LEAKAGE-RESILIENT PUBLIC-KEY ENCRYPTION FROM OBFUSCATION

Dana Dachman-Soled, S. Dov Gordon, Feng-Hao Lui, **Adam, O'Neill**, and Hong-Sheng Zhou

OUTLINE OF TALK

Leakage Models for PKE —

- Bounded, Continual, and Continual w/ Leakage on Key Update

Results in Continual Model: A Generic Compiler to Achieve Leakage on Key Update

Results in Bounded Model: A New Approach to Optimal Leakage Rate

Conclusion and Open Problems

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Leakage Models for PKE

- Bounded, Continual, a
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Uses indistinguishability obfuscation [BGIRSVY'01,GGHRSW'13] and techniques from "deniable encryption" [SW'14].

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BOUNDED LEAKAGE FOR PKE [AGV'09]

Fix a public-key encryption scheme $(\mathcal{K}, \mathcal{E}, \mathcal{D})$.

$(pk, sk) \leftarrow_{\$} \mathcal{K}$

Adversary

Challenger

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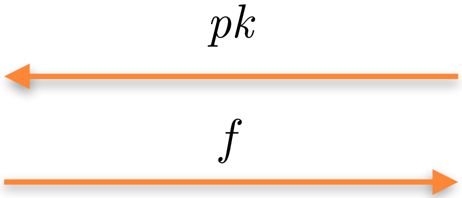

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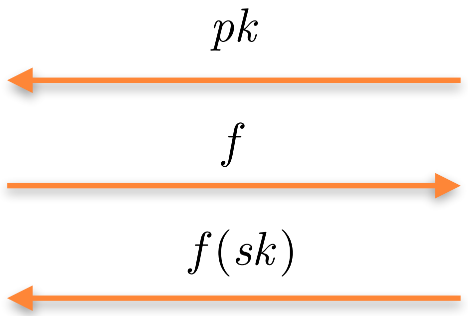

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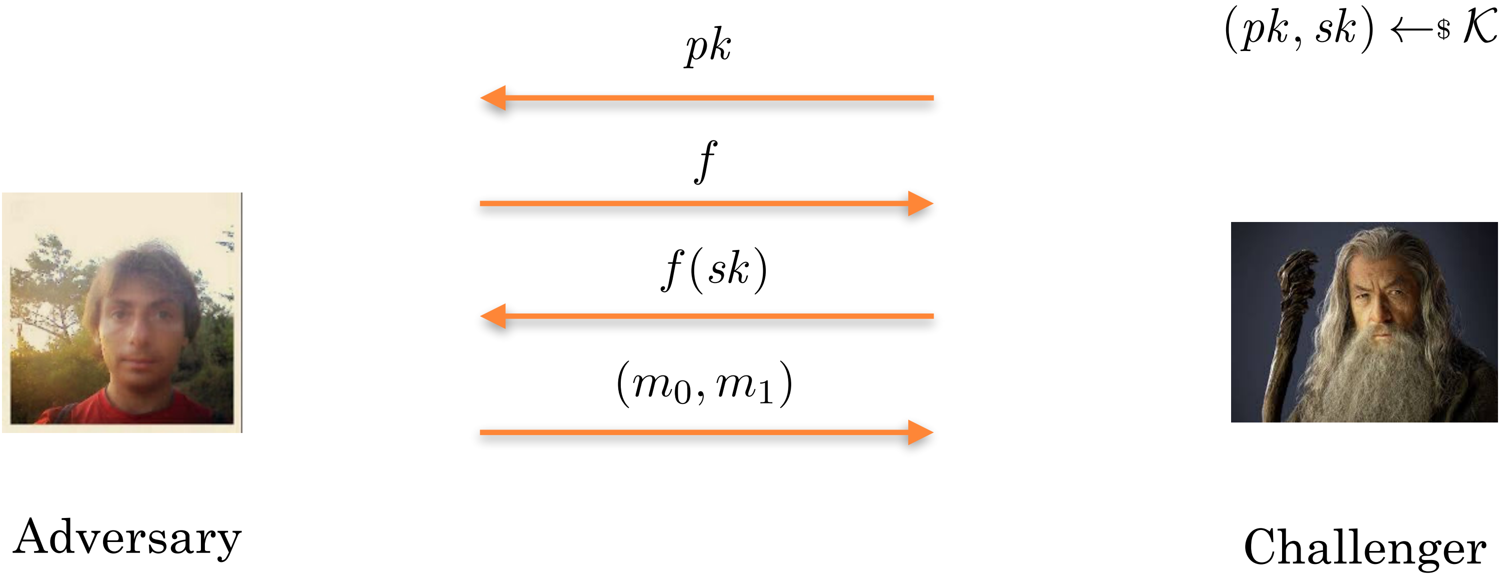

$(pk, sk) \leftarrow_{\$} \mathcal{K}$

pk

f

$f(sk)$

(m_0, m_1)

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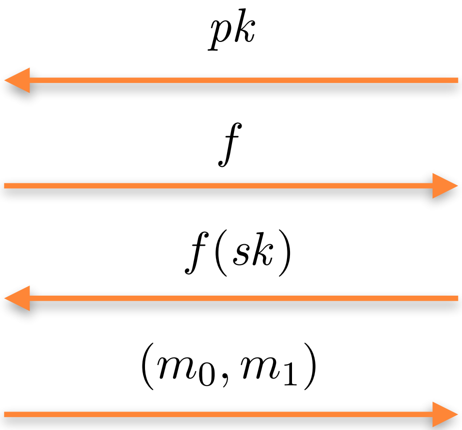

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$$\xleftarrow{\quad pk \quad}$$

$$\xrightarrow{\quad f \quad}$$

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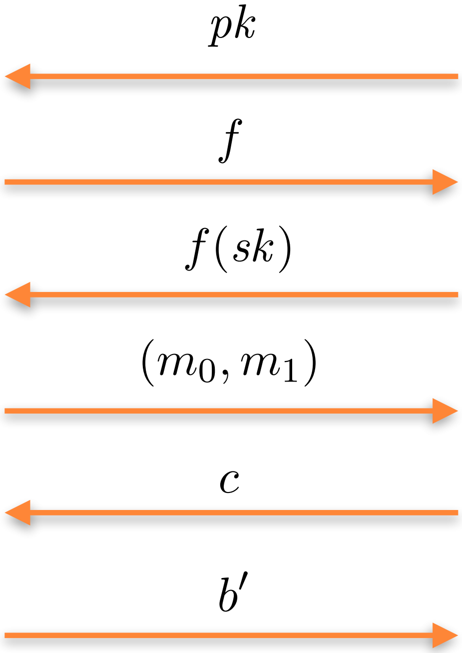

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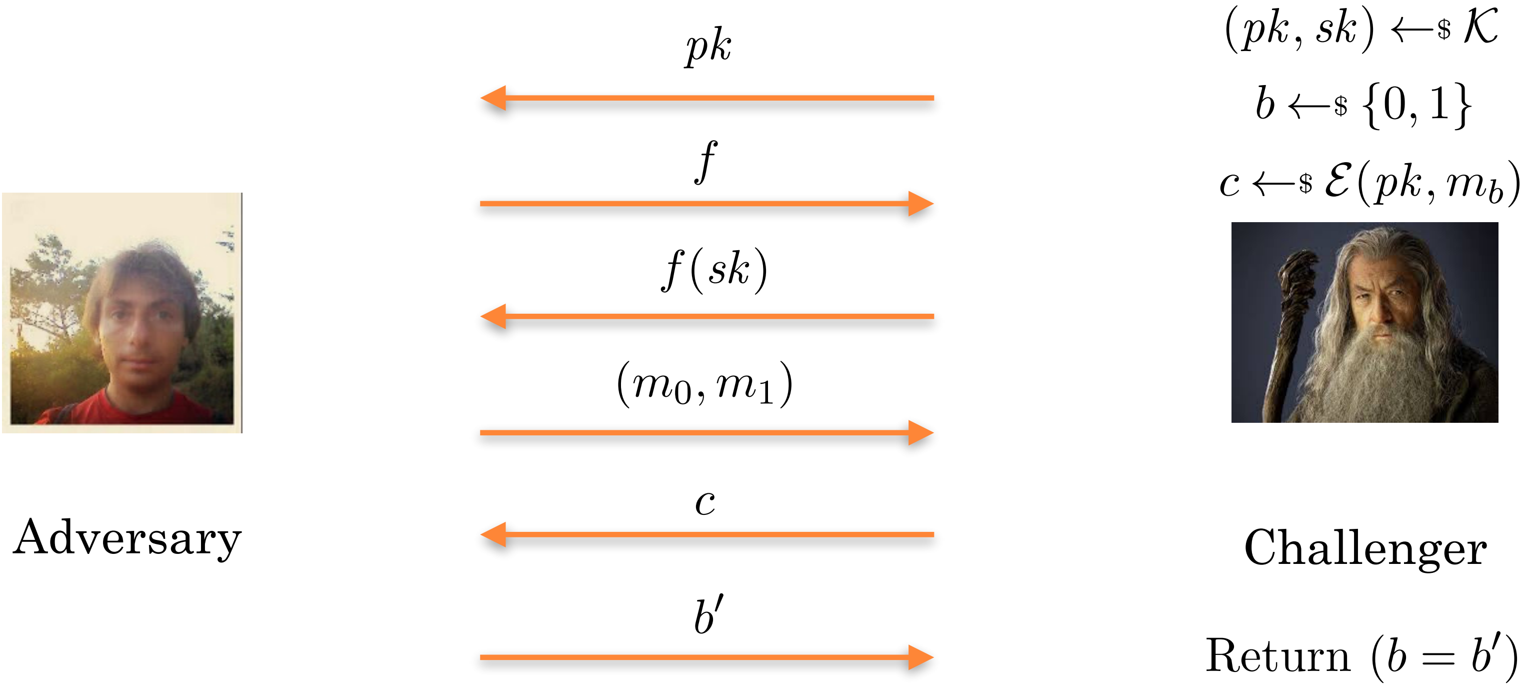

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Fix a public-key encryption scheme "with key update" $(\mathcal{K}, \mathcal{E}, \mathcal{D}, \mathcal{U})$
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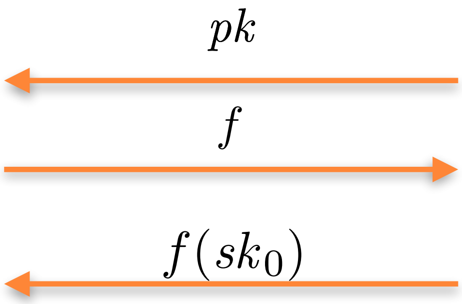

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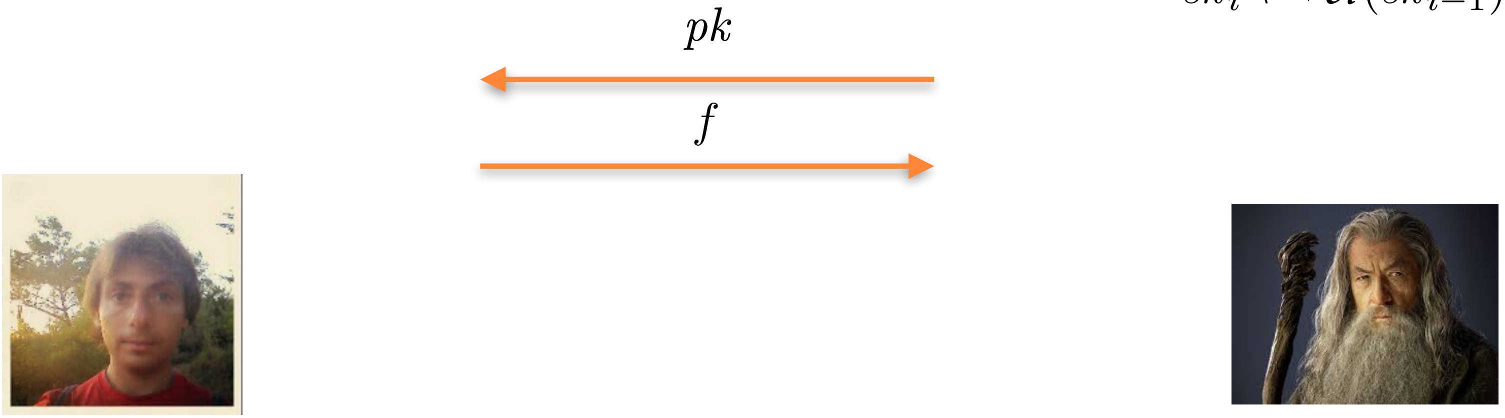

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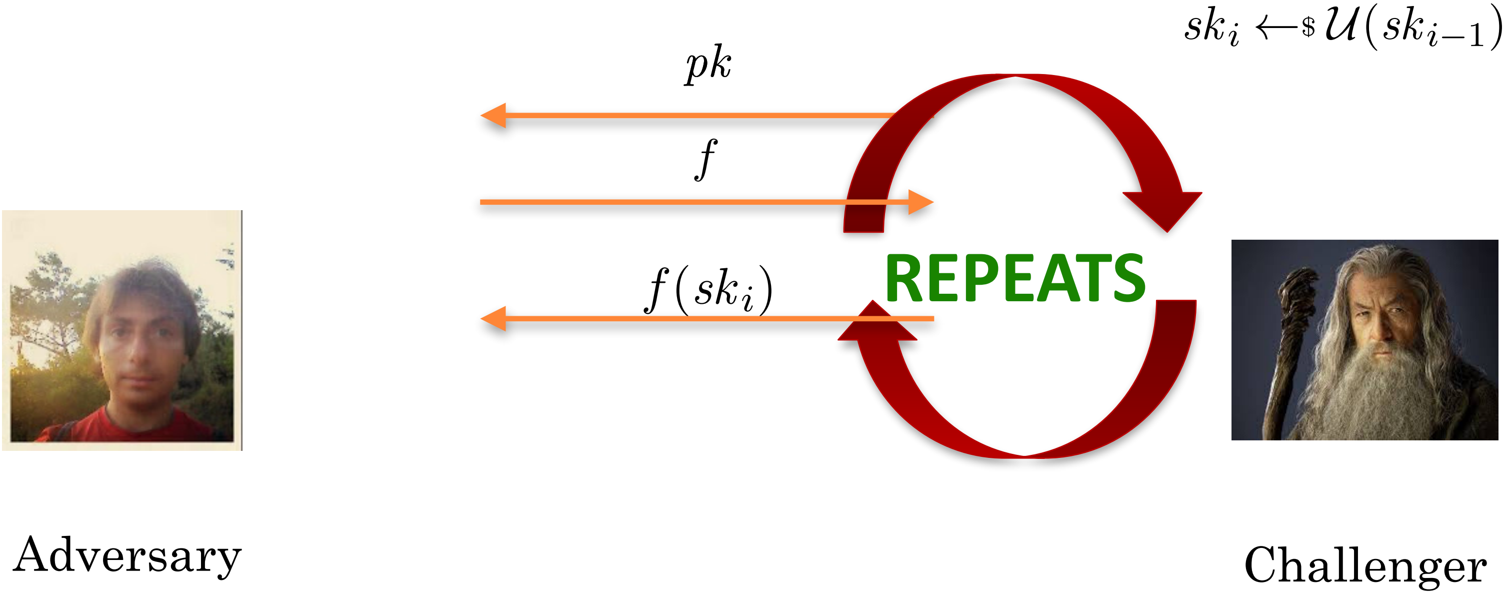

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$f(sk_i)$

REPEATS

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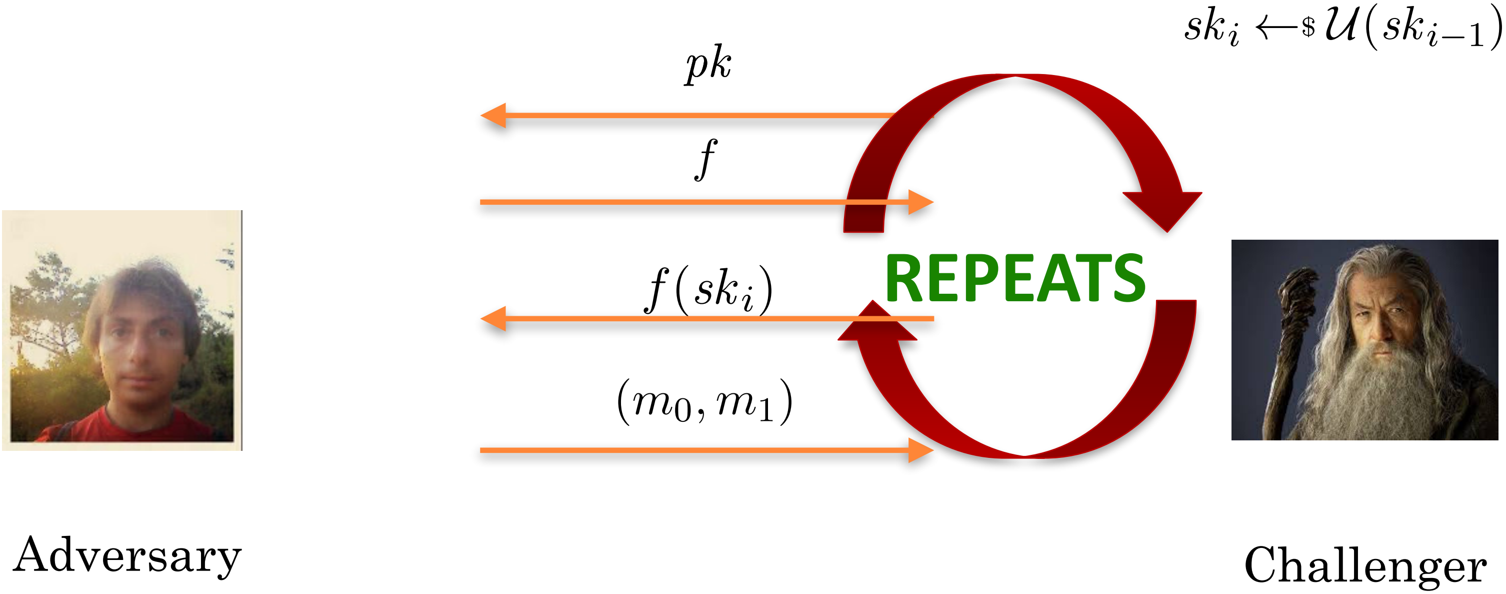

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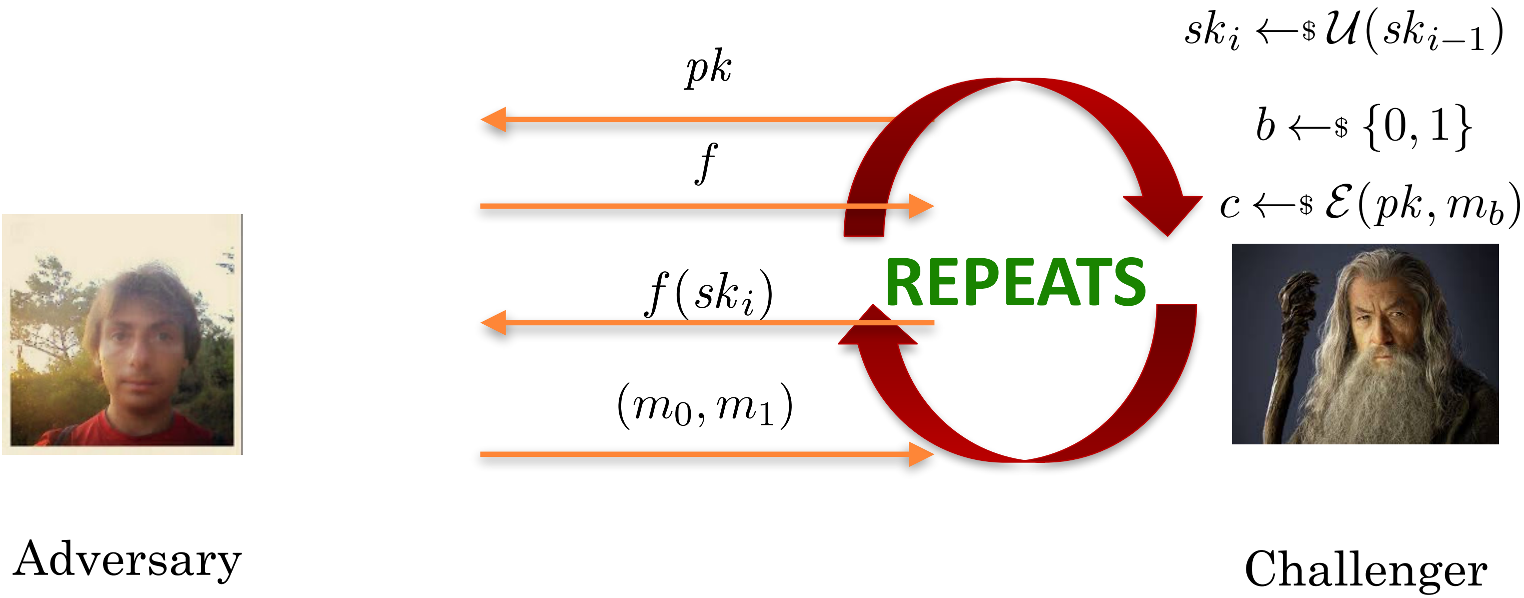

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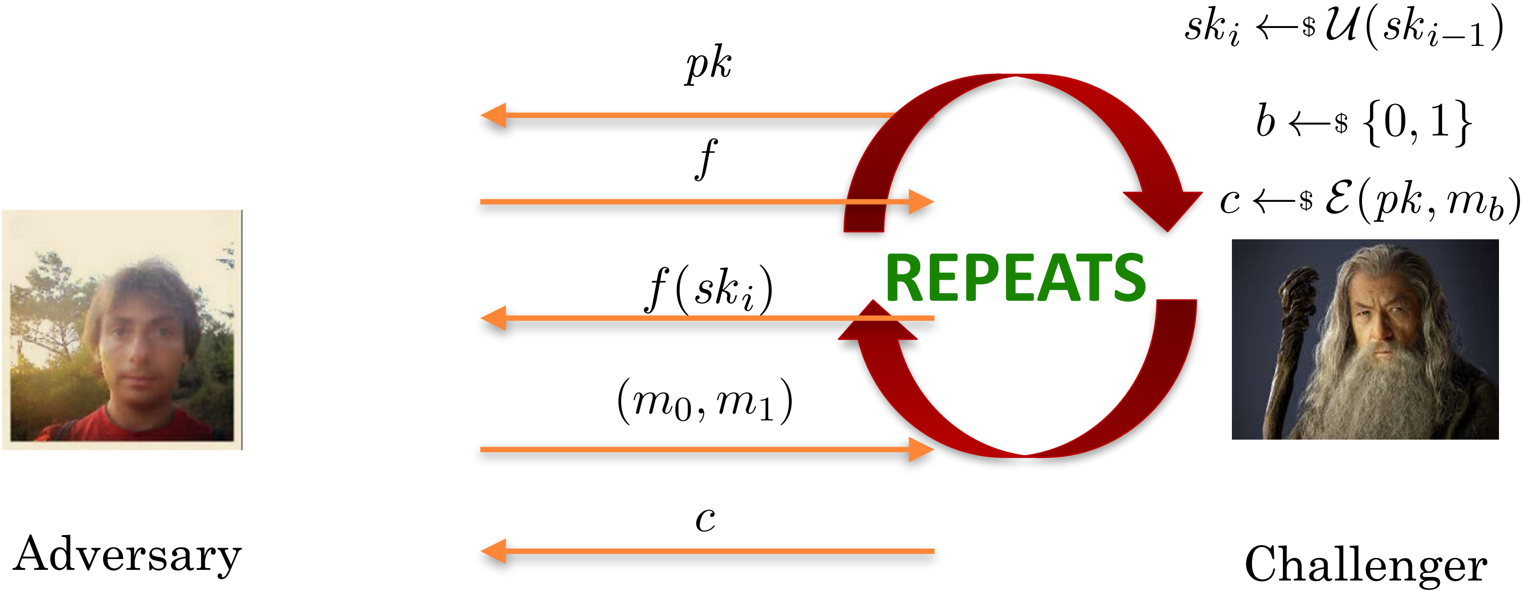

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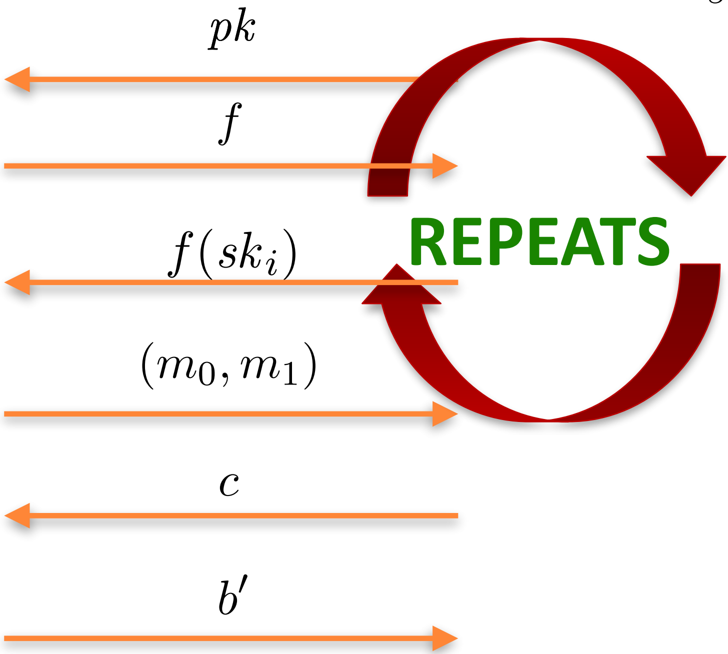

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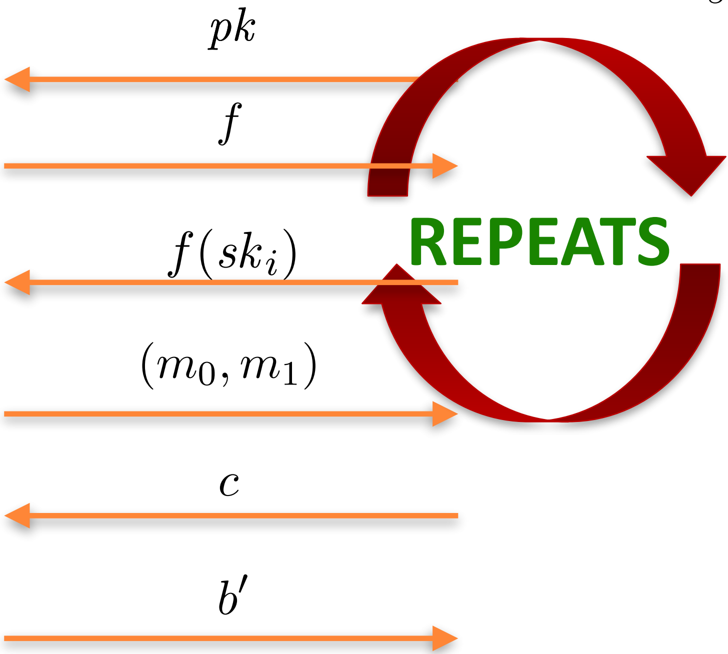

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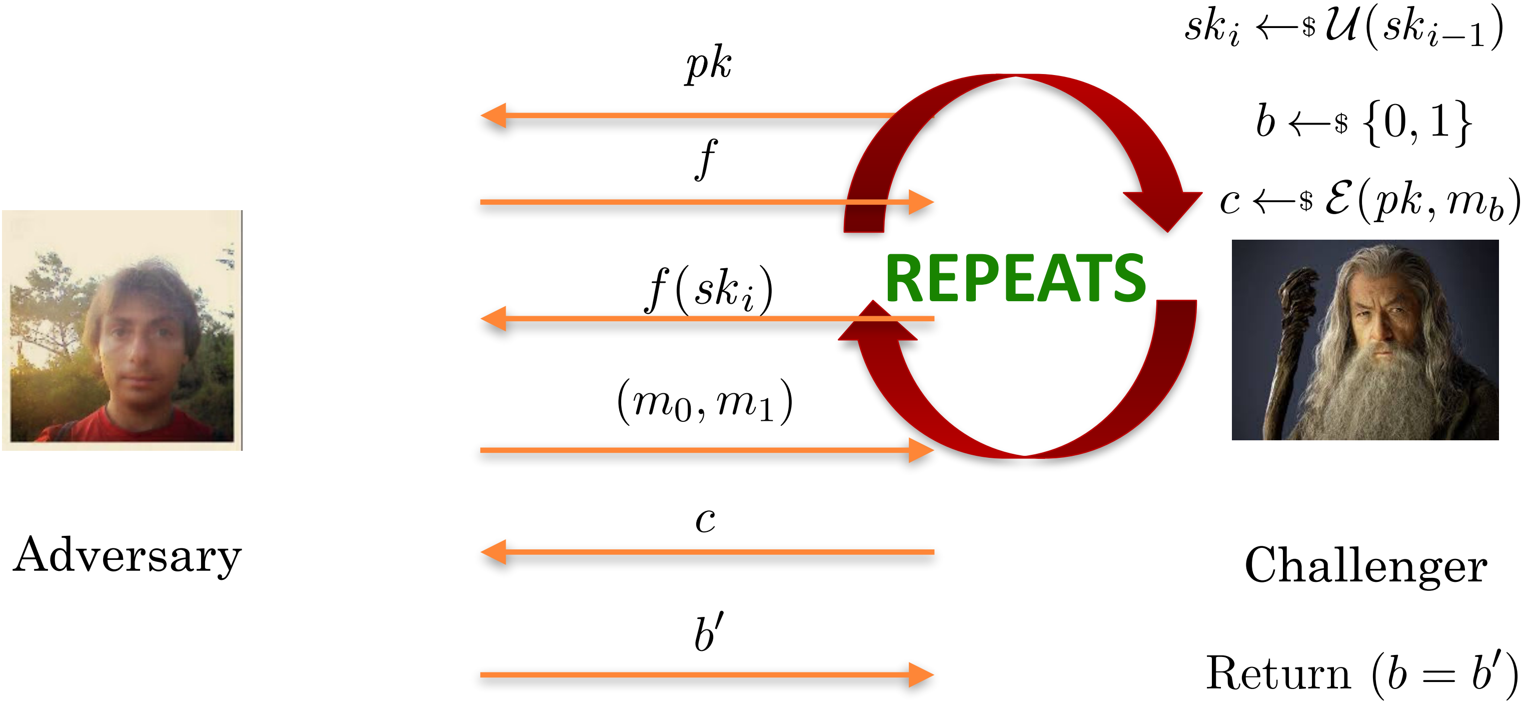

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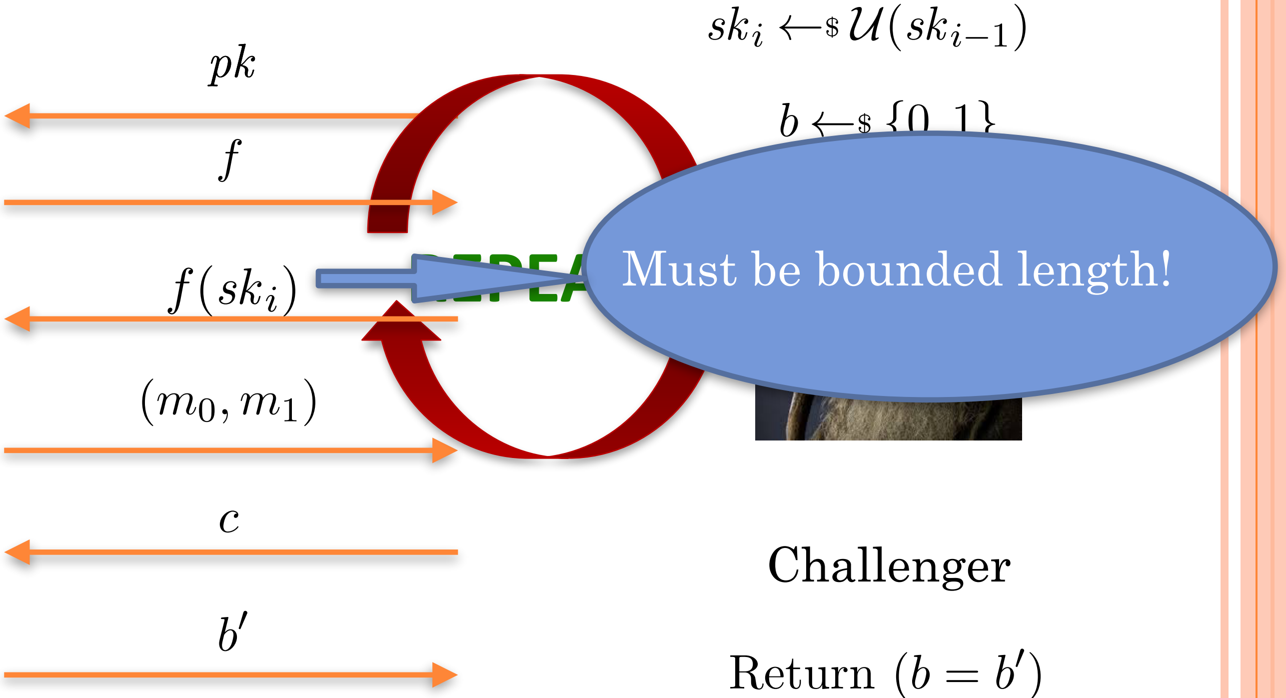

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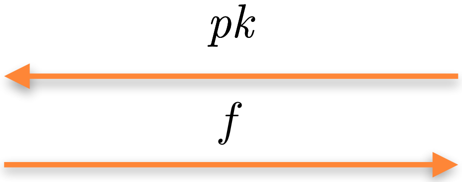

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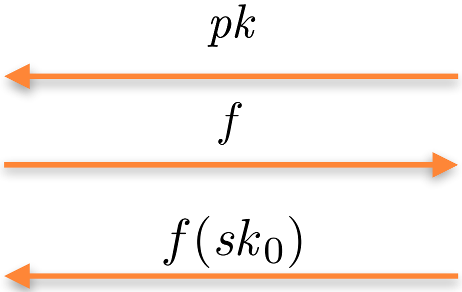

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$sk_i \leftarrow\!\!{\scriptstyle\$}\, \mathcal{U}(sk_{i-1}; r_i)$

$$\xleftarrow{\quad pk \quad}$$

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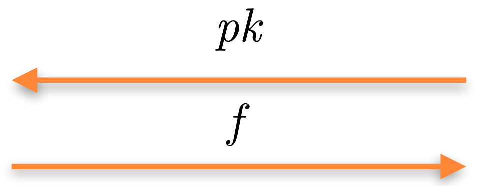

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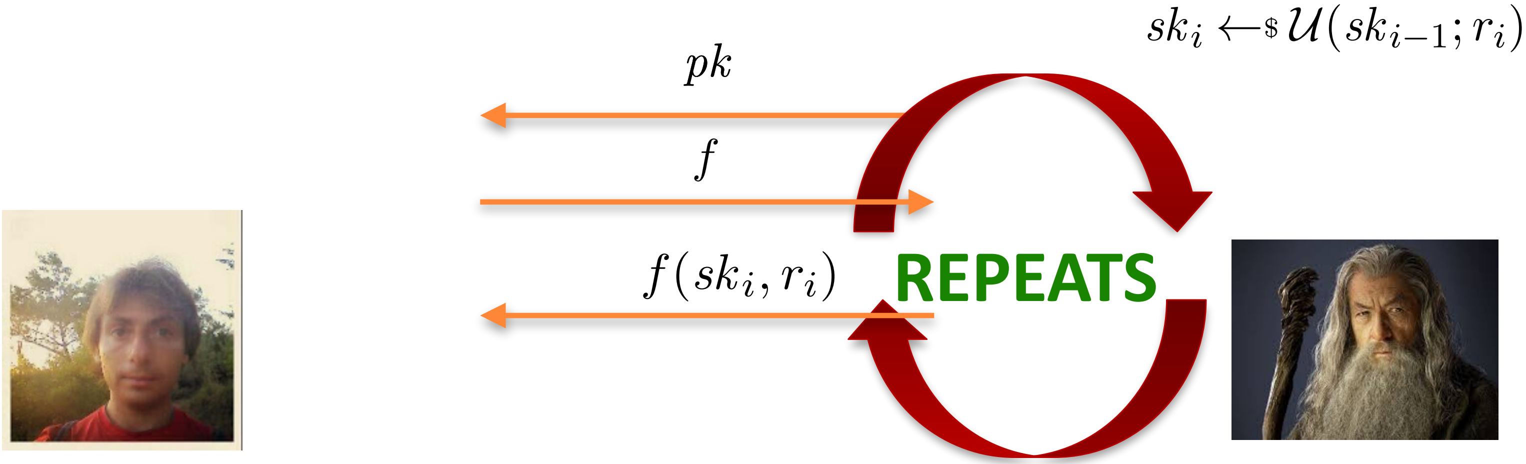

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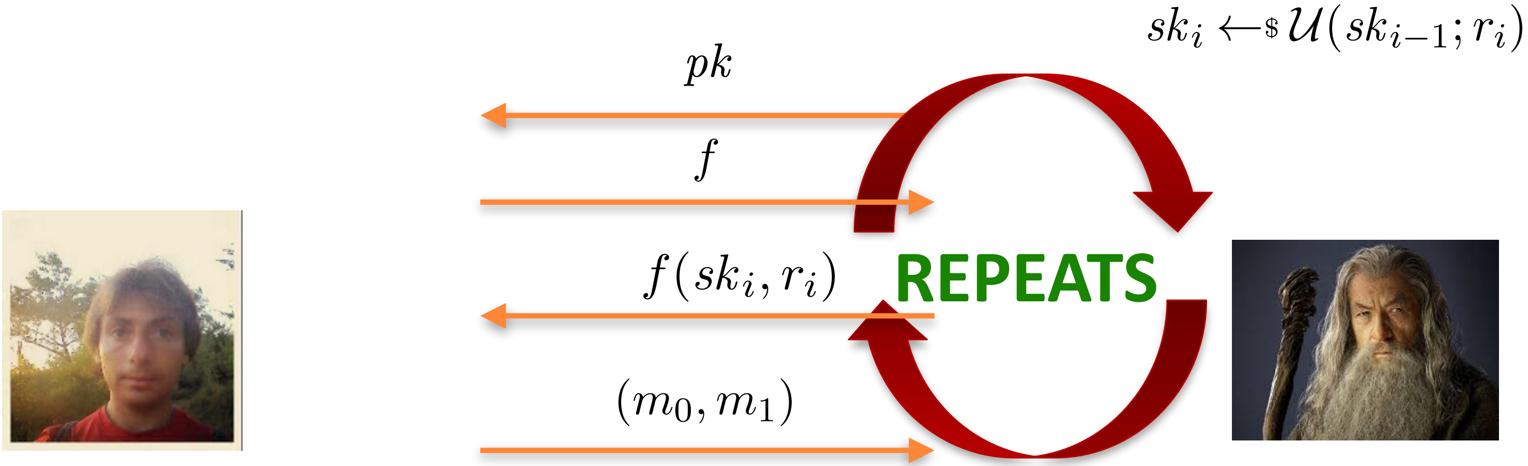

$sk_i \leftarrow_{\$} \mathcal{U}(sk_{i-1}; r_i)$

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REPEATS

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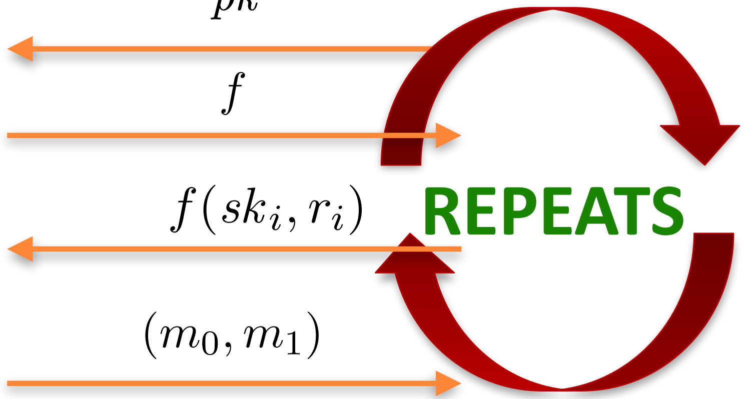

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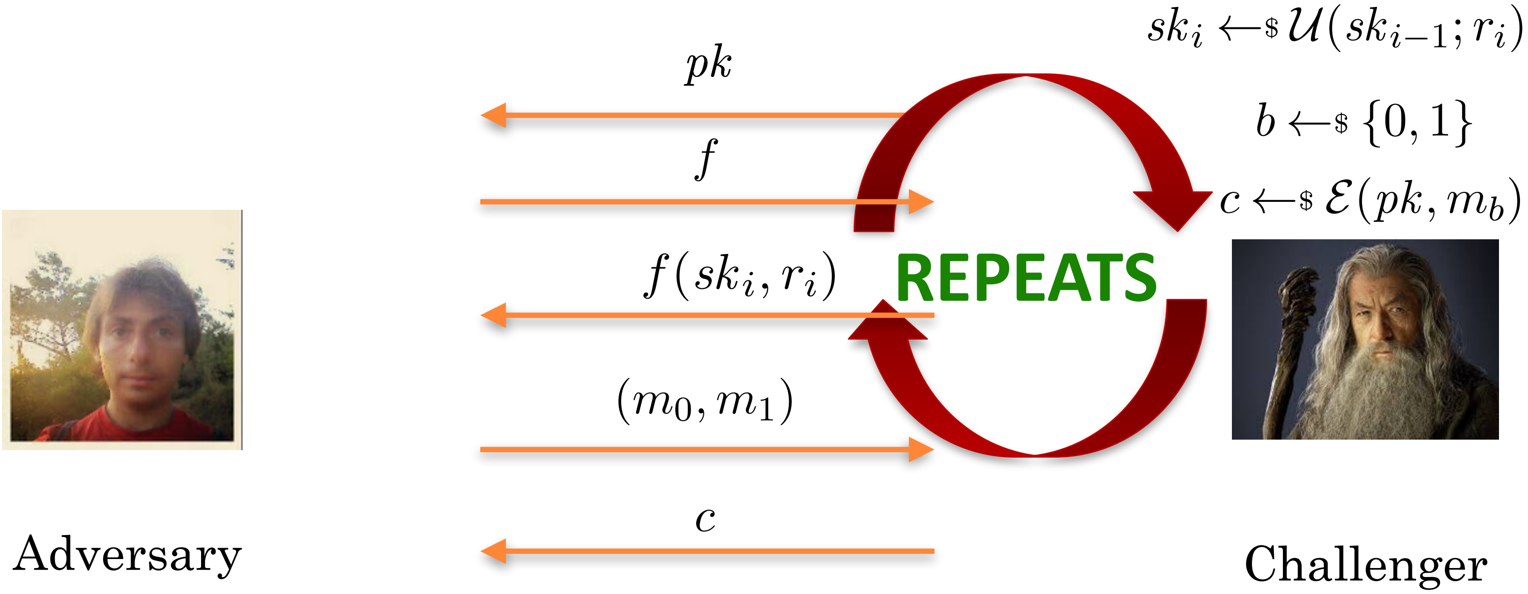

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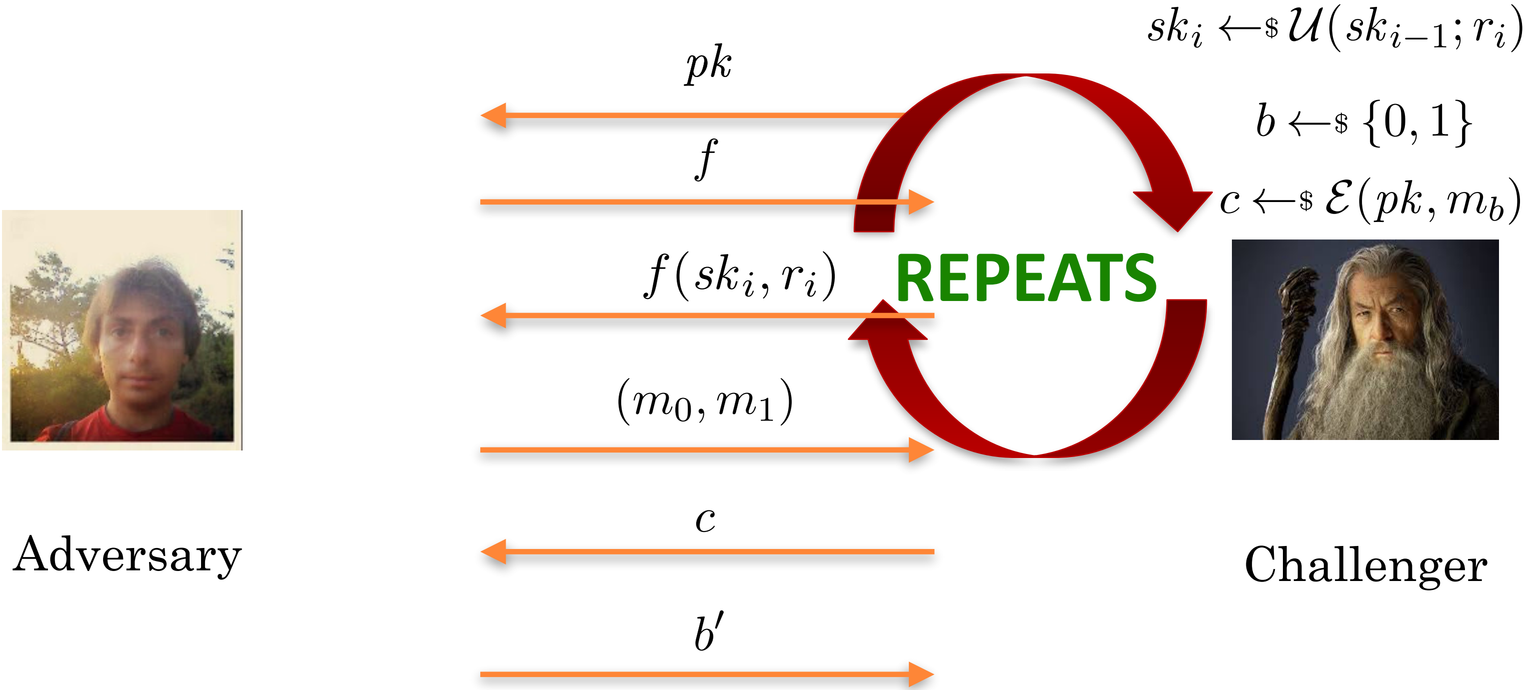

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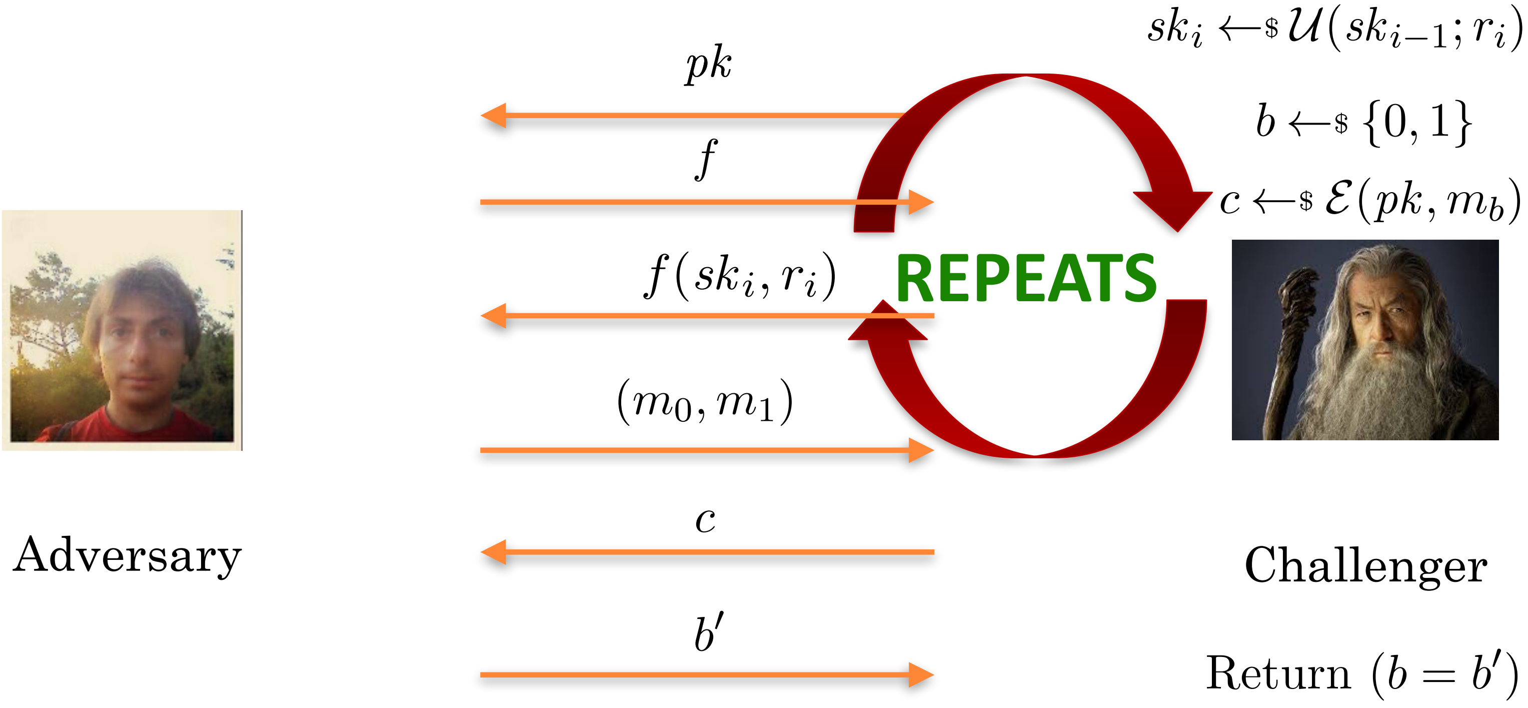

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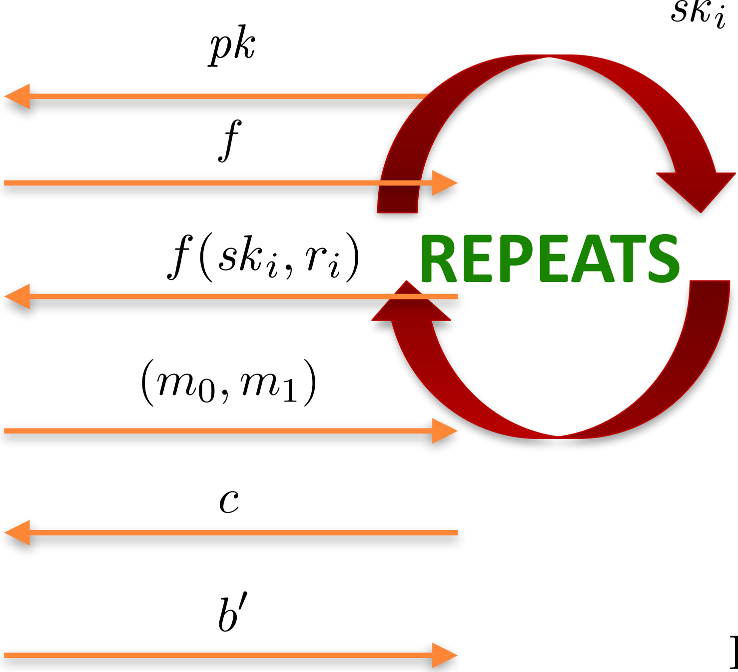


pk

f

$f(sk_i, r_i)$

REPEATS

(m_0, m_1)

c

b'

$sk_i \leftarrow_{\$} \mathcal{U}(sk_{i-1}; r_i)$

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

$c \leftarrow_{\$} \mathcal{E}(pk, m_b)$

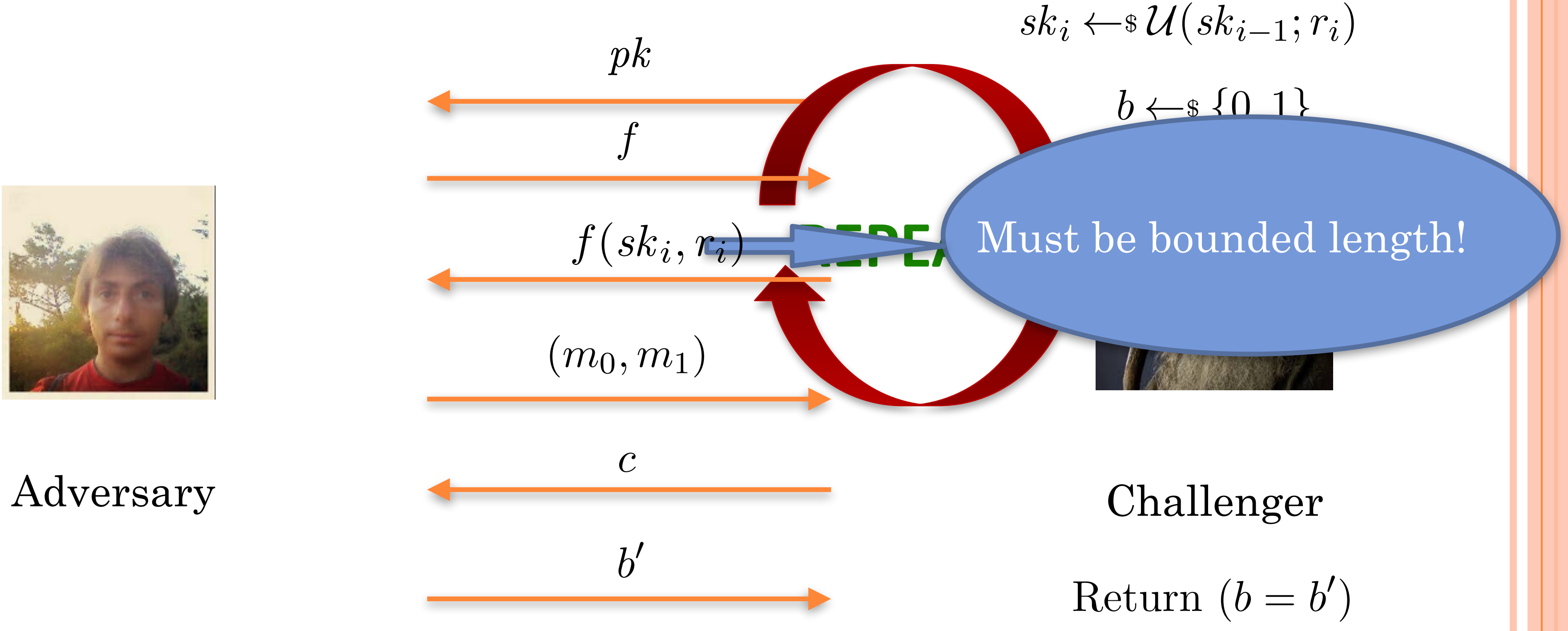
Challenger

Return $(b = b')$

Require $2 \cdot \Pr\left[\, b = b' \,\right] - 1$ is negligible.

LEAKAGE ON KEY-UPDATE FOR PKE [BKKV'10,LLW'11]

Fix a public-key encryption scheme "with key update" $(\mathcal{K}, \mathcal{E}, \mathcal{D}, \mathcal{U})$
i.e. where update algorithm $\mathcal{U}$ computes $sk' \leftarrow_{\$} \mathcal{U}(sk)$.



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OUTLINE OF TALK

Leakage Models for PKE —

- Bounded, Continual, and Continual w/ Leakage on Key Update

Results in Continual Model: A Generic Compiler to Achieve Leakage on Key Update

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This is very similar to deniable encryption as recently achieved by Sahai and Waters [SW’14].

THE COMPILER

Let $\mathsf{PKE} = (\mathsf{Gen}, \mathsf{Enc}, \mathsf{Dec}, \mathsf{Update})$ be a PKE scheme with key update.

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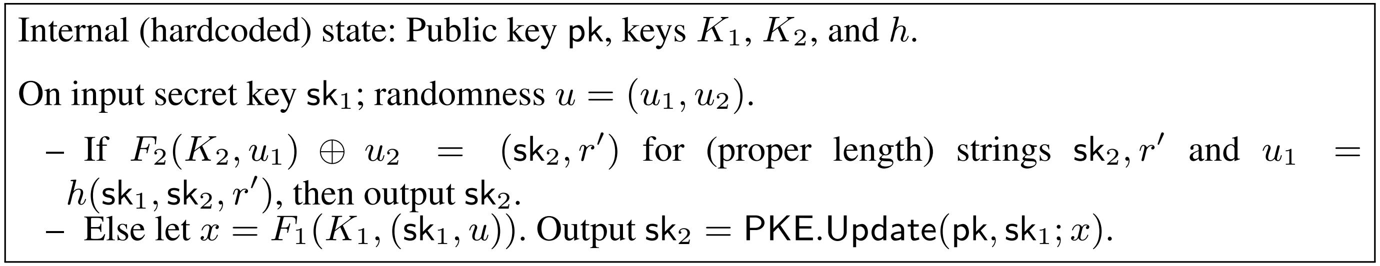
Define a new scheme whose public-key additionally contains obfuscations of two programs:

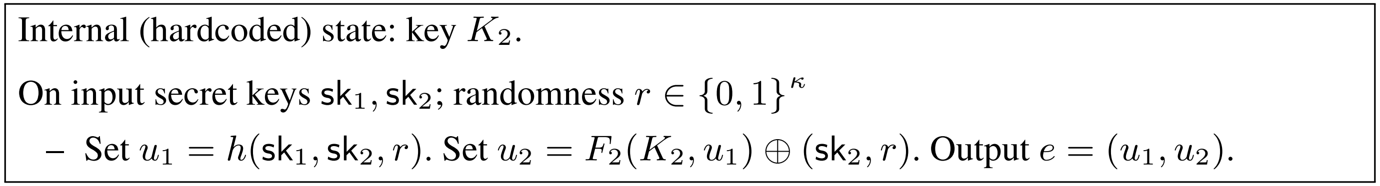


Internal (hardcoded) state: Public key pk, keys K_1, K_2, and h.

On input secret key sk_1; randomness $u = (u_1, u_2)$.

- If $F_2(K_2, u_1) \oplus u_2 = (\mathsf{sk}_2, r')$ for (proper length) strings sk_2, r' and $u_1 = h(\mathsf{sk}_1, \mathsf{sk}_2, r')$, then output sk_2.
- Else let $x = F_1(K_1, (\mathsf{sk}_1, u))$. Output $\mathsf{sk}_2 = \mathsf{PKE.Update}(\mathsf{pk}, \mathsf{sk}_1; x)$.

Fig. 1. Program Update



Internal (hardcoded) state: key K_2.

On input secret keys $\mathsf{sk}_1, \mathsf{sk}_2$; randomness $r \in \{0,1\}^\kappa$

- Set $u_1 = h(\mathsf{sk}_1, \mathsf{sk}_2, r)$. Set $u_2 = F_2(K_2, u_1) \oplus (\mathsf{sk}_2, r)$. Output $e = (u_1, u_2)$.

Fig. 2. Program Explain

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ANALYSIS 2

Theorem (informal). The compiled scheme is secure with leakage on key-updates if the original scheme is consecutive continual leakage resilient and the obfuscator is a "public-coin" differing-inputs [IPS'15] obfuscator.

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Note: Worse leakage rate achievable only using indistinguishability obfuscation.

ACHIEVING CONSECUTIVE CONTINUAL LEAKAGE-RESILIENCE

We show that existing continual leakage-resilient PKE schemes [BKKV’10,DHLW’10] can be upgraded to consecutive continual leakage without changing the underlying assumptions.

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Via our compiler we get PKE with leakage on key-updates with optimal leakage rate under bilinear map assumptions + public-coin differing-inputs obfuscation [IPS'15].

COMPARISON TO PRIOR WORK

[LLW'11] achieves continual leakage resilience with leakage on key updates from bilinear map assumptions but worse leakage rate.

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Key-Generation: Choose a key K and output K as the secret key and the obfuscation of a program Encrypt that on inputs x,r outputs $F(K,r) + x$.

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SW'13 shows (a modification of) this scheme is IND-CPA using indistinguishability obfuscation.

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2. Make the secret decryption key not K but obfuscation of program Decrypt that on input y,r outputs F(K,r)+y.

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But note we can now leak on this hardcoded value since encryption uses a randomness extractor.

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Solution: Make the program take an additional short signed input to run, this short signed input then becomes the new secret key.

COMPARISON TO PRIOR WORK

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Our result can be viewed as showed that obfuscation + OWF is sufficient for optimal leakage rate.

Optimal leakage rate is also known from other specific assumptions, e.g. DDH [NS'09].

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1. Compiler from (consecutive) continual leakage-resilience to leak on key-updates.

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1. Compiler from (consecutive) continual leakage-resilience to leak on key-updates.
2. Modification of [SW'13] to achieve bounded leakage with optimal leakage rate.

OPEN QUESTIONS

Can we achieve leakage on key-updates with optimal leakage rate?

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Can we achieve continual leakage resilience from (differing-inputs) obfuscation?

THANK YOU!

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