Broadcast, Trace and Revoke with Optimal Parameters from Polynomial Hardness

Shweta Agrawal
IIT Madras, India

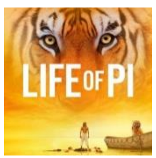
Simran Kumari
IIT Madras, India

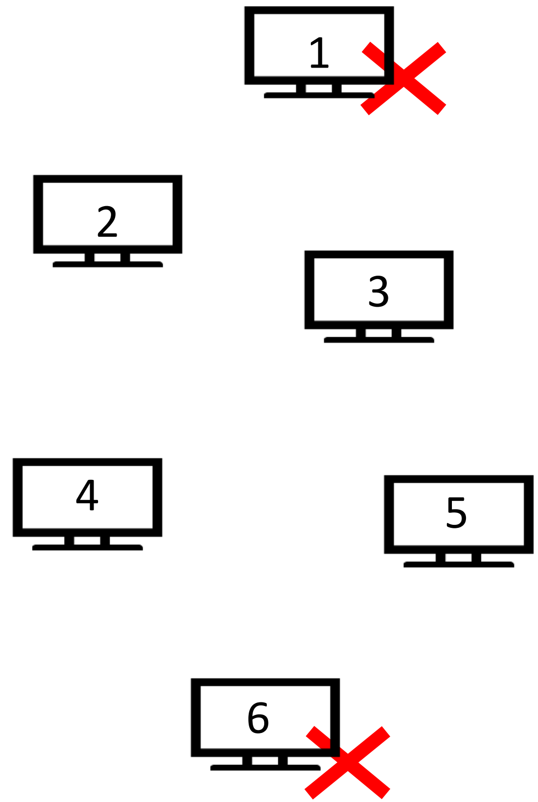
Anshu Yadav
IIT Madras, India

Shota Yamada
AIST, Japan

EUROCRYPT 2023

Motivation





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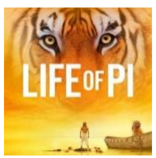

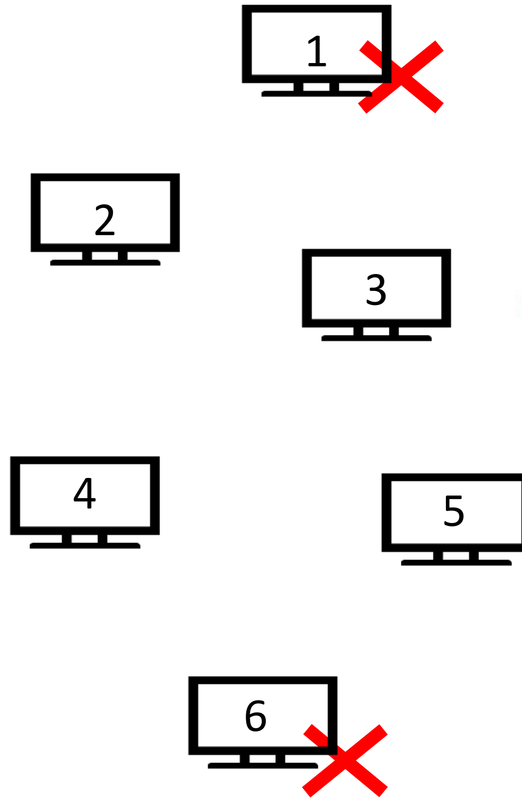

Trivial Approach : Using Public Key Encryption

|**ct**| grows linearly with the no. of users

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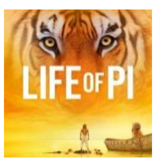

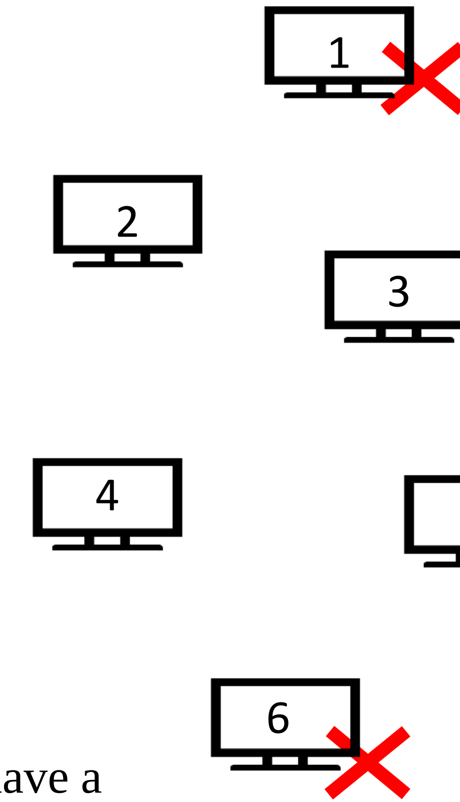

Trivial Approach : Using Public Key Encryption

|ct| grows linearly with the no. of users

A better approach? Can we have a **short** common ct for all the users?

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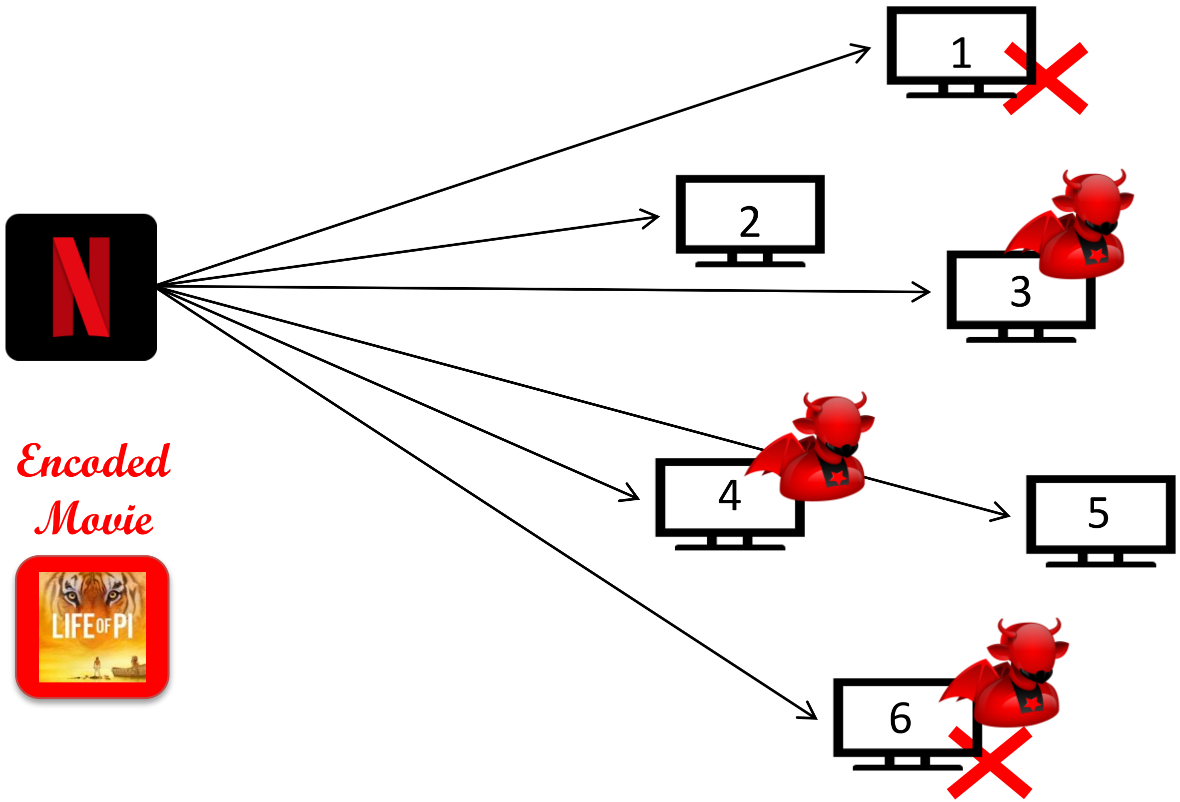

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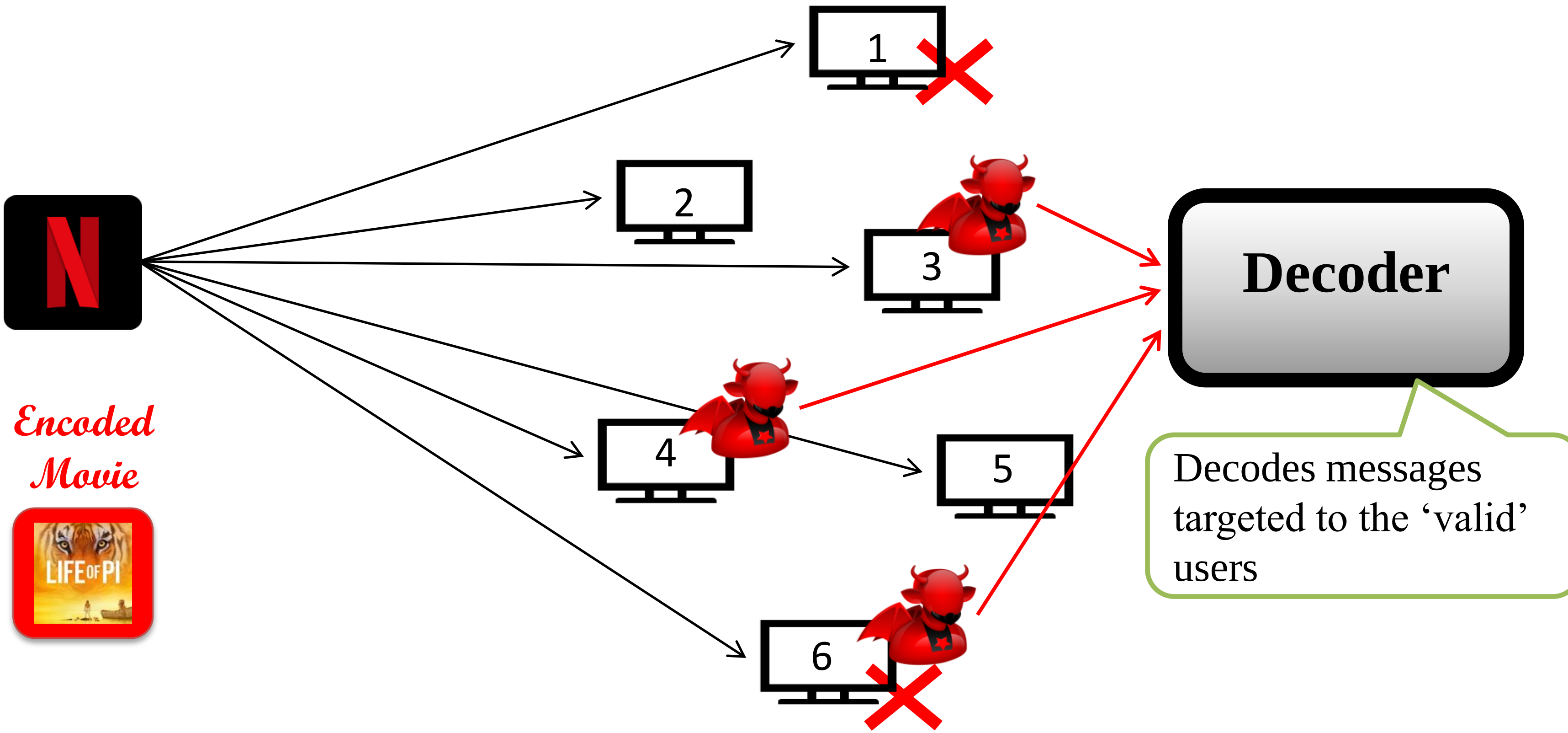
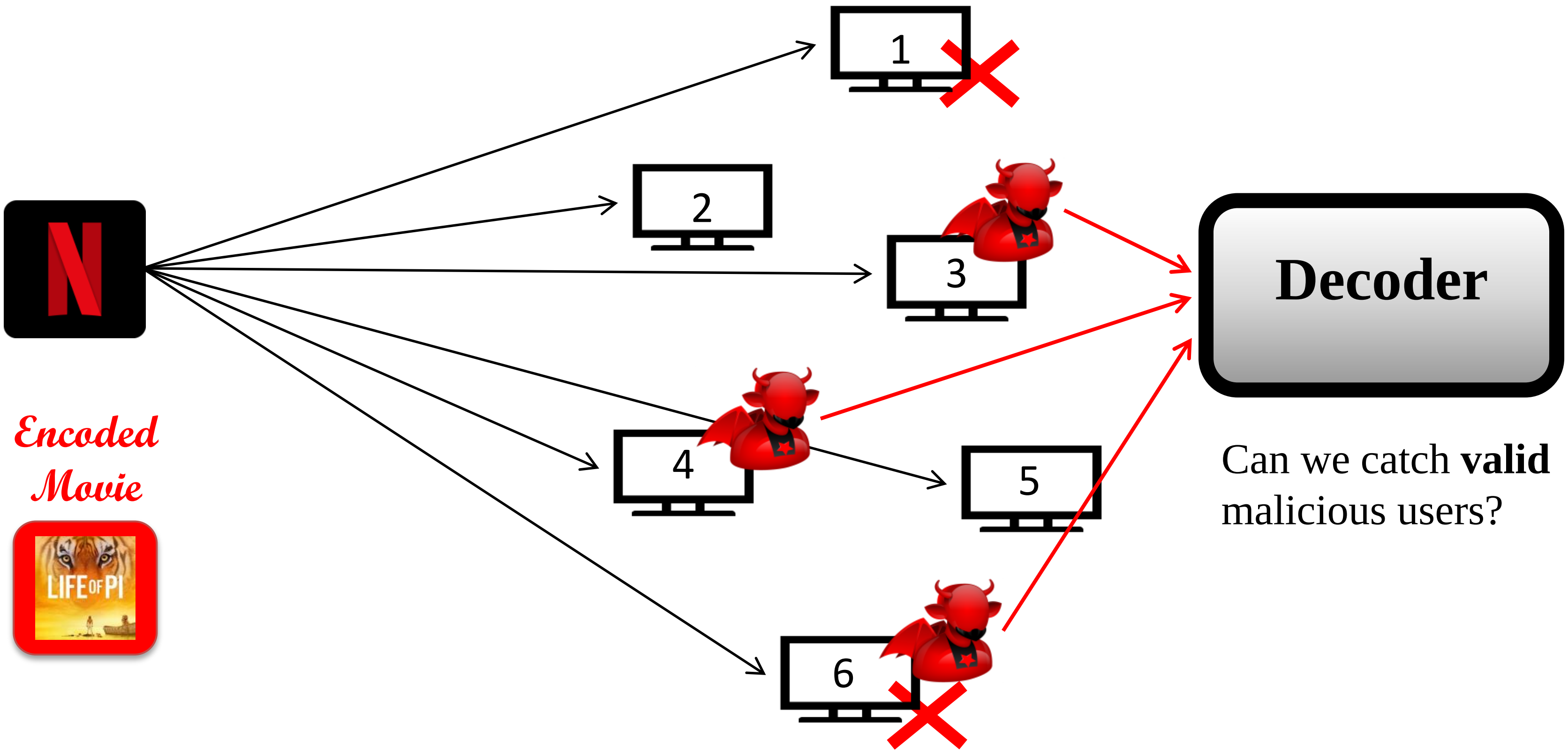


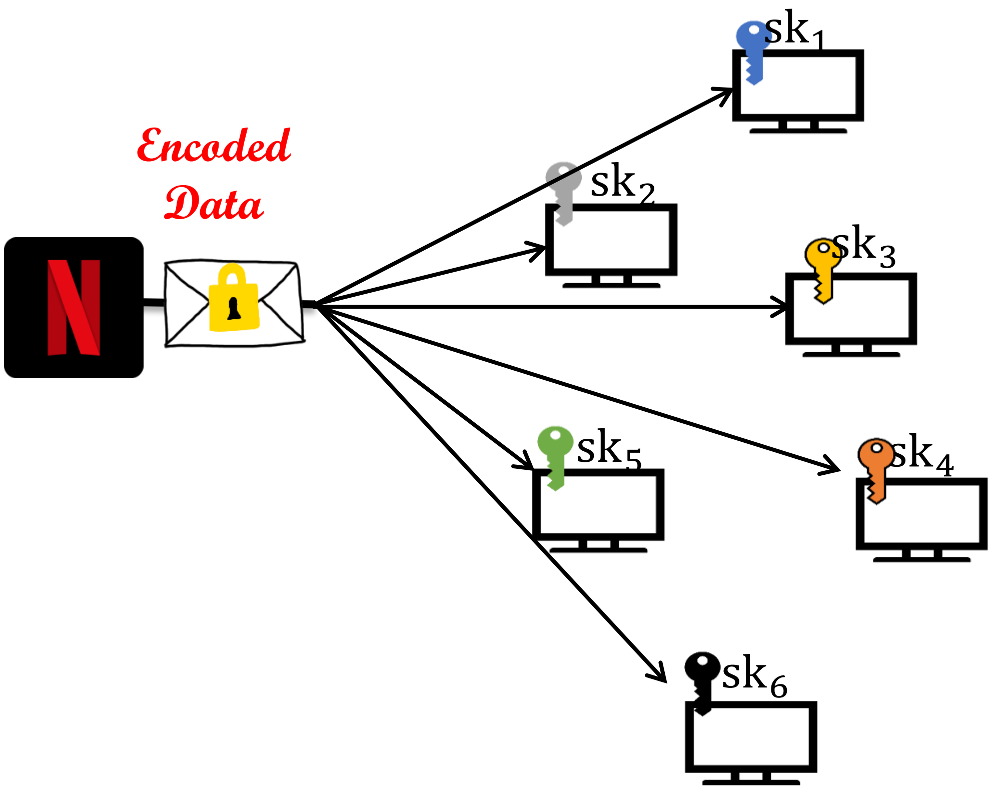
Encoded Movie
LIFE OF PI
1
2
3
4
5
6
Decoder
Decodes messages targeted to the 'valid' users

Motivation



Can we catch **valid** malicious users?

Broadcast, Trace and Revoke[NP00]



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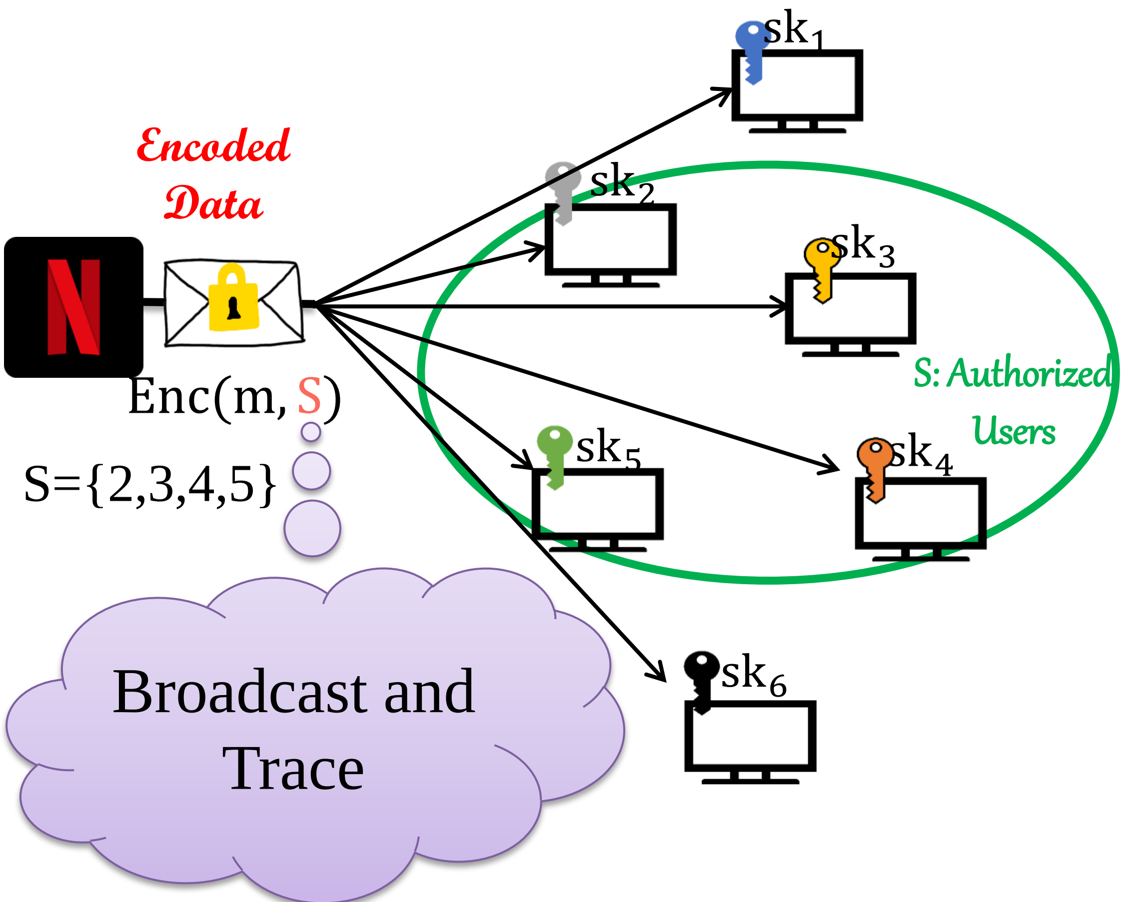
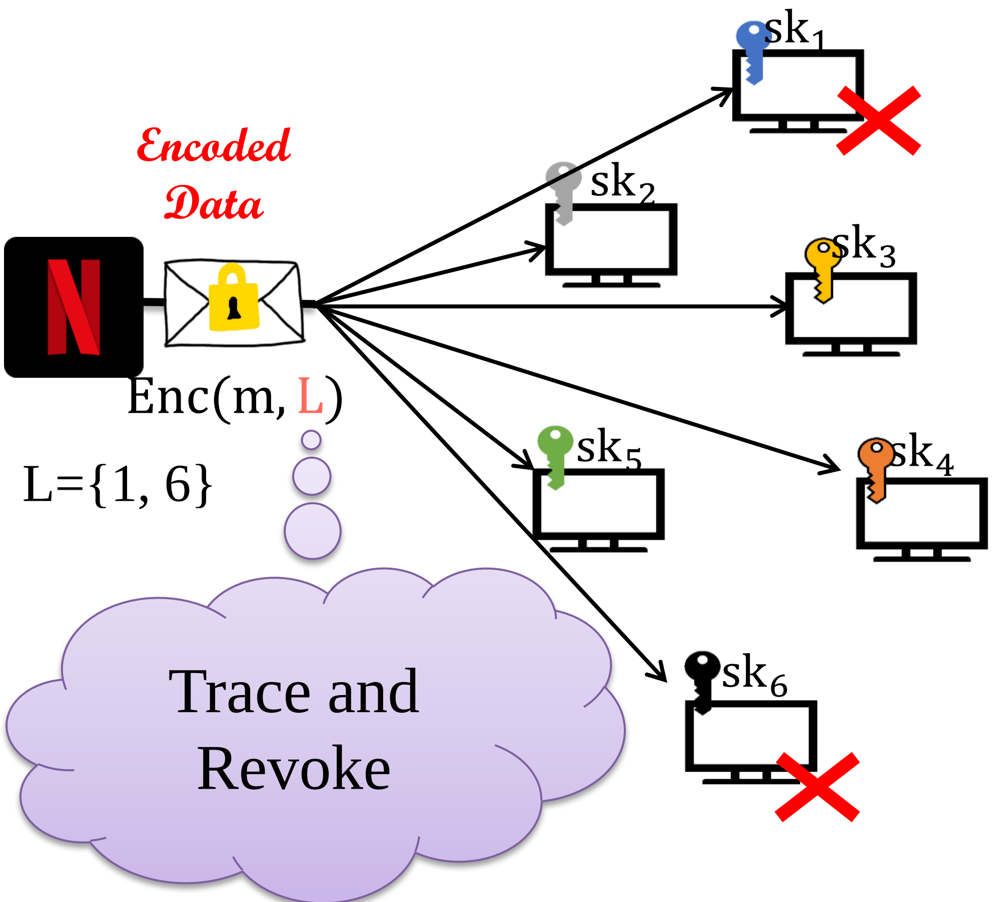


❖ Correctness: Any user in S can decrypt

Broadcast, Trace and Revoke[NP00]



- Correctness: Any user outside L can decrypt

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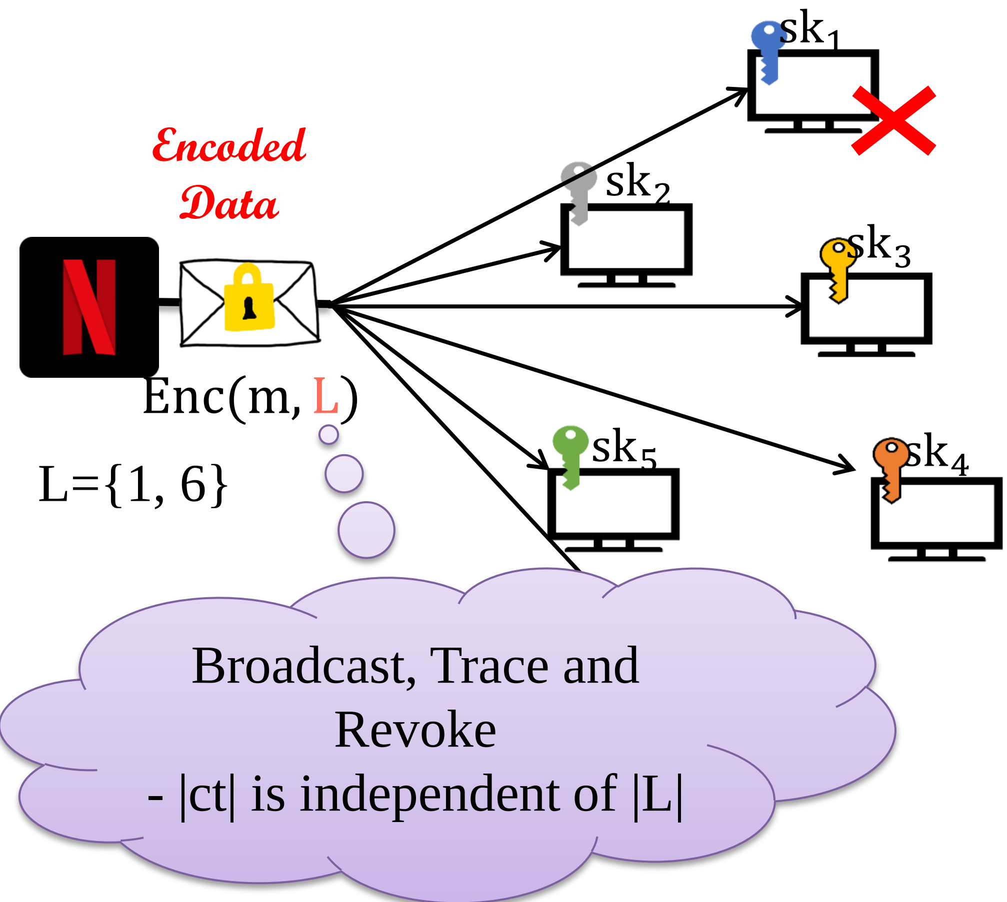

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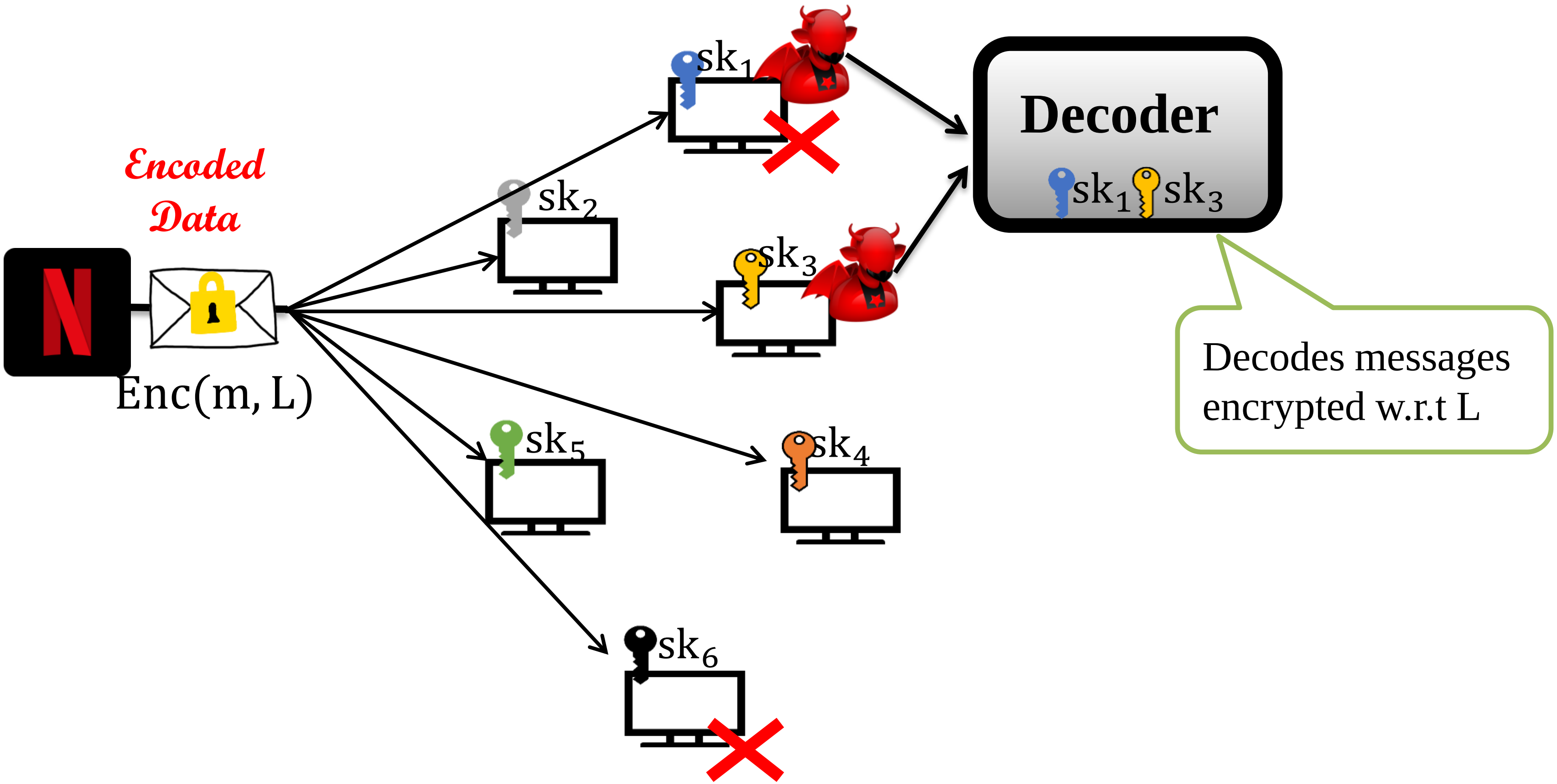

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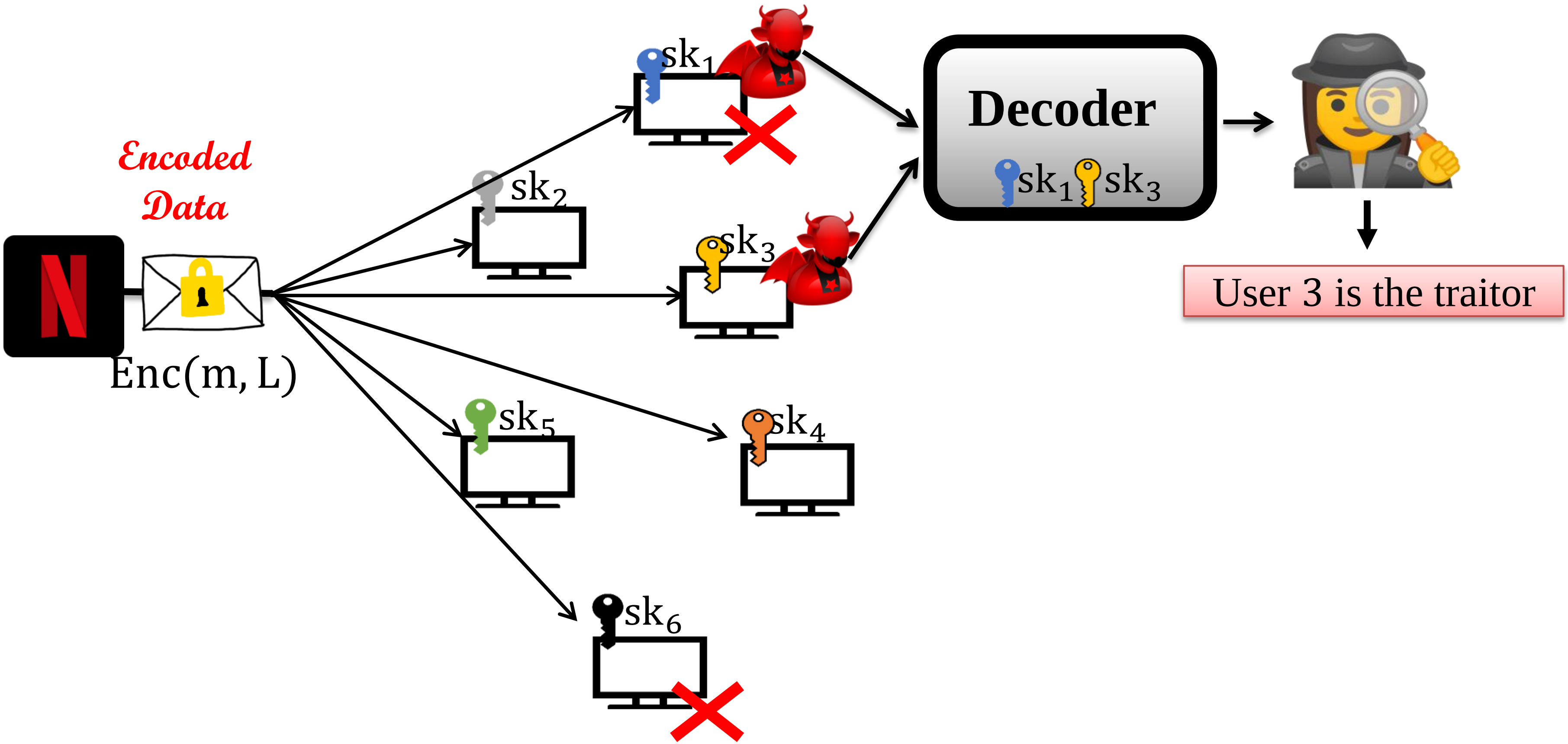

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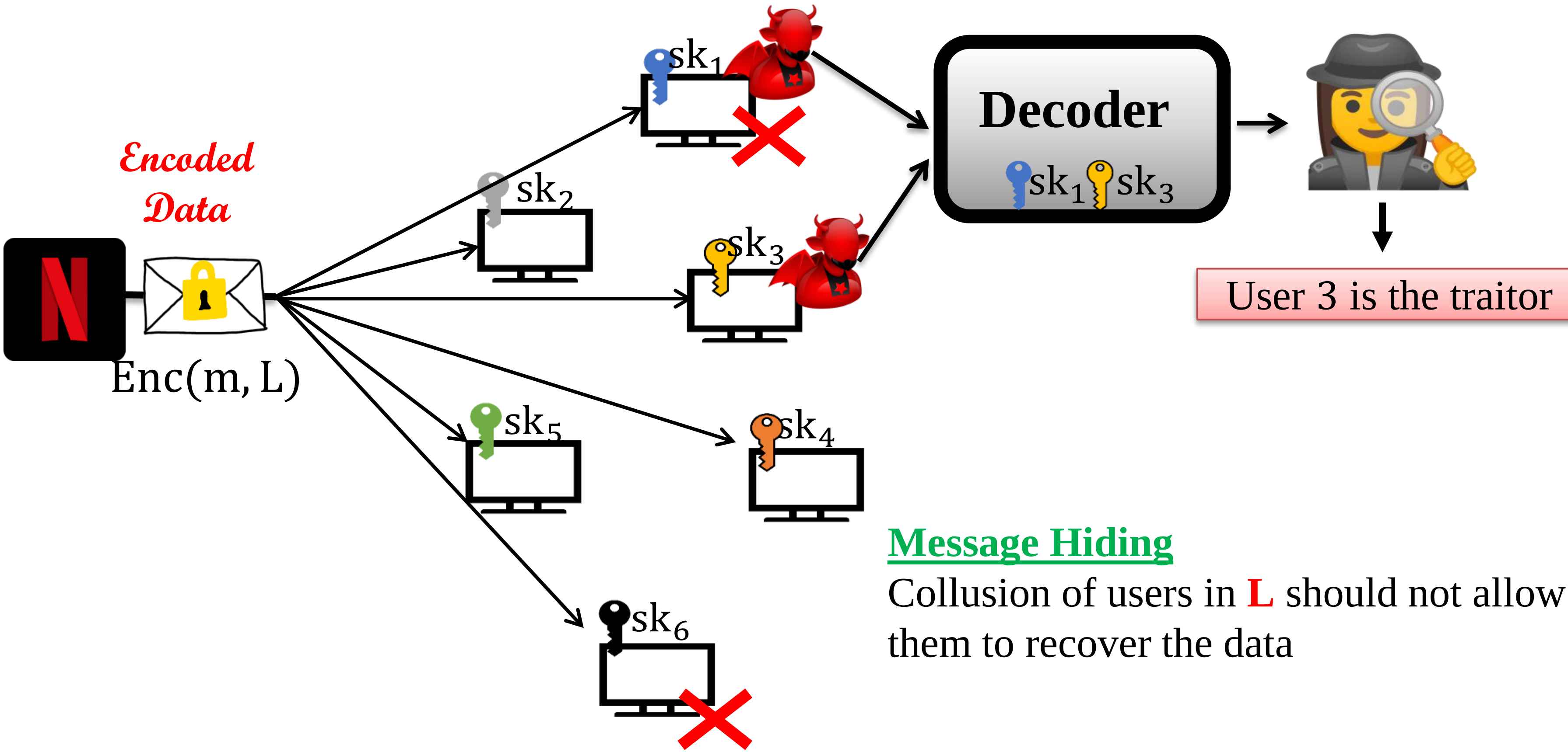
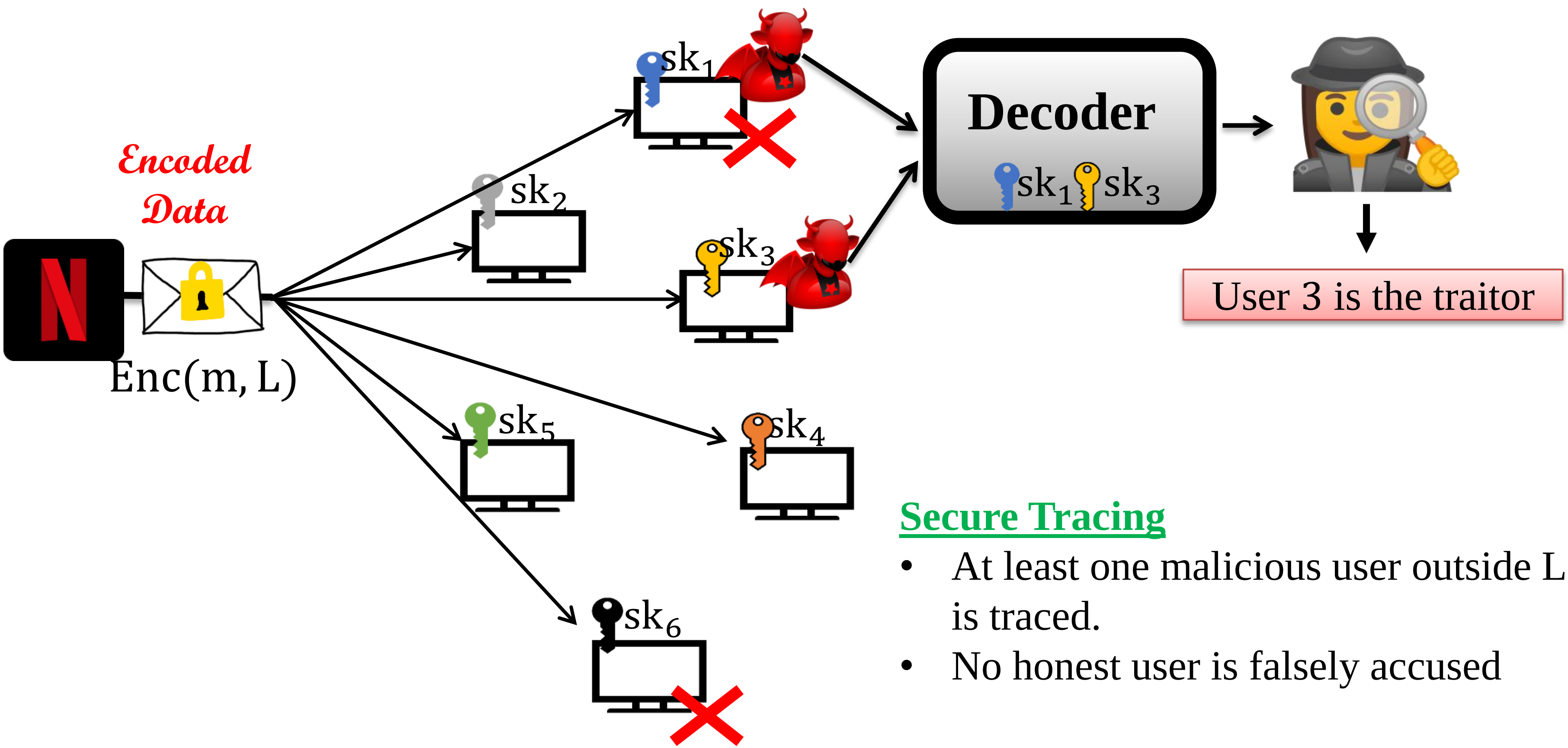


Message Hiding

Collusion of users in **L** should not allow them to recover the data

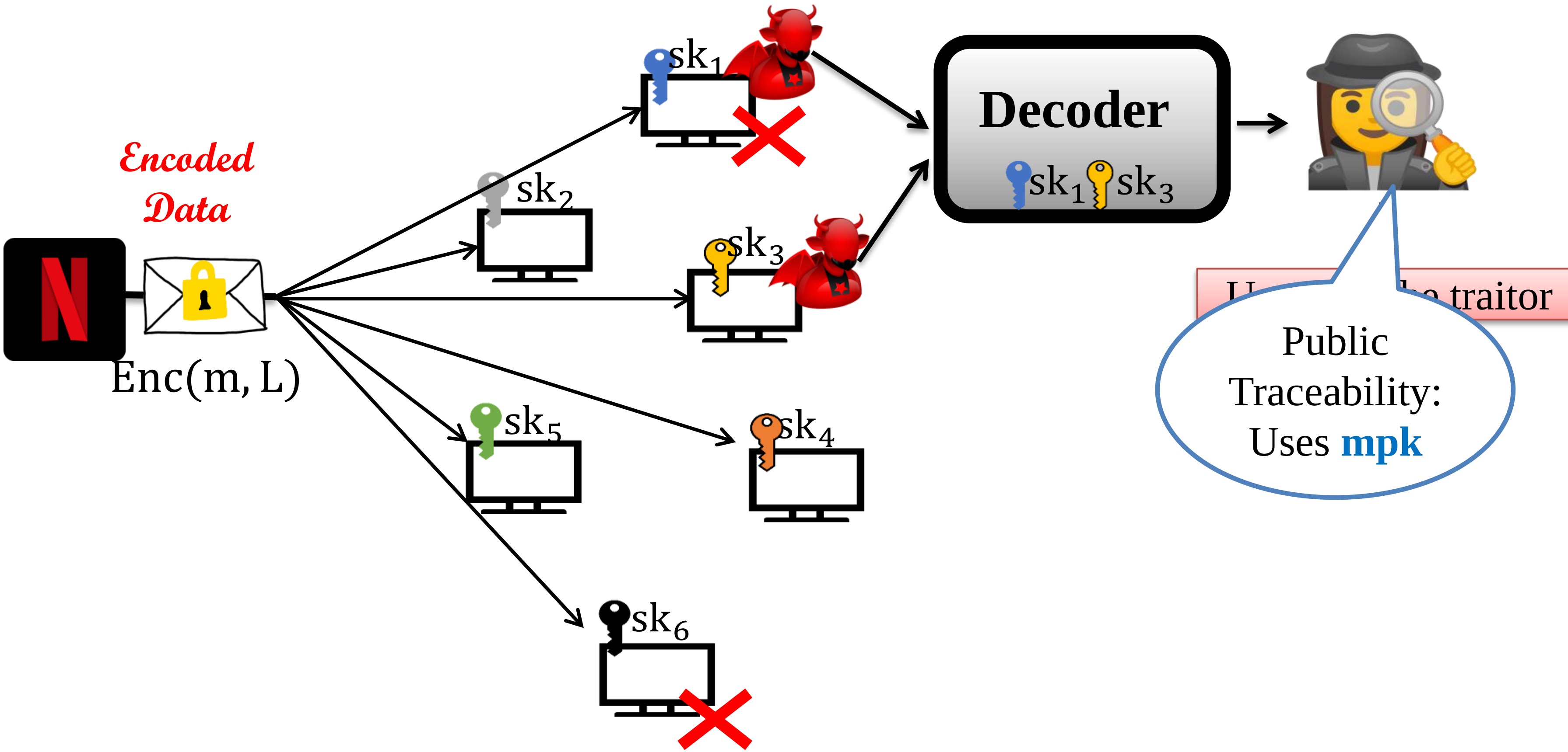
Broadcast, Trace and Revoke[NP00]



Secure Tracing

- At least one malicious user outside L is traced.
- No honest user is falsely accused

Broadcast, Trace and Revoke[NP00]



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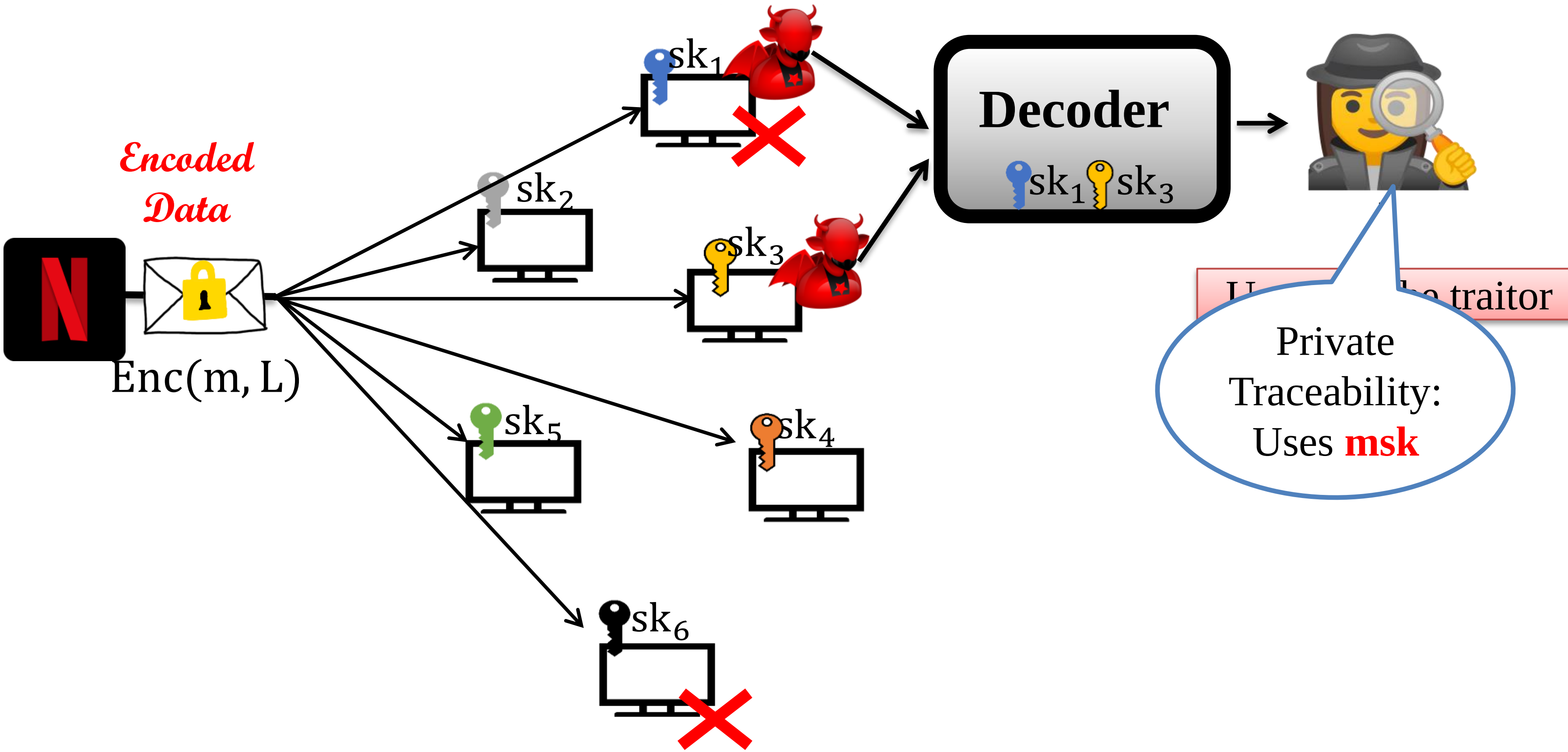
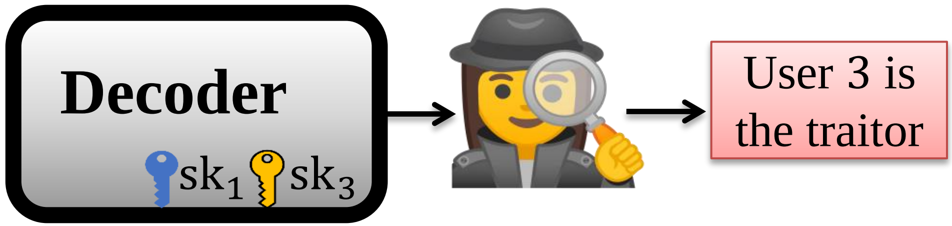


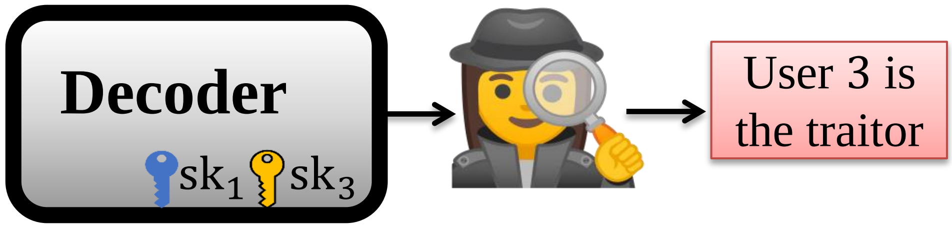
Embedded Identities [NWZ16]



User Index	User Identity
1	Nisha
2	Sampan
3	Rohin
4	Anuja
5	Anshu

'Rohin' is the traitor.
Revoke 'Rohin'

Embedded Identities[NWZ16]



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Limitations

- The authority needs to maintain user index-identity mapping
- Violates user's identity privacy.

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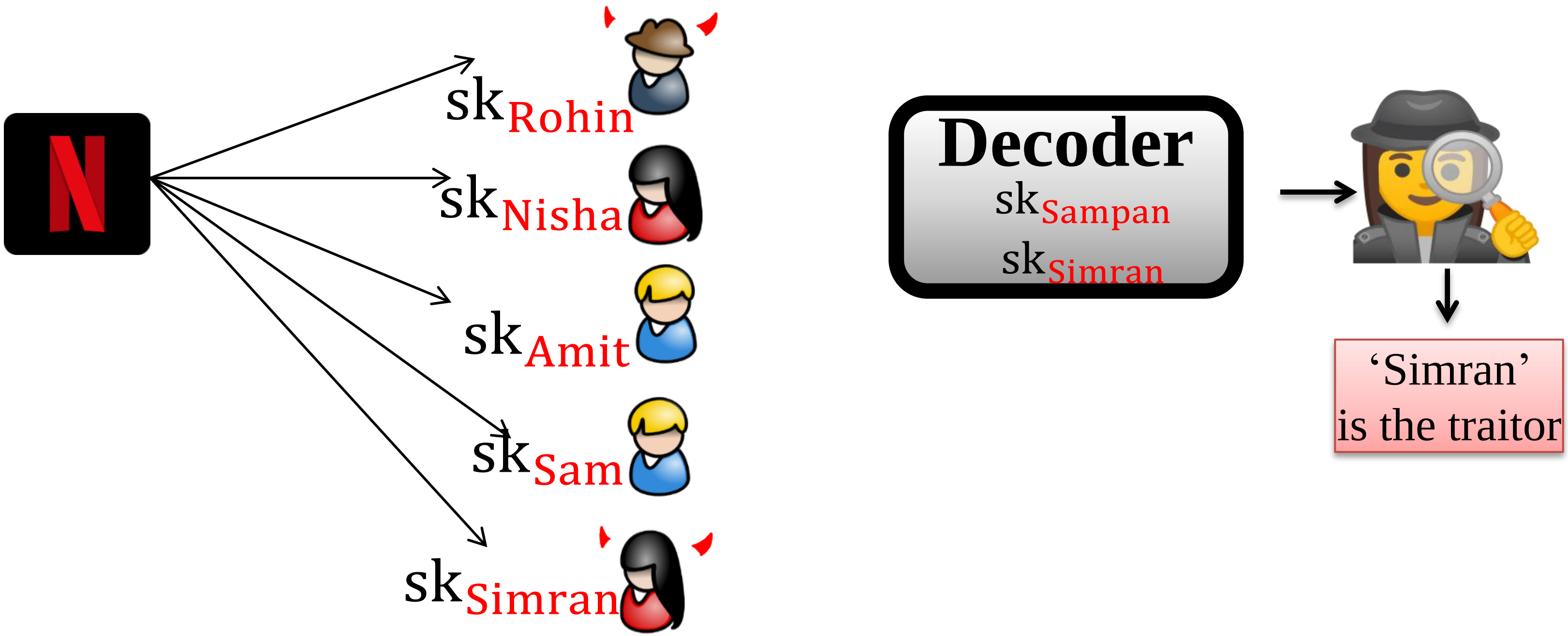

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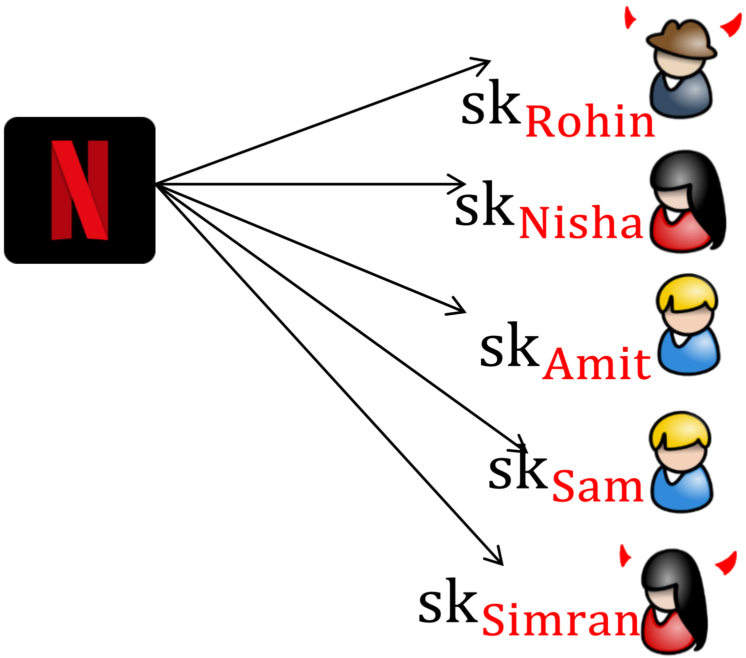

Challenges:

- Traditional tracing method - ***linear search*** on the user space.
- Identity space can be exponential -- *exponential time* to output traitors

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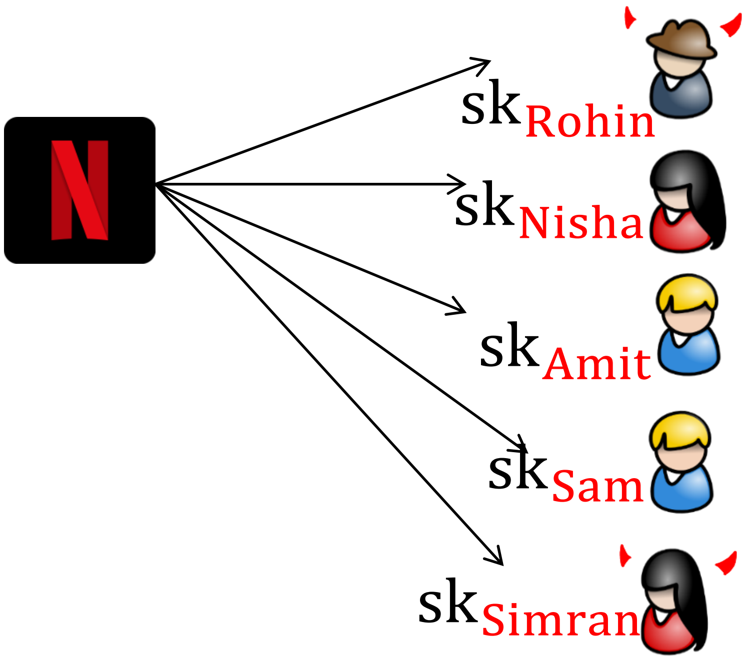

Solutions:

- [Nishimaki-Wichs-Zhandry16] - Traitor Tracing & Trace and Revoke schemes with embedded identities.
- [Goyal-Koppula-Waters19] - Traitor tracing scheme with embedded identities

Broadcast, Trace and Revoke : Goals

Optimal Parameters

|ct|, |pk| and |sk| independent of no. of users

Broadcast, Trace and Revoke : Goals

Optimal Parameters

Adaptive Security w.r.t Revocation List L

$ct \leftarrow Enc(m, L)$

Adaptive: L can be chosen after the adversary gets the public parameters and user secret keys.

Broadcast, Trace and Revoke : Goals

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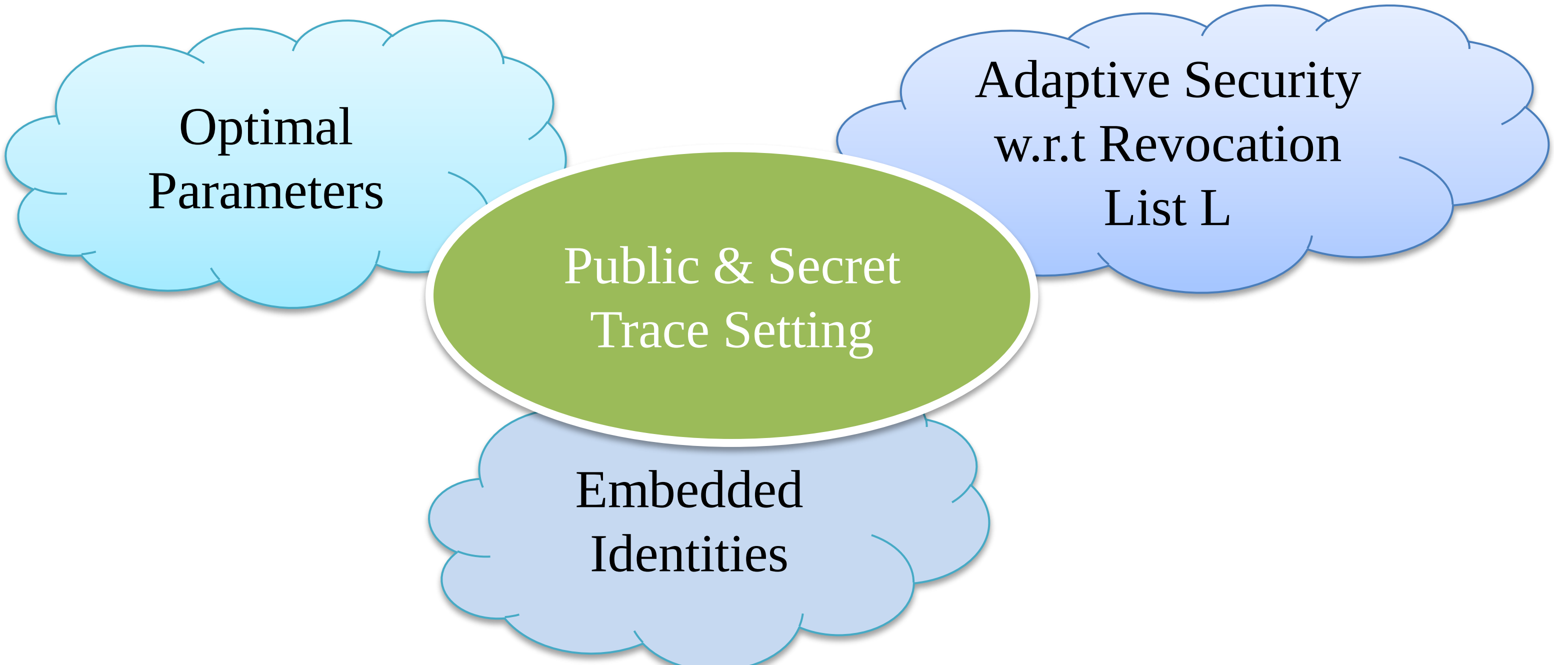
Embedded Identities

Broadcast, Trace and Revoke : Goals



Prior Work : Public Traceability

	|CT|	|SK|	|PK|	Trace Space	Selective/ Adaptive	Asspn	Identities
[NWZ16]	1	1	1	Exp	Selective	Subexp (iO)	Yes

polylog(N, L) and poly(sec param) shown as 1.

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[NWZ16]	1	1	1	Exp	Selective	Subexp (iO)	Yes
[GVW19]	1	1	1	Poly	Adaptive	Subexp (subexp Positional Witness Enc)	No

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This Work	**1**	**1**	**1**	**Exp**	**Adaptive**	**Poly (FE and Spcl ABE)**	**Yes**

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Public Traceability : Assumptions

[NWZ16] **iO** Inherently sub-exponential assumption

[GVW19] **Sub-exp PWE** No construction from poly hardness known

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This Work	**Spcl FE**	**Spcl ABE**

Building Blocks

Functional Encryption (FE)

$$sk_C + Enc(m) \xrightarrow{\text{Decrypt}} C(m)$$

The decryptor learns **only** $C(m)$ and nothing else.

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Key Policy Attribute Based Encryption (KP-ABE)

$$sk_C + Enc(m, x) \xrightarrow{\text{Decrypt}} m \text{ iff } C(x) = 1$$

Restricted access using the secret key

Building Blocks

Functional Encryption (FE)

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CT Policy Attribute Based Encryption (CP-ABE)

$$sk_x + Enc(m, C) \xrightarrow{\text{Decrypt}} m \text{ iff } C(x) = 1$$

Restricted access using the secret key

Public Traceability : Assumptions

[NWZ16]	**iO**	Inherently sub-exponential assumption
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This Work	**Spcl FE [JLS21,JLS22]** **Spcl KP-ABE [BGG+14]**	

Known from polynomially hard assumptions

Prior Work: Secret Traceability

	|CT|	|SK|	|PK|	Trace Space	Asspn	Identities
[GQWW19]	N^a	N^c	N	Poly	LWE and Pairings	No

$0 < a < 1$, c large constant.

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This Work: Modified [GQWW19]	**1**	$\boldsymbol{N^c}$	$\boldsymbol{N}$	**Poly**	**LWE and Pairings**	**No**

polylog(N, L) and poly(sec param) shown as 1.
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This Work	**1**	**1**	**1**	**Exp**	**Poly (spcl CP-ABE & KP-ABE)**	**Yes**

polylog(N, L) and poly(sec param) shown as 1.

Secret Traceability : Assumptions

[GQWW19]

[Zha20]

Pairings Post-Quantum insecure

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[GQWW19] [Zha20]	**Pairings**	Post-Quantum insecure
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This Work	**Spcl CP-ABE** **Spcl KP-ABE**	

Secret Traceability : Assumptions

[GQWW19] [Zha20]	**Pairings**	Post-Quantum insecure
[KW19]	**Sub-exp LWE**	|ct| linear in size of revocation list
This Work	**Spcl CP-ABE** Evasive & Tensor LWE [Wee22] **Spcl KP-ABE** Std. LWE [BGG+14]	• Polynomially hard • Lattice based – conjectured post quantum safe

Public-Key vs Secret-Key BTR

Public Traceability

- Succinct KP-ABE
- Compact FE

Secret Traceability

- Succinct KP-ABE
- Compact CP-ABE

Public-Key vs Secret-Key BTR

Public Traceability

- Succinct KP-ABE
- Compact FE

Secret Traceability

- Succinct KP-ABE
- Compact CP-ABE

ABE is weaker than FE since ABE is an all or nothing primitive in contrast to FE.

Outline

Public-Key
Revocable Predicate Encryption (RPE)

→

Public-Key
Broadcast, Trace and Revoke with Embedded Identity (EI-BTR)

Secret-Key
Revocable Predicate Encryption (RPE)

→

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Broadcast, Trace and Revoke with Embedded Identity (EI-BTR)

Revocable Predicate Encryption[KW19]

Revoked labels
L=$\{lb_2, lb_5\}$

sk_{lb_1,x_1}

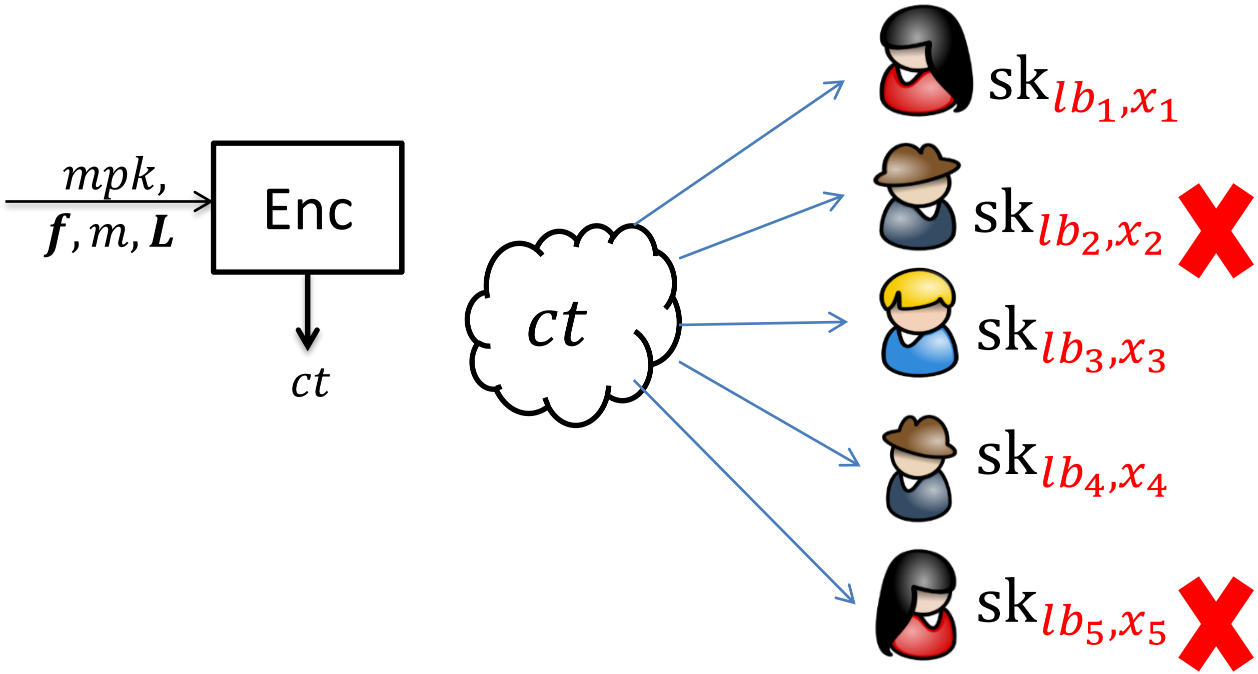
sk_{lb_2,x_2}

sk_{lb_3,x_3}

sk_{lb_4,x_4}

sk_{lb_5,x_5}

Revocable Predicate Encryption[KW19]



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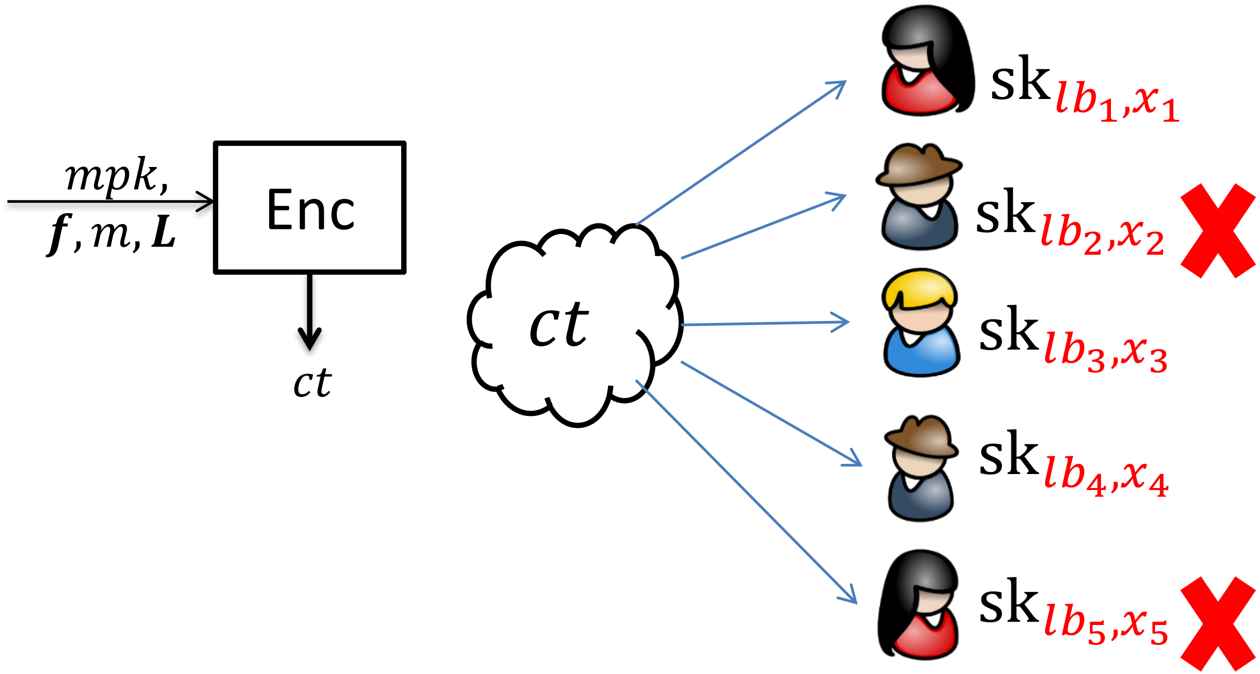
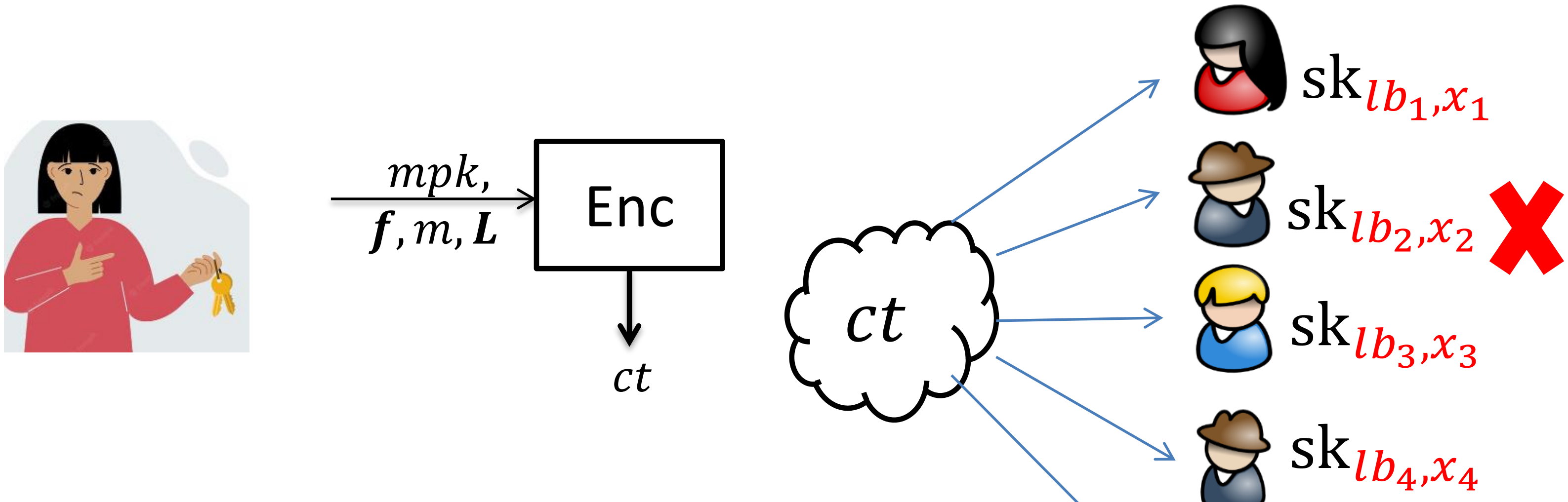


Revoked labels
L={lb_2, lb_5}

Correctness : A user with associated (lb_i, x_i) can recover message m if $\boldsymbol{f(x_i) = 1}$ **and** $\boldsymbol{lb_i \notin L}$

Revocable Predicate Encryption[KW19]



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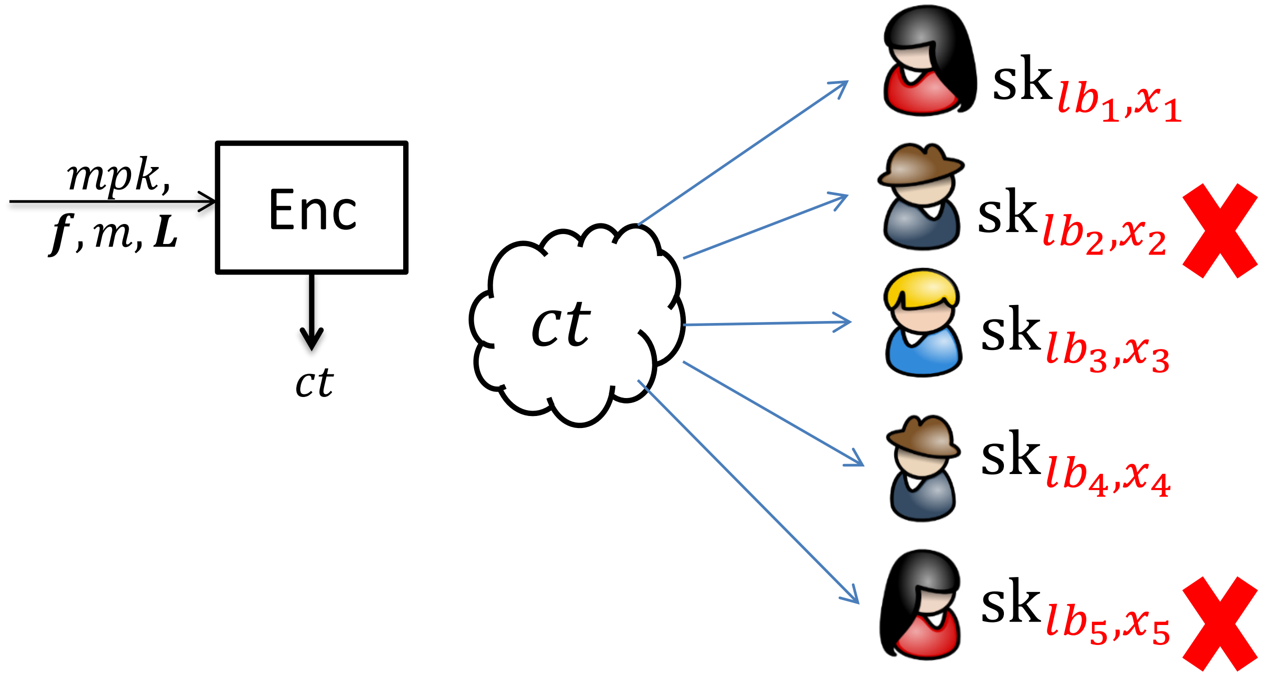
Message Hiding Security

$\mathrm{Enc}(mpk, f, m_0, L) \approx \mathrm{Enc}(mpk, f, m_1, L)$; if for all key queries (lb, x)

$\boldsymbol{f(x) = 0}$ or $\boldsymbol{lb \in L}$

Revocable Predicate Encryption[KW19]



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Function Hiding Security

$$\mathrm{Enc}(mpk, f_0, m, L) \approx \mathrm{Enc}(mpk, f_1, m, L) \text{ ; if for all key queries } (lb, x)$$

$$\boldsymbol{f_0(x) = f_1(x)} \text{ or } \boldsymbol{lb \in L}$$

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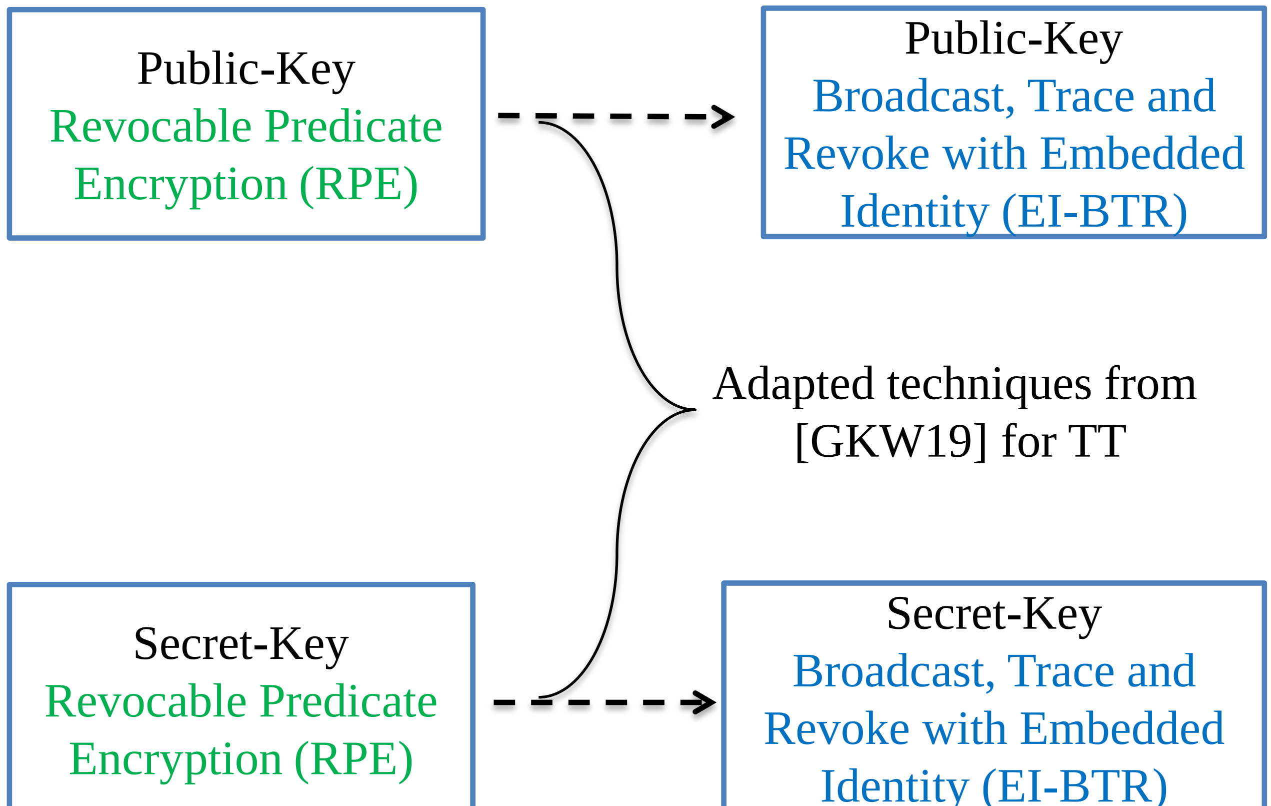
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Broadcast, Trace and Revoke with Embedded Identity (EI-BTR)
Adapted techniques from [GKW19] for TT
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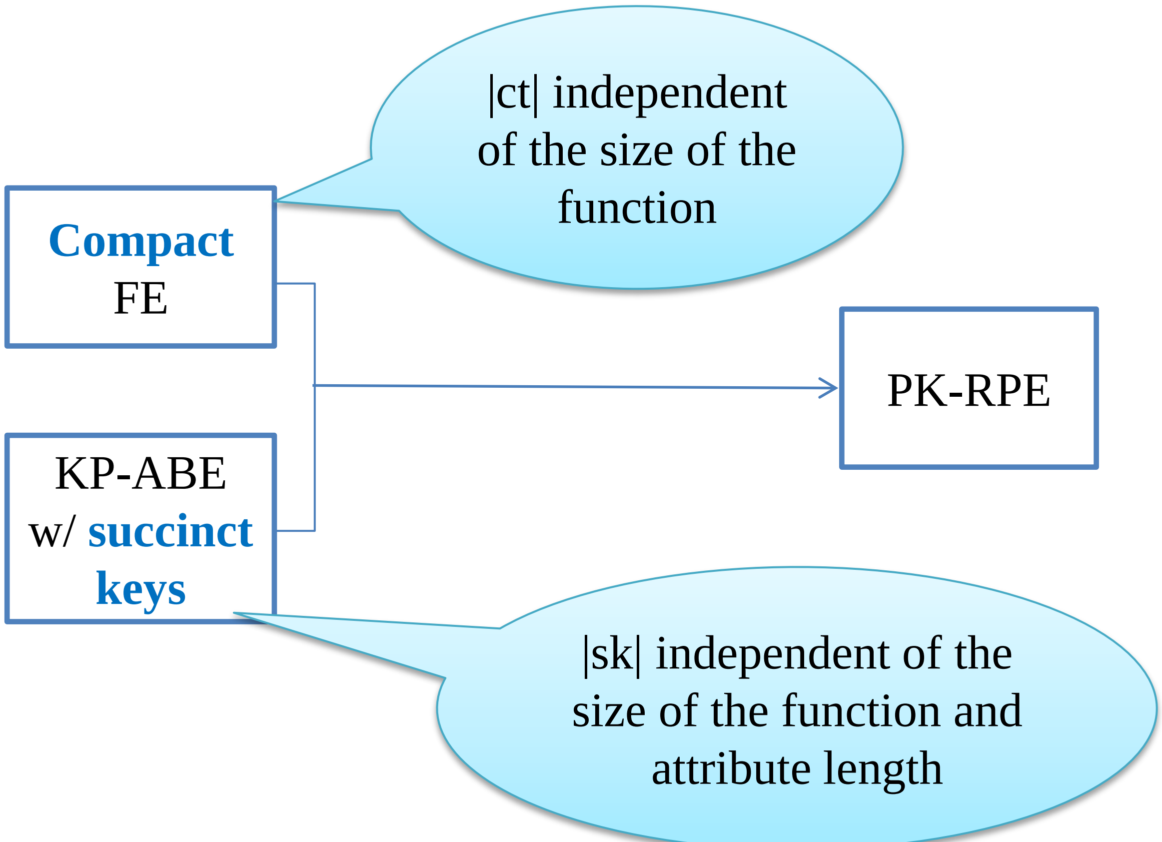
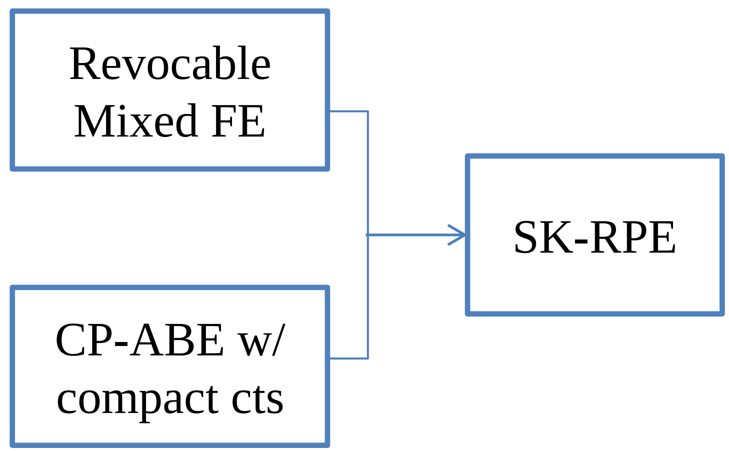
Public Key RPE : Outline

Public Key RPE : Optimal Parameters



Secret Key RPE : Outline



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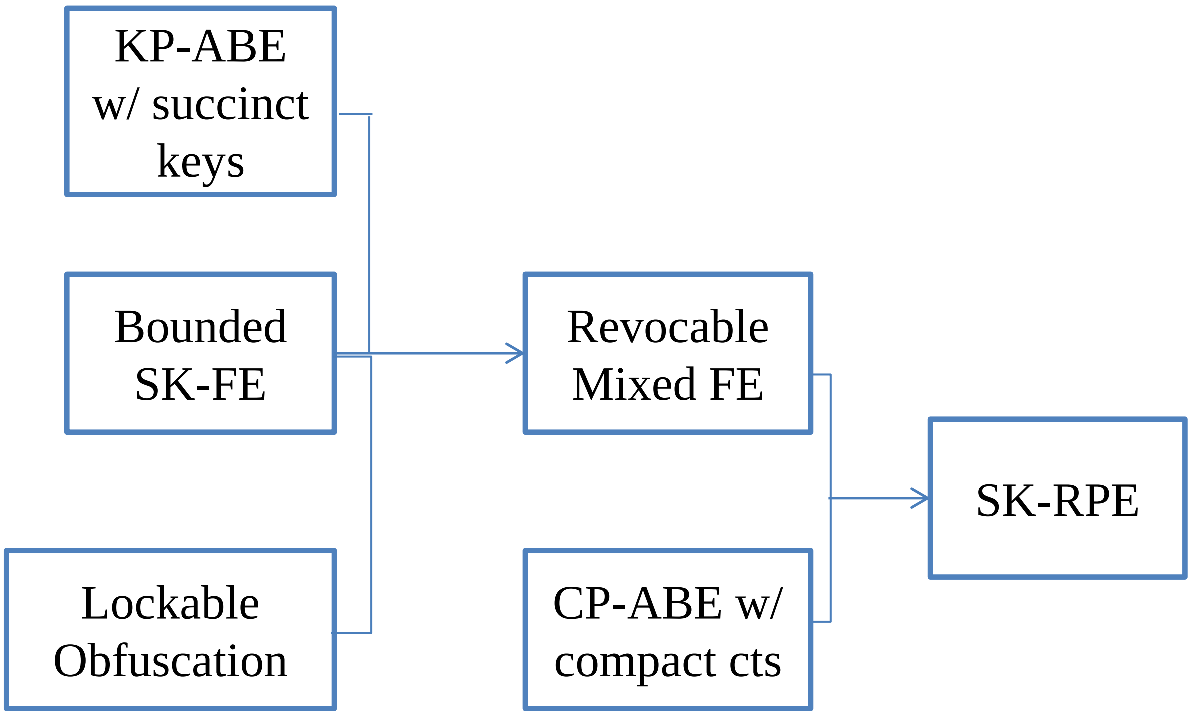

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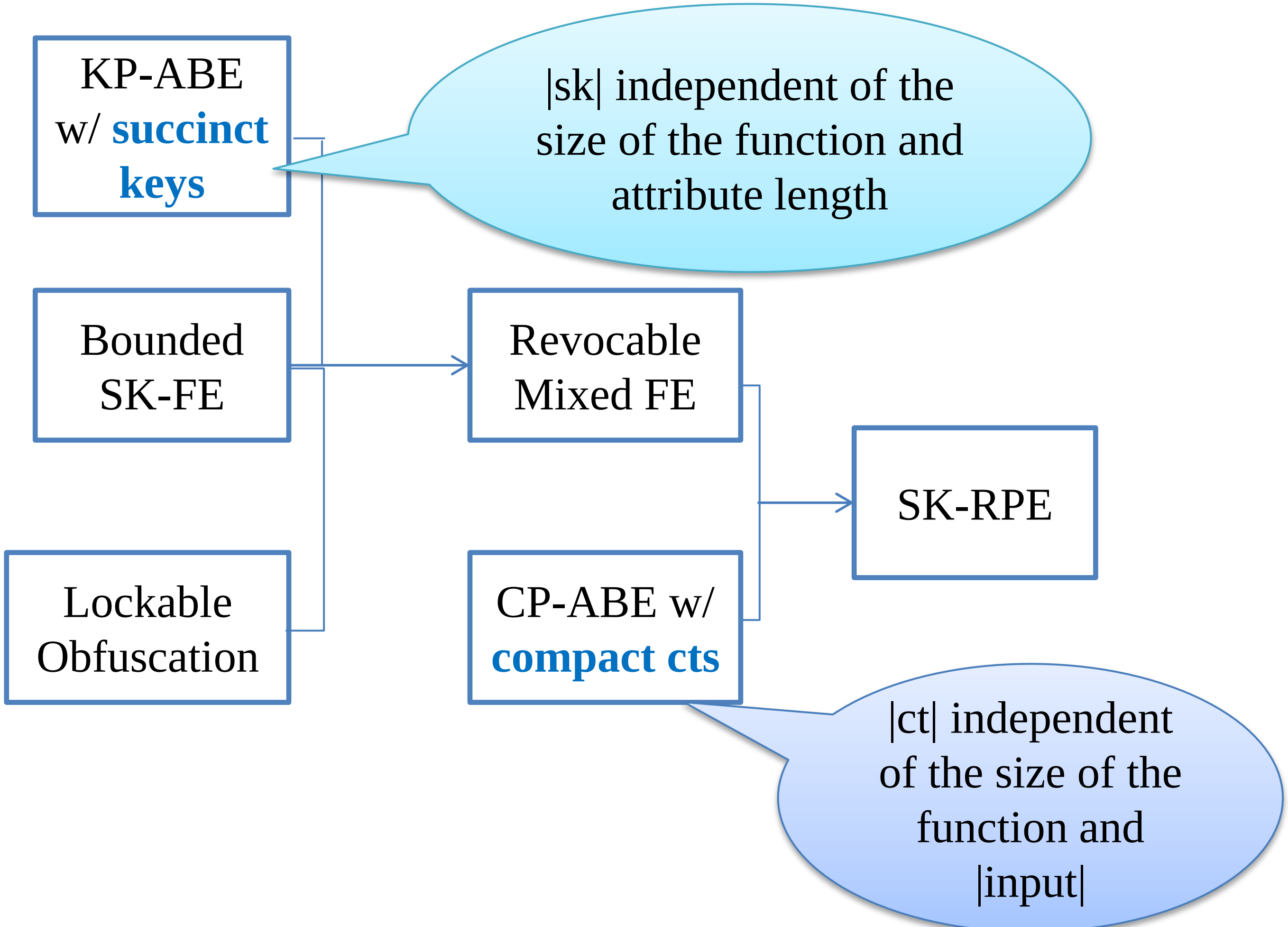

Summary

Unified framework for secret and public EI-BTR via RPE

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- Optimal size of CT, PK, SK
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- Adaptive security
- Poly hard assumptions: FE, ABE

Open: Weaker version of FE to allow post quantum scheme?

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First work to support superpoly revocation list size!
(with efficient representation & membership testing)

Thank you!