Pi-Cut-Choo and Friends

Compact Blind Signatures via Parallel Instance Cut-and-Choose and More

https://ia.cr/2022/007

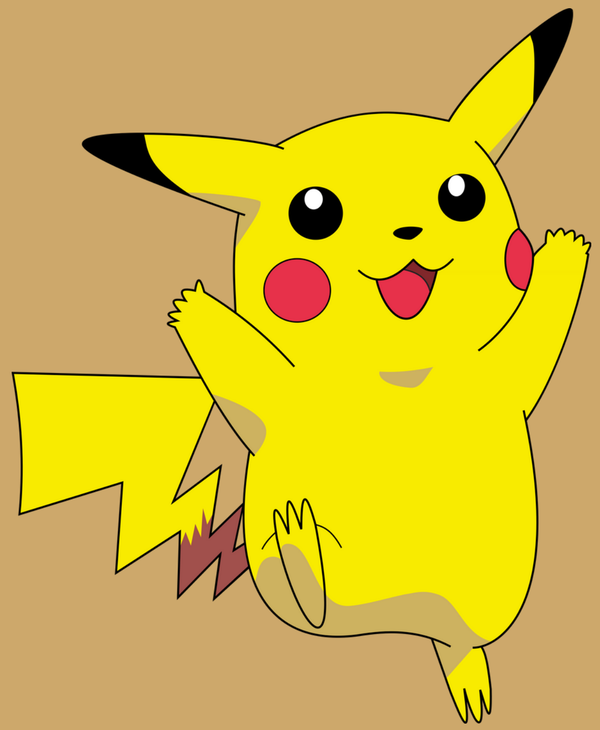


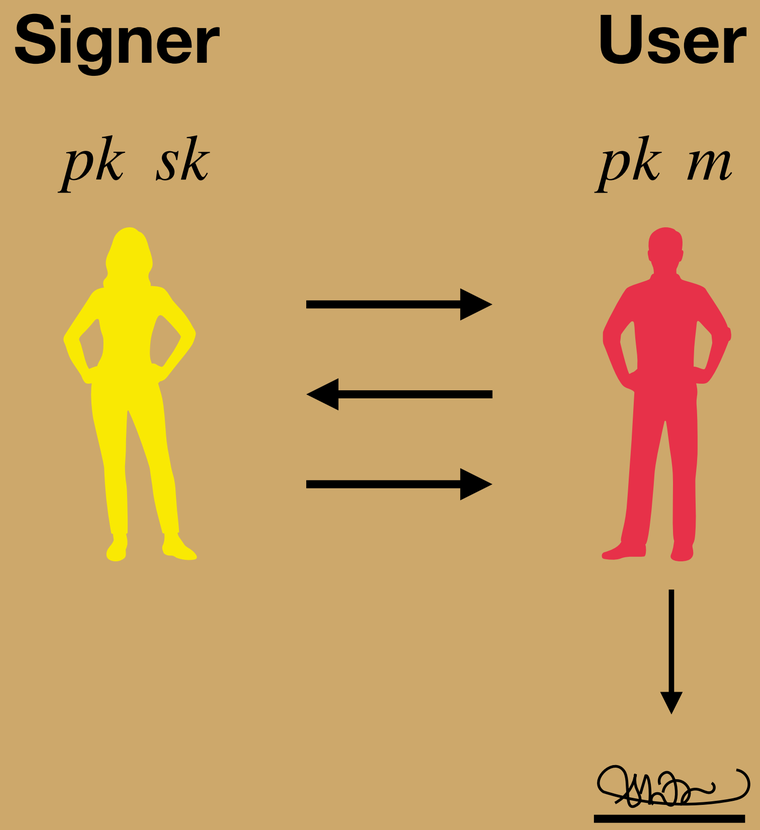
Image Source: shorturl.at/cDZ06

Rutchathon Chairattana-Apirom
Lucjan Hanzlik
Julian Loss
Anna Lysyanskaya
Benedikt Wagner

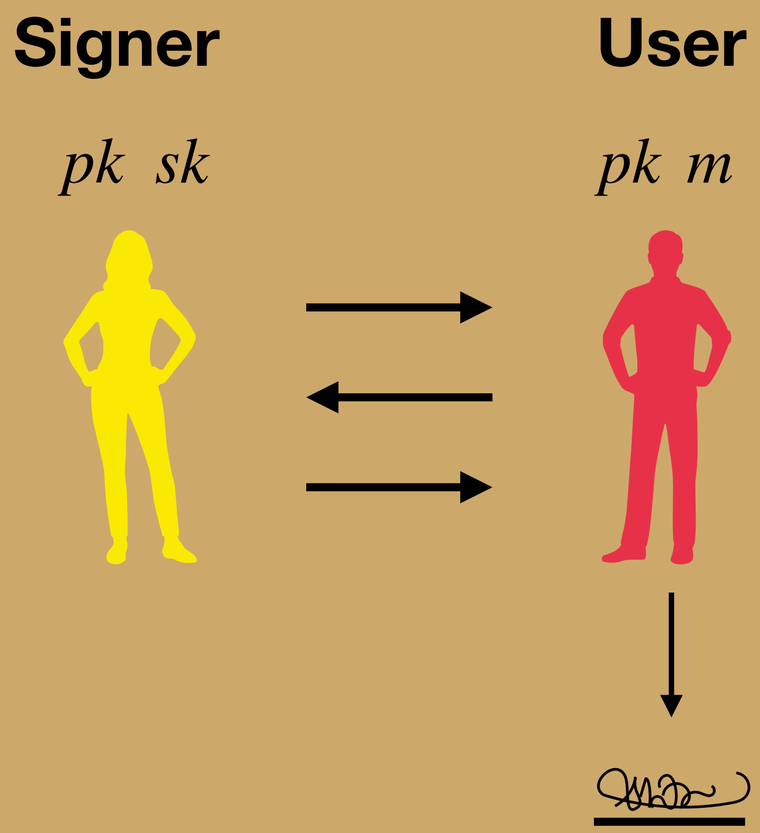
BROWN

CISPA
HELMHOLTZ CENTER FOR INFORMATION SECURITY

Blind Signatures [Cha82]



Blind Signatures [Cha82]



Applications:

- **Unlinkable Payments**
- **E-Cash**
- **Voting**

Goal: Efficient Parameter

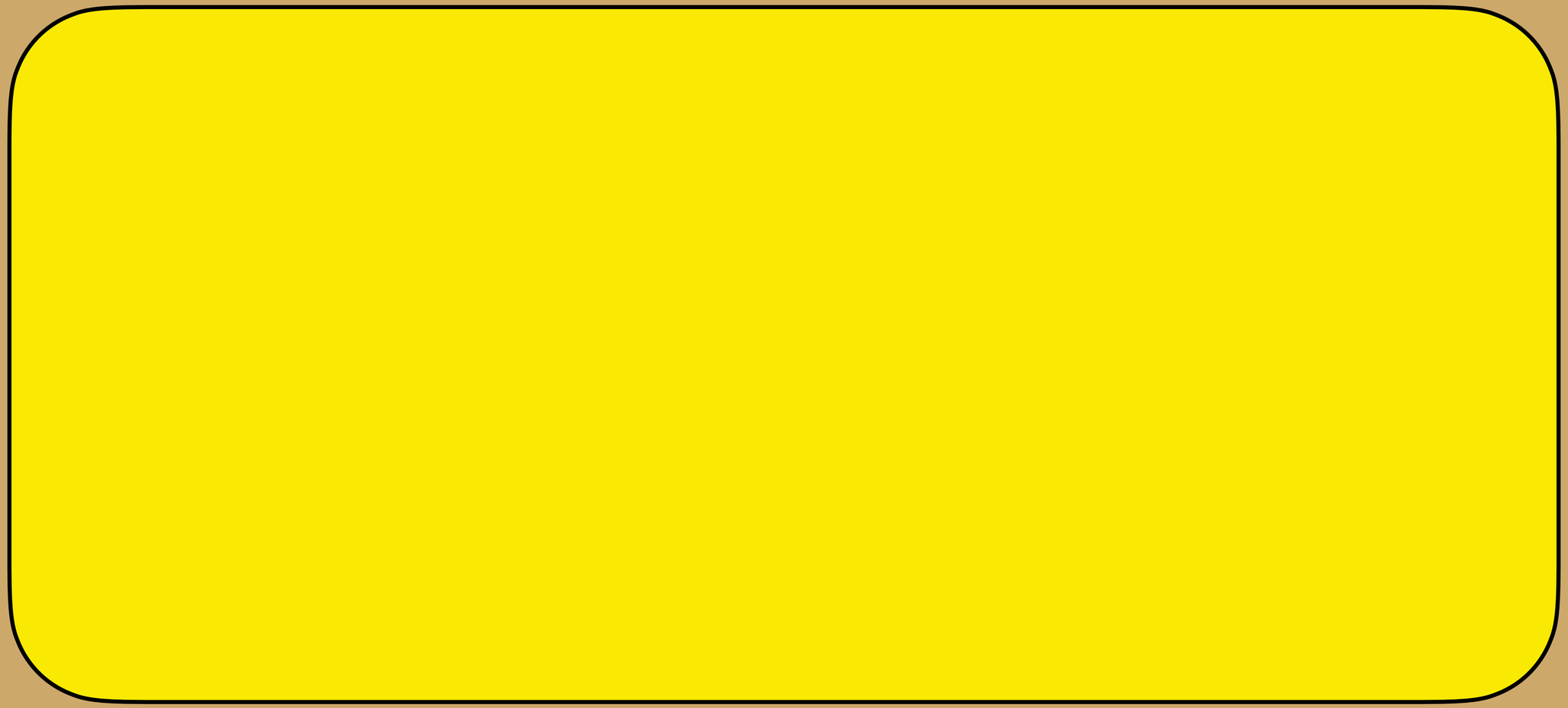
Blind Signatures - Security

Blind Signatures - Security

Blindness

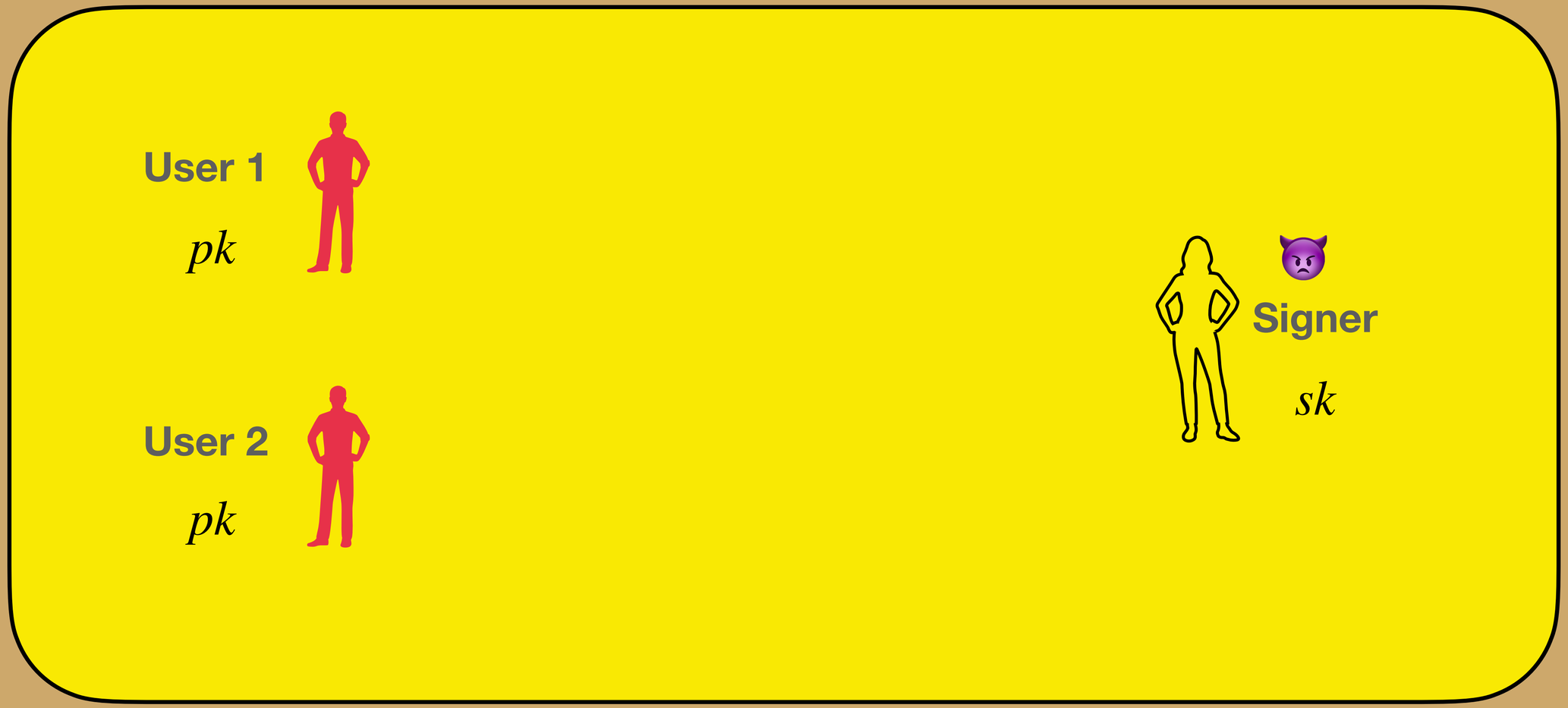
Blind Signatures - Security

Blindness



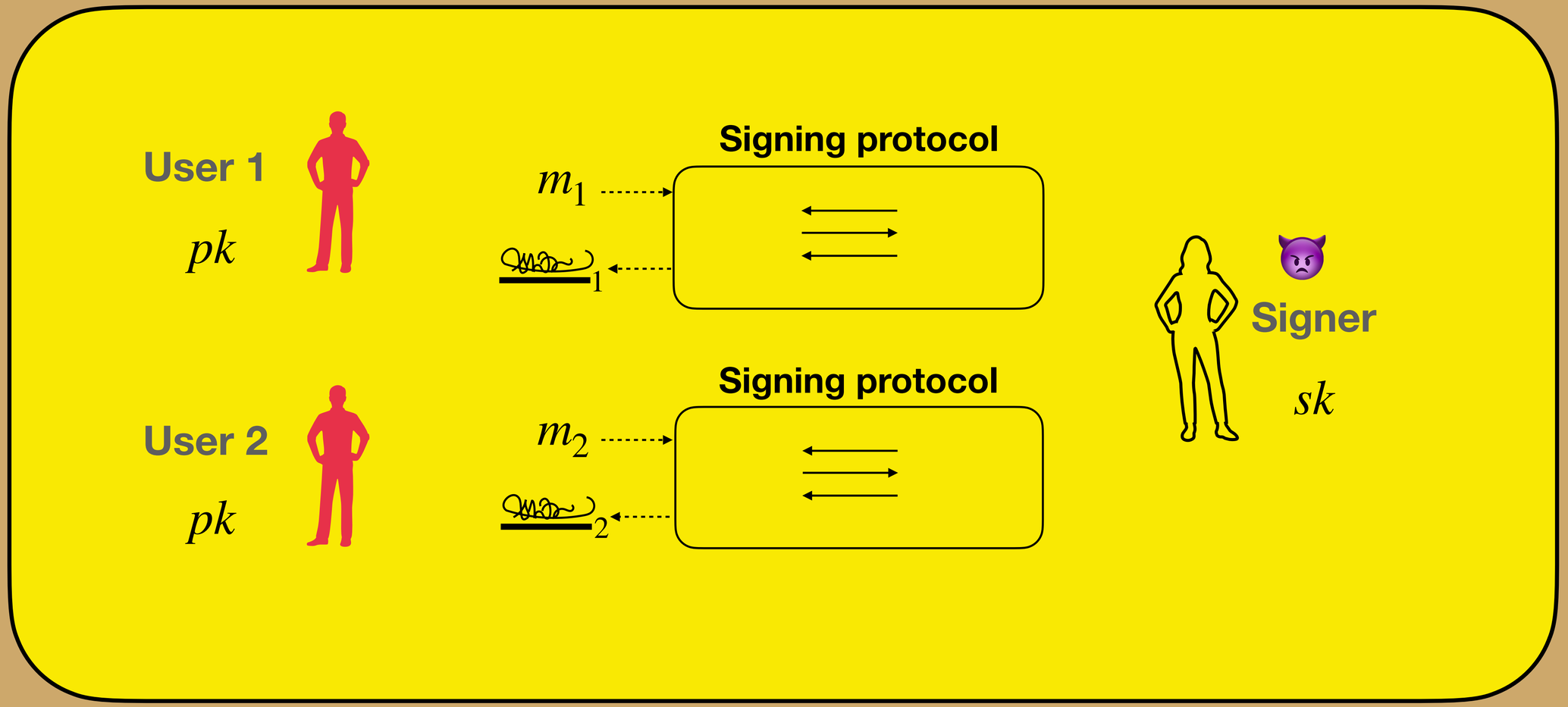
Blind Signatures - Security

Blindness



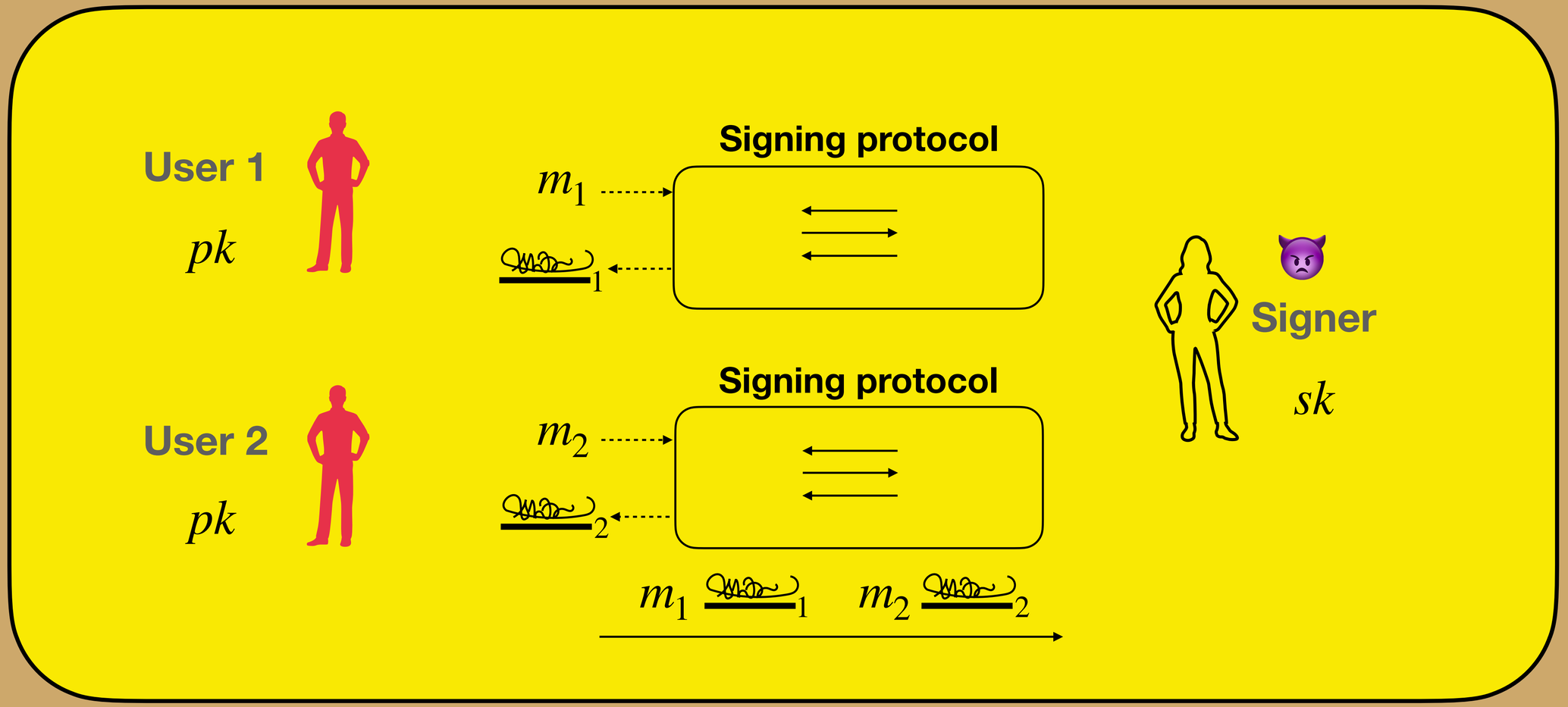
Blind Signatures - Security

Blindness



Blind Signatures - Security

Blindness



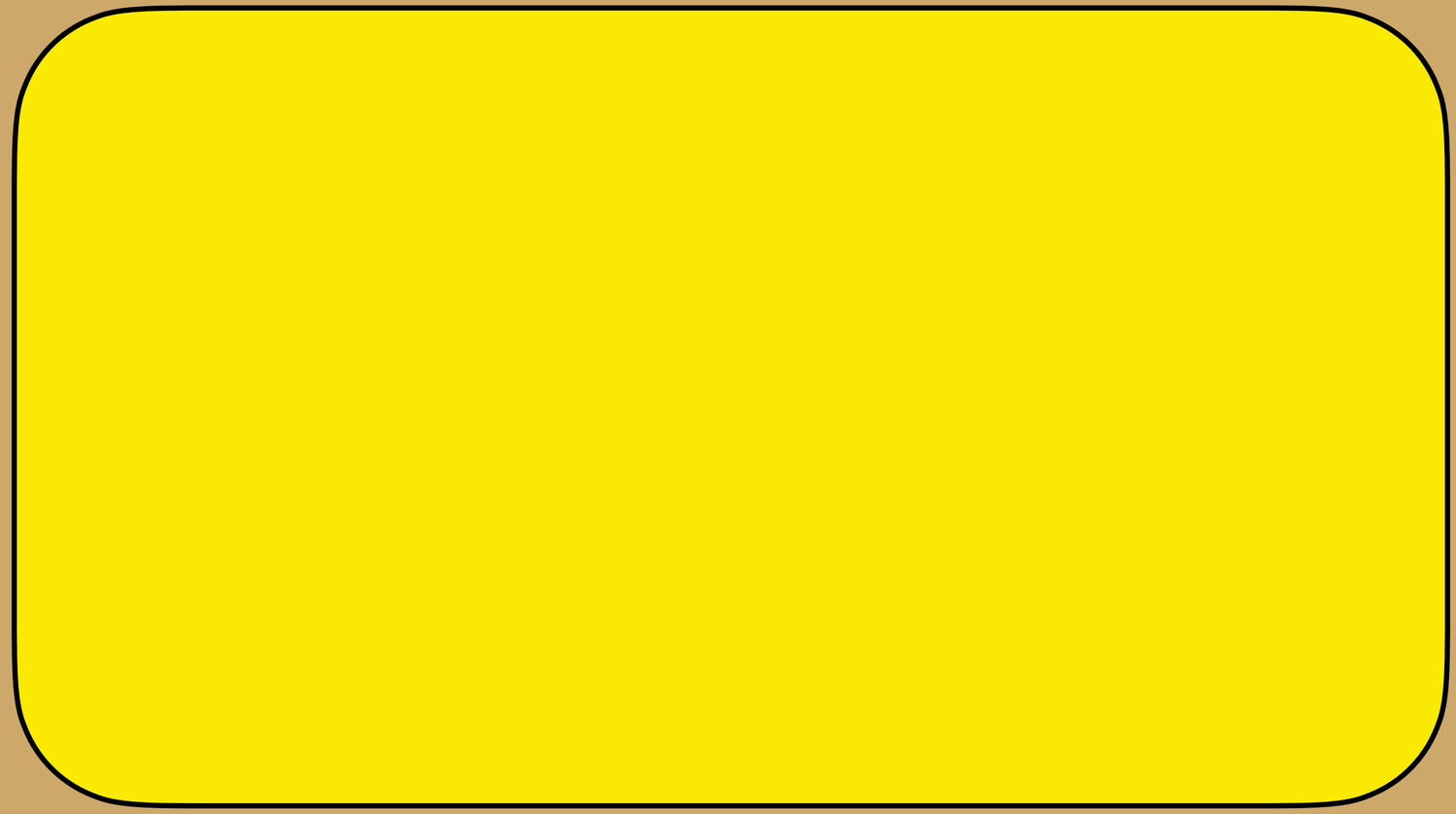
Blind Signatures - Security

Blind Signatures - Security

One-more unforgeability

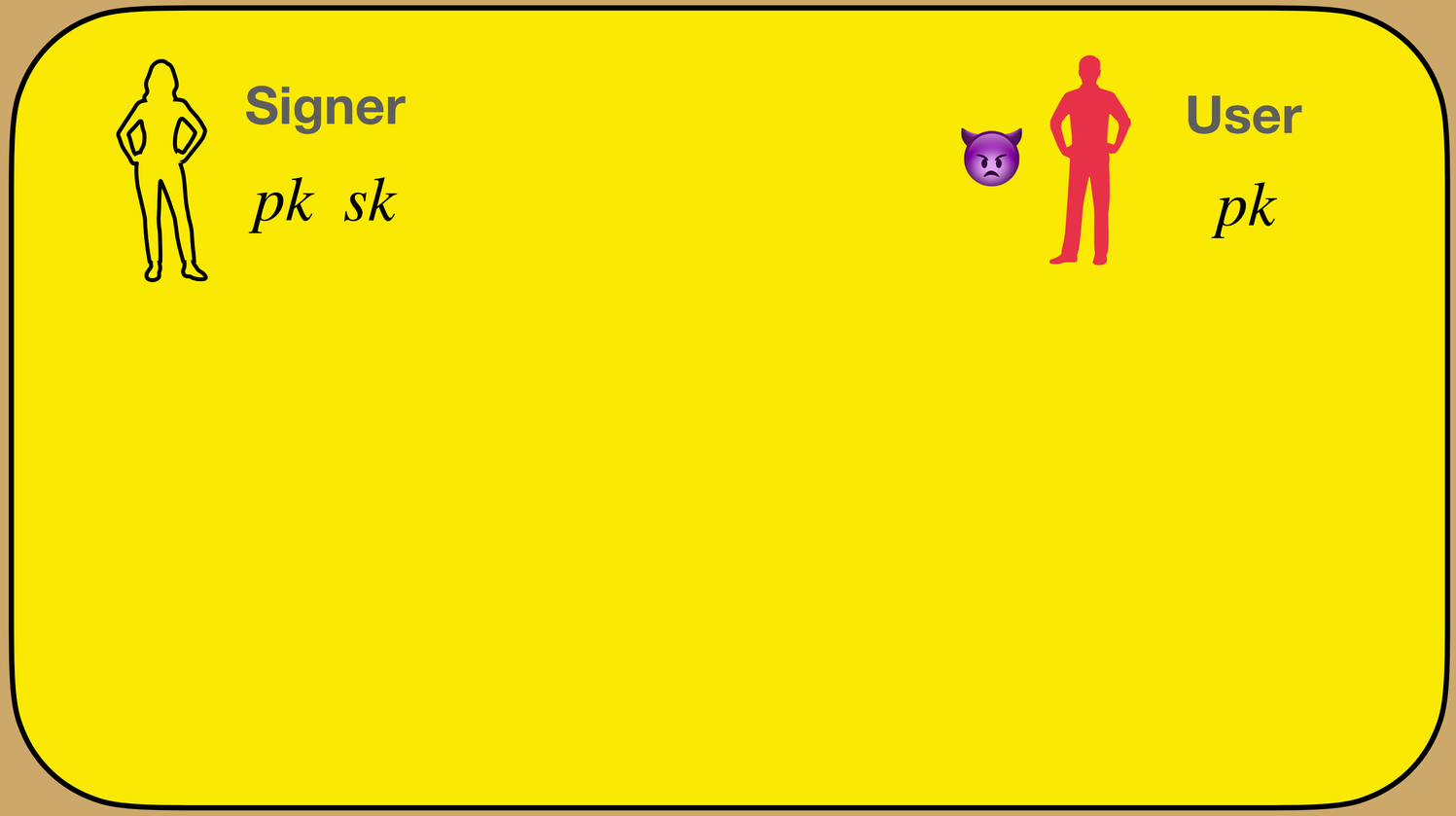
Blind Signatures - Security

One-more unforgeability



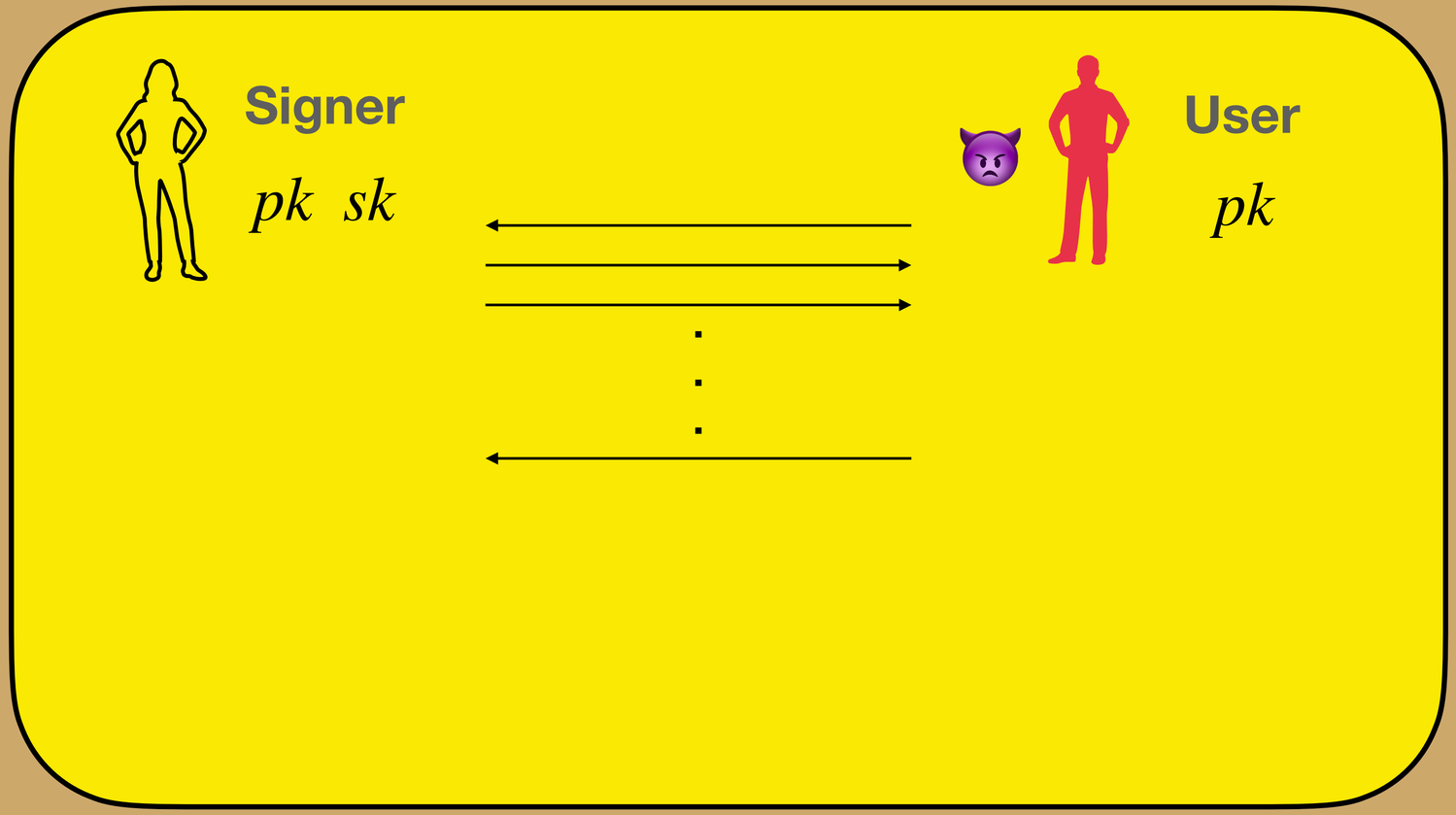
Blind Signatures - Security

One-more unforgeability



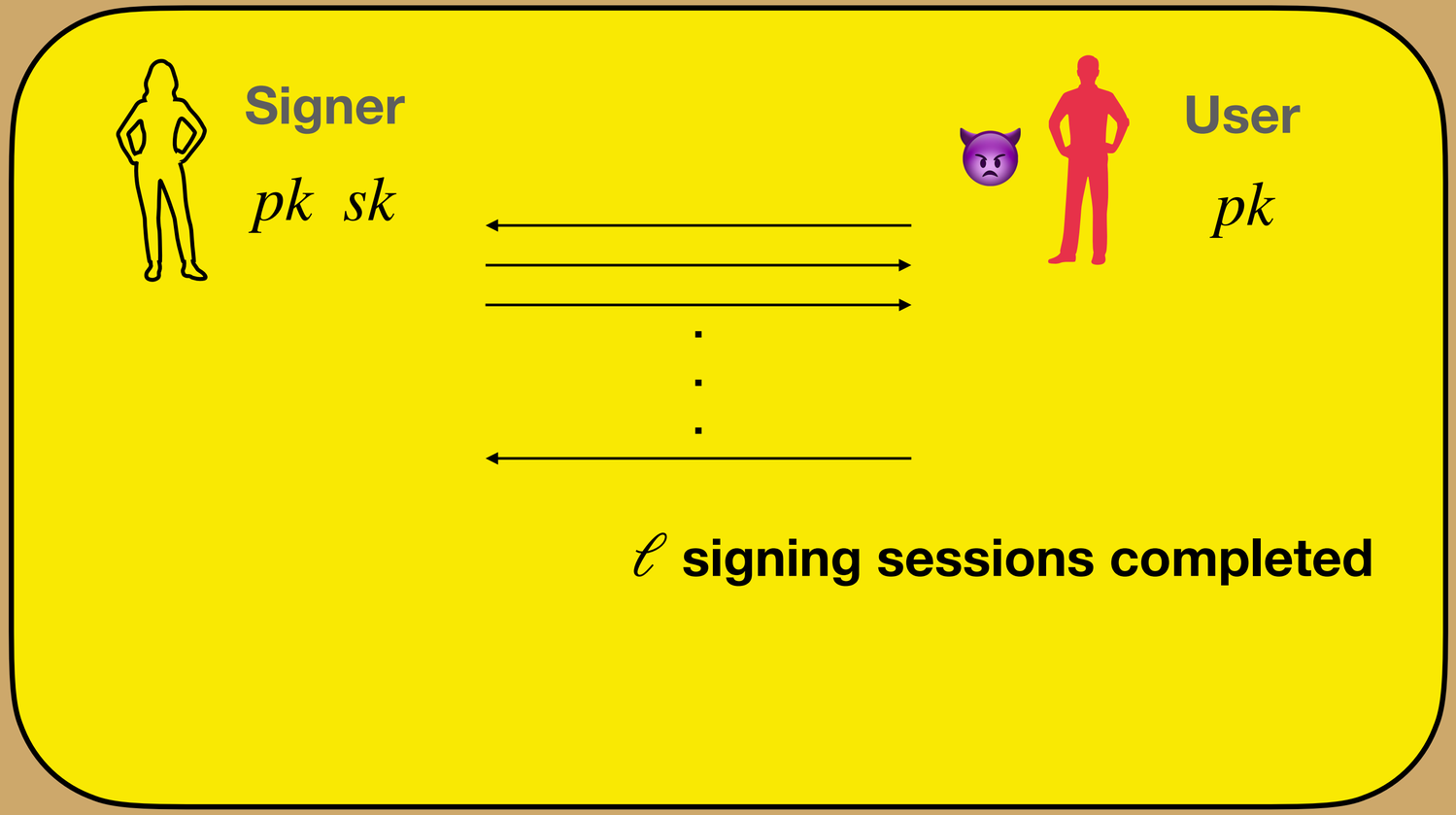
Blind Signatures - Security

One-more unforgeability



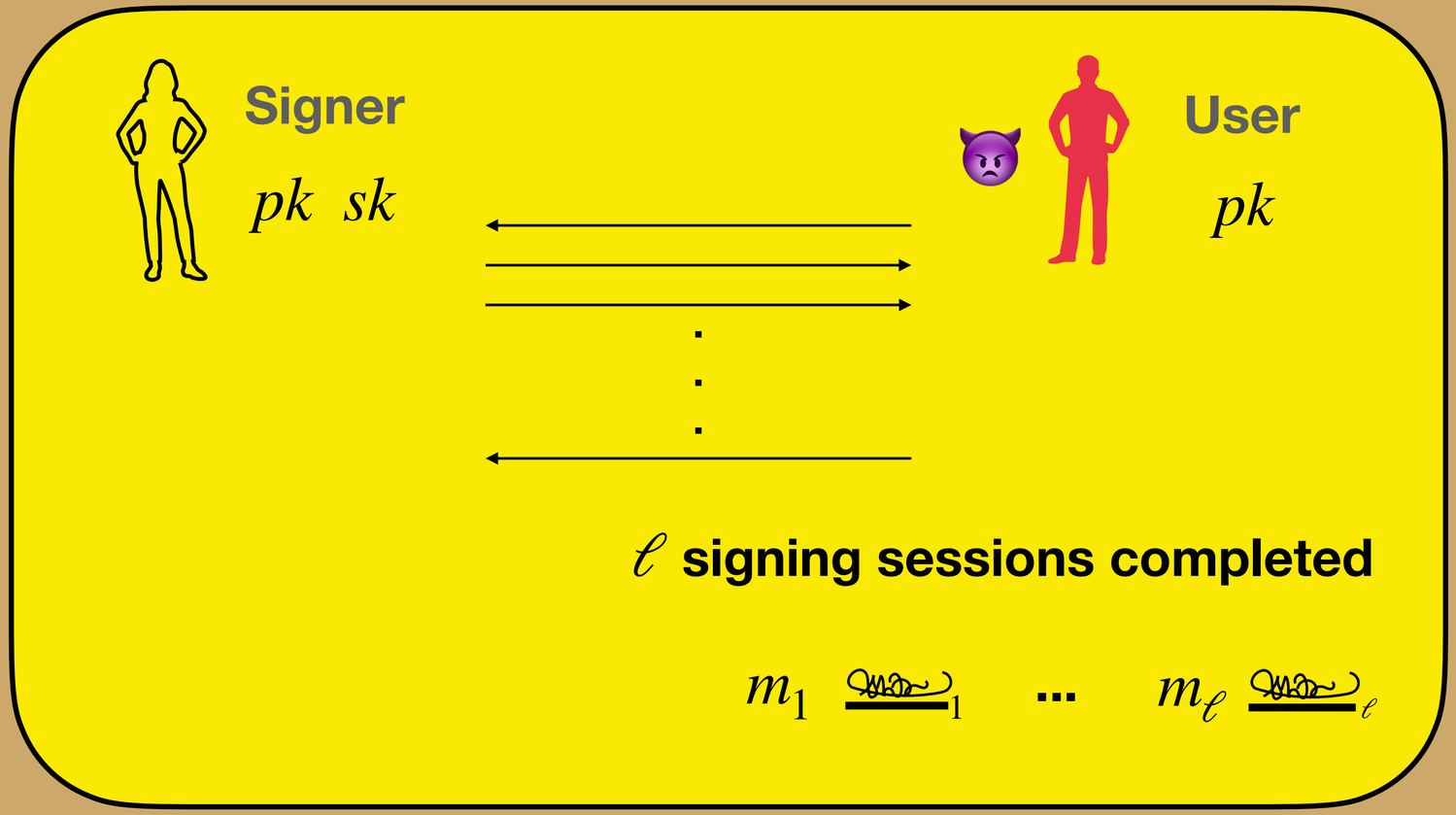
Blind Signatures - Security

One-more unforgeability



Blind Signatures - Security

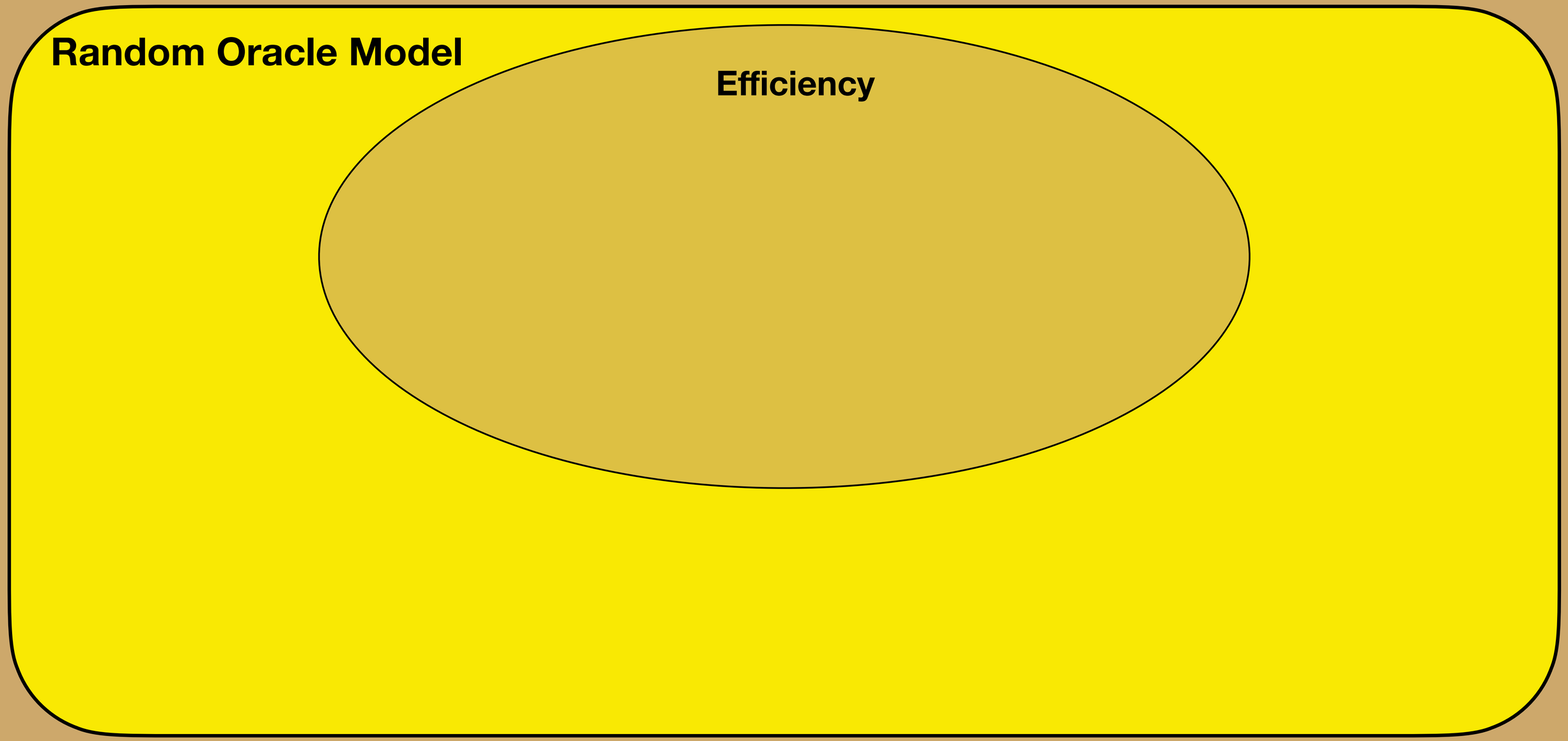
One-more unforgeability



State of The Art

Random Oracle Model

State of The Art



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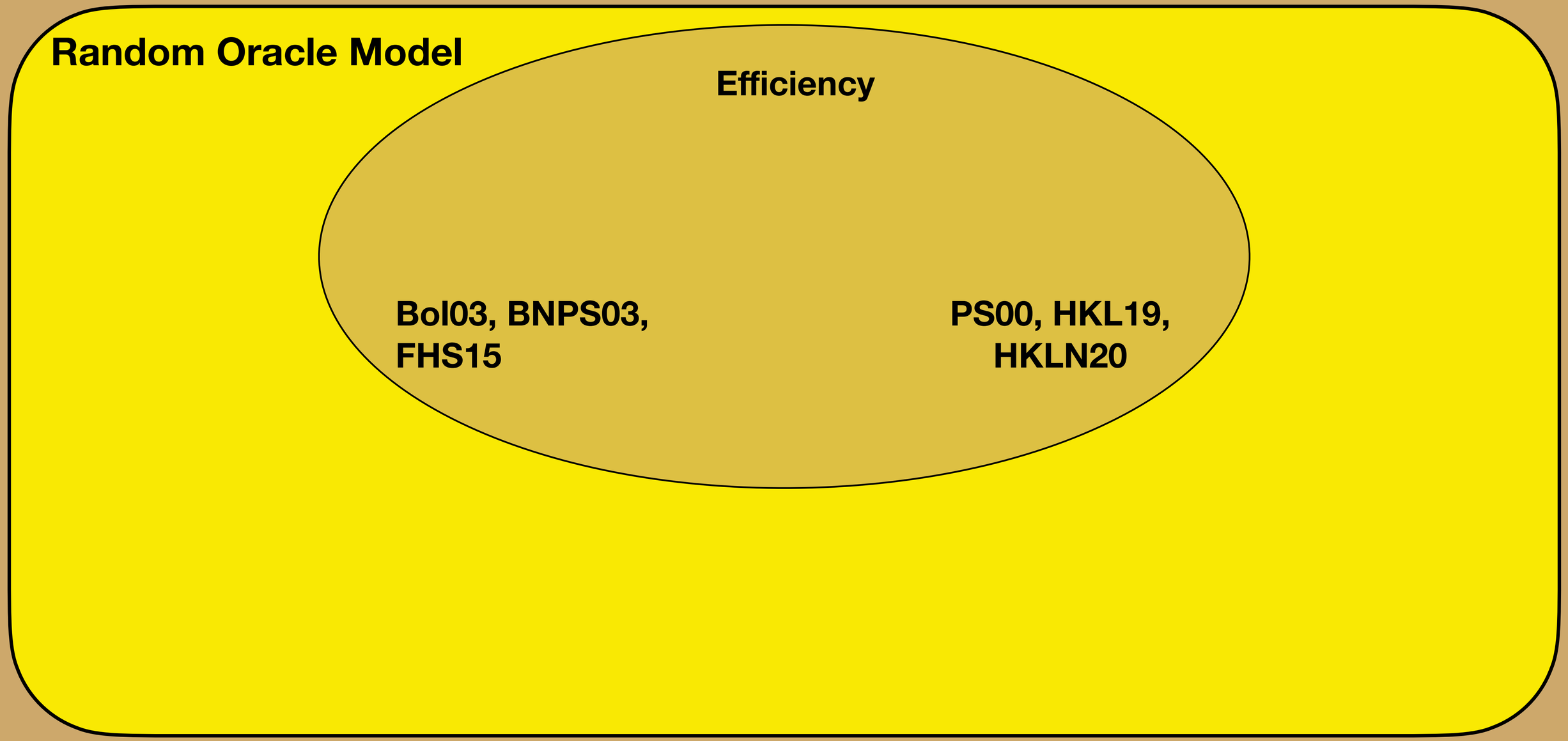
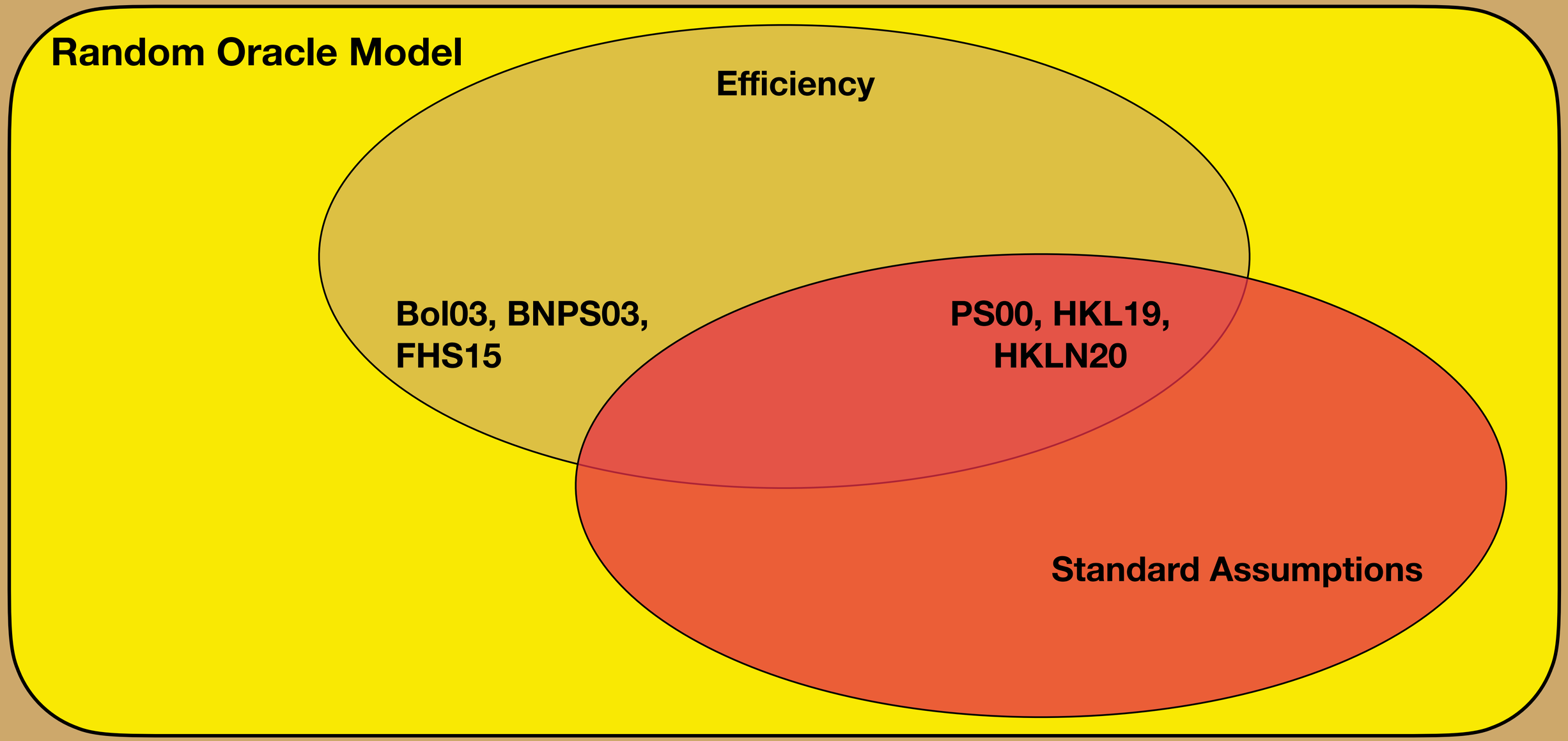


State of The Art



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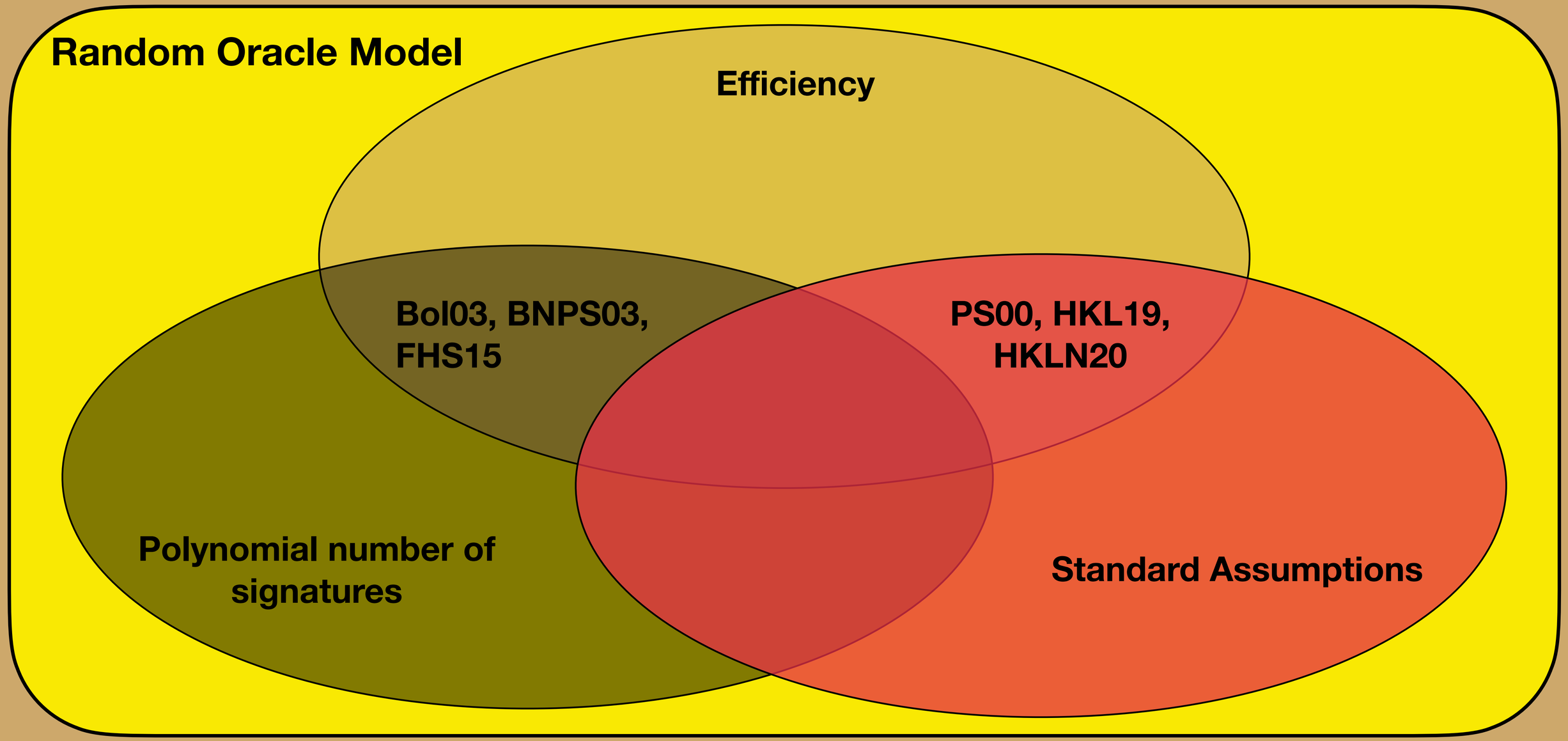

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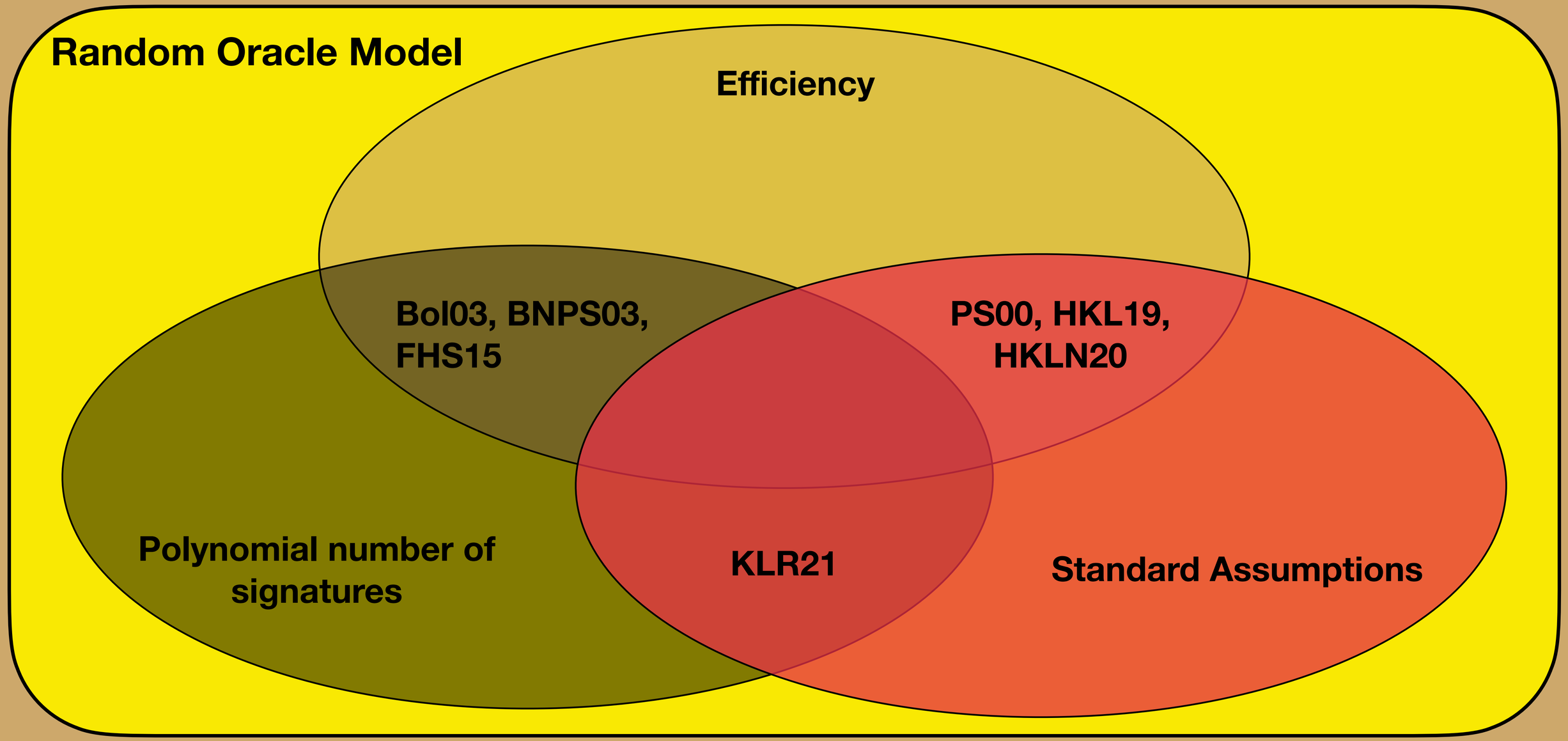
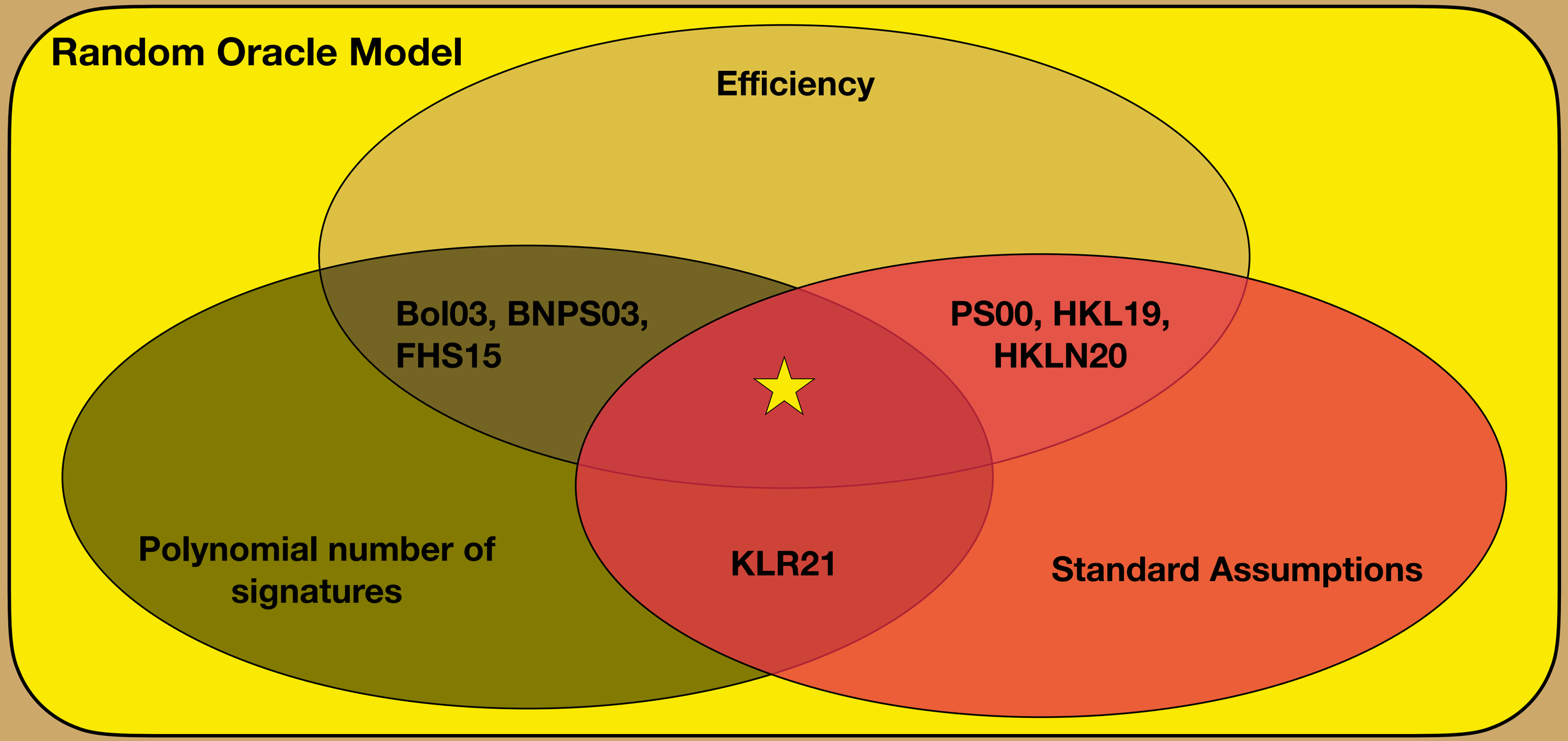
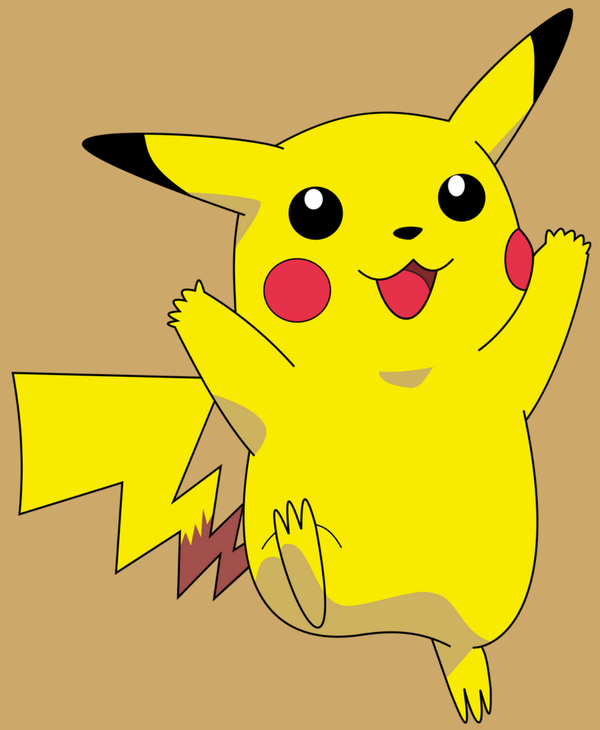


State of The Art





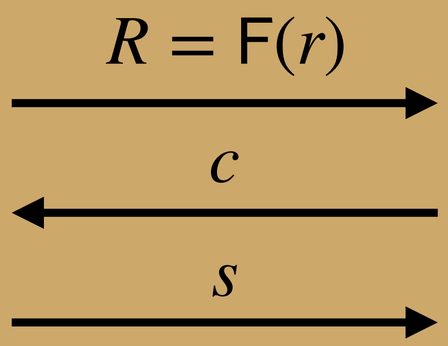
The Boosting Transform

Image Source: shorturl.at/cDZ06

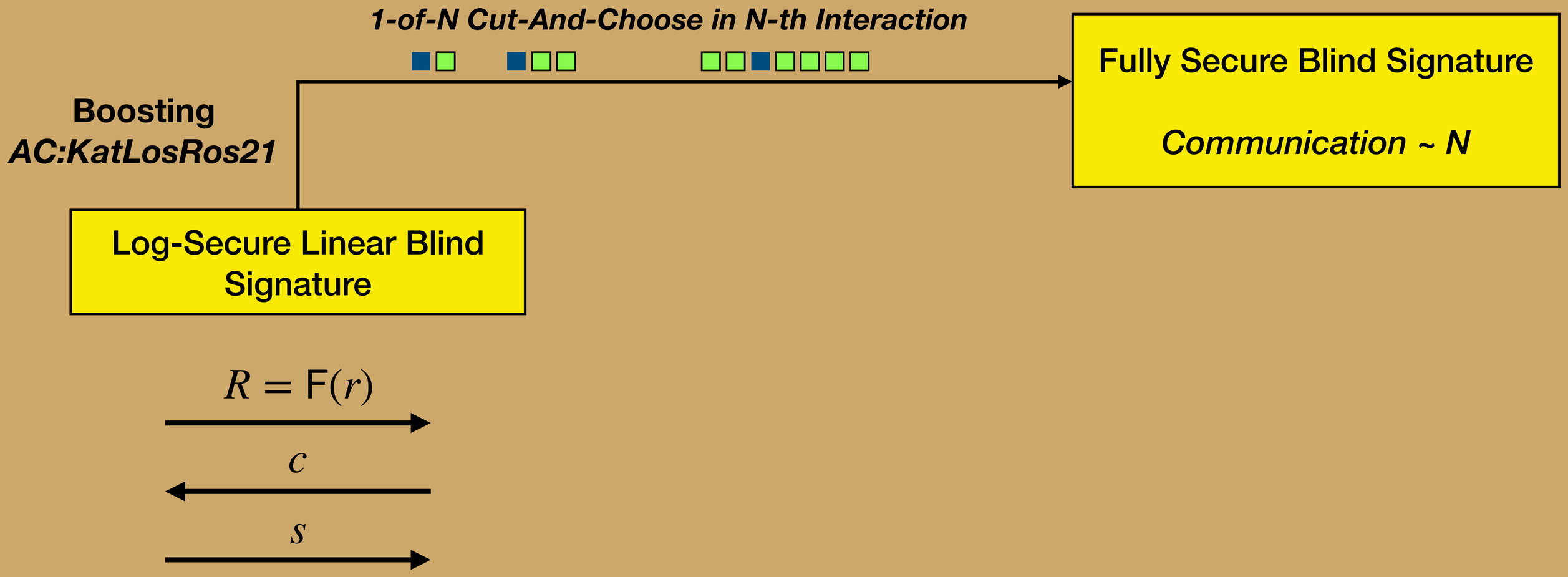
The Boosting Transform

The Boosting Transform

Log-Secure Linear Blind Signature



The Boosting Transform



The Boosting Transform

1-of-N Cut-And-Choose in N-th Interaction

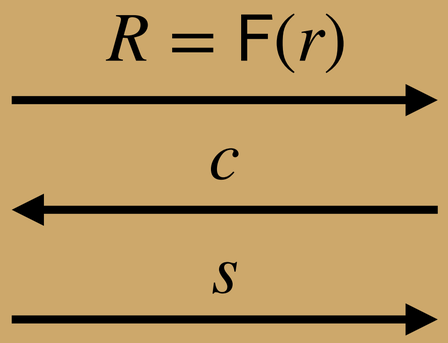
Boosting
AC:KatLosRos21

Fully Secure Blind Signature

Communication ~ N

Log-Secure Linear Blind Signature

★ Simulation knowing Message + Randomness



The Boosting Transform

Signer

$pk \quad sk$

User

$pk \quad m$

The Boosting Transform

In the N-th interaction

Signer

$pk \quad sk$

User

$pk \quad m$

The Boosting Transform

In the N-th interaction

N

Signer

$pk \quad sk$

User

$pk \quad m$

The Boosting Transform

Signer

$pk \quad sk$

In the N-th interaction

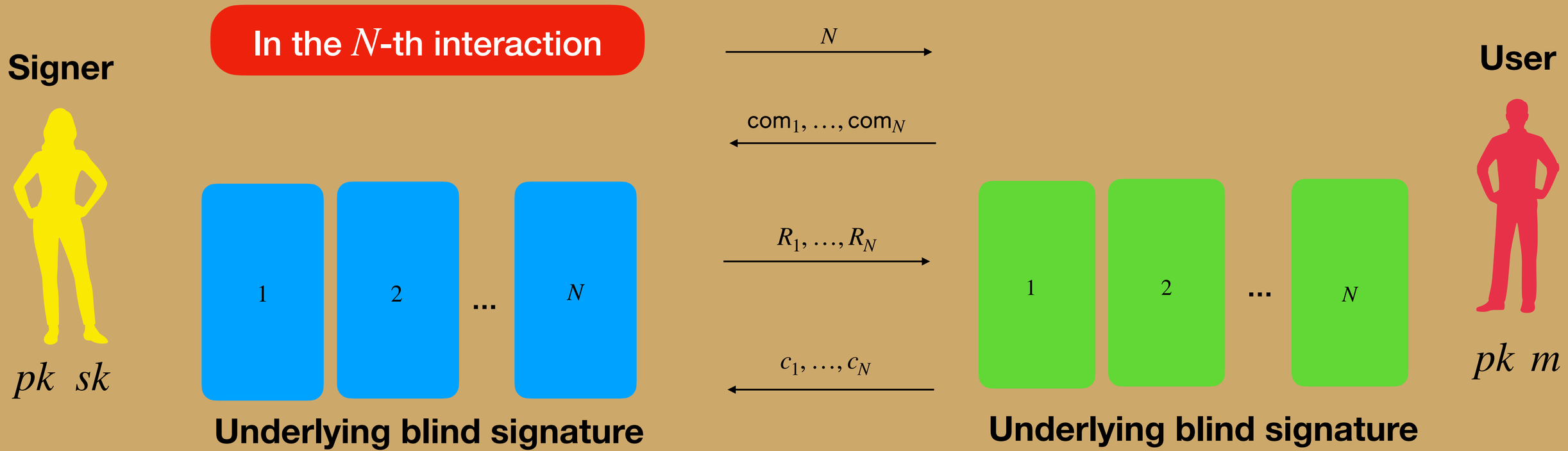
N →

← $\mathsf{com}_1, \ldots, \mathsf{com}_N$

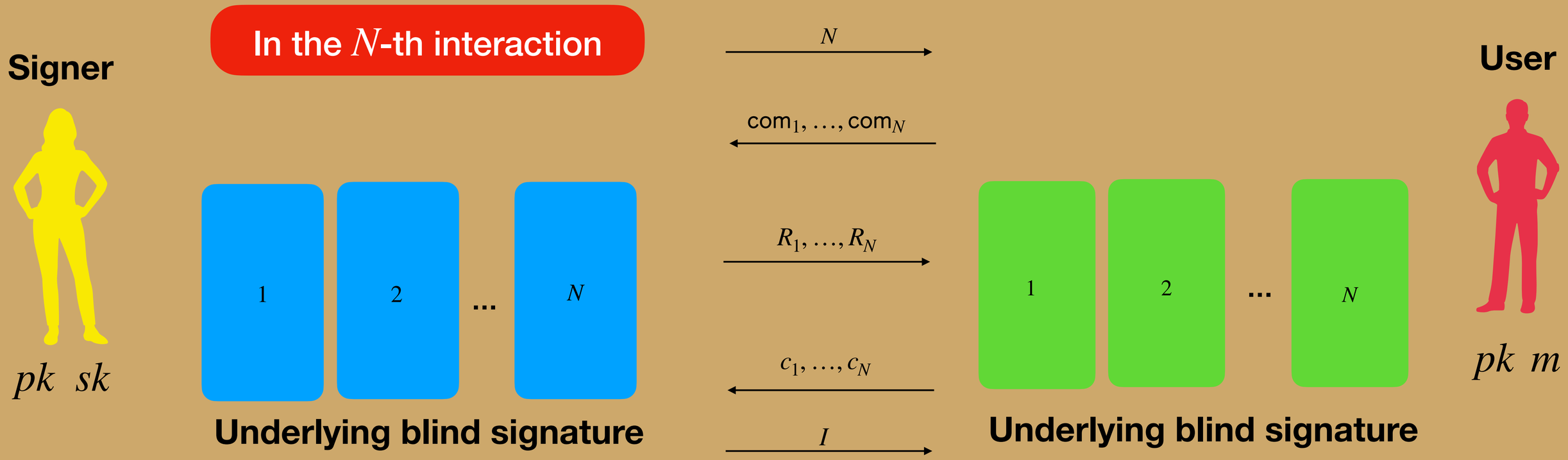
User

$pk \quad m$

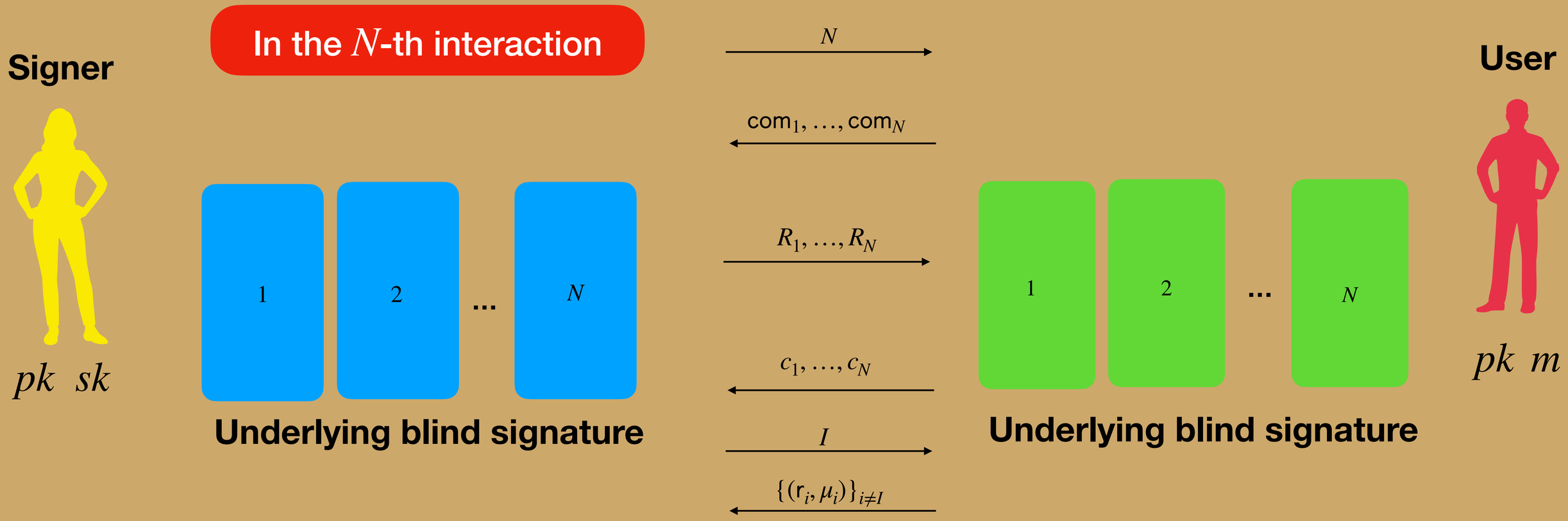
The Boosting Transform



The Boosting Transform



The Boosting Transform

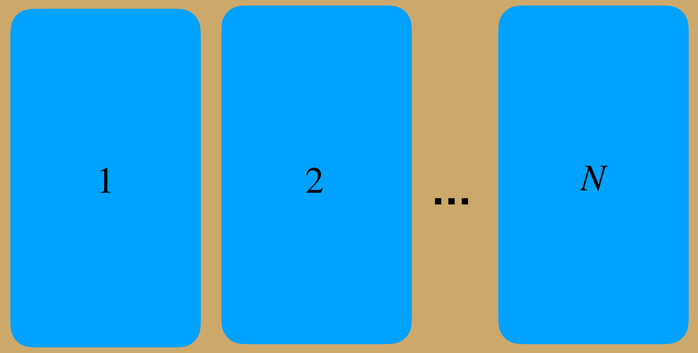


The Boosting Transform

Signer

$pk \quad sk$

In the N-th interaction



Underlying blind signature

N

$\mathsf{com}_1, \ldots, \mathsf{com}_N$

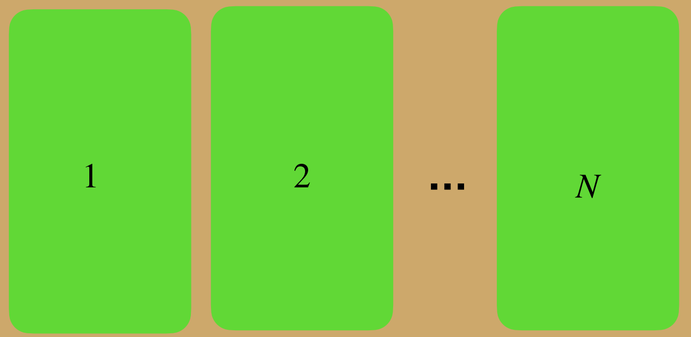
$R_1, \ldots, R_N$

$c_1, \ldots, c_N$

I

$\{(\mathsf{r}_i, \mu_i)\}_{i \neq I}$

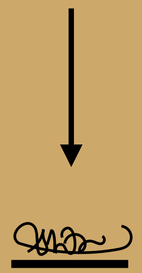
s_I



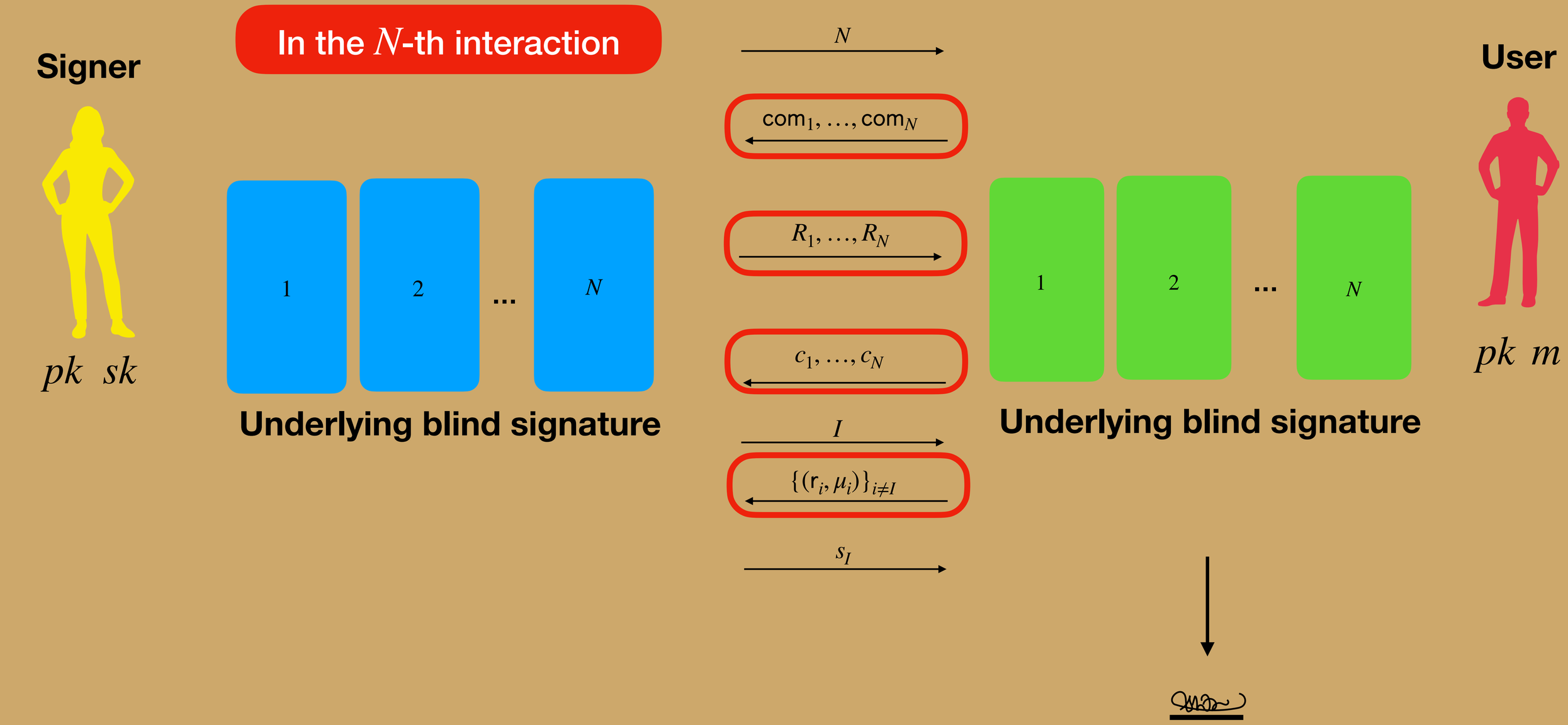
Underlying blind signature

User

$pk \quad m$



The Boosting Transform



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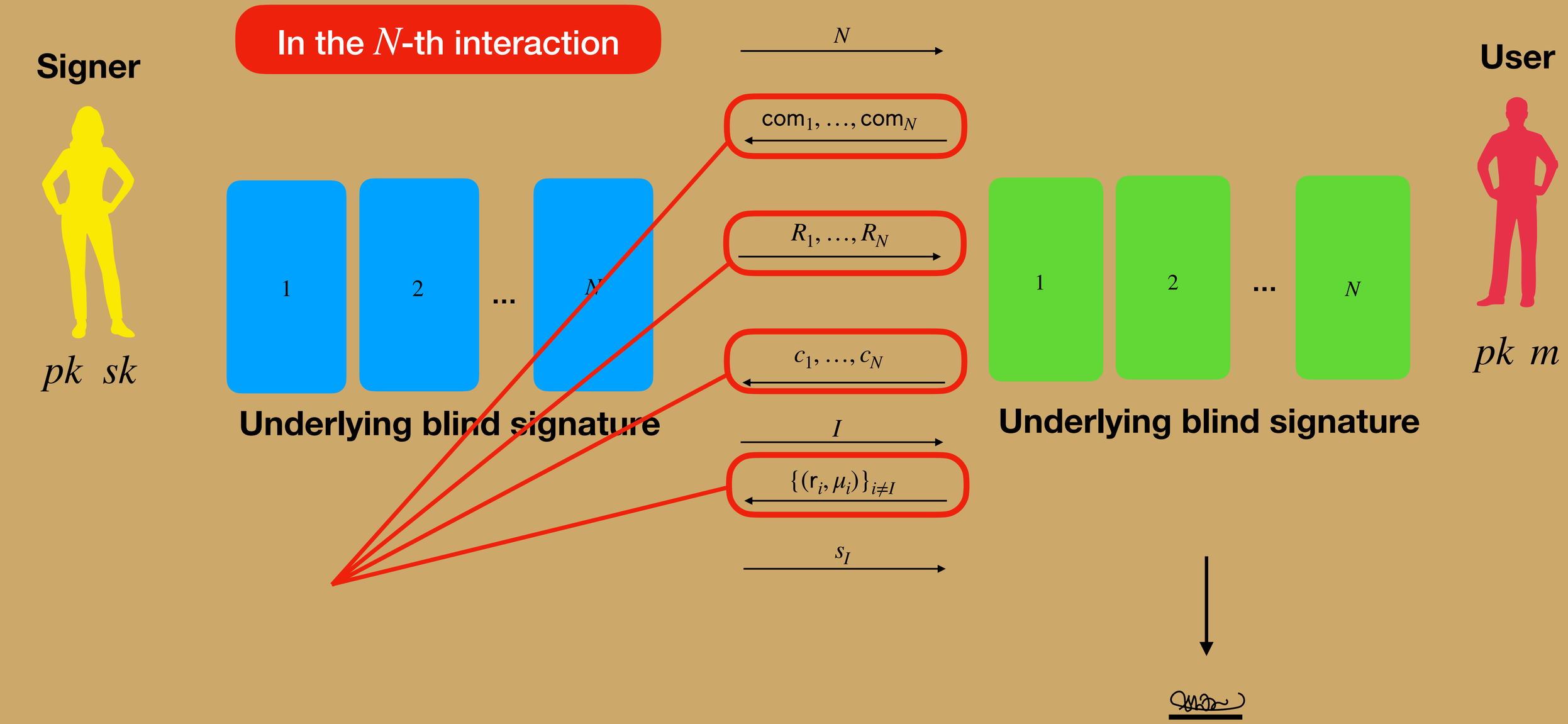
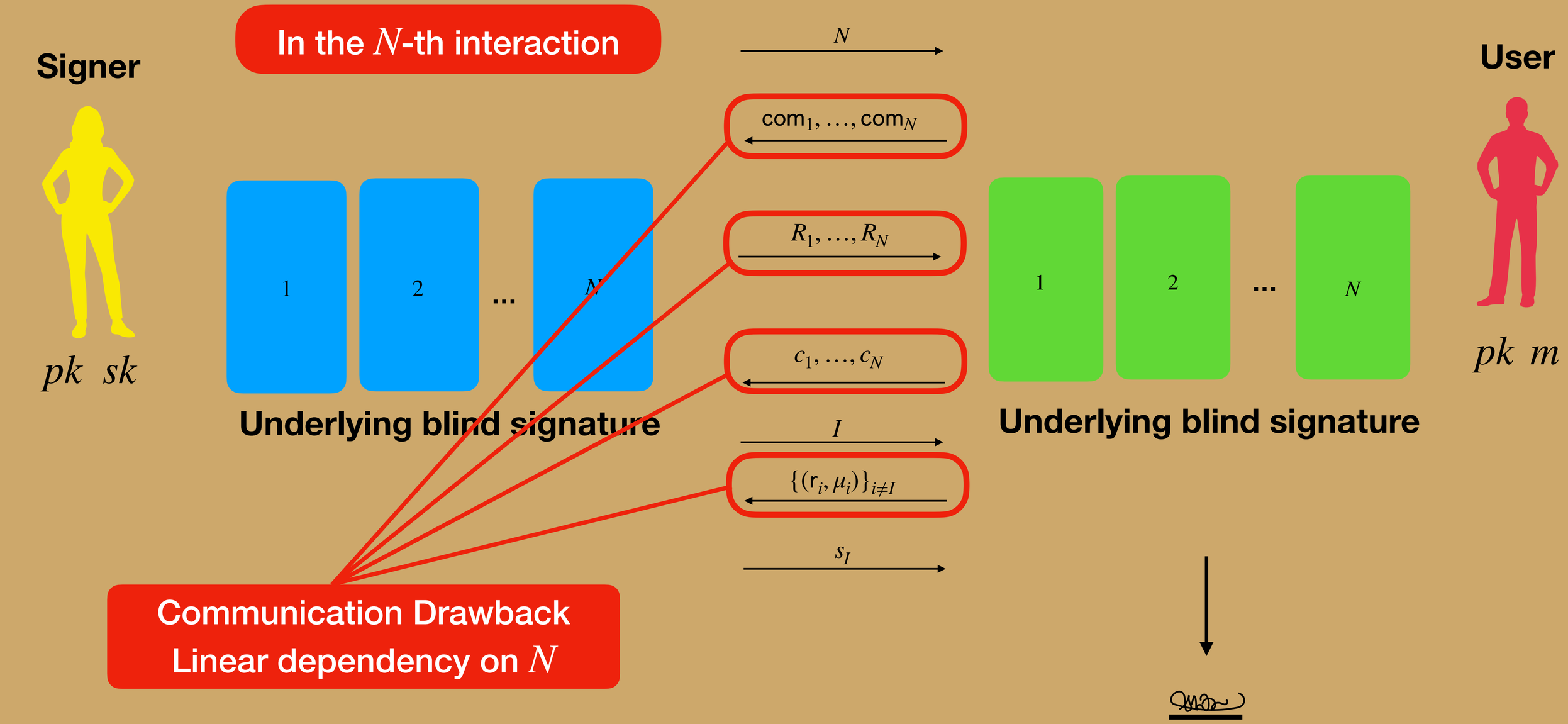


The Boosting Transform



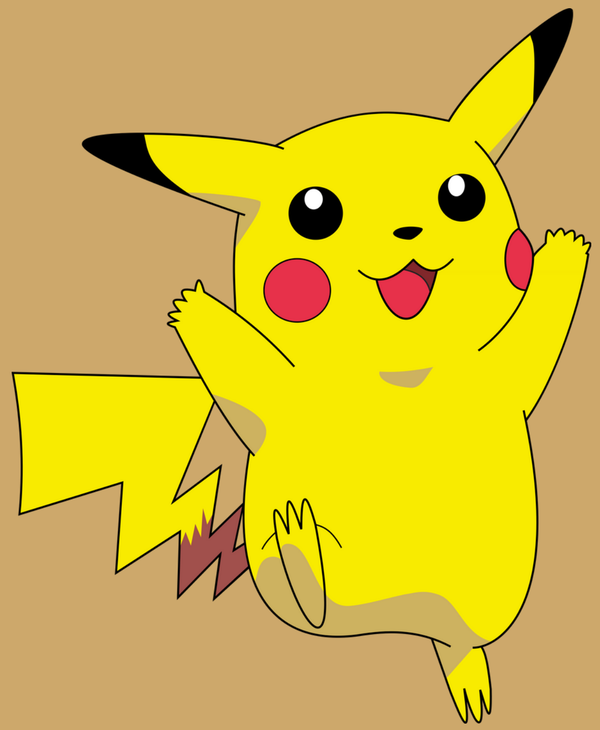
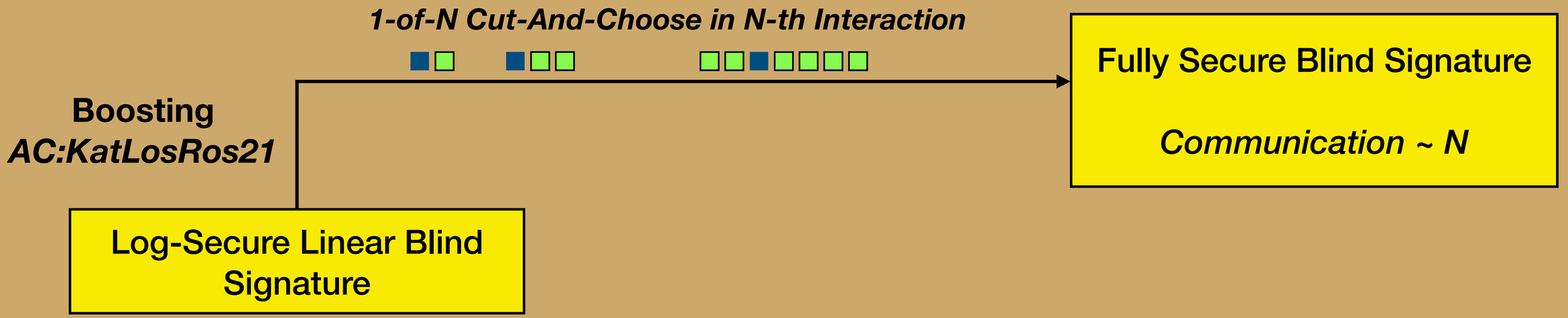


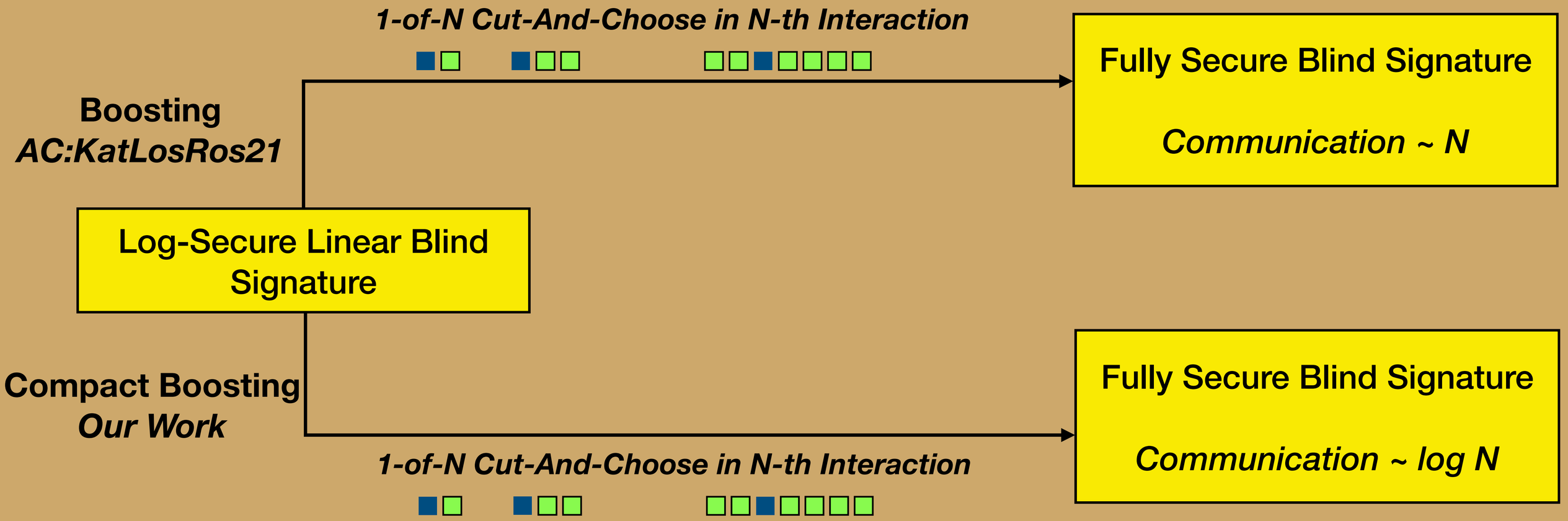
Image Source: shorturl.at/cDZ06

Our Results

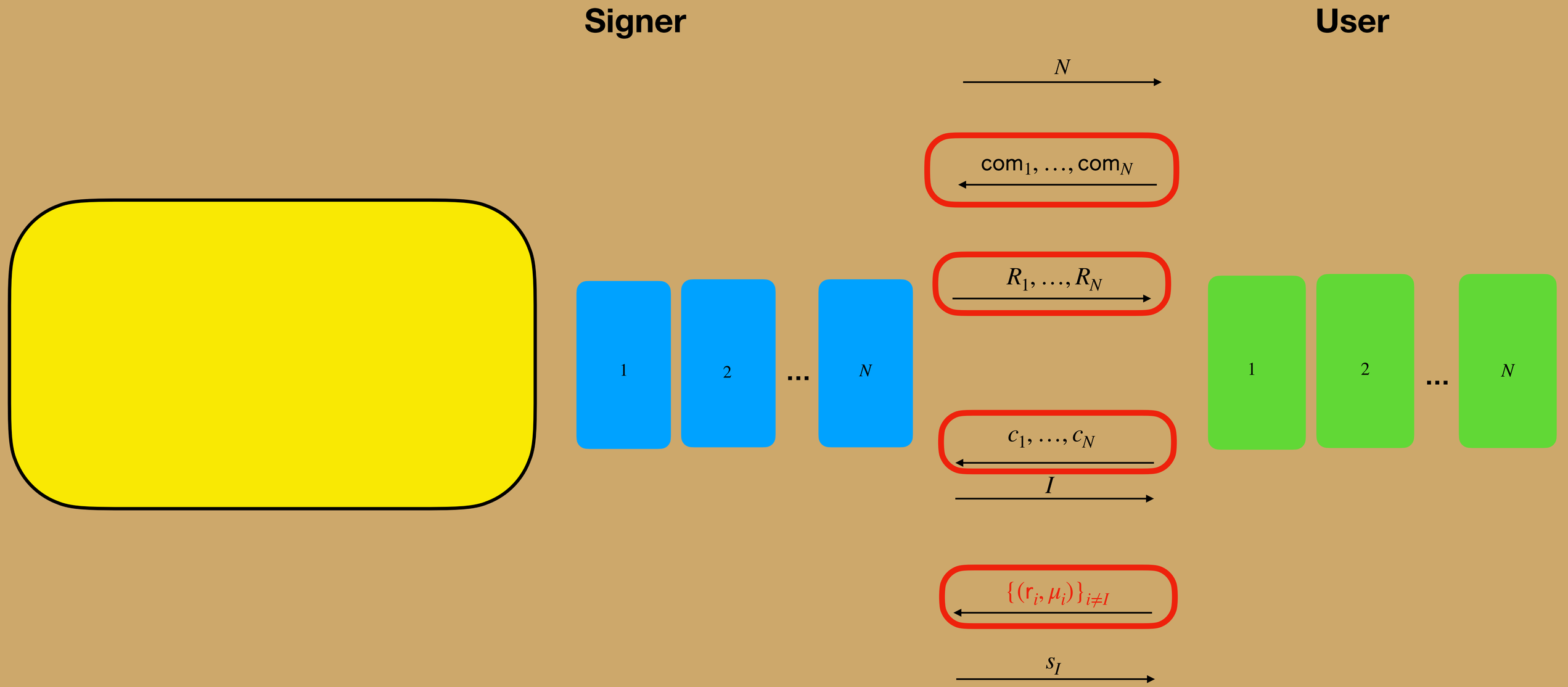
Our Results


1-of-N Cut-And-Choose in N-th Interaction
Boosting
AC:KatLosRos21
Log-Secure Linear Blind Signature
Fully Secure Blind Signature
Communication ~ N

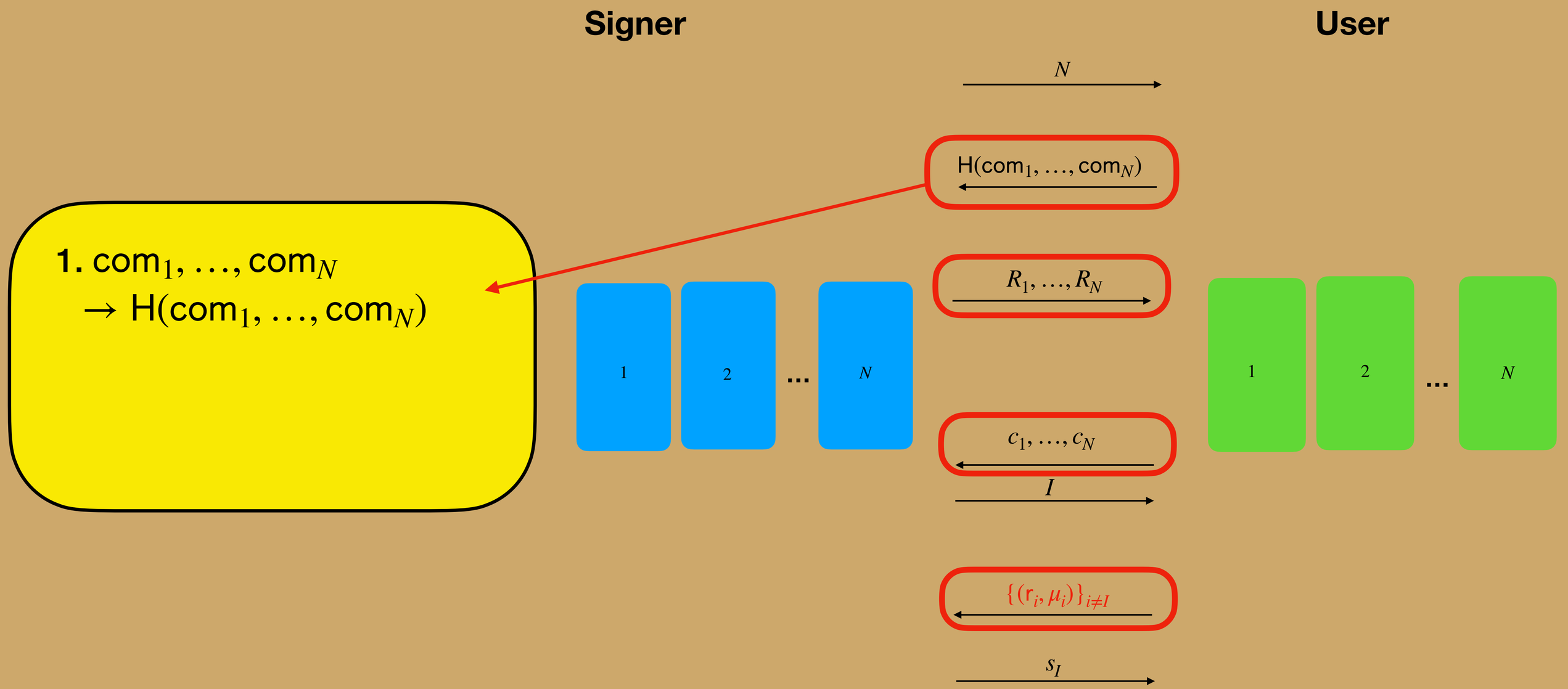
Our Results


1-of-N Cut-And-Choose in N-th Interaction
Boosting
AC:KatLosRos21
Log-Secure Linear Blind Signature
Compact Boosting
Our Work
1-of-N Cut-And-Choose in N-th Interaction
Fully Secure Blind Signature
Communication ~ N
Fully Secure Blind Signature
Communication ~ log N

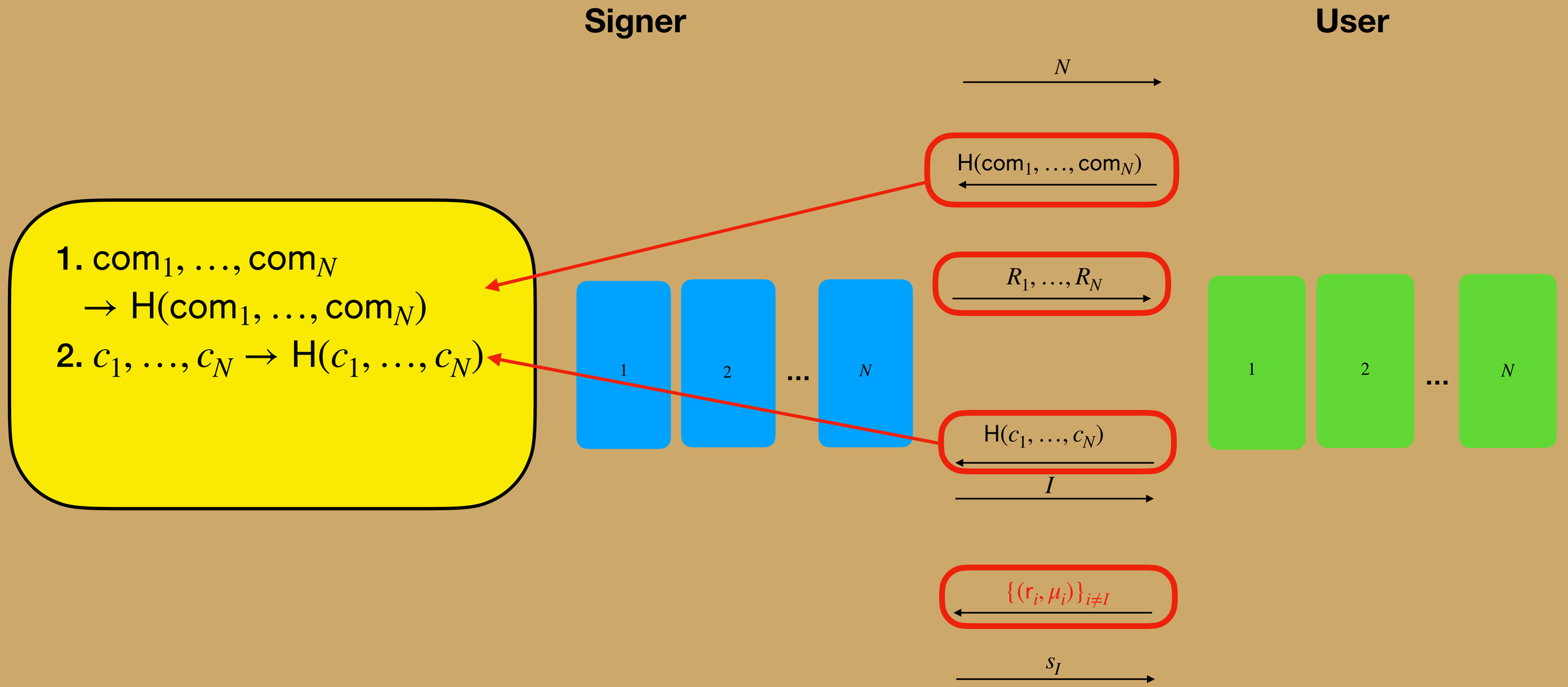
The *Compact* Boosting Transform



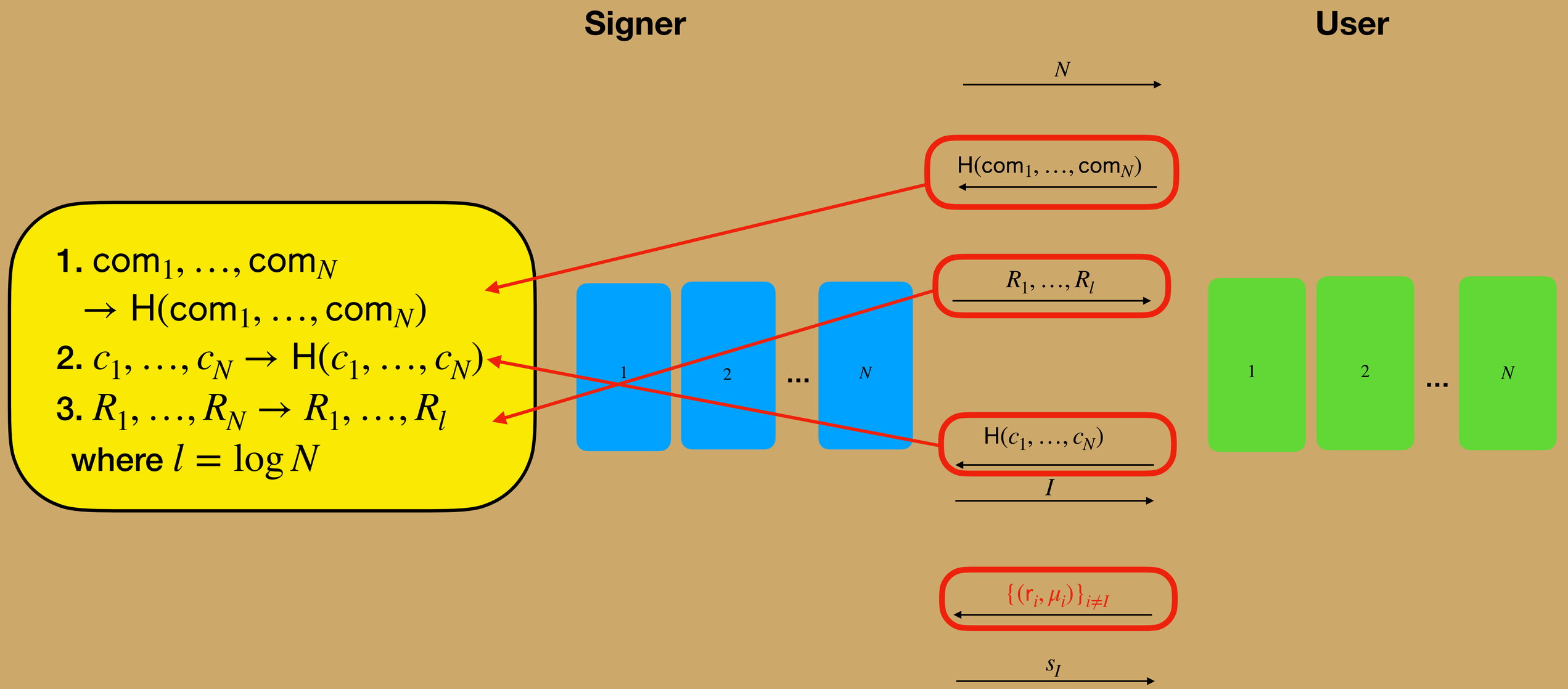
The *Compact* Boosting Transform



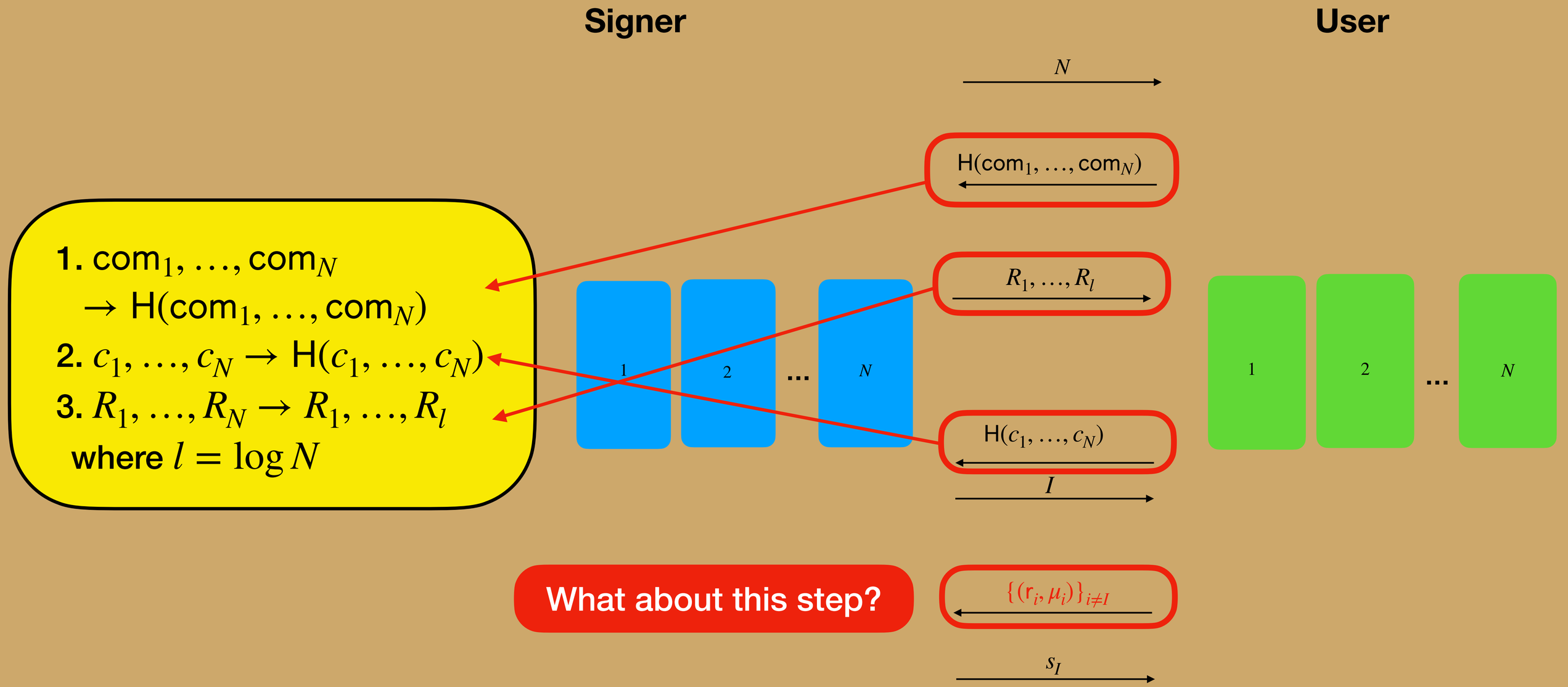
The *Compact* Boosting Transform



The *Compact* Boosting Transform



The *Compact* Boosting Transform



The *Compact* Boosting Transform

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**

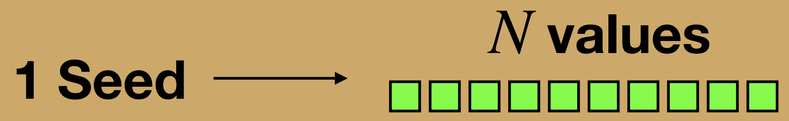
The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**

  1 Seed

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**



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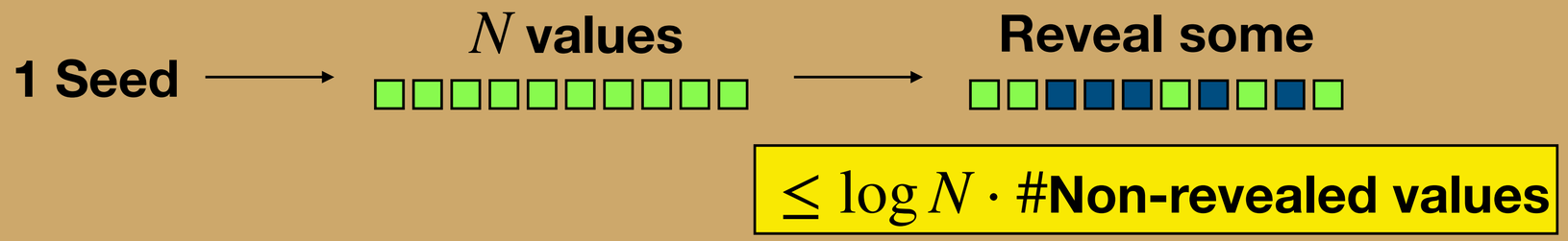

The *Compact* Boosting Transform

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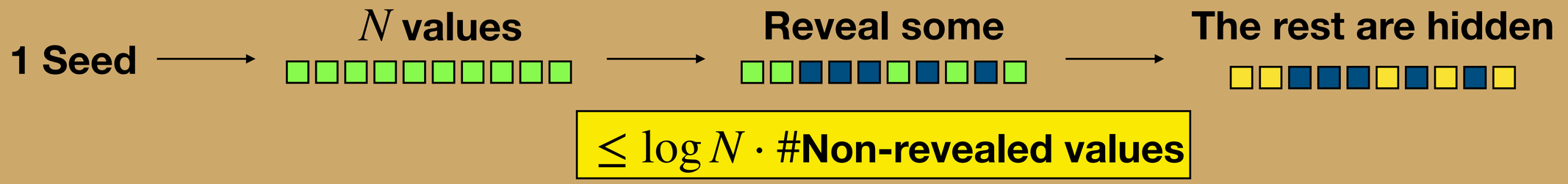

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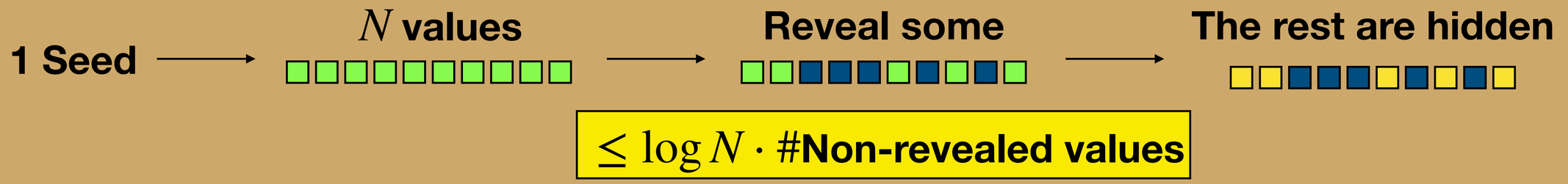
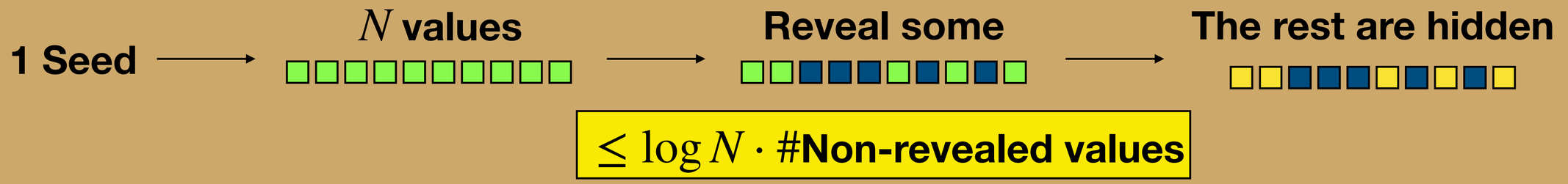


- **Applying to Cut-and-Choose Transform**

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**



- **Applying to Cut-and-Choose Transform**

1 Seed

The *Compact* Boosting Transform

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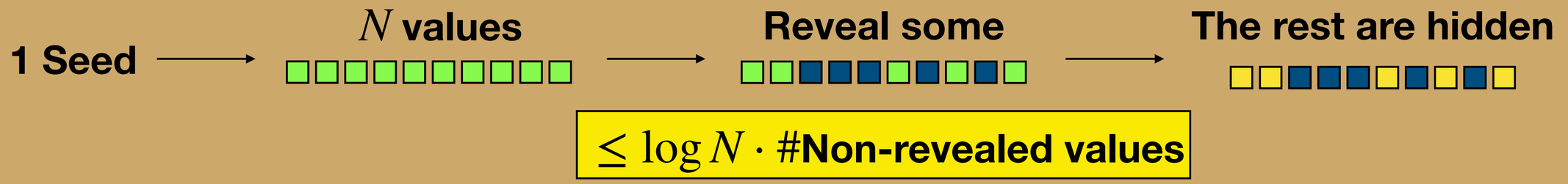
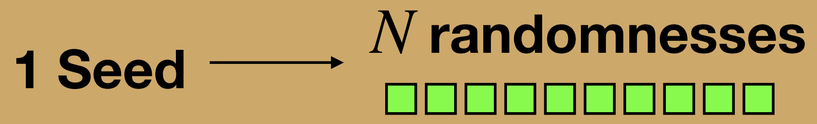


- **Applying to Cut-and-Choose Transform**



The *Compact* Boosting Transform

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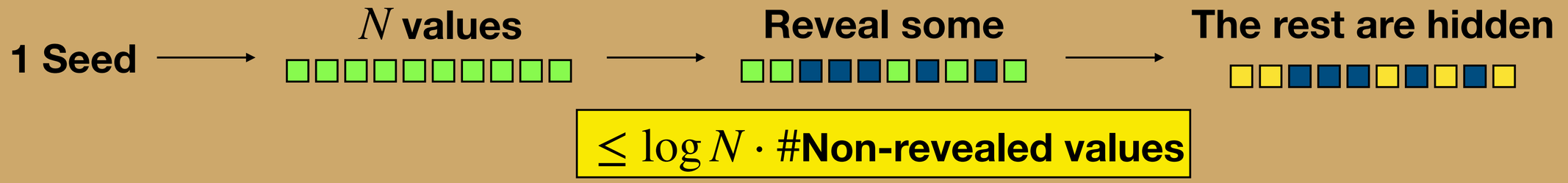
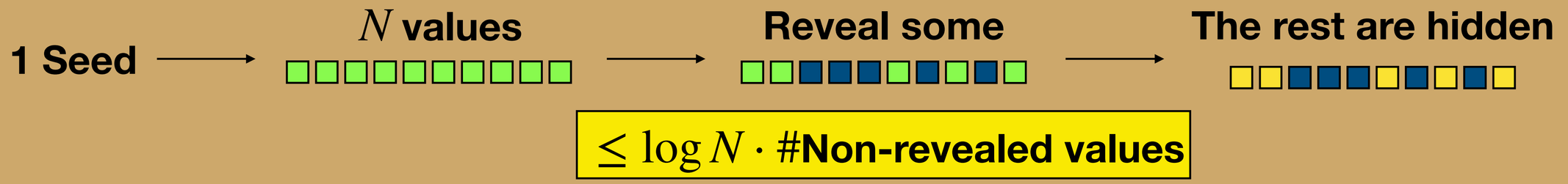


- **Applying to Cut-and-Choose Transform**

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**



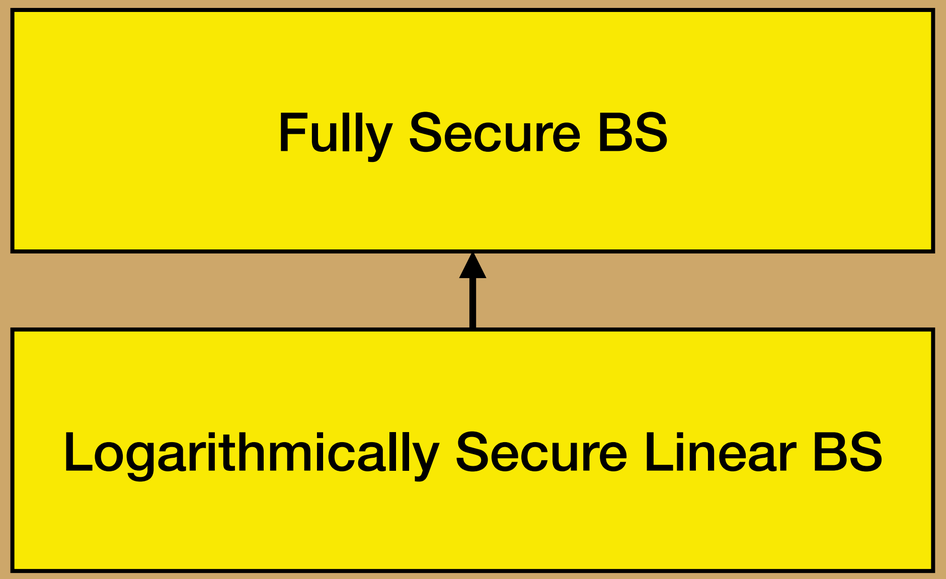
- **Applying to Cut-and-Choose Transform**

Now the protocol is $O(\log N)$ communication!

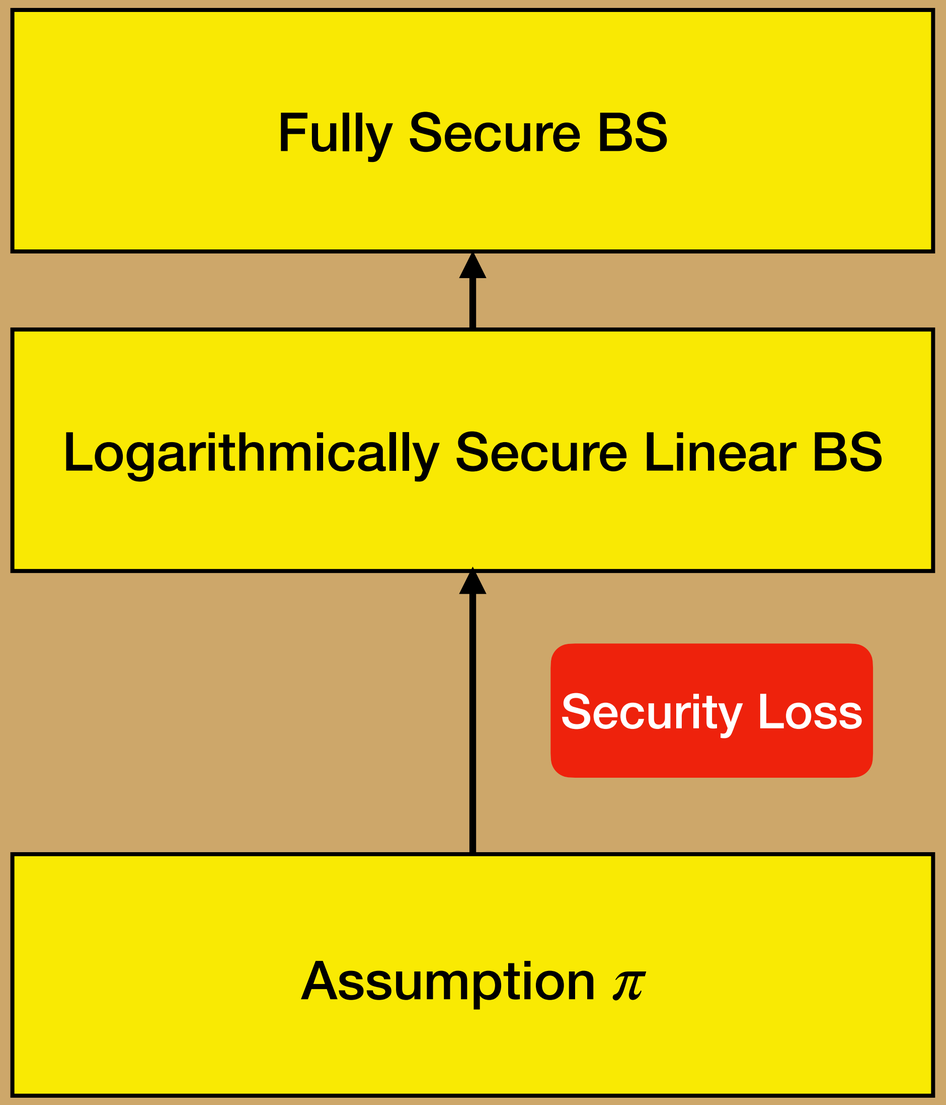
Source: shorturl.at/cDZ06

Remaining Problems

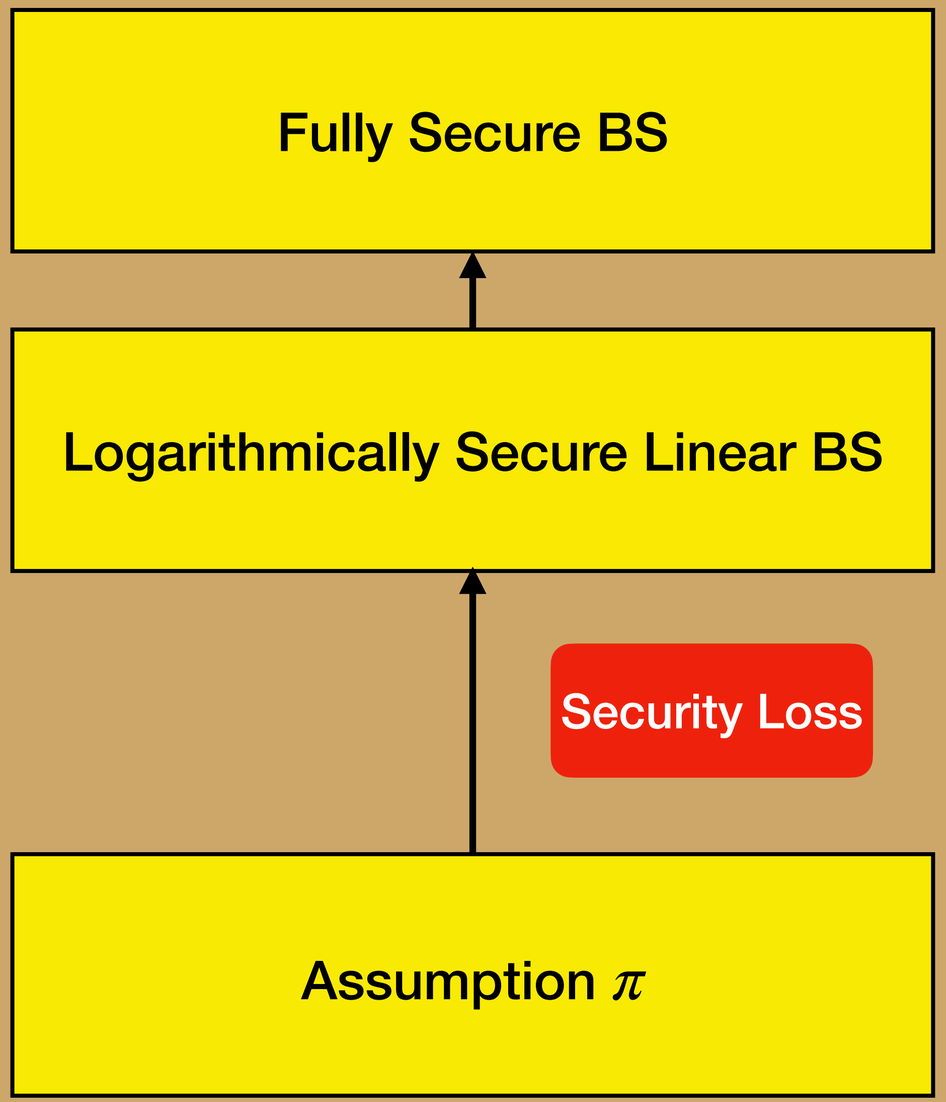
Remaining Problems



Remaining Problems



Remaining Problems



Communication $C_\pi \cdot \log(N) + C$
depends on Assumption!

Remaining Problems

Fully Secure BS

Logarithmically Secure Linear BS

Assumption π

Security Loss

Communication $C_\pi \cdot \log(N) + C$
depends on Assumption!

Inefficient Concrete Parameters

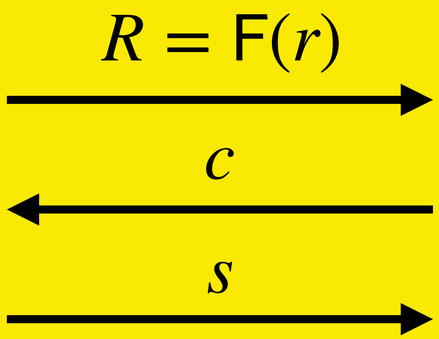
Schnorr:
2^{30} ***Signatures*** $\Longrightarrow$ ***~ 12000 Bit Group***

Source: shorturl.at/drsW5

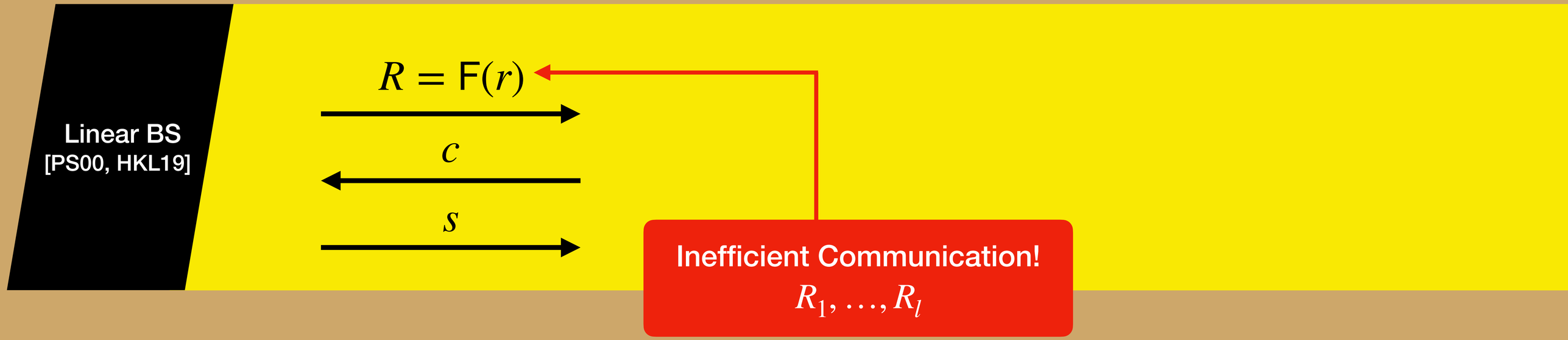
Improving Concrete Parameters

Improving Concrete Parameters

Linear BS
[PS00, HKL19]



Improving Concrete Parameters



Improving Concrete Parameters

Linear BS
[PS00, HKL19]

$R = \mathsf{F}(r)$

c

s

Inefficient Communication!
$R_1, \ldots, R_l$

BLS
[Bol03]

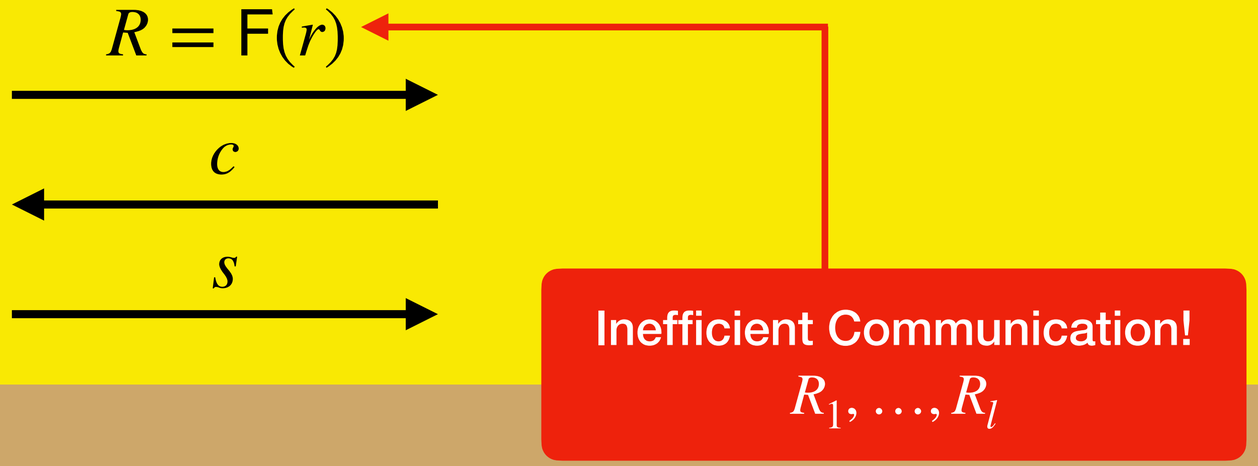
$pk = g^{sk}$

c $\quad c := H(m) \cdot g^{\alpha}$

$s := c^{sk}$ $\quad \sigma := s \cdot pk^{-\alpha}$

Improving Concrete Parameters

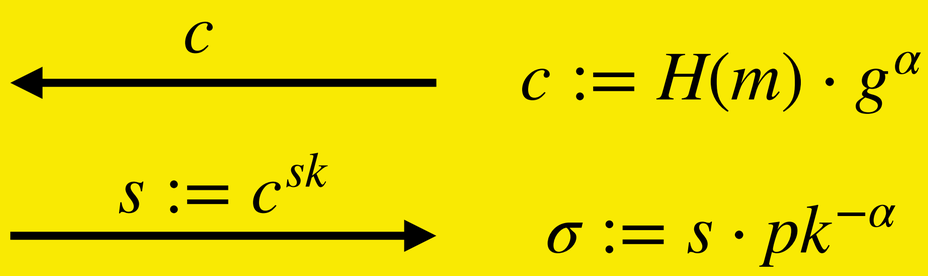
Linear BS
[PS00, HKL19]



★ Simulation knowing Message + Randomness

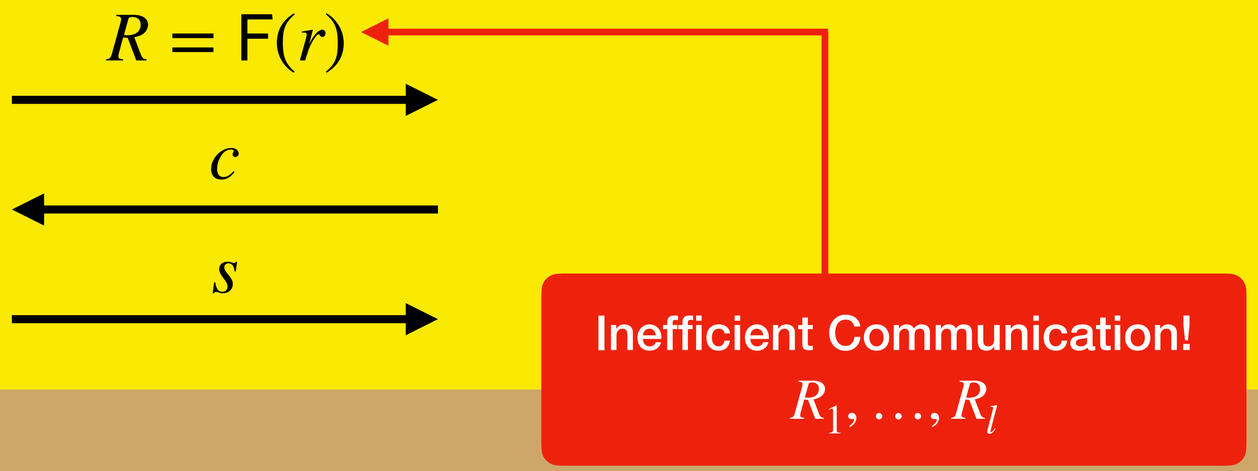
Logarithmic Security

BLS
[Bol03]



Improving Concrete Parameters

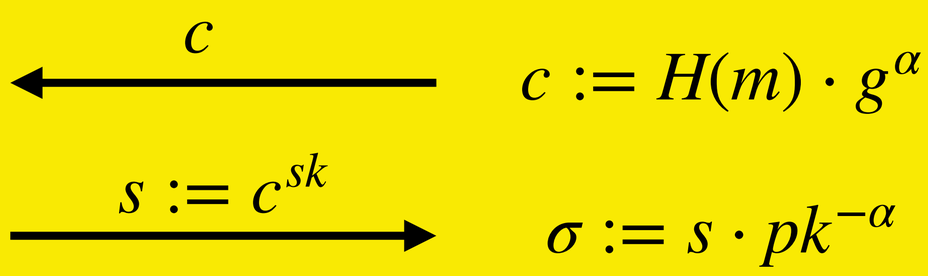
Linear BS
[PS00, HKL19]



★ Simulation knowing Message + Randomness

Logarithmic Security

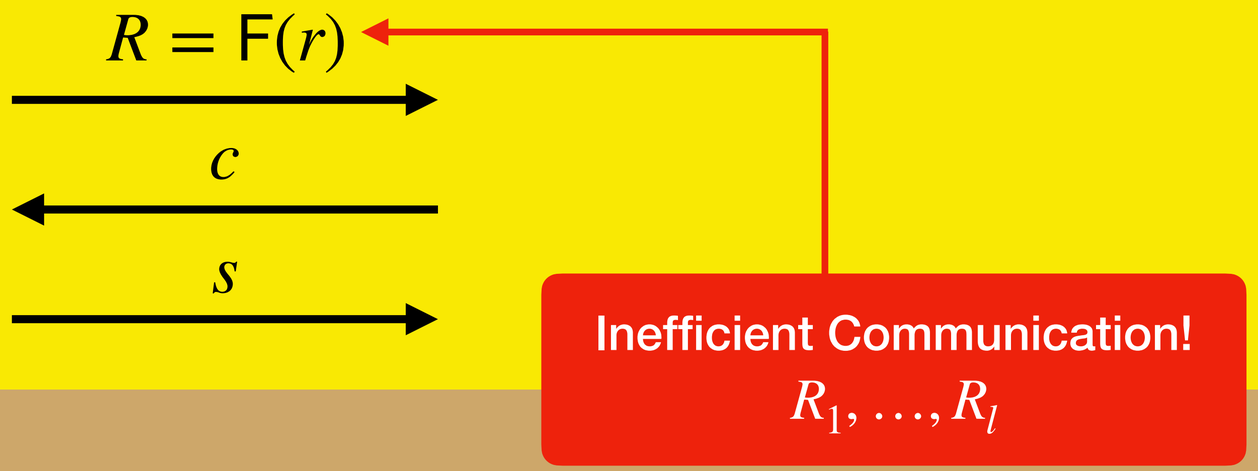
BLS
[Bol03]



★ Simulation knowing Message + Randomness

Improving Concrete Parameters

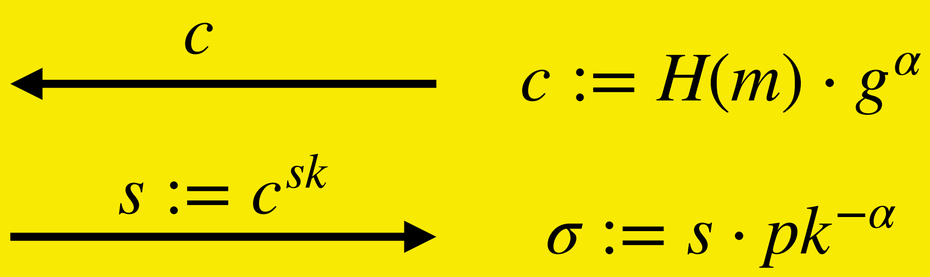
Linear BS
[PS00, HKL19]



★ **Simulation knowing Message + Randomness**

Logarithmic Security

BLS
[Bol03]



★ **Simulation knowing Message + Randomness**

Only Key-Only Security!

Parallel Instance Cut-and-Choose

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

Parallel Instance Cut-and-Choose

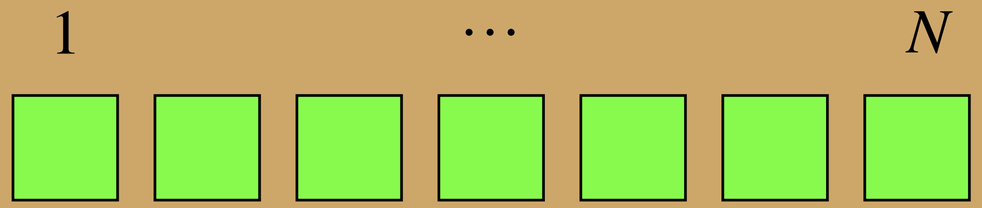
Source: shorturl.at/cDZ06

AC:KLR21 Idea

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

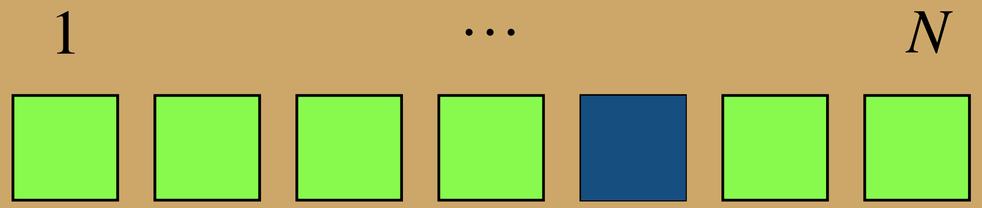
AC:KLR21 Idea



Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

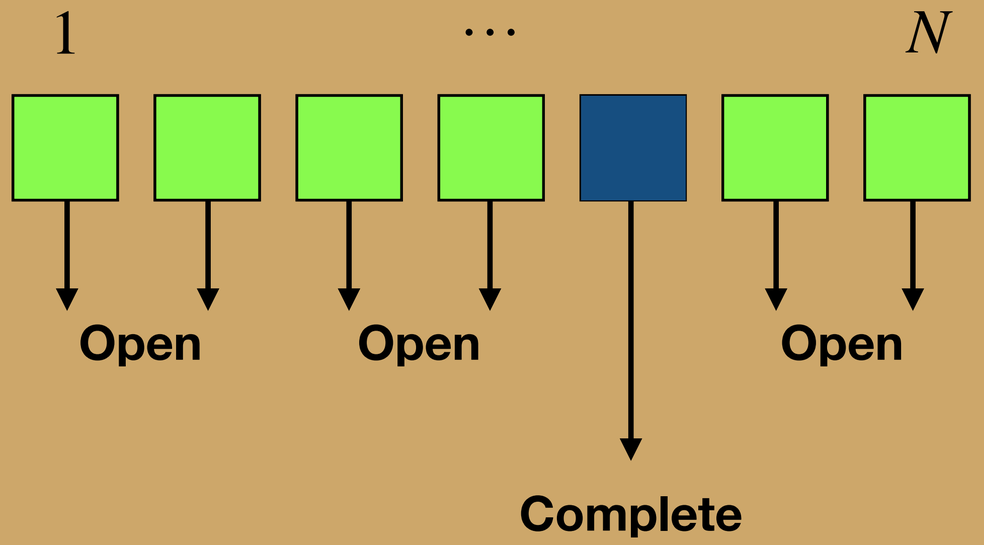
AC:KLR21 Idea



Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea



Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Malformed …

… more than one session

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Malformed …

… more than one session

No Response Required

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Malformed …

… more than one session

No Response Required

… no session

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Malformed …

… more than one session

No Response Required

… no session

Response using ★

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Malformed …

… more than one session

No Response Required

… no session

Response using ★

… exactly one session

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Malformed …

… more than one session

No Response Required

… no session

Response using ★

… exactly one session

Need Signer Oracle

$$\Pr[\text{cheat}] = \frac{1}{N}$$

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Interactions

...

$$\Pr[\text{cheat}] = \frac{1}{2} \qquad \Pr[\text{cheat}] = \frac{1}{3} \qquad \Pr[\text{cheat}] = \frac{1}{q}$$

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

AC:KLR21 Idea

Interactions

$$\Pr[\text{cheat}] = \frac{1}{2} \qquad \Pr[\text{cheat}] = \frac{1}{3} \qquad \Pr[\text{cheat}] = \frac{1}{q}$$

$$\mathbb{E}[\#\text{cheat}] = \sum_{i=2}^{q} \frac{1}{i} \leq \Theta(\log q)$$

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

Our Idea

Interactions →

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

Our Idea

Interactions →

1. Scale

$\mathbb{E}[\#\text{cheat}] < 1$

$\Pr[\#\text{cheat} \geq 1] \leq const$

Source: shorturl.at/kNPR7

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

Our Idea

Interactions →

1. Scale

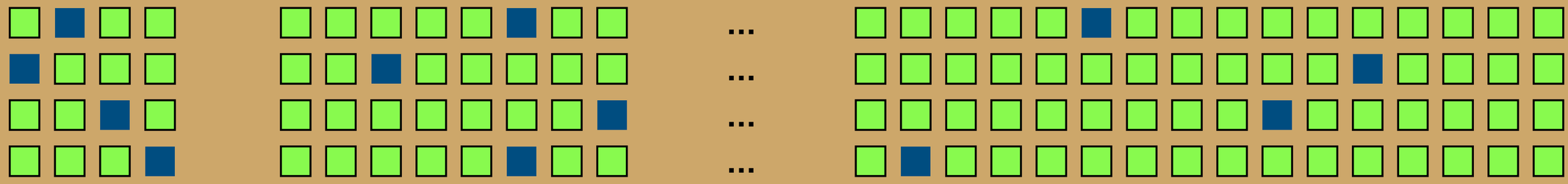
pk 

$\mathbb{E}[\#\text{cheat}] < 1$

$\Pr[\#\text{cheat} \geq 1] \leq const$

Source: shorturl.at/kNPR7

2. Parallel Instance

pk_1 

pk_K

$\Pr[\exists i^* : \#\text{cheat}_{i^*} < 1] \geq 1 - negl$

Parallel Instance Cut-and-Choose

Source: shorturl.at/cDZ06

Our Idea

Interactions →

1. Scale

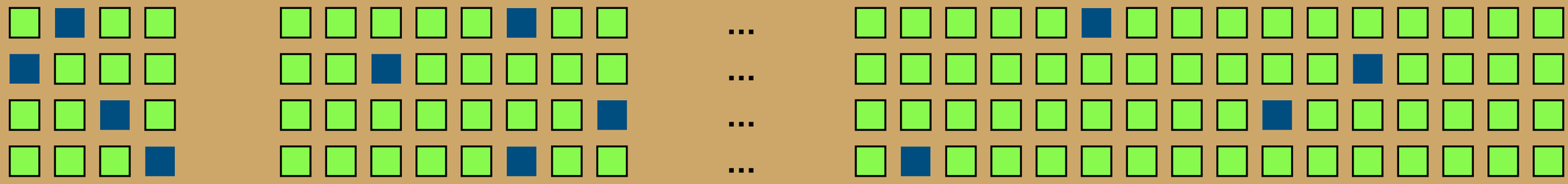
pk 

$\mathbb{E}[\#\text{cheat}] < 1$

$\Pr[\#\text{cheat} \geq 1] \leq const$

Source: shorturl.at/kNPR7

2. Parallel Instance

pk_1 

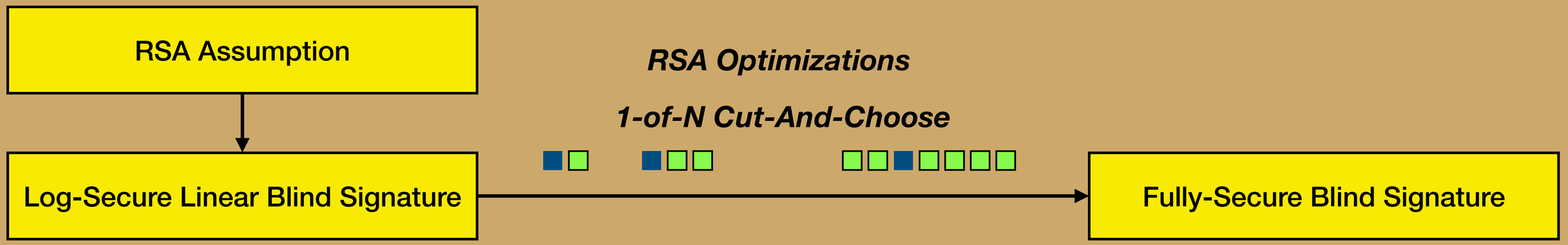
pk_K

$\Pr[\exists i^* : \#\text{cheat}_{i^*} < 1] \geq 1 - negl$

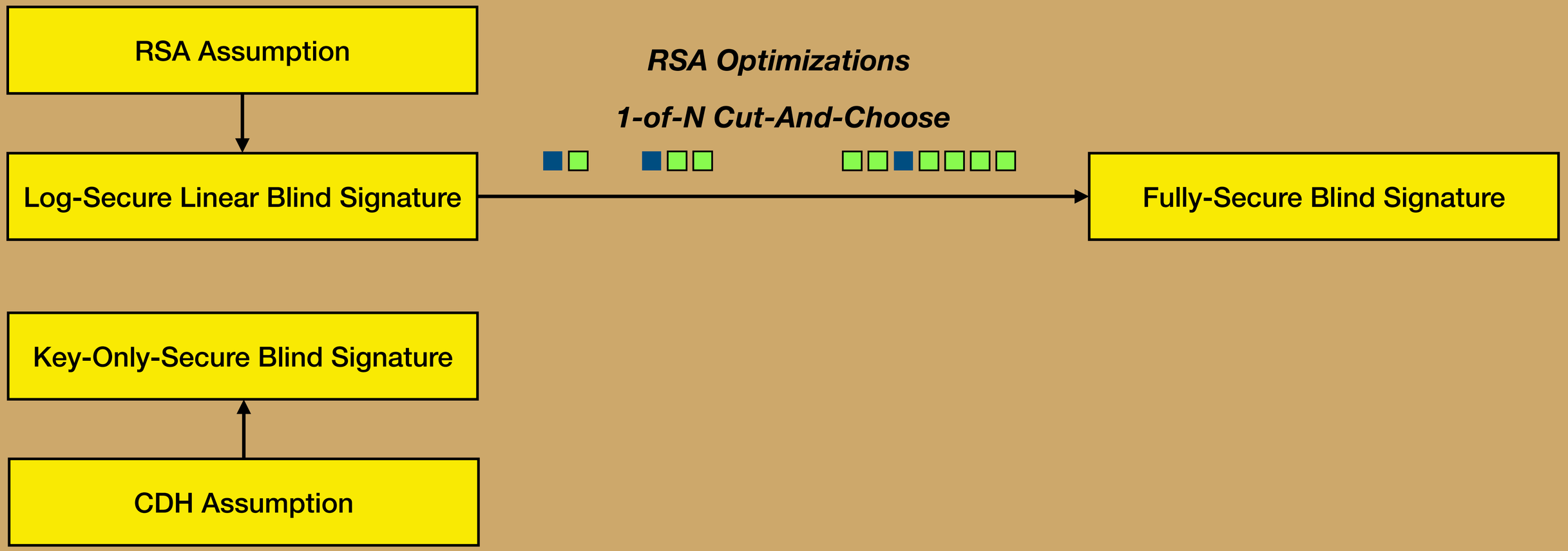
Aggregate: $\sigma_1, \ldots, \sigma_K \Longrightarrow \bar{\sigma}$

Concrete Schemes

Concrete Schemes



Concrete Schemes



Concrete Schemes

RSA Assumption

Log-Secure Linear Blind Signature

RSA Optimizations

1-of-N Cut-And-Choose

Fully-Secure Blind Signature

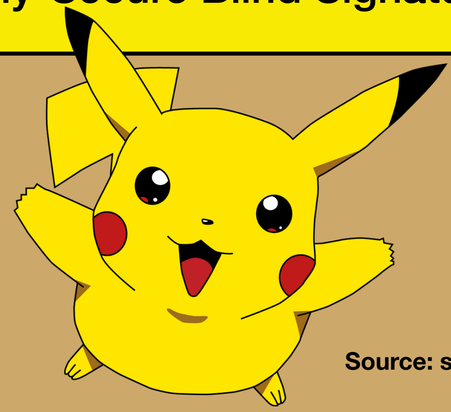
Key-Only-Secure Blind Signature

Parallel Instance 1-of-N Cut-And-Choose

Fully-Secure Blind Signature

CDH Assumption

CDH Optimizations



Source: shorturl.at/EKPQX

Overview

Overview

Generic

Overview


Generic
AC:KatLosRos21
$\Theta(N)$ Communication
Ours
$\Theta(\log N)$ Communication

Overview

Generic

AC:KatLosRos21
$\Theta(N)$ **Communication**

Ours
$\Theta(\log N)$ **Communication**

Concrete

Overview

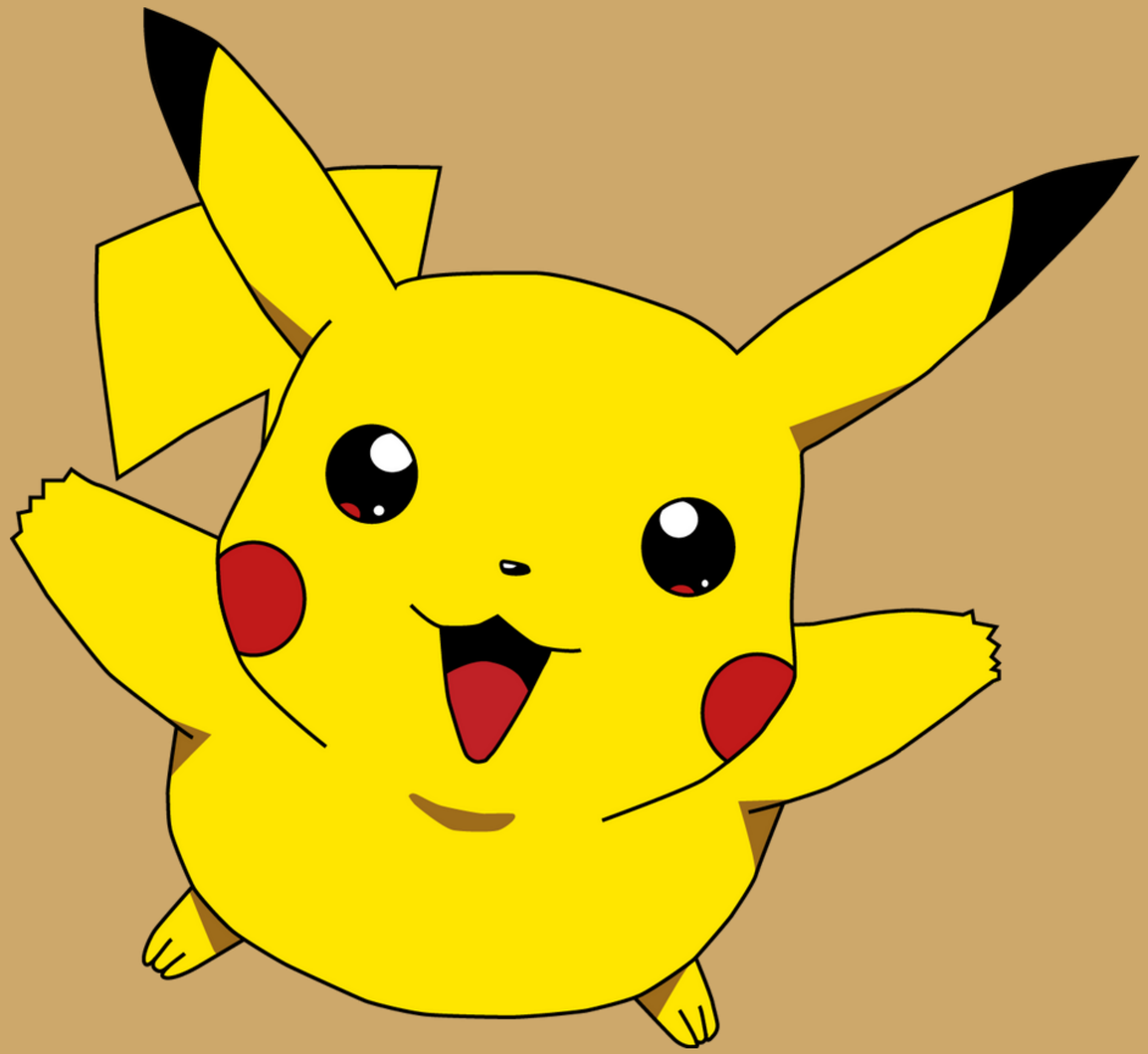
Generic

AC:KatLosRos21
$\Theta(N)$ **Communication**

Ours
$\Theta(\log N)$ **Communication**

Concrete

Assumption	Max. Communication	Signature Size
RSA	8 KB	9 KB
CDH	120 KB	3 KB



https://ia.cr/2022/007

Source: shorturl.at/EKPQX

The Boosting Transform

The Boosting Transform

Signer

User

The Boosting Transform

Signer

In the N-th interaction

User

The Boosting Transform

Signer

In the N-th interaction

N

User

The Boosting Transform

Signer

In the N-th interaction

N

(r_1, μ_1) (r_2, μ_2) ... (r_I, μ_I) ... (r_N, μ_N)

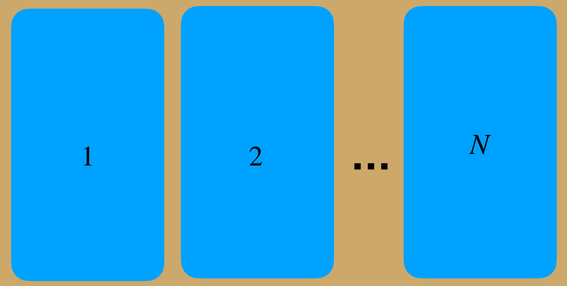
User

The Boosting Transform

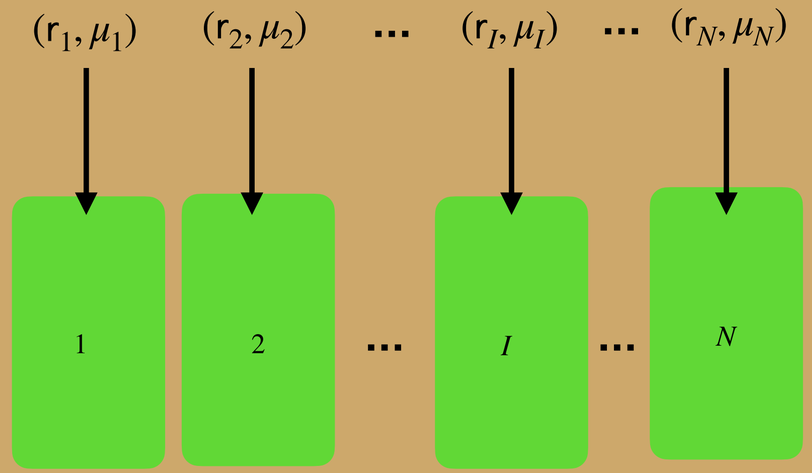
Signer

In the N-th interaction

N



Signer's side of the original blind signature protocol



User

User's side of the original blind signature protocol

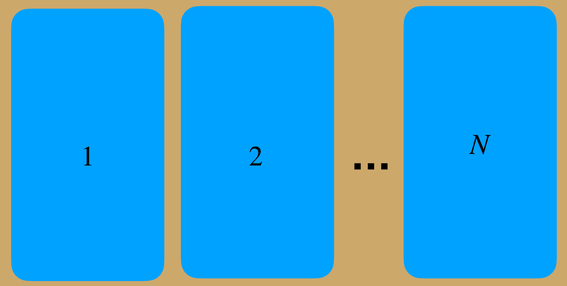
The Boosting Transform

Signer

In the N-th interaction

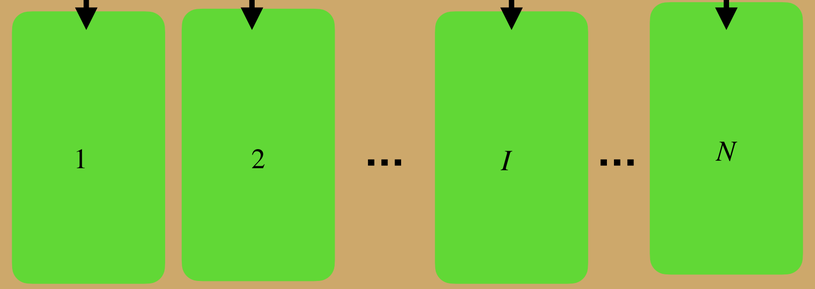
N

$\mathsf{com}_1, \ldots, \mathsf{com}_N$



Signer's side of the original blind signature protocol

(r_1, μ_1) (r_2, μ_2) ... (r_I, μ_I) ... (r_N, μ_N)



User

User's side of the original blind signature protocol

The Boosting Transform

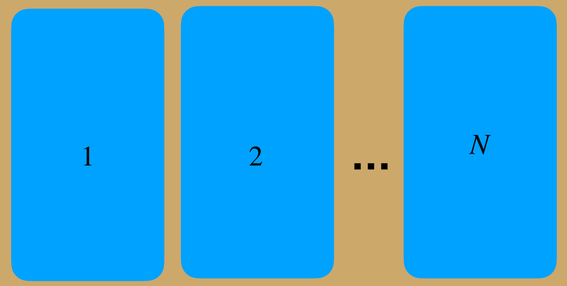
Signer

In the N-th interaction

N

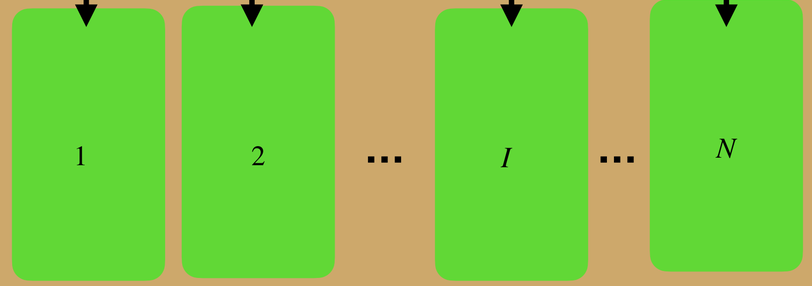
$\mathsf{com}_1, \ldots, \mathsf{com}_N$

$R_1, \ldots, R_N$



Signer's side of the original blind signature protocol

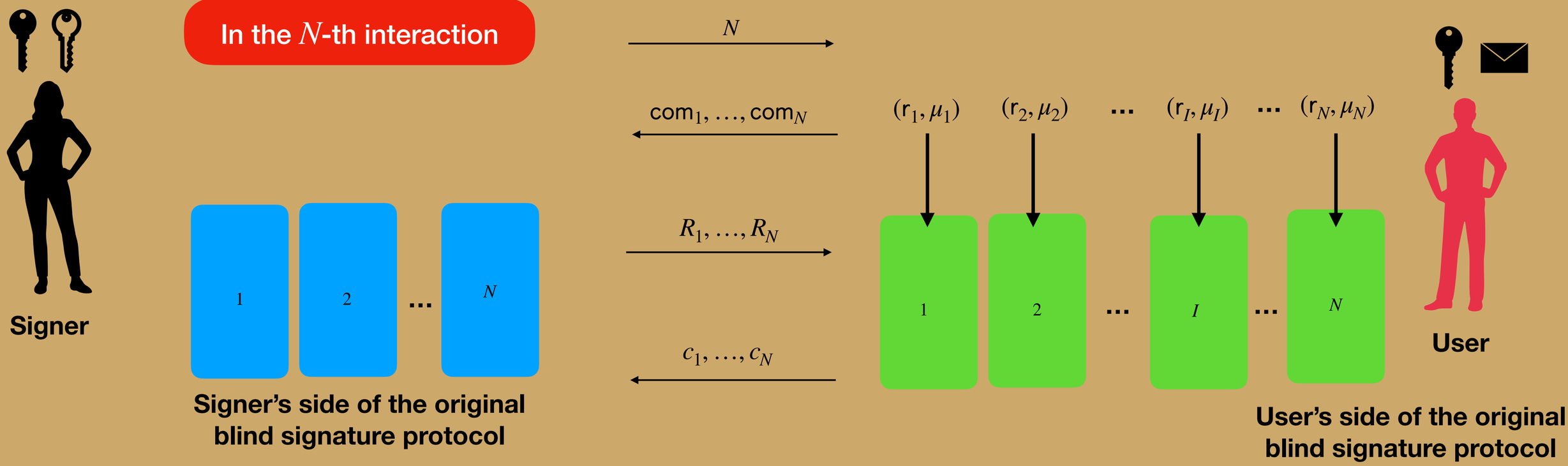
(r_1, μ_1) (r_2, μ_2) ... (r_I, μ_I) ... (r_N, μ_N)



User

User's side of the original blind signature protocol

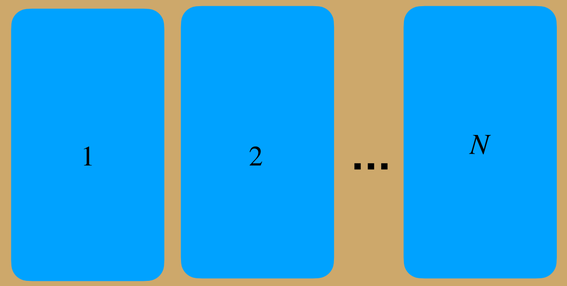
The Boosting Transform



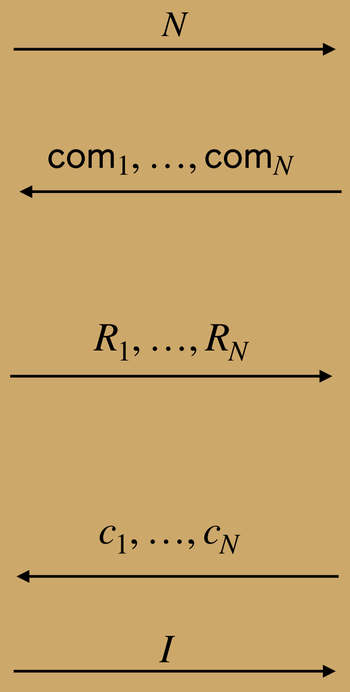
The Boosting Transform

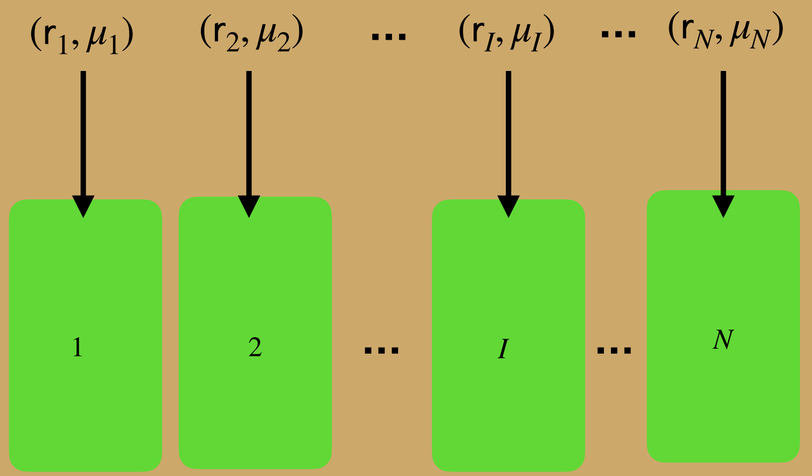
Signer

In the N-th interaction



Signer's side of the original blind signature protocol





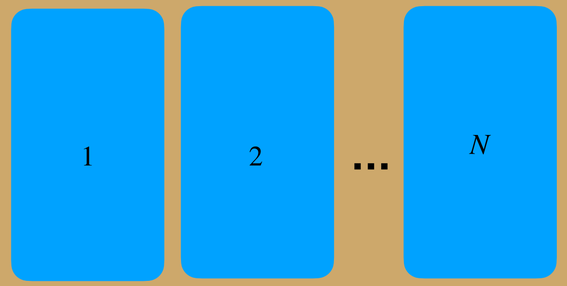
User

User's side of the original blind signature protocol

The Boosting Transform

Signer

In the N-th interaction



Signer's side of the original blind signature protocol

N

$\mathsf{com}_1, \ldots, \mathsf{com}_N$

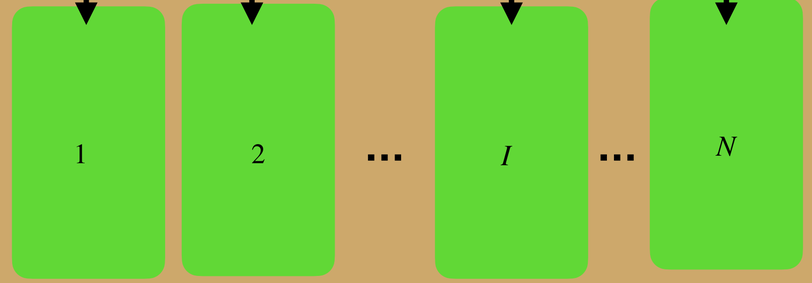
$R_1, \ldots, R_N$

$c_1, \ldots, c_N$

I

$\{(\mathsf{r}_i, \mu_i)\}_{i \neq I}$

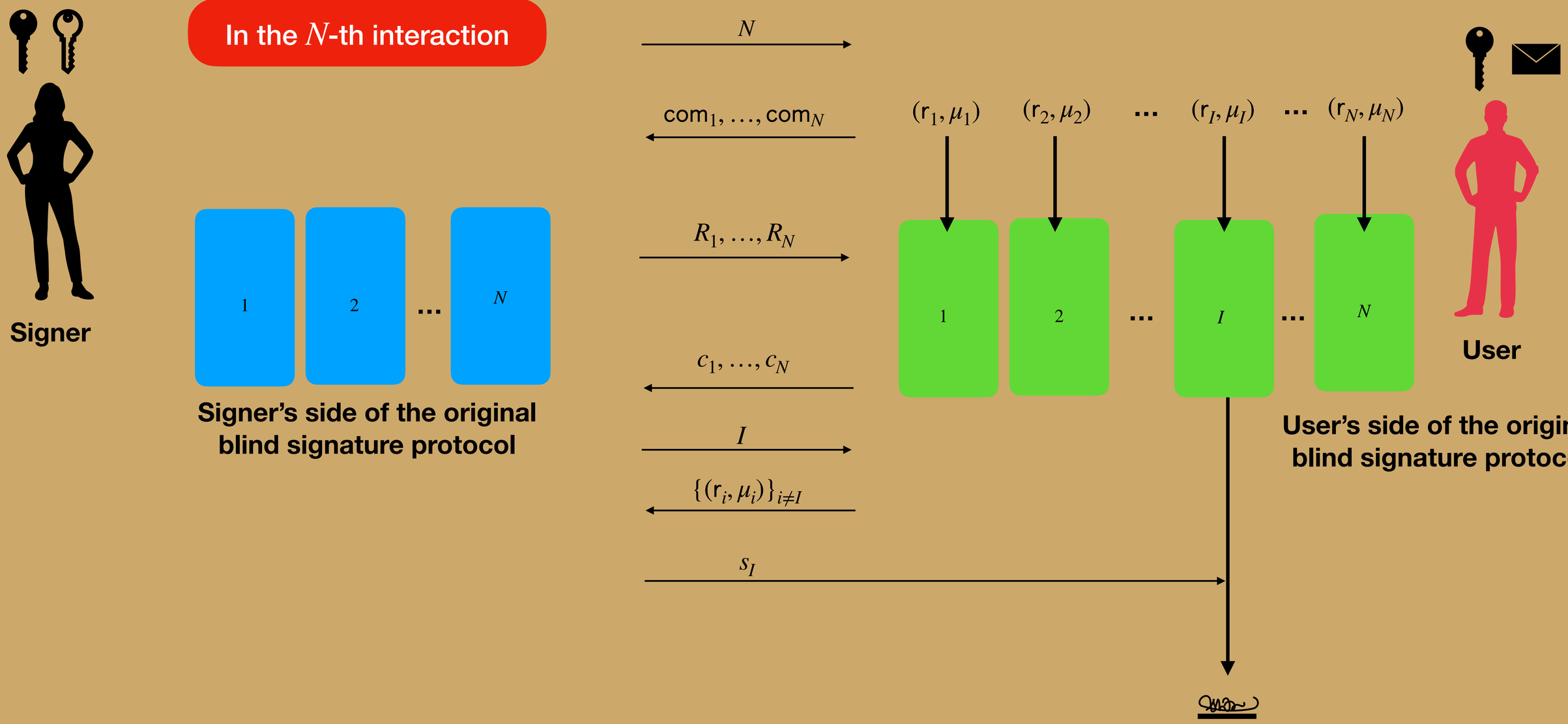
(r_1, μ_1) (r_2, μ_2) ... (r_I, μ_I) ... (r_N, μ_N)



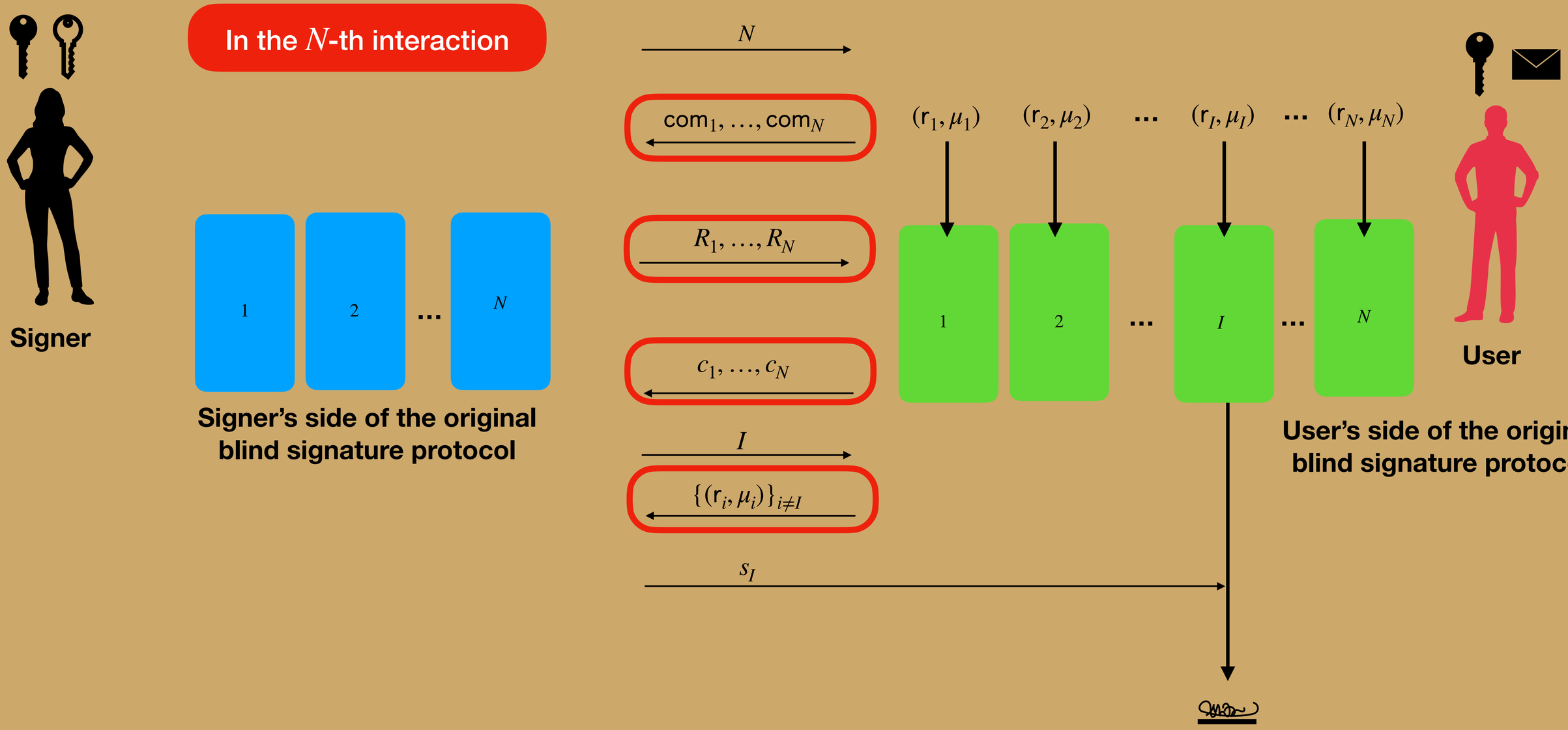
User

User's side of the original blind signature protocol

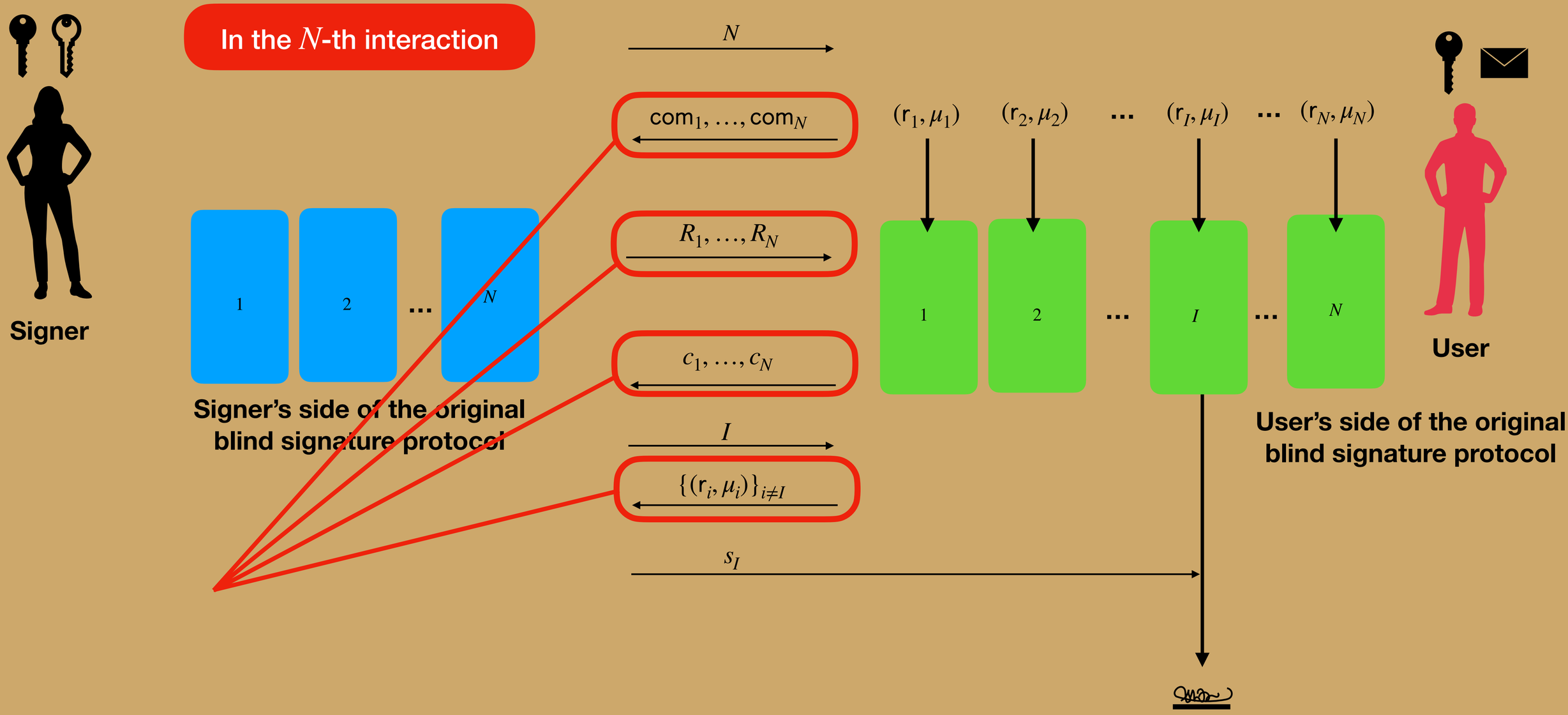
The Boosting Transform



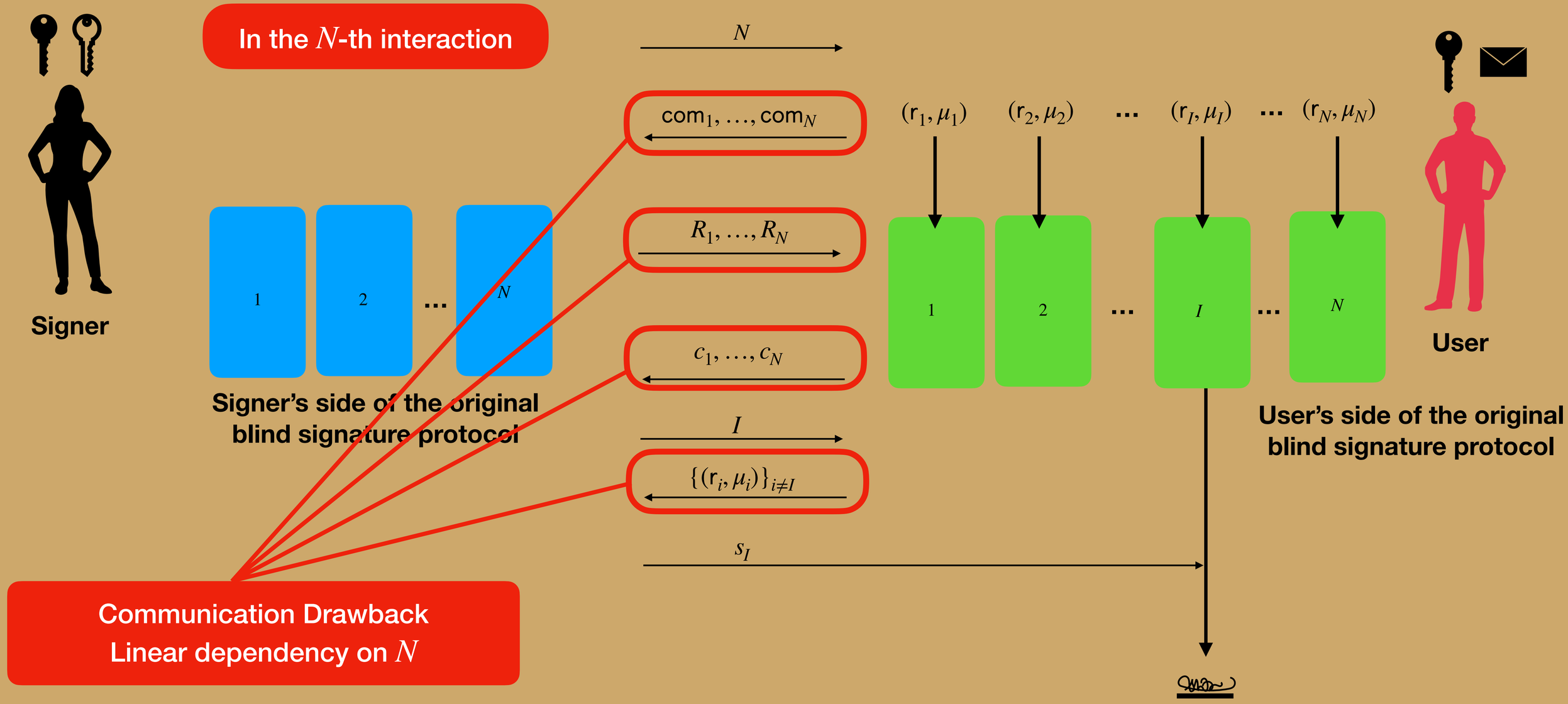
The Boosting Transform



The Boosting Transform



The Boosting Transform



The *Compact* Boosting Transform

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**

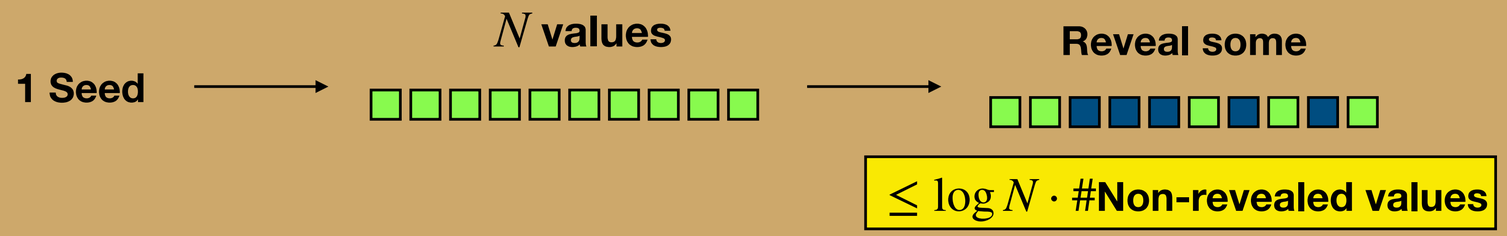
  1 Seed

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**

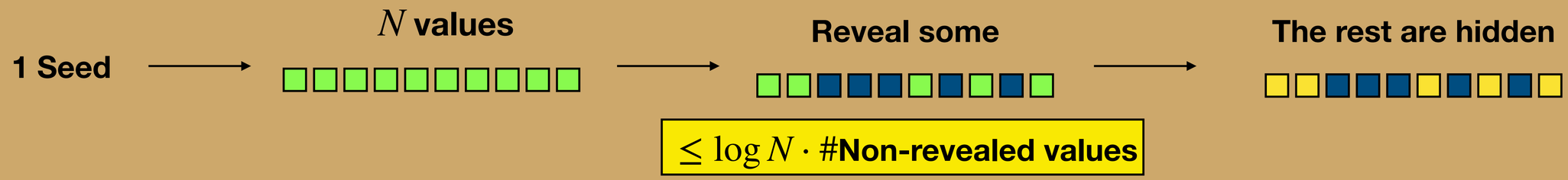
The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**



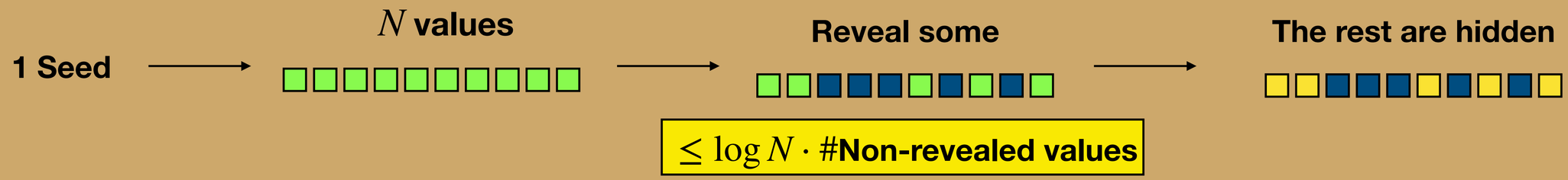
The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**



The *Compact* Boosting Transform

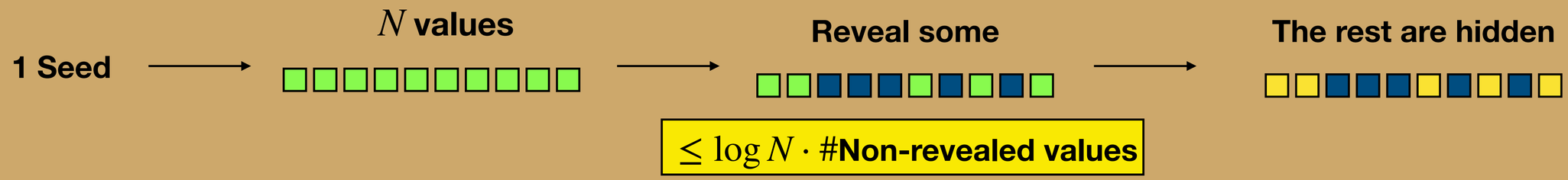
- **Puncturable Pseudorandom Function (PPRF) [SW14]**



- **Randomness Homomorphic Commitment**

The *Compact* Boosting Transform

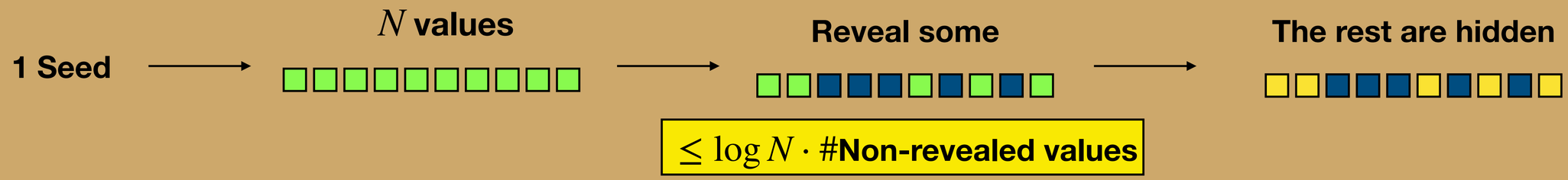
- **Puncturable Pseudorandom Function (PPRF) [SW14]**



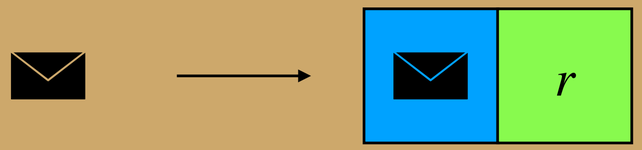
- **Randomness Homomorphic Commitment**

The *Compact* Boosting Transform

- **Puncturable Pseudorandom Function (PPRF) [SW14]**



- **Randomness Homomorphic Commitment**



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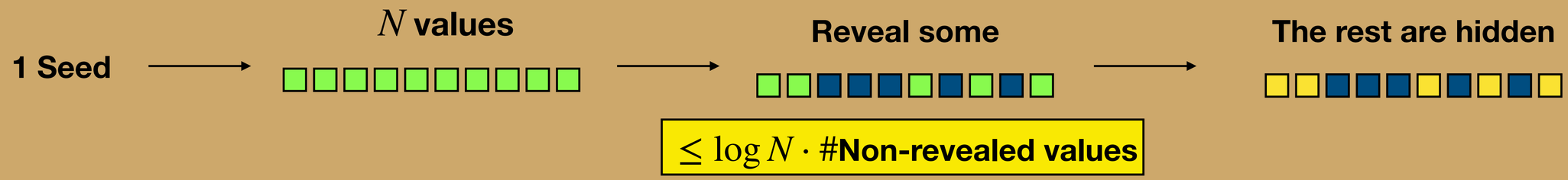

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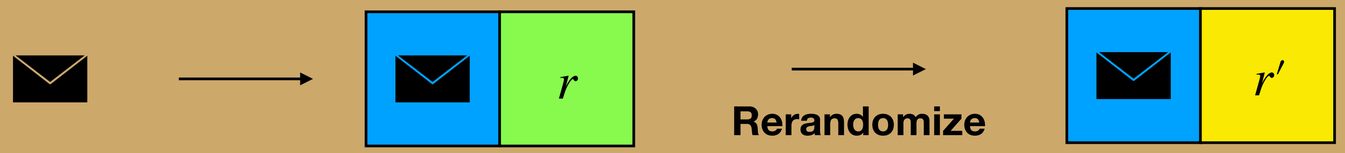

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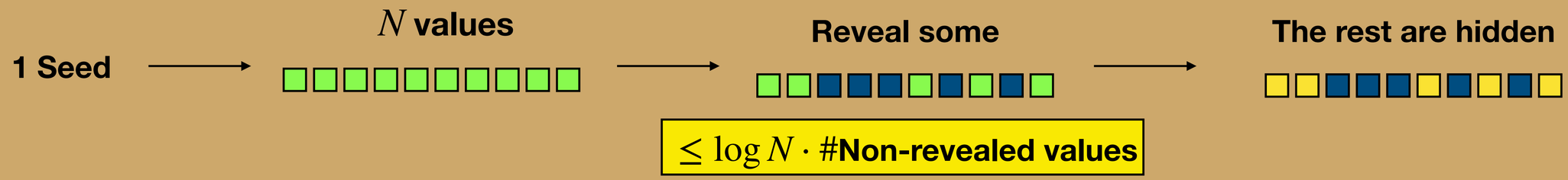

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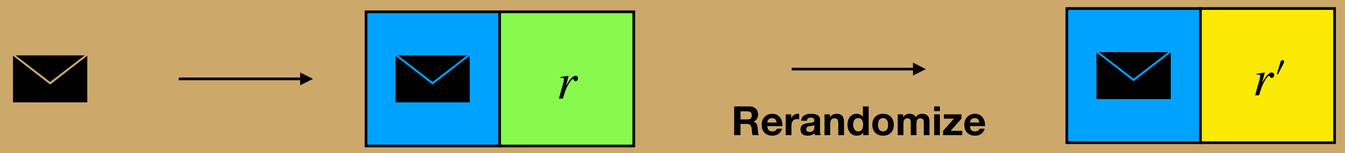

- **Applying to Cut-and-Choose Transform**

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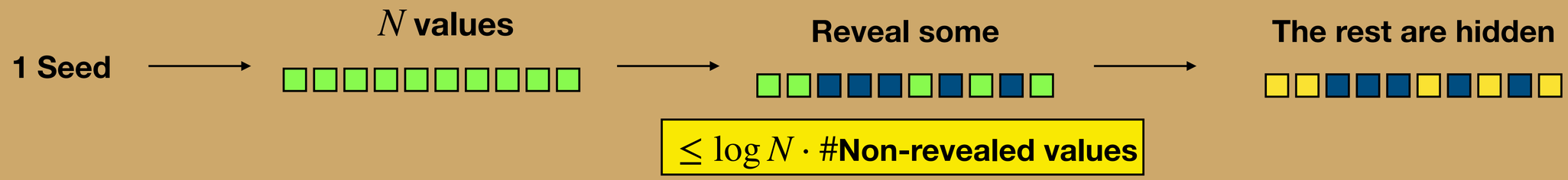

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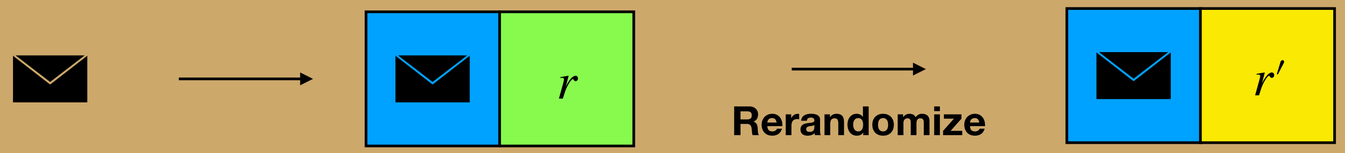

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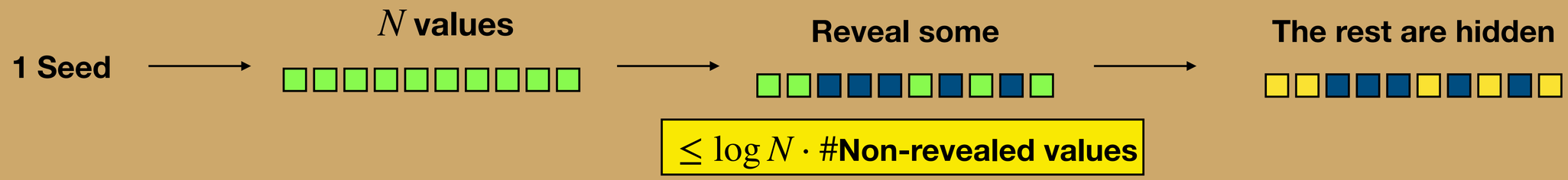

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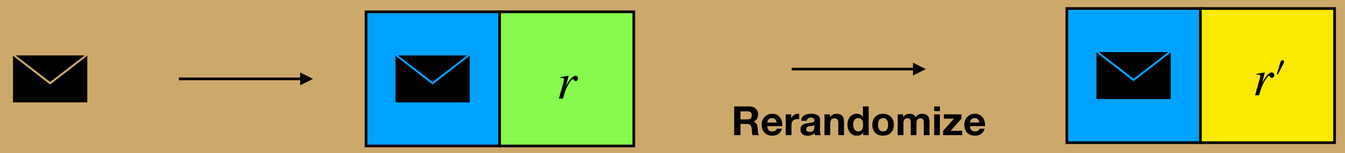

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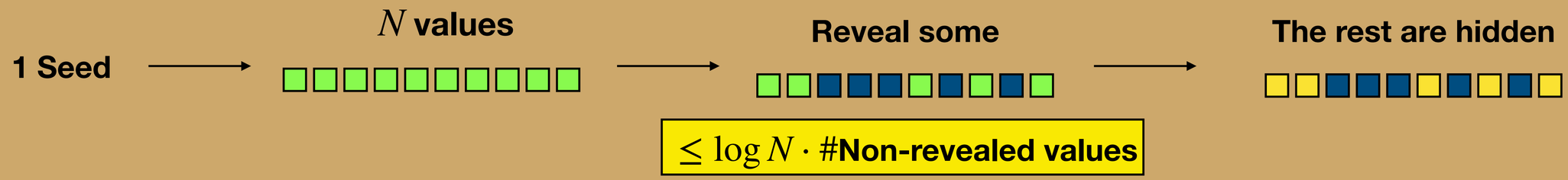

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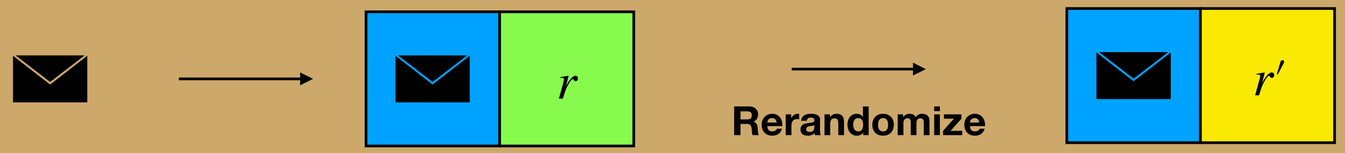

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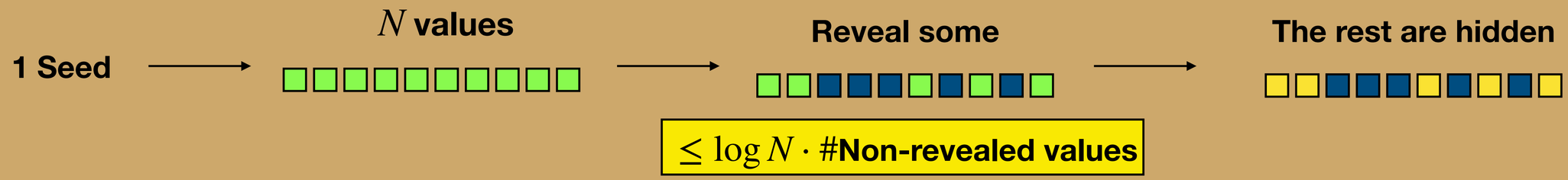

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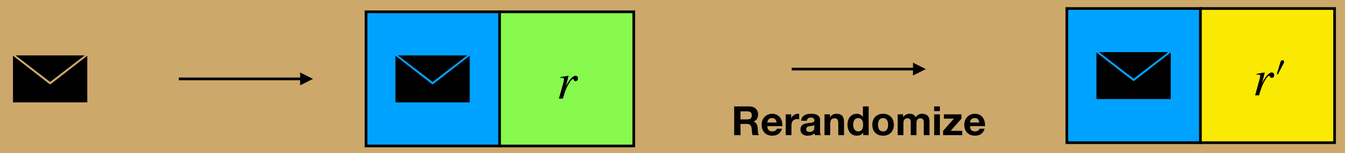

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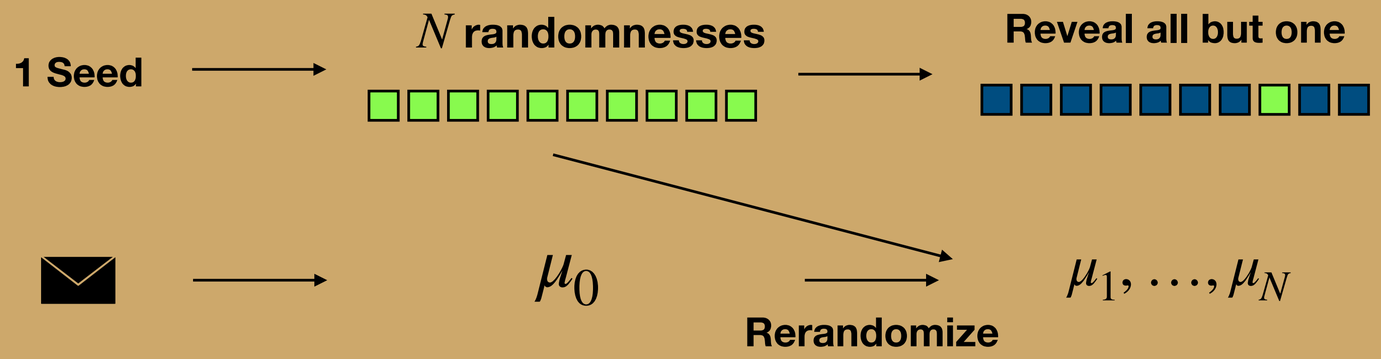

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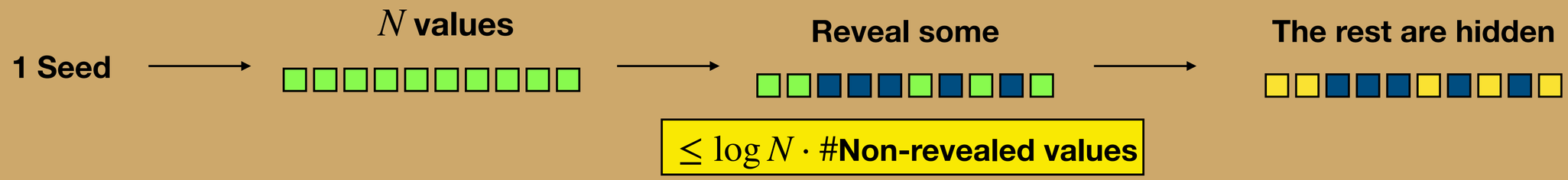

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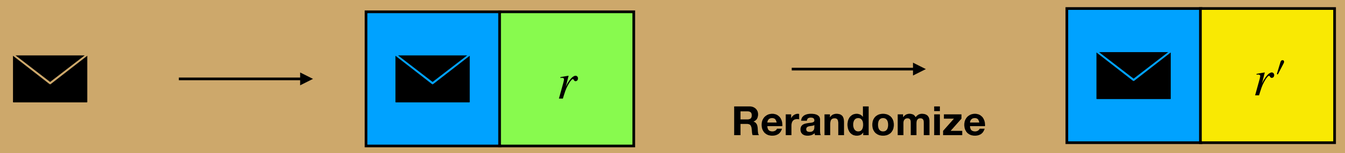

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