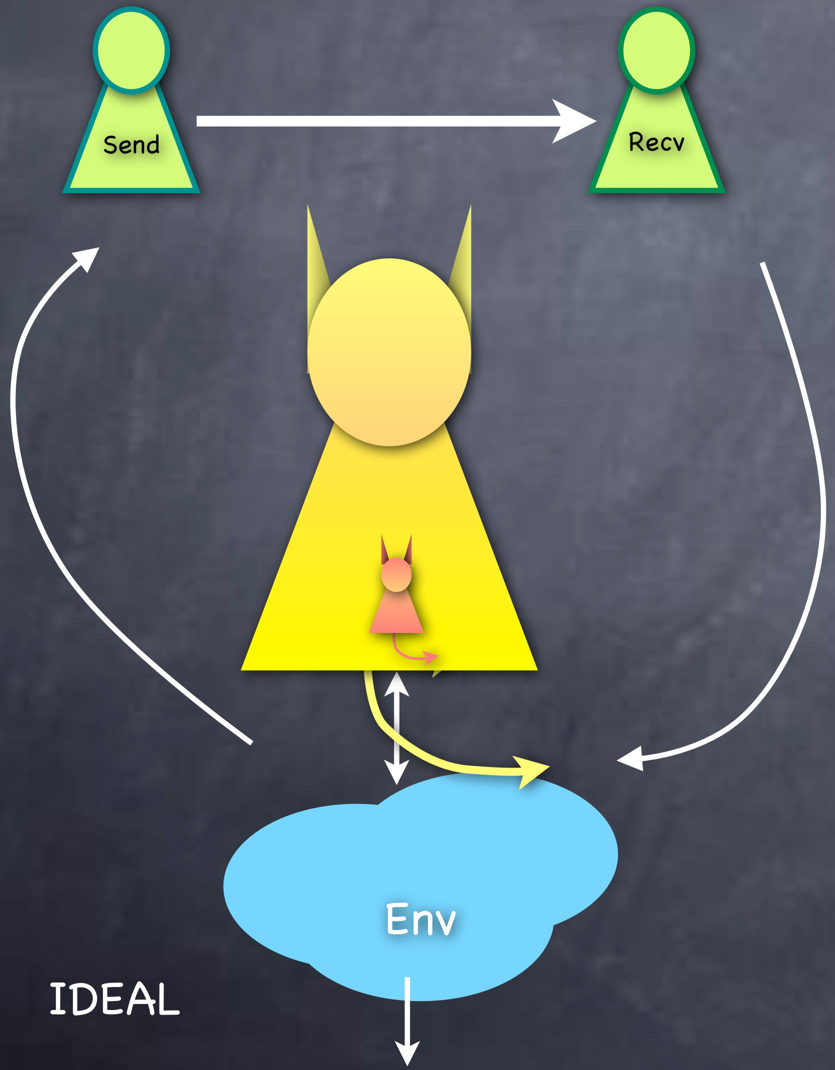

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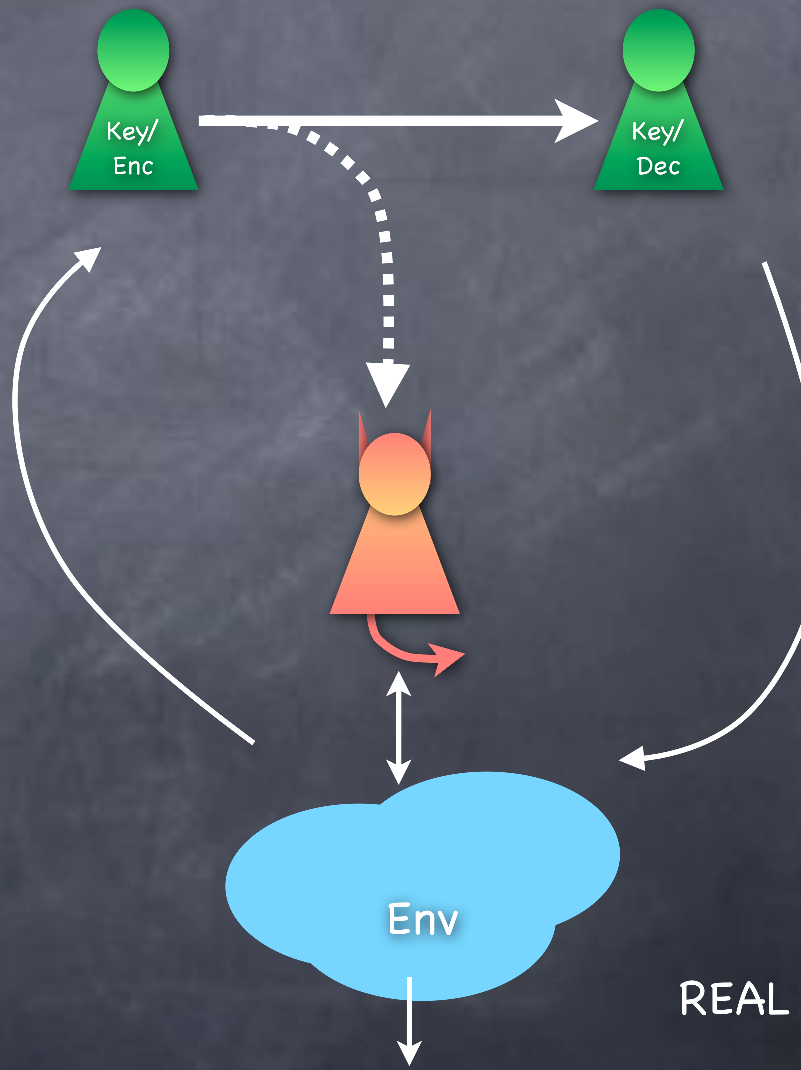

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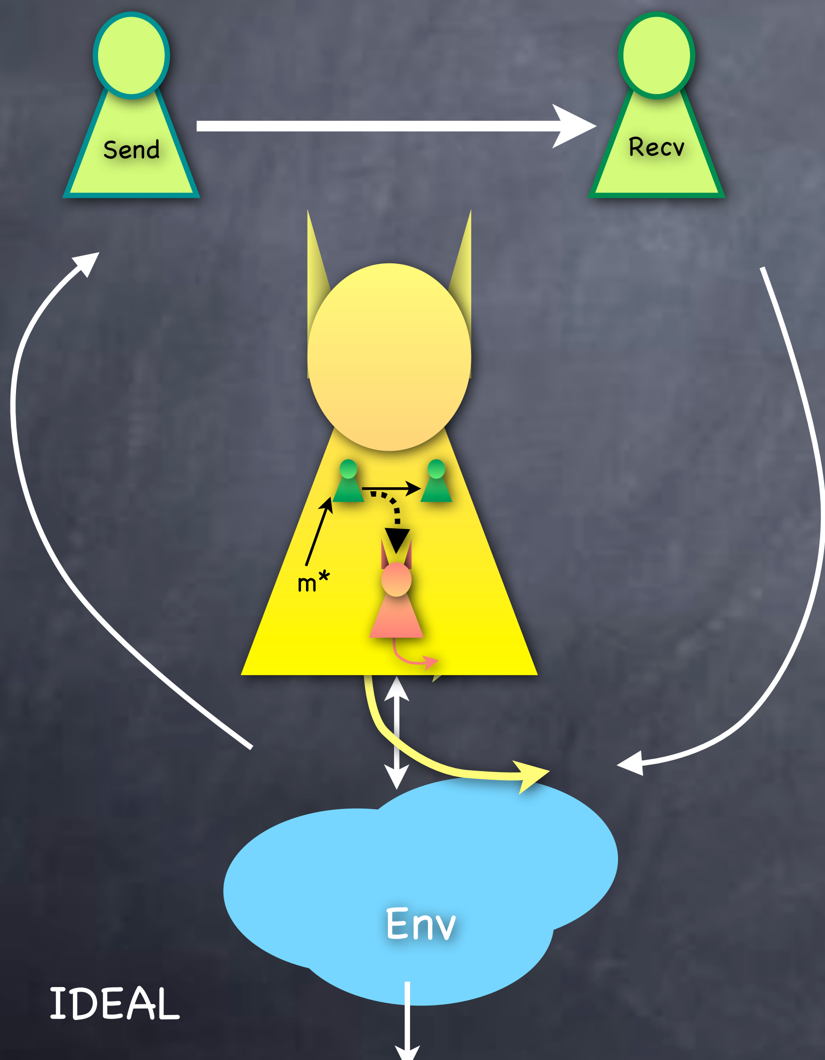

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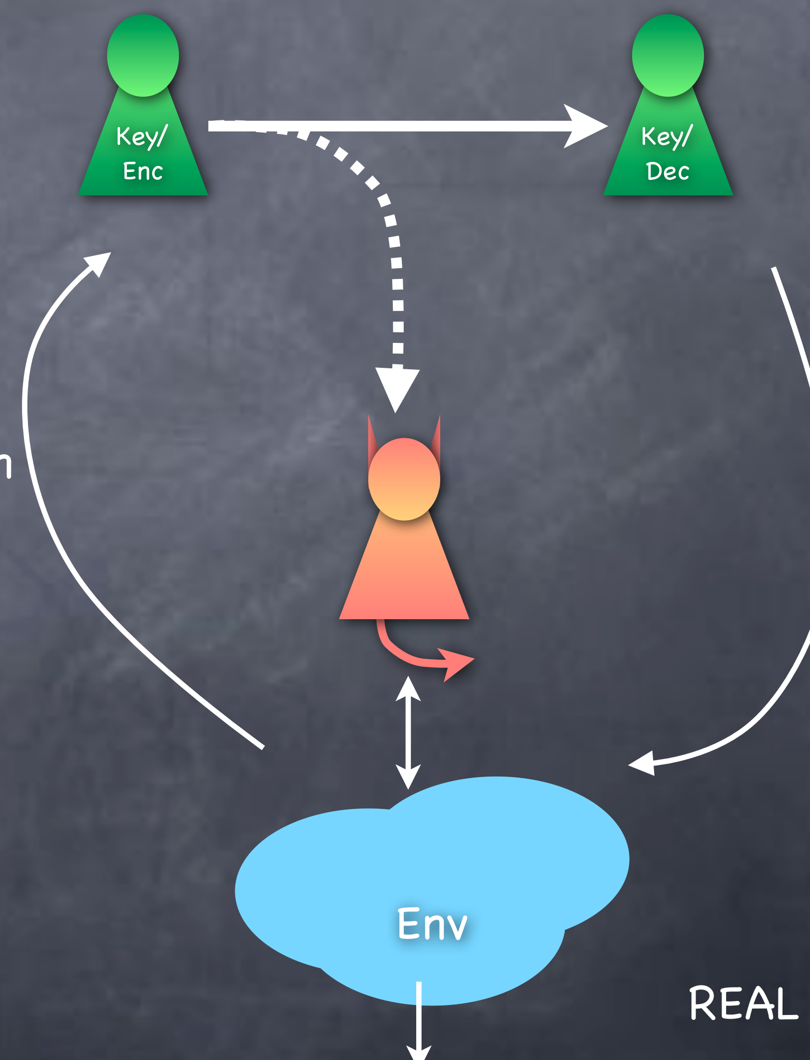

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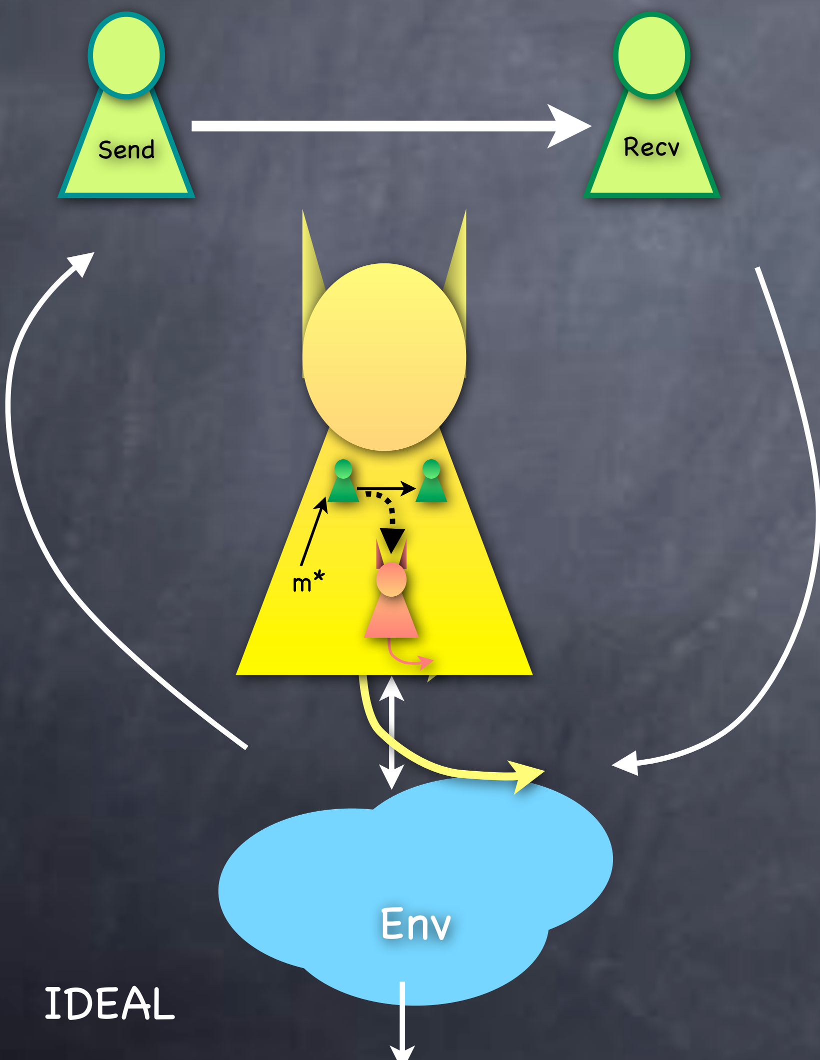

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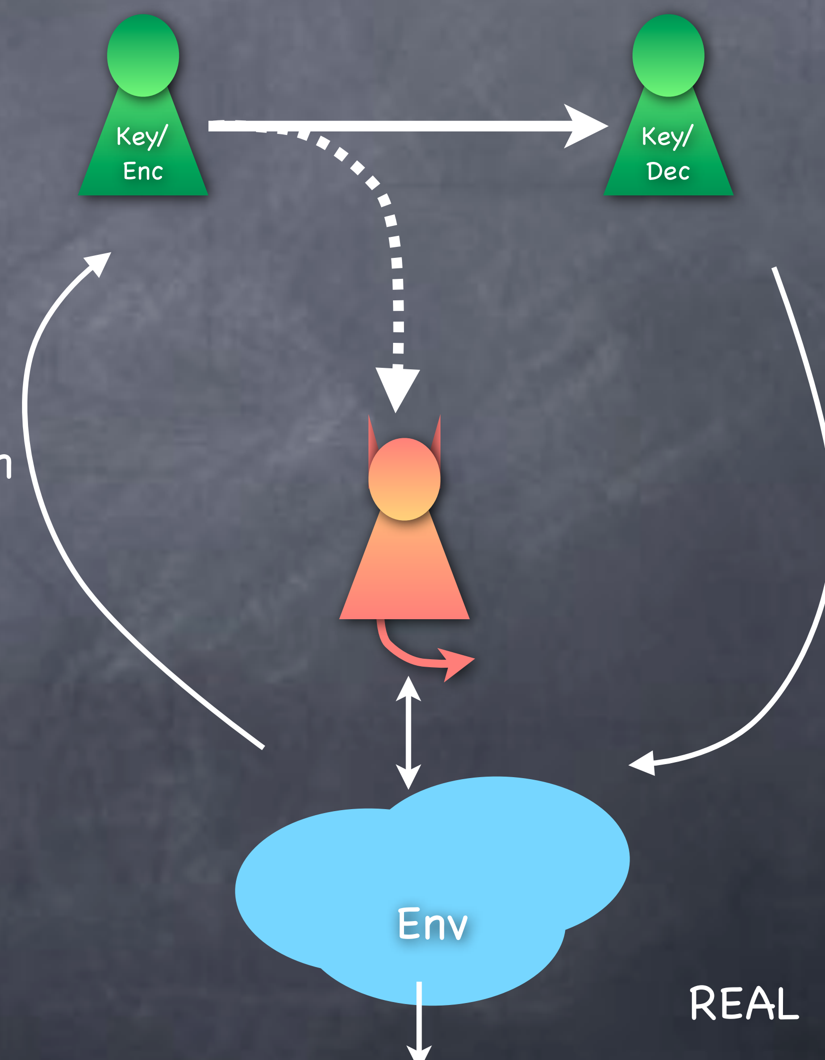
Can show that REAL=IDEAL



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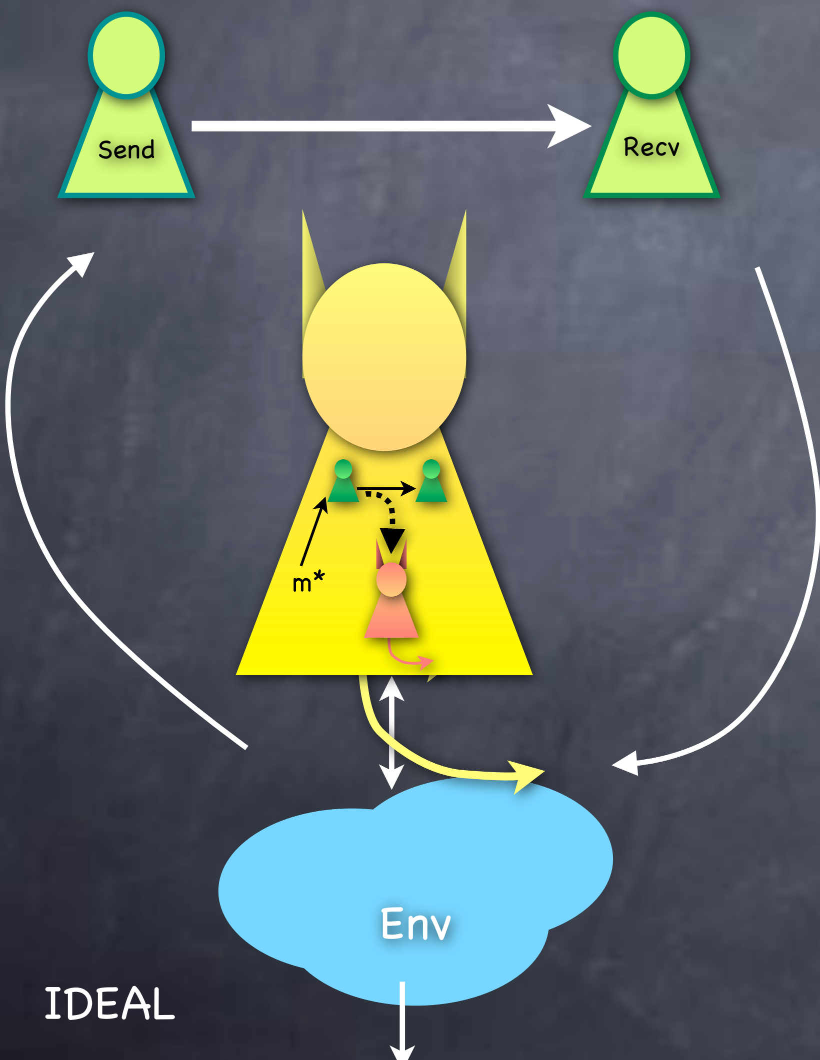

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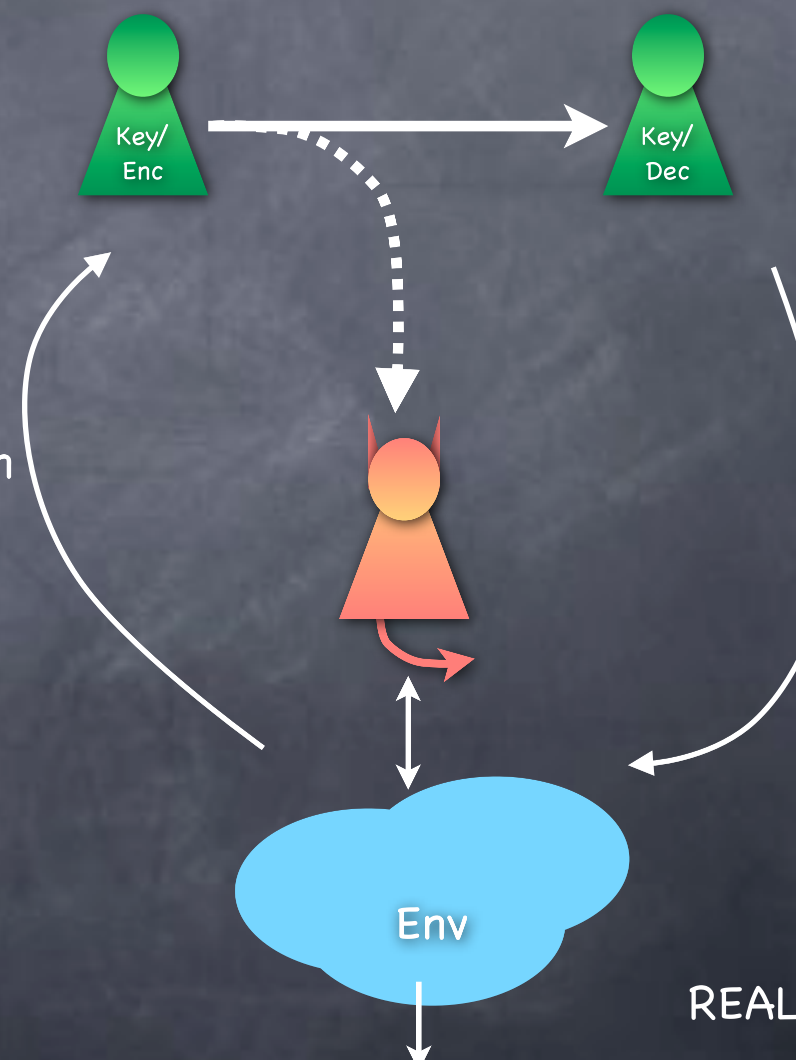
(Consider view of + for both)



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IND-Onetime Security

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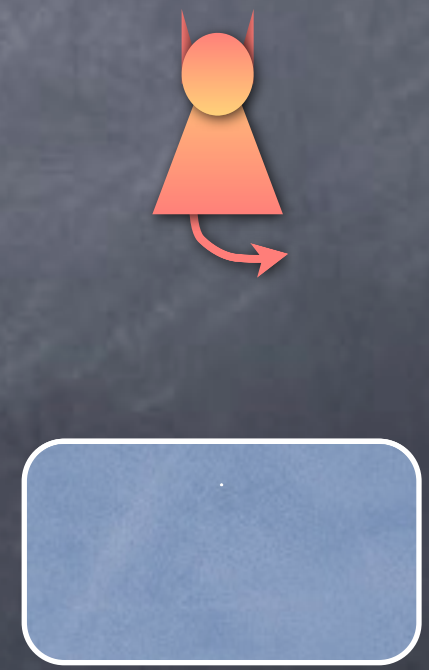

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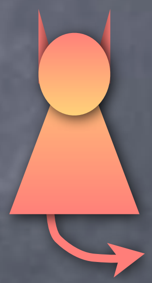

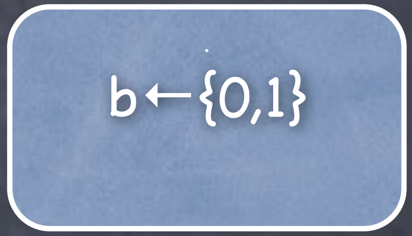

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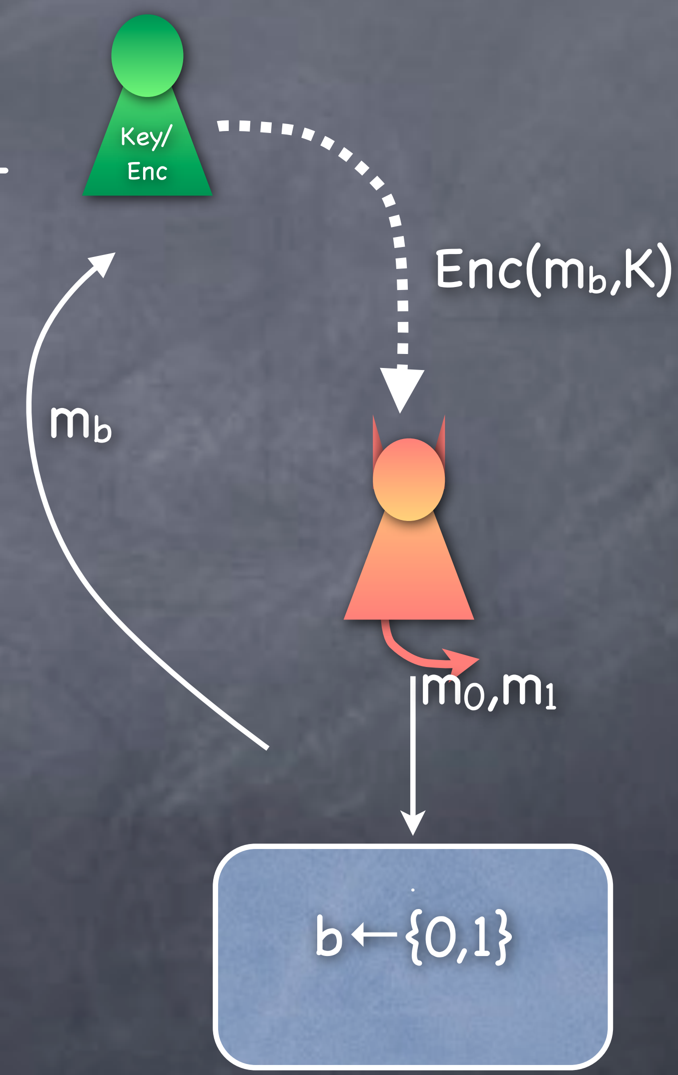

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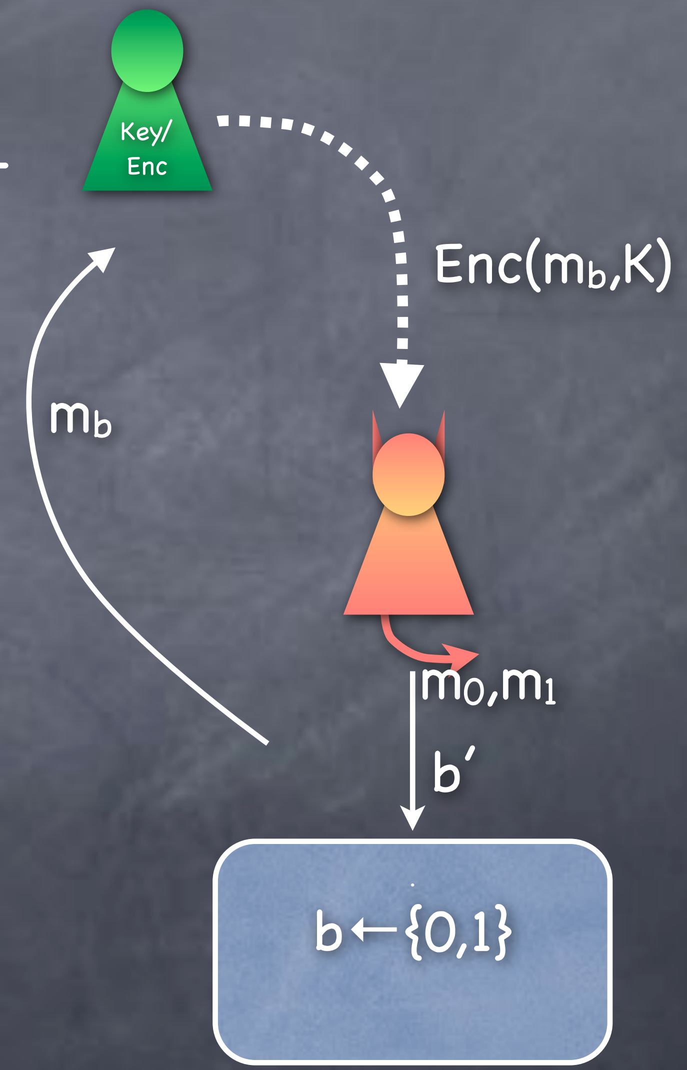

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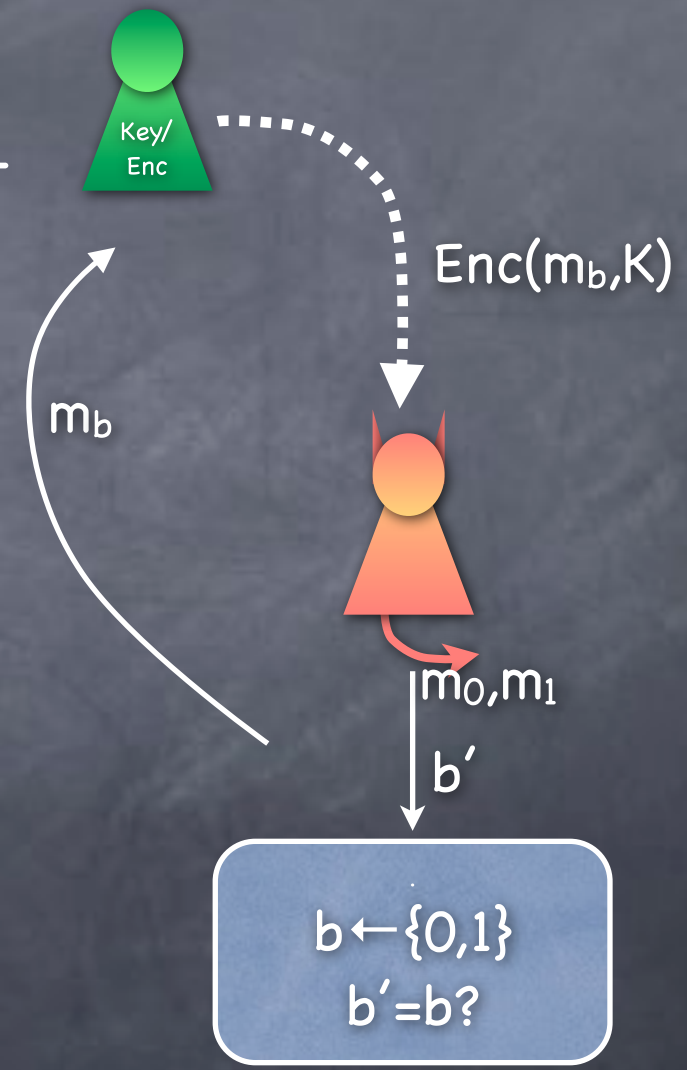

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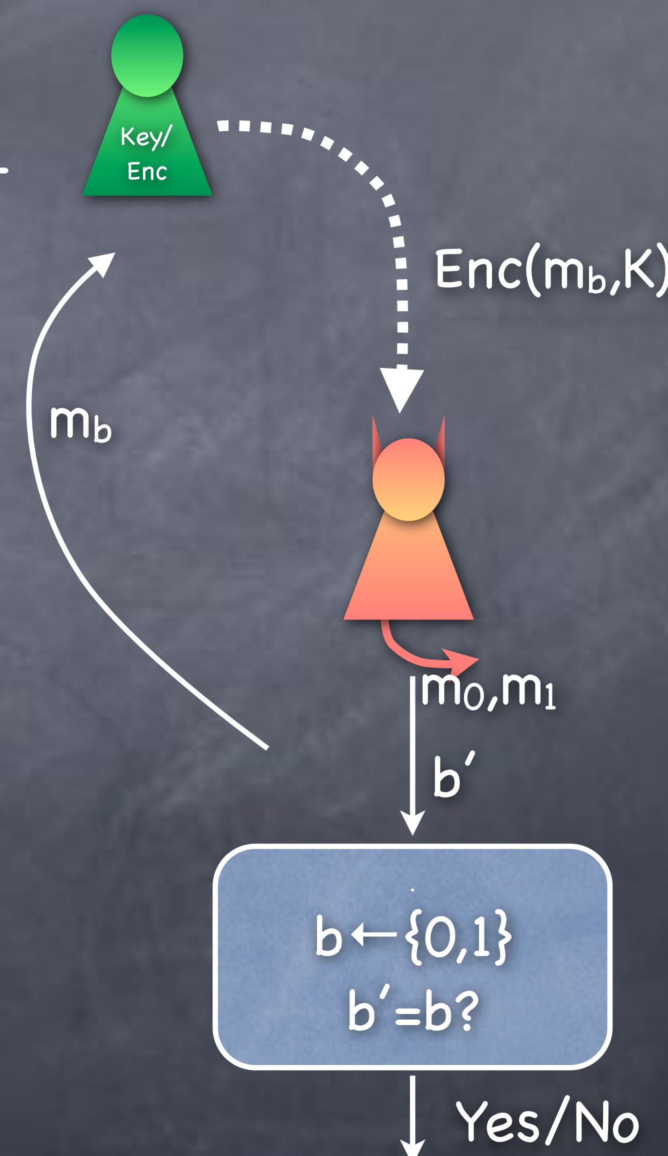

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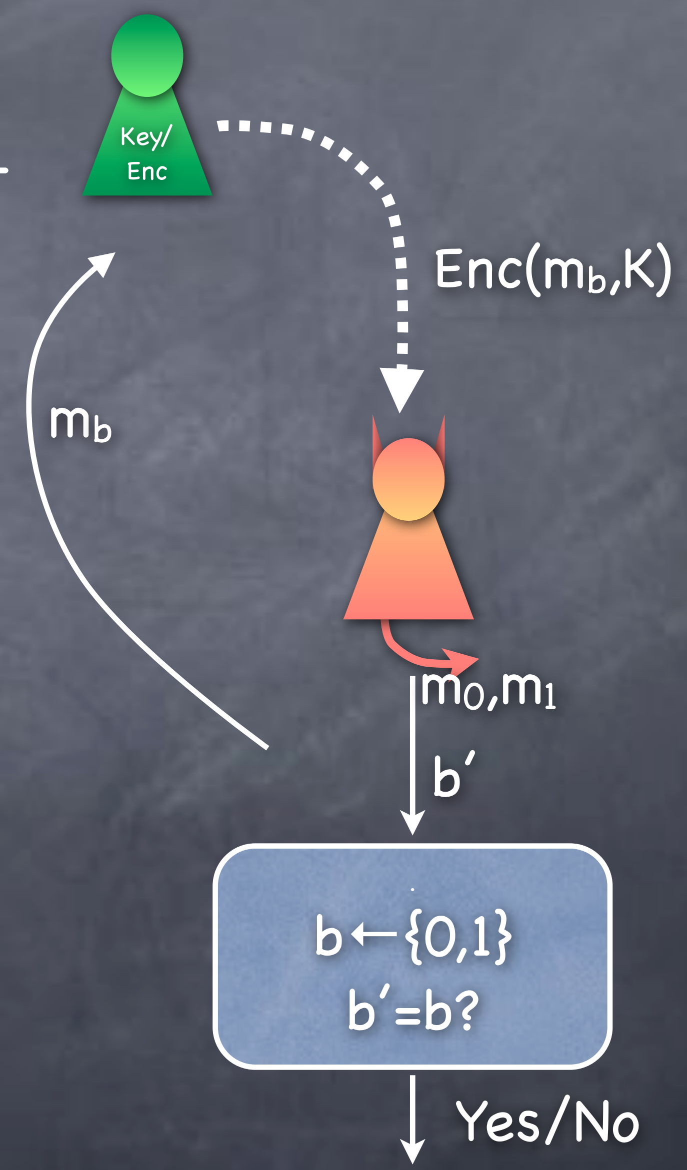

Onetime Encryption

IND-Onetime Security

Equivalent to perfect secrecy

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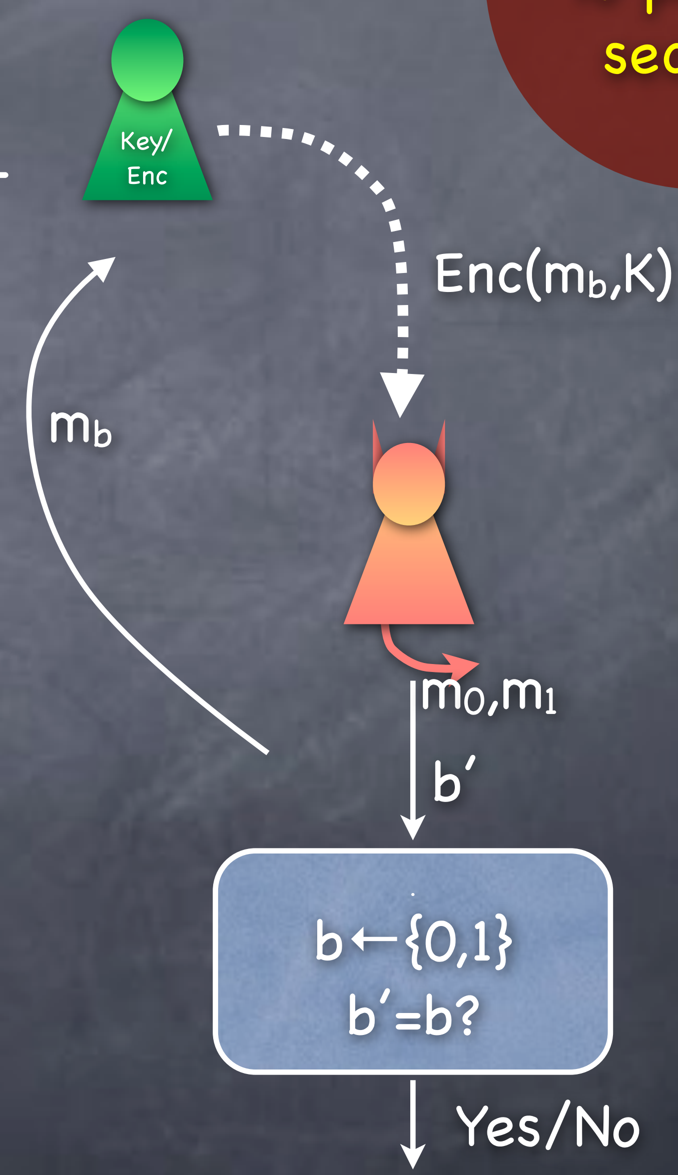

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- Best of both worlds when they are equivalent:
  use IND- definition while say, proving security of a construction;
  use SIM- definition when low-level details are not important