Defining Encryption

Lecture 2

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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- Today: defining encryption

Building the Model

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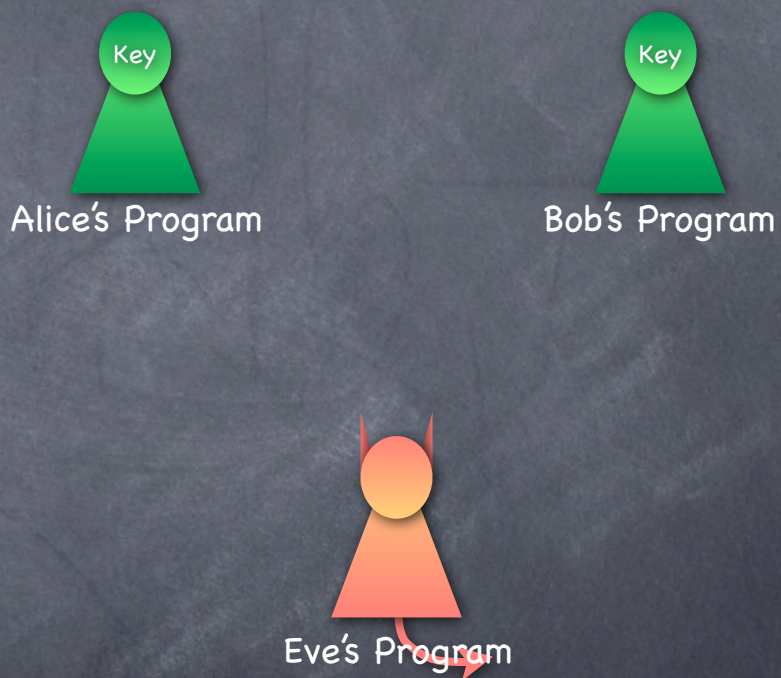
- Alice, Bob and Eve. Alice and Bob share a key (a bit string)



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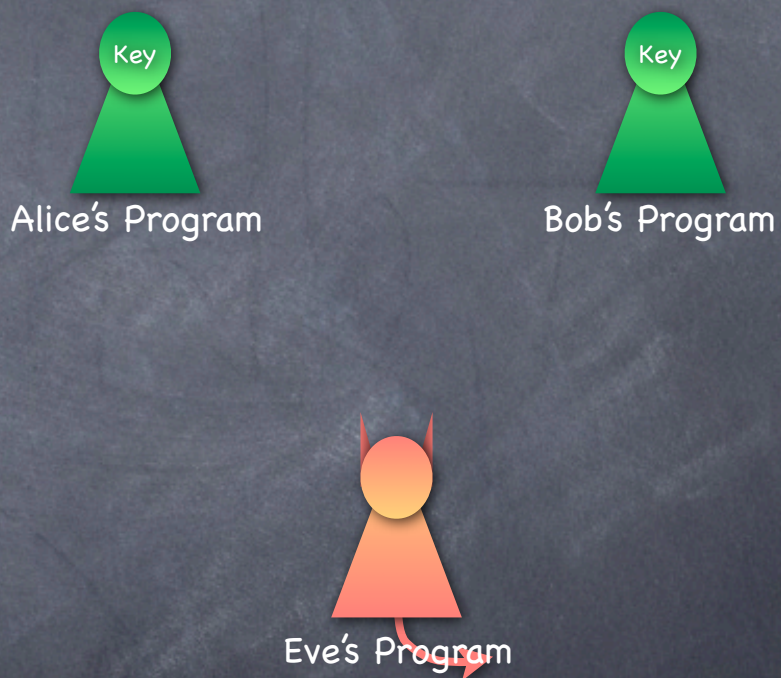
- Alice wants Bob to learn a message, "without Eve learning it"



Building the Model

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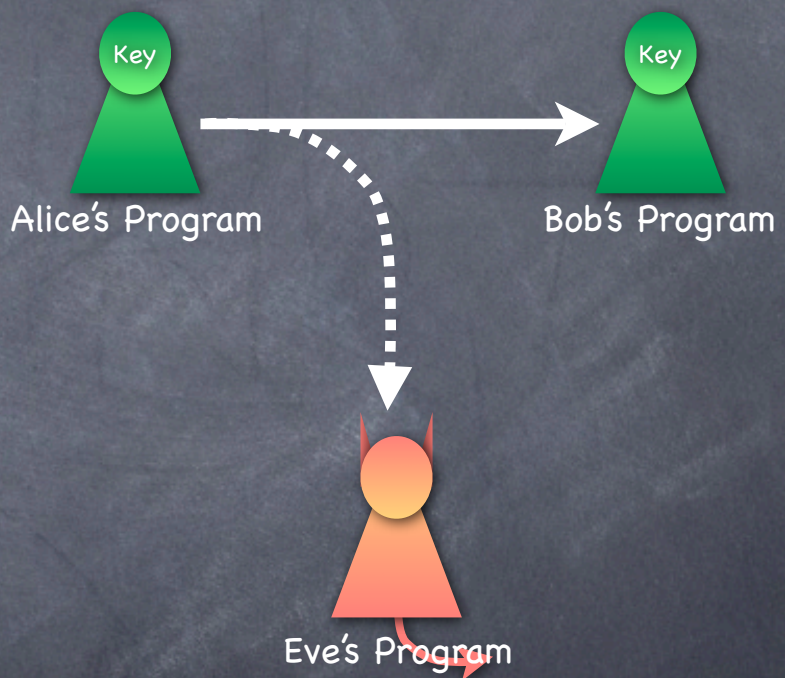
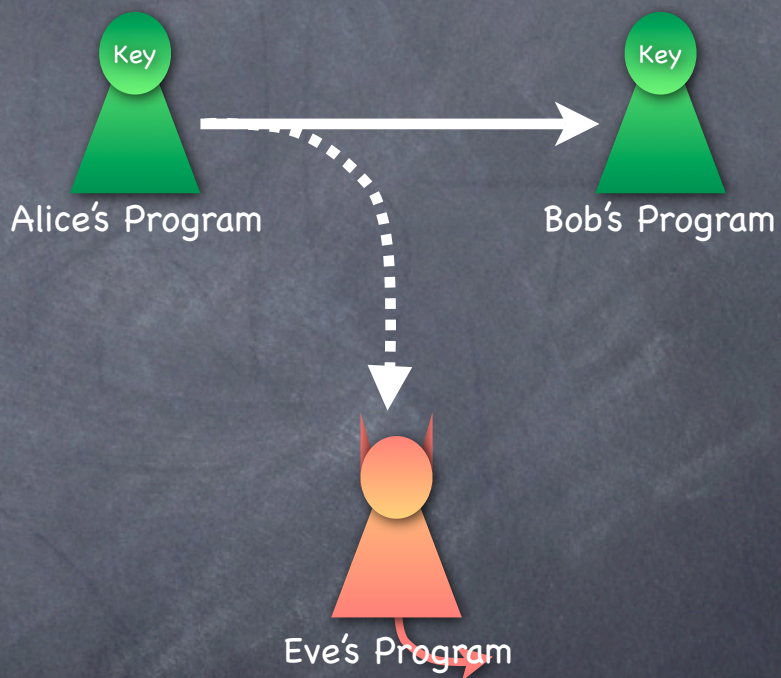
- Alice can send out a bit string on the channel. Bob and Eve both get it



Encryption: Syntax



Encryption: Syntax

- Three algorithms
  - Key Generation: What Alice and Bob do a priori, for creating the shared secret key
  - Encryption: What Alice does with the message and the key to obtain a "ciphertext"
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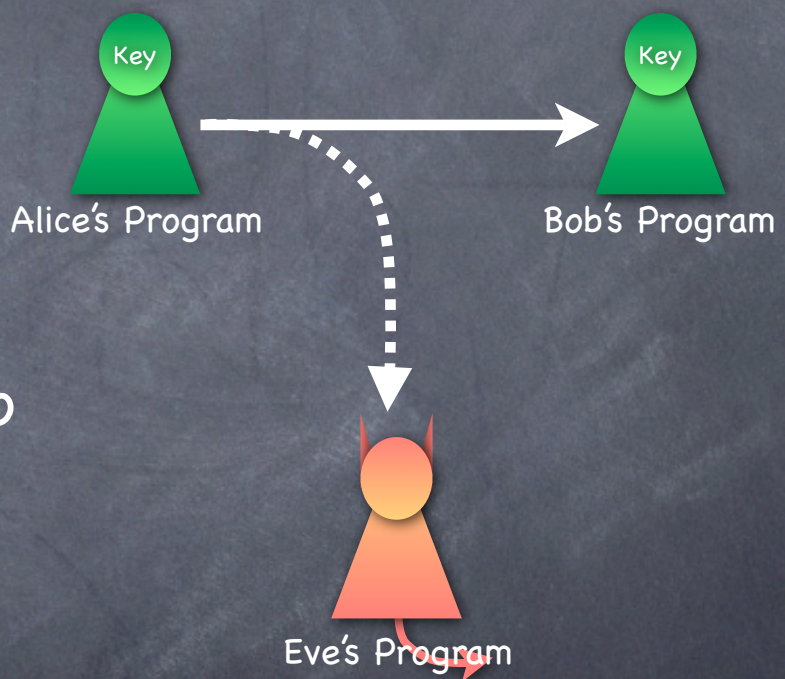

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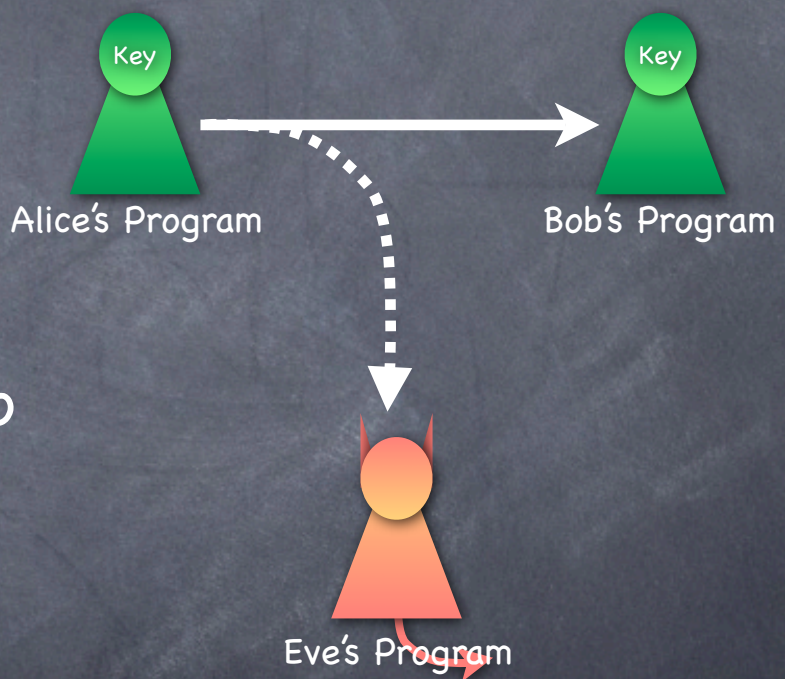
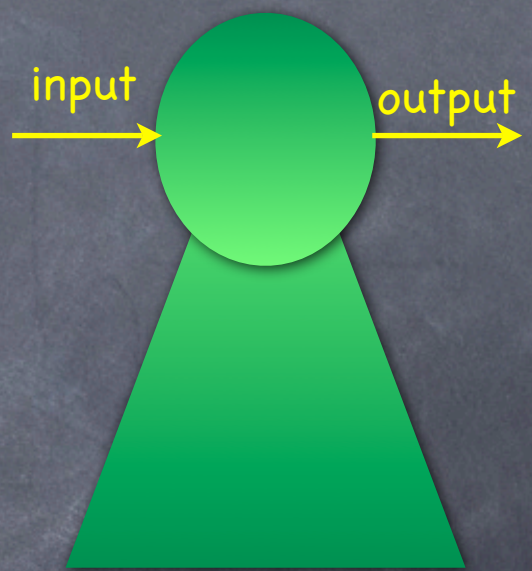
- All of these are (probabilistic) computations



Modeling Computation



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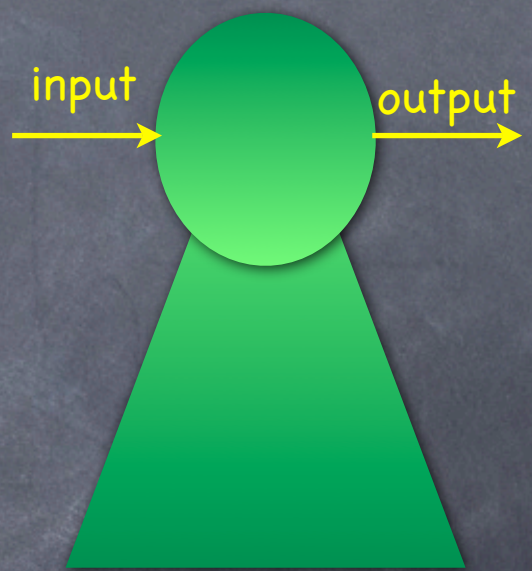

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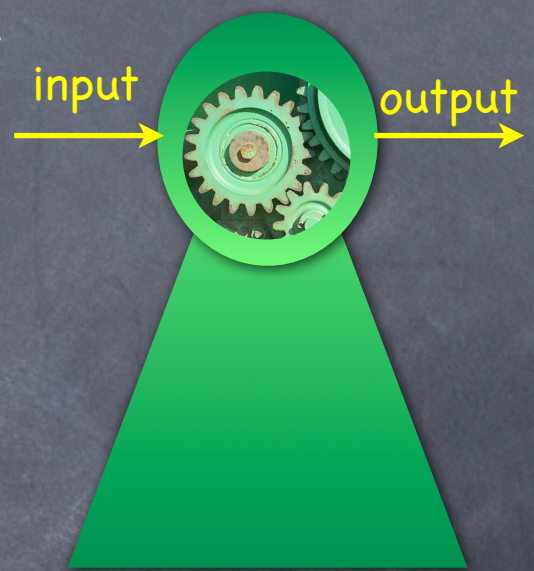

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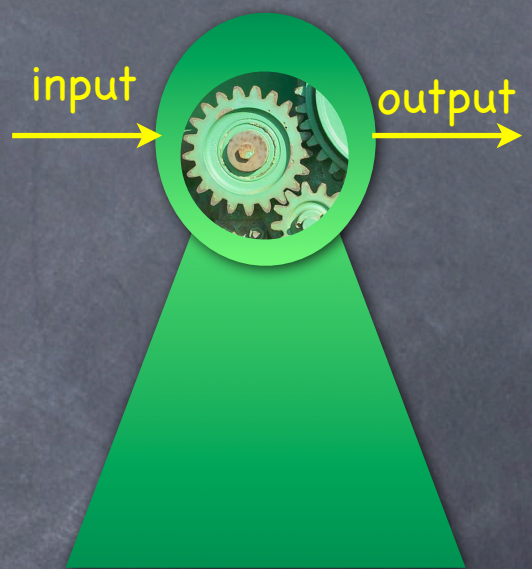

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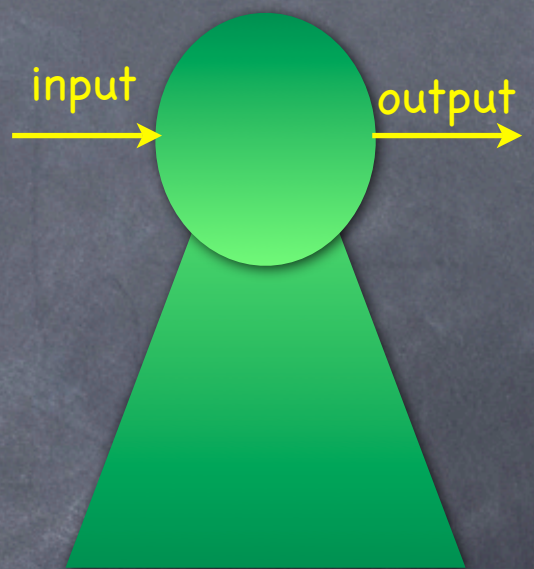

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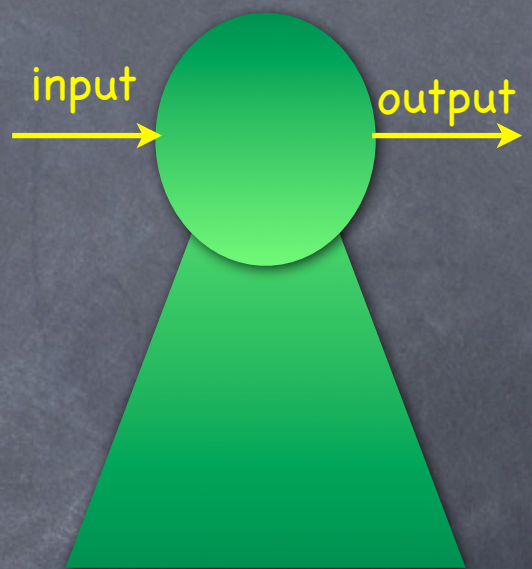

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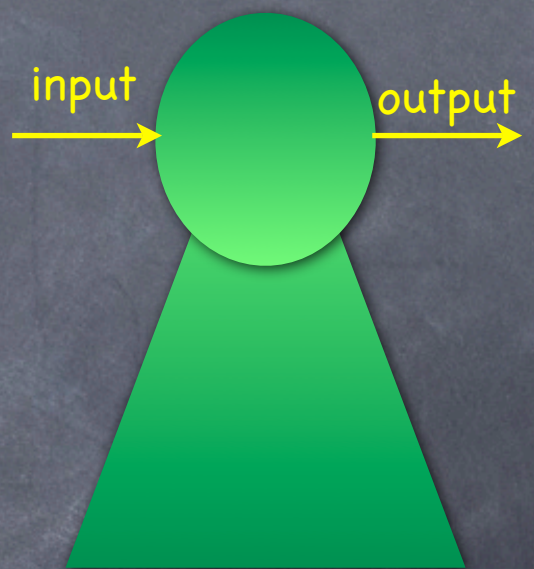

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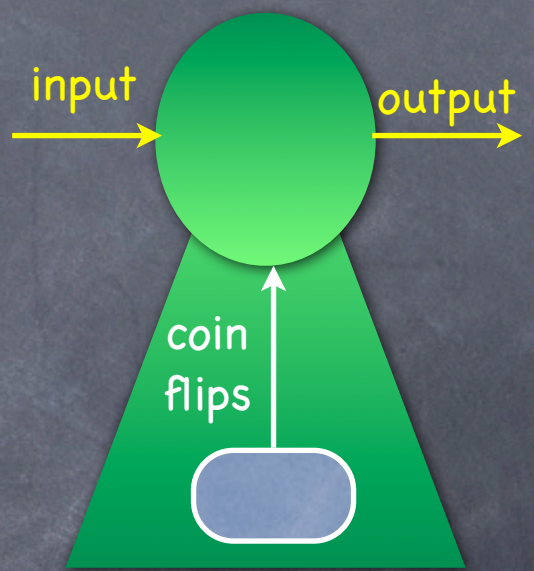

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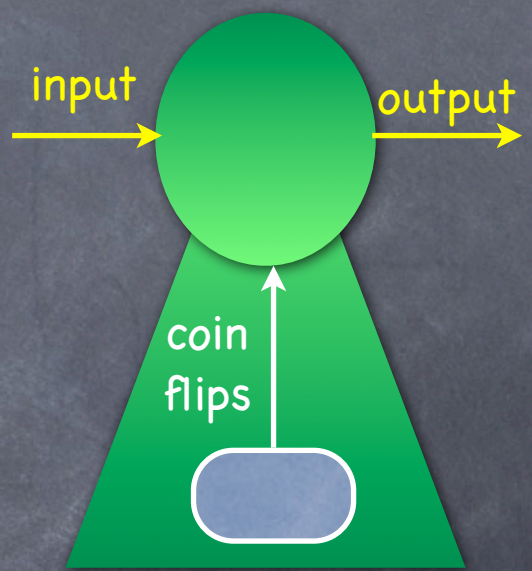

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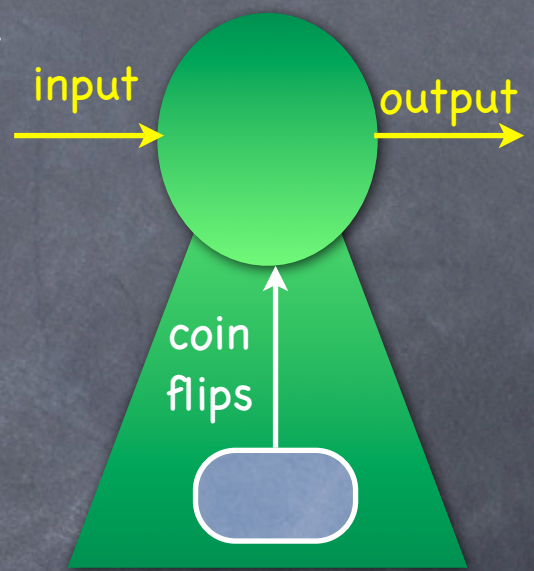

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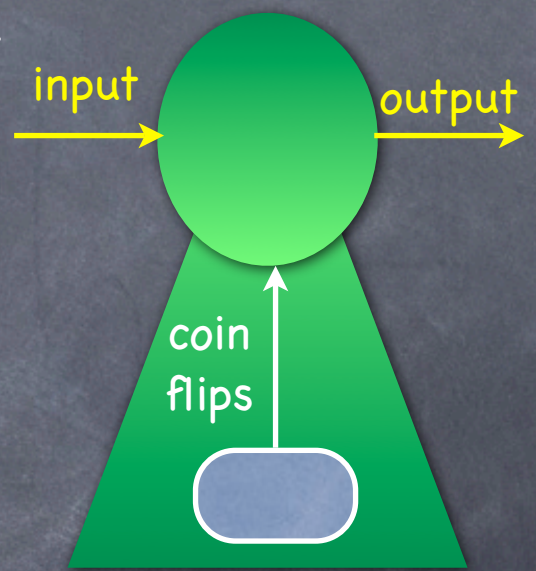

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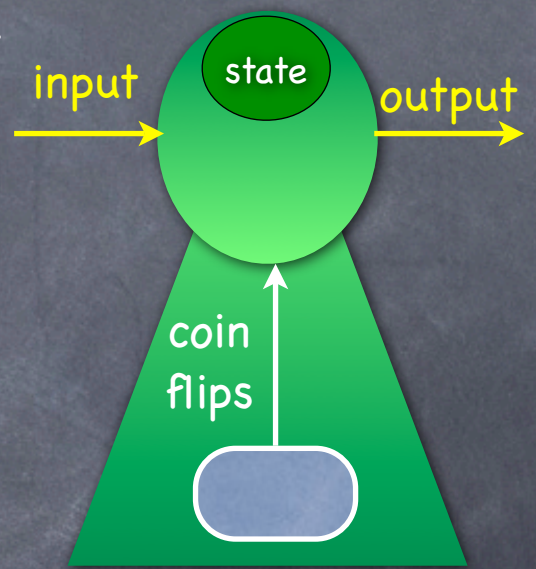

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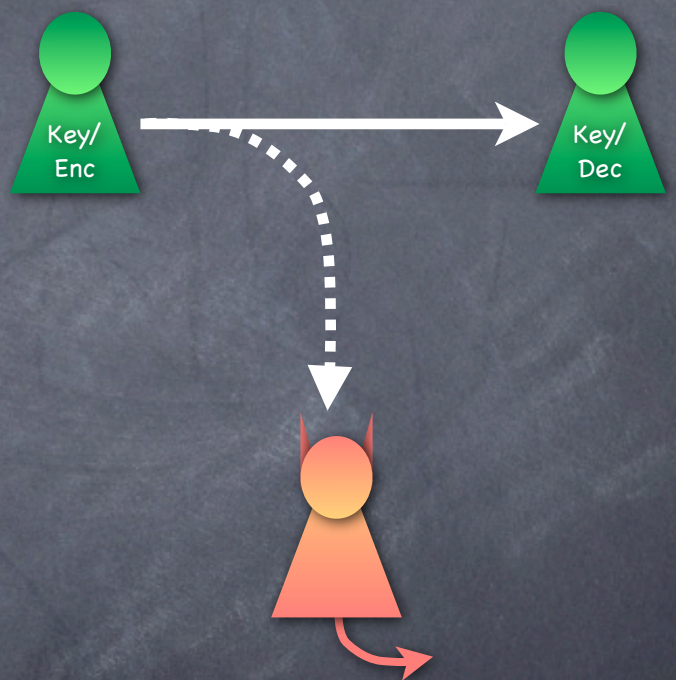

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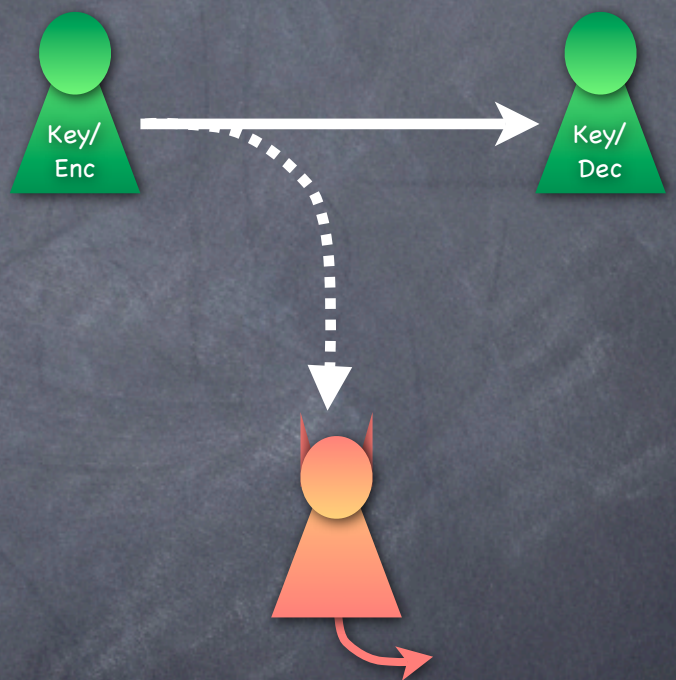

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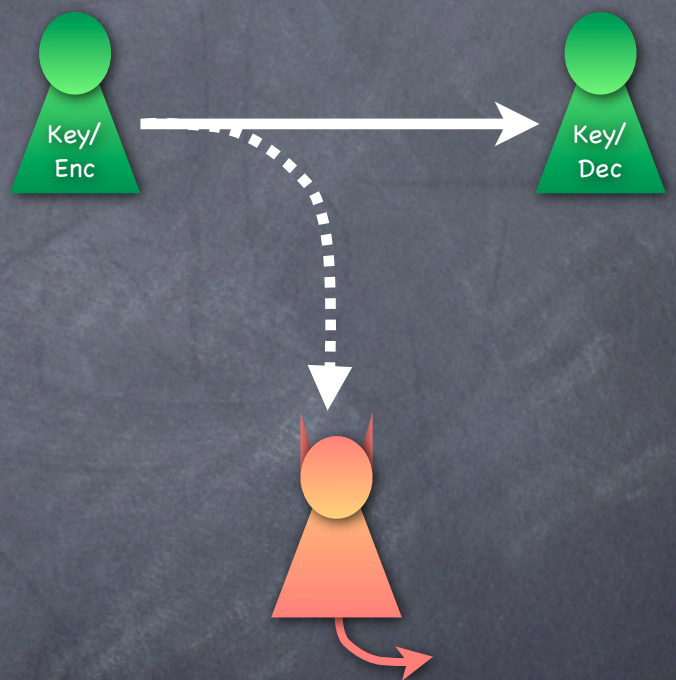

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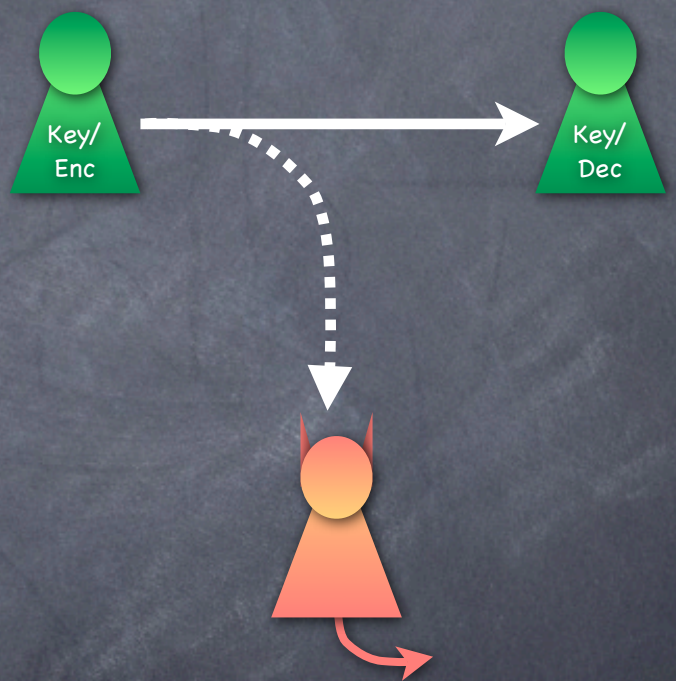

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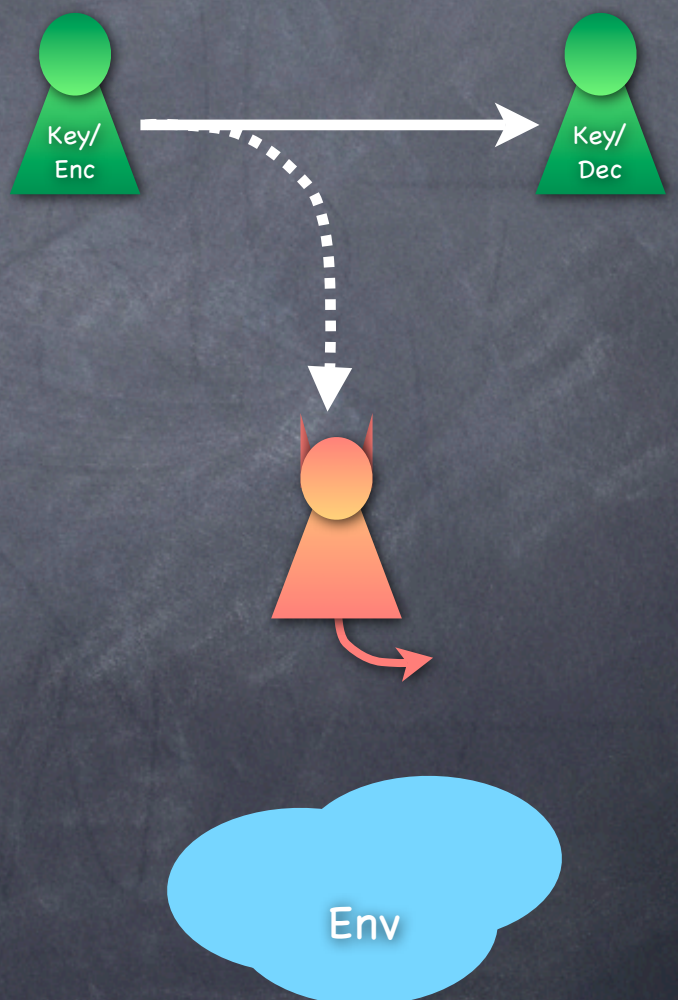

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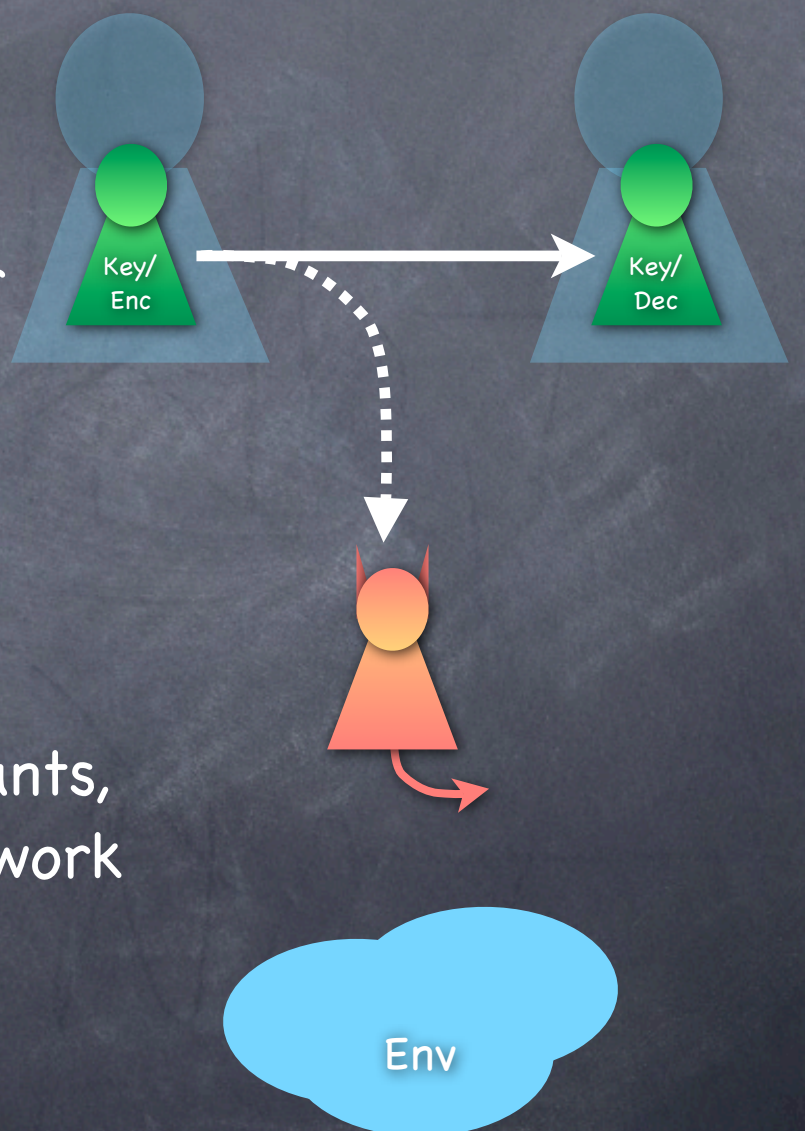

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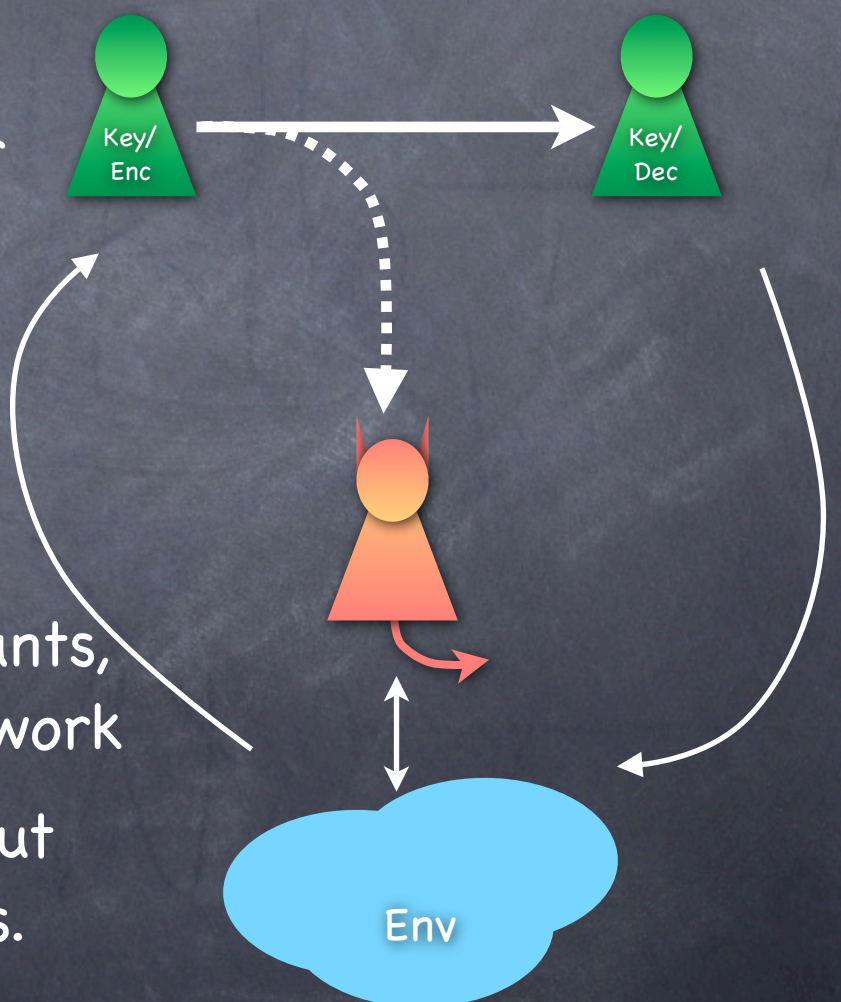
  - Abstract entity from which the input comes and to which the output goes. Arbitrarily influenced by Eve



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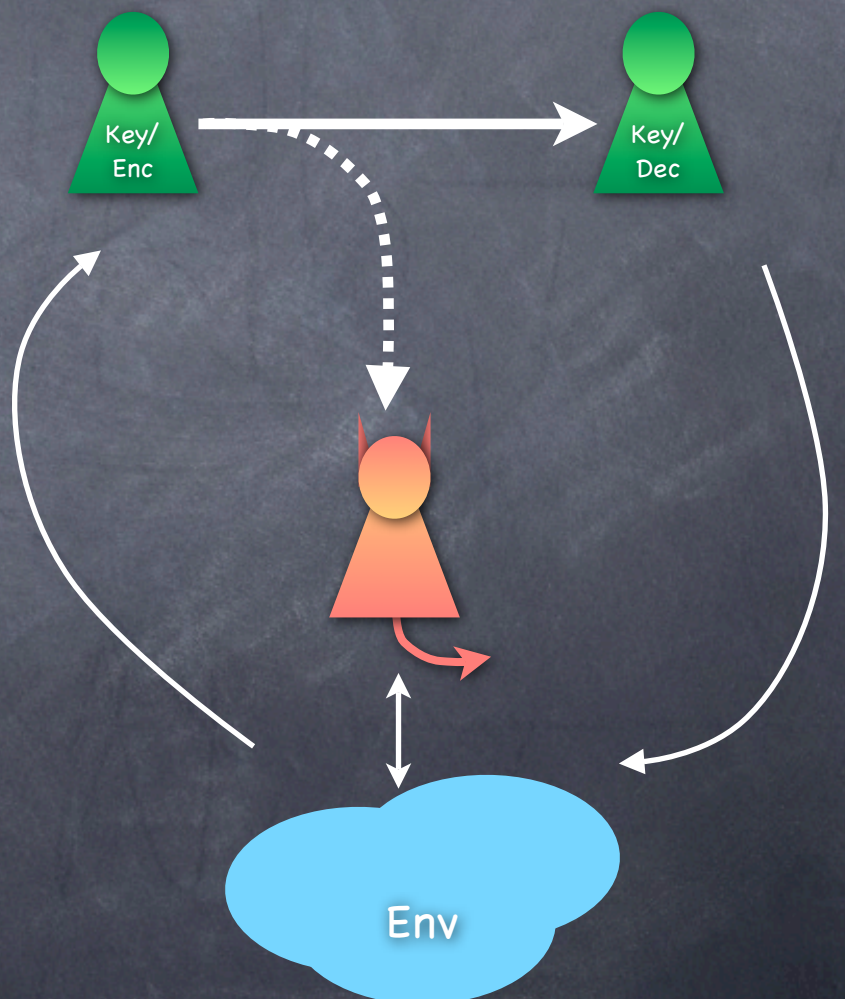
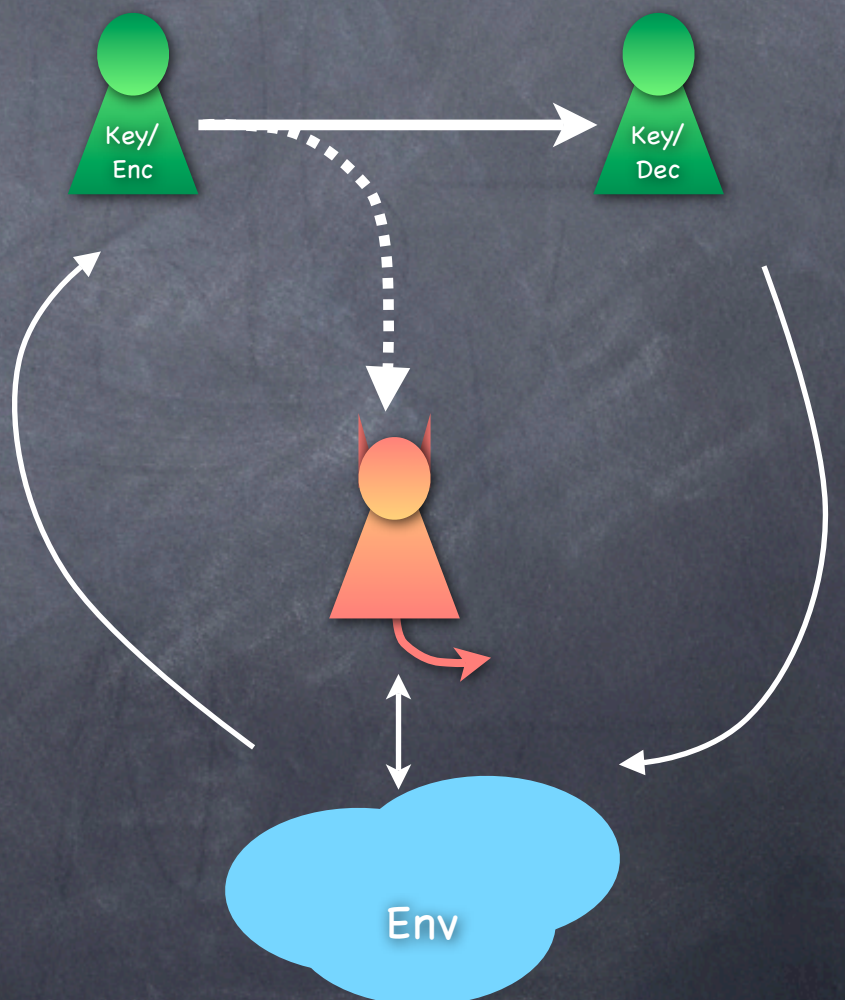


Defining Security

- Eve shouldn't be able to produce any "bad effects" in any environment



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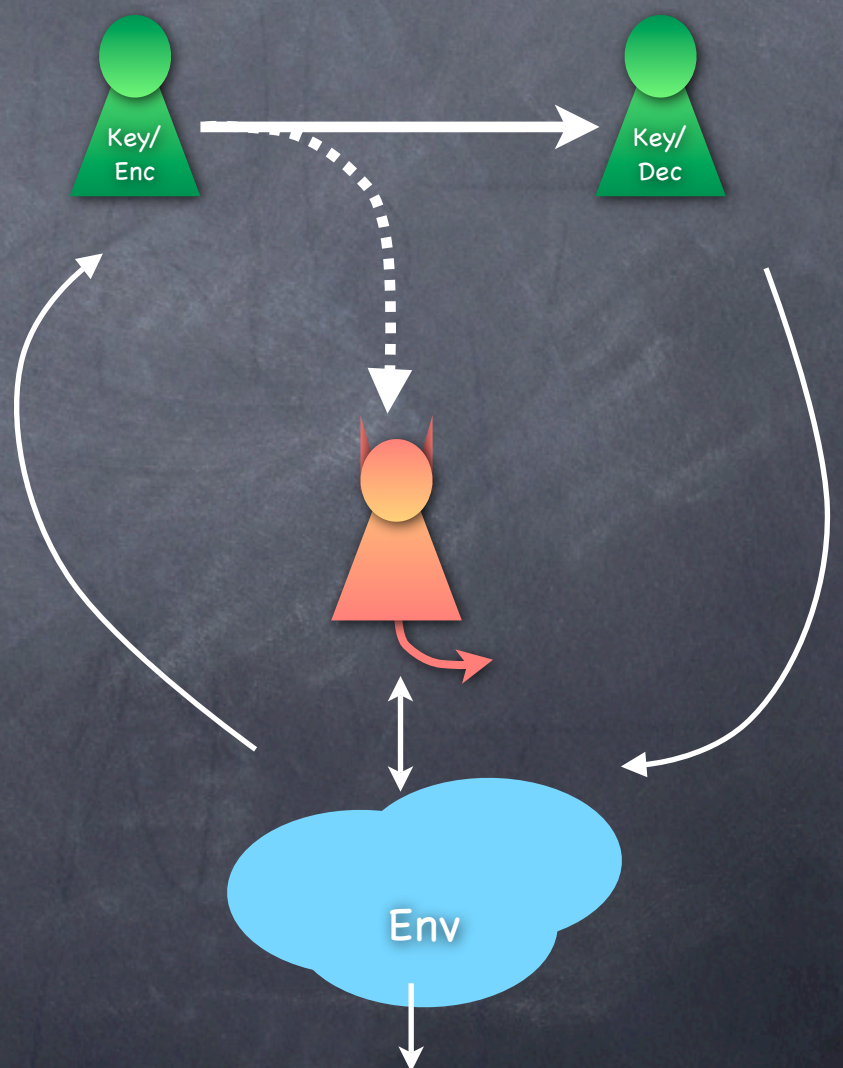

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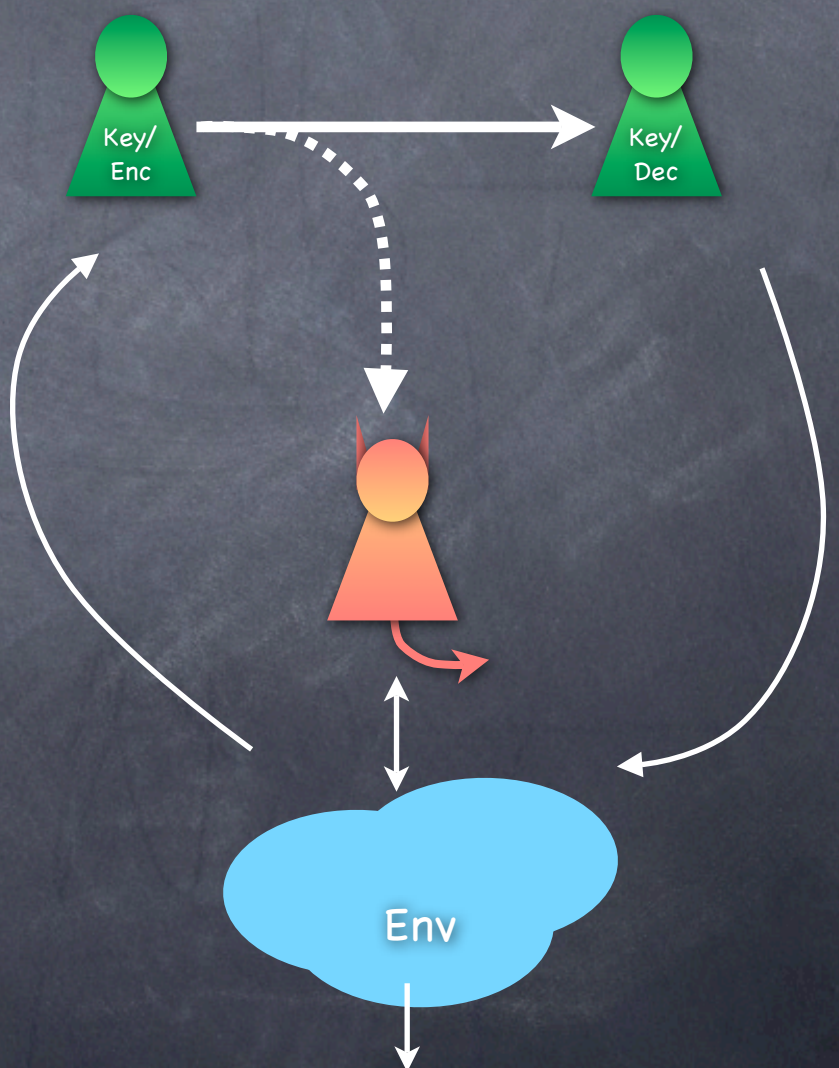

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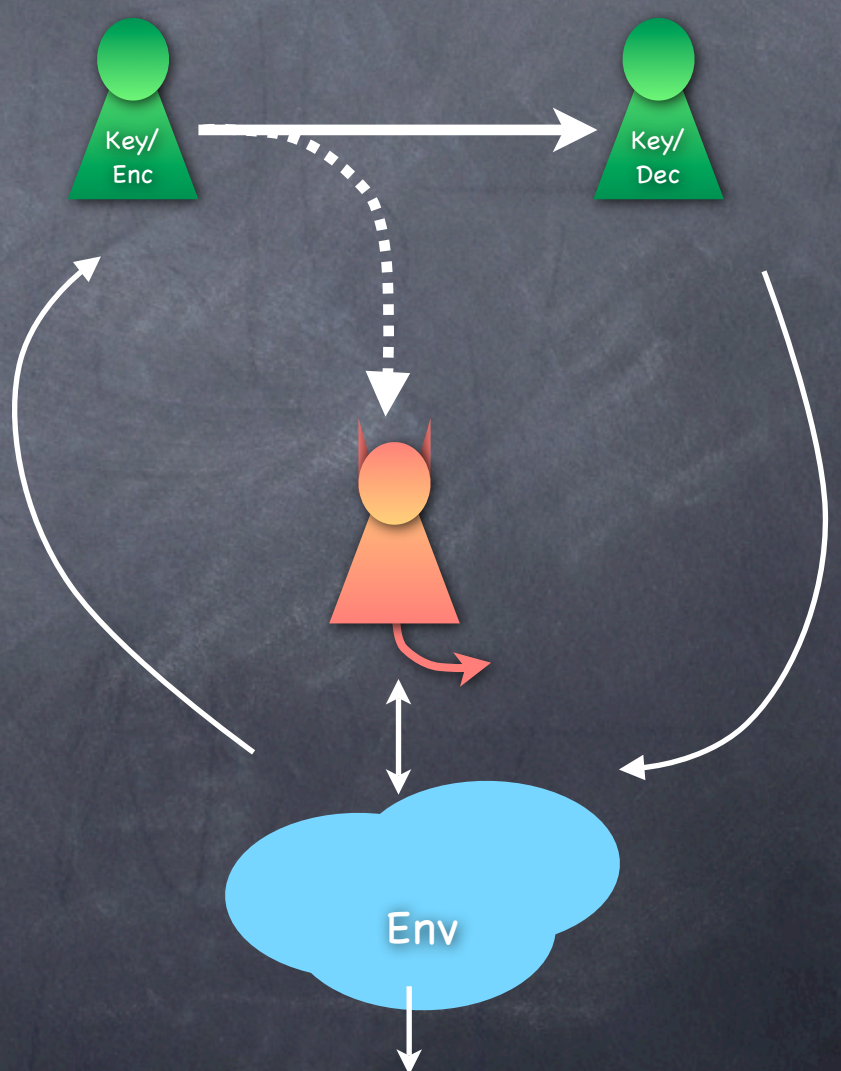
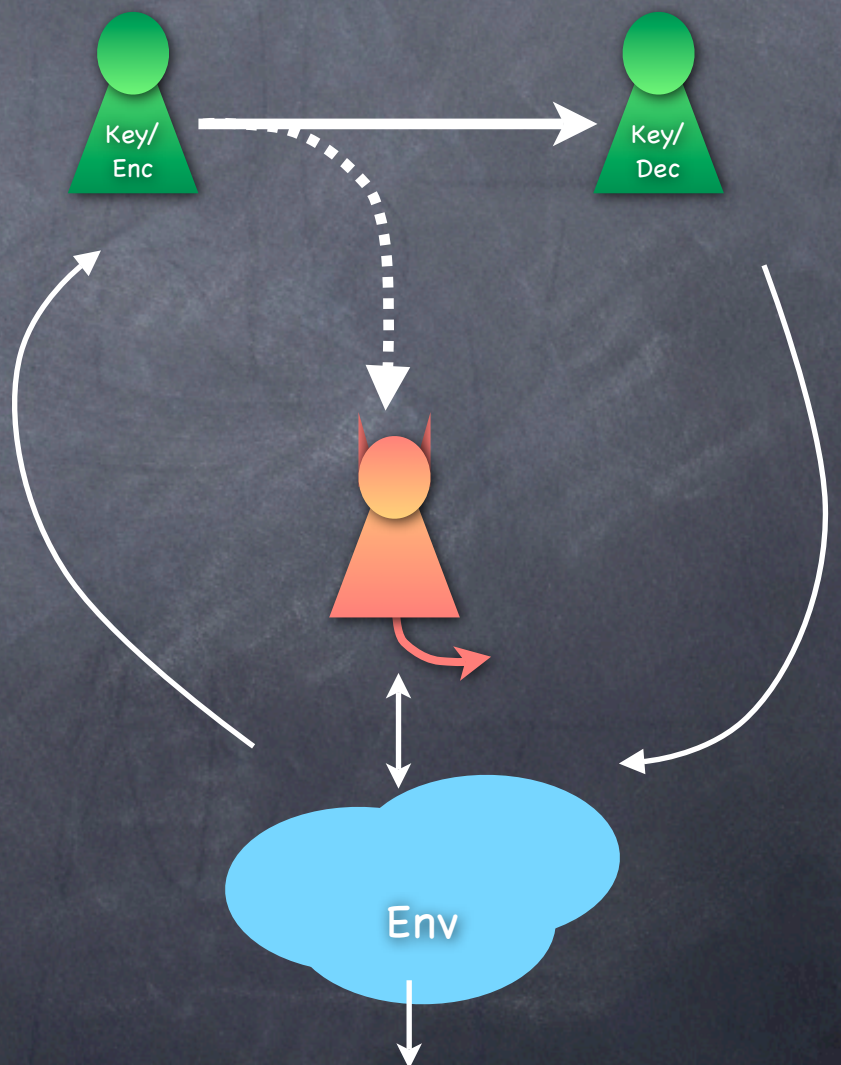
- What is bad?
  - Anything that Eve couldn't have caused if an "ideal channel" was used



Defining Security

The REAL/IDEAL Paradigm



Defining Security

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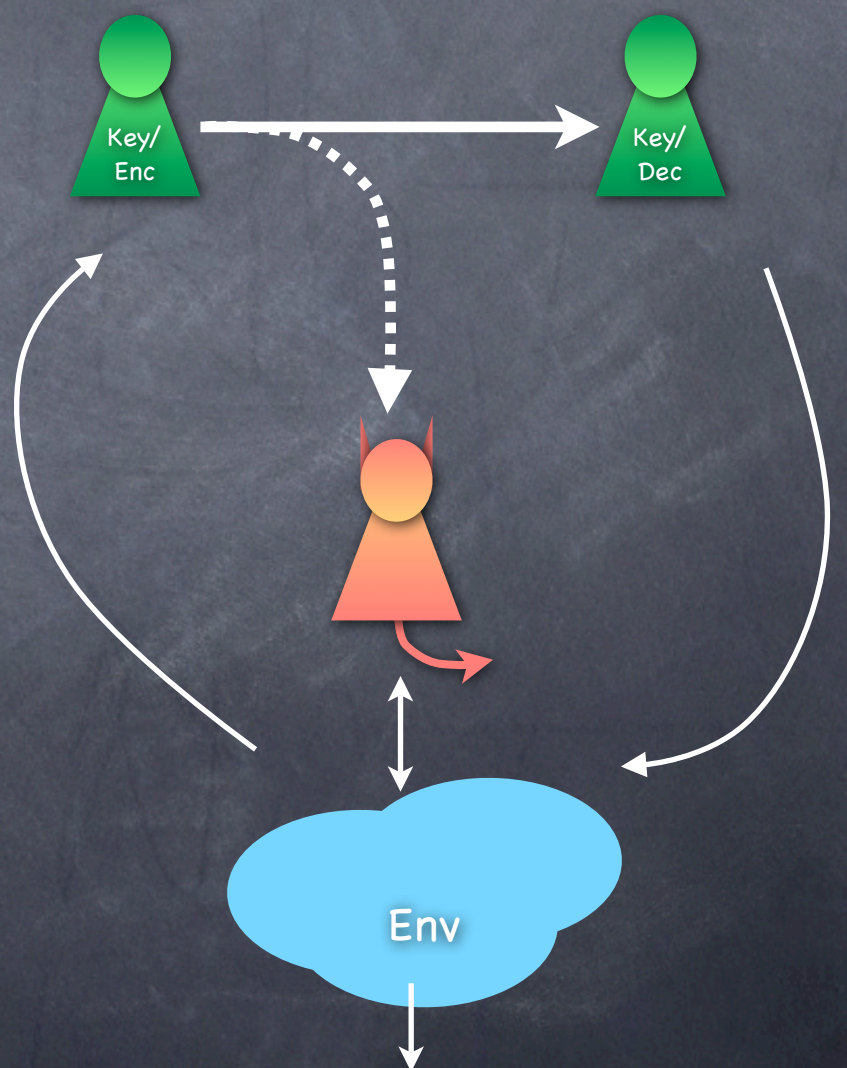

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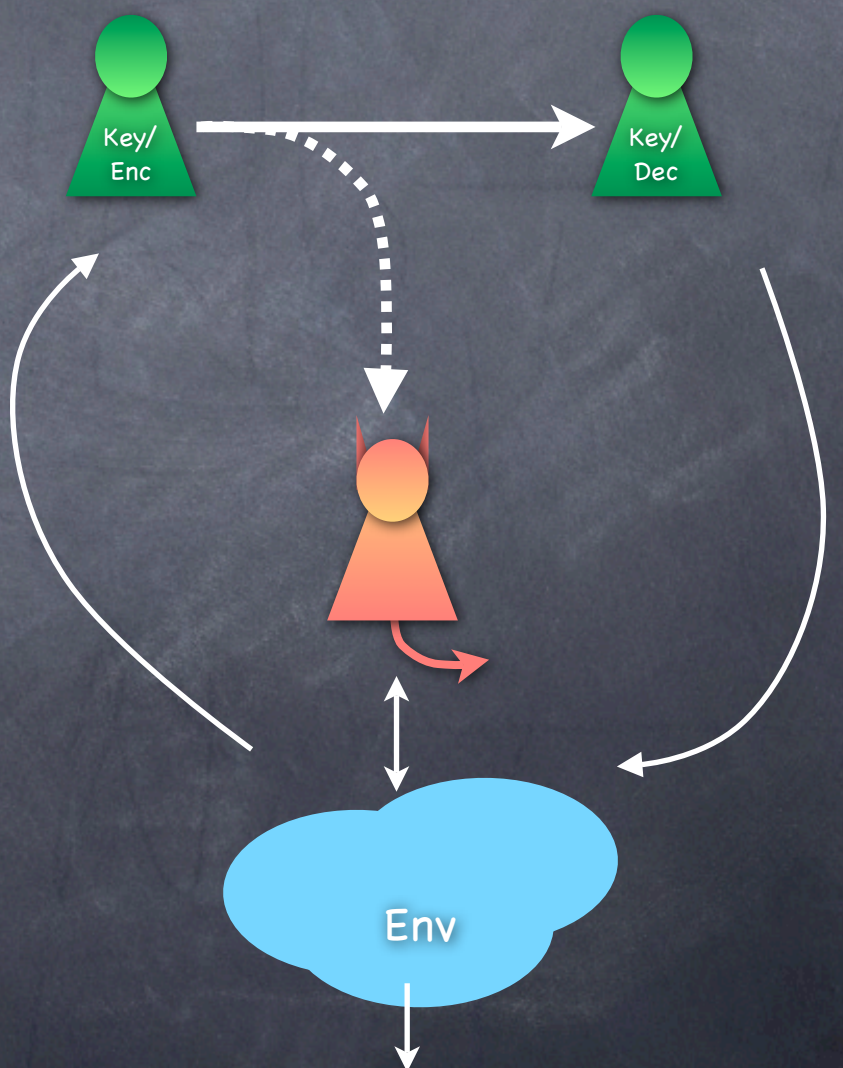

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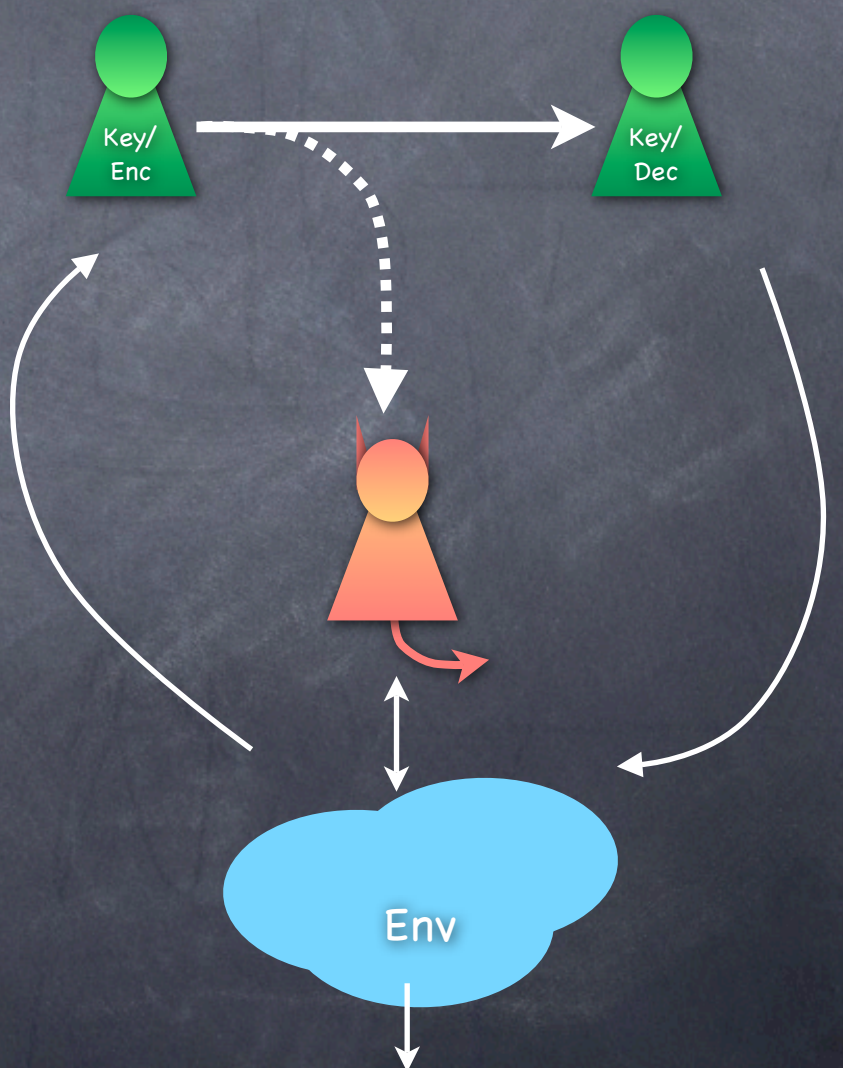

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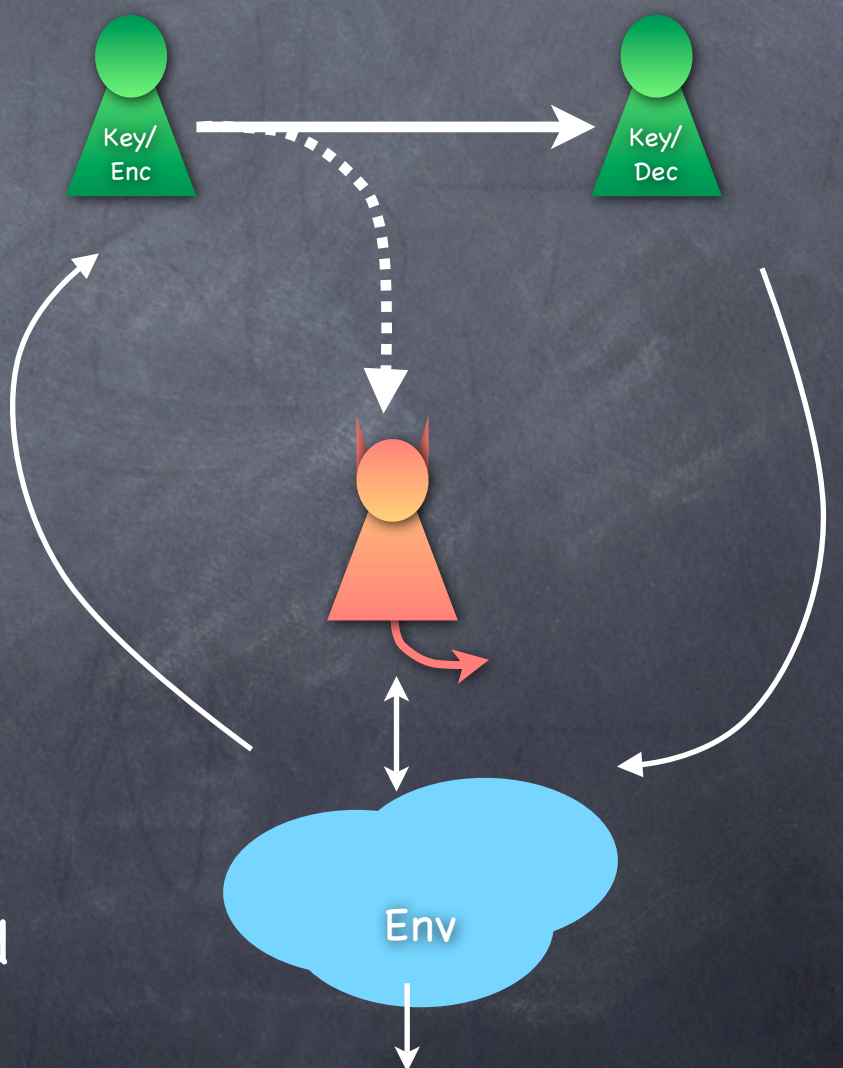
  - REAL world: Using encryption
  - Encryption is secure if whatever an Eve can do in the REAL world, an Eve' can do in the IDEAL world



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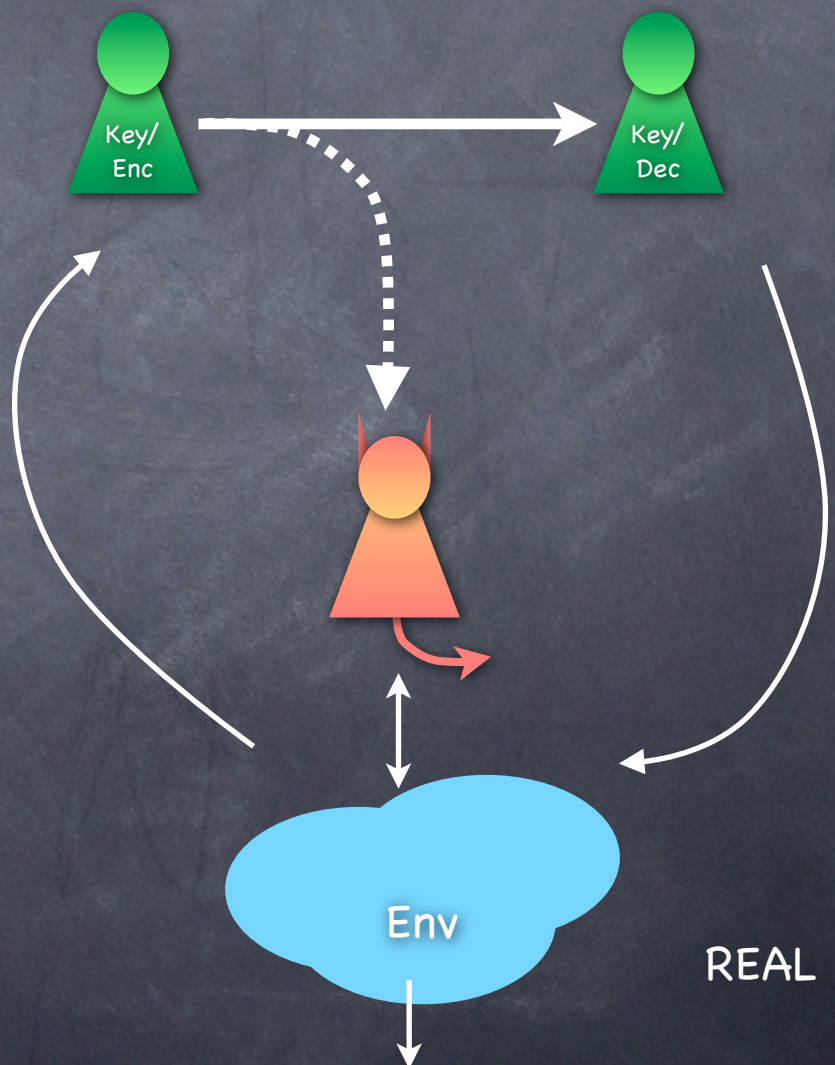

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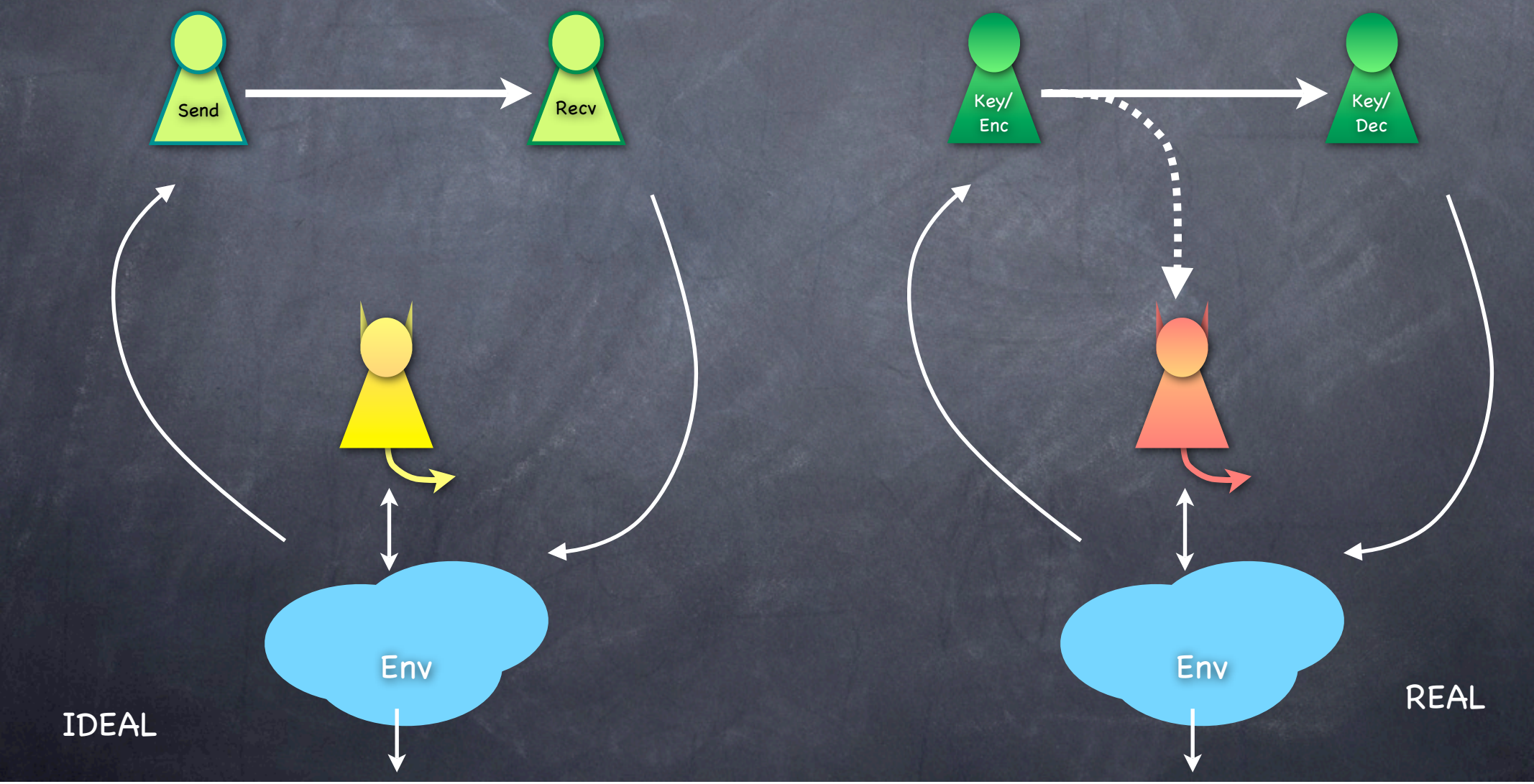

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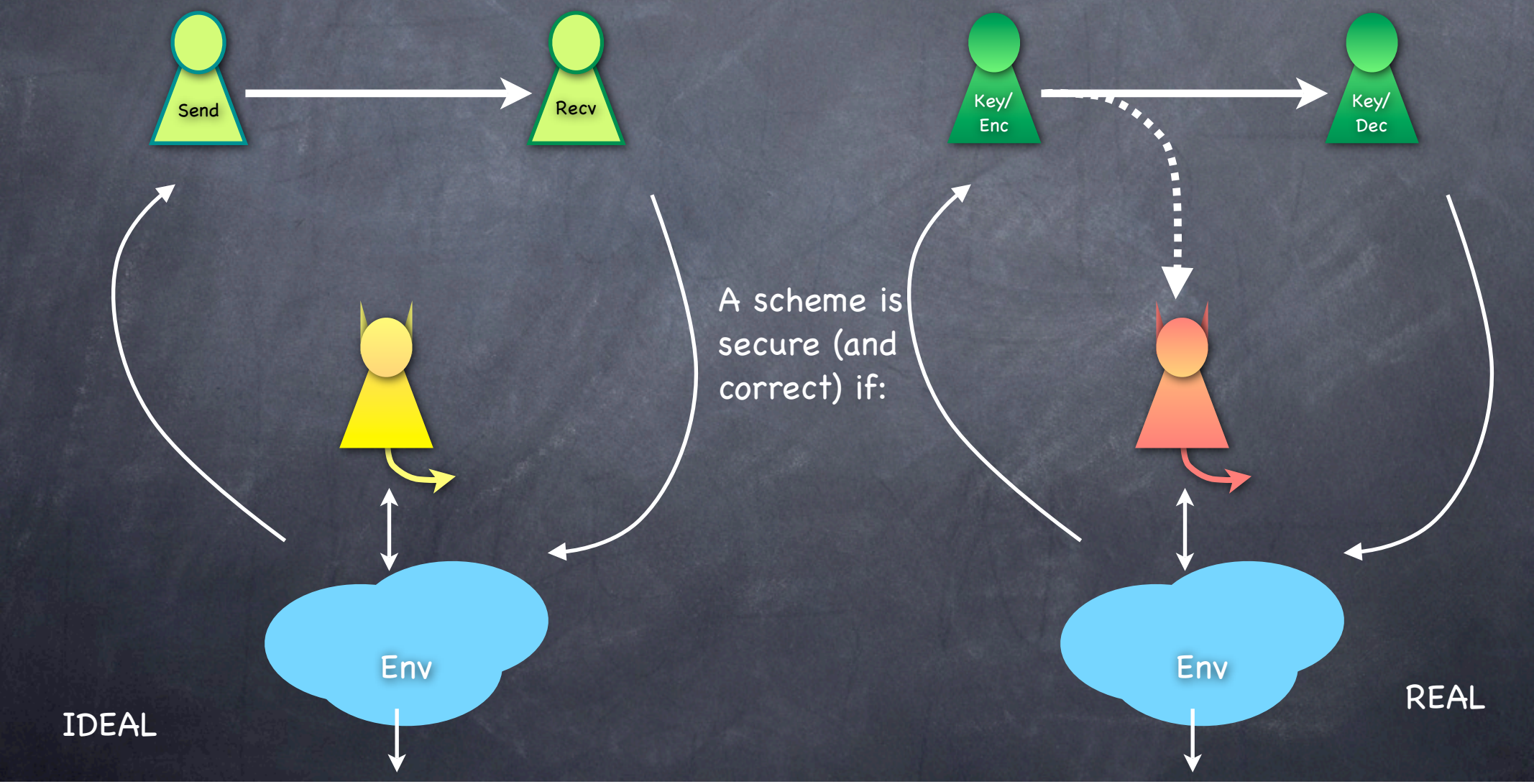

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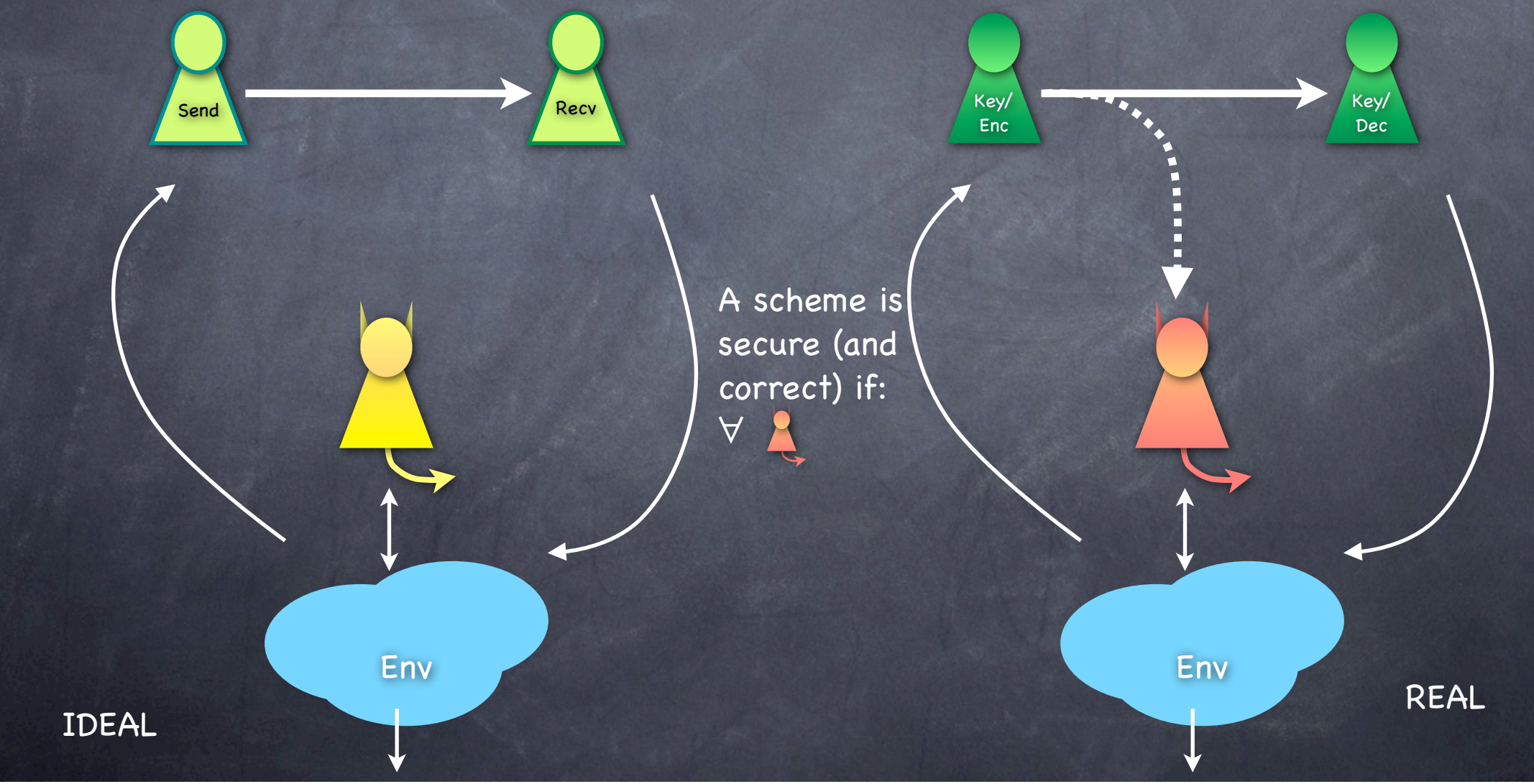

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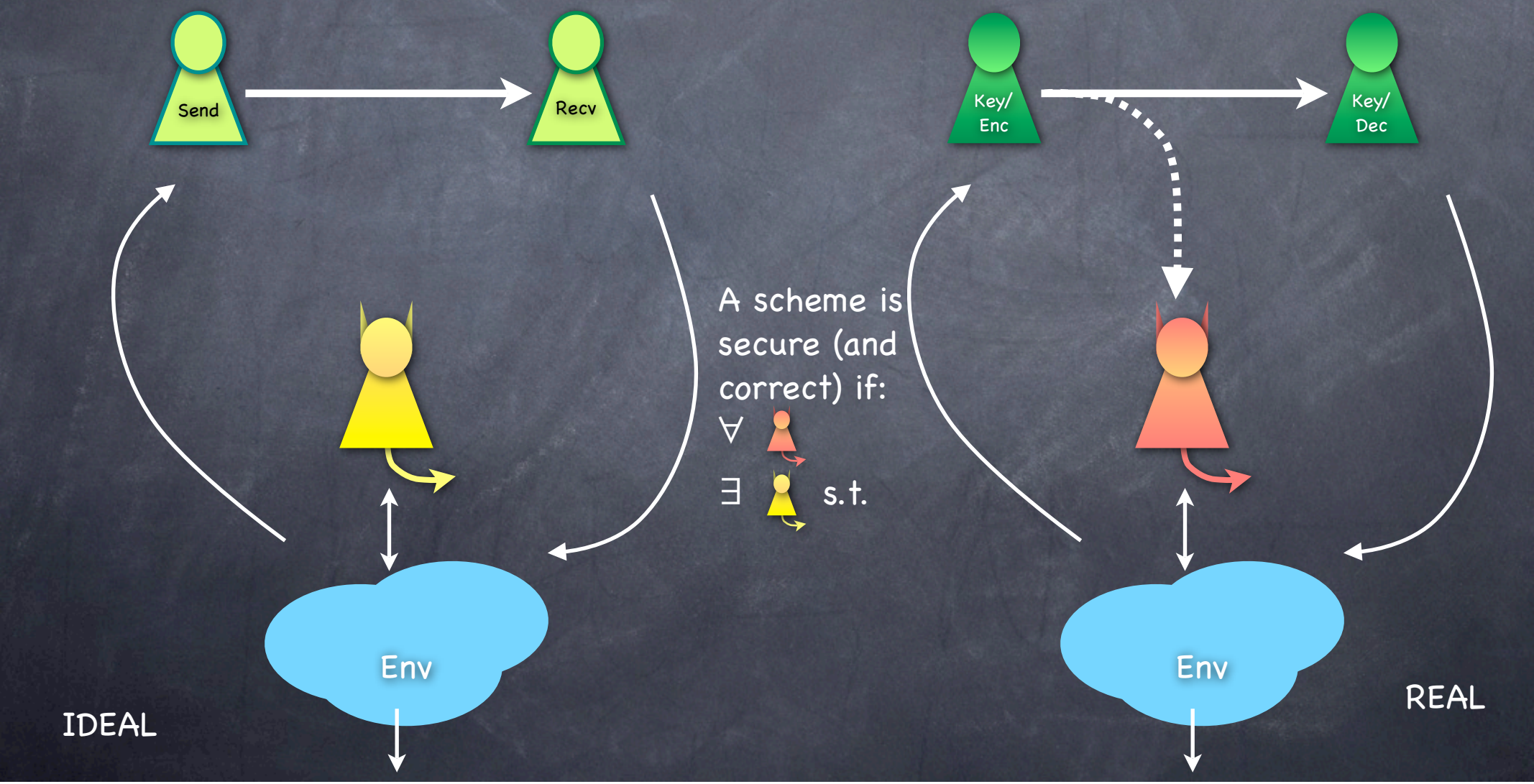

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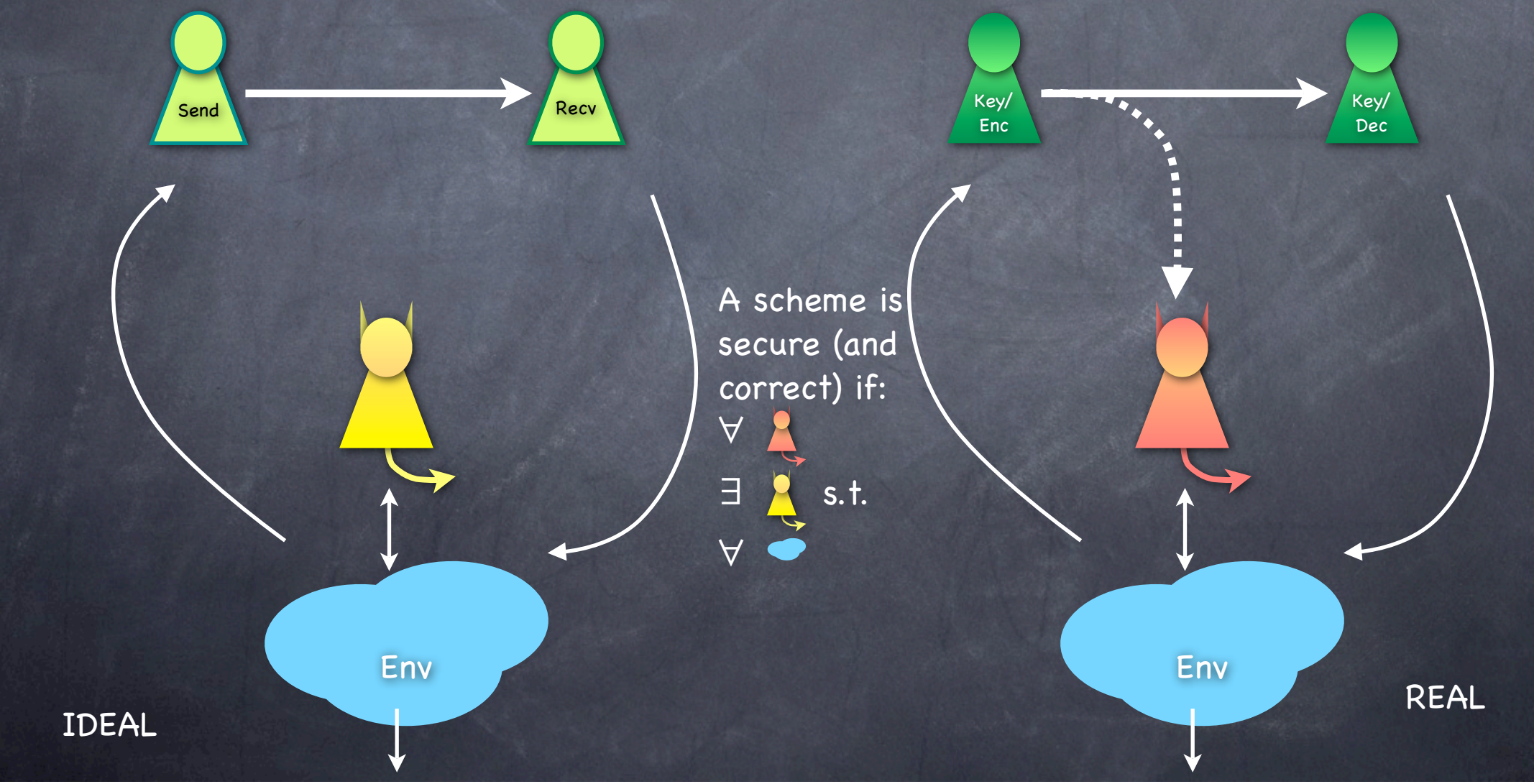

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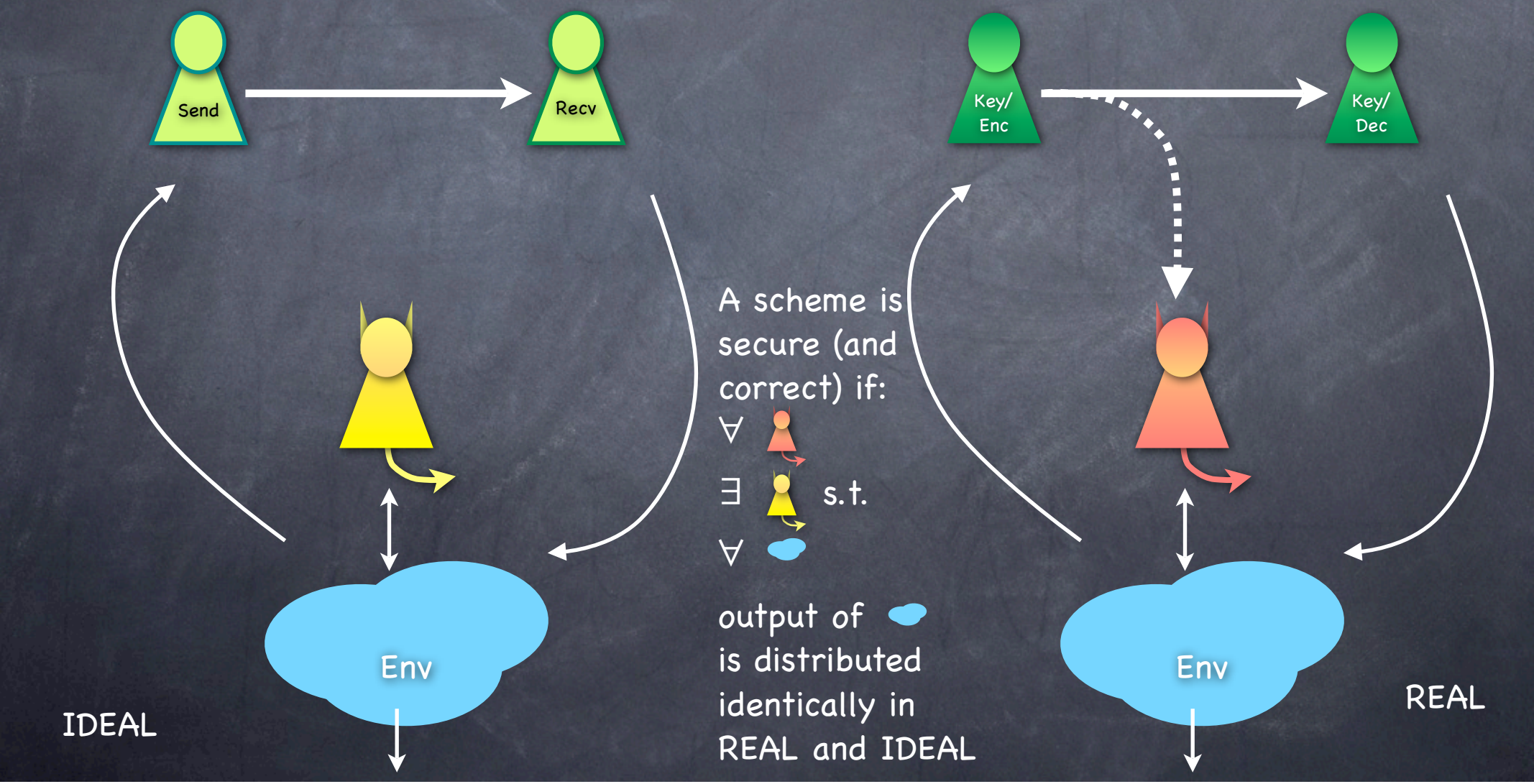

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- REAL/IDEAL (a.k.a simulation-based) security forms the basic template for a large variety of security definitions
- We will see three definitions of encryption
  - Security of "one-time encryption"
  - Security of (muti-message) encryption
  - Security 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
    - $K \leftarrow \mathcal{K}$, uniformly randomly drawn from the key-space (or according to a key-distribution)
  - Encryption: Deterministic
    - Enc: $\mathcal{M} \times \mathcal{K} \rightarrow \mathcal{C}$
  - Decryption: Deterministic
    - Dec: $\mathcal{C} \times \mathcal{K} \rightarrow \mathcal{M}$

Onetime Encryption

Perfect Secrecy

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- For all messages m, m′ in $\mathcal{M}$
  - $\{Enc(m,K)\}_{K \leftarrow KeyGen} = \{Enc(m',K)\}_{K \leftarrow KeyGen}$

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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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- E.g. One-time pad: $\mathcal{M} = \mathcal{K} = \mathcal{C} = \{0,1\}^n$ and Enc(m,K) = m⊕K, Dec(c,K) = c⊕K

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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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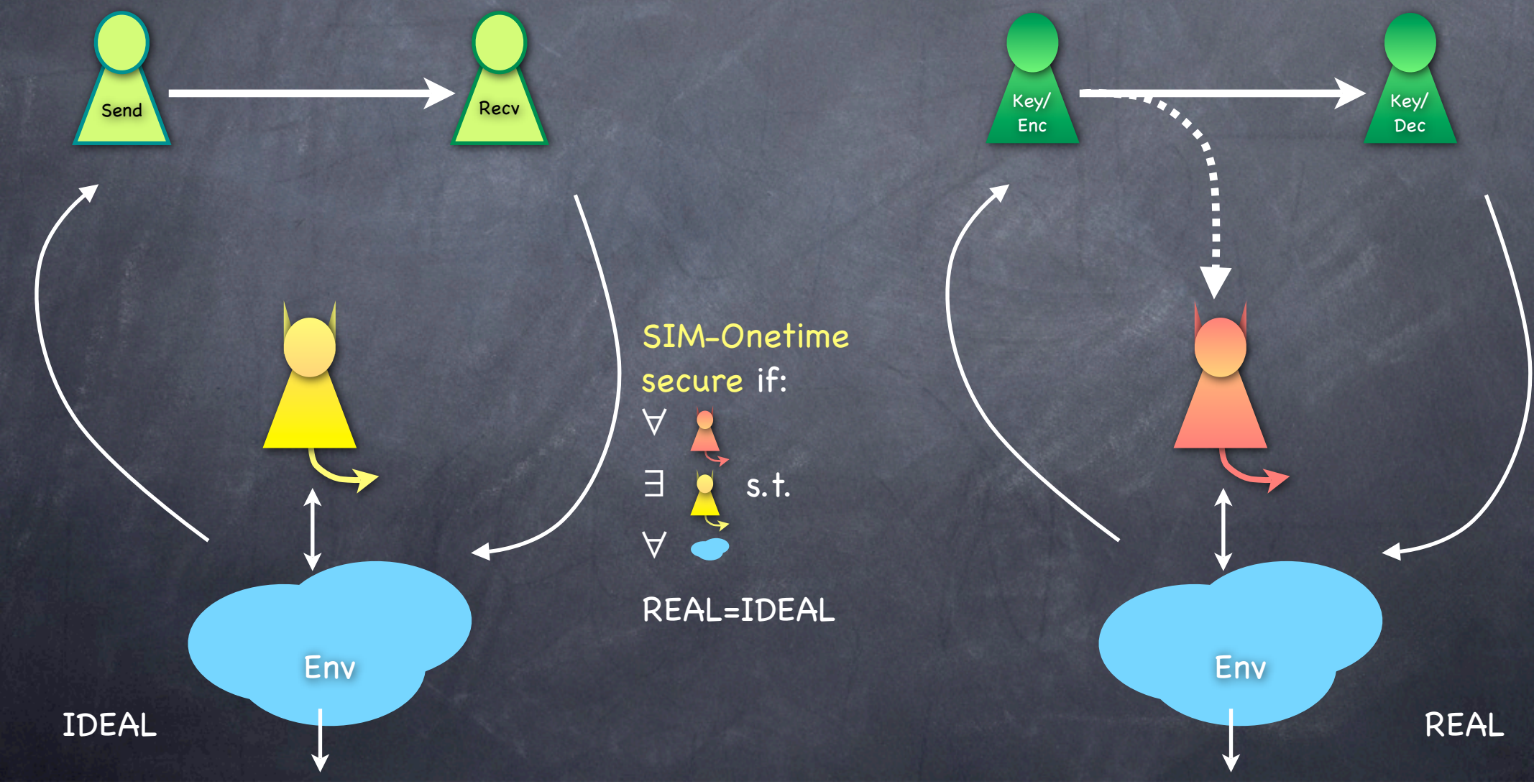
Onetime Encryption

SIM-Onetime Security



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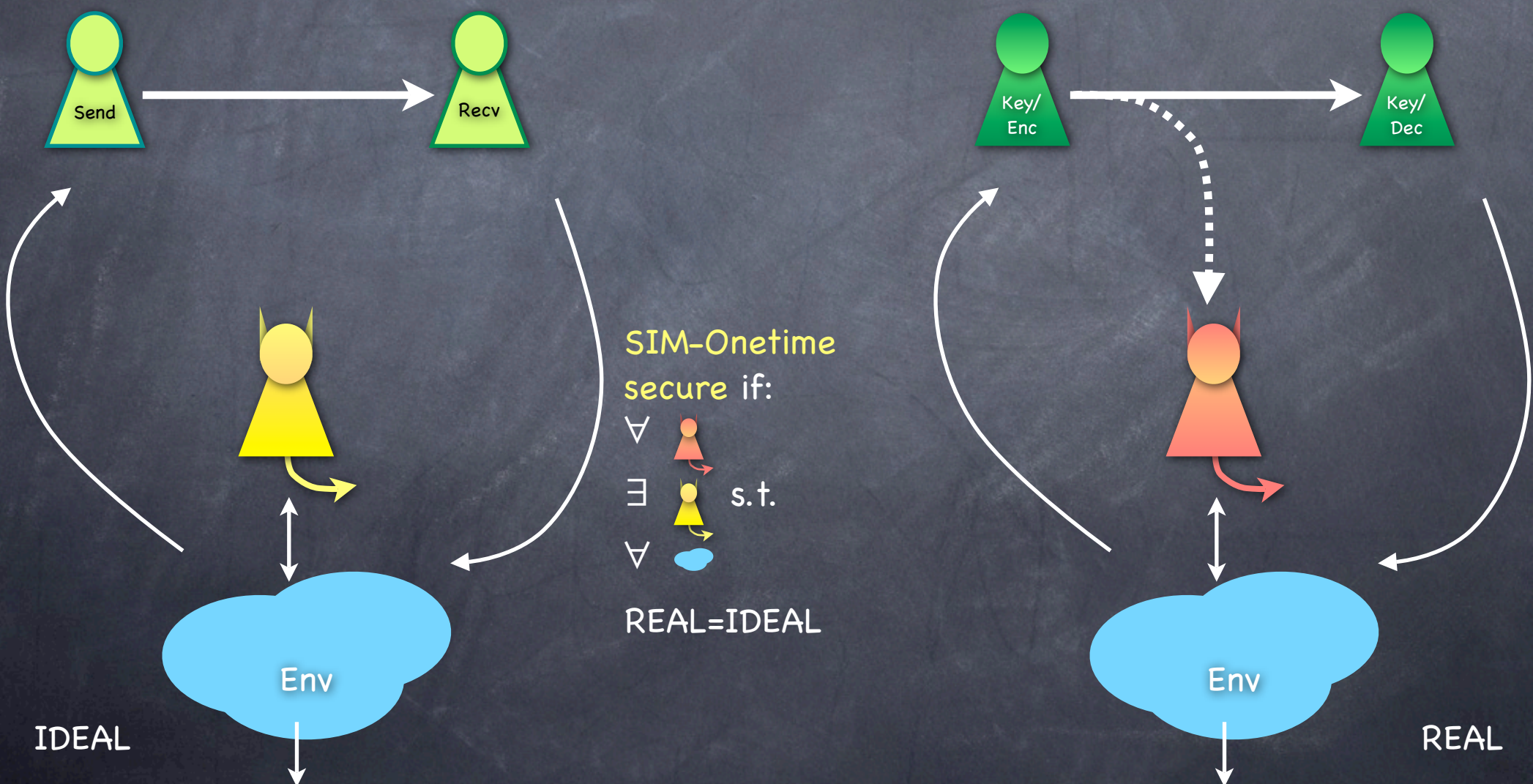
- Class of environments which send only one message



Onetime Encryption

SIM-Onetime Security

Equivalent to perfect secrecy + correctness

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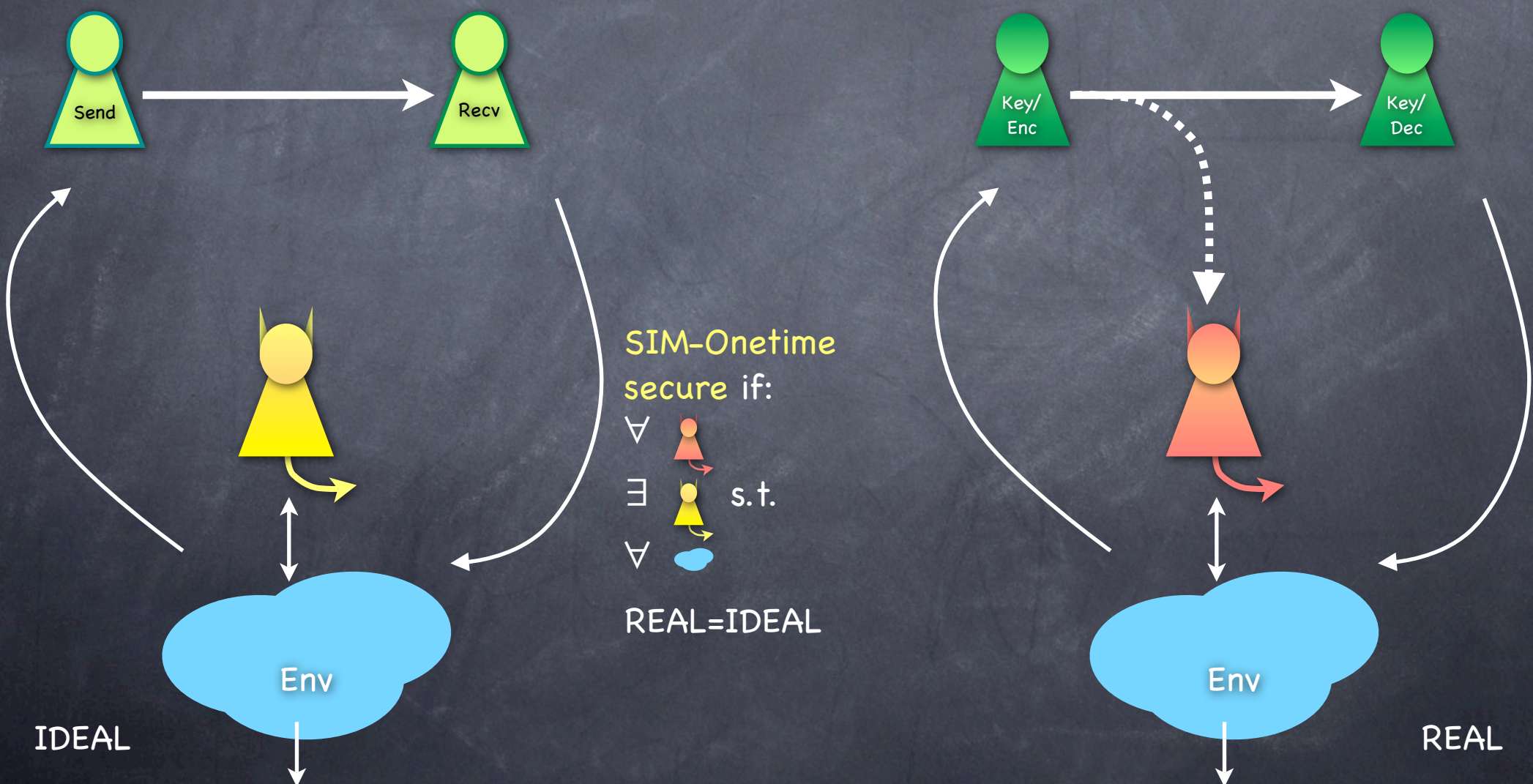
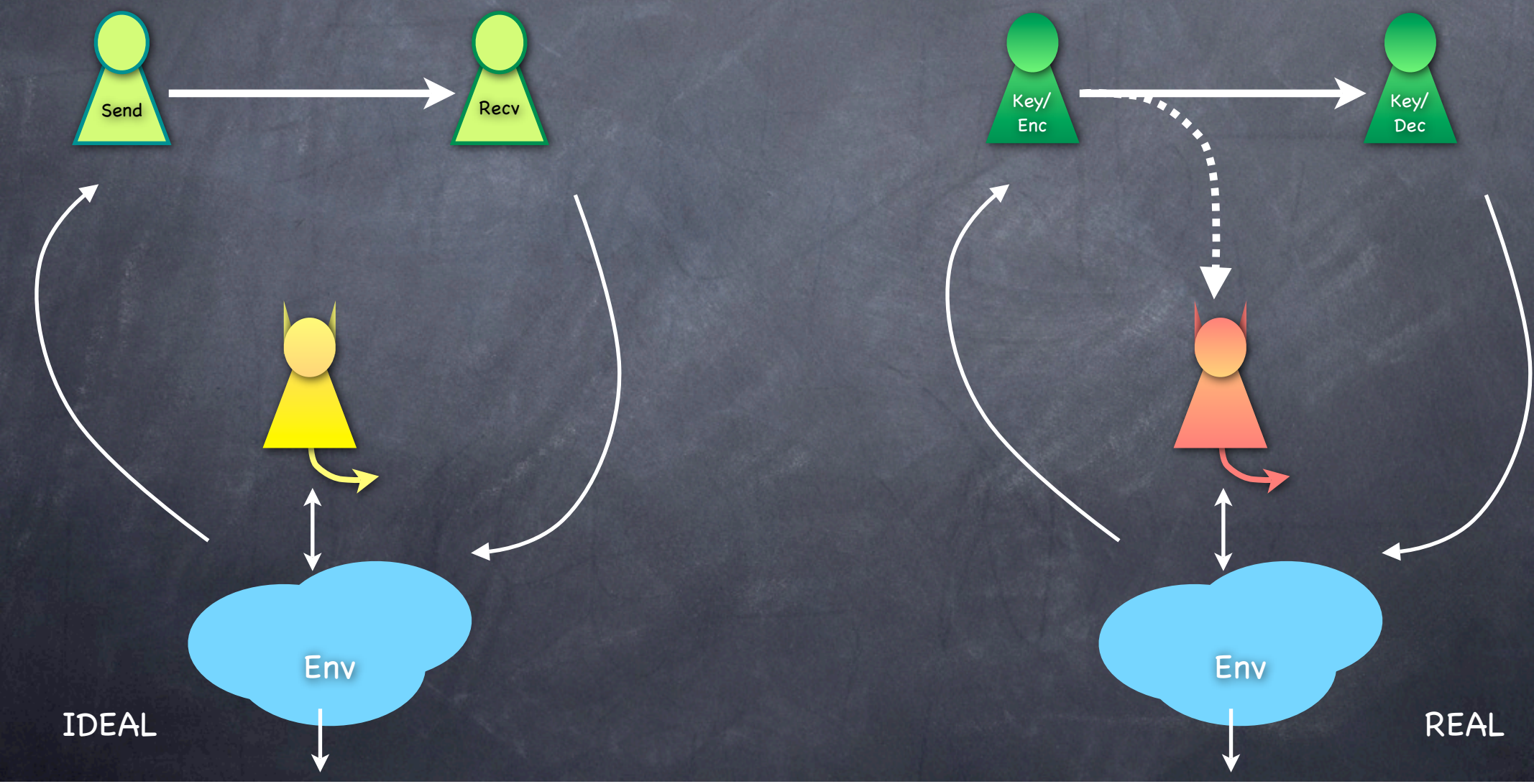


Perfect Secrecy + Correctness ⇒ SIM-Onetime Security



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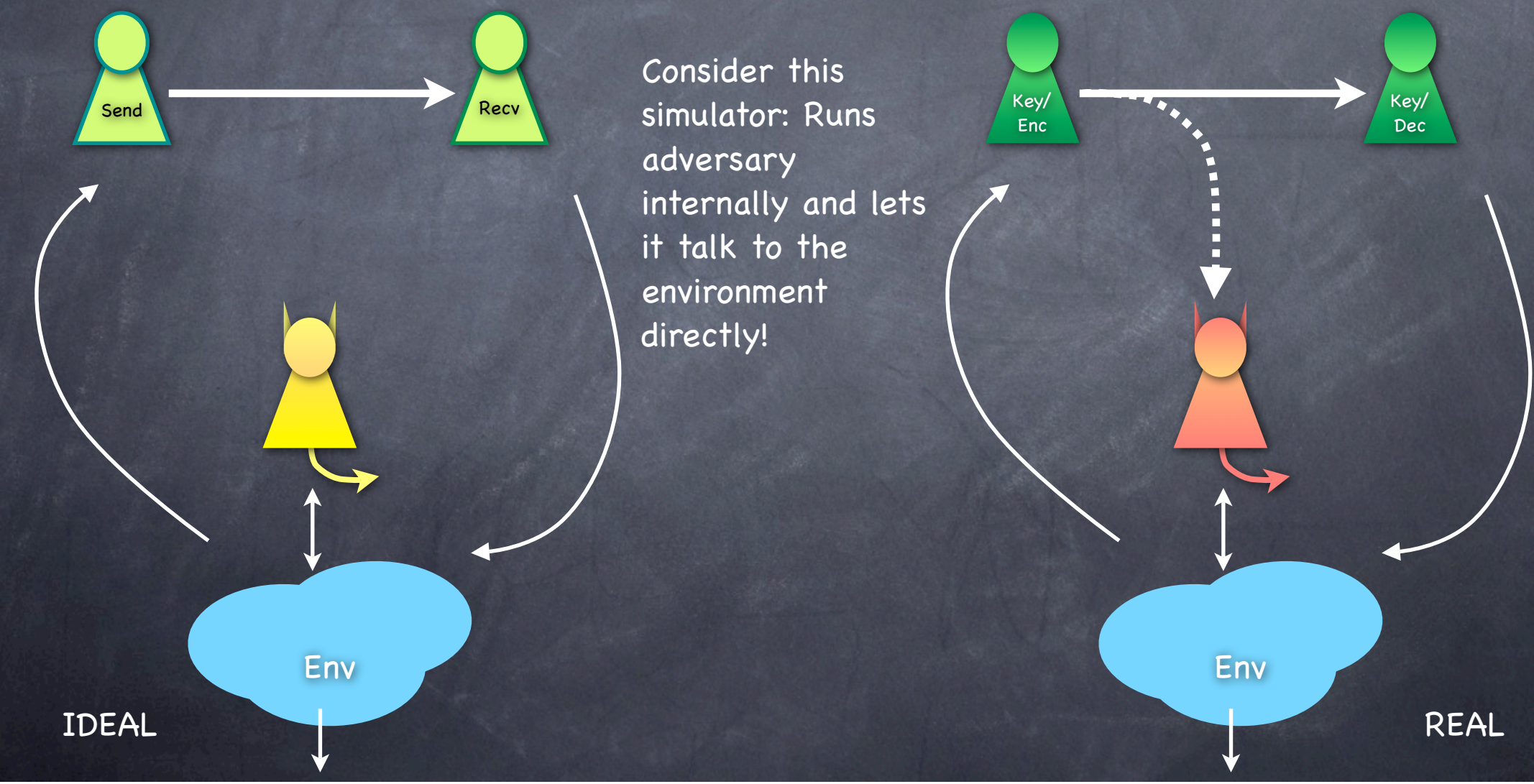

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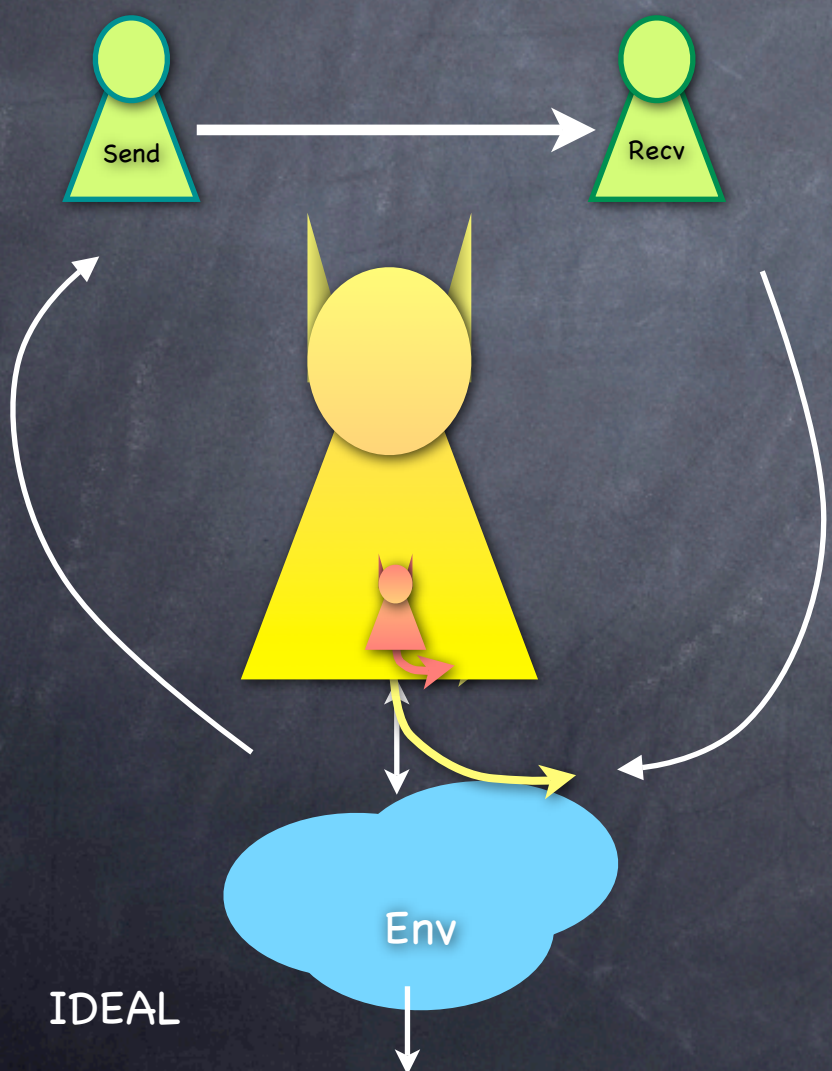

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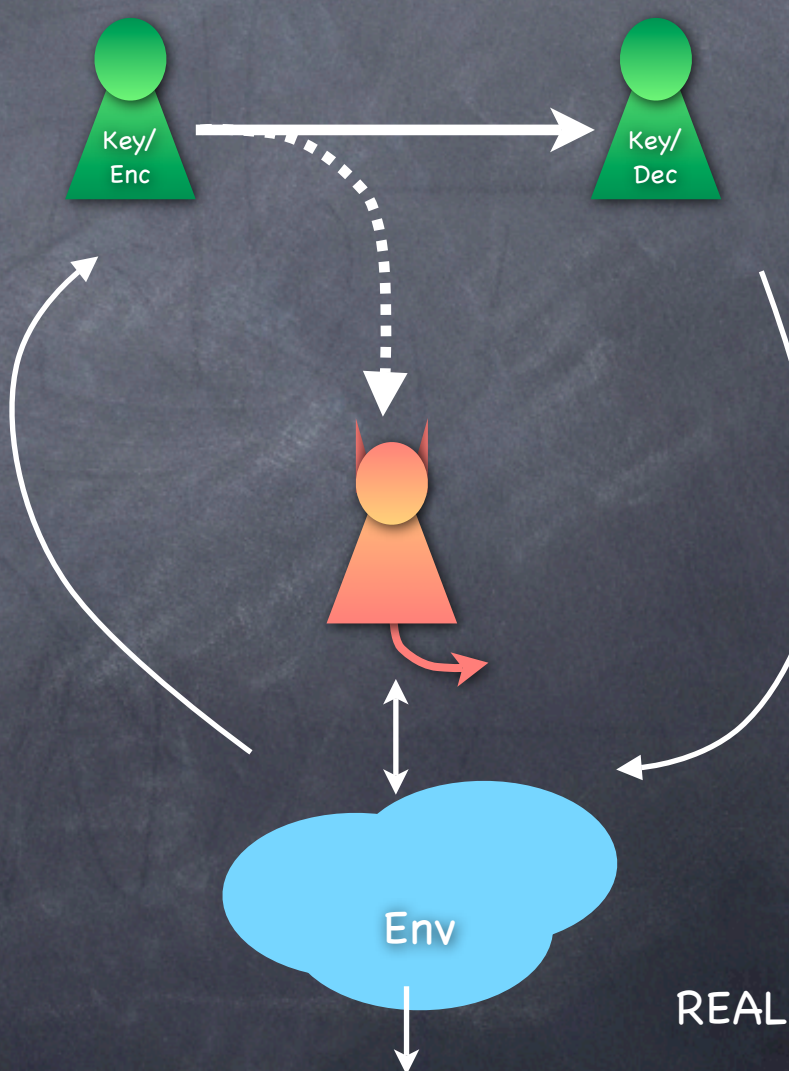

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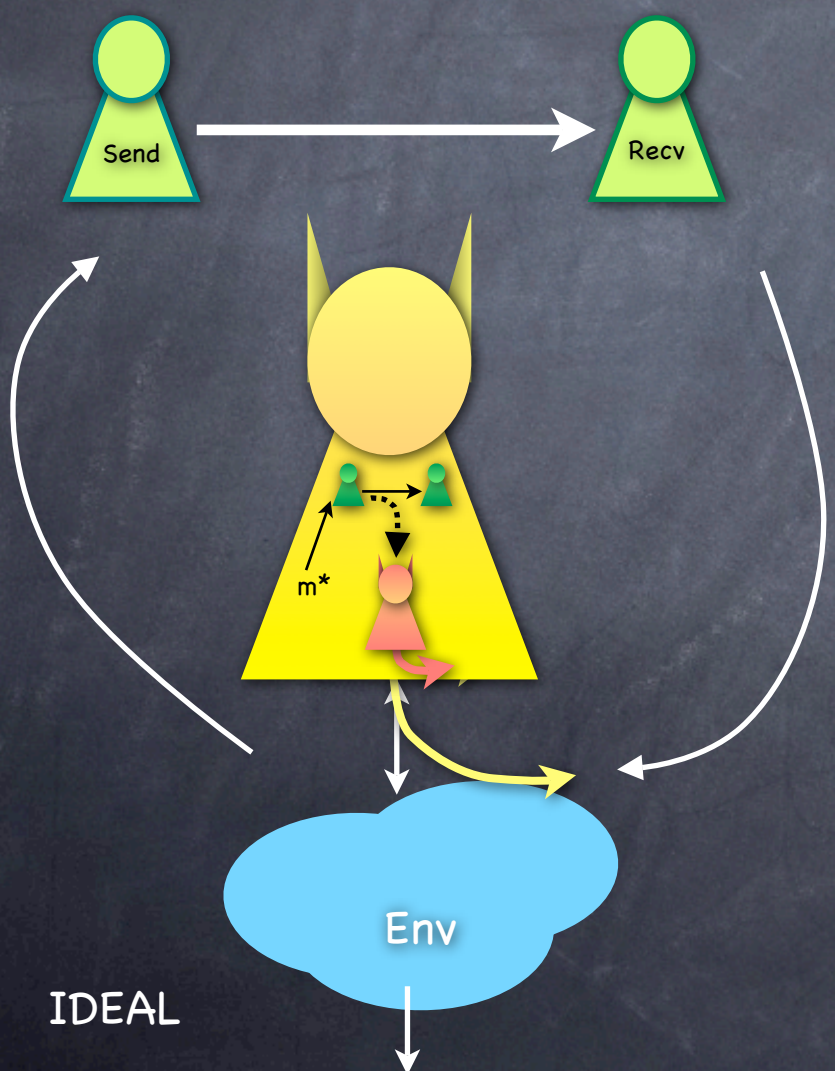

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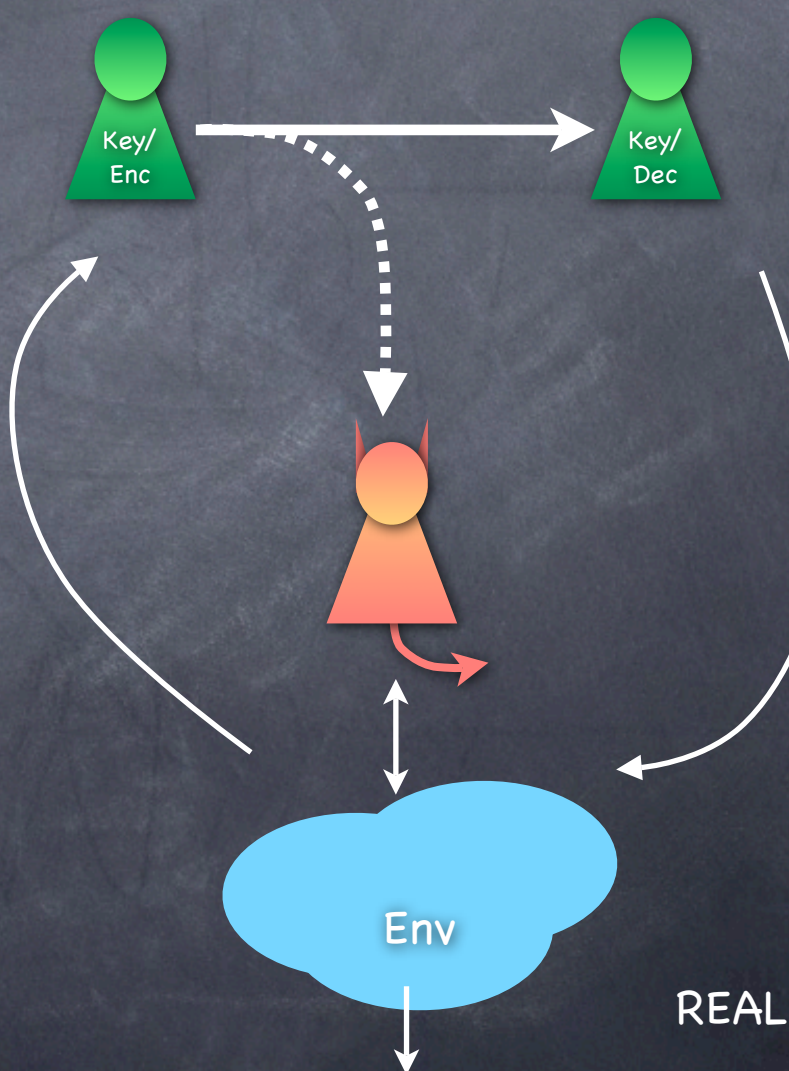

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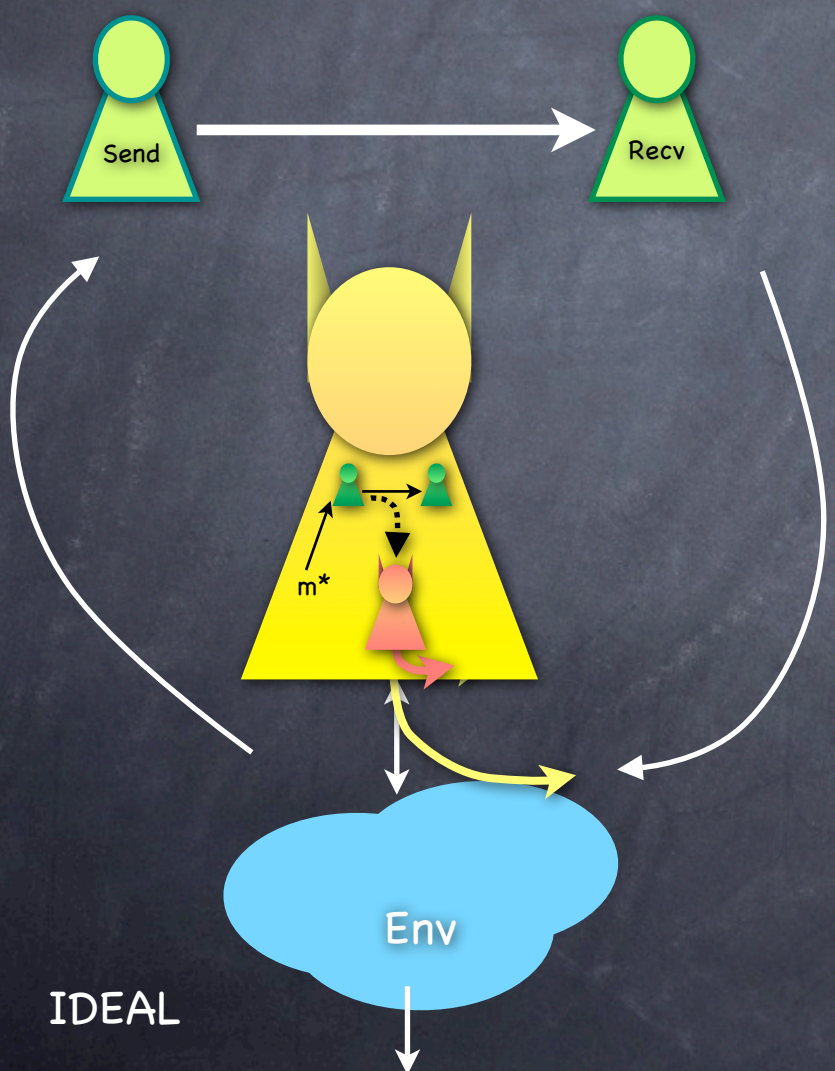

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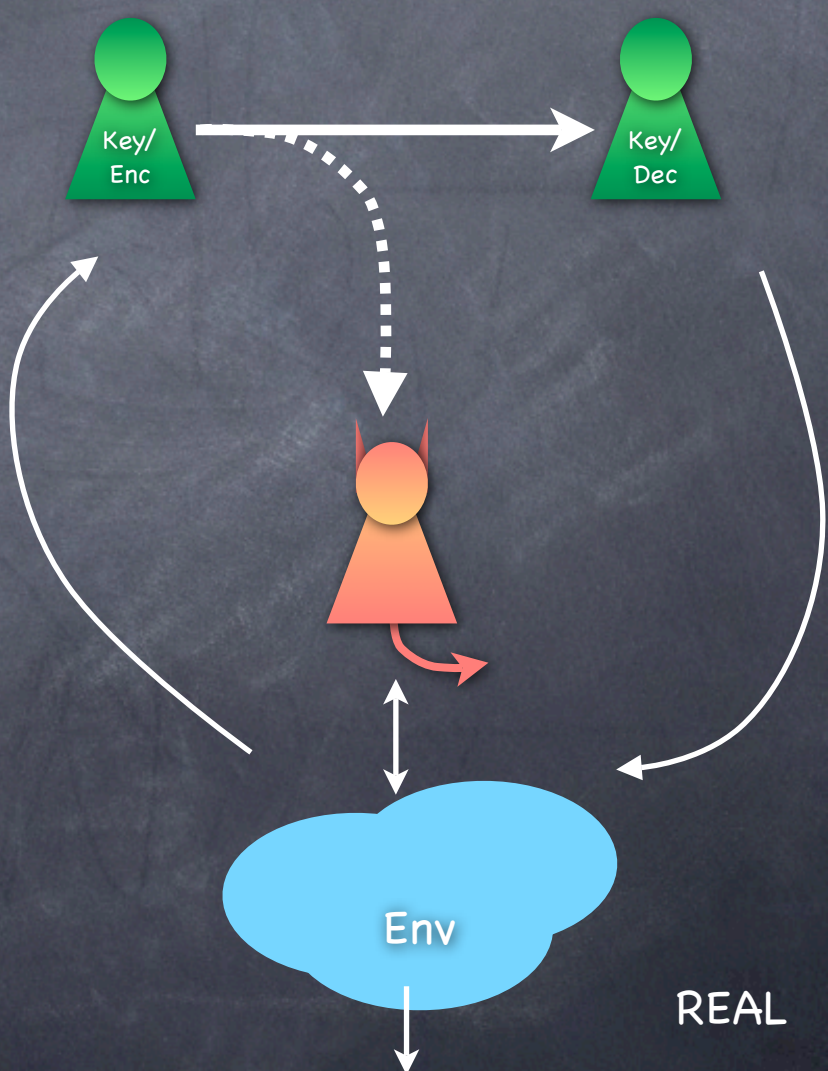
Can show that REAL=IDEAL



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  - Also, Eve' allowed to learn when a message is sent

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IND-Onetime Security

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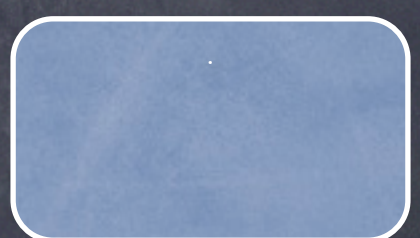

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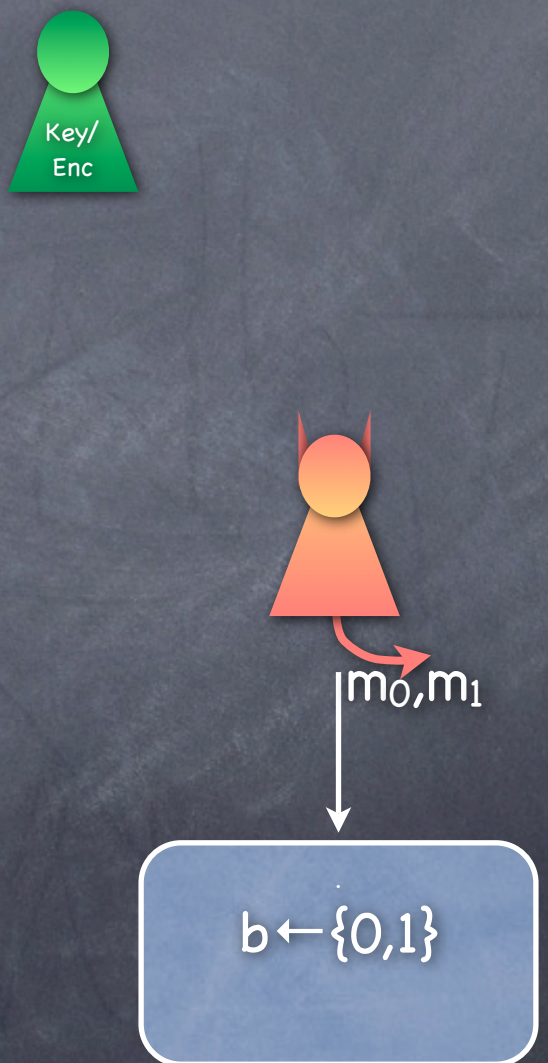

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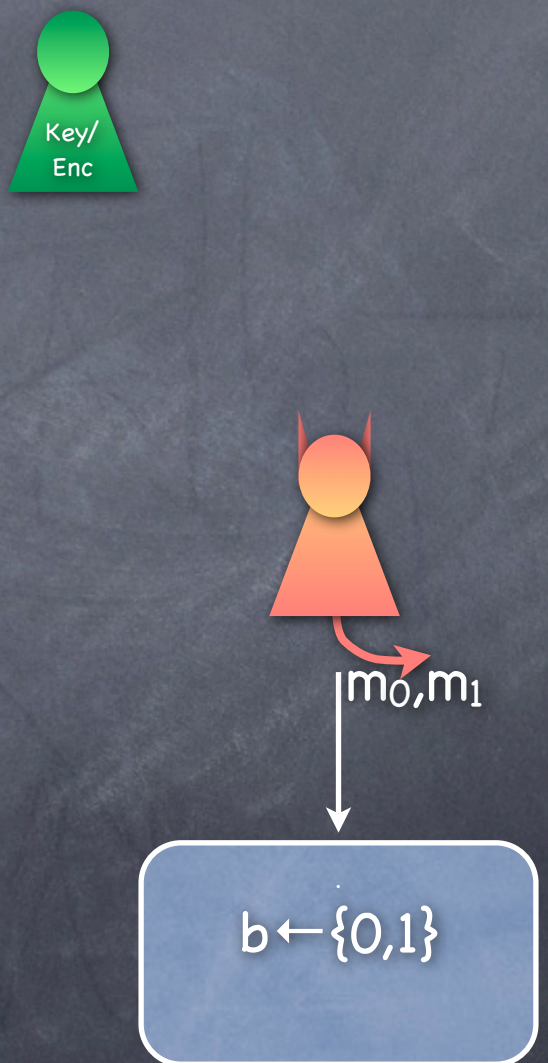

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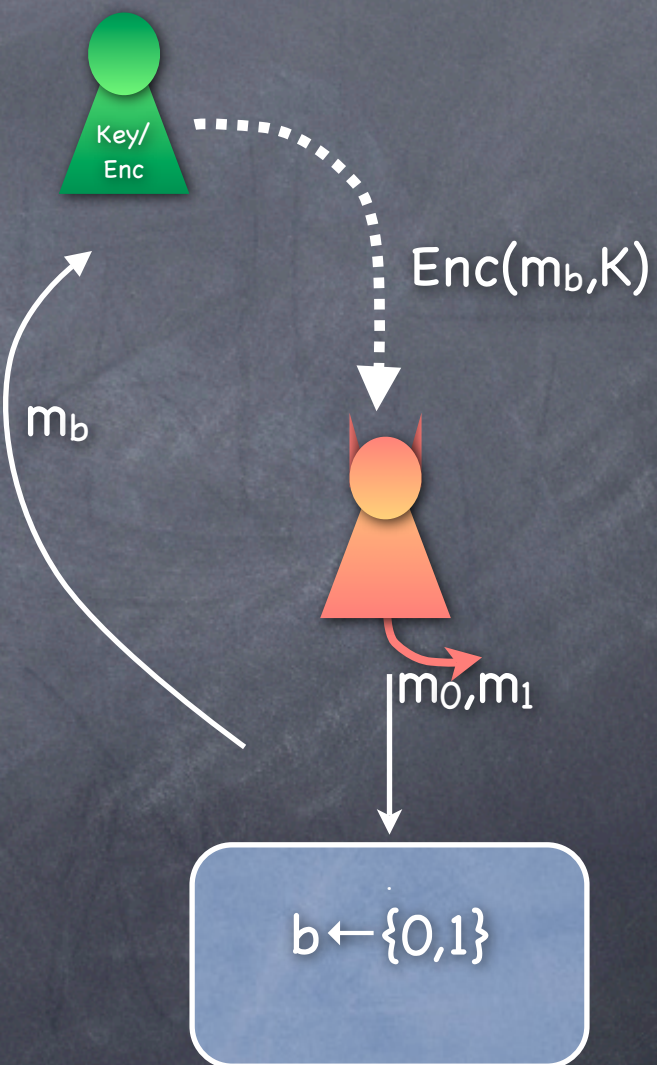

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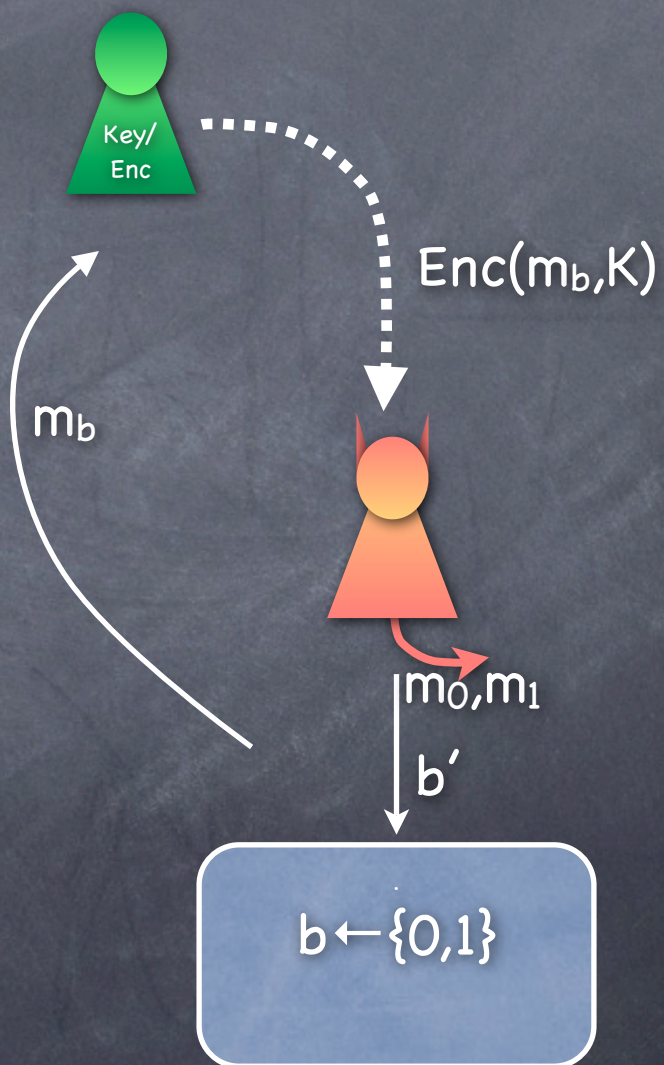

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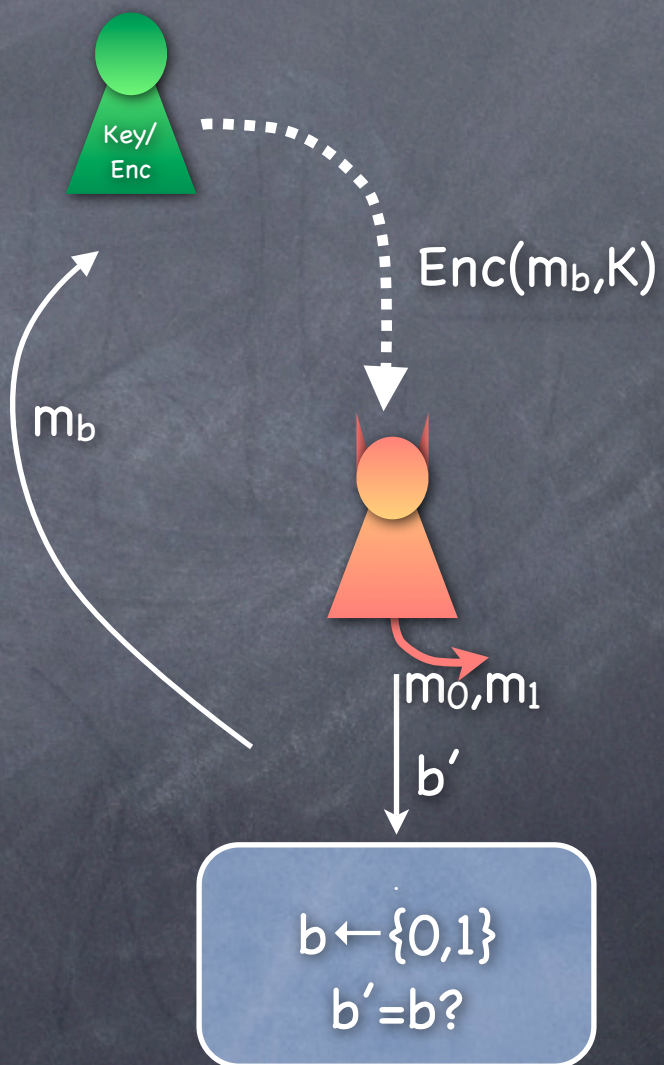

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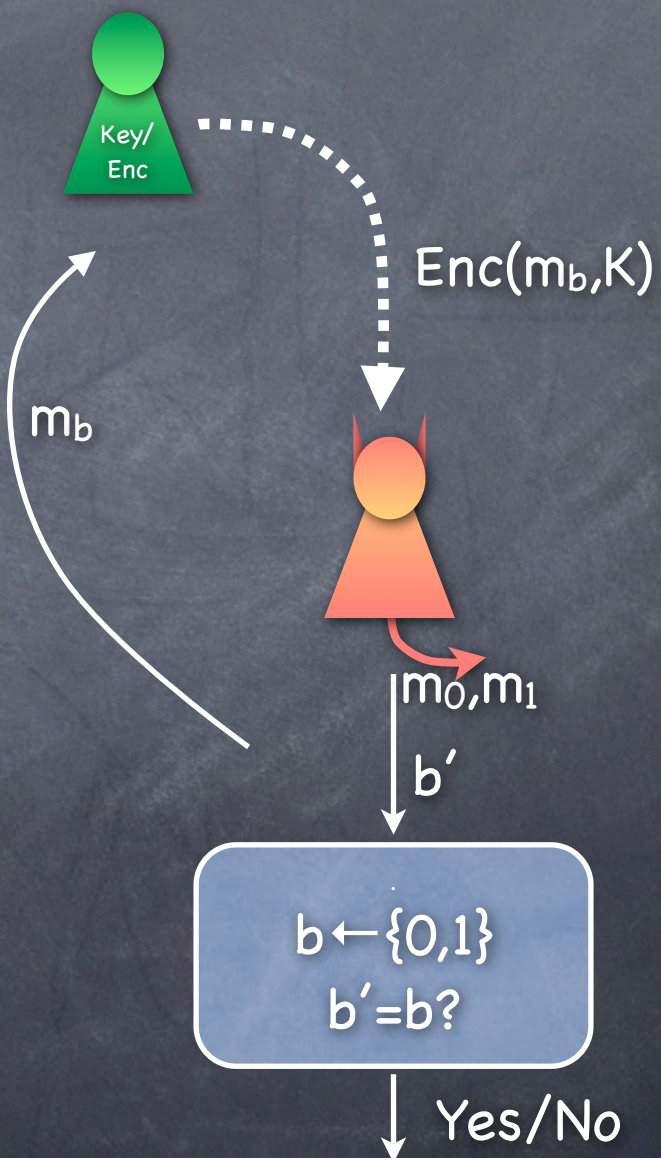

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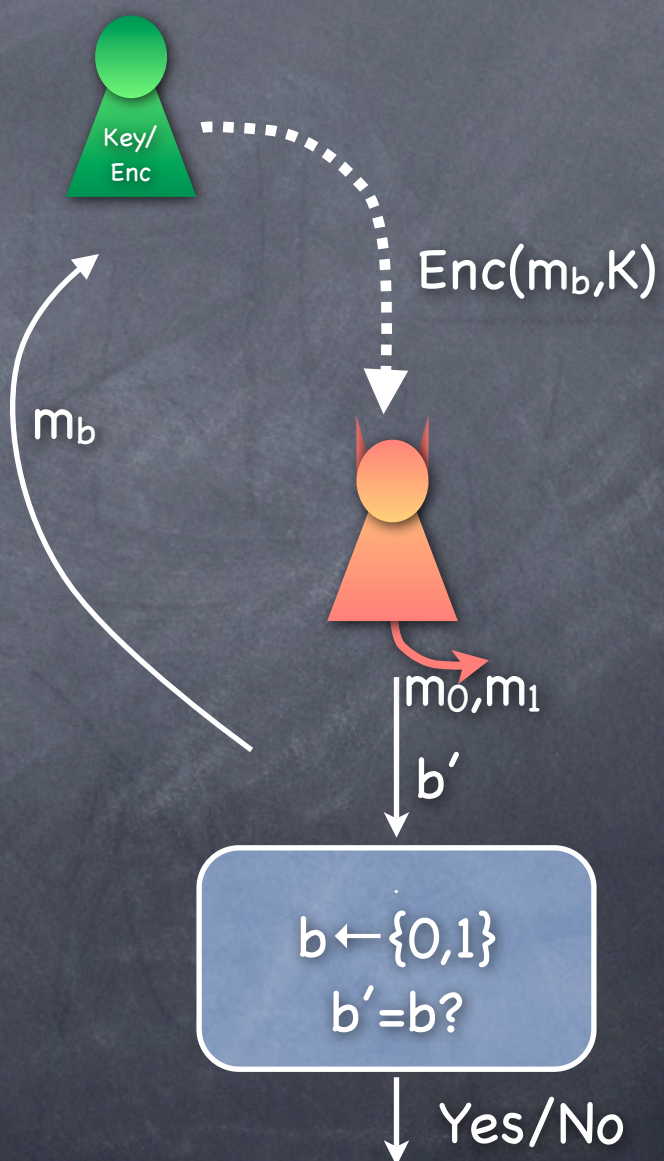

Onetime Encryption

IND-Onetime Security

Equivalent to perfect secrecy

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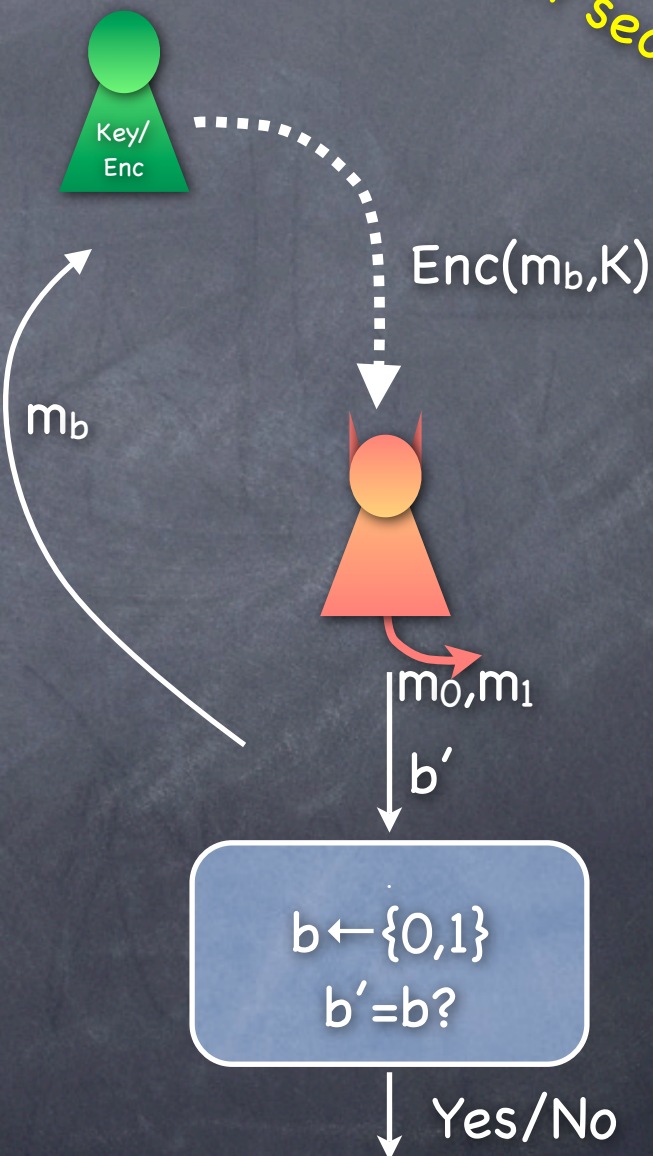

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  - Encryption: Randomized
    - Enc: $\mathcal{M} \times \mathcal{K} \times \mathcal{R} \rightarrow \mathcal{C}$. During encryption a fresh random string will be chosen uniformly at random from $\mathcal{R}$
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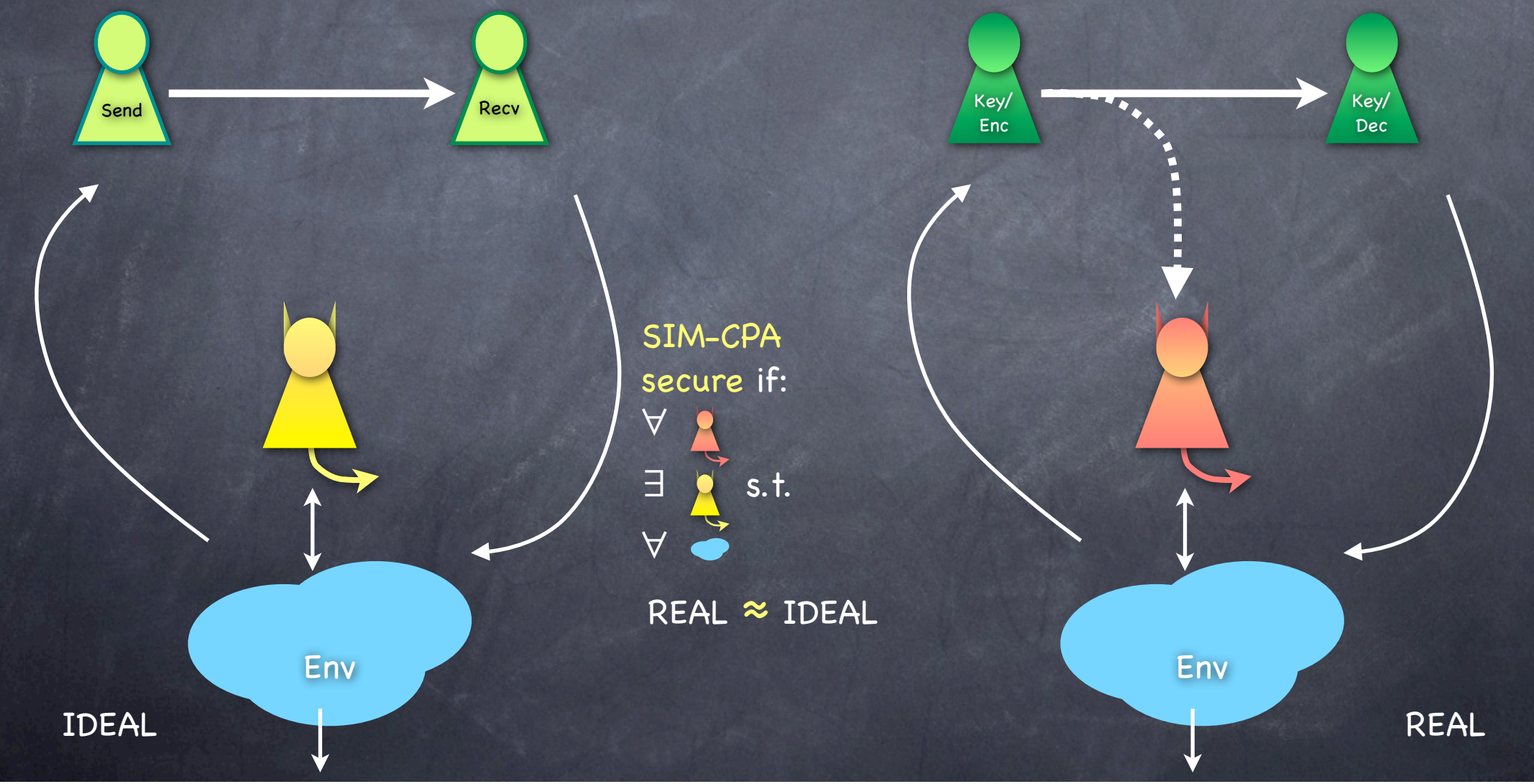
    - Dec: $\mathcal{C} \times \mathcal{K} \rightarrow \mathcal{M}$

Symmetric-Key Encryption

SIM-CPA Security



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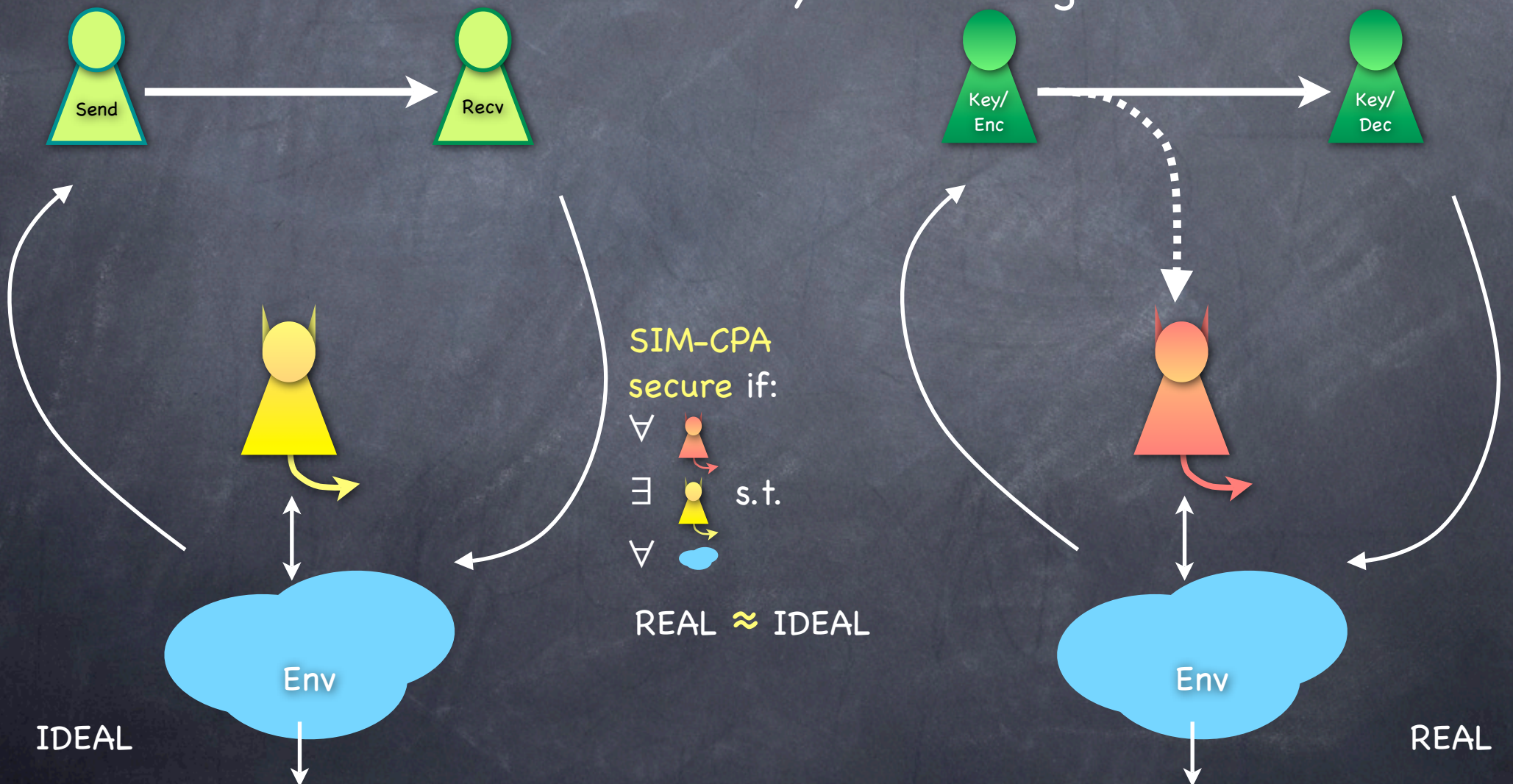
- Same as SIM-onetime security, but not restricted to environments which send only one message



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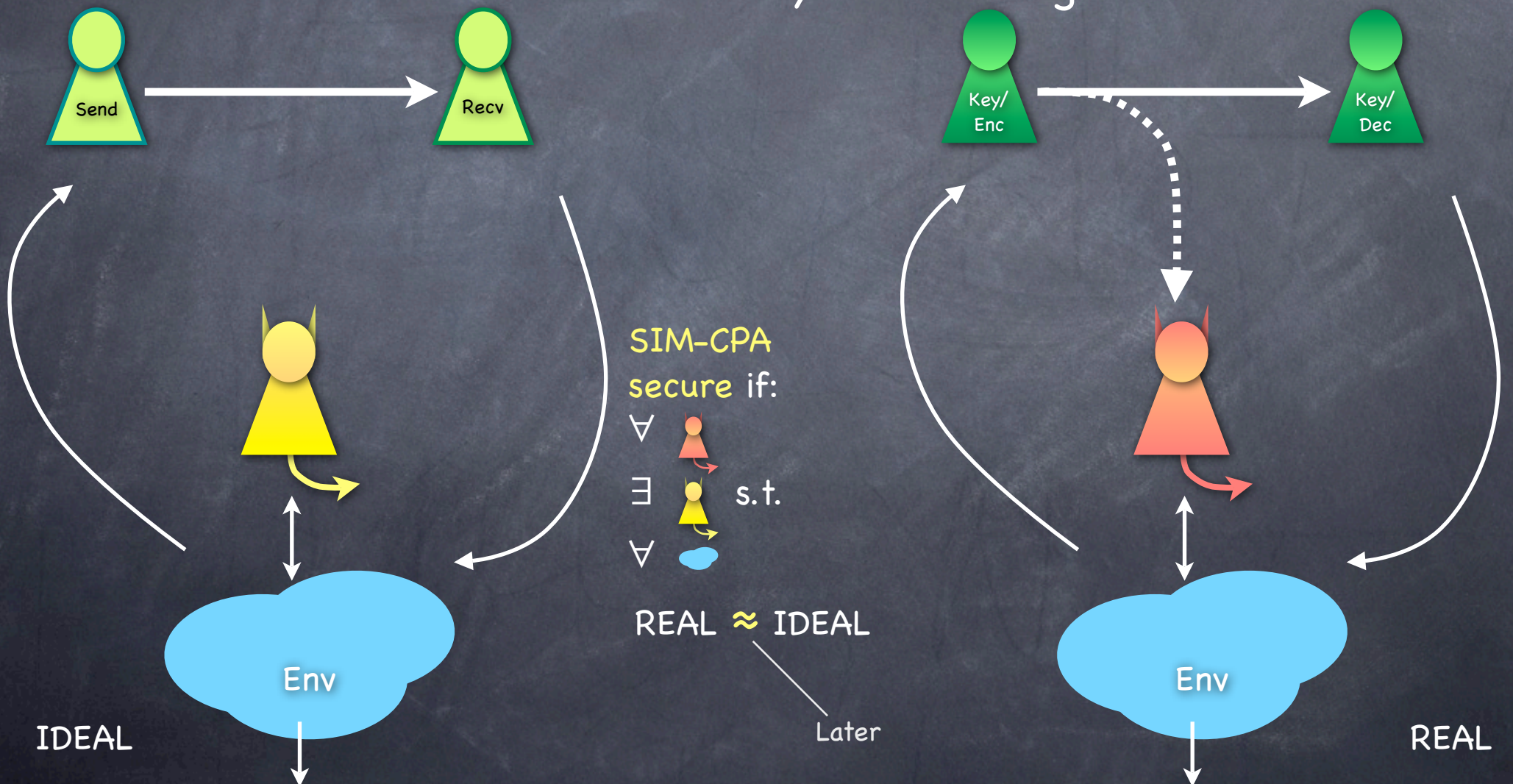

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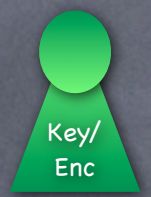

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IND-CPA Security

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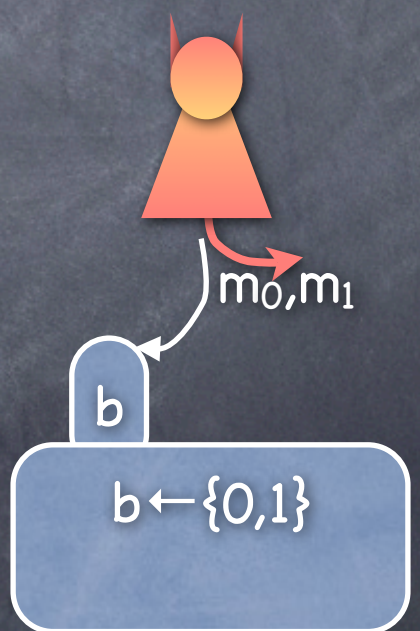

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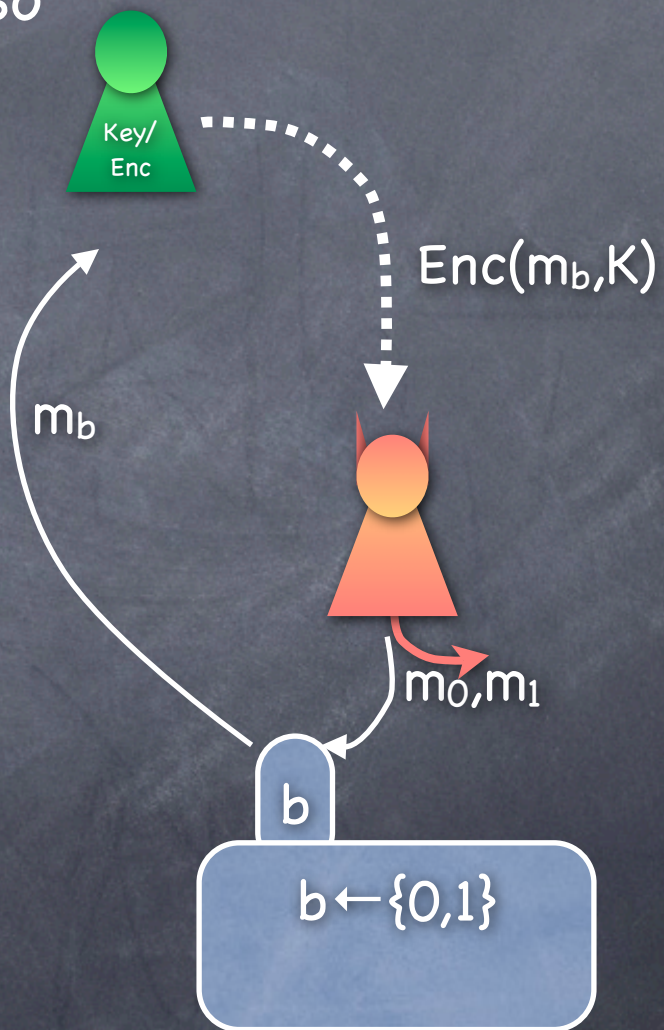

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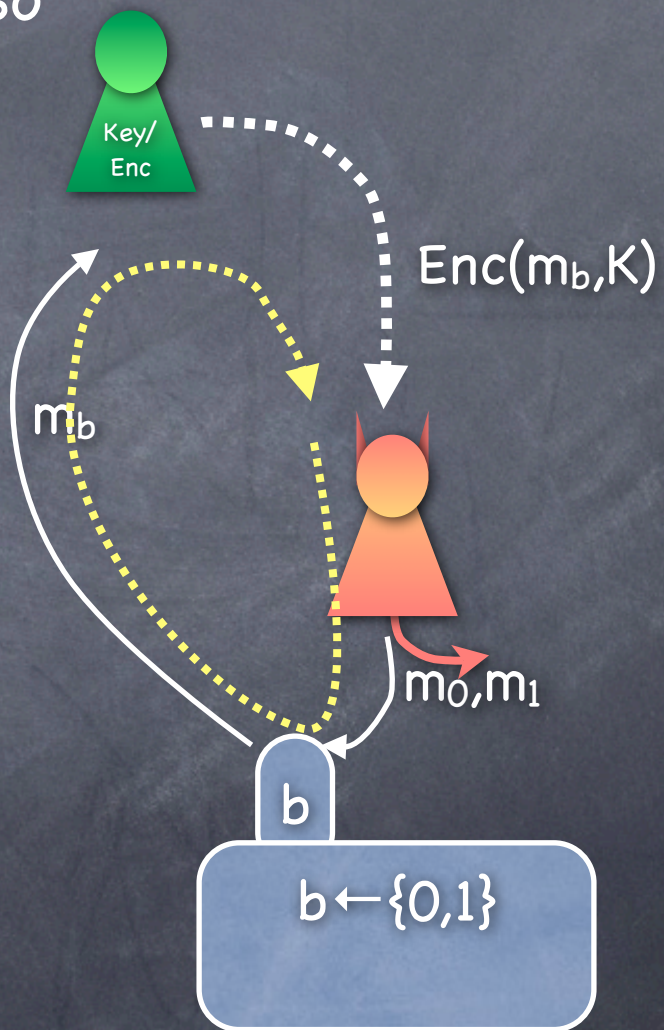

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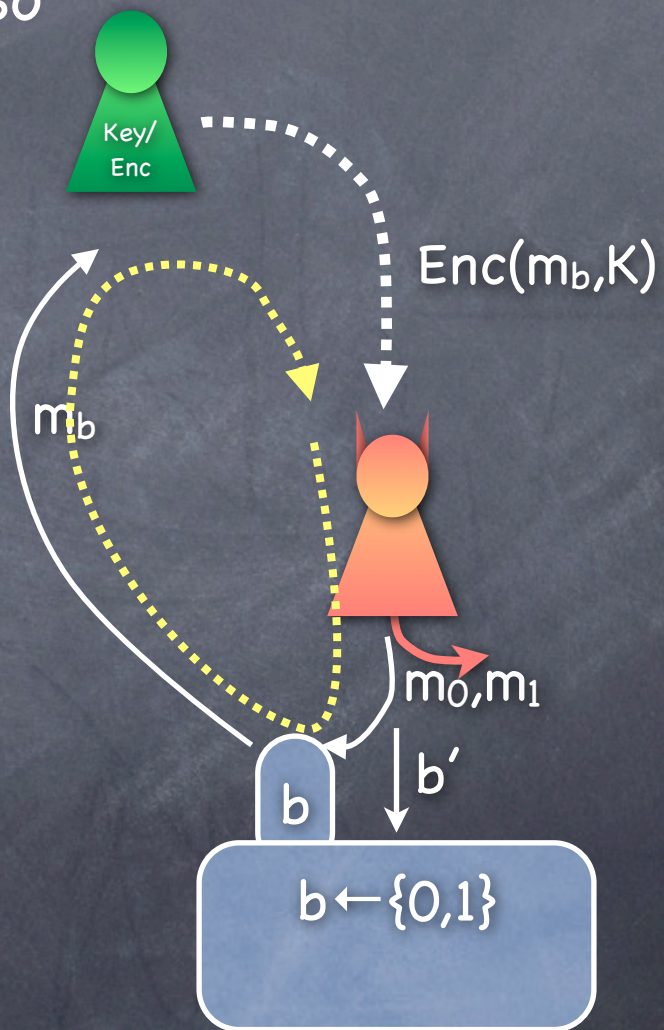

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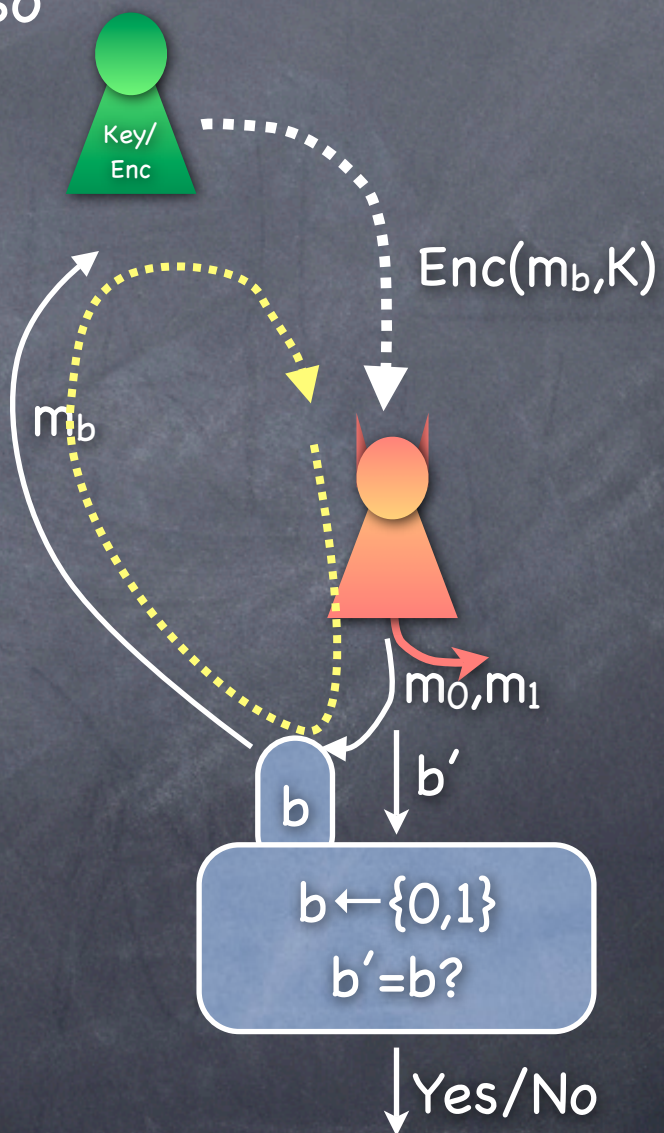

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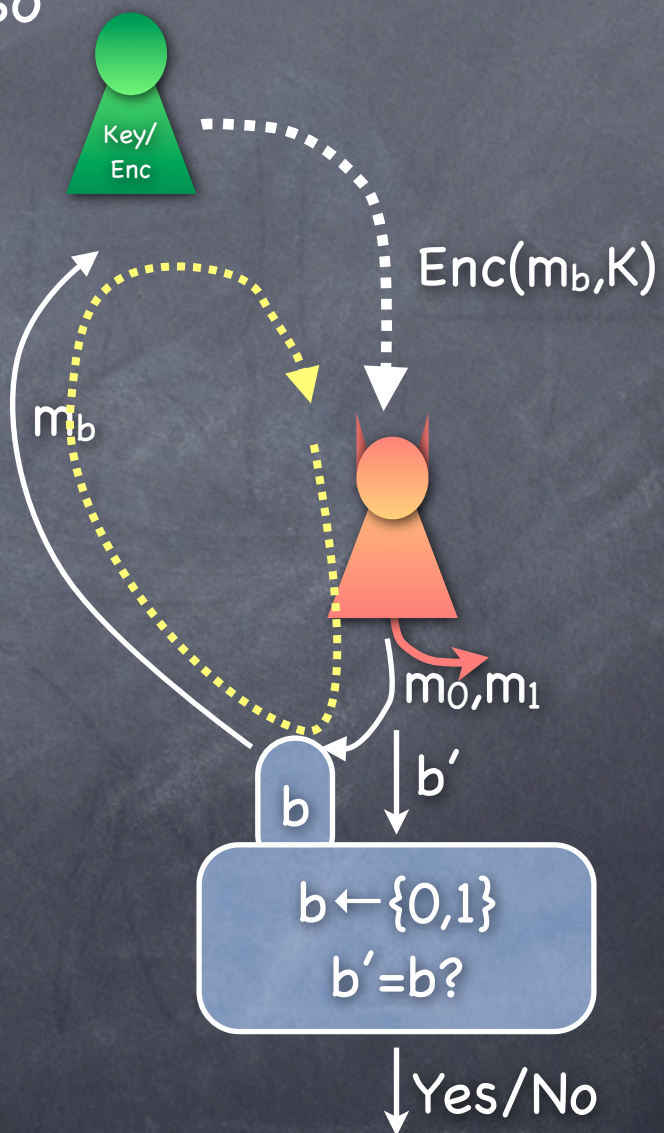

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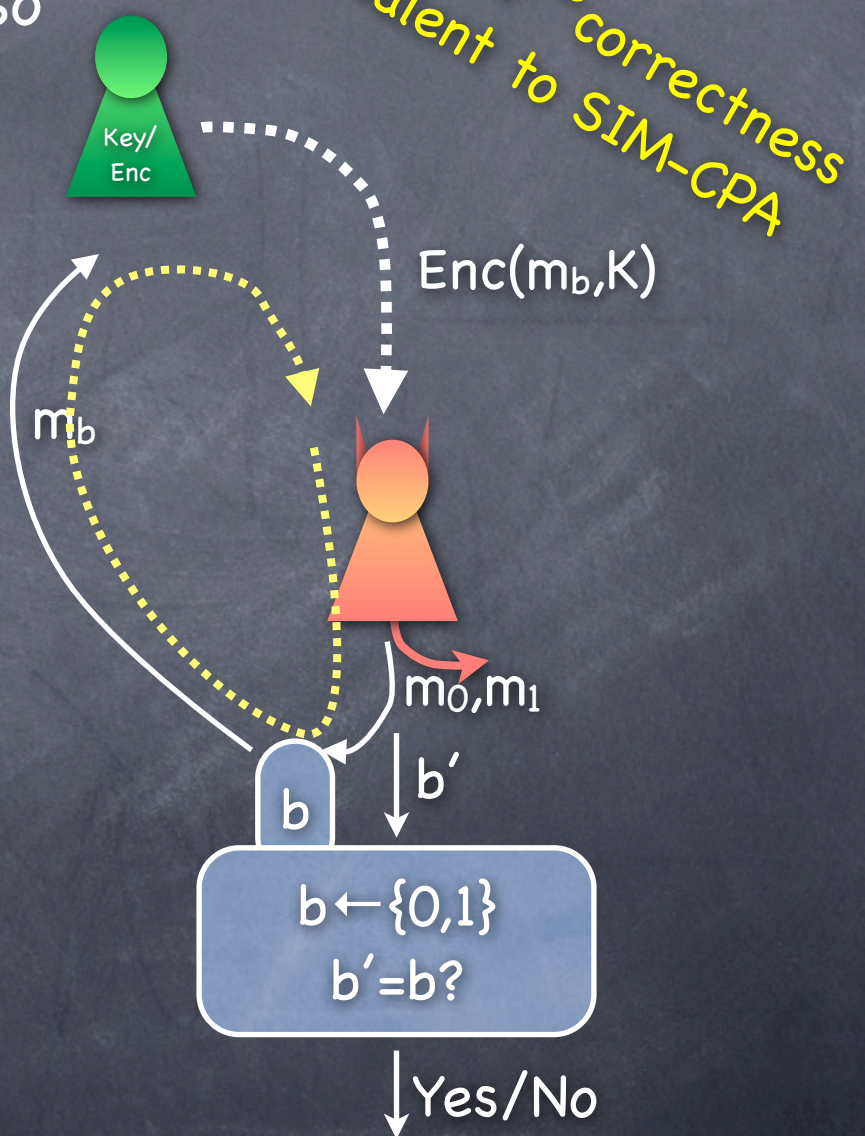
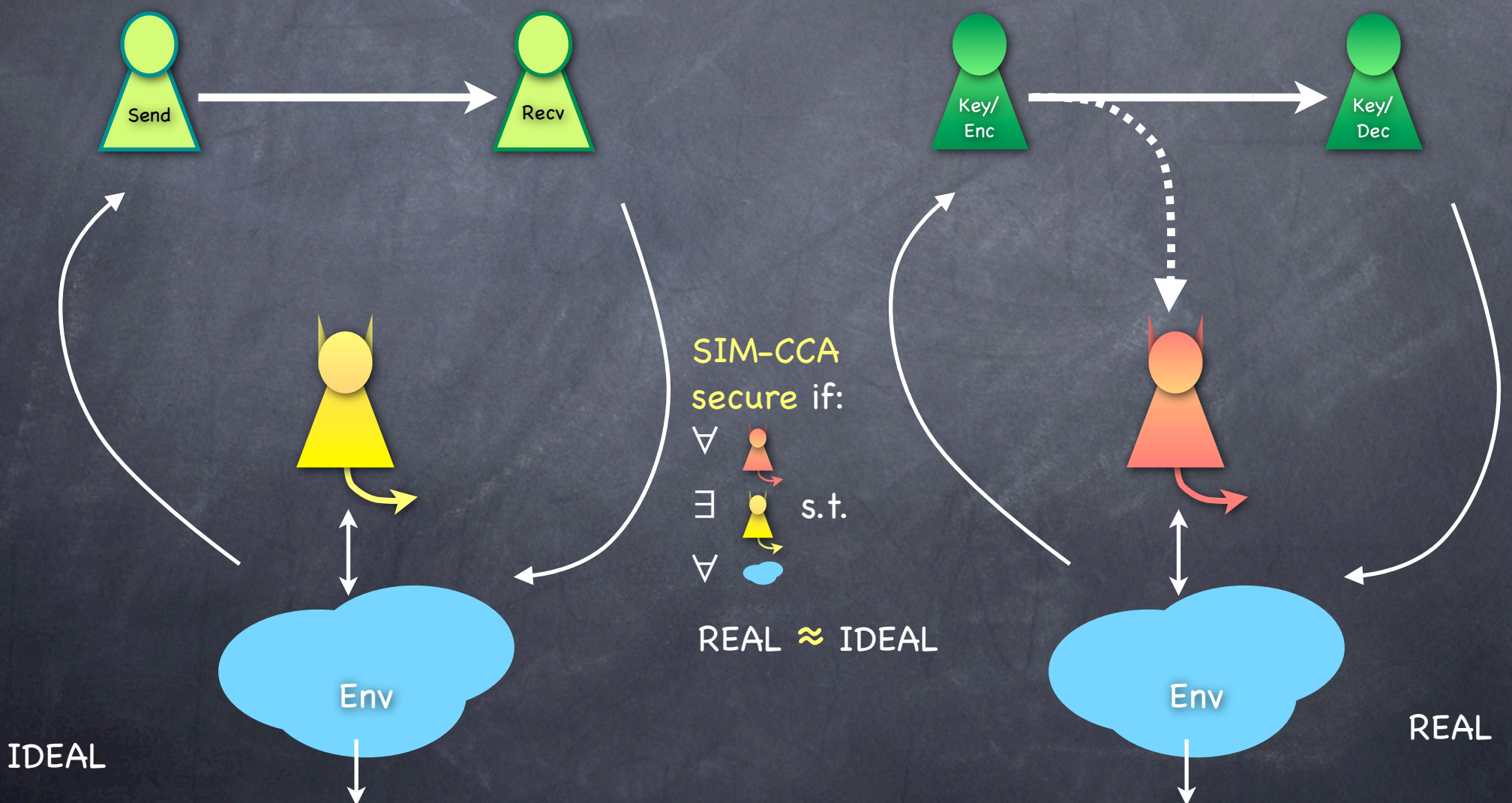


Symmetric-Key Encryption

SIM-CCA Security



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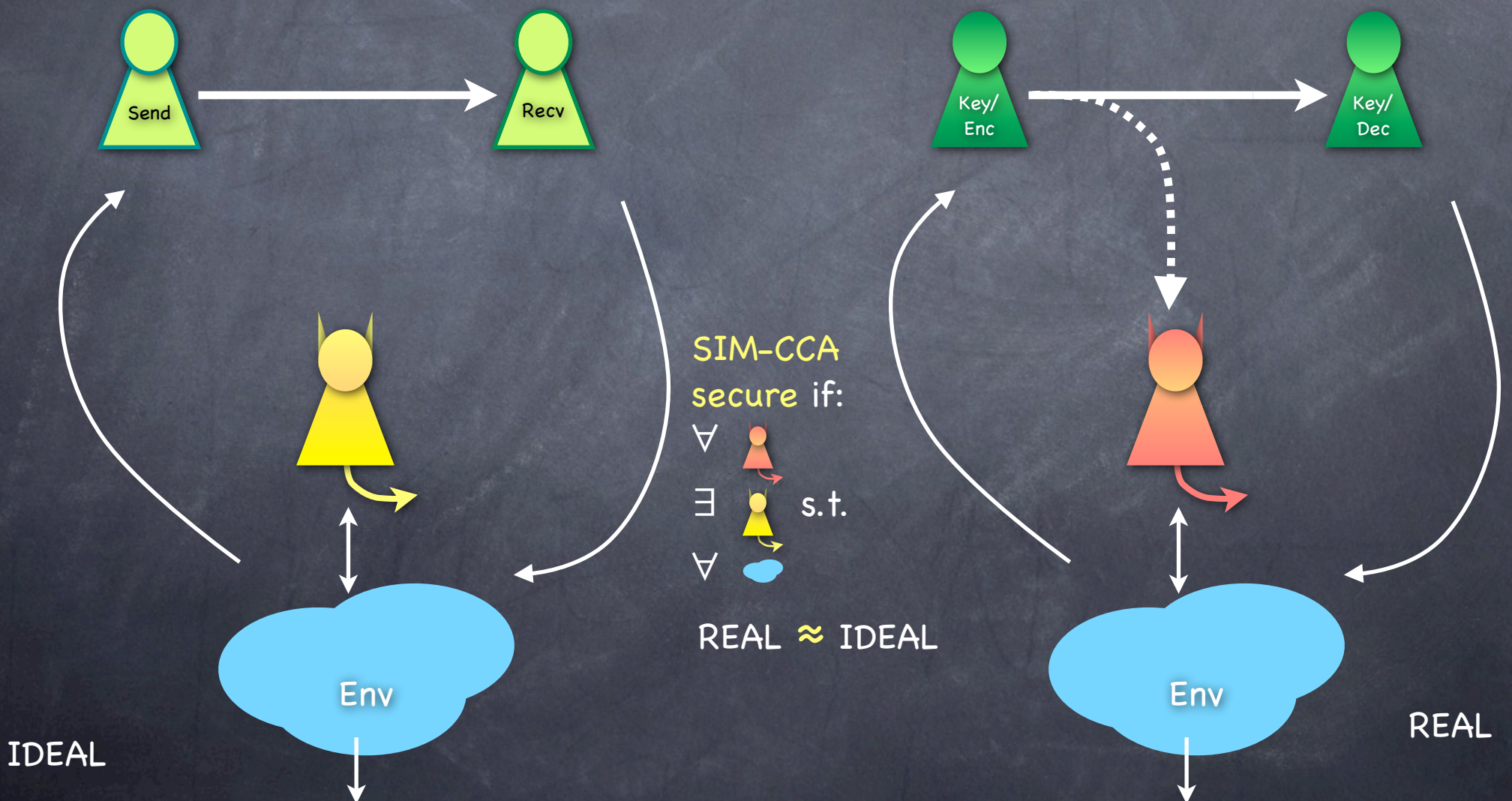
SIM-CCA Security

- An active adversary can inject messages into the channel



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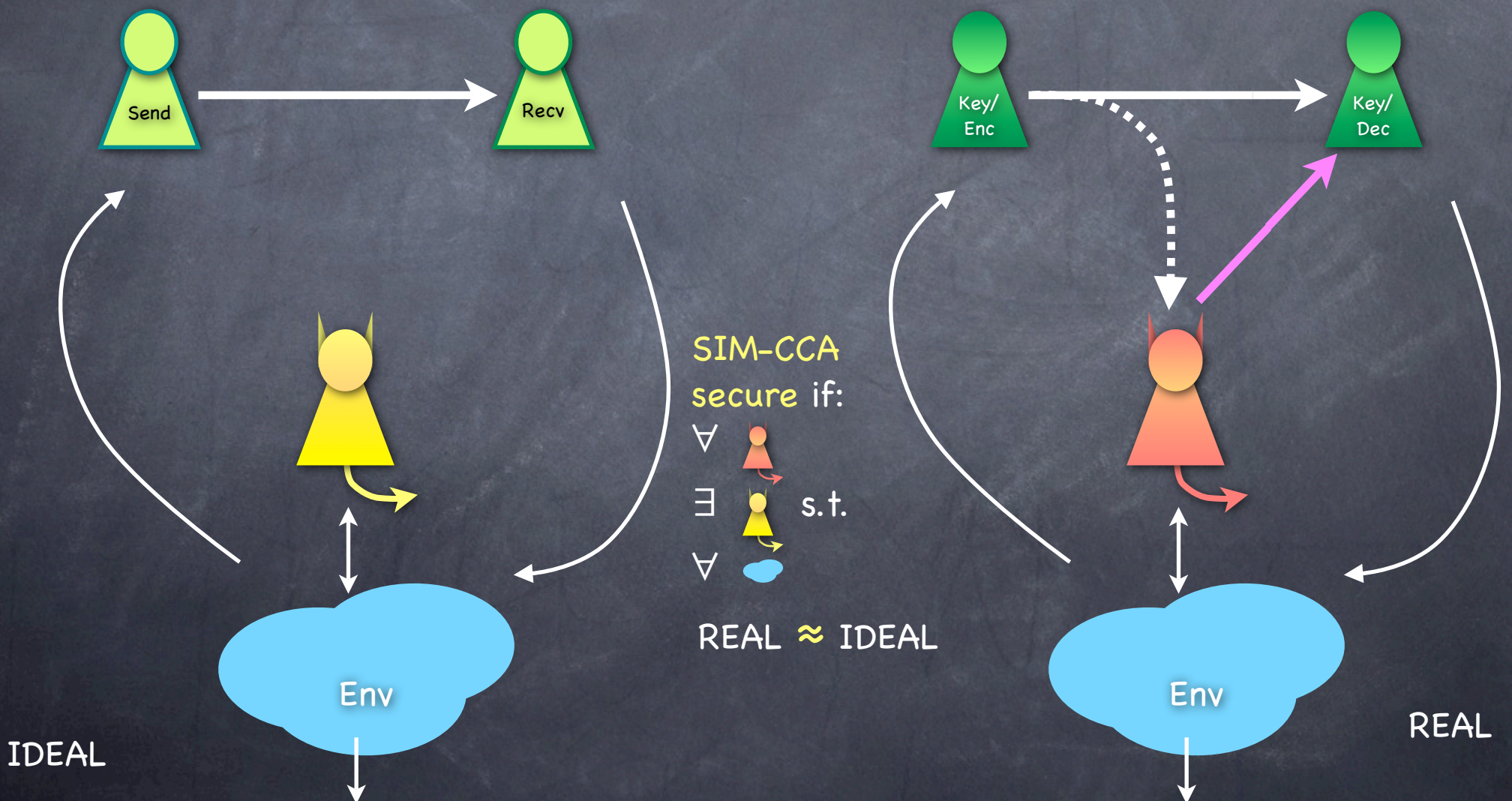

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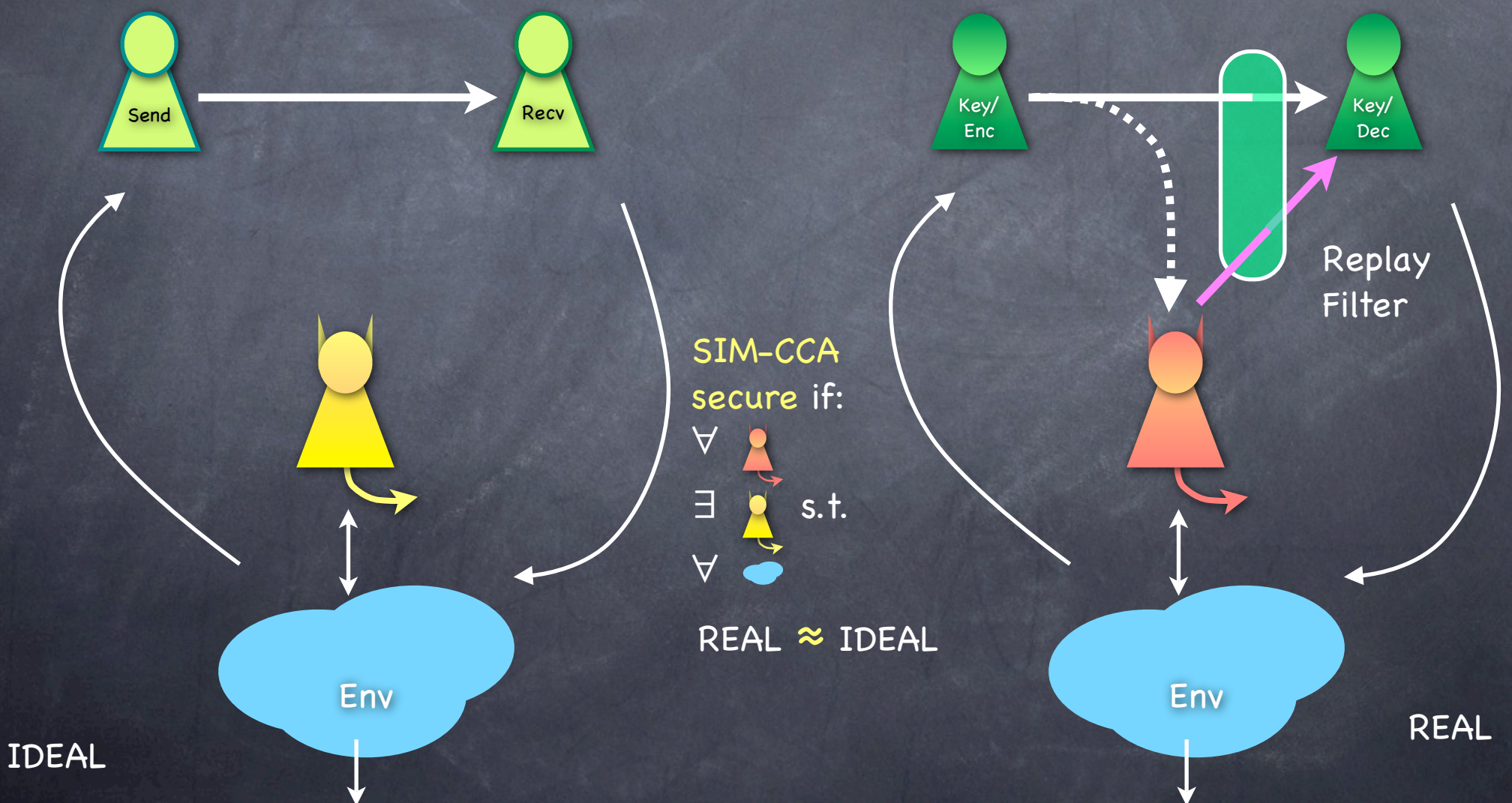

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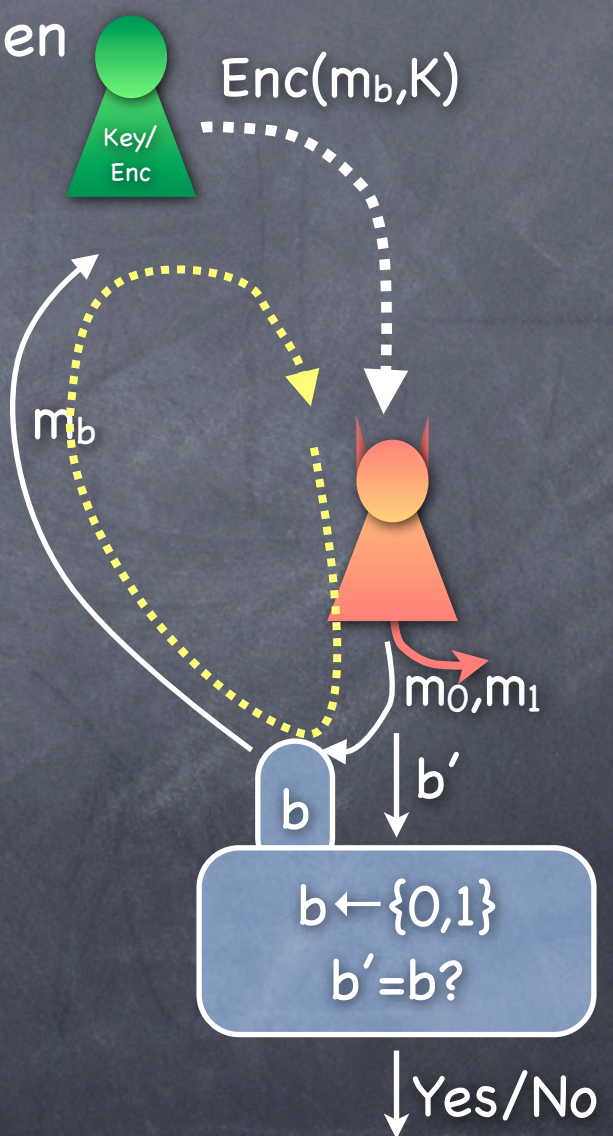

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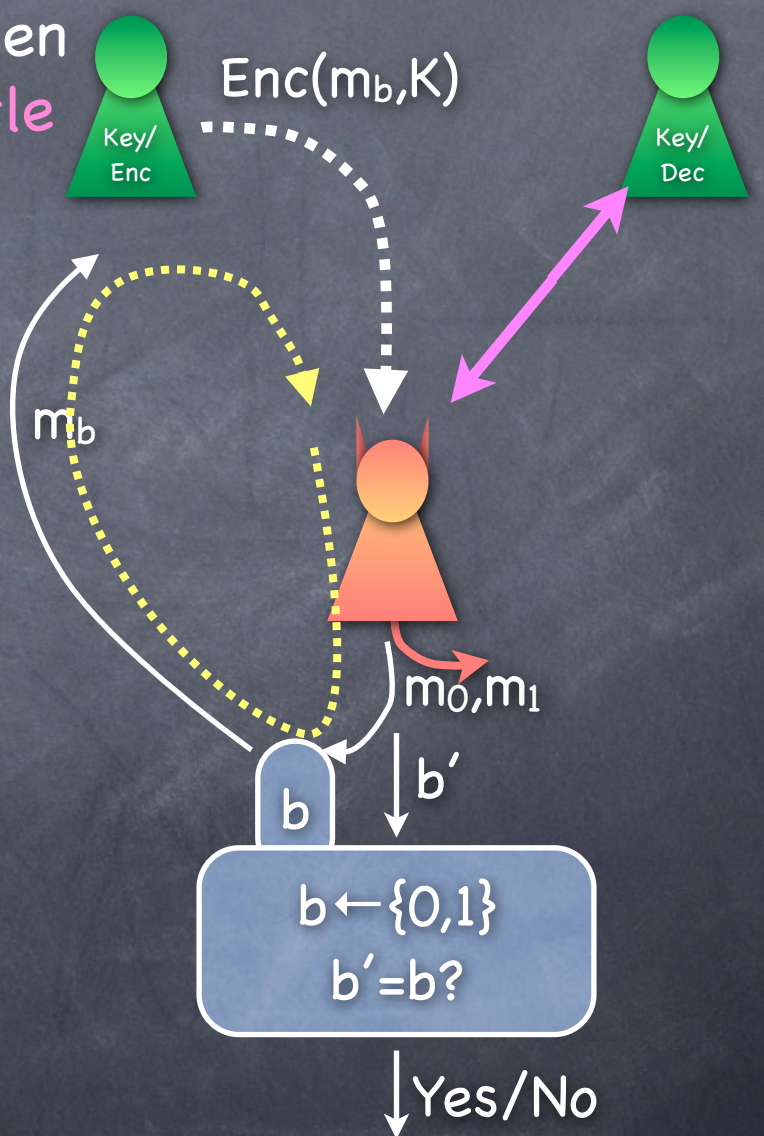

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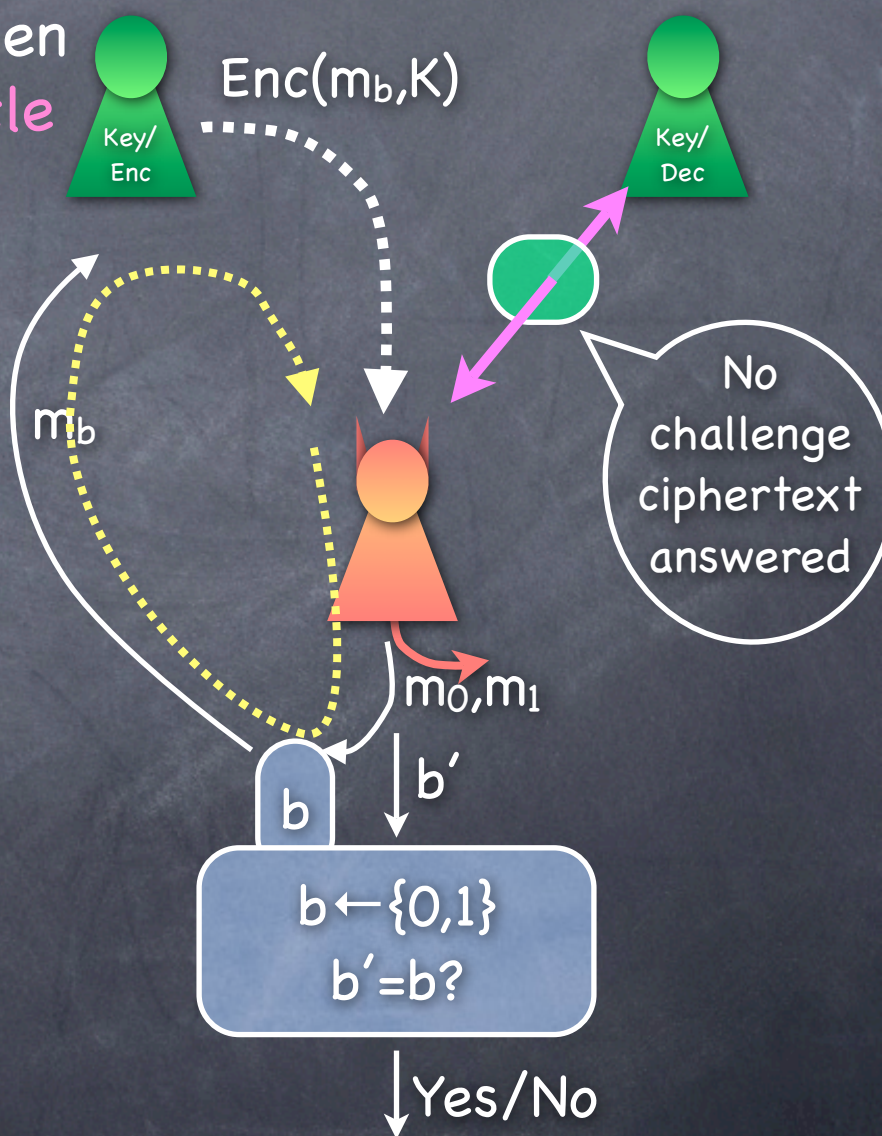

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IND-CCA + correctness ~ equivalent to SIM-CCA

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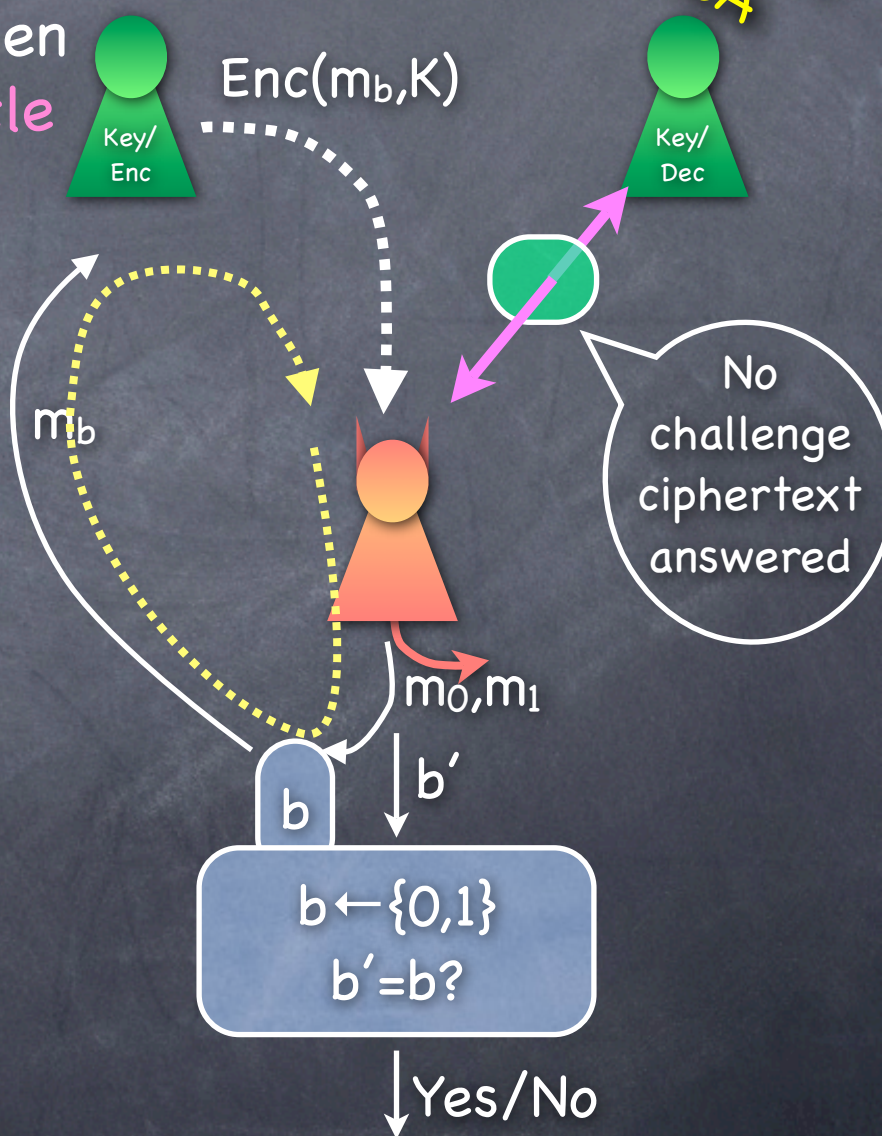

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- SIM- definitions give the big picture, but may not give details of what is involved in satisfying it. Could be "too strong"
- Best of both worlds when they are equivalent:
  use IND- definition while say proving security of a construction;
  use SIM- definition when low-level details are not important

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  - For multi-message schemes we relaxed the "perfect" simulation requirement
  - But what is $\approx$?
  - And, how to build symmetric-key encryption schemes