Broadcast Steganography
or
How to Broadcast a Secret *Covertly*

Nelly Fazio
The City College of CUNY
fazio@cs.ccny.cuny.edu

Antonio R. Nicolosi
Stevens Institute of Technology
nicolosi@cs.stevens.edu

Irippuge Milinda Perera
The Graduate Center of CUNY
iperera@gc.cuny.edu

NY
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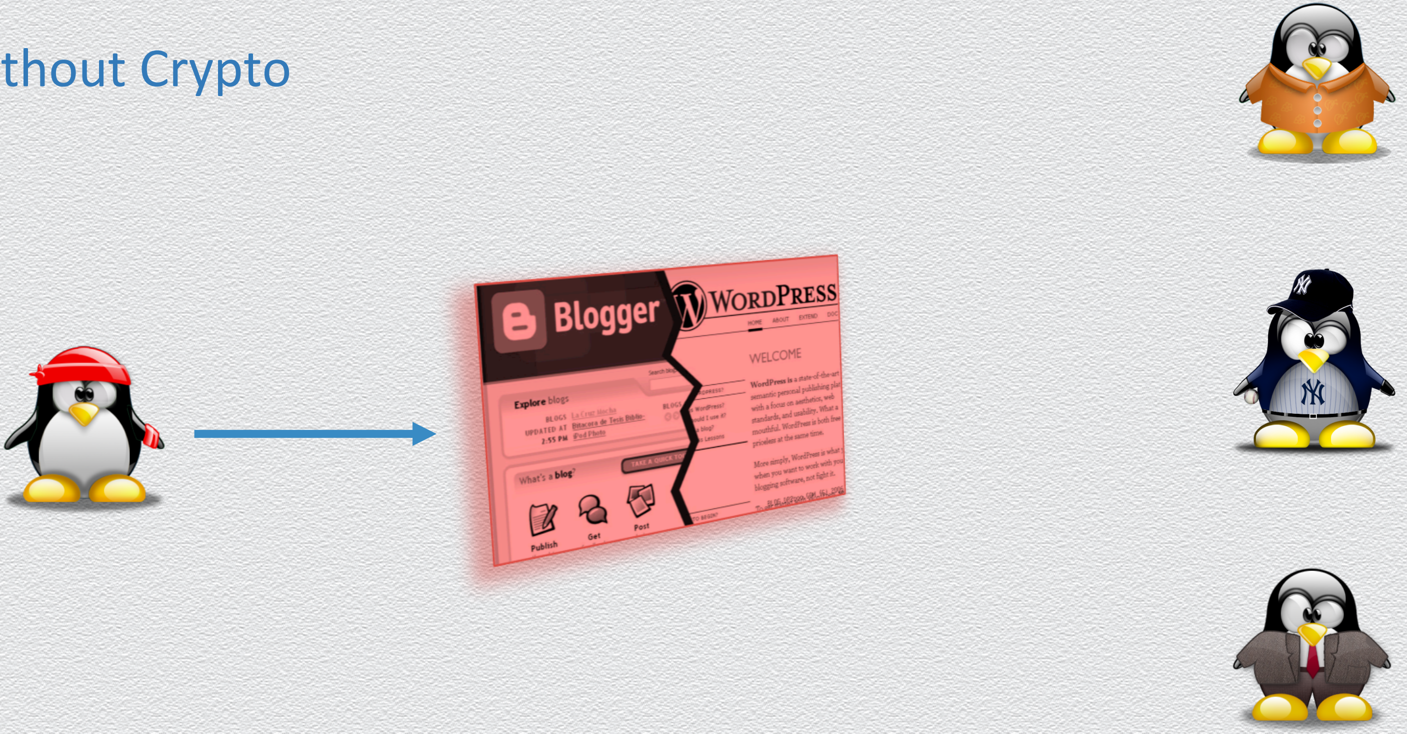
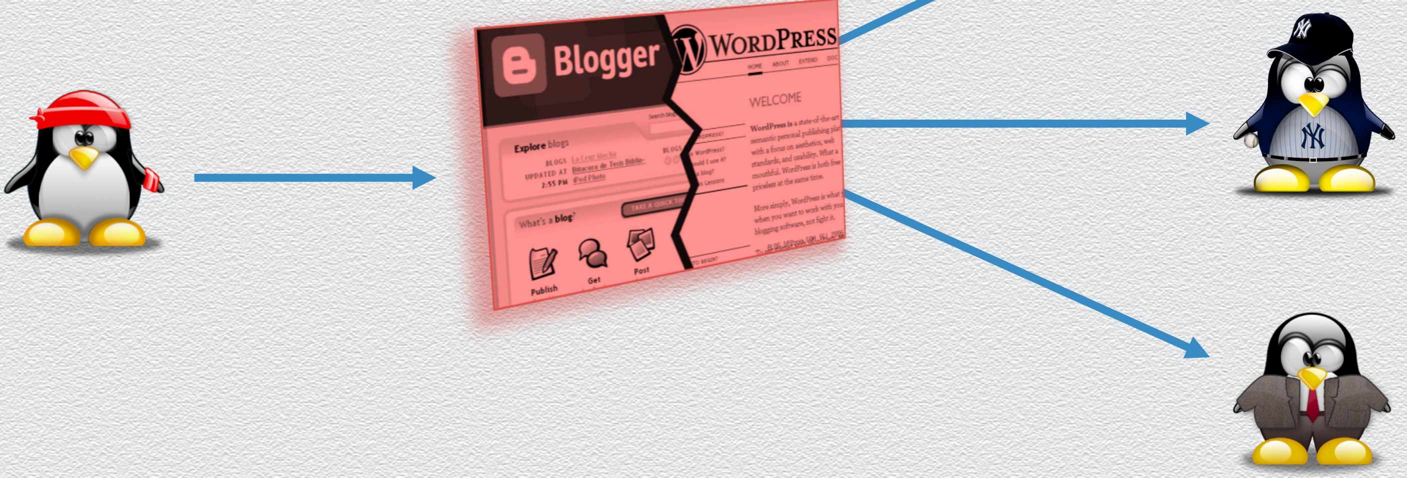
Without Crypto



Without Crypto



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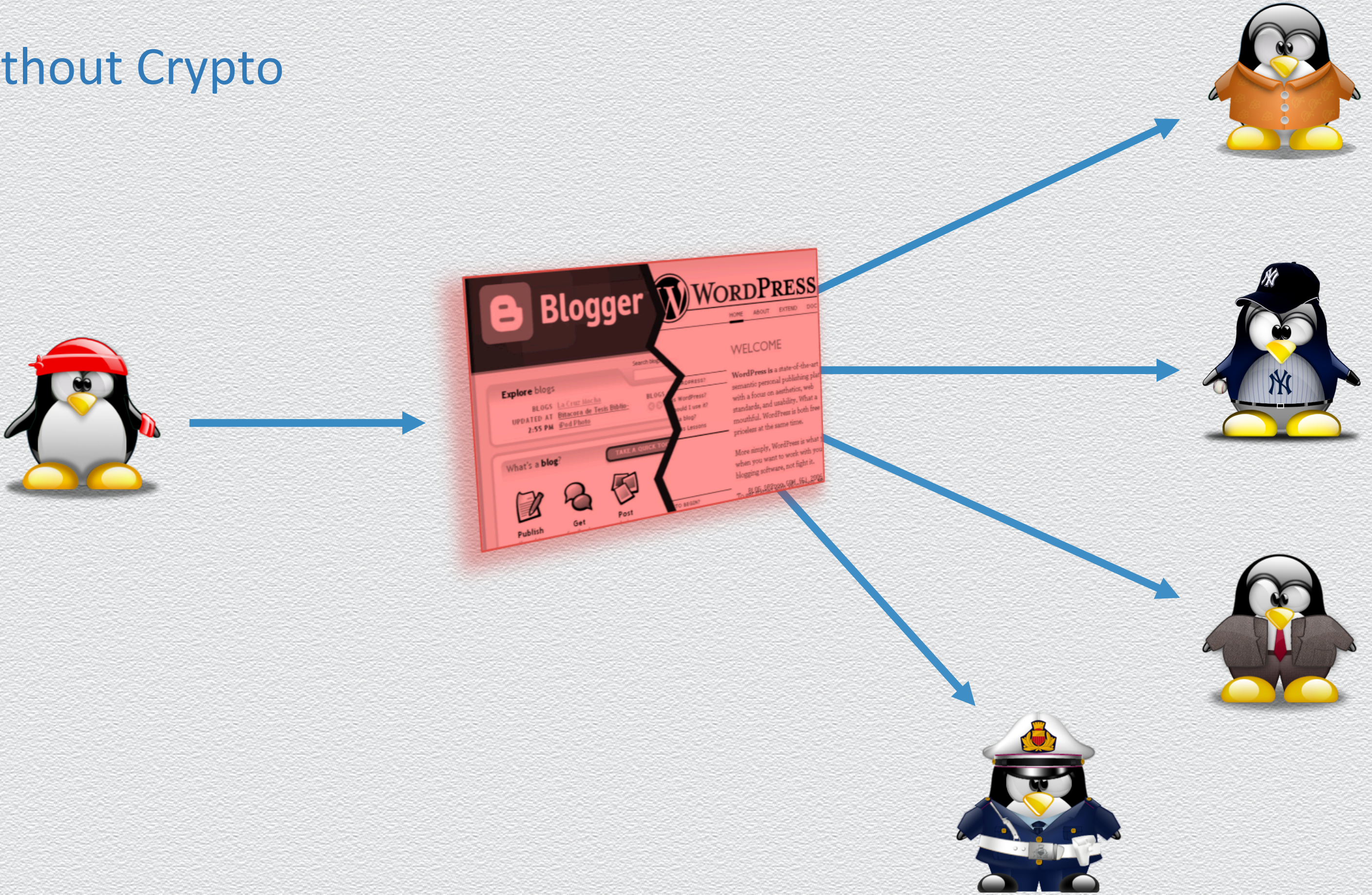
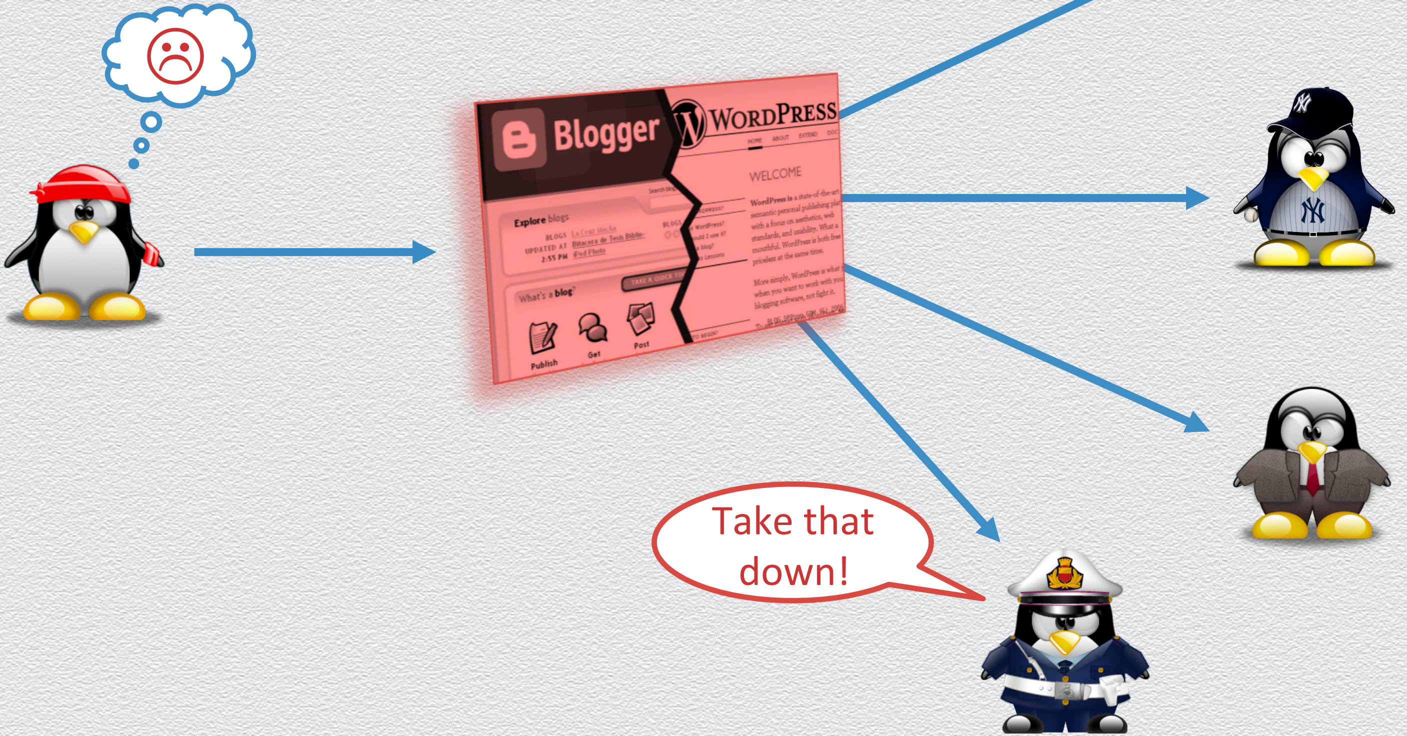


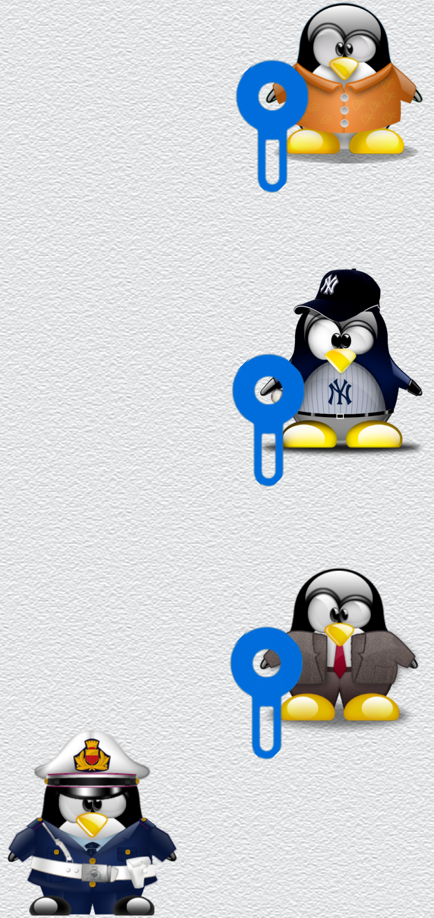
WordPress is a state-of-the-art semantic personal publishing plat with a focus on aesthetics, web standards, and usability. What a mouthful. WordPress is both free priceless at the same time.

More simply, WordPress is what y when you want to work with you blogging software, not fight it.

Without Crypto



With Encryption



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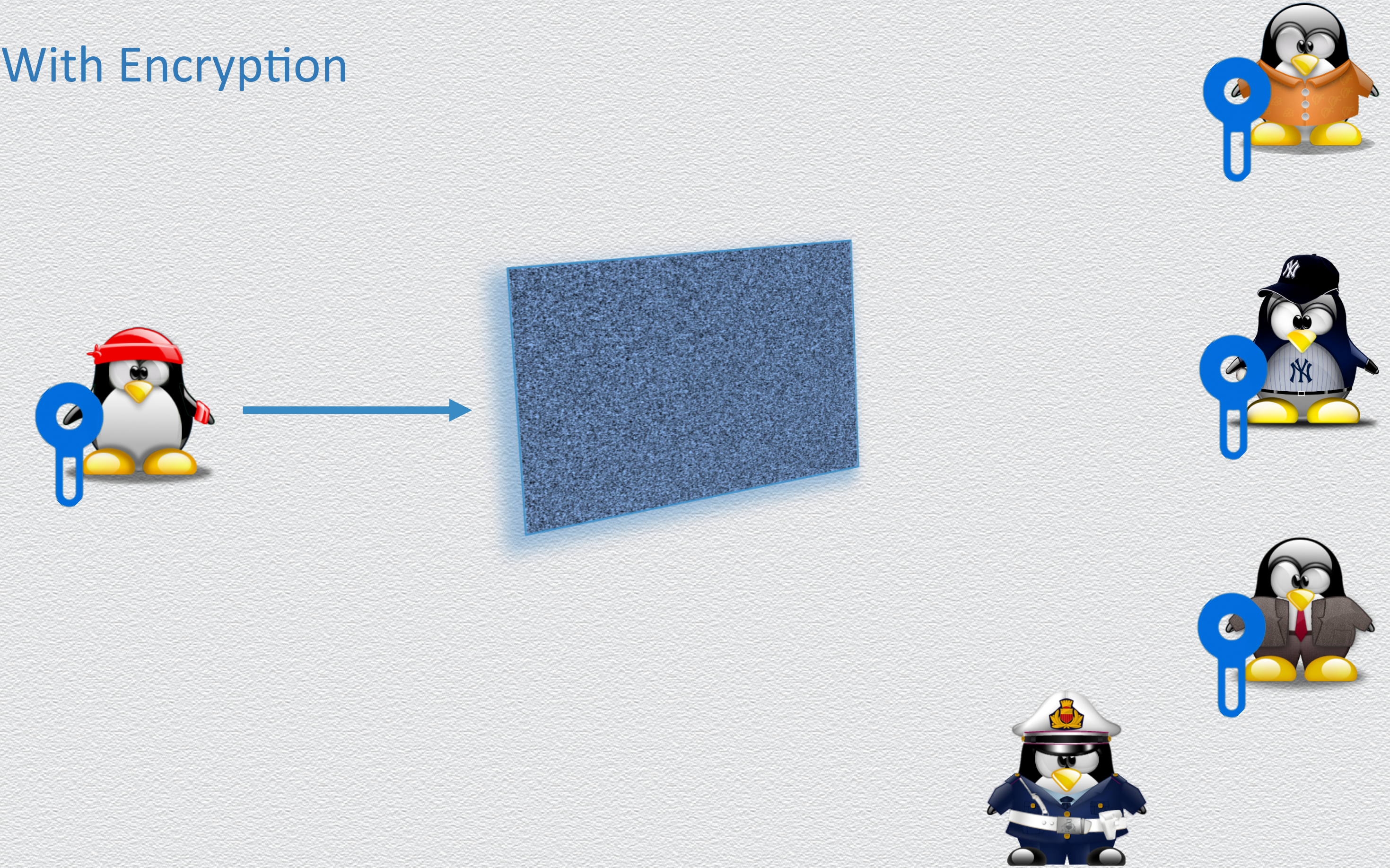

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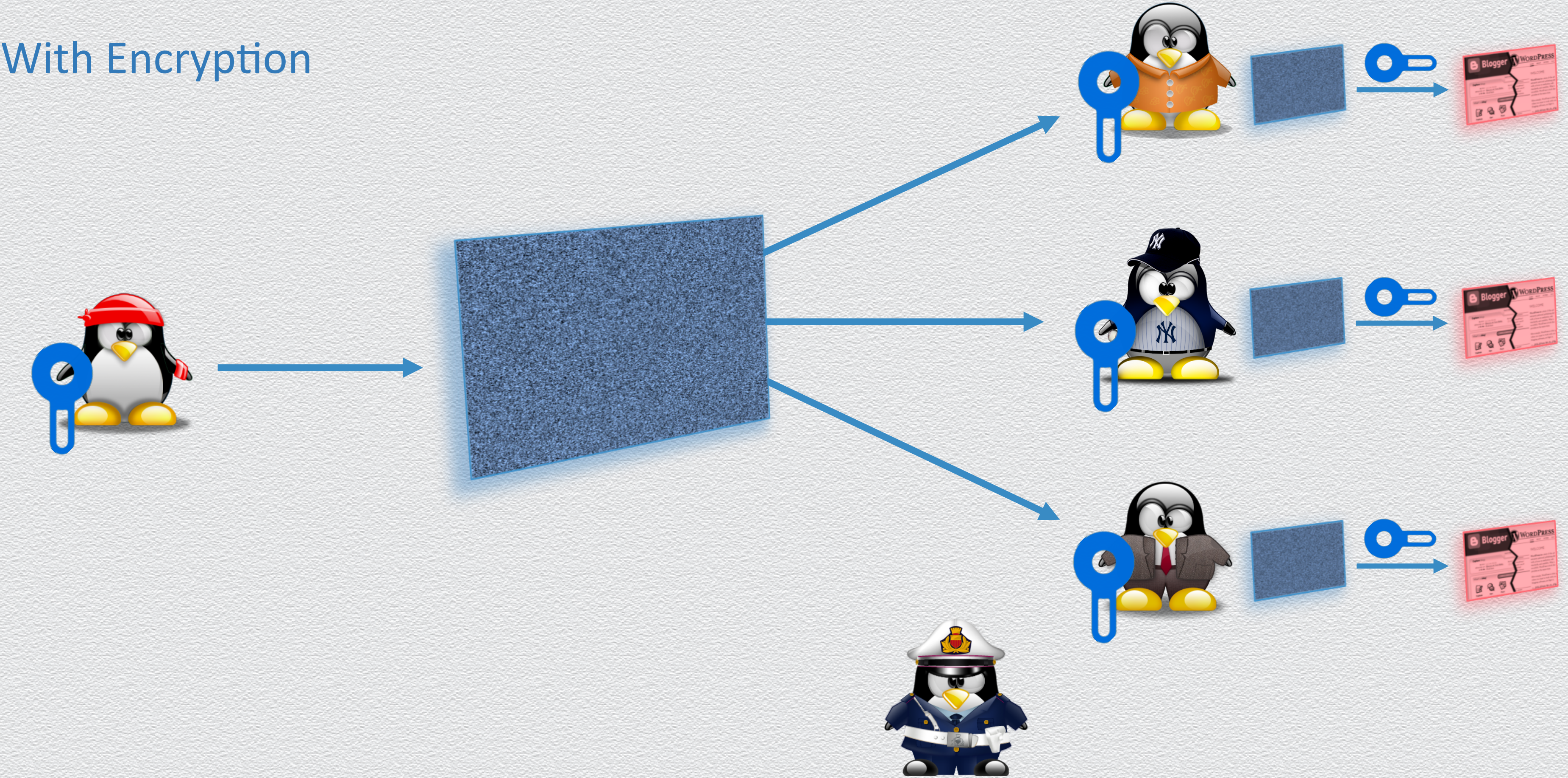

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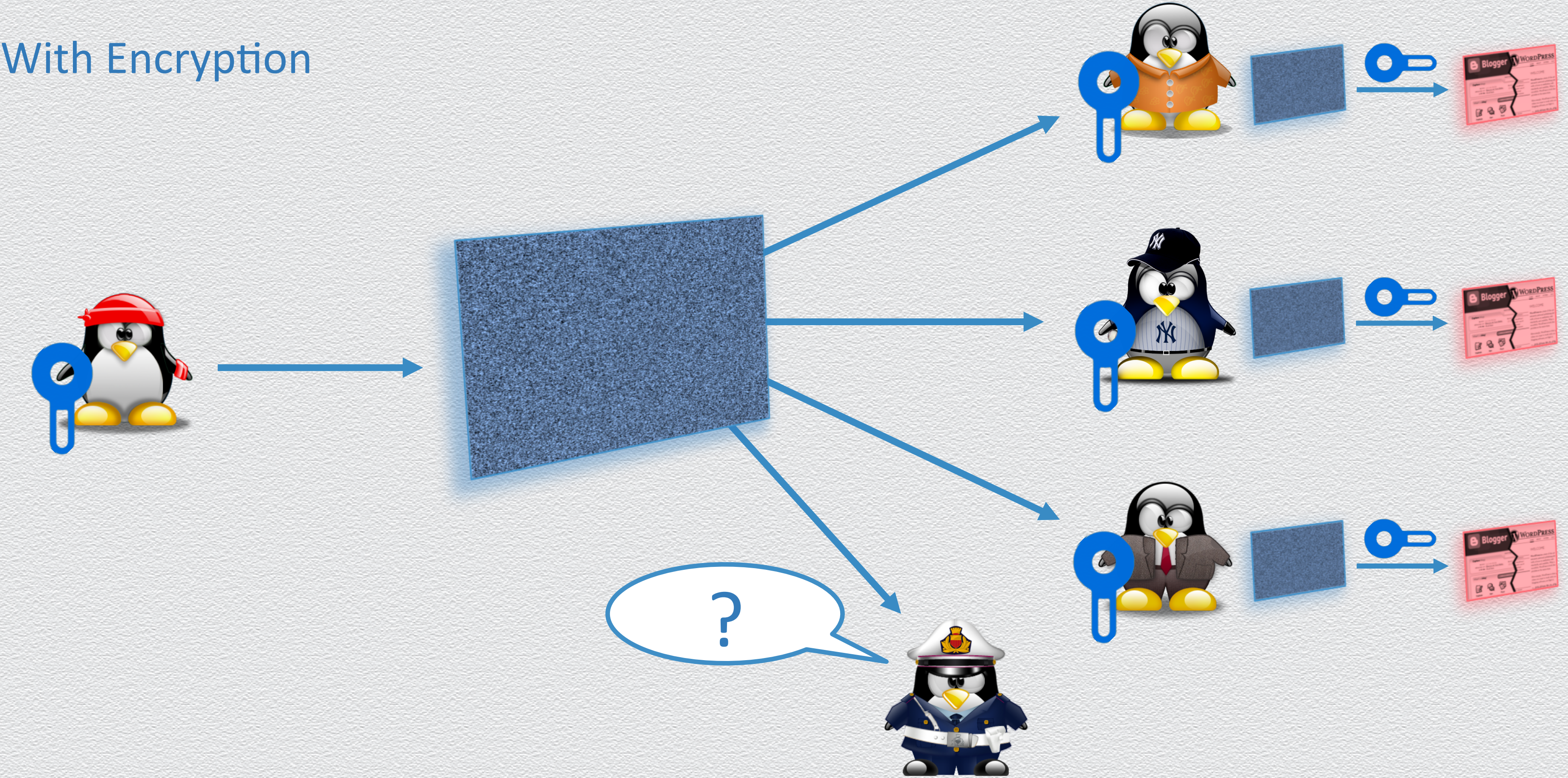

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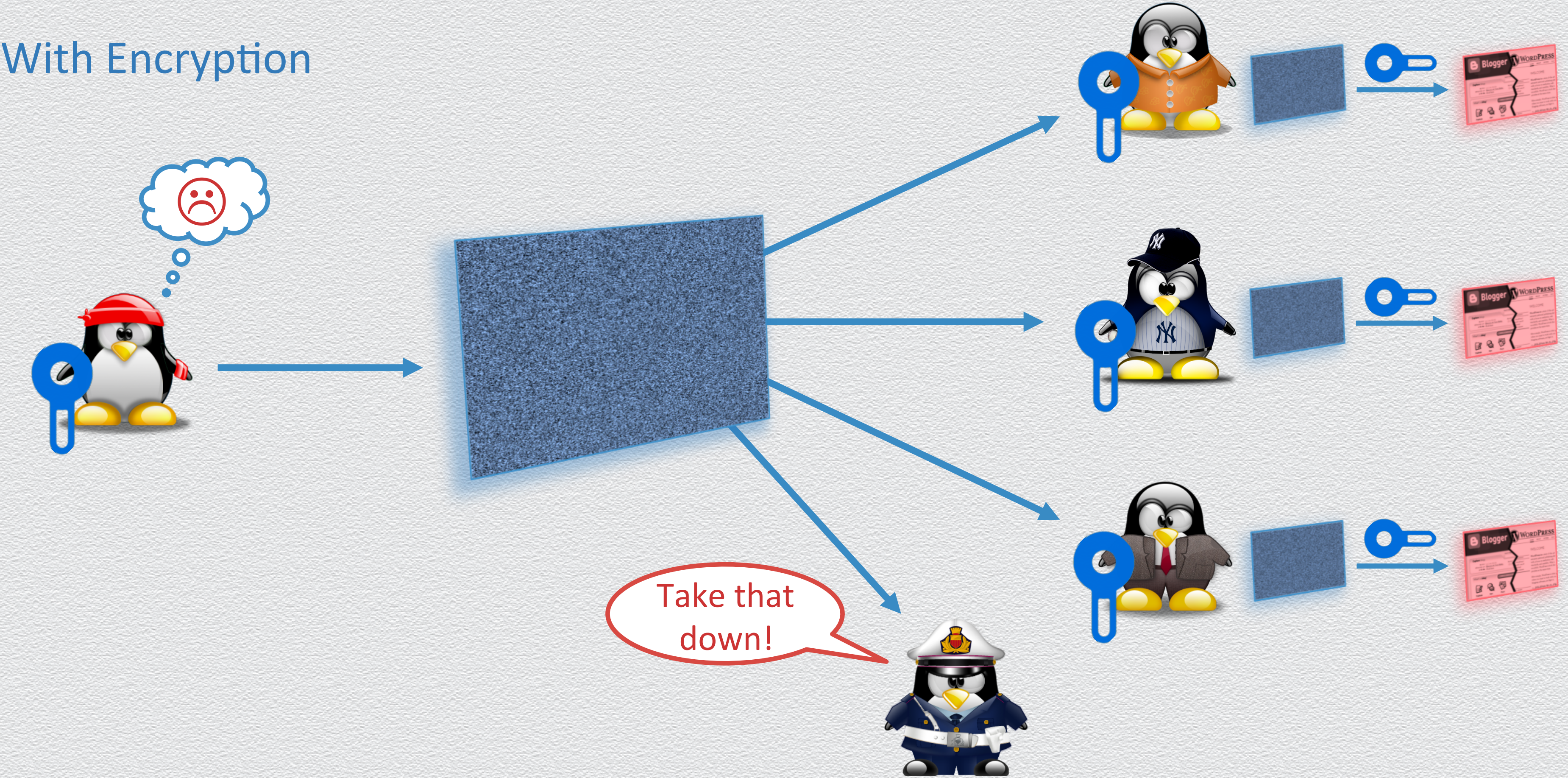

With Steganography

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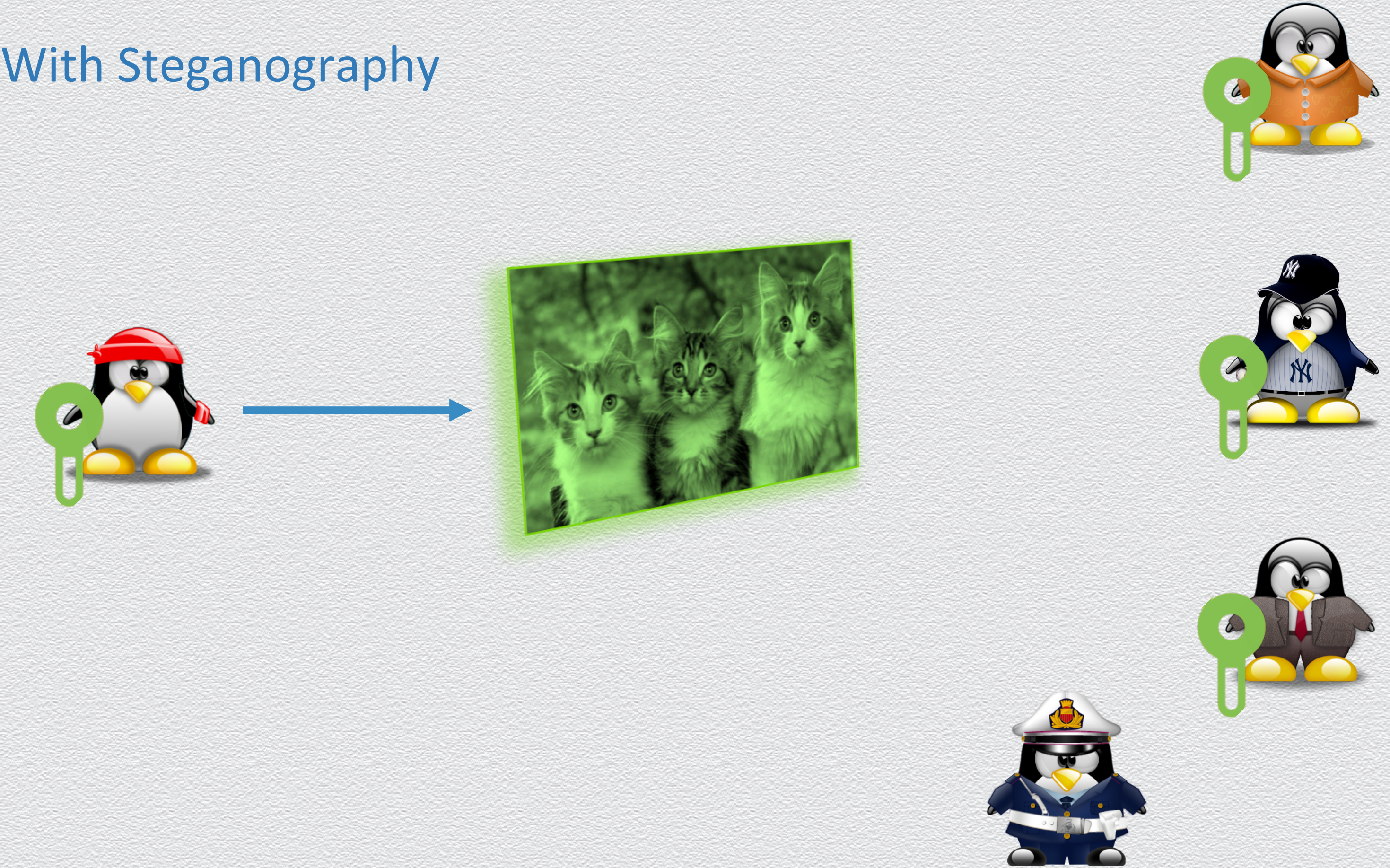

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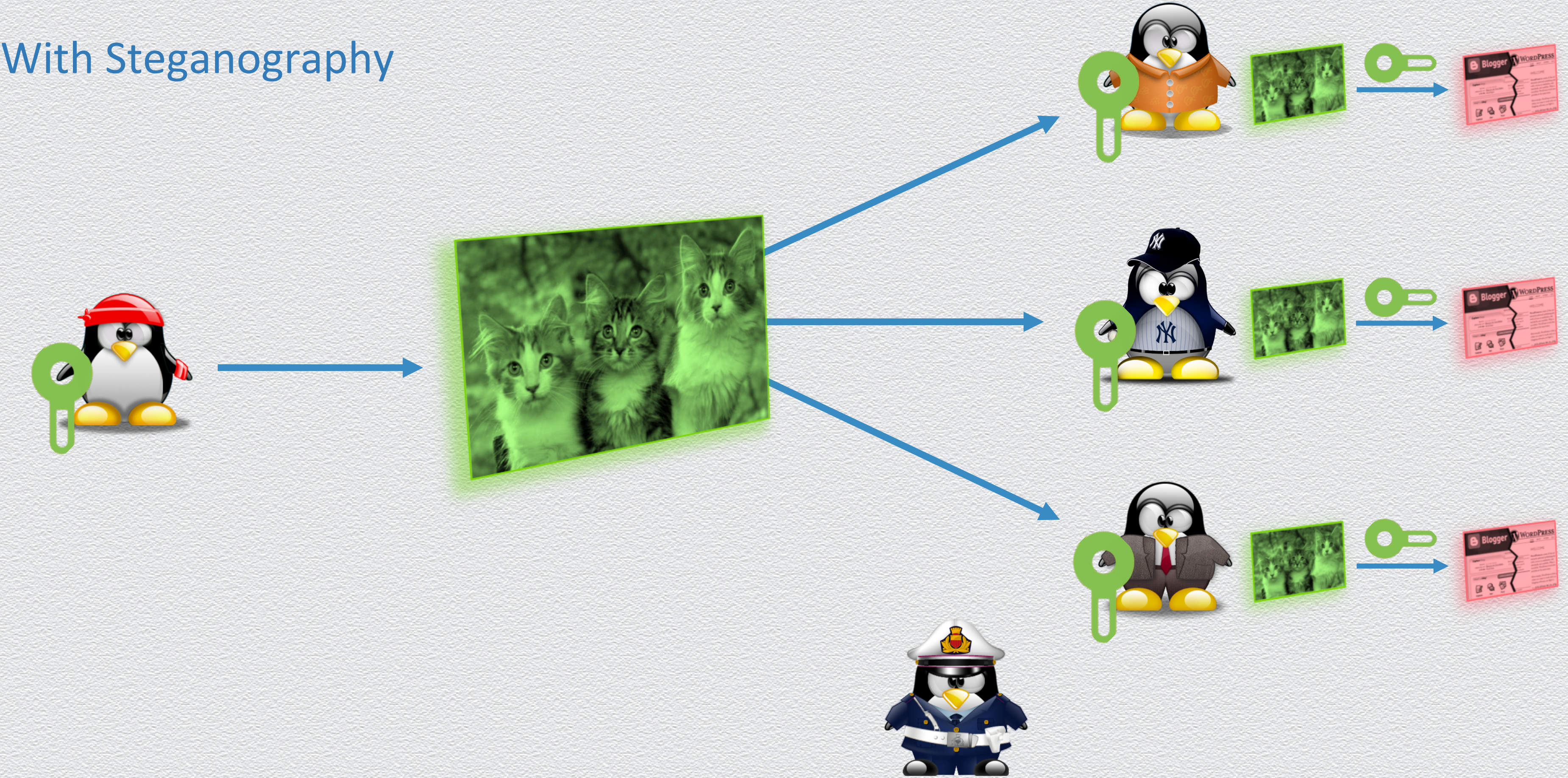

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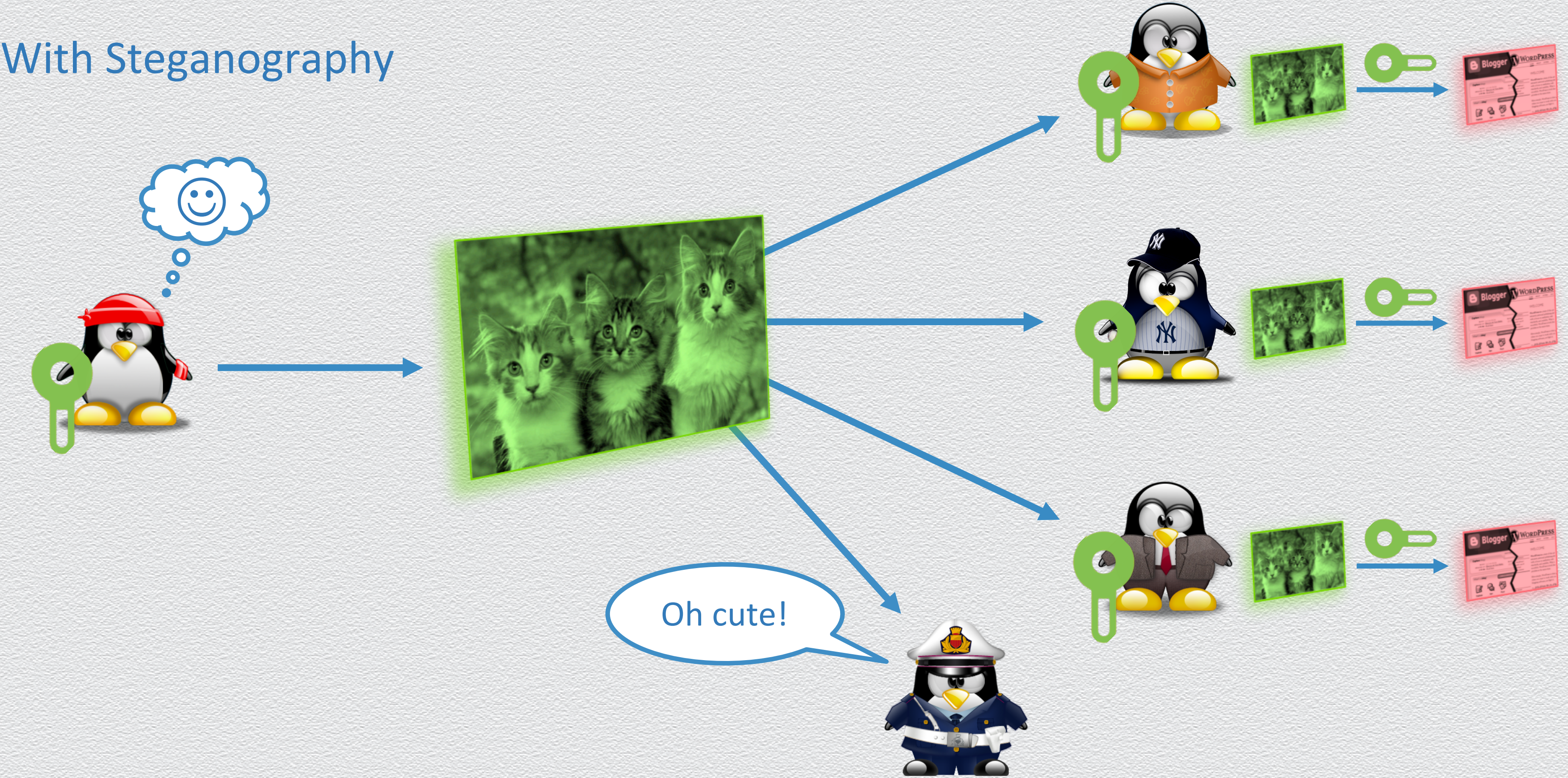

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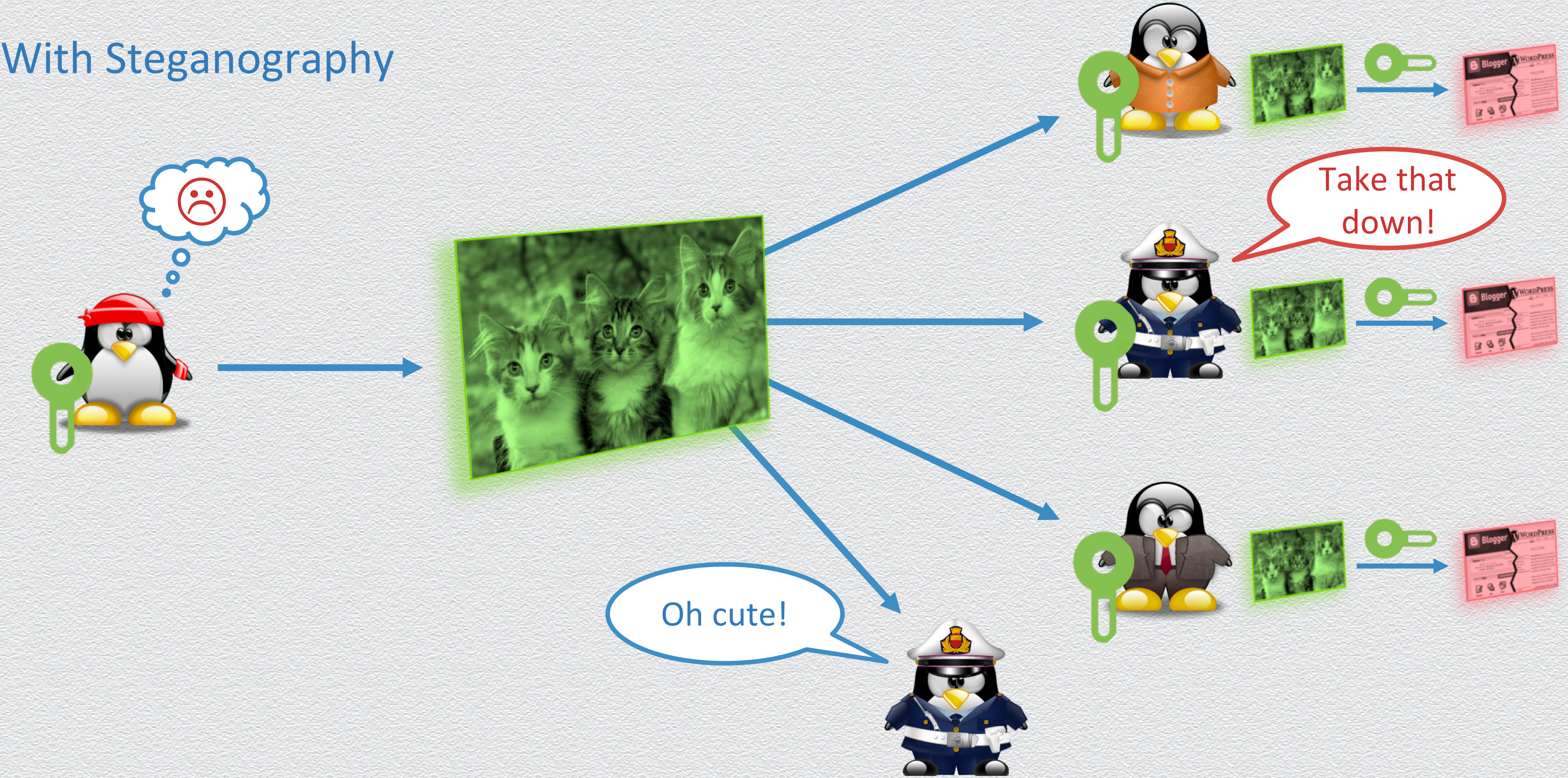

With Broadcast Steganography [This Work]

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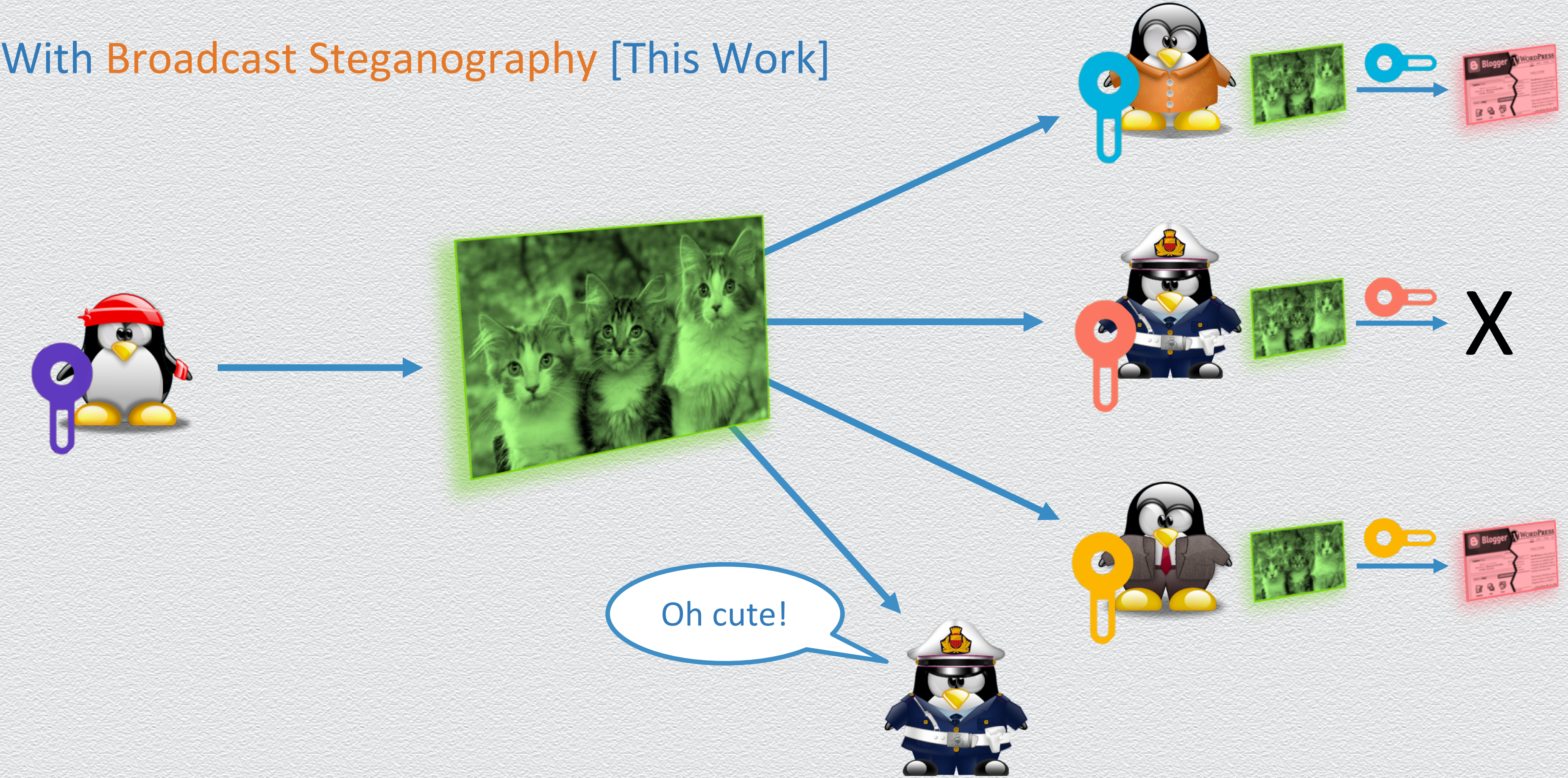

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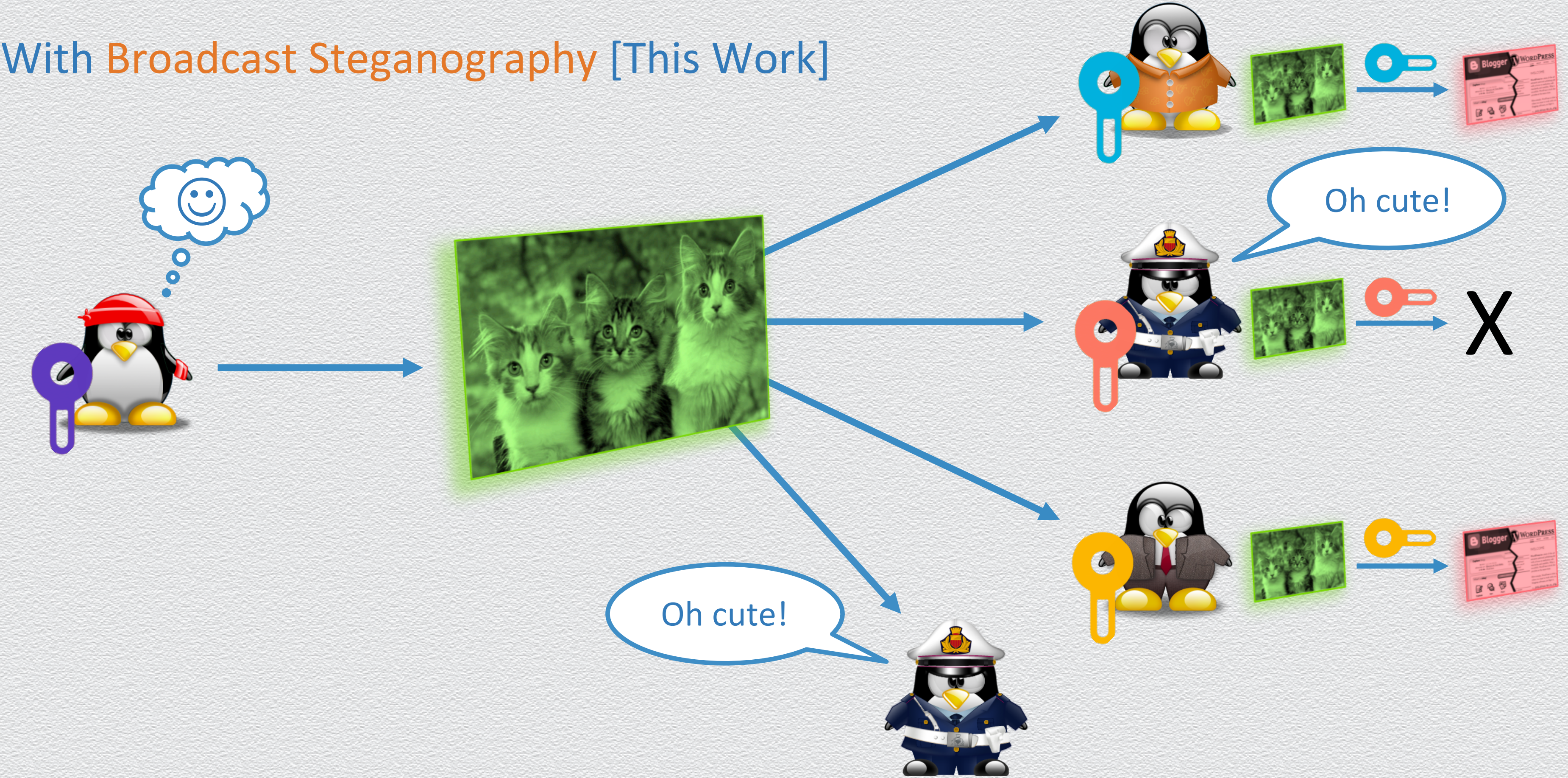
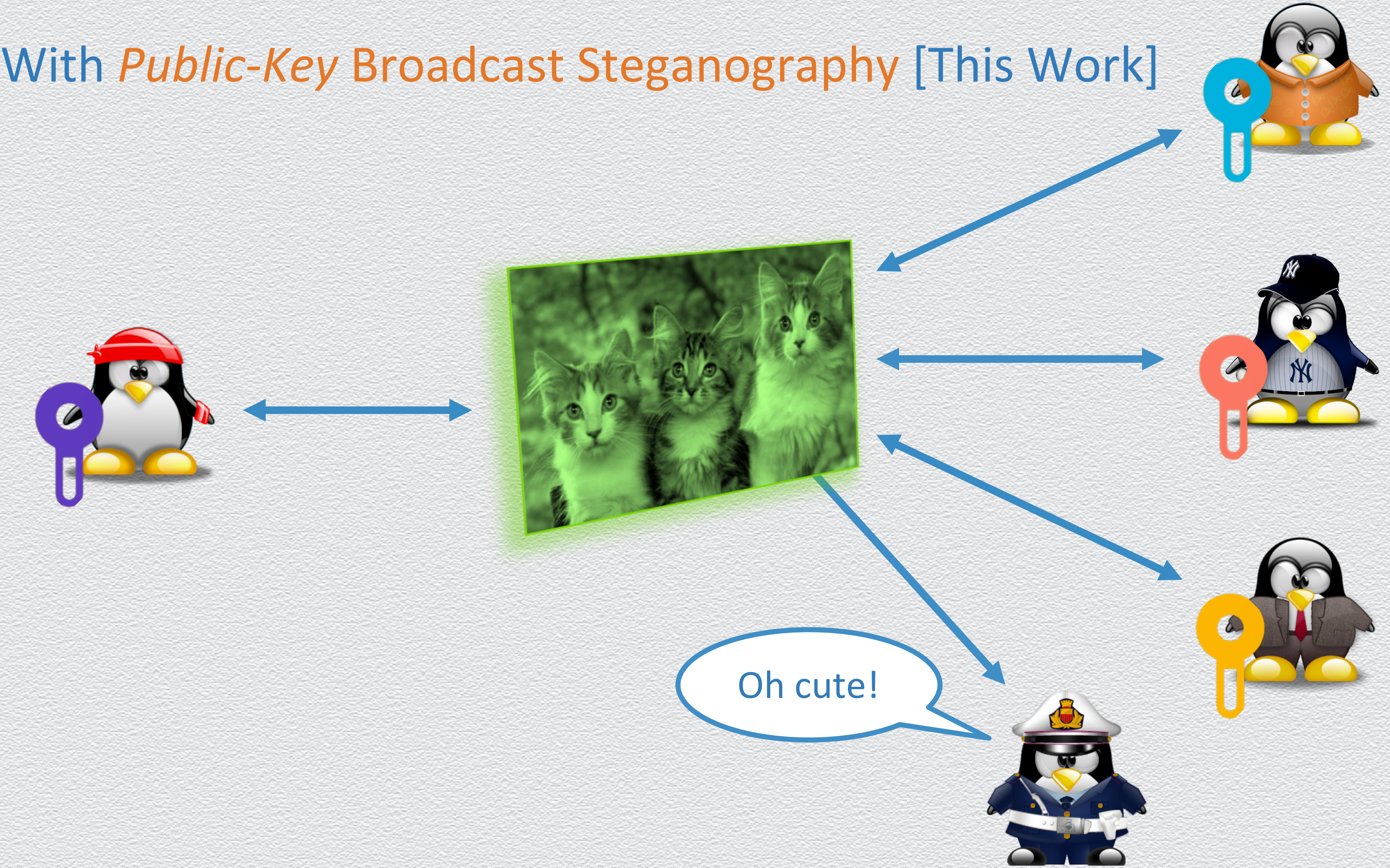


With *Public-Key* Broadcast Steganography [This Work]



- Broadcast Steganography (BS)
- Constructions
- Summary

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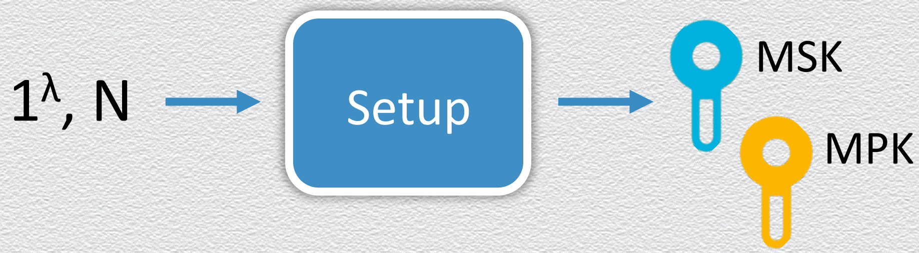
- ○ Constructions
- ○ Summary

The Setting

Setup

The Setting



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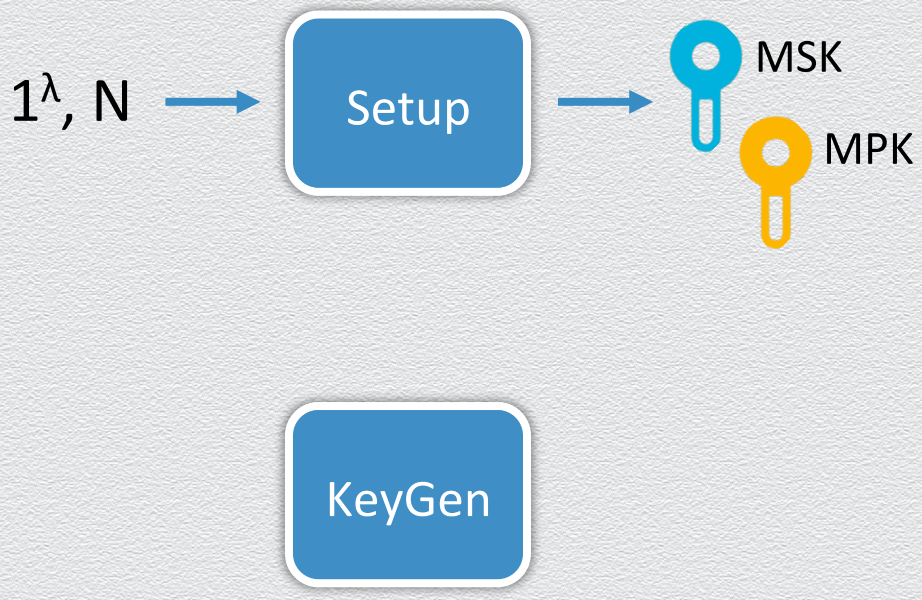


1^λ, N

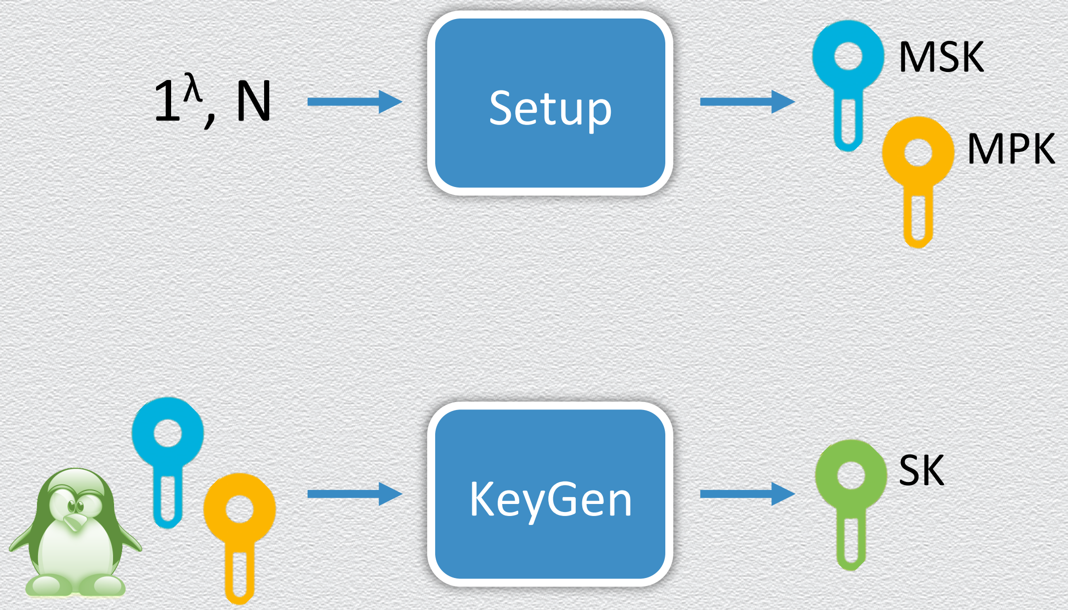
Setup

MSK

MPK

KeyGen

The Setting



1^λ, N

Setup

MSK

MPK

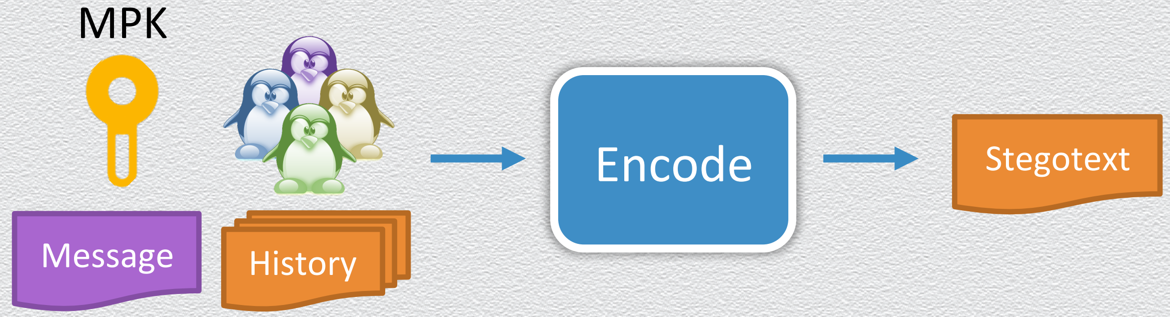
KeyGen

SK

The Setting

Encode

The Setting



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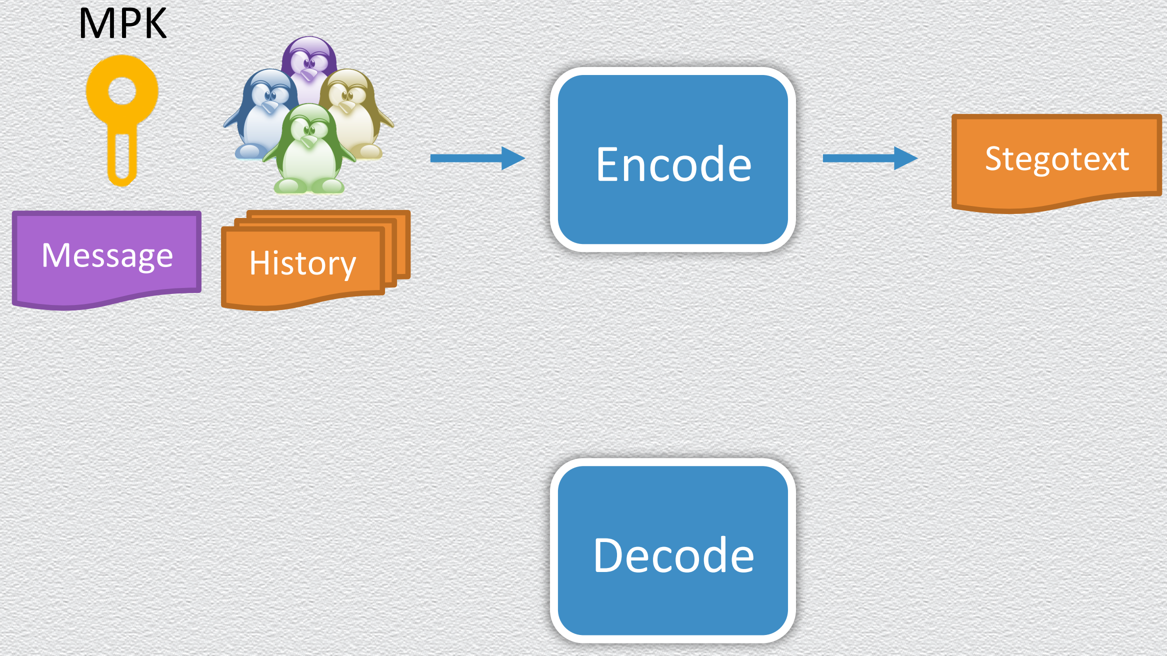

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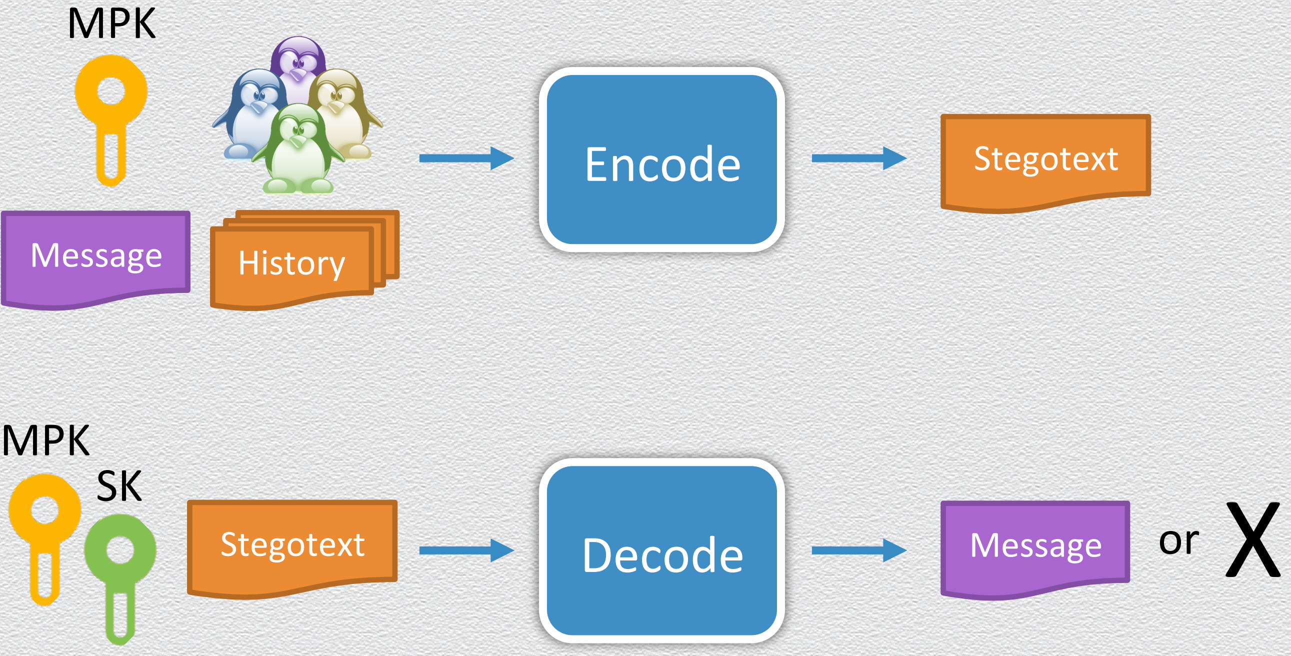
MPK
Message
History
Encode
Stegotext
MPK
SK
Stegotext
Decode
Message
or
X

The Security Model

1. Chosen-Covertext Attack (BS-IND-CCA)
    - Analogous to BE-IND-CCA model
    - Adversary is allowed to corrupt users
    - Adversary is also given access to a decoding oracle
2. Publicly-Detectable Replayable Chosen Covertext Attack (BS-IND-PDR-CCA)
    - Similar to BS-IND-CCA, but with stricter restrictions on allowable decoding queries
3. Chosen-Hiddentext Attack (BS-IND-CHA)
    - Analogous to BE-IND-CPA model
    - Adversary is only allowed to corrupt users
    - No decoding queries

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The Security Model

BS-IND-CCA Game

① Setup

② Oracle Phase 1

③ Challenge

④ Oracle Phase 2

⑤ Guess

The Security Model

① Setup

The Security Model

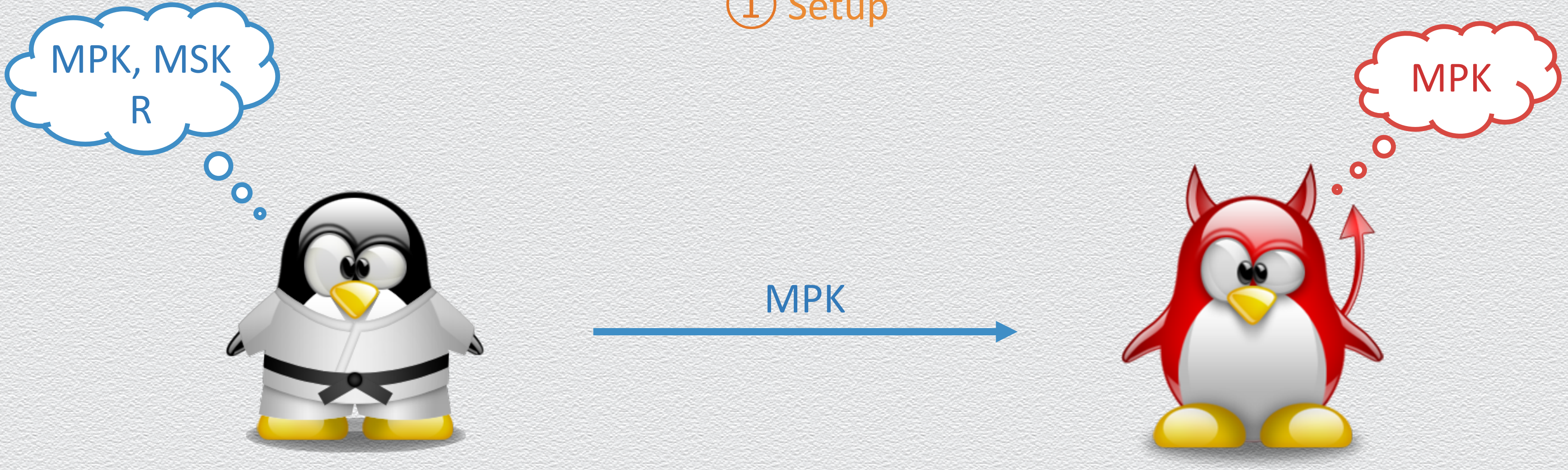
① Setup

$(\mathrm{MPK}, \mathrm{MSK}) \leftarrow \mathrm{Setup}(1^{\lambda}, N)$

$\mathrm{R} := \emptyset$

The Security Model

① Setup



MPK, MSK
R

MPK

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The Security Model

② Oracle Phase 1

The Security Model

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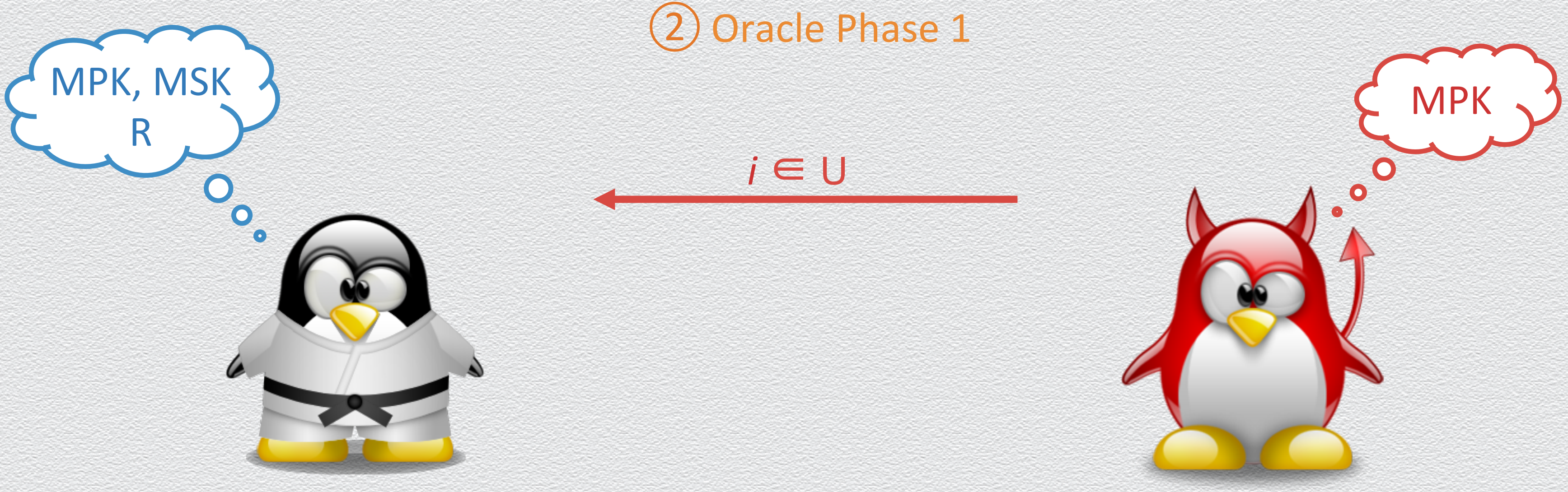


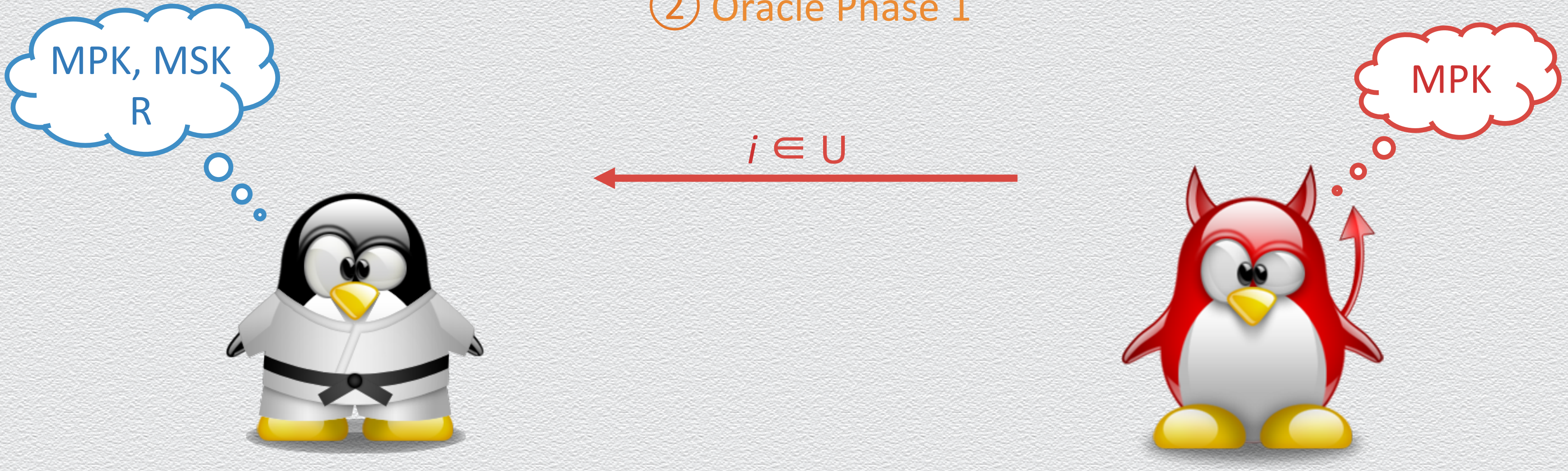
MPK, MSK
R

$i \in U$

MPK

The Security Model

② Oracle Phase 1



MPK, MSK

R

$i \in$ U

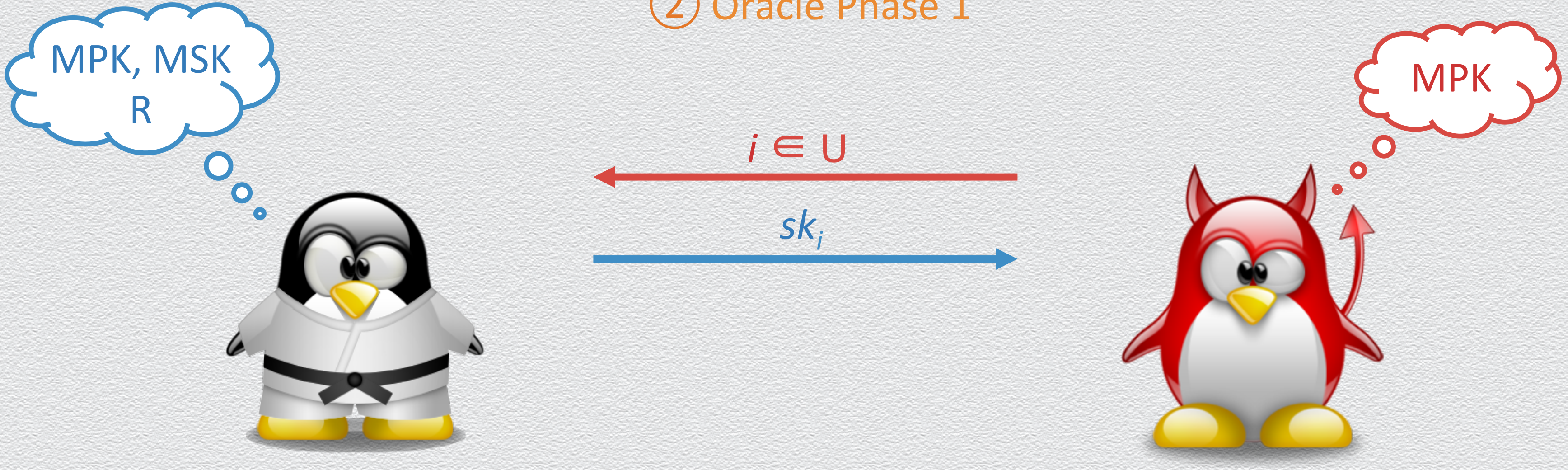
MPK

$\mathrm{R} := \mathrm{R} \cup \{i\}$

$sk_i \leftarrow \mathrm{KeyGen}(\mathrm{MPK}, \mathrm{MSK}, i)$

The Security Model

② Oracle Phase 1



MPK, MSK
R

$i \in$ U

sk_i

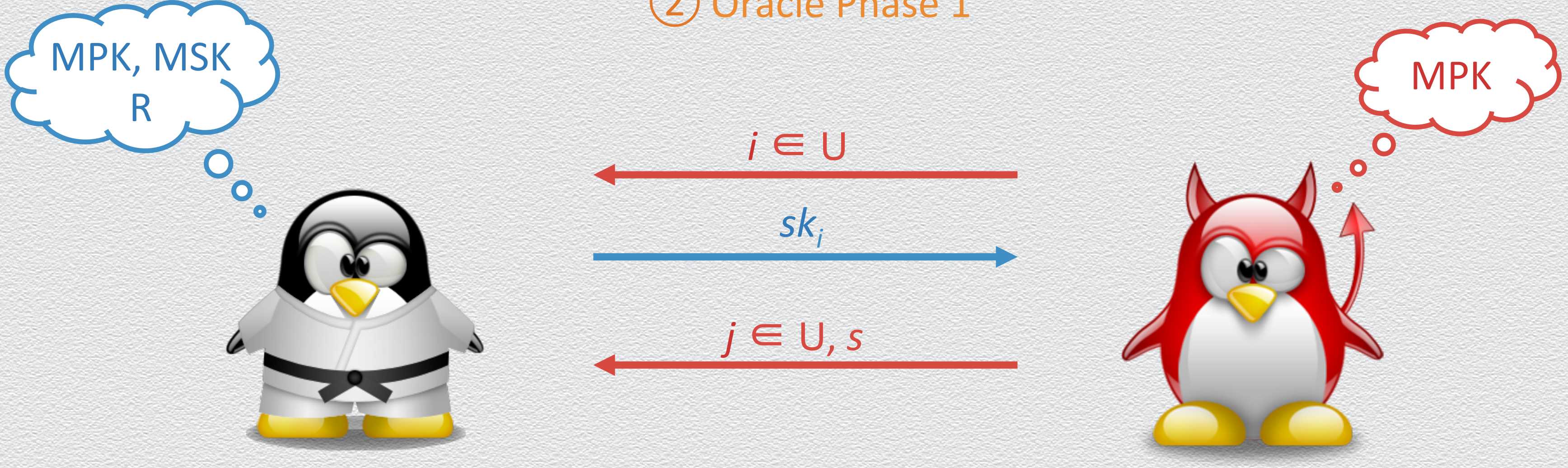
MPK

R := R ∪ { i }

$sk_i \leftarrow$ KeyGen(MPK, MSK, i)

The Security Model

② Oracle Phase 1



MPK, MSK
R

$i \in U$

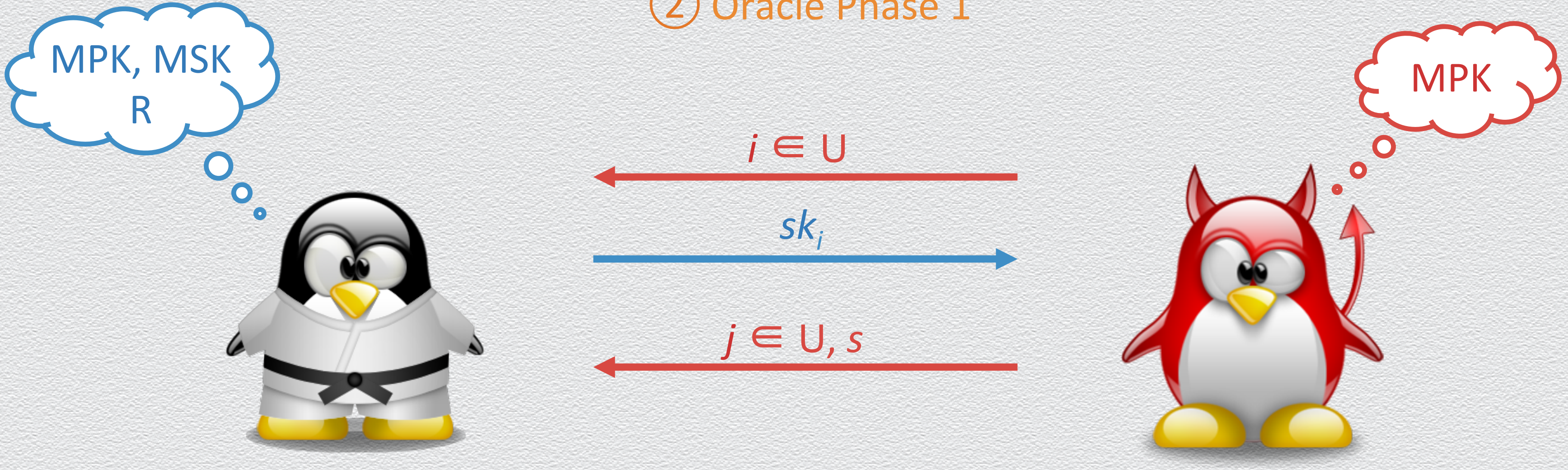
sk_i

$j \in U, s$

MPK

The Security Model

② Oracle Phase 1



MPK, MSK
R

$i \in \mathrm{U}$

sk_i

$j \in \mathrm{U}, s$

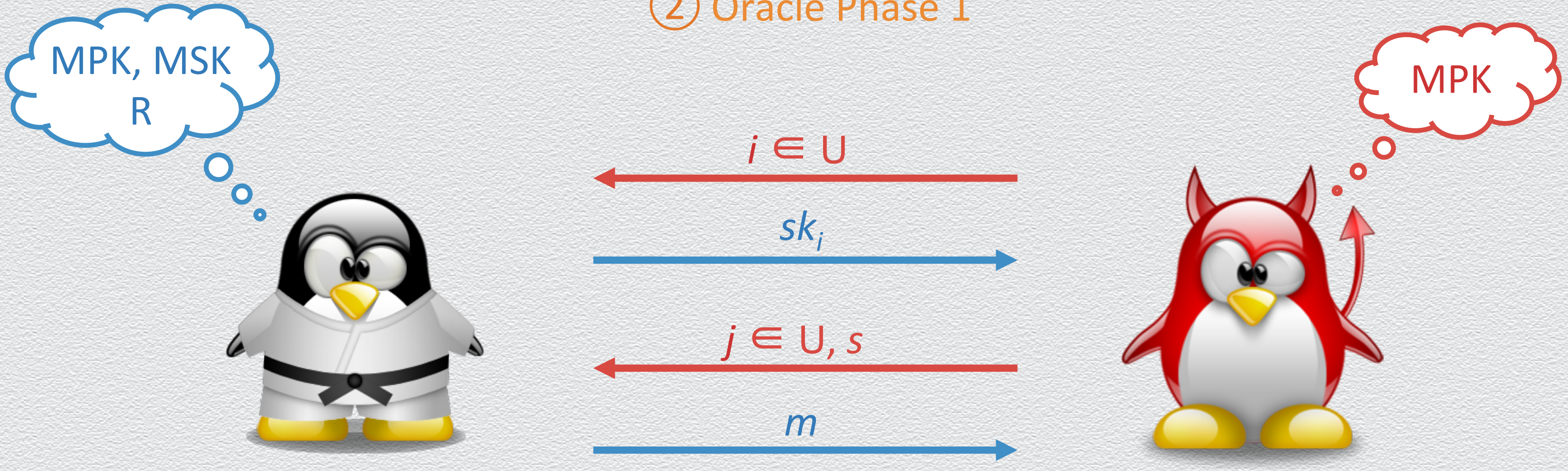
MPK

$sk_j \leftarrow \mathrm{KeyGen}(\mathrm{MPK}, \mathrm{MSK}, j)$

$m := \mathrm{Decode}(\mathrm{MPK}, sk_j, s)$

The Security Model

② Oracle Phase 1



MPK, MSK
R

MPK

$i \in$ U

sk_i

$j \in$ U, s

m

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The Security Model

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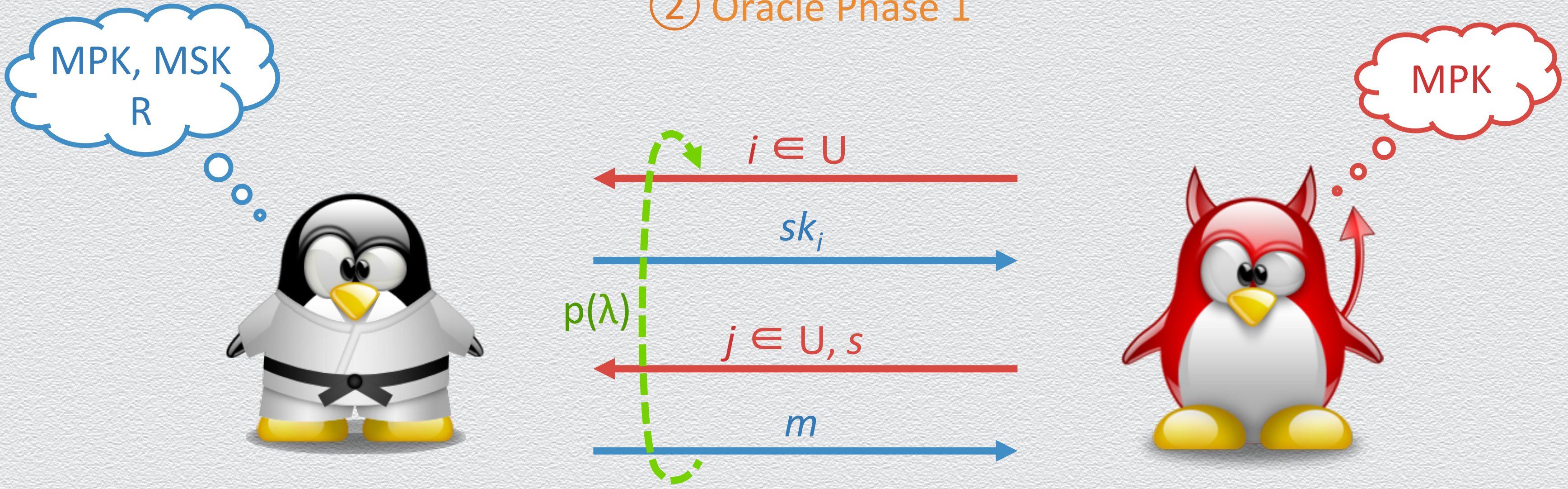

The Security Model

③ Challenge

The Security Model

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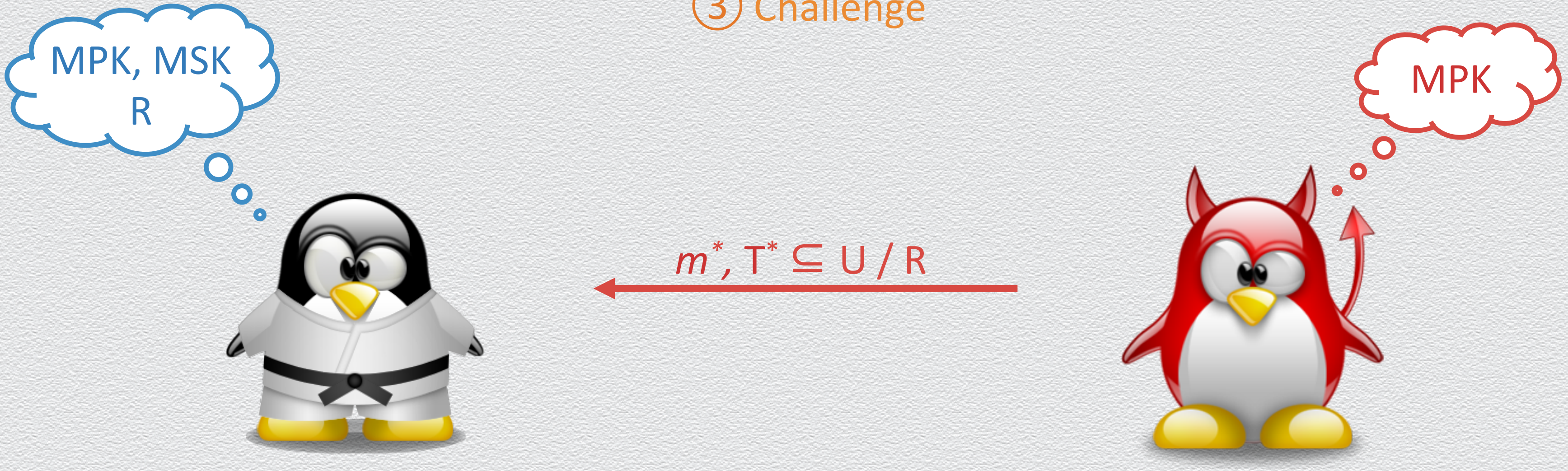


MPK, MSK
R

$m^*, T^* \subseteq U / R$

MPK

The Security Model

③ Challenge

MPK, MSK
R

$m^*, \mathrm{T}^* \subseteq \mathrm{U} / \mathrm{R}$ ←

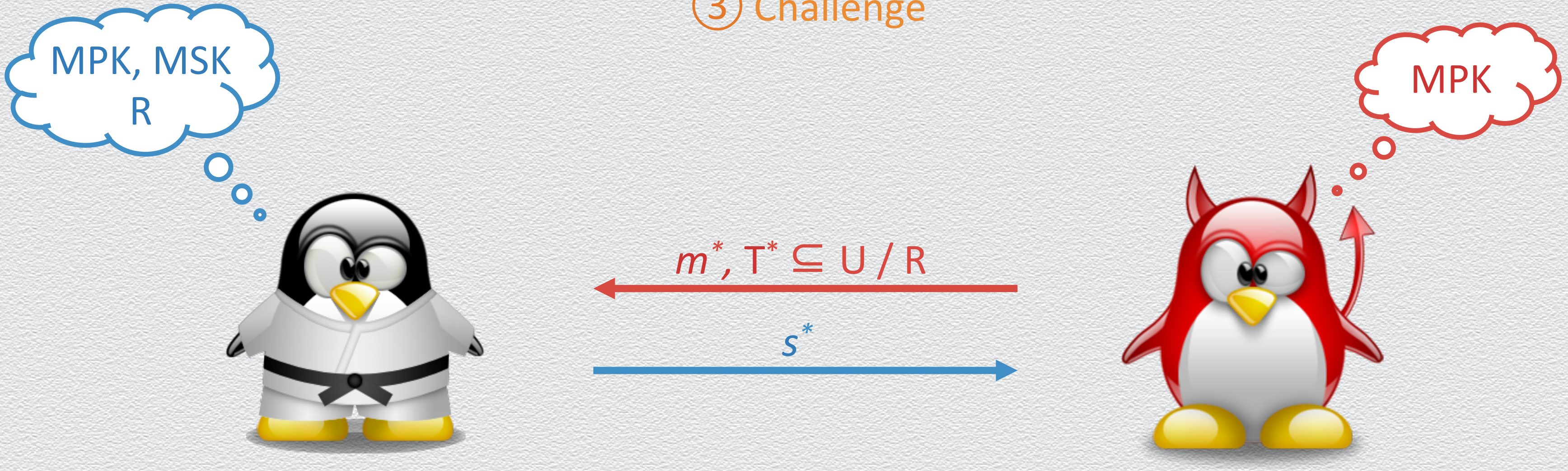
MPK

$b^* \leftarrow \{0,1\}$

$$s^* \leftarrow \begin{cases} \text{Encode}(\text{MPK}, \text{T}^*, m^*) & \text{if } b^* = 0 \\ \text{a random covertext} & \text{otherwise} \end{cases}$$

The Security Model

③ Challenge



MPK, MSK
R

m^*, $\mathrm{T}^* \subseteq \mathrm{U} / \mathrm{R}$

s^*

MPK

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The Security Model

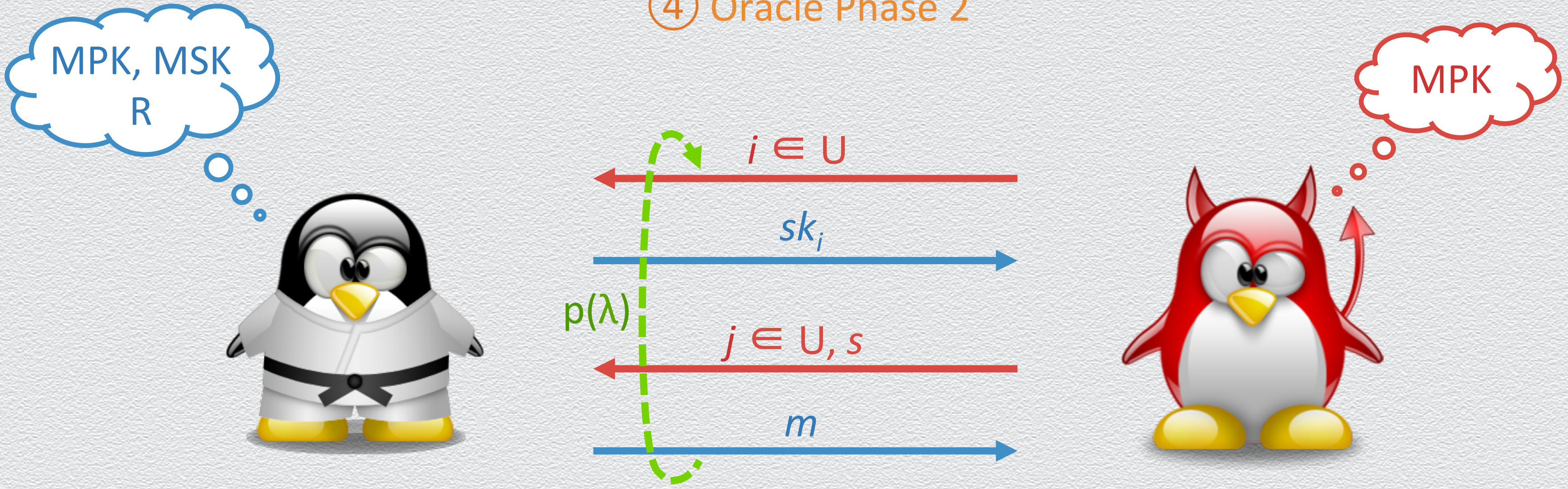
④ Oracle Phase 2

MPK, MSK
R

MPK

The Security Model

④ Oracle Phase 2

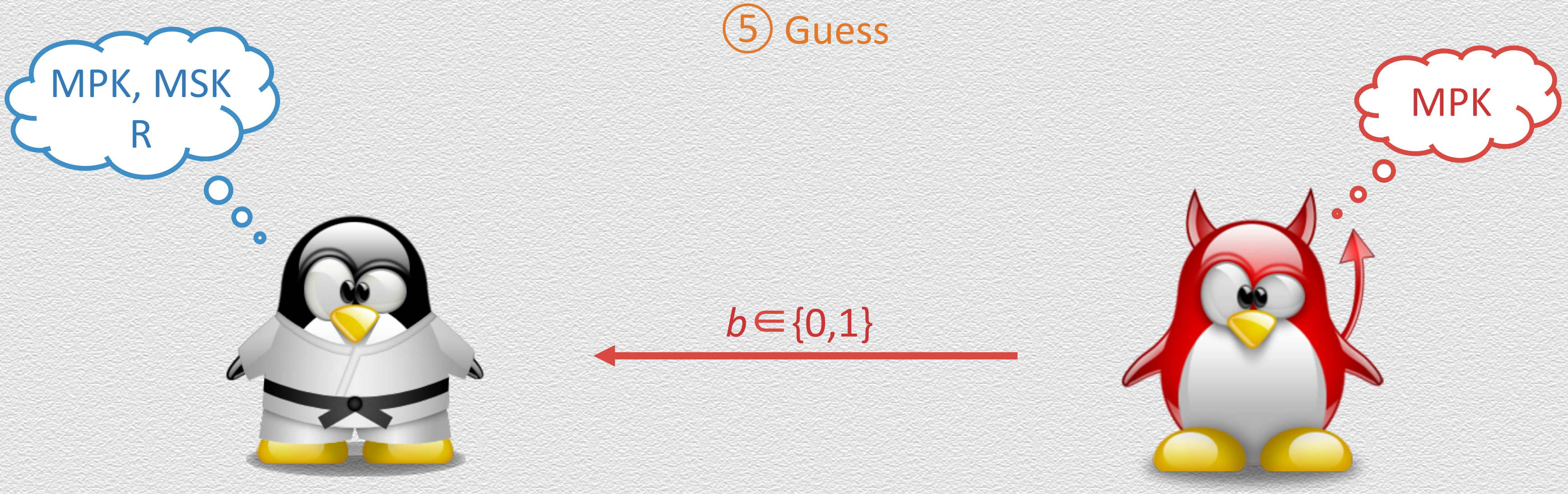


1) $i \notin T^*$
2) if $j \in T^*$, then $s \neq s^*$

The Security Model

⑤ Guess

The Security Model



⑤ Guess

MPK, MSK
R

MPK

$b \in \{0,1\}$

$\mathrm{Adv}_A = |\Pr[b = b^*] - ½|$

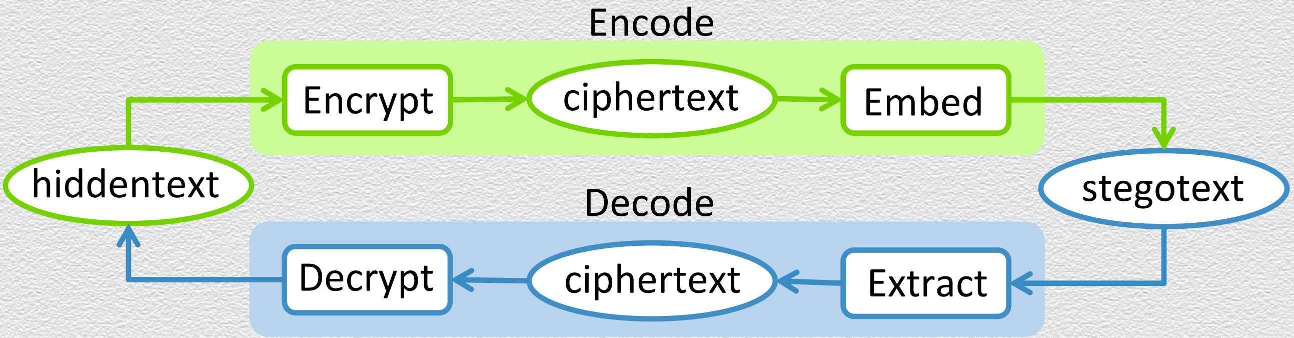
◉ Broadcast Steganography (BS)

◉ Constructions

○ Summary

Realizing Broadcast Steganography

- Encrypt-then-Embed Paradigm [HLvA02, BaCa05]



Realizing Broadcast Steganography

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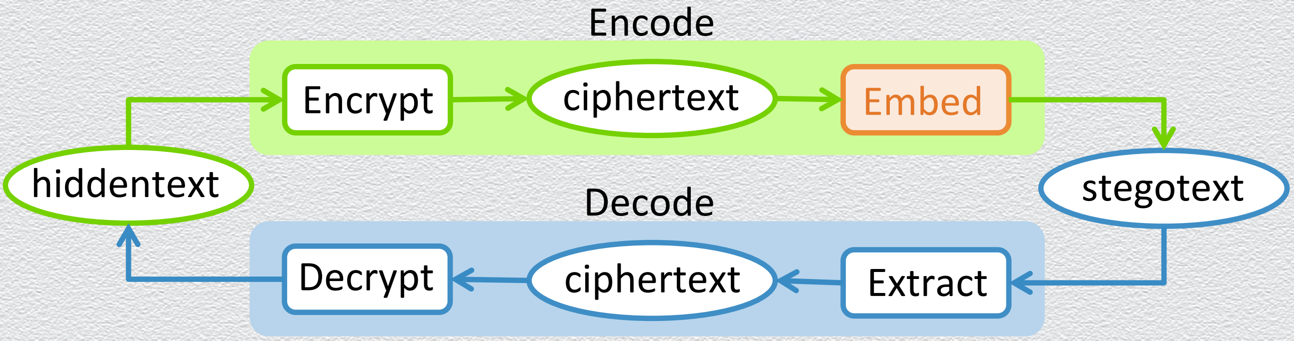
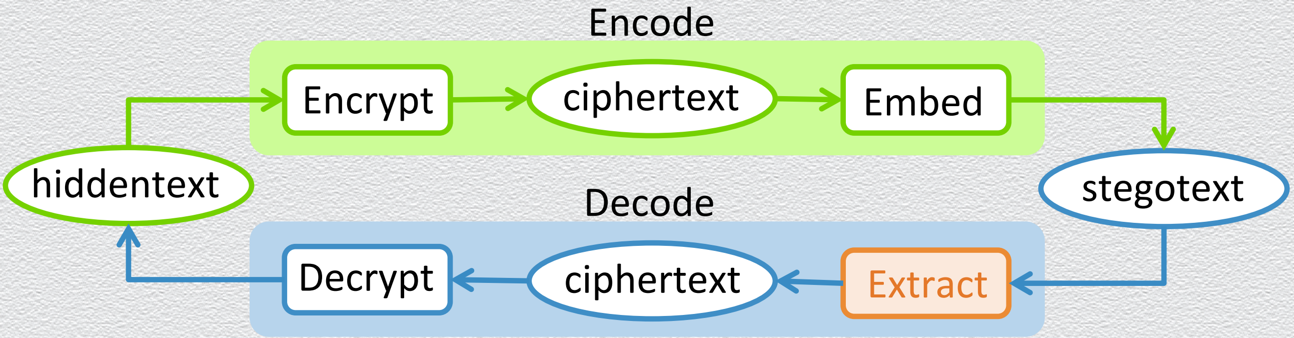


- Embed (rejection-sampling)
  1. Let H be a strongly universal hash function
  2. Break the ciphertext c into bits $c_1,c_2,\ldots,c_l$
  3. To embed c_i, sample s_i from the channel until $\mathrm{H}(s_i) = c_i$
  4. Output $s = s_1||s_2|| \cdots ||s_l$

Realizing Broadcast Steganography

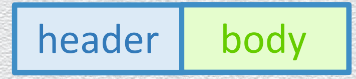
- Encrypt-then-Embed Paradigm [HLvA02, BaCa05]



- Extract
  1. Break the stegotext s into documents $s_1,s_2,\ldots,s_l$
  2. Set $c_i = \mathrm{H}(s_i)$
  3. Output $c = c_1||c_2||\cdots||c_l$

Broadcast Encryption + Encrypt-then-Embed = Broadcast Steganography?

- Encrypt-then-Embed requires pseudorandom ciphertexts …
- … but, Broadcast ciphertexts have structure



broadcast ciphertext format

- Neither header nor body is pseudorandom

Outsider-Anonymous Broadcast Encryption [FaPe12]

- Motivation: Anonymous Broadcast Encryption with short ciphertexts
  - A fully anonymous ciphertext length is subject to a linear lower bound [KiSa12]
  - In some applications, content may give recipient set away
    - ⇒ Suffices to protect anonymity of receivers from outsiders

- Outsider-Anonymity in Broadcast Encryption
  - Trades some degree of anonymity for better efficiency
  - Allows constructions with sub-linear ciphertext length

oABE Encryption in [FaPe12]

- Encrypt(S, m)
    1. Group users in S into S’, a set of disjoint subsets
        - |S’| is sub-linear in |S|
    2. Generate a ciphertext c_i for each s_i in S’ (using anonymous IBE)
    3. Attach a tag t_i to each c_i (for efficient decryption at the receivers)
    4. Bundle all (t_i, c_i) components using one-time signature

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c_1 … c_l

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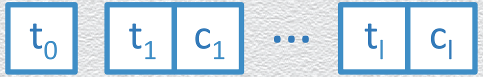

t_0 t_1 c_1 … t_l c_l

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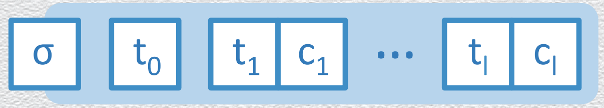

σ | t_0 | t_1 c_1 | … | t_l c_l

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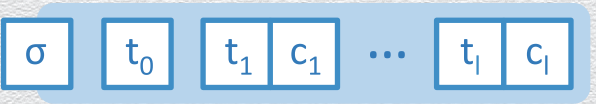
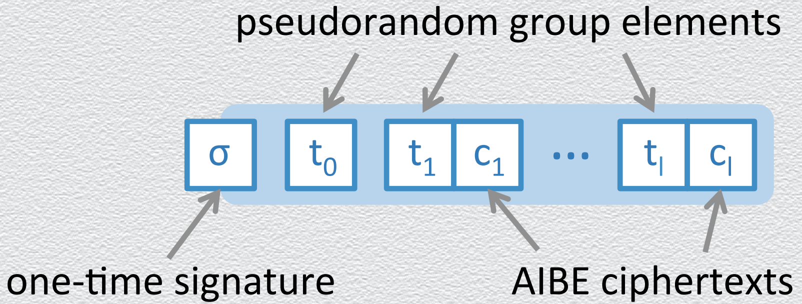


σ t_0 t_1 c_1 … t_l c_l

- Notice that ciphertexts have no header …
- … but still exhibit structure due to tags and signature
- Idea: Toward a BS construction, make these components pseudorandom

oABE with Pseudorandom Ciphertexts (oABE$) [This Work]



- How to make oABE ciphertexts pseudorandom?

1. Replace the underlying AIBE with AIBE$ [AgBo09]
2. Apply an entropy smoothing hash to group elements
3. Replace one-time signature with a MAC (implemented via PRF)

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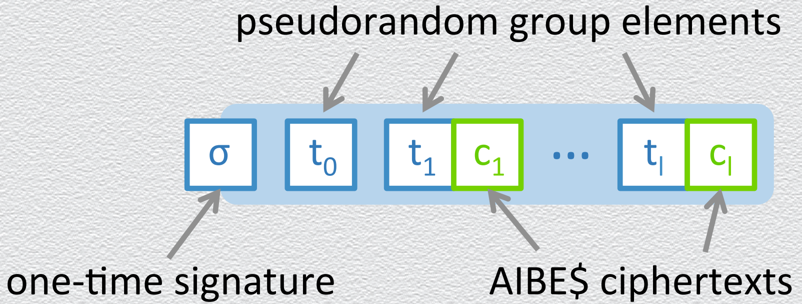

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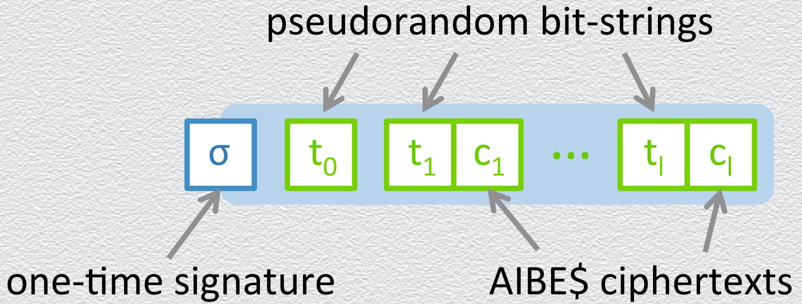

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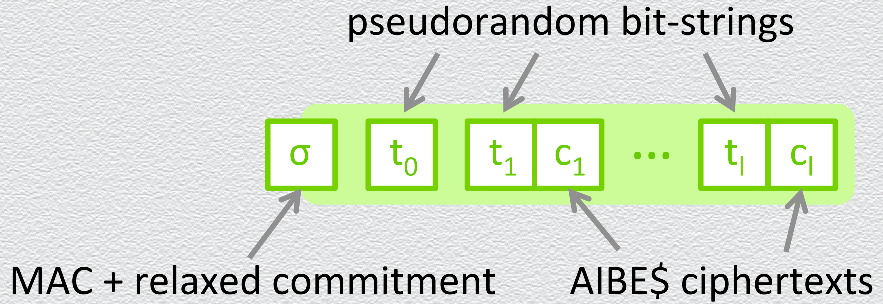

- How to make oABE ciphertexts pseudorandom?
  1. Replace the underlying AIBE with AIBE$ [AgBo09]
  2. Apply an entropy smoothing hash to group elements
  3. Replace one-time signature with a MAC (implemented via PRF)

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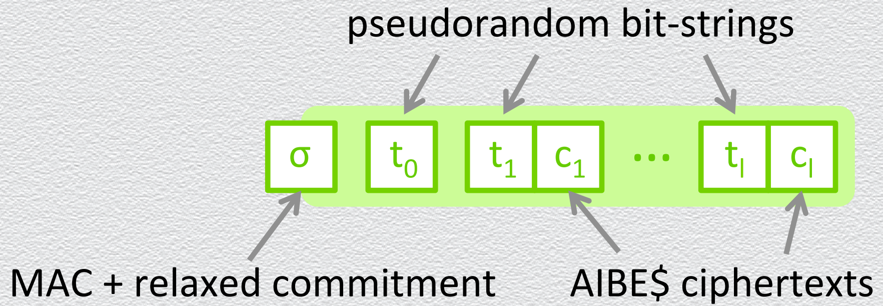

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  1. Replace the underlying AIBE with AIBE$ [AgBo09]
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Question: How to embed the MAC key in c_i's and still obtain CCA security?

Solution: Construct an encapsulation mechanism [DoKa05, BoKa05] with pseudorandom commitments

Comparison of BE Schemes with Anonymity Properties

Scheme	|PK|	|sk|	|c|	Security Model	Anonymity
BBW06	O(N)	O(1)	O(N-r)	Static, RO	Full
LPQ12	O(N)	O(1)	O(N-r)	Adaptive, Standard	Full
FaPe12a	O(N)	O(log N)	O(r log (N/r))	Adaptive, Standard	Outsider
FaPe12b	O(N log N)	O(N)	O(r)	Adaptive, Standard	Outsider
This Work	O(N)	O(log N)	O(r log (N/r))	Adaptive, Standard	Outsider

N: total number of users, r: number of revoked users

- Only oABE$ provides pseudorandom ciphertexts

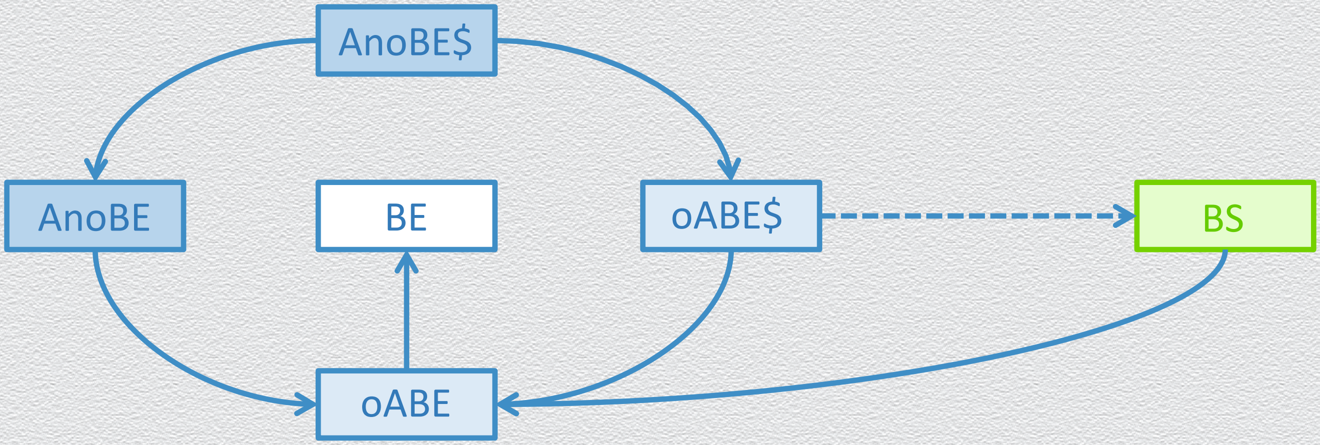
Our Construction of Broadcast Steganography

- Highlights
  - oABE$ + Encrypt-then-Embed = Broadcast Steganography
  - Our constructions have sub-linear stegotext length
  - For CCA security, requires stateless channel

- Constructions:
  1. BS-CHA
  2. BS-PDR-CCA
  3. BS-CCA

- ⦿ Broadcast Steganography (BS)
- ⦿ Constructions
- ⦿ Summary

BE and Friends



Summary

- Initiated the study of Broadcast Steganography
  - A multi-recipient communication tool to plant undetectable messages in innocent-looking conversations
- Put forth sublinear constructions of broadcast steganography under a range of security notions
- In the process, devised efficient broadcast encryption schemes with pseudorandom ciphertexts and anonymity properties
  - Implementing CCA checks without imposing structure on broadcast ciphertexts required overcoming multiple technical hurdles