Key Exchange in the Post-Snowden Era: Universally Composable Subversion-Resilient PAKE

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Bird's eye view

Intro to subversion	$\mathcal{F}_{RE}$ from srOT
$\mathcal{F}_{RE}$ to $\mathcal{F}_{PAKE}$	Wrapping up

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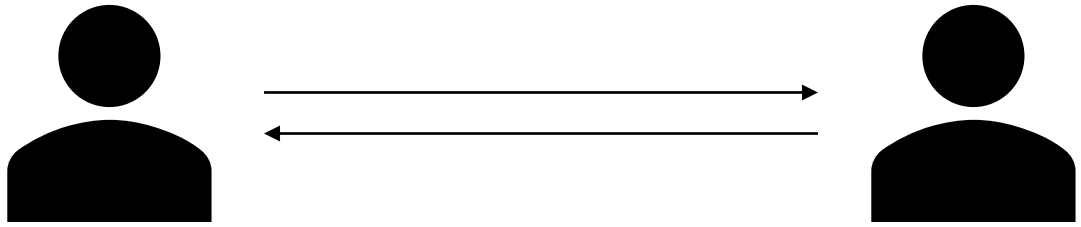
“Traditional” MPC



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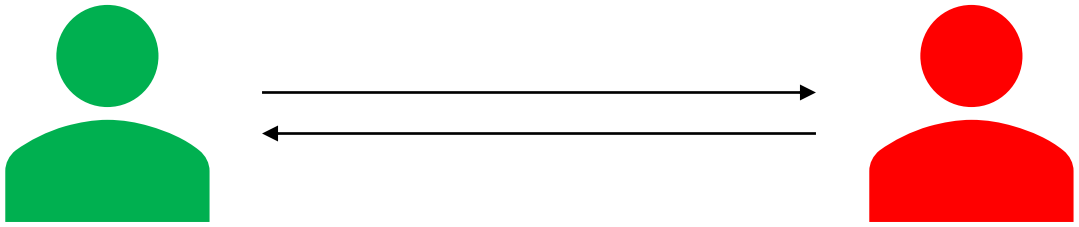

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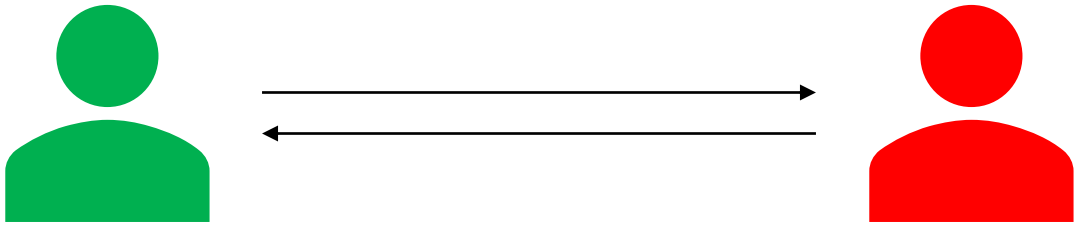
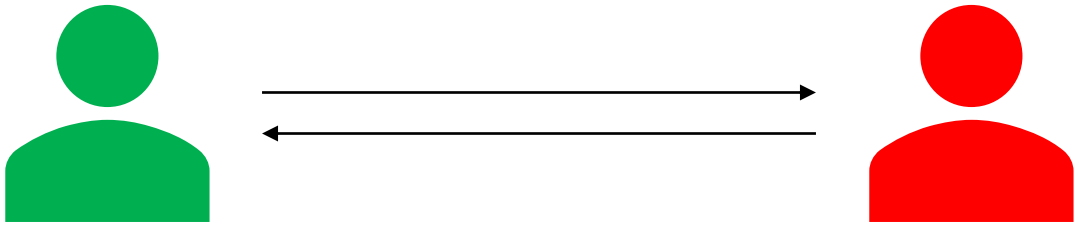


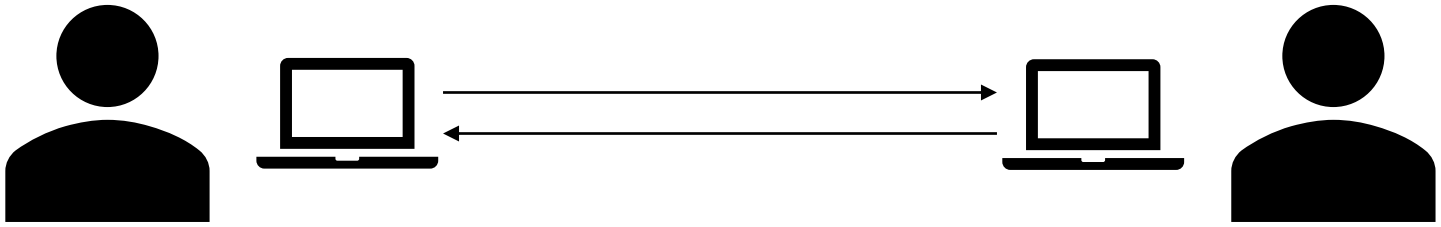
- **Malicious corruptions** are very general.

“Traditional” MPC



- **Malicious corruptions** are very general.
- What about **honest parties**?

MPC with Subversion Attacks



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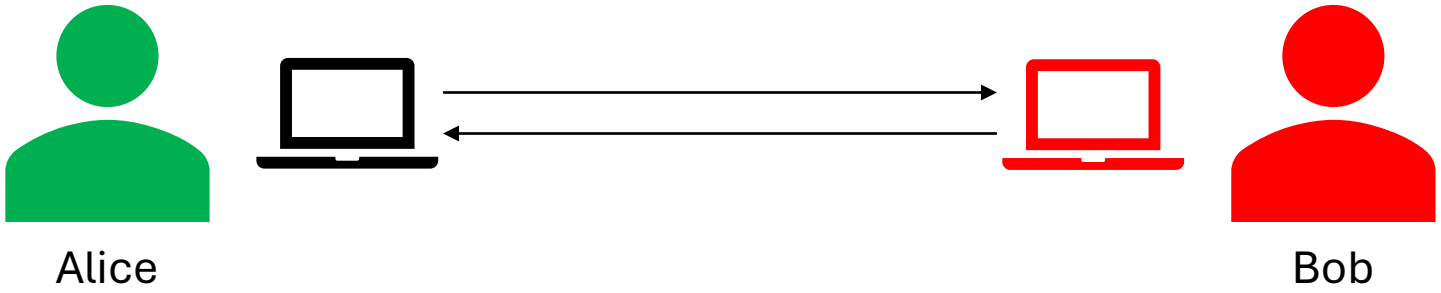

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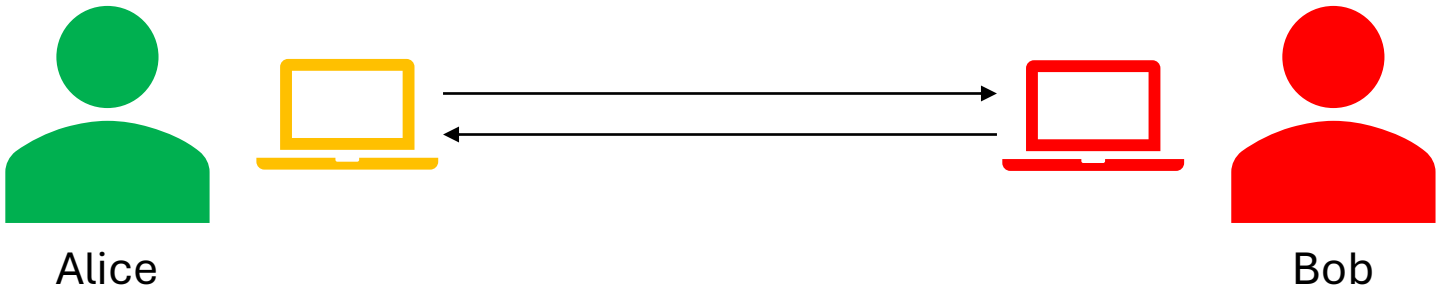

MPC with Subversion Attacks

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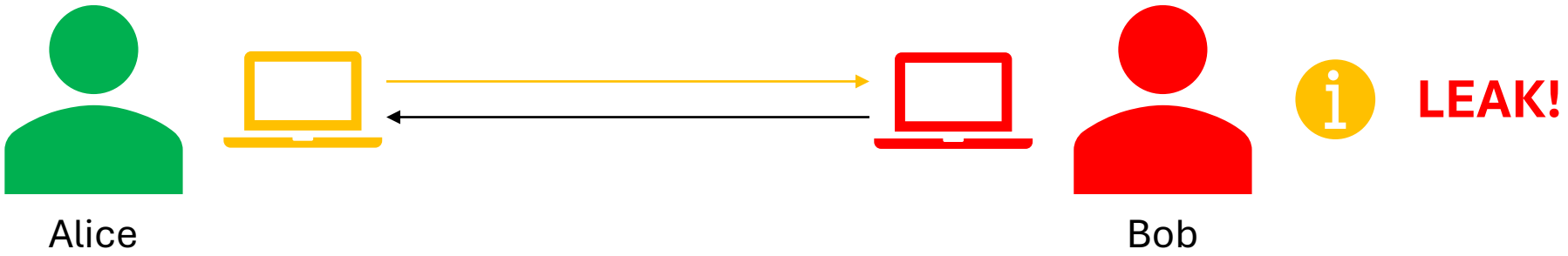
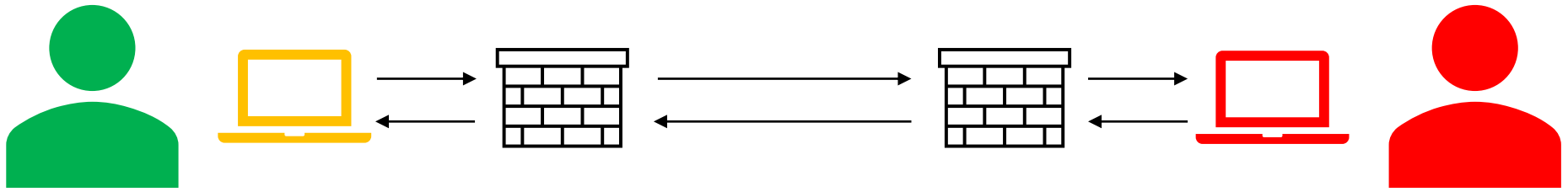


Cryptographic Reverse Firewalls



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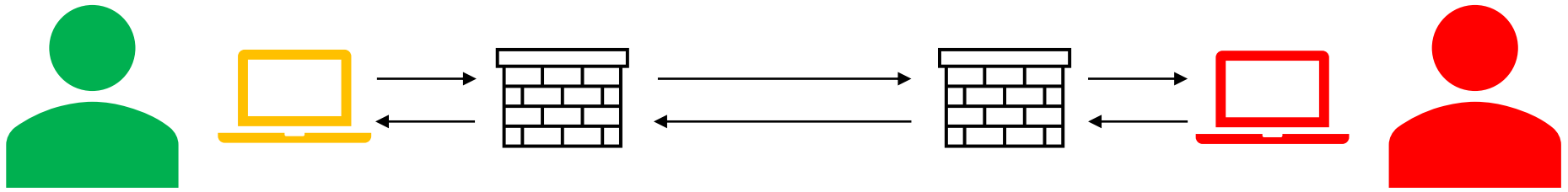

- First formalized in [**MS14**] (EUROCRYPT'15).

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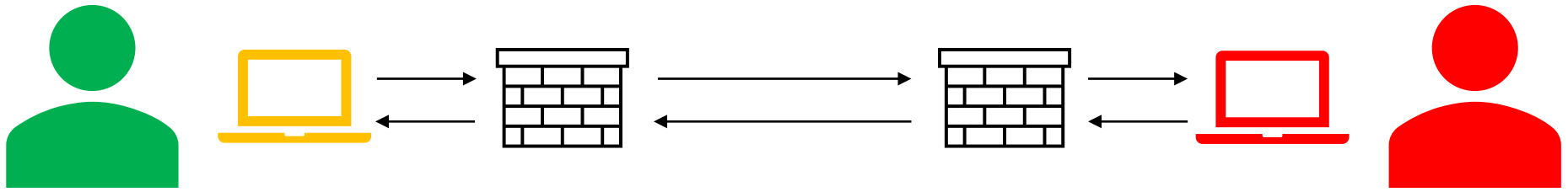

- First formalized in [**MS14**] (EUROCRYPT'15).
- Extended to the UC framework in [**CMNV22**] (EUROCRYPT'22).

Bird's eye view

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PAKE from OT

- **Starting point:** PAKE from OT due to **[CDVW12]** (PKC'12).

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- **First**: PAKE from OT assuming authenticated channels (AKA **Randomized Equality**).

PAKE from OT

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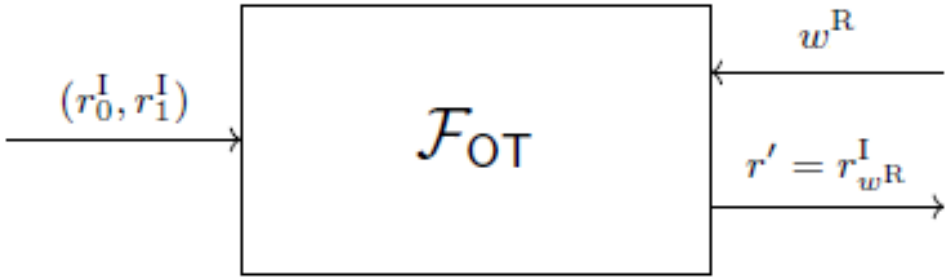
- **First**: PAKE from OT assuming authenticated channels (AKA **Randomized Equality**).
- **Then:** Remove authenticated channels.

Building block for PAKE

Initiator I (w^{I})

Responder R (w^{R})

$(r_0^{\mathrm{I}}, r_1^{\mathrm{I}}) \leftarrow_{\$} \{0,1\}^{2\lambda}$



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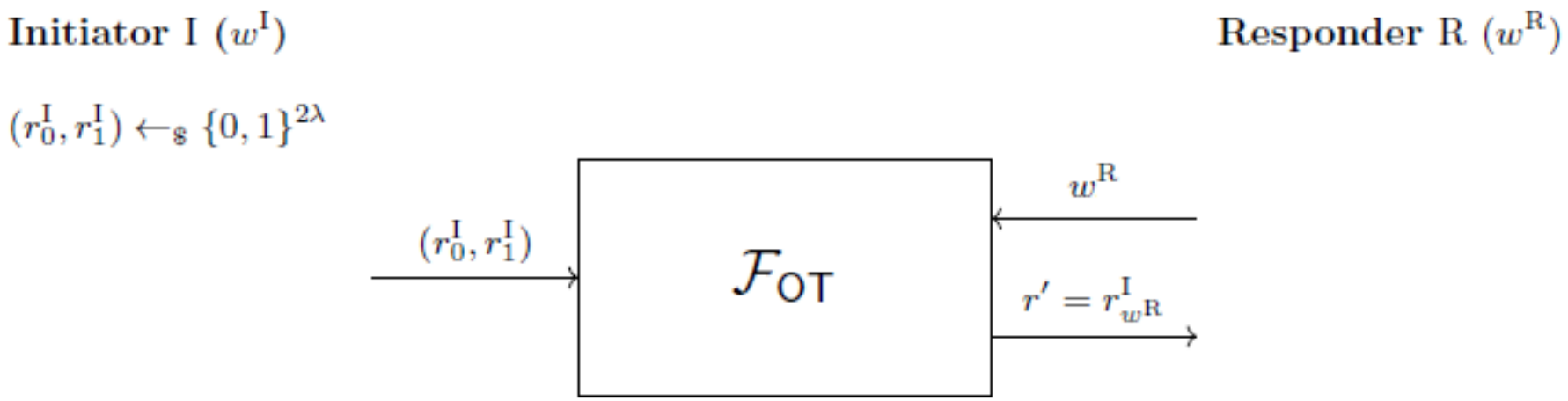
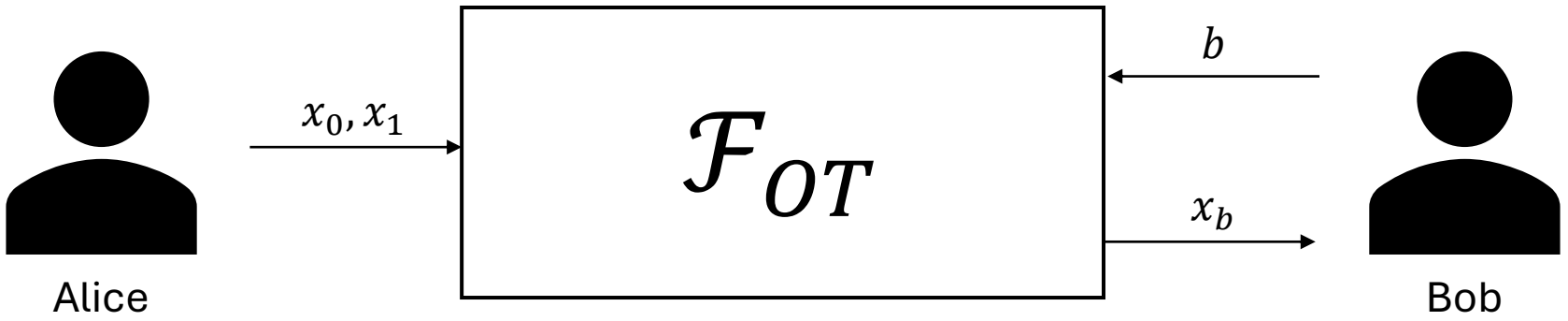


- Both parties do the same for **every bit** of the password.

Oblivious Transfer in the presence of subversion



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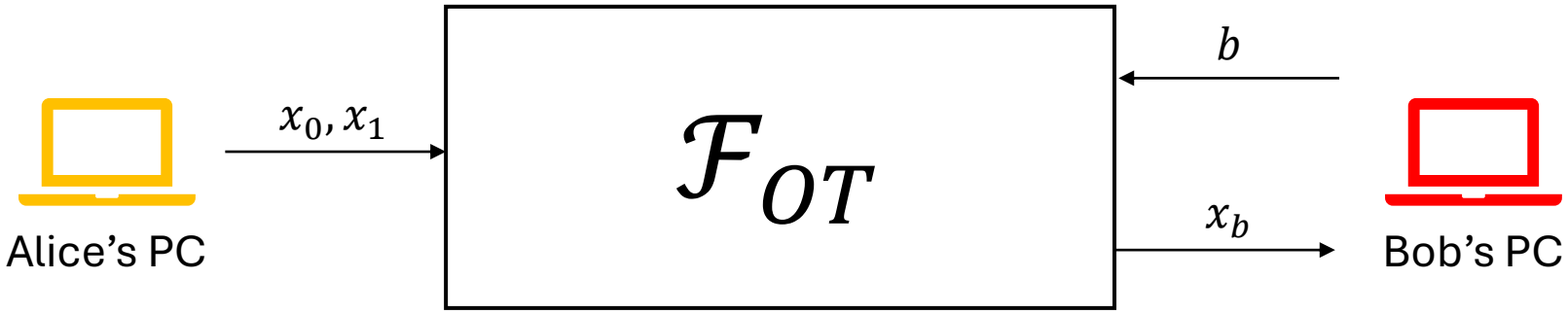

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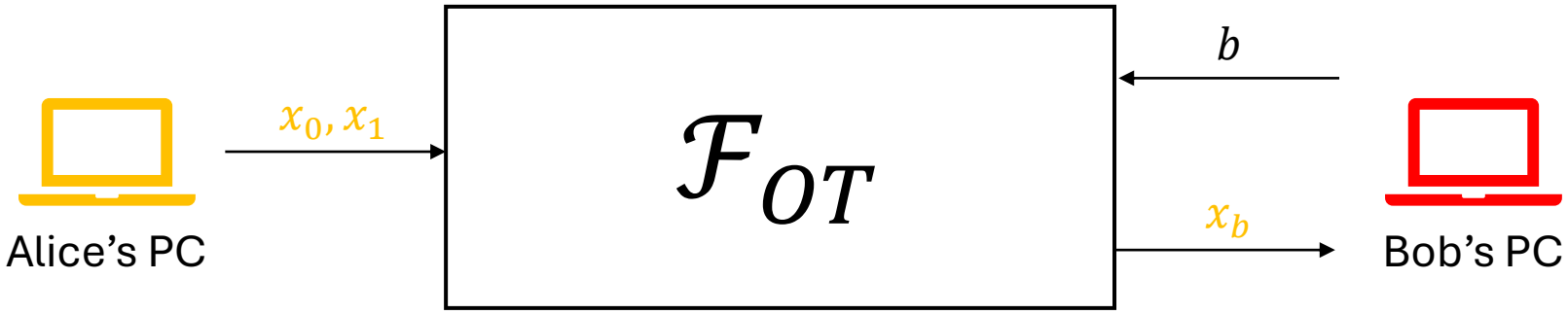

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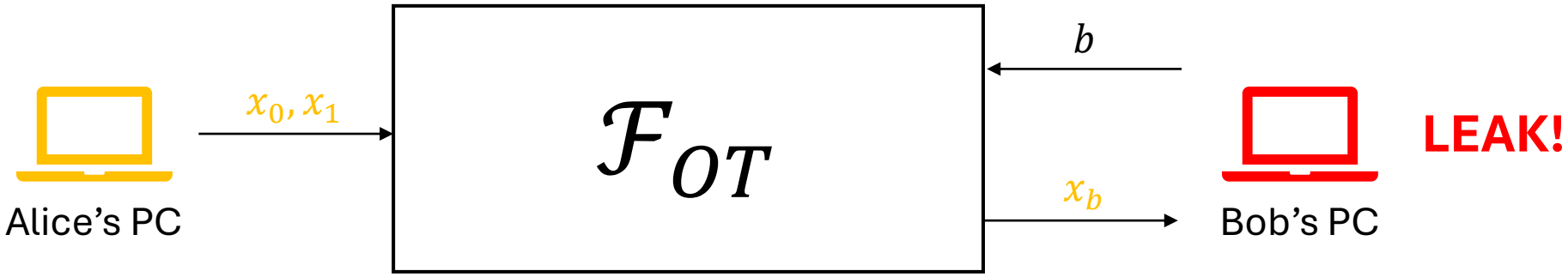

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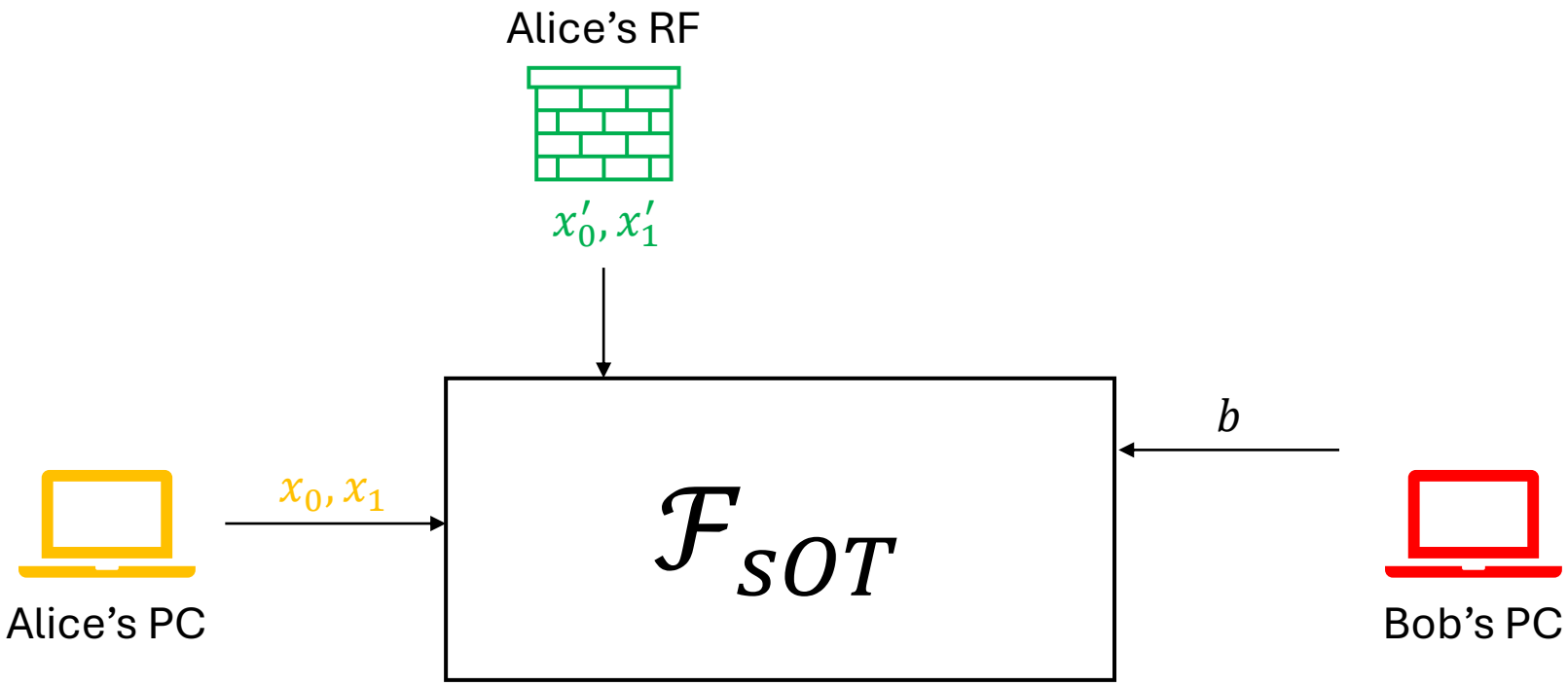

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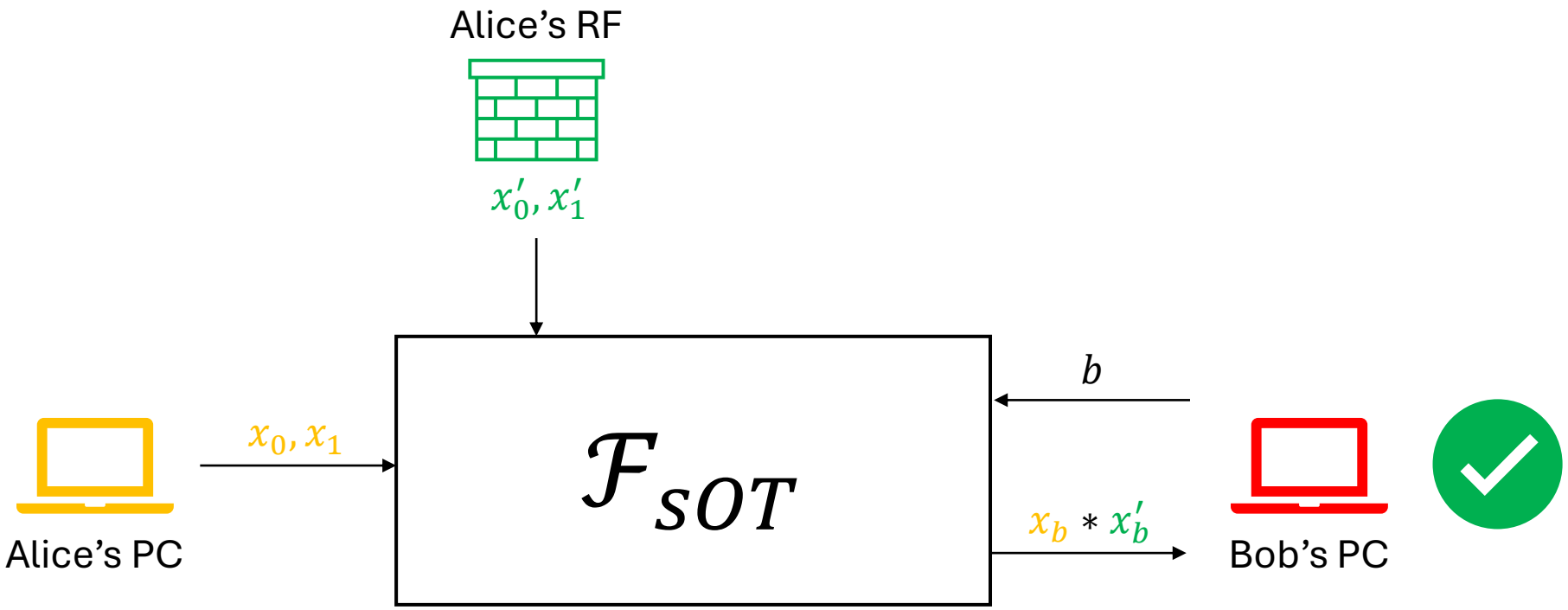

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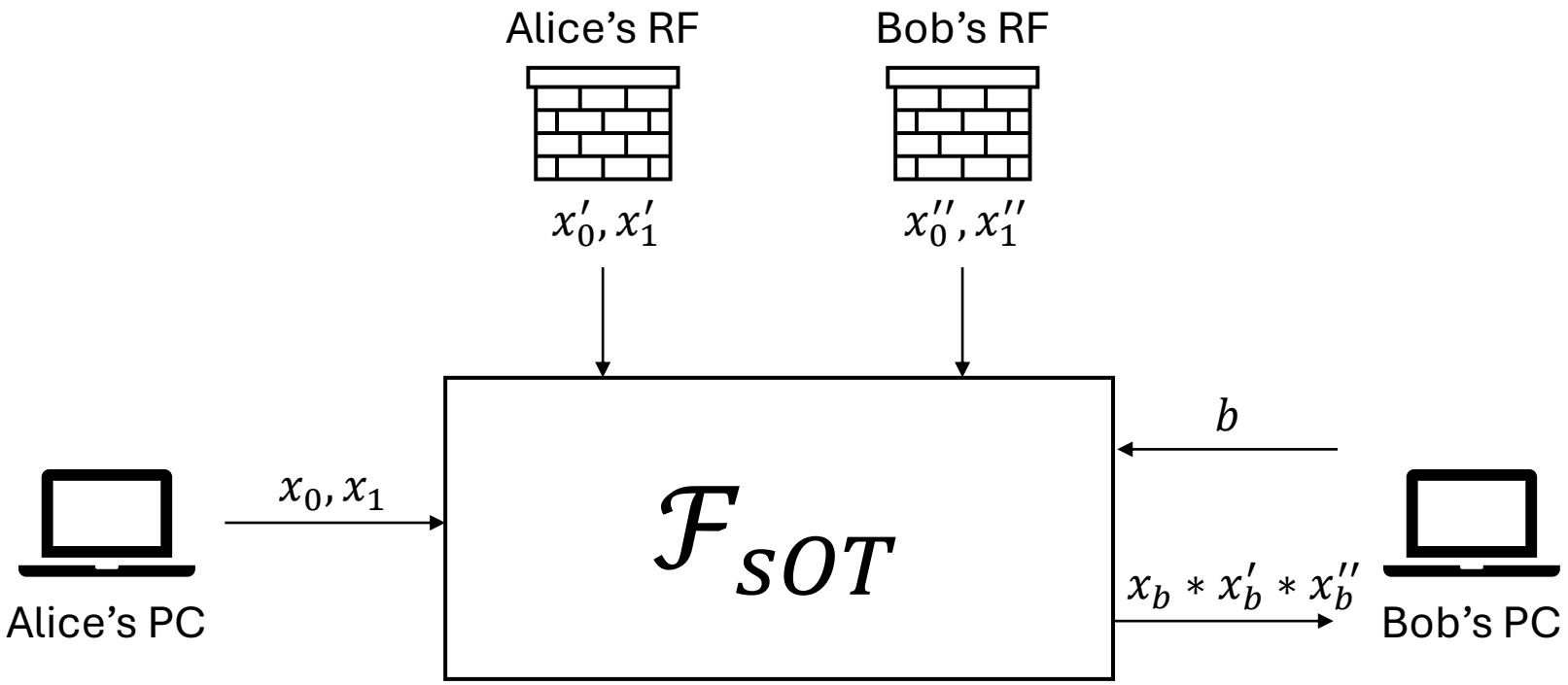

$\mathcal{F}_{OT}$ from Dual-Mode Cryptosystems [PVW08]

Sender $\mathrm{S}(x_0, x_1)$ | **Receiver** $\mathrm{R}(\sigma)$

$\mathrm{CRS} = \mathsf{crs}$

$(sk, pk) \leftarrow_{\$} \mathsf{KeyGen}(\sigma)$

$pk \longleftarrow$

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$\xrightarrow{(y_0, y_1)}$

Output $\mathrm{Dec}(sk, y_\sigma)$

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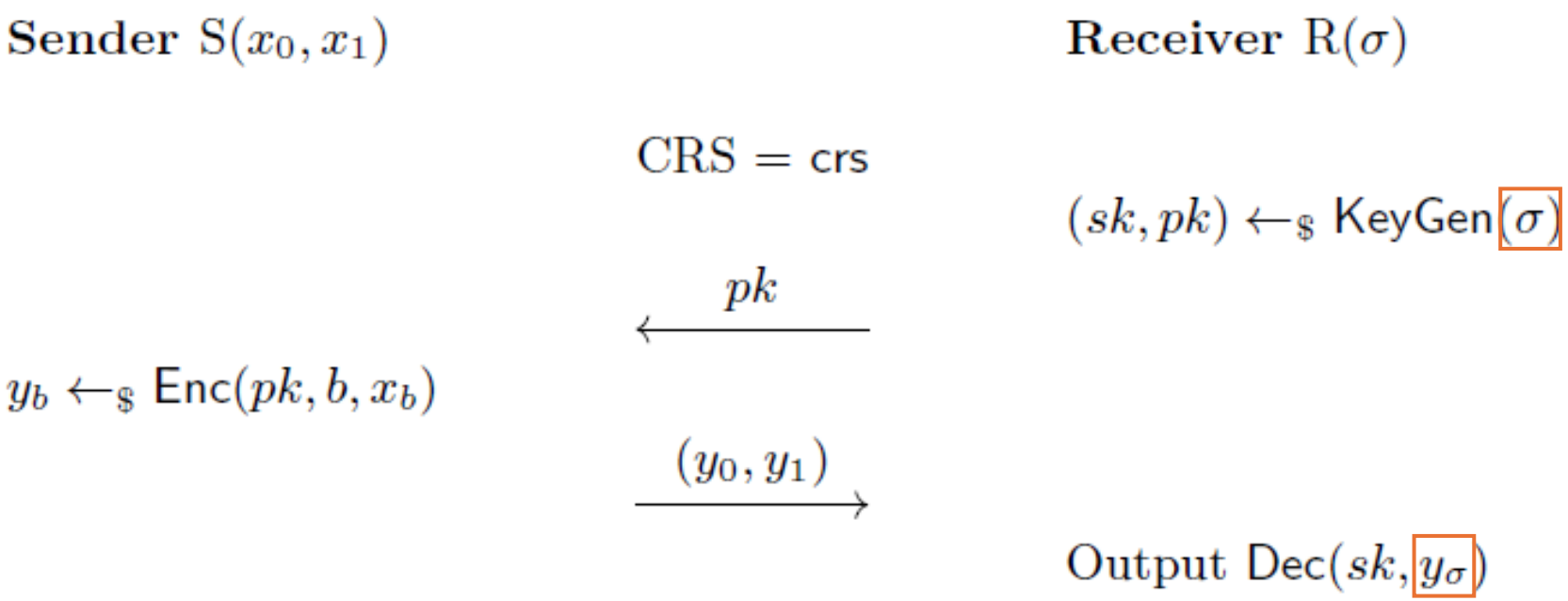
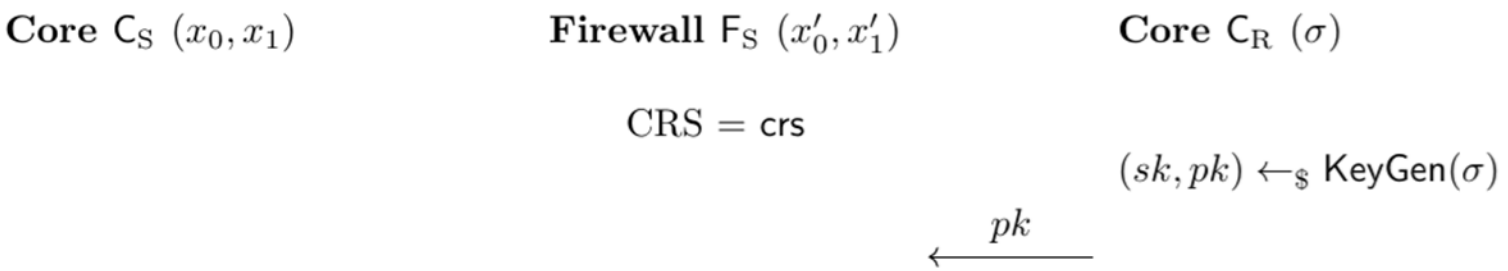


- Only y_b for which $b = \sigma$ can be decrypted.

Instantiating $\mathcal{F}_{sOT}$



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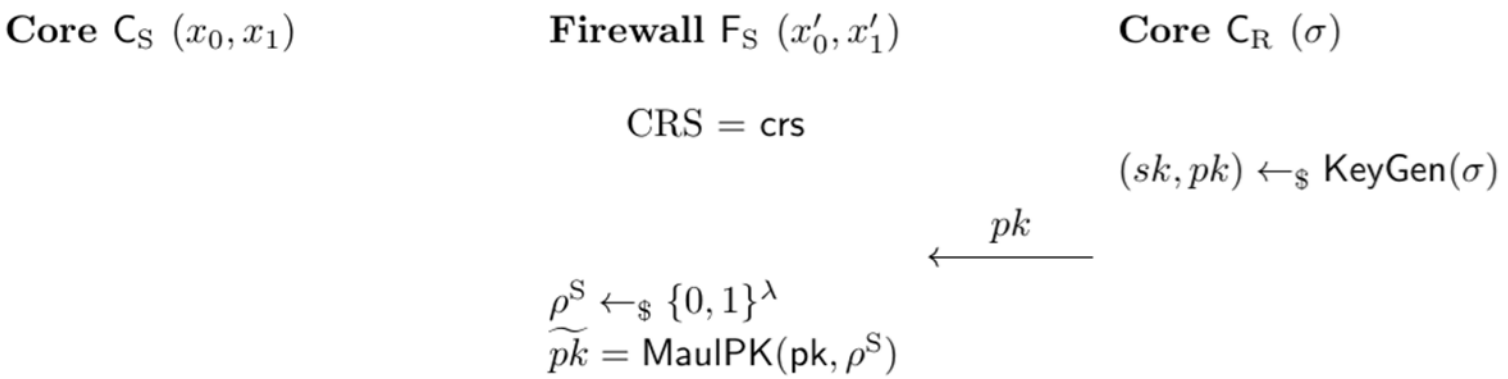

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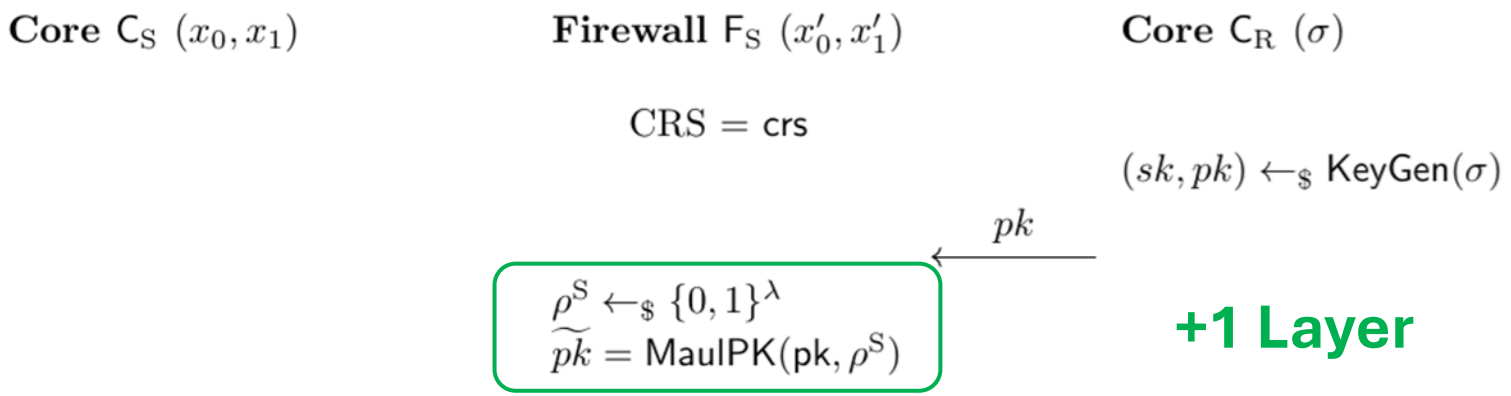
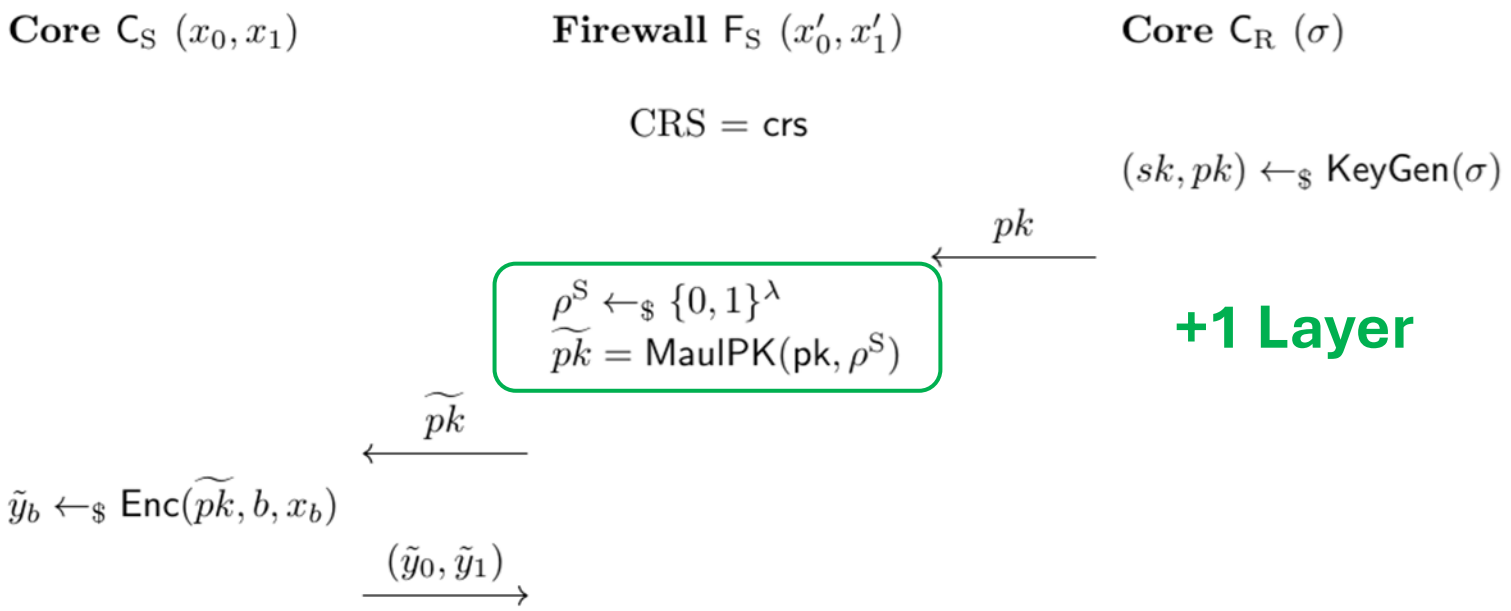


+1 Layer

Instantiating $\mathcal{F}_{sOT}$



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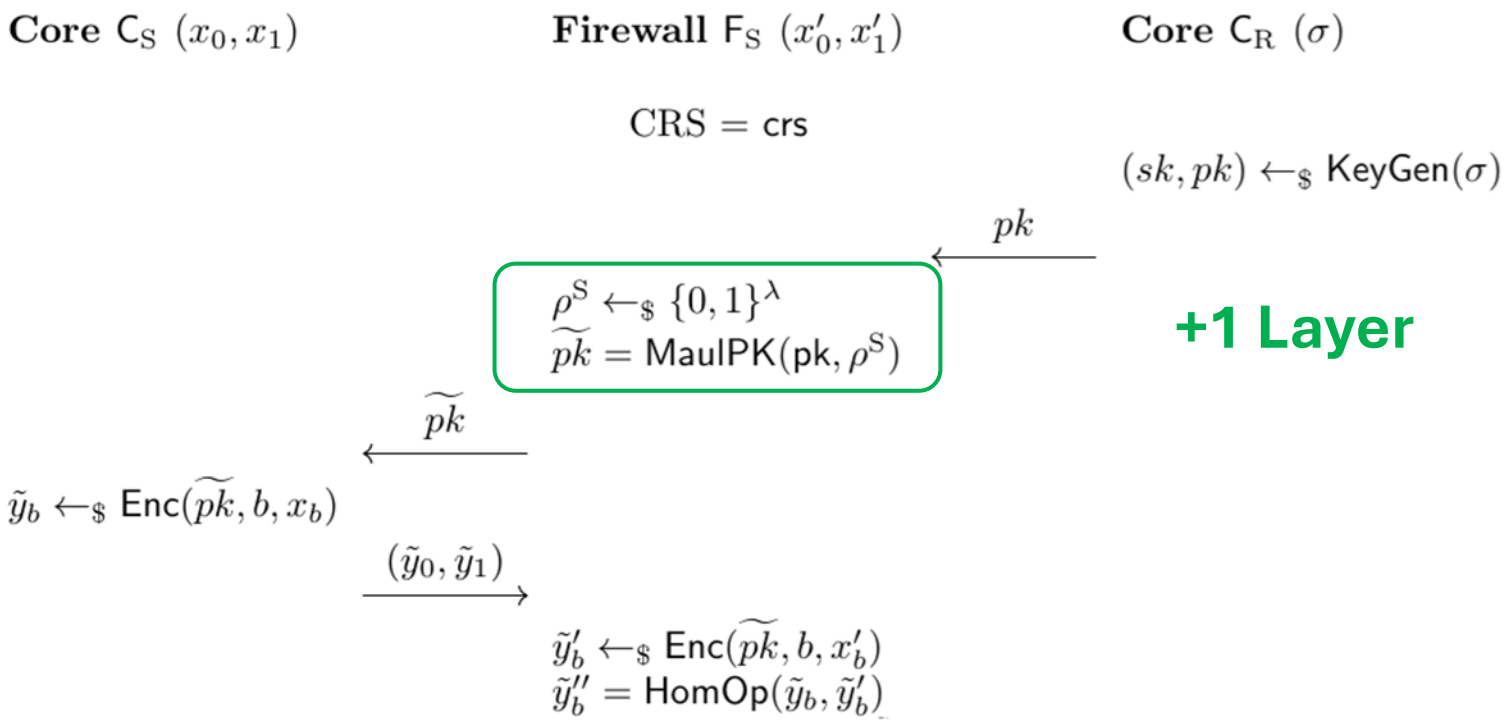

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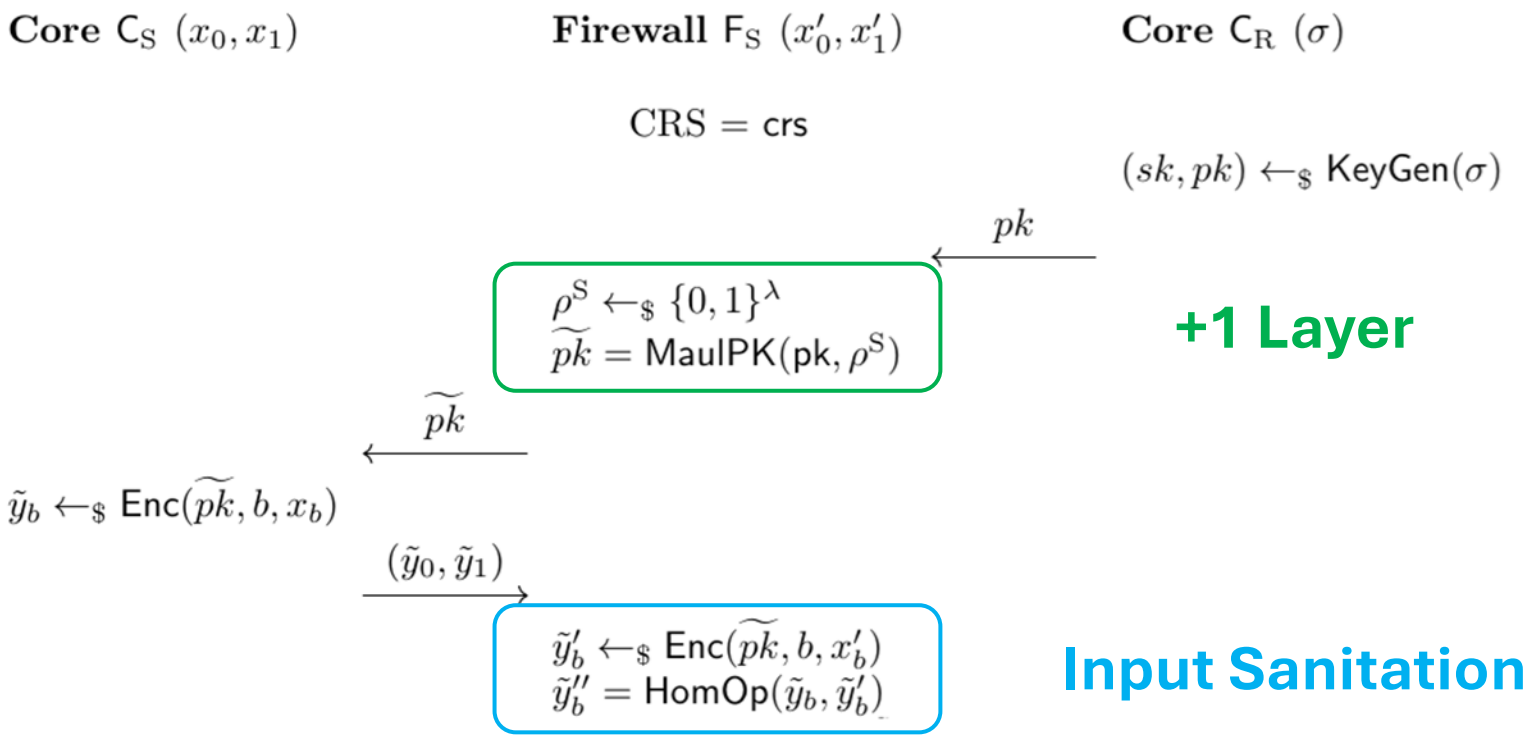

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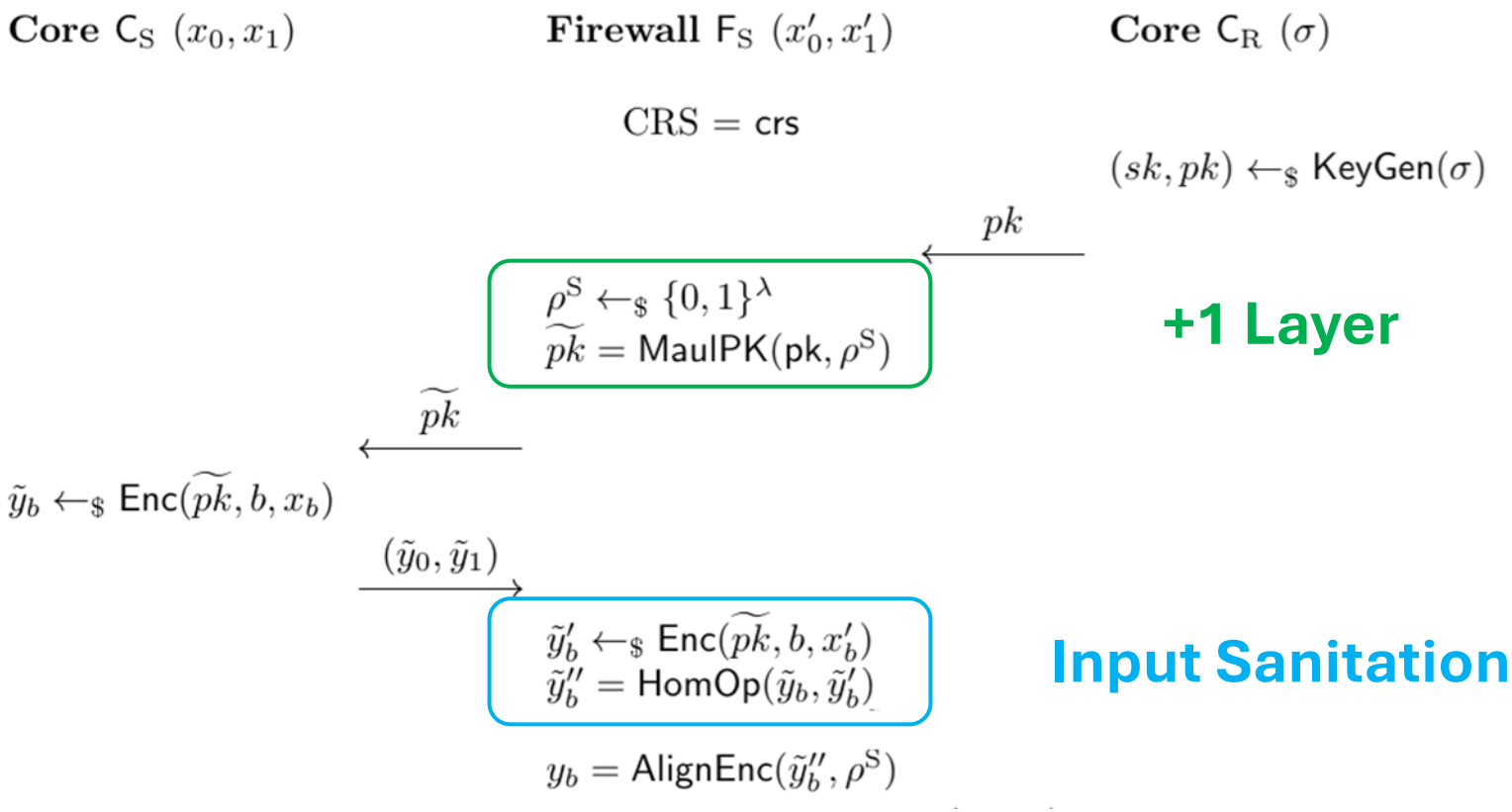

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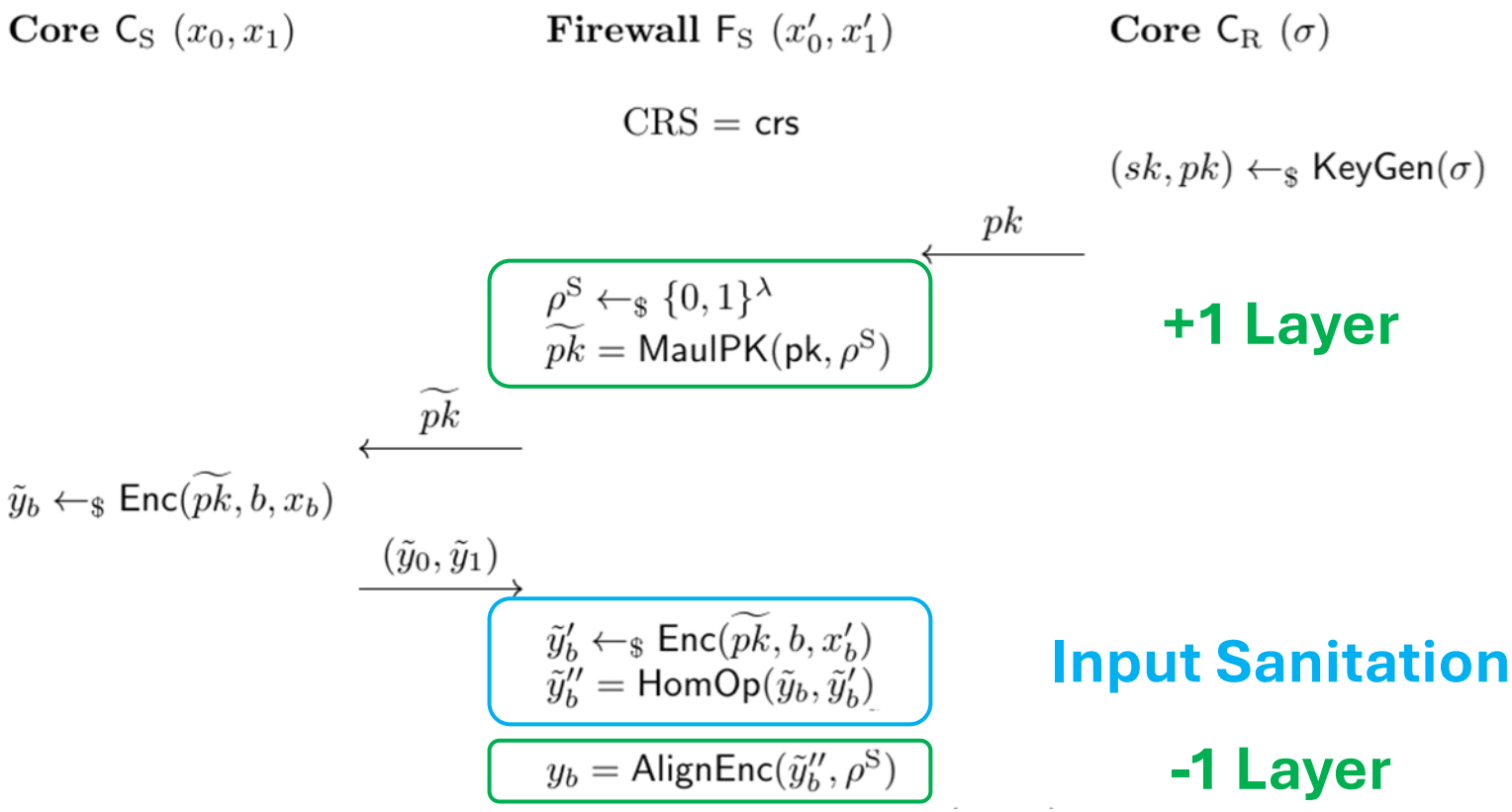

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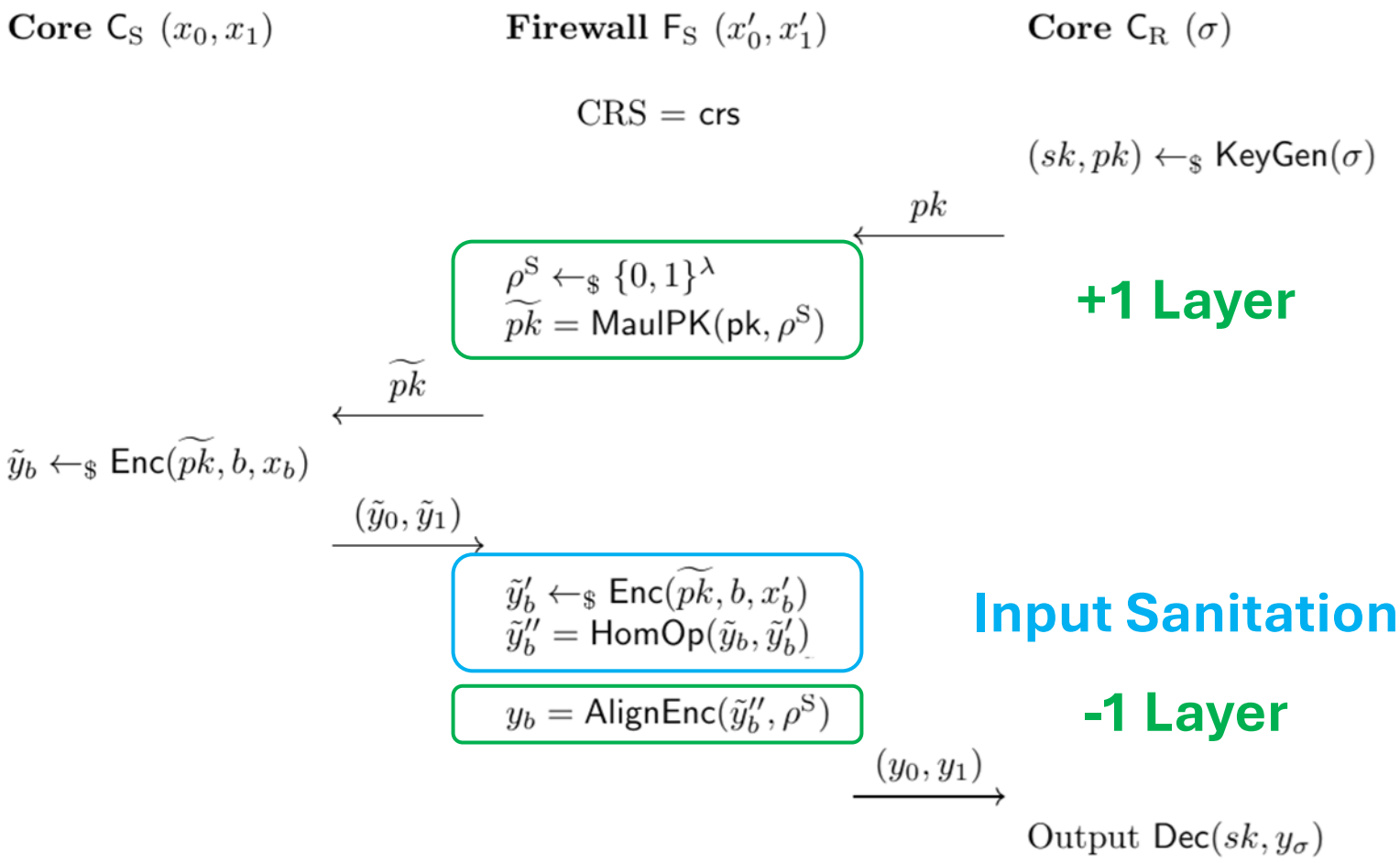
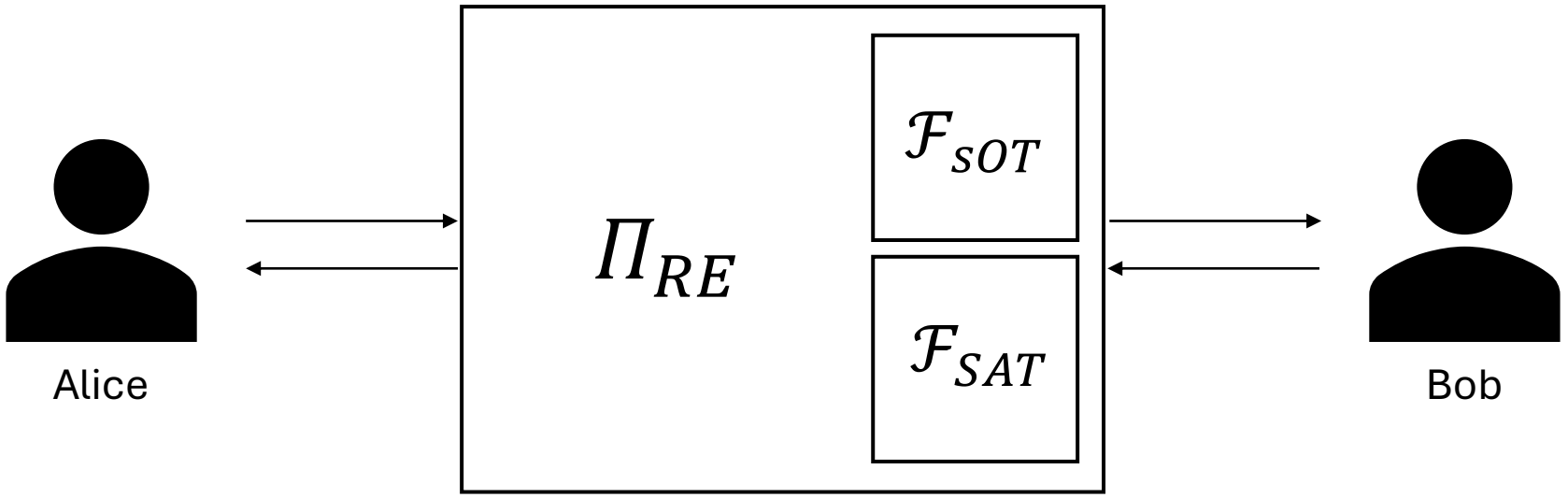


Randomized Equality from $\mathcal{F}_{sOT}$



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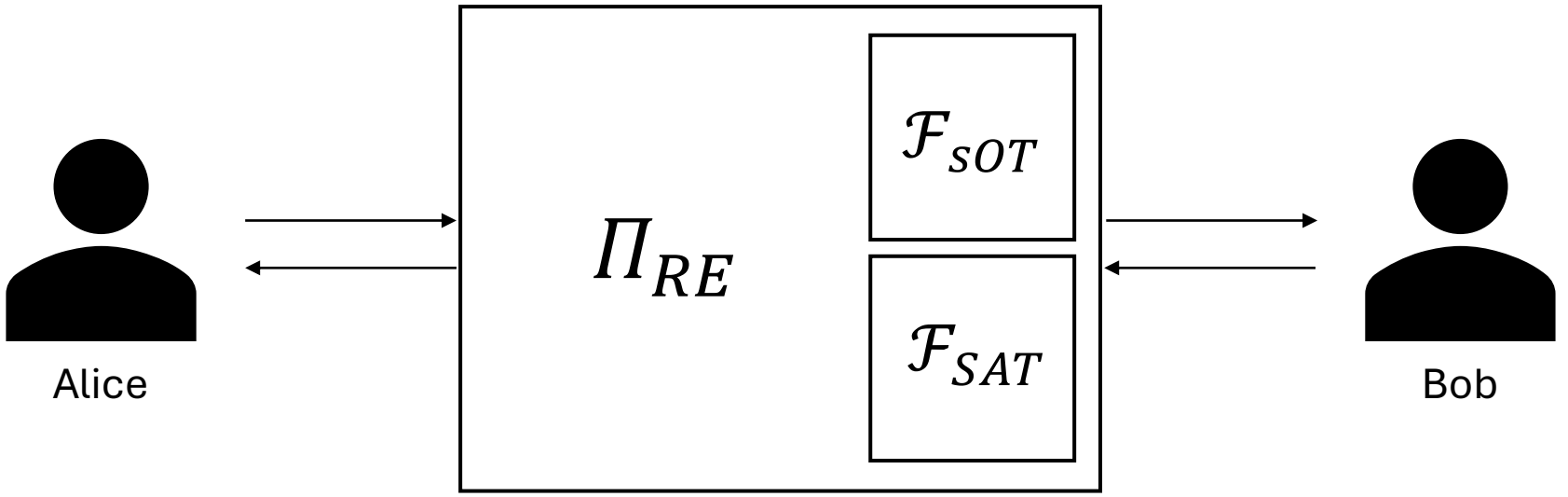
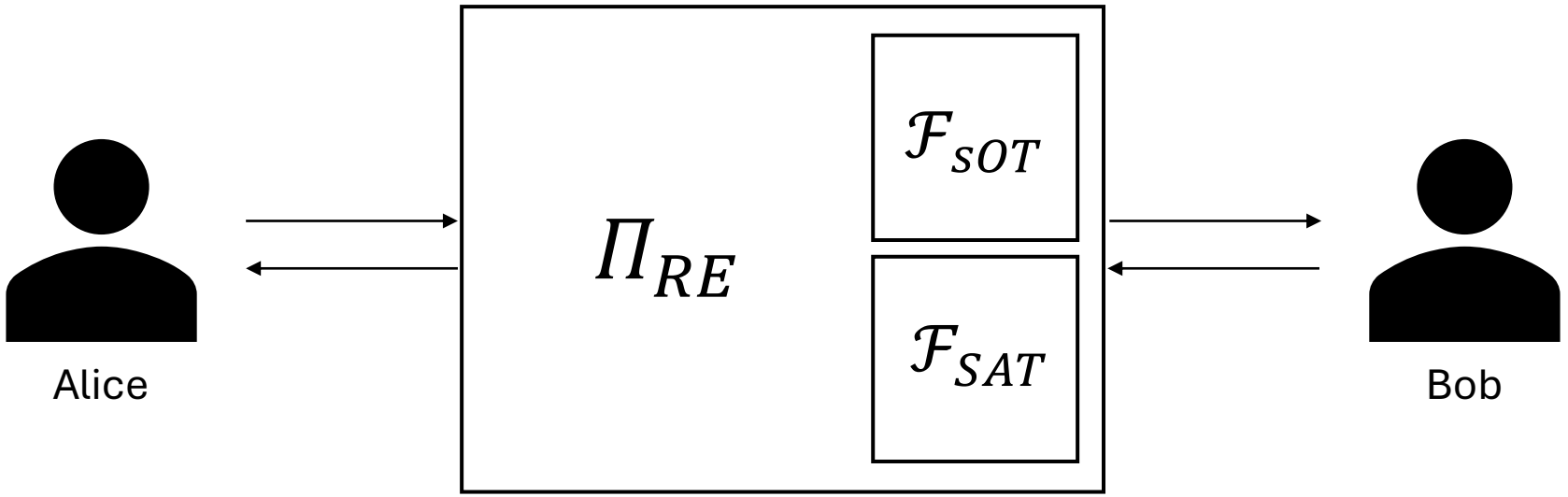


- Given $\boldsymbol{\mathcal{F}_{sOT}}$, we realize Randomized Equality in the srUC framework.

Randomized Equality from $\mathcal{F}_{sOT}$



- Given $\mathcal{F}_{sOT}$, we realize Randomized Equality in the srUC framework.
- Similar protocol structure to **[CDVW12]** - details on the paper!

Bird's eye view

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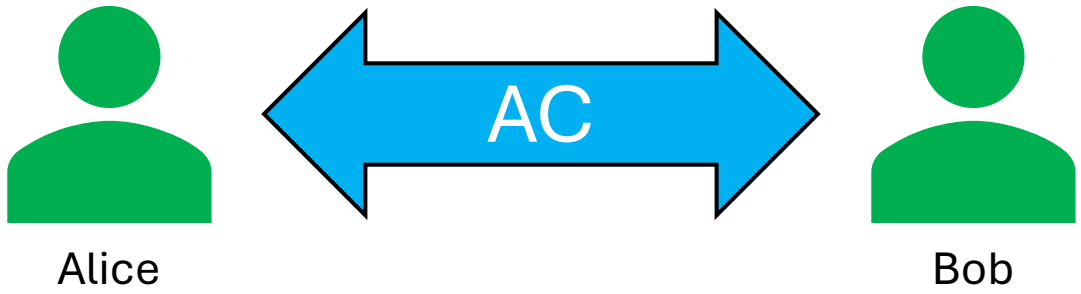
Removing authenticated channels in standard UC



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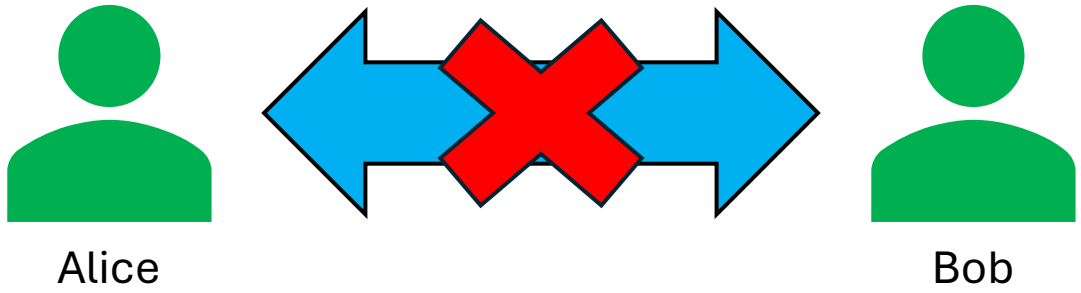

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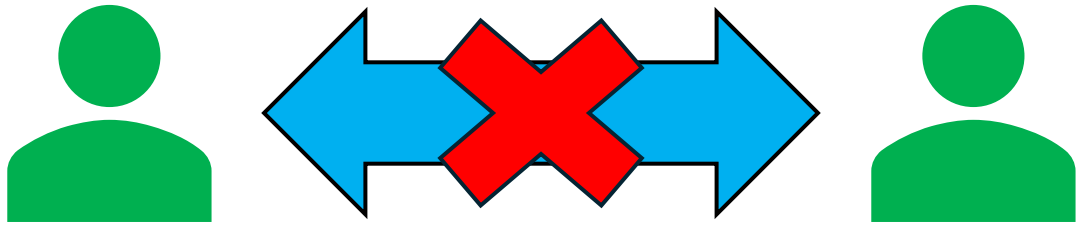
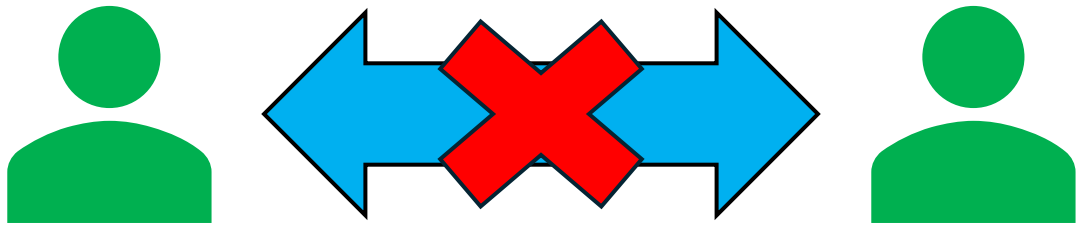


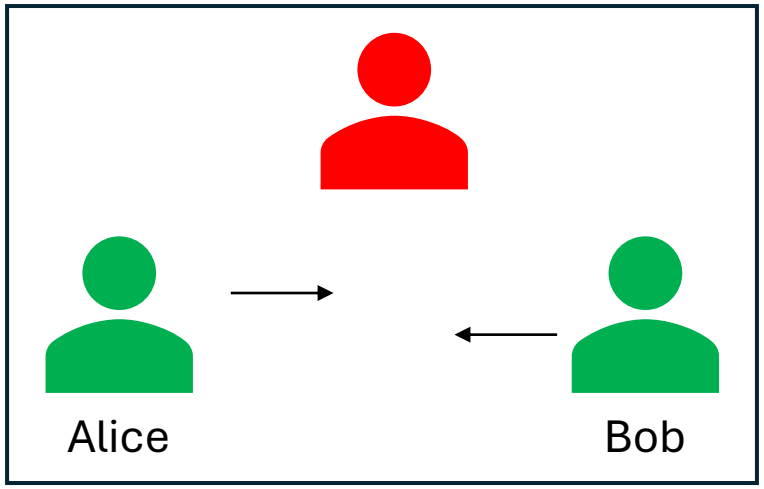
- **Idea**: leverage on **split** functionalities [**BCL+05**] (CRYPTO'05, JoC'07).

Removing authenticated channels in standard UC



- **Idea**: leverage on **split** functionalities [**BCL+05**] (CRYPTO'05, JoC'07).
- The **worse** the adversary can do is partition parties before the protocol run.

Split authentication in standard UC



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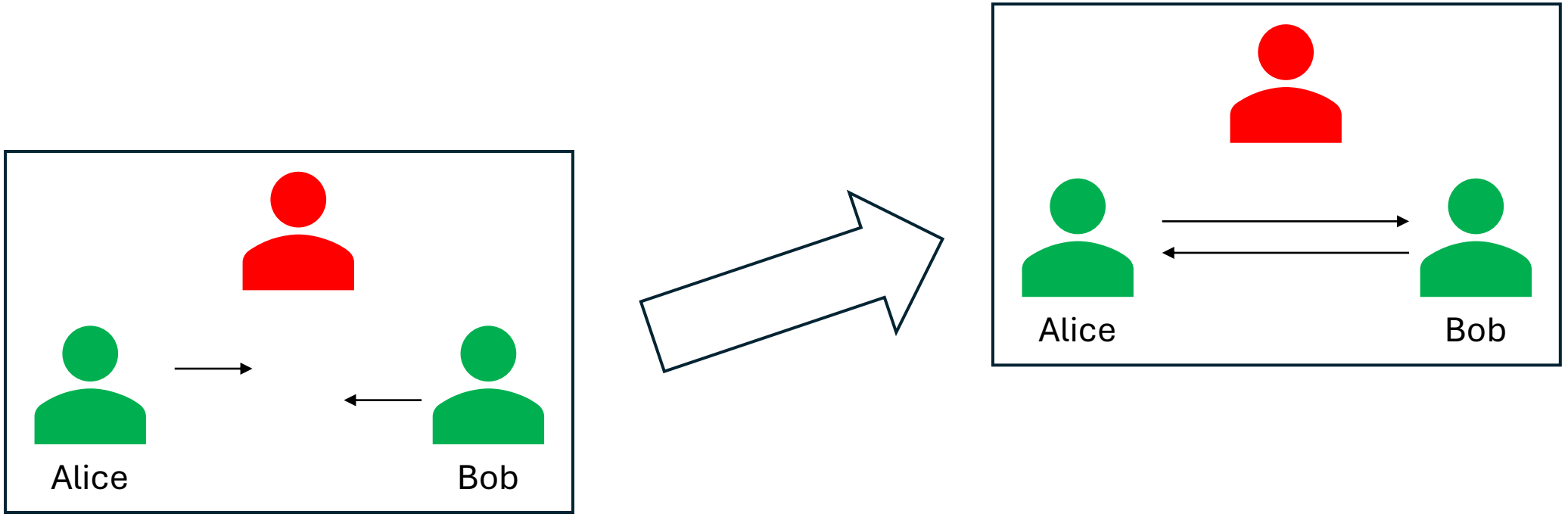

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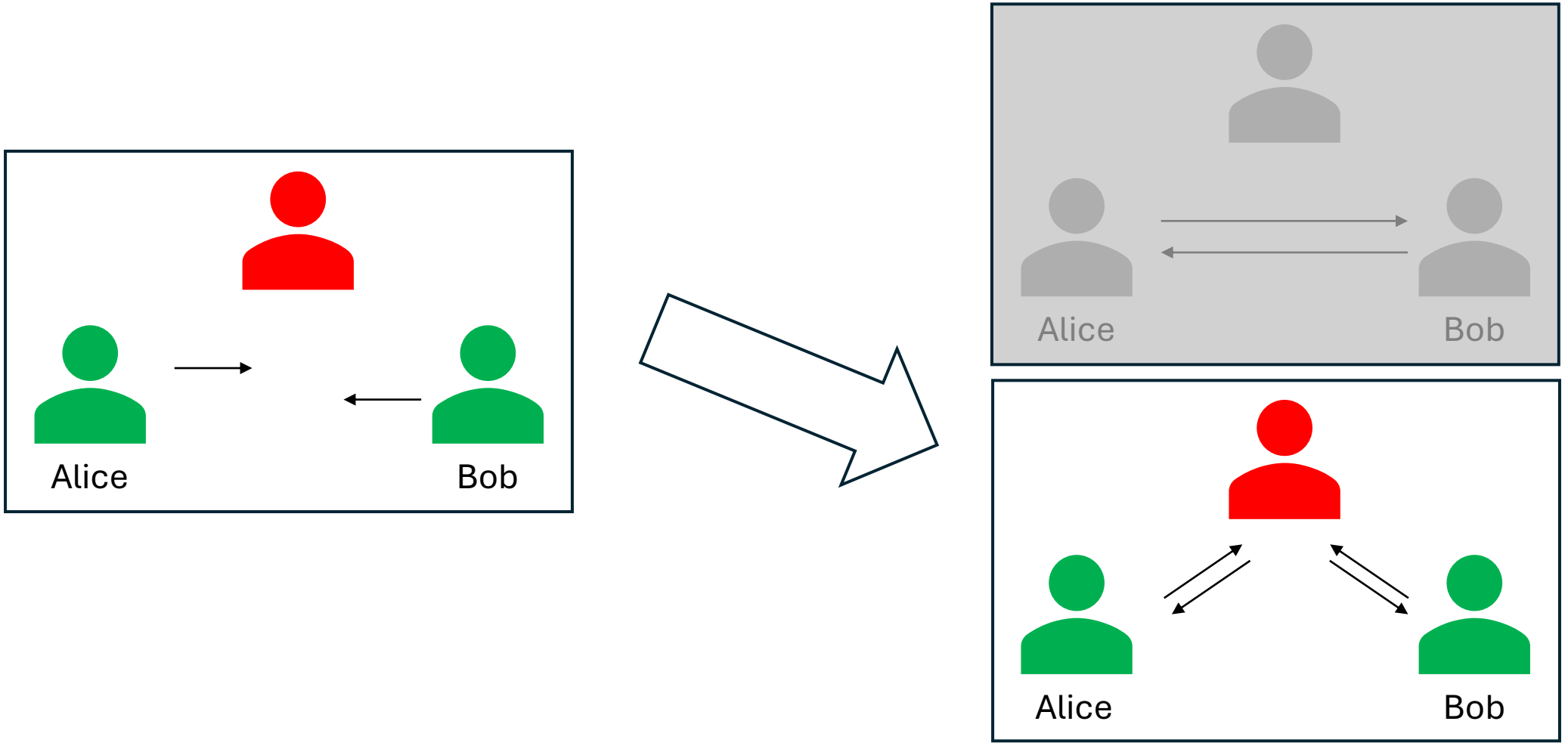


Split authentication in standard UC [BCL+05]

Client P_i

$(\mathsf{sk}_i, \mathsf{vk}_i) \leftarrow_{\$} \mathsf{KeyGen}(1^\lambda)$

$\mathsf{vk}_i \longrightarrow$

$\longleftarrow \mathsf{vk}_j$

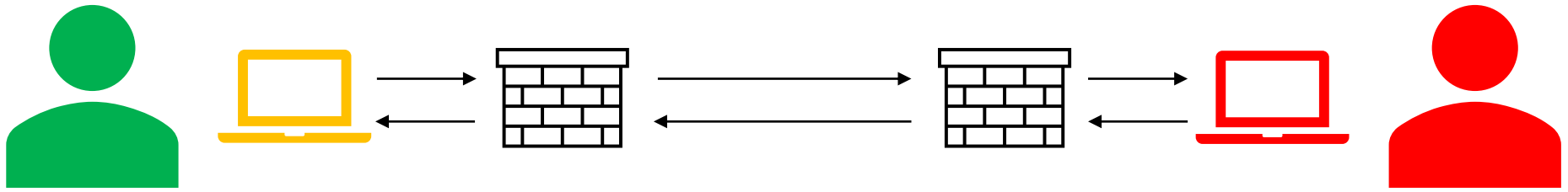
$\mathsf{sid}_i = (\mathsf{vk}_i, \mathsf{vk}_j)$
$\sigma_i = \mathsf{Sign}_{\mathsf{sk}_i}(\mathsf{sid}_i)$

$(\sigma_i, \mathsf{sid}_i) \longrightarrow$

$\longleftarrow (\sigma_j, \mathsf{sid}_j)$

If $\mathsf{sid}_i \neq \mathsf{sid}_j$, abort.
If $\mathsf{Vrfy}_{\mathsf{vk}_j}(\mathsf{sid}_j, \sigma_j) = 0$, abort.

Backbone of communication in srUC



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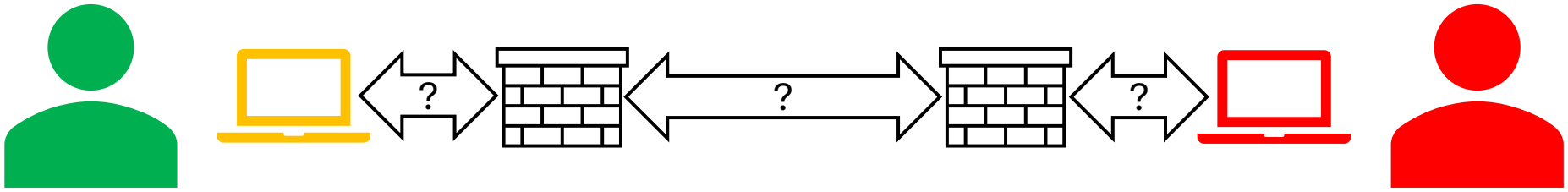
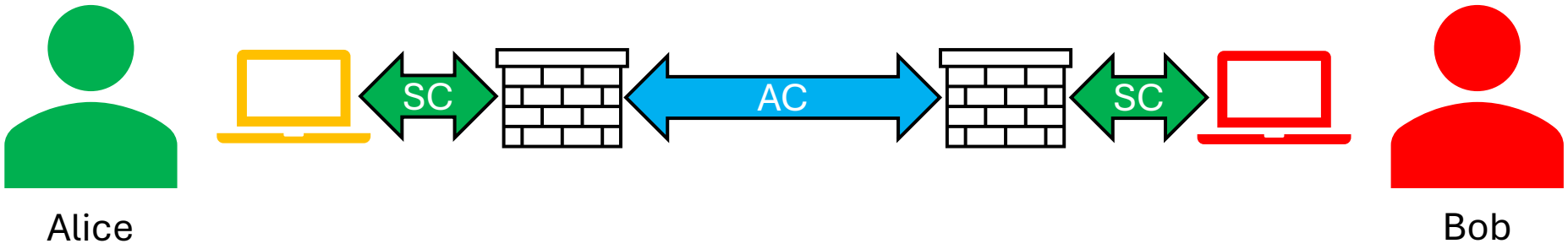
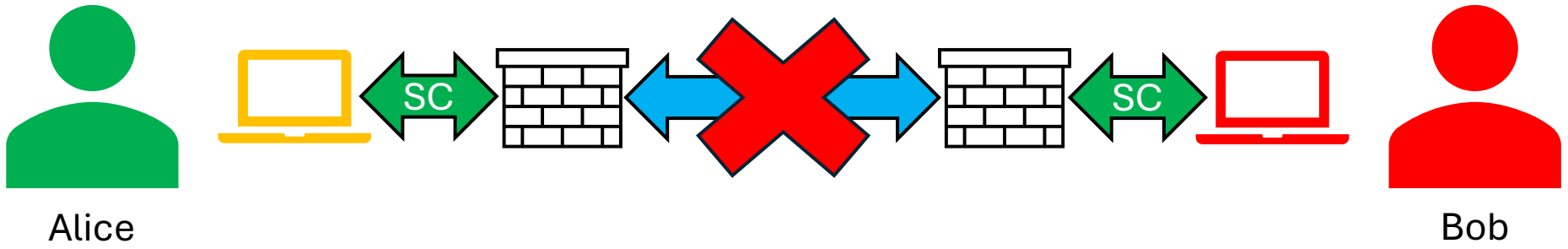


Backbone of communication in srUC ($\mathcal{F}_{SAT}$)



Backbone of communication in srUC (split $\mathcal{F}_{SAT}$)



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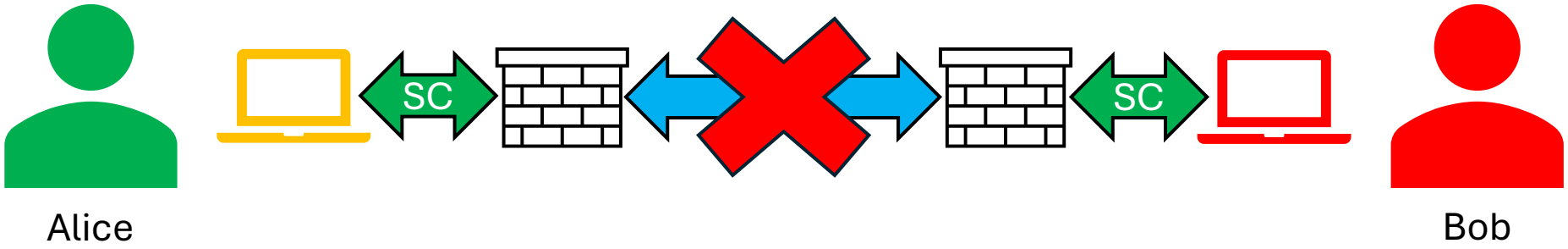
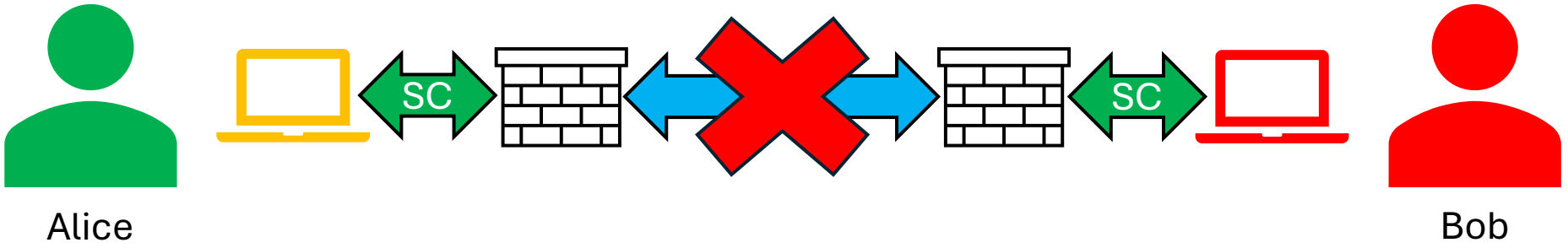


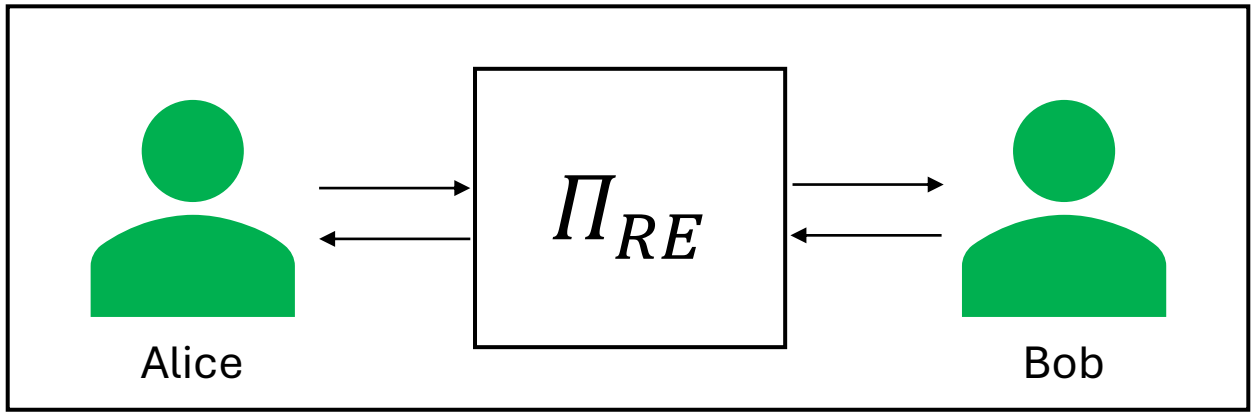
- Proper instantiation by sanitizing the protocol for split-auth shown before.

Backbone of communication in srUC (split $\mathcal{F}_{SAT}$)



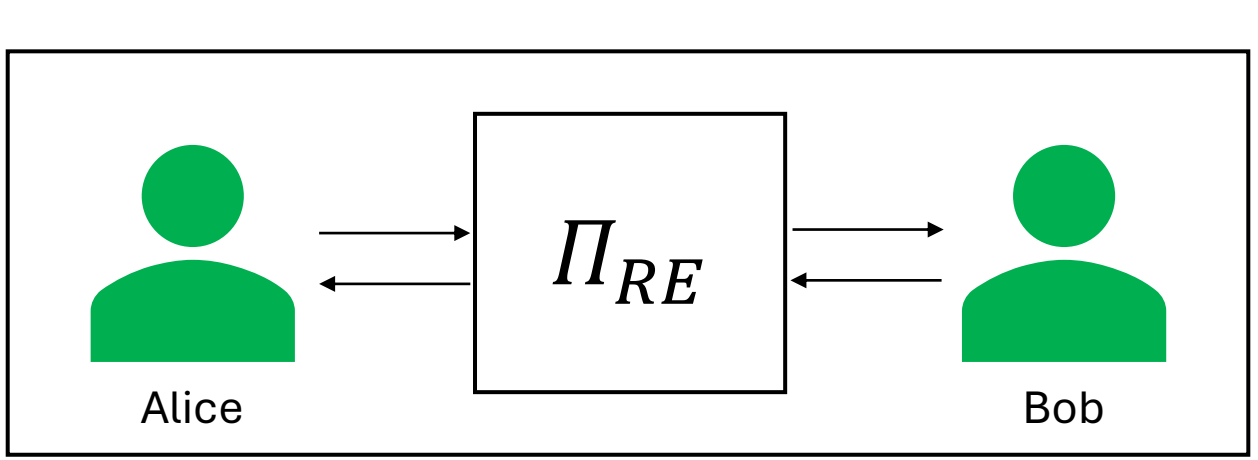
- Proper instantiation by sanitizing the protocol for split-auth shown before.
- Improving on an open problem: $\mathcal{F}_{SAT}$ was never instantiated in [**CMNV22**]!

From Π_{RE} to Π_{PAKE}



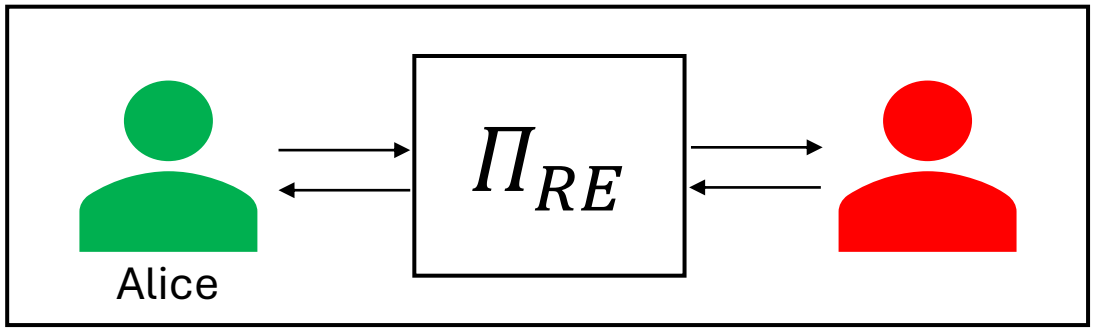
AUTH

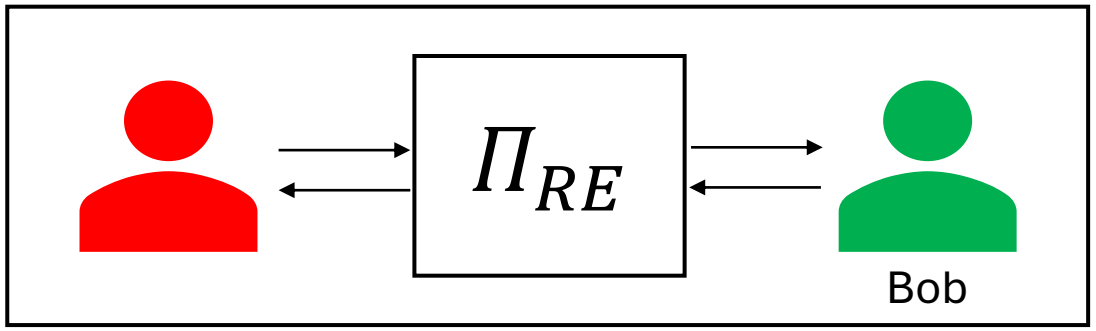
From Π_{RE} to Π_{PAKE}



AUTH

UNAUTH





Bird's eye view

Intro to subversion	$\mathcal{F}_{RE}$ from srOT
$\mathcal{F}_{RE}$ to $\mathcal{F}_{PAKE}$	**Wrapping up**

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- Introduction of the **first** PAKE protocol in the srUC framework.

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- Several new **sanitation-friendly** primitives.

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- Several new **sanitation-friendly** primitives.
- Extension of the srUC framework to the **unauthenticated** setting.
- **Open**: more efficient PAKE, other functionalities, new primitives – the sky's the limit!

Thanks!