QuietOT:
Lightweight Oblivious Transfer with a Public-Key Setup

INSTITUT
DE RECHERCHE
EN INFORMATIQUE
FONDAMENTALE

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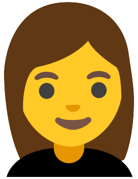
MIT CSAIL

Joint work with
Geoffroy Couteau, Lalita Devadas, Srinivas Devadas, and Alexander Koch

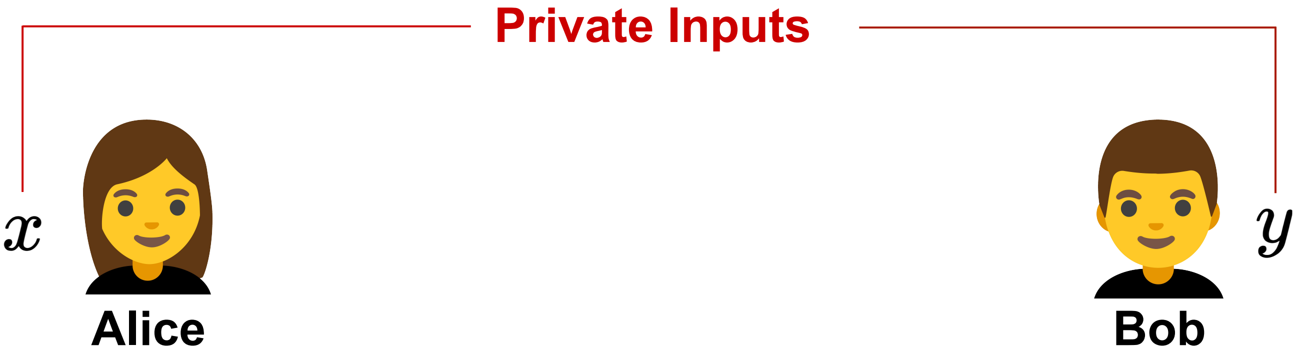
Secure Computation



Alice

Bob

Secure Computation



Private Inputs

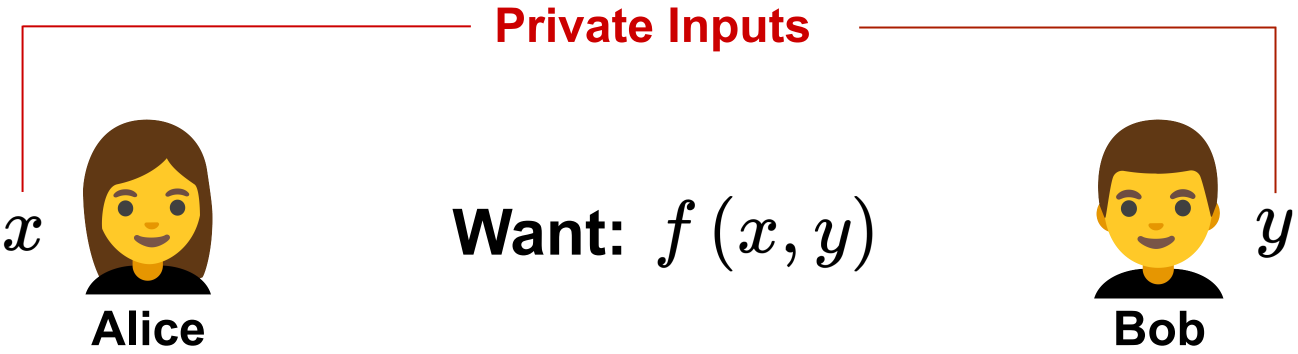
x

Alice

Bob

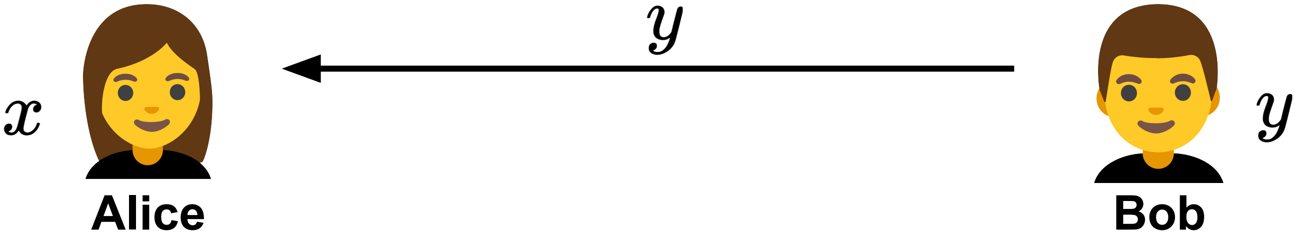
y

Secure Computation



Want: $f\left(x, y\right)$

Secure Computation

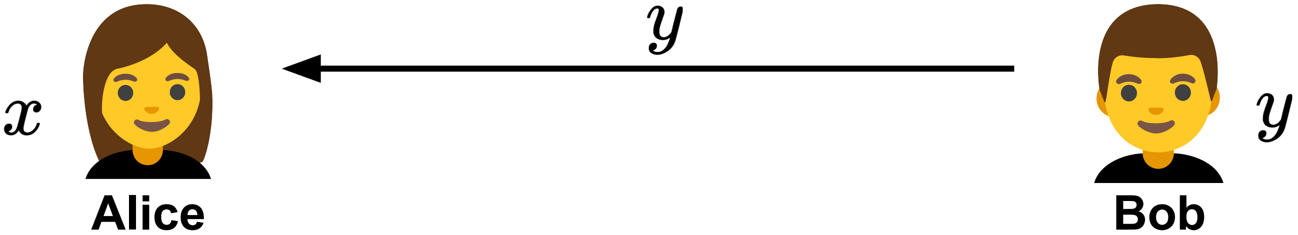


y

x **Alice**

Bob y

Secure Computation



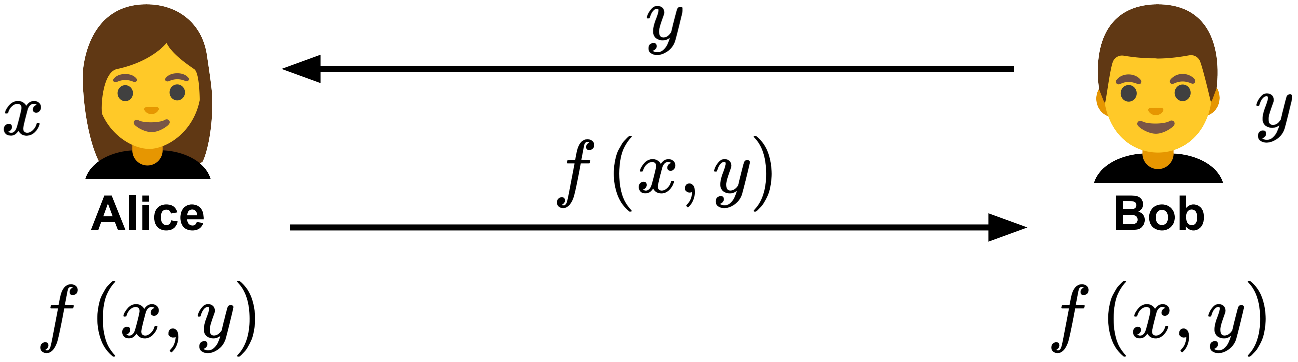
y

x **Alice**

Bob y

$f\left(x, y\right)$

Secure Computation



y

x **Alice**

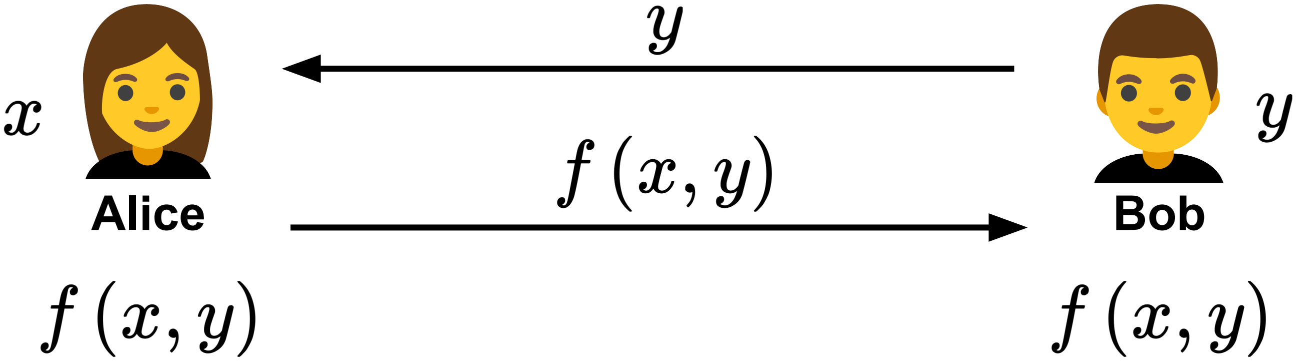
$f(x, y)$

Bob y

$f(x, y)$ $f(x, y)$

Secure Computation

Alice learns y ☹



x

Alice

y

$f(x, y)$

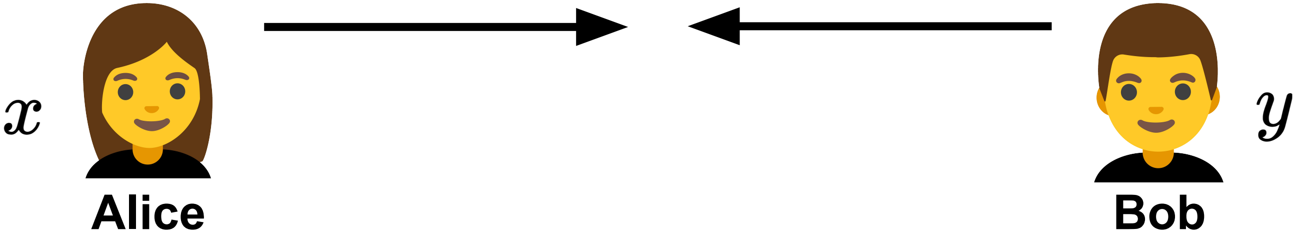
Bob

y

$f(x, y)$

$f(x, y)$

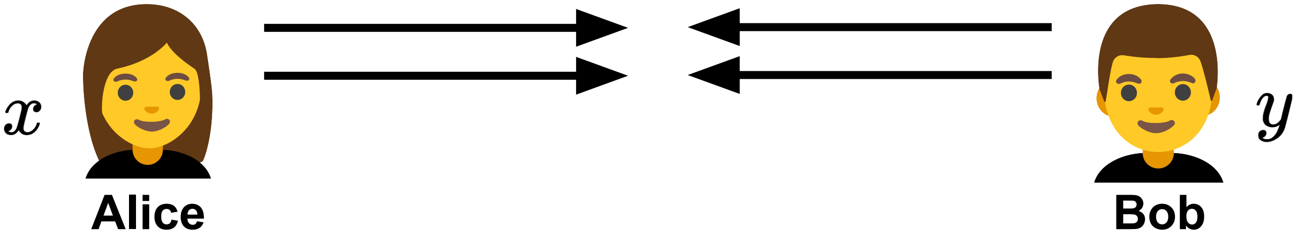
Secure Computation



x **Alice**

Bob y

Secure Computation



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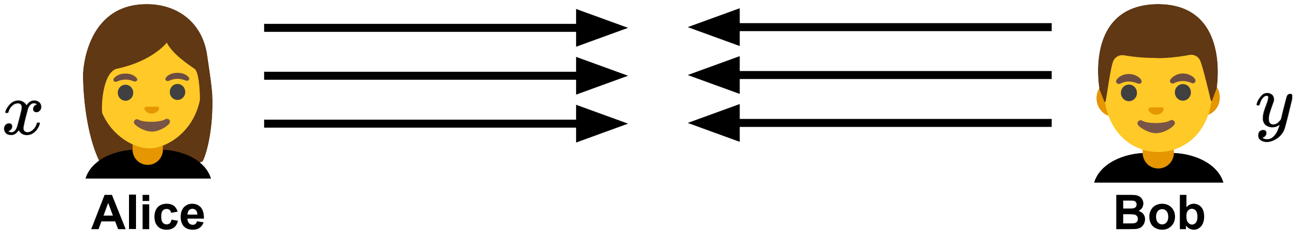

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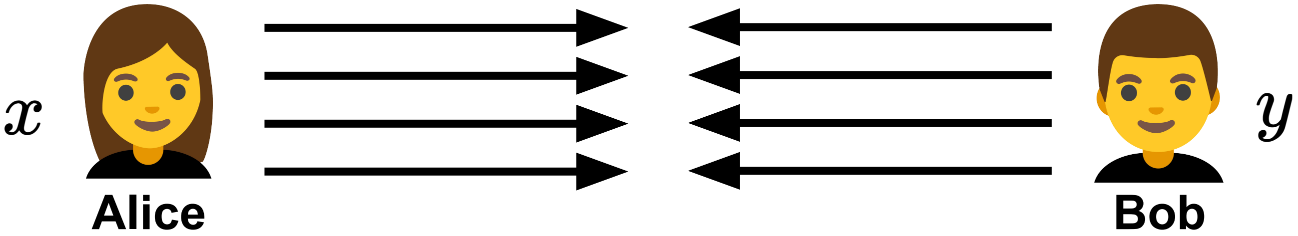

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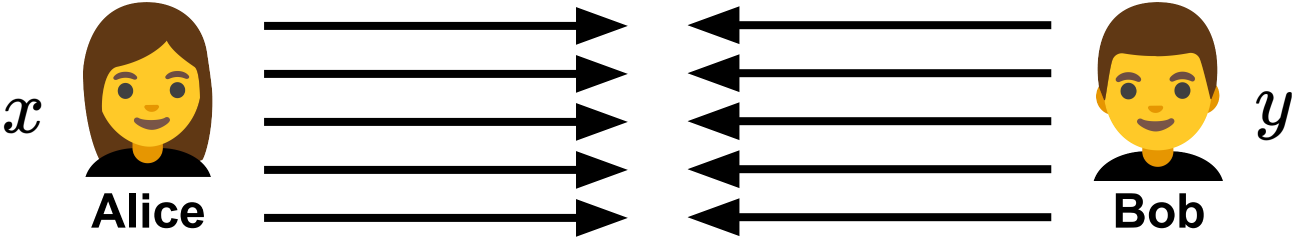

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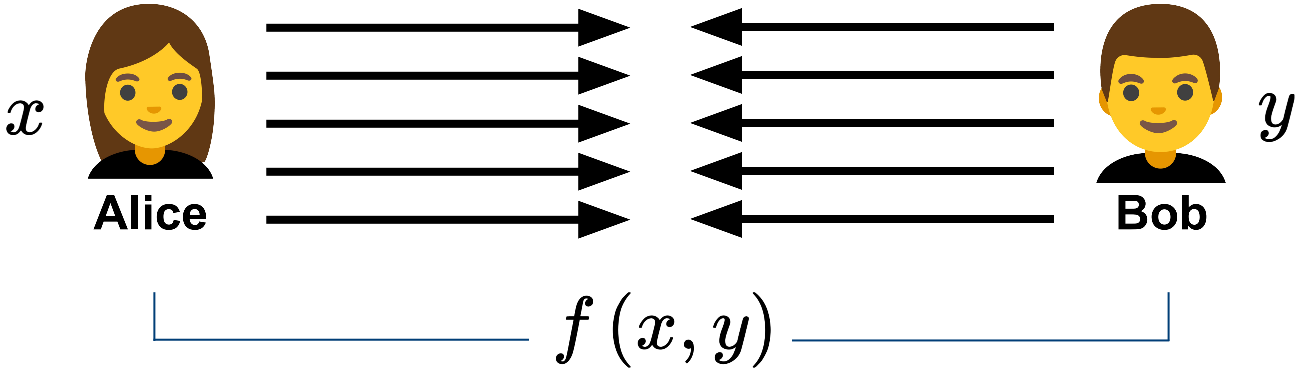

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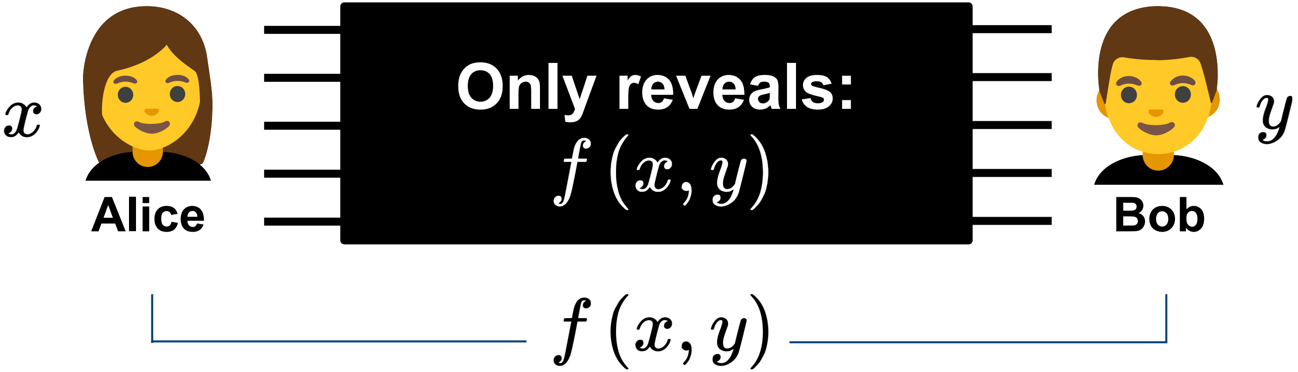


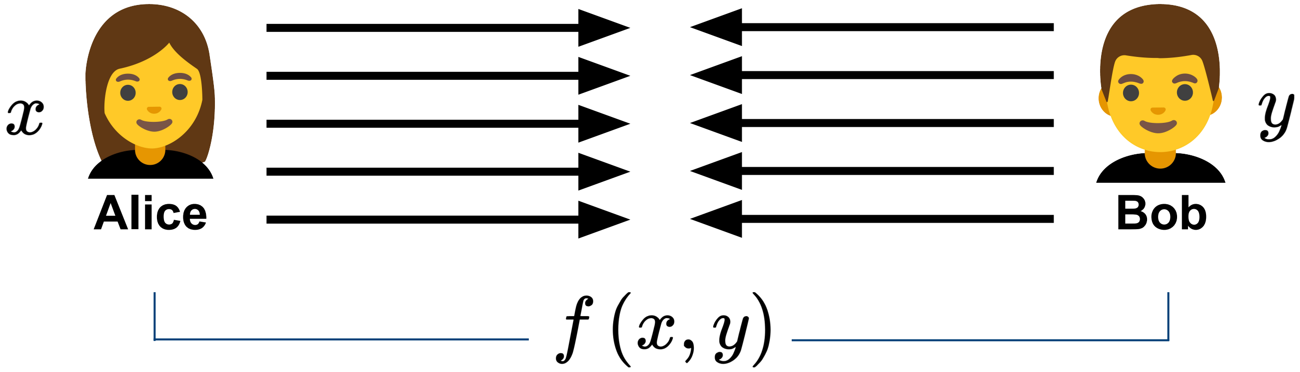
x **Alice**

Only reveals:
$f\left(x, y\right)$

Bob y

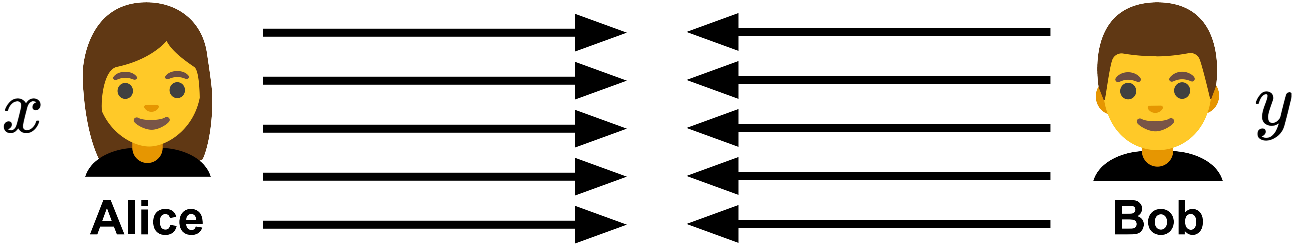
$f\left(x, y\right)$

Secure Computation

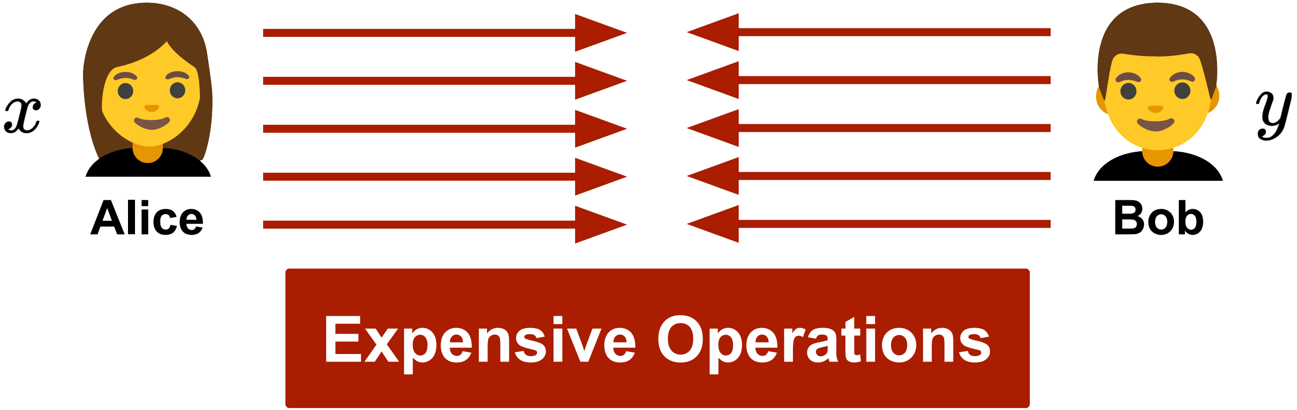


The Preprocessing Model

Preprocessing Model



Preprocessing Model



x

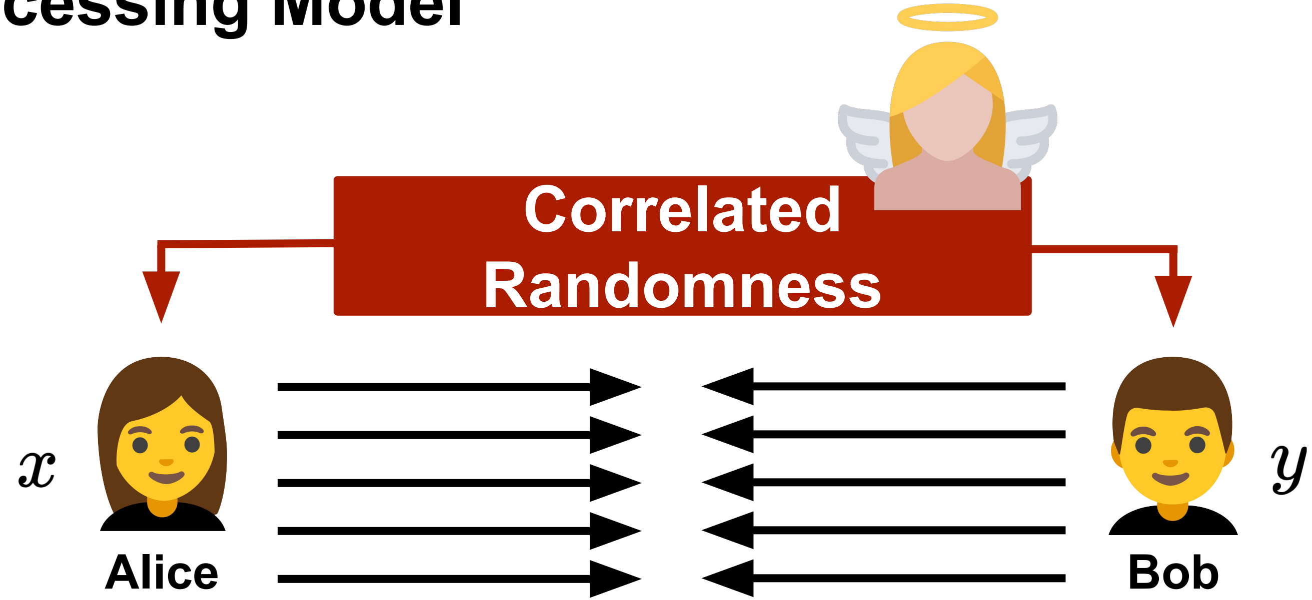
Alice

Bob

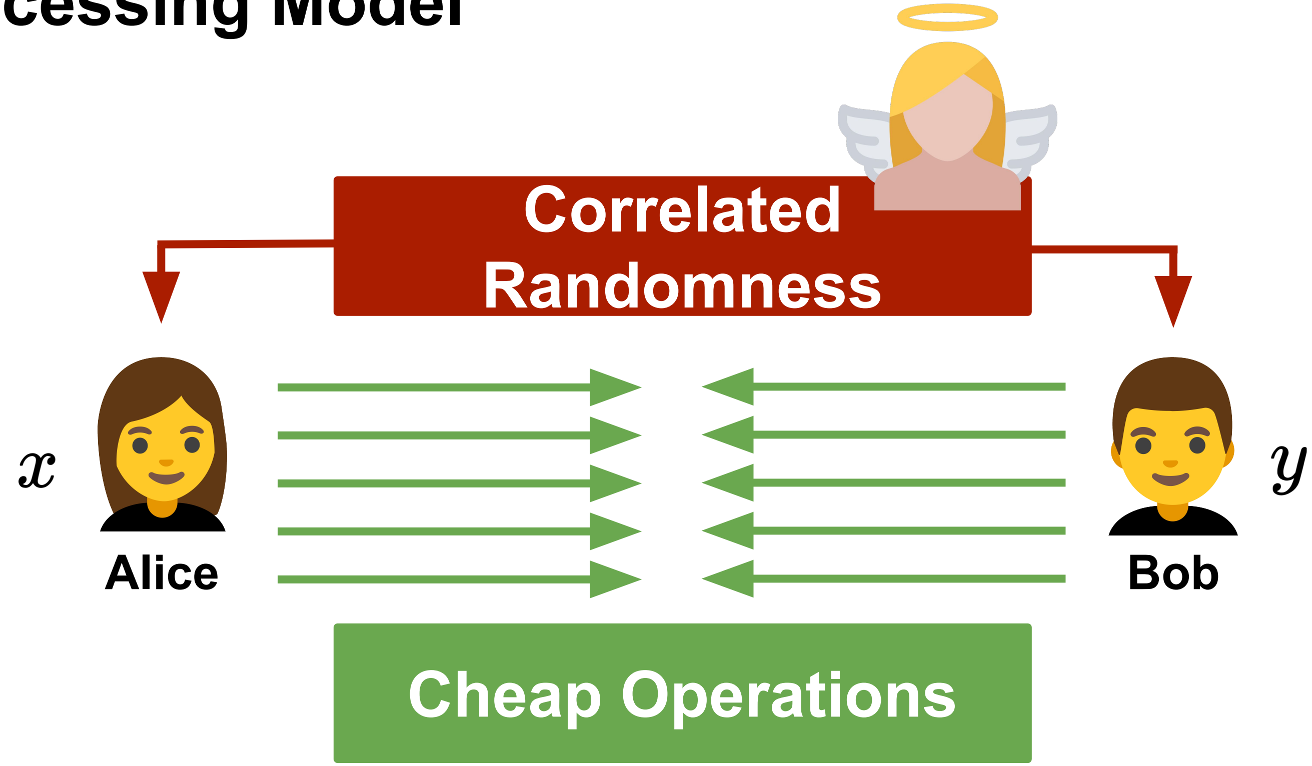
y

Expensive Operations

Preprocessing Model



Preprocessing Model



Correlated Randomness

x

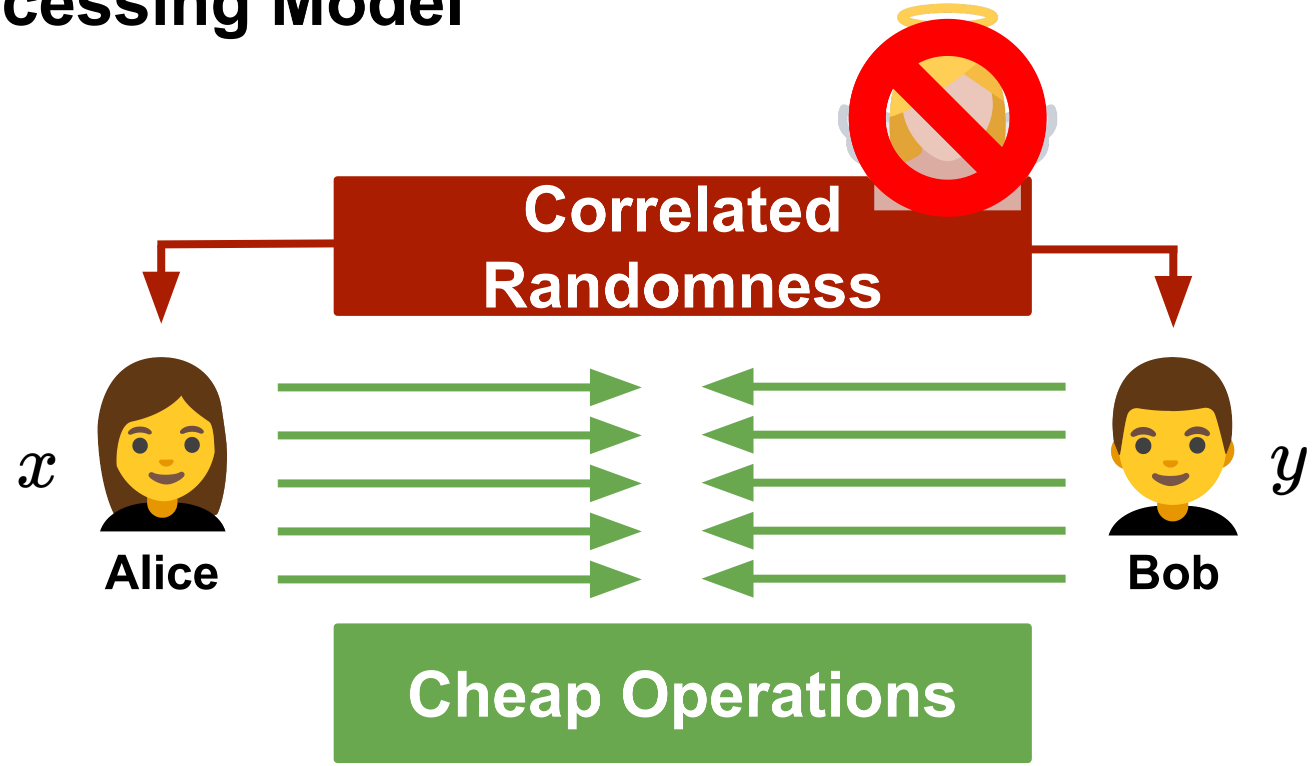
Alice

Bob

y

Cheap Operations

Preprocessing Model



Correlated Randomness

x

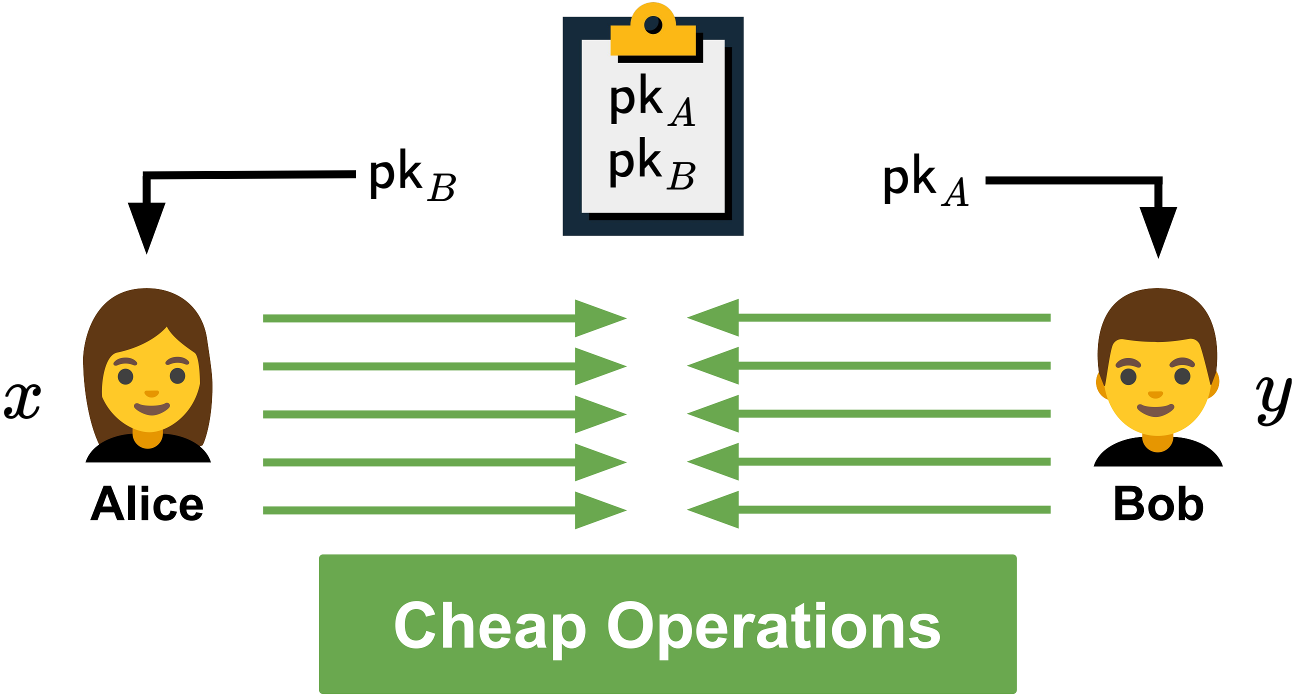
Alice

Bob

y

Cheap Operations

Preprocessing Model with a Public-Key Setup



pk_A
pk_B

pk_B

pk_A

x

Alice

y

Bob

Cheap Operations

This talk: Fast oblivious transfer with QuietOT

Overview

This talk: Fast oblivious transfer with QuietOT

Overview

- **Background on oblivious transfer**

This talk: Fast oblivious transfer with QuietOT

Overview

- **Background on oblivious transfer**
- **Background on OT extension**

This talk: Fast oblivious transfer with QuietOT

Overview

- **Background on oblivious transfer**
- **Background on OT extension**
- **QuietOT framework**

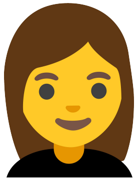
This talk: Fast oblivious transfer with QuietOT

Overview

- **Background on oblivious transfer**
- **Background on OT extension**
- **QuietOT framework**
- **Evaluation**

Oblivious Transfer

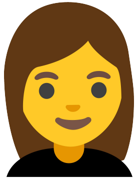
Oblivious Transfer



Alice

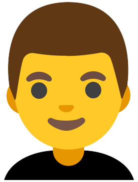
Bob

Oblivious Transfer



Alice

(m_0, m_1)



Bob

b

Oblivious Transfer

Alice

(m_0, m_1)

Wants: $\perp$

Bob

b

Wants: m_b

Oblivious Transfer

OT Protocol

b

(m_0, m_1)

m_b

Alice

Bob

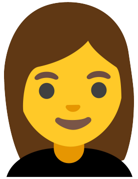
(m_0, m_1)

b

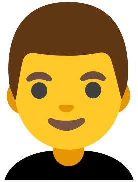
Wants: $\perp$

Wants: m_b

Oblivious Transfer for secure computation



Alice



Bob

Oblivious Transfer for secure computation

Secure Computation

Alice

x

Bob

y

Oblivious Transfer for secure computation

Alice

Secure Computation

Bob

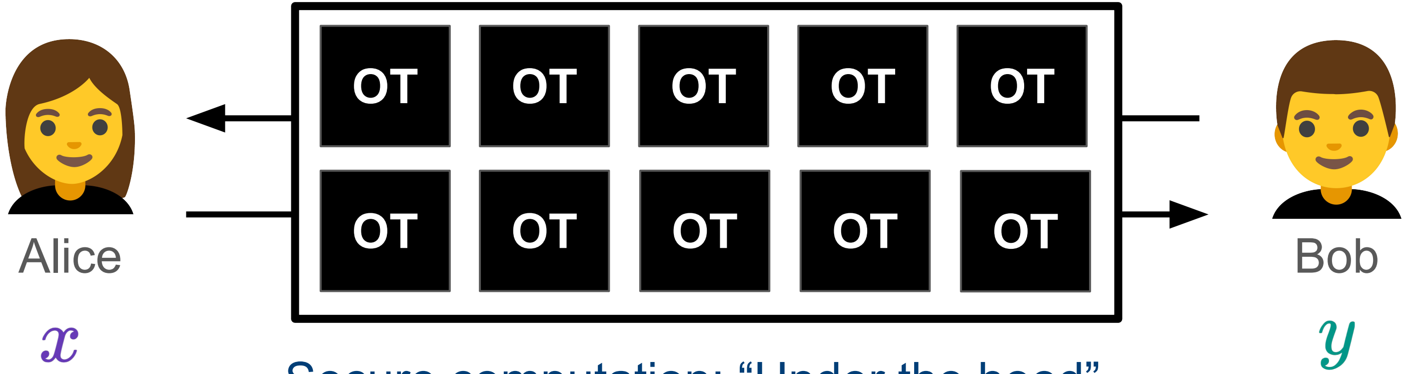
x

y

Wants: $\perp$

Wants: $f\left(x, y\right)$

Oblivious Transfer for secure computation



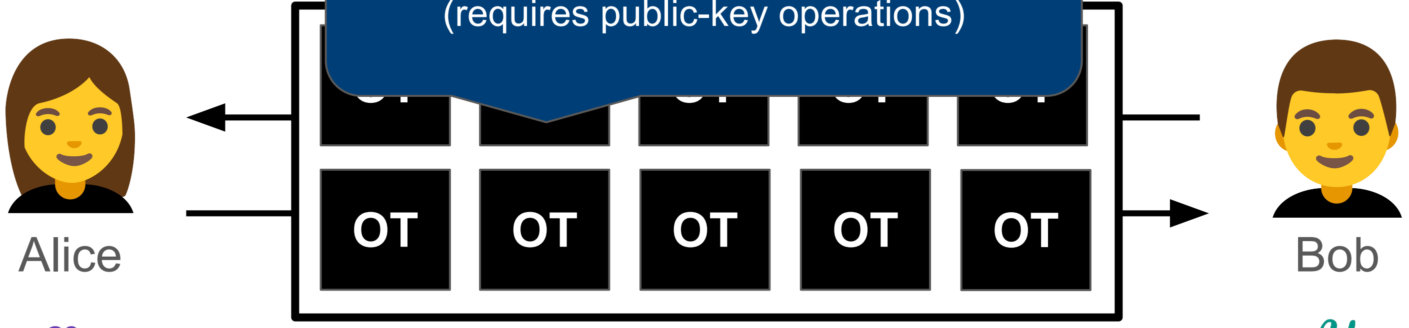
Secure computation: “Under the hood”

Wants: $\perp$

Wants: $f\left(x, y\right)$

Oblivious Transfer for secure computation

Each OT is computationally expensive
(requires public-key operations)



x

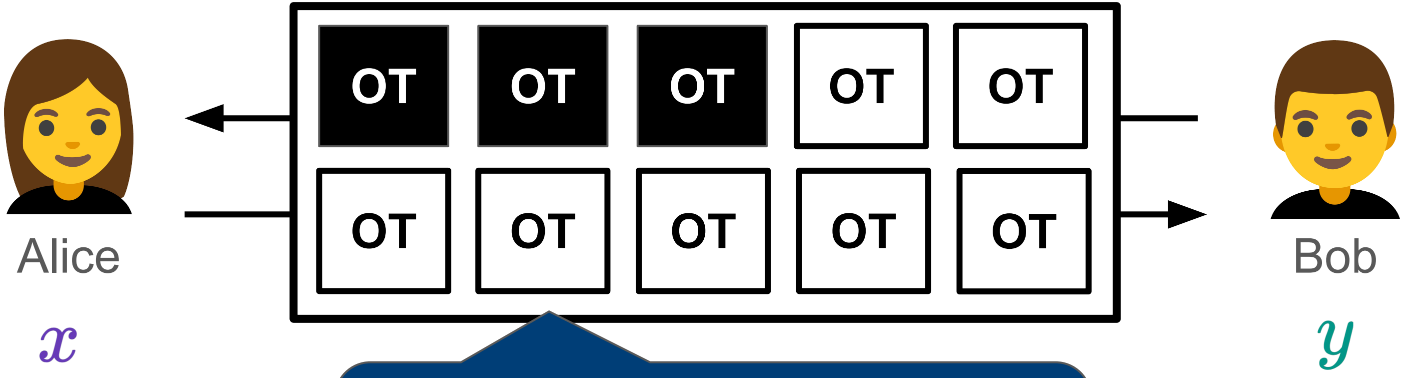
y

Secure computation: “Under the hood”

Wants: $\perp$

Wants: $f(x, y)$

Oblivious Transfer for secure computation



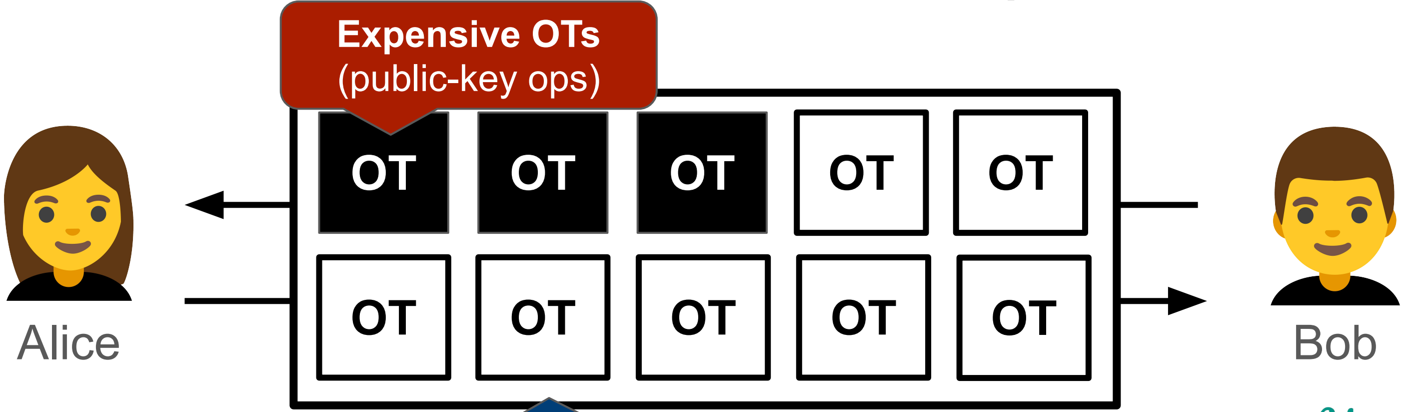
Idea: OT Extension [Beaver'96],[IKNP'03]

1. Compute a small number of OT
2. "Extend" them to many OTs

Wants: $\perp$

Wants: $f(x, y)$

Oblivious Transfer for secure computation



Expensive OTs
(public-key ops)

x

y

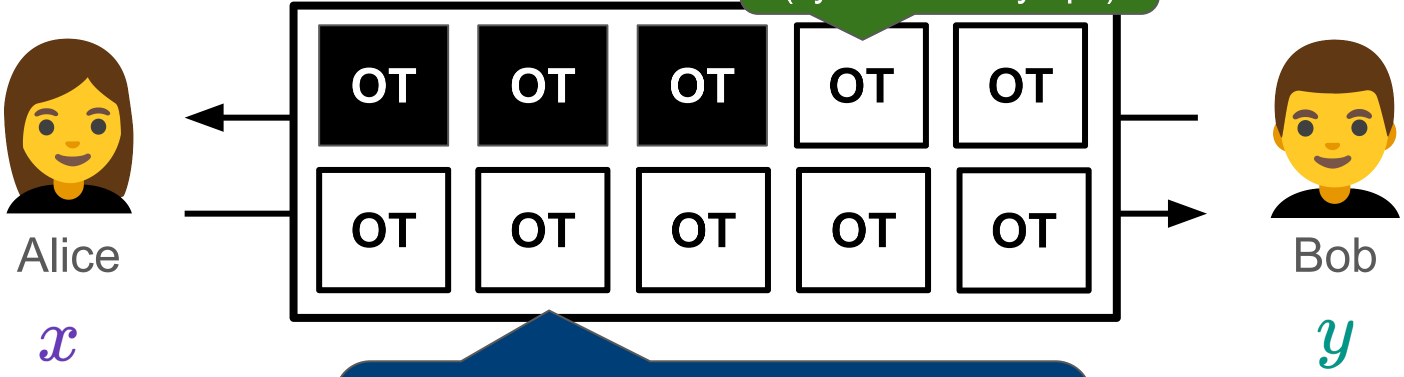
Wants: $\perp$

Idea: OT Extension [Beaver'96],[IKNP'03]

1. Compute a small number of OT
2. "Extend" them to many OTs

Wants: $f(x, y)$

Oblivious Transfer for secure computation



Cheap OTs
(symmetric-key ops)

Idea: OT Extension [Beaver'96],[IKNP'03]

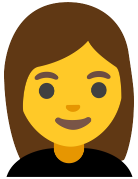
1. Compute a small number of OT
2. "Extend" them to many OTs

Wants: $\perp$

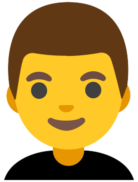
Wants: $f(x, y)$

OT Extension

OT Extension

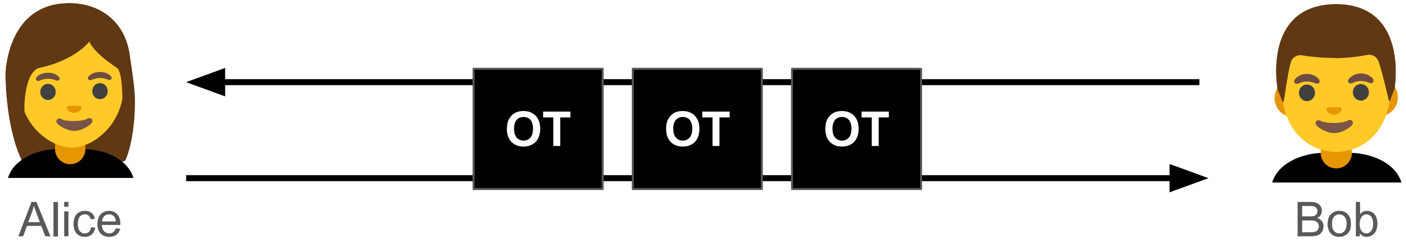


Alice



Bob

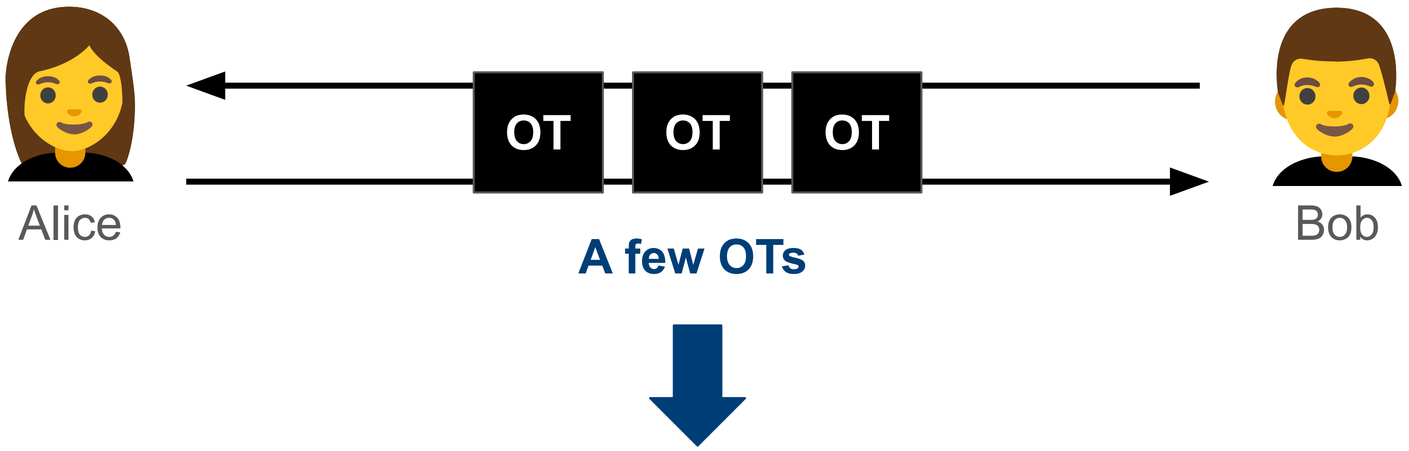
OT Extension



OT Extension

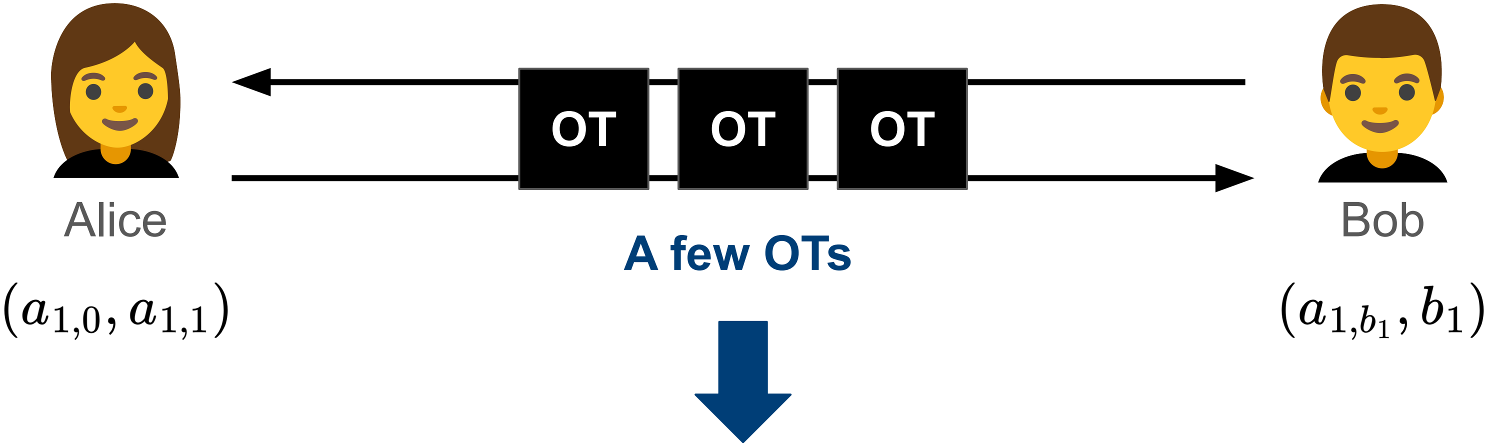
A few OTs

OT Extension



A few OTs

OT Extension



OT OT OT

Alice

$(a_{1,0}, a_{1,1})$

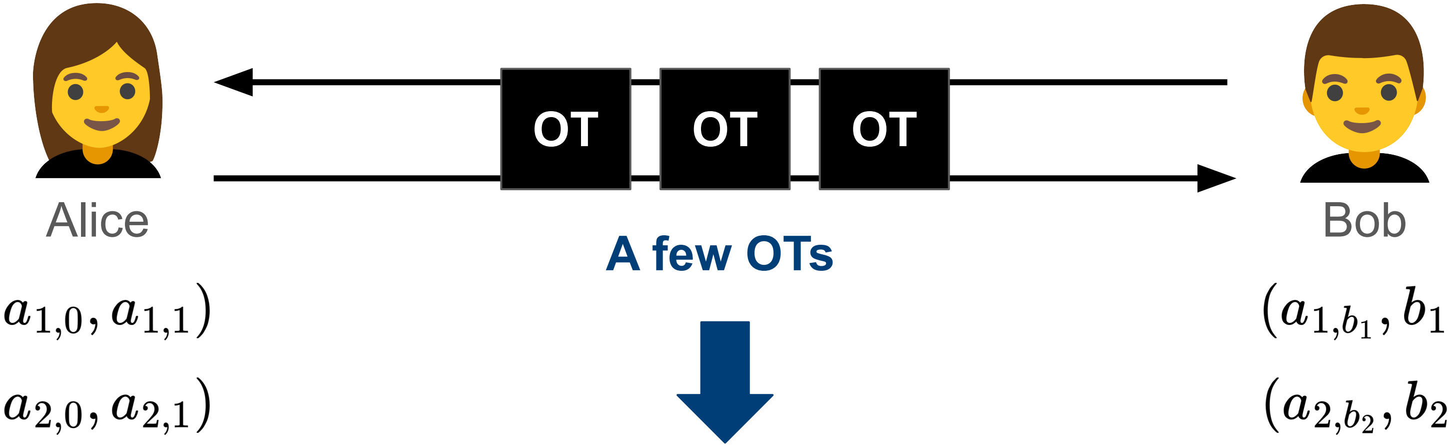
Bob

(a_{1,b_1}, b_1)

A few OTs

Many *Pseudo*random
OT Correlations

OT Extension



Alice

Bob

A few OTs

$(a_{1,0}, a_{1,1})$

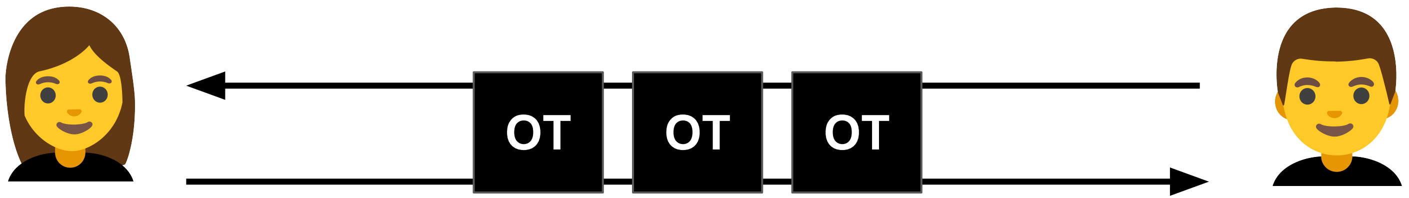
$(a_{2,0}, a_{2,1})$

(a_{1,b_1}, b_1)

(a_{2,b_2}, b_2)

Many *Pseudo*random OT Correlations

OT Extension



Alice

$(a_{1,0}, a_{1,1})$

$(a_{2,0}, a_{2,1})$

$(a_{3,0}, a_{3,1})$

A few OTs

Many *Pseudo*random OT Correlations

Bob

(a_{1,b_1}, b_1)

(a_{2,b_2}, b_2)

(a_{3,b_3}, b_3)

OT Extension

A few OTs

Many *Pseudo*random OT Correlations

$(a_{1,0}, a_{1,1})$

$(a_{2,0}, a_{2,1})$

$(a_{3,0}, a_{3,1})$

$(a_{4,0}, a_{4,1})$

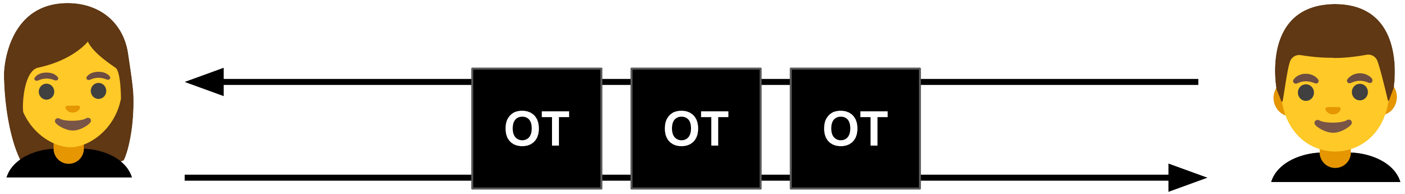
(a_{1,b_1}, b_1)

(a_{2,b_2}, b_2)

(a_{3,b_3}, b_3)

(a_{4,b_4}, b_4)

OT Extension



Alice

Bob

A few OTs

Many *Pseudo*random OT Correlations

$(a_{1,0}, a_{1,1})$

$(a_{2,0}, a_{2,1})$

$(a_{3,0}, a_{3,1})$

$(a_{4,0}, a_{4,1})$

$\vdots$

(a_{1,b_1}, b_1)

(a_{2,b_2}, b_2)

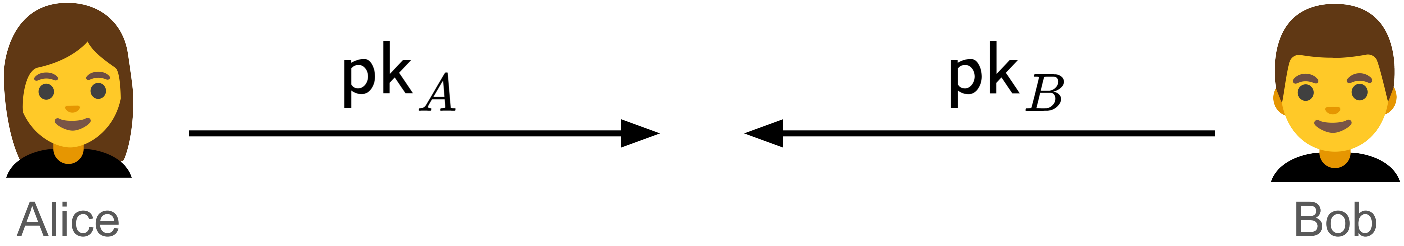
(a_{3,b_3}, b_3)

(a_{4,b_4}, b_4)

$\vdots$

OT Extension with a public-key setup

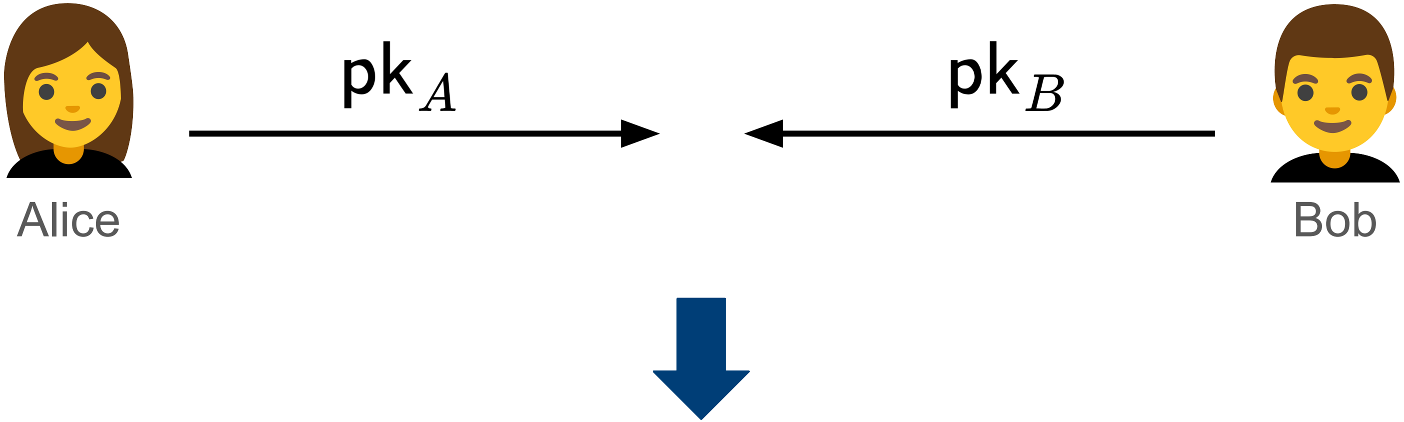
OT Extension with a public-key setup



Alice $\xrightarrow{\mathsf{pk}_A}$

$\xleftarrow{\mathsf{pk}_B}$ Bob

OT Extension with a public-key setup



Alice

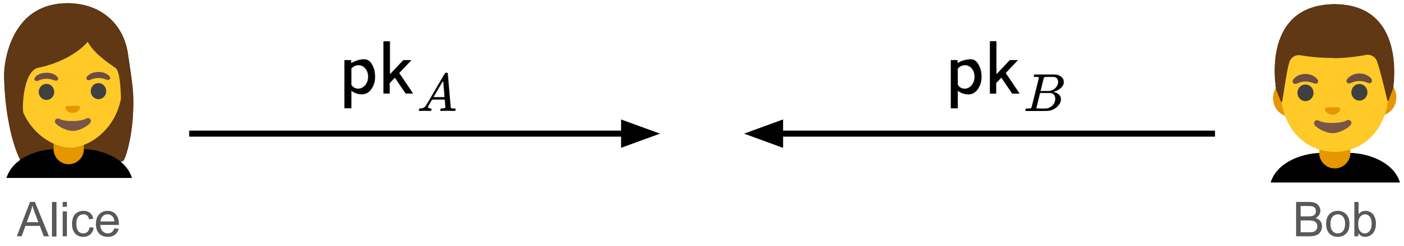
pk_A

pk_B

Bob

Many *Pseudo*random
OT Correlations

OT Extension **with a public-key setup**



Alice:

$(a_{1,0}, a_{1,1})$

$(a_{2,0}, a_{2,1})$

$(a_{3,0}, a_{3,1})$

$(a_{4,0}, a_{4,1})$

$\vdots$

Many *Pseudo*random OT Correlations

Bob:

(a_{1,b_1}, b_1)

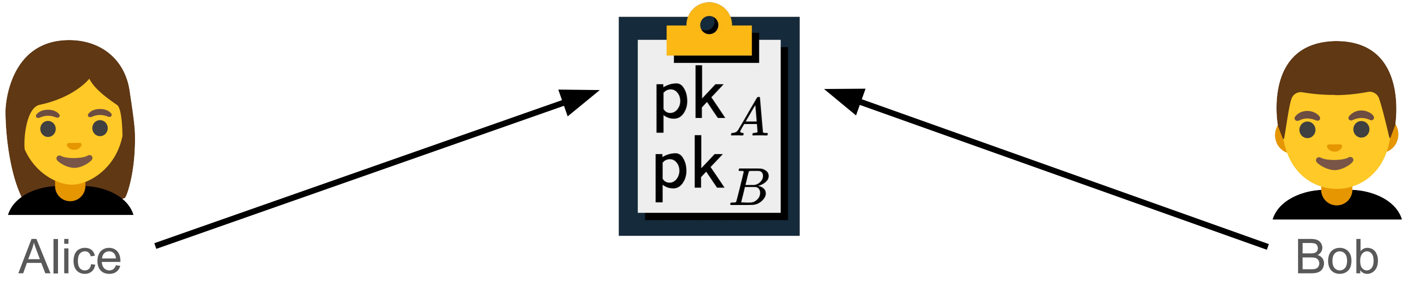
(a_{2,b_2}, b_2)

(a_{3,b_3}, b_3)

(a_{4,b_4}, b_4)

$\vdots$

OT Extension with a public-key setup



$(a_{1,0}, a_{1,1})$

$(a_{2,0}, a_{2,1})$

$(a_{3,0}, a_{3,1})$

$(a_{4,0}, a_{4,1})$

$\vdots$

Many *Pseudo*random OT Correlations

(a_{1,b_1}, b_1)

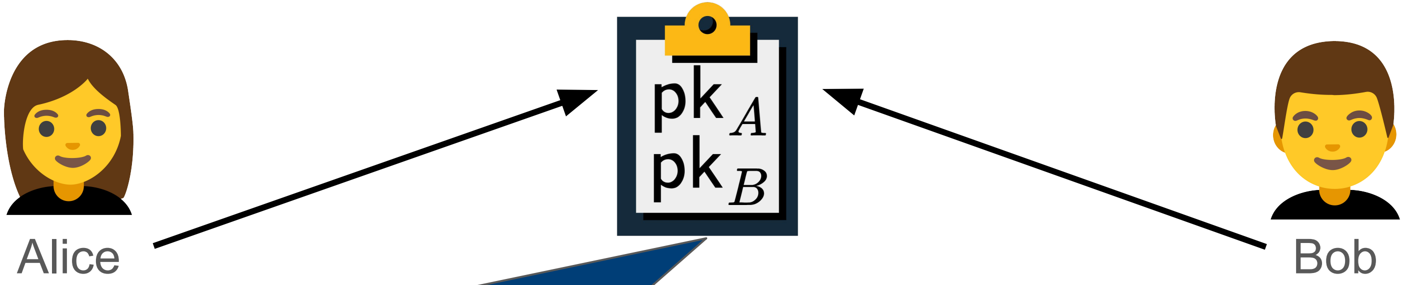
(a_{2,b_2}, b_2)

(a_{3,b_3}, b_3)

(a_{4,b_4}, b_4)

$\vdots$

OT Extension with a public-key setup



$(a_{1,0}, a_{1,1})$

$(a_{2,0}, a_{2,1})$

$(a_{3,0}, a_{3,1})$

$(a_{4,0}, a_{4,1})$

$\vdots$

**“Diffie–Hellman”
for OT extension**

**Many *Pseudo*random
OT Correlations**

(a_{1,b_1}, b_1)

(a_{2,b_2}, b_2)

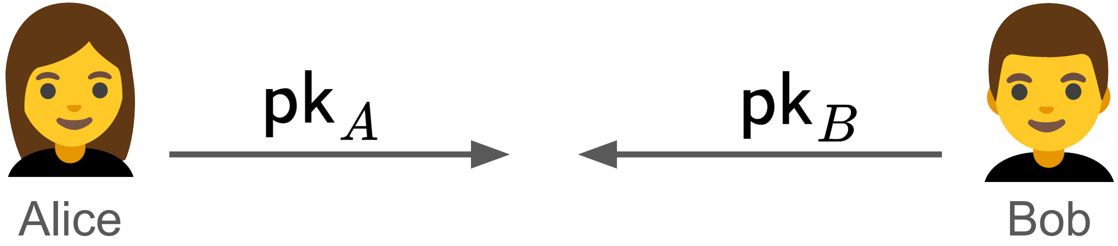
(a_{3,b_3}, b_3)

(a_{4,b_4}, b_4)

$\vdots$

QuietOT Framework

QuietOT: Communication model and syntax



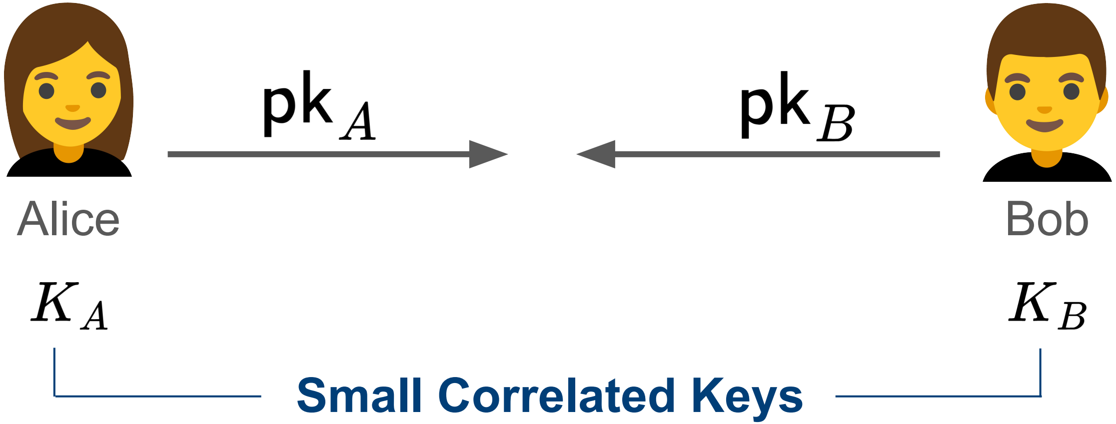
pk_A

pk_B

Alice

Bob

QuietOT: Communication model and syntax



pk_A

pk_B

Alice

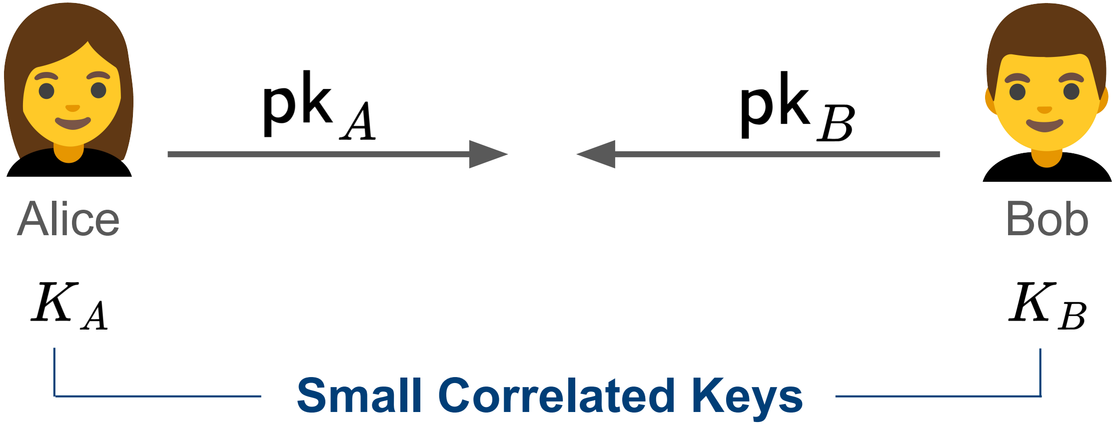
Bob

K_A

K_B

Small Correlated Keys

QuietOT: Communication model and syntax



$$((a_{1,0}, a_{1,1}), \ldots, (a_{n,0}, a_{n,1})) \leftarrow \mathsf{Extend}_A(K_A)$$

$$((a_{1,b_1}, b_1), \ldots (a_{n,b_n}, b_n)) \leftarrow \mathsf{Extend}_B(K_B)$$

Locally generate many pseudorandom "OTs"

QuietOT: The main ingredients

QuietOT: The main ingredients

CPRF for
Inner-Products

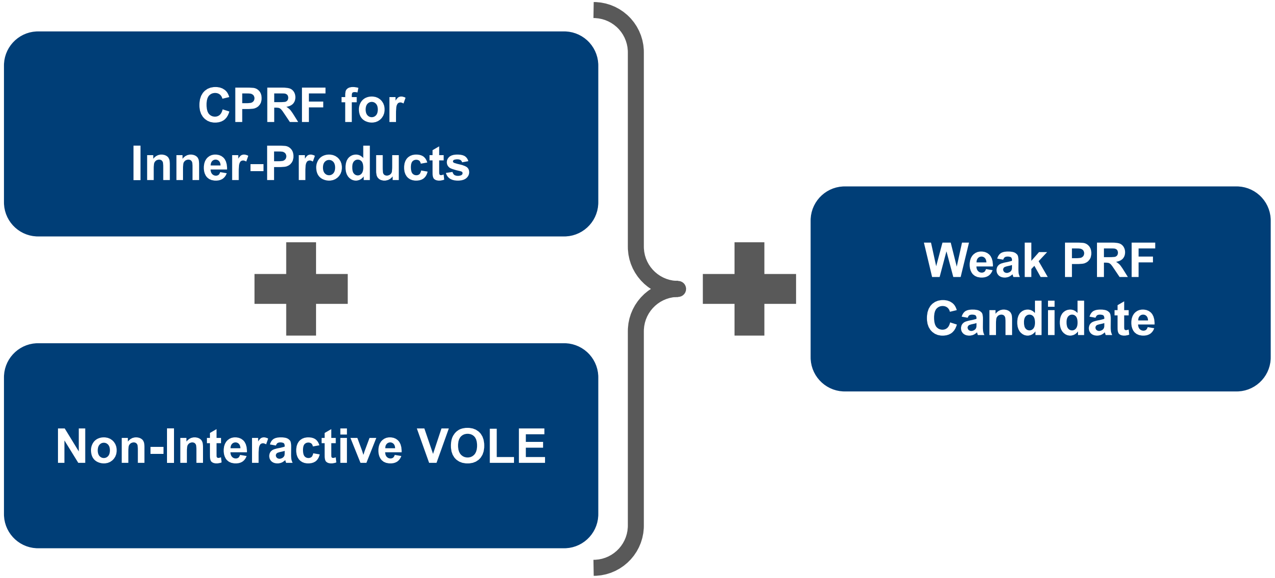
QuietOT: The main ingredients

CPRF for Inner-Products

+

Non-Interactive VOLE

QuietOT: The main ingredients

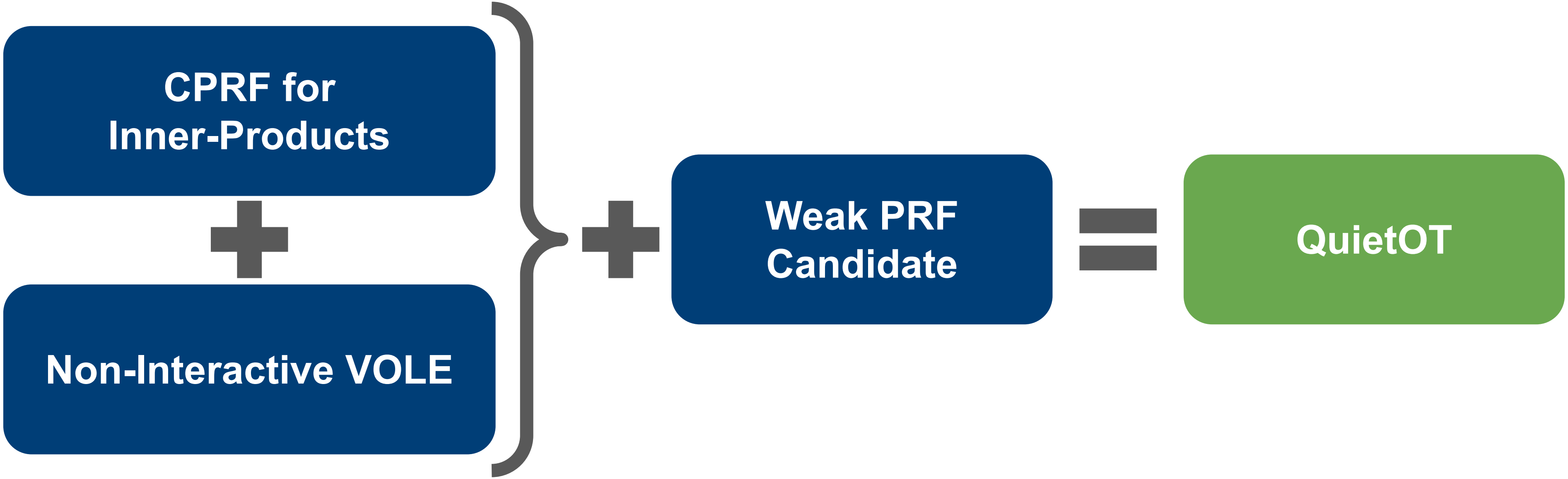


CPRF for Inner-Products

Non-Interactive VOLE

Weak PRF Candidate

QuietOT: The main ingredients



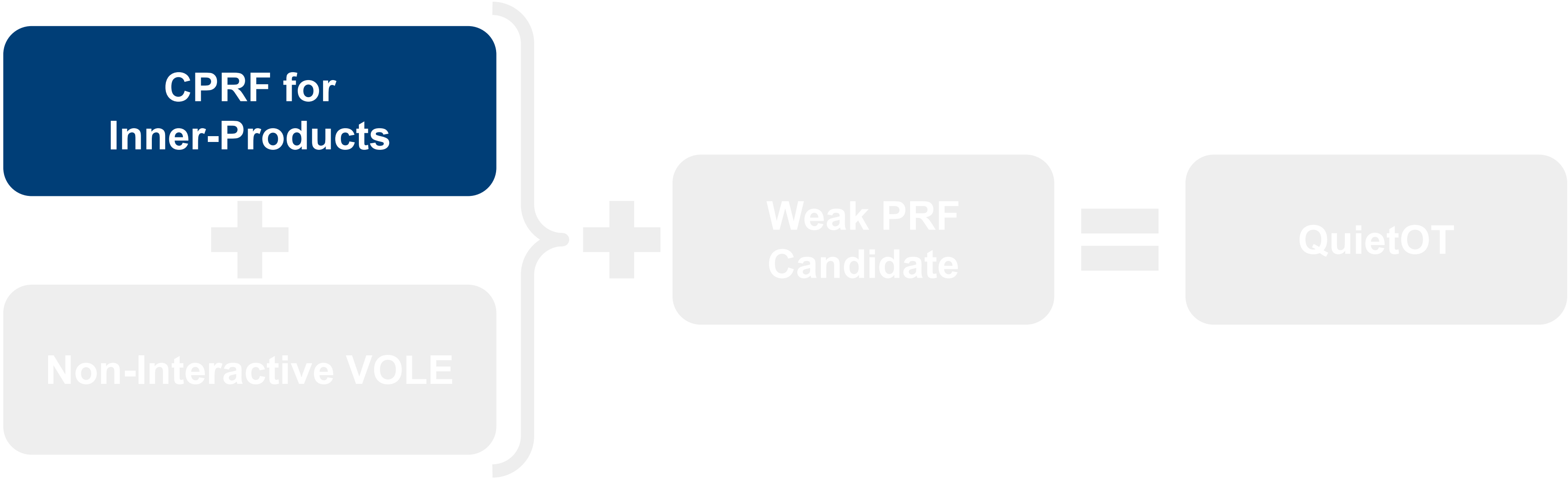
CPRF for Inner-Products

Non-Interactive VOLE

Weak PRF Candidate

QuietOT

QuietOT: The main ingredients



CPRF for Inner-Products

+

Non-Interactive VOLE

+

Weak PRF Candidate

=

QuietOT

Ingredient I: CPRF for Inner-Products

Constrained Pseudorandom Function (CPRF) [BW’13][KPTZ’13][BGI’14]

CPRFs have an additional **constrain** functionality for a class of circuits $\mathcal{C}$:

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Master PRF Key

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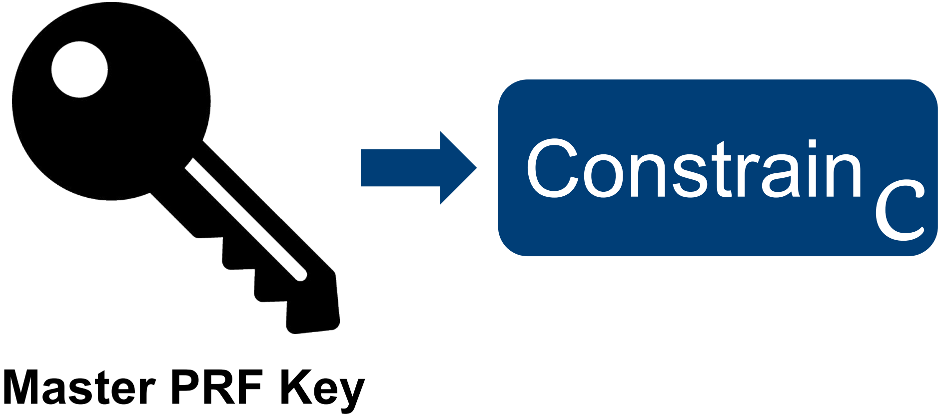

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Constrain_C

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Constrained PRF Key

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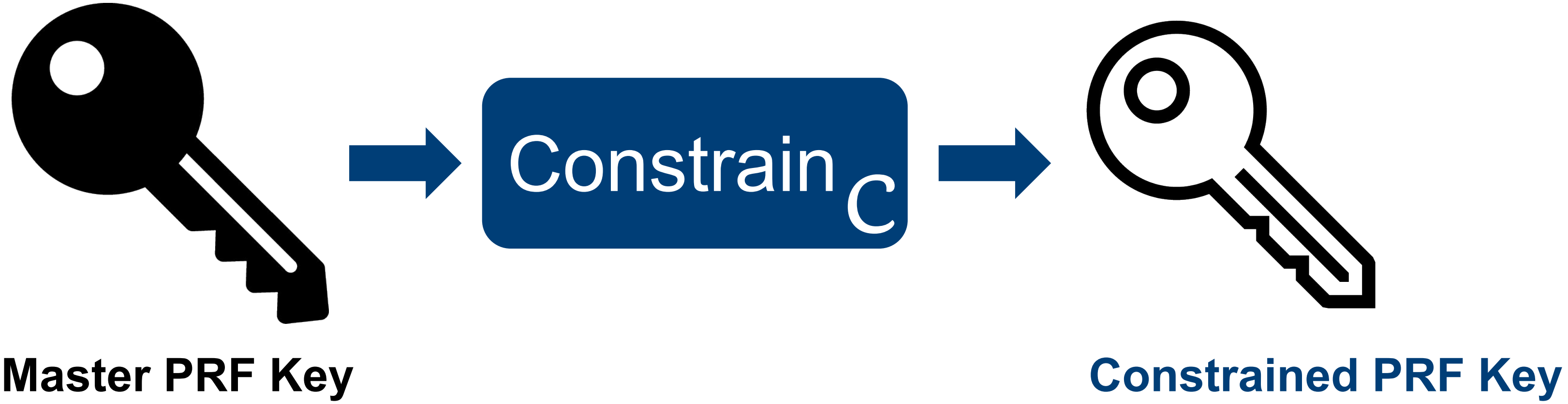


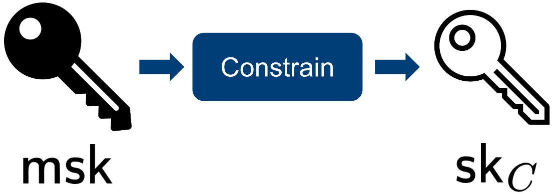
Constrain$_C$

Master PRF Key

Constrained PRF Key

Constrained key 🗝 can be used to evaluate PRF$($🔑$, x)$ for all $x \in \mathcal{X}$ where $C(x) = 0$

Ingredient I: CPRF for Inner-Products

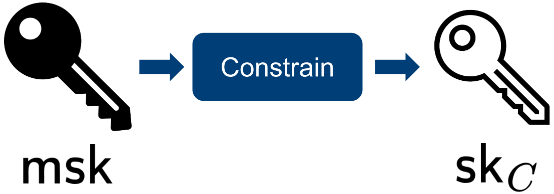


msk

Constrain

sk_C

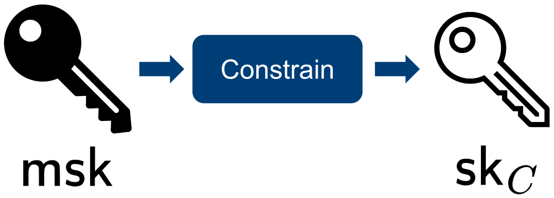
Ingredient I: CPRF for Inner-Products



msk → Constrain → sk_C

$$C(x) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

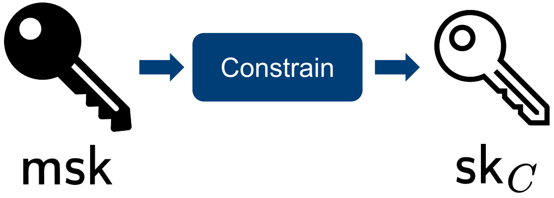
Ingredient I: CPRF for Inner-Products



$$C(x) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

Correctness: If $C(x) = 0$ then $\mathsf{PRF}(\mathsf{msk}, x) = \mathsf{PRF}(\mathsf{sk}_C, x)$

Ingredient I: CPRF for Inner-Products



$$C(x) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

Correctness: If $C(x) = 0$ then $\mathsf{PRF}(\mathsf{msk}, x) = \mathsf{PRF}(\mathsf{sk}_C, x)$

Pseudorandomness: If $C(x) \neq 0$ then $\mathsf{PRF}(\mathsf{msk}, x)$ is pseudorandom given sk_C

Ingredient I: CPRF for Inner-Products

For efficiency: Use CPRF with inner-product predicate

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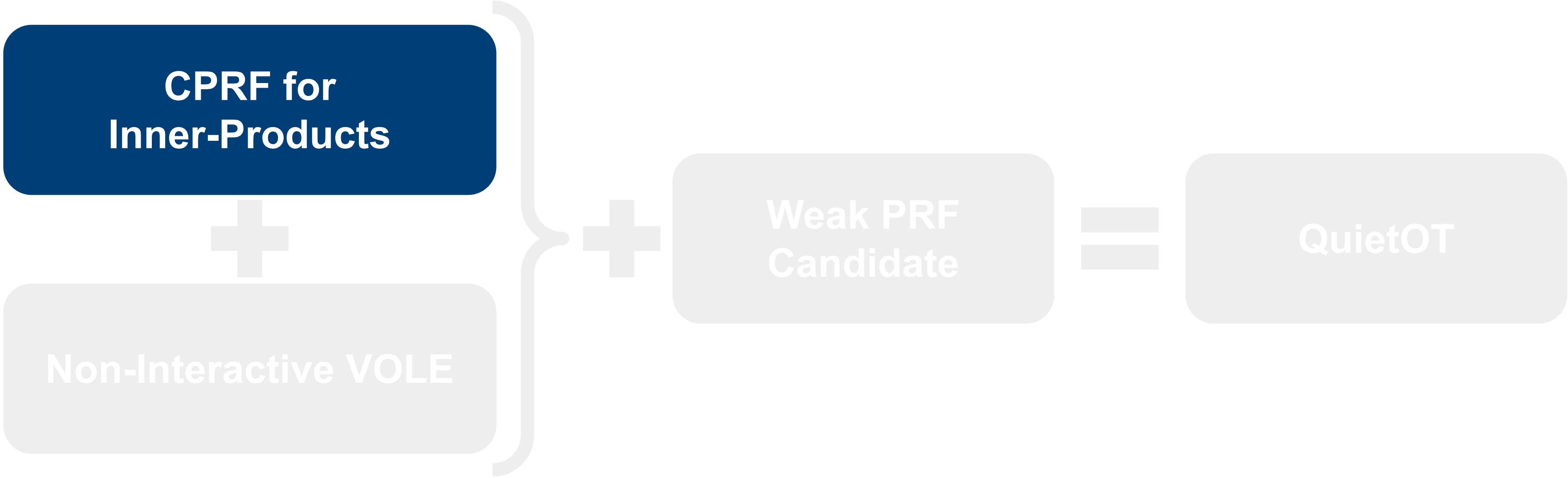
Ingredient I: CPRF for Inner-Products

For efficiency: Use CPRF with inner-product predicate

$$C\left(\mathbf{x}\right) = \left\langle \mathbf{z}, \mathbf{x} \right\rangle \in \mathcal{R} \text{ where } \mathbf{z}, \mathbf{x} \in \mathcal{R}^{\ell}$$

We use the random-oracle based CPRF construction of [S’24]

QuietOT: The main ingredients



CPRF for Inner-Products

Non-Interactive VOLE

Weak PRF Candidate

QuietOT

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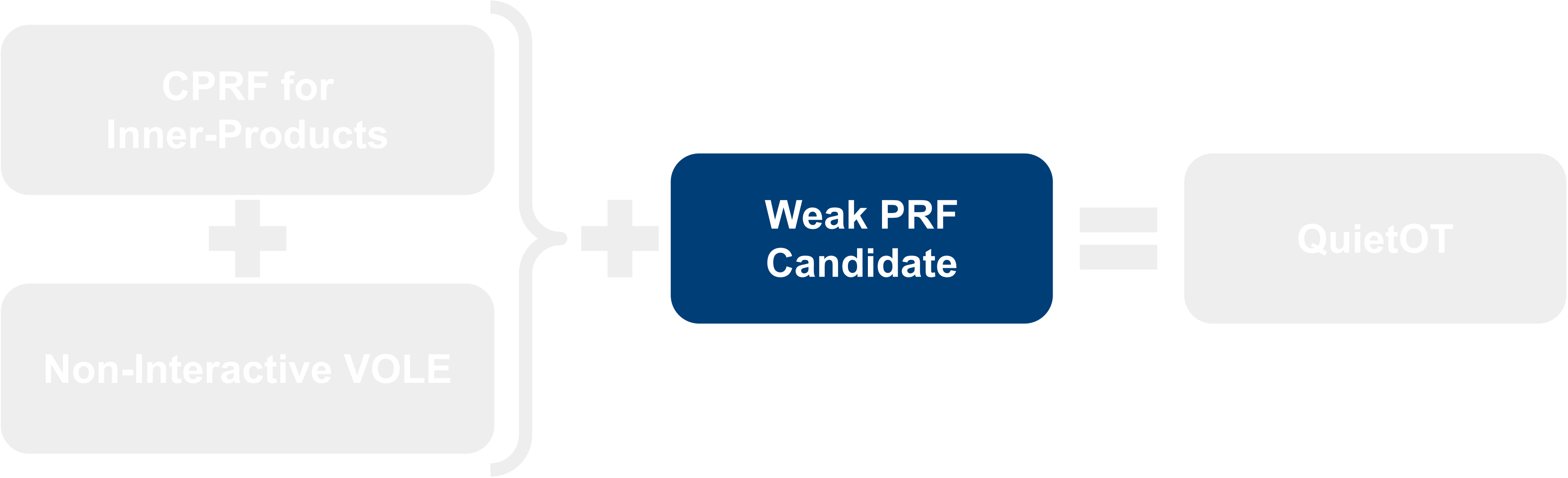

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Ingredient II: “Inner-Product Membership” PRF

BIPSW weak PRF candidate: [BIPSW’18]

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$$f_{\mathbf{k}}(\mathbf{x}) := \lceil \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \rfloor_2$$

Ingredient II: “Inner-Product Membership” PRF

BIPSW weak PRF candidate: [BIPSW’18]

$$f_{\mathbf{k}}(\mathbf{x}) := \lceil \underbrace{\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6}_{\text{Just an inner product}} \rfloor_2$$

Ingredient II: “Inner-Product Membership” PRF

BIPSW weak PRF candidate: [BIPSW’18]

$$f_{\mathbf{k}}(\mathbf{x}) := \underbrace{\lceil \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \rfloor_2}_{\text{Cannot be evaluated as an inner product}}$$

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BIPSW weak PRF candidate: [BIPSW’18]

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$$f_{\mathbf{k}}(\mathbf{x}) = 0 \iff \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \in \{0, 1, 2\}$$

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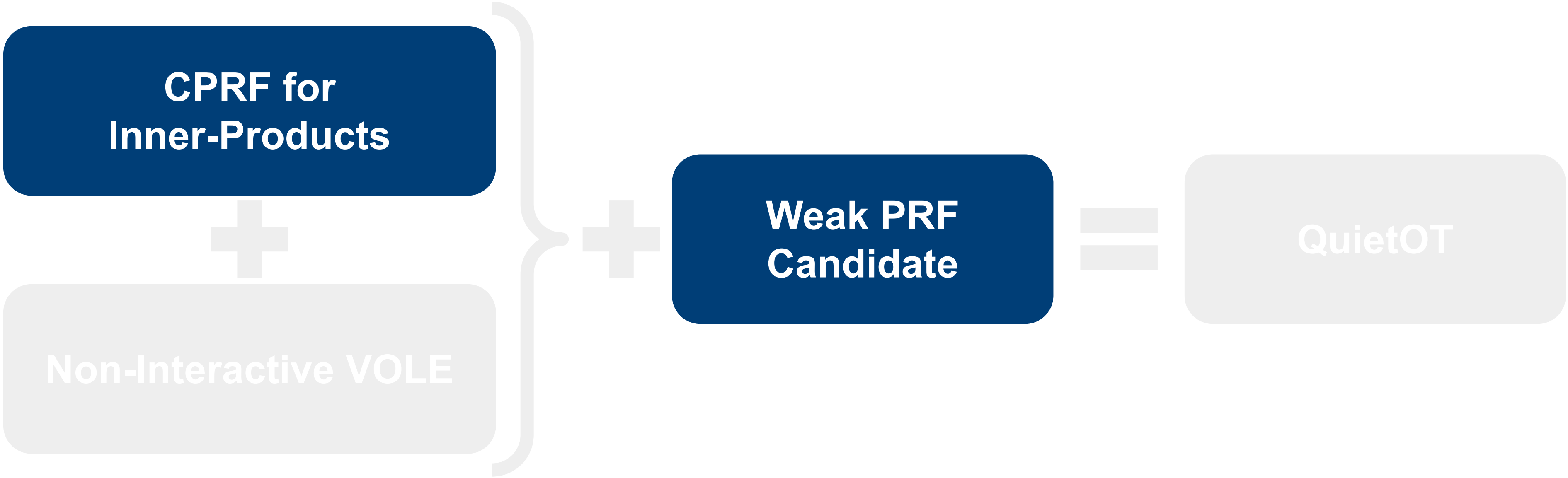
$$f_{\mathbf{k}}(\mathbf{x}) = 1 \iff \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \in \{3, 4, 5\}$$

QuietOT: The main ingredients



CPRF for Inner-Products

+

Non-Interactive VOLE

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Weak PRF Candidate

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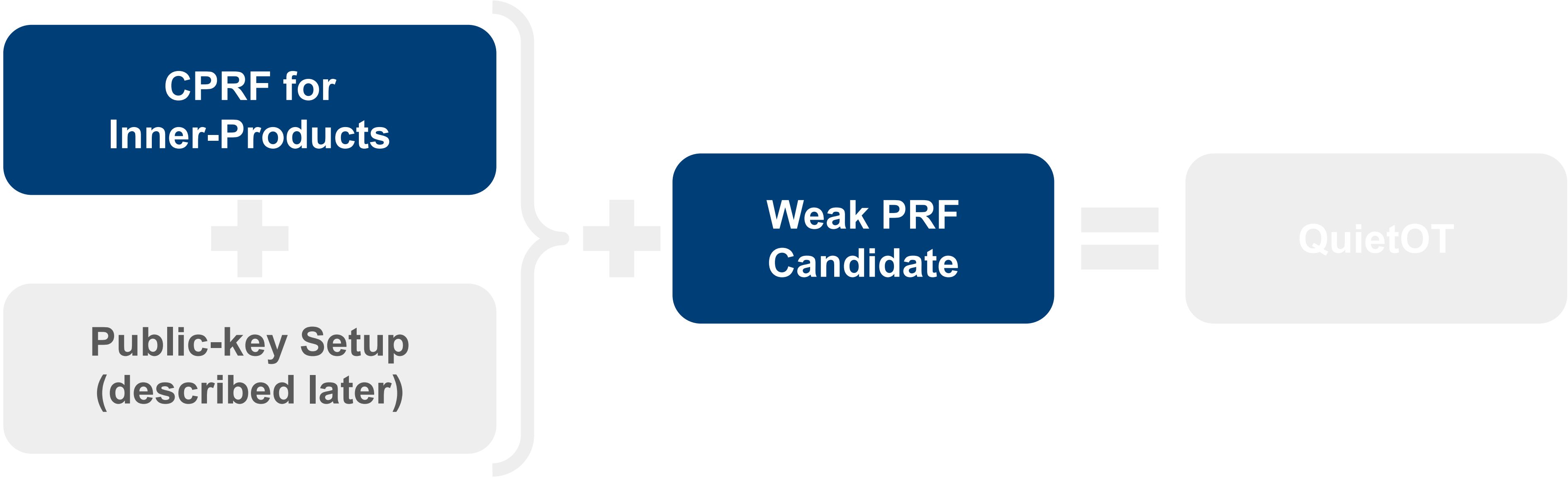
QuietOT

QuietOT: The main ingredients

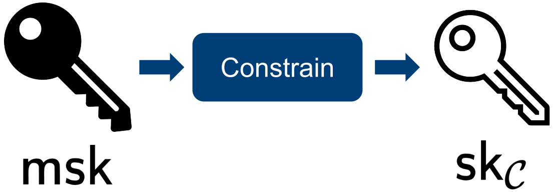


Putting things together

Idea: Use a PRF as the constraint predicate

Inspired by previous constructions building OT extension, in particular [BCMPR'24]

Idea: Use a PRF as the constraint predicate



msk → Constrain → $\mathsf{sk}_{\mathcal{C}}$

$$C\left(x\right) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

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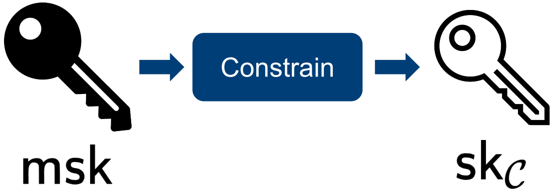

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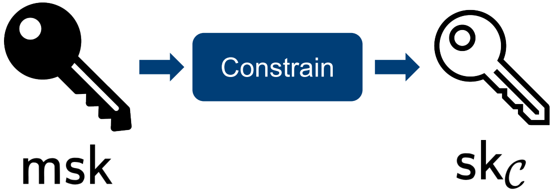

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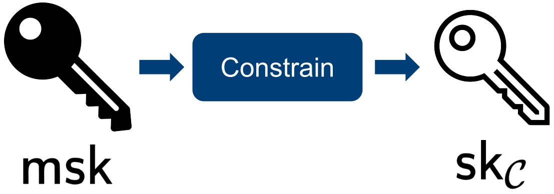

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A PRF

A *pseudorandom* subset of the CPRF domain is authorized.

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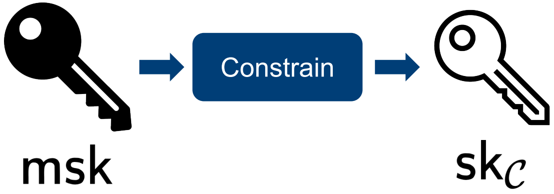

$$C\left(x\right) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

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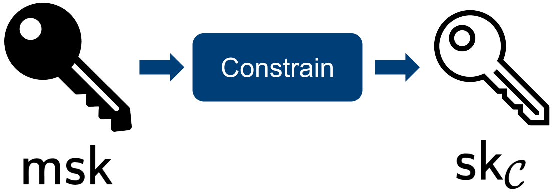
$$f_k\left(0\right) = 0$$

✓

Idea: Use a PRF as the constraint predicate



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A *pseudorandom* subset of the CPRF domain is authorized.

$$f_k\left(0\right) = 0$$

✓

$$f_k\left(1\right) = 1$$

✗

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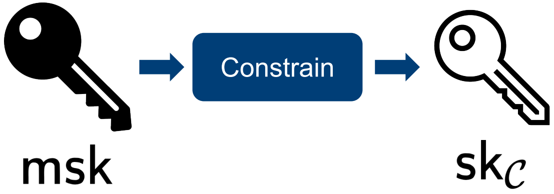

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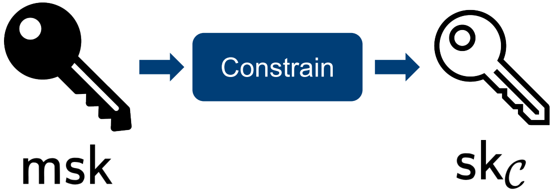

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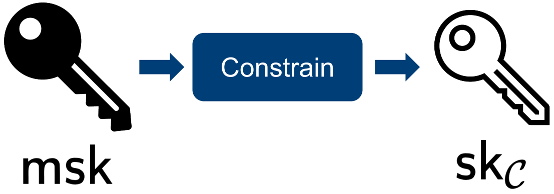
A *pseudorandom* subset of the CPRF domain is authorized.

$f_k\left(0\right) = 0$	$f_k\left(1\right) = 1$	$f_k\left(2\right) = 1$	$f_k\left(3\right) = 0$
✓	✗	✗	✓

Idea: Use a PRF as the constraint predicate



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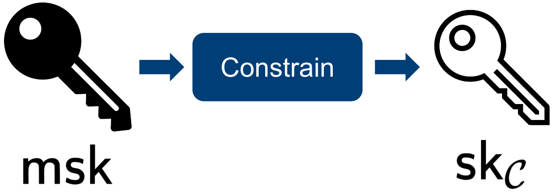
A PRF

A *pseudorandom* subset of the CPRF domain is authorized.

$f_k(0) = 0$	$f_k(1) = 1$	$f_k(2) = 1$	$f_k(3) = 0$	$f_k(4) = 0$
✓	✗	✗	✓	✓

Idea: Use BIPSW weak PRF as the predicate

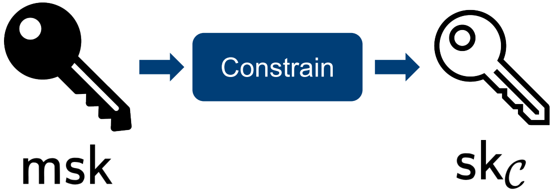


$$C(x) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

BIPSW weak PRF

$$\lceil \langle \mathbf{k}, \mathbf{x} \rangle \rfloor_2 = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

Idea: Use BIPSW weak PRF as the predicate



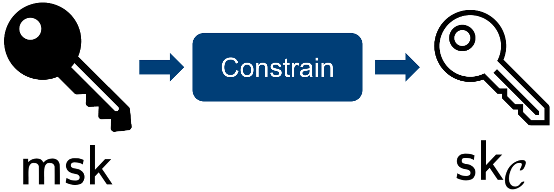
$$C(x) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

BIPSW weak PRF

$$\lceil \langle \mathbf{k}, \mathbf{x} \rangle \rfloor_2 = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

Problem: inner-product predicate isn’t powerful enough

Idea: Use BIPSW weak PRF as the predicate



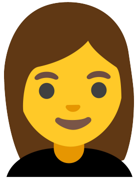
$$C(x) = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

BIPSW weak PRF →

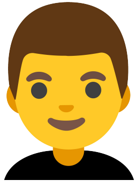
$$\lceil \langle \mathbf{k}, \mathbf{x} \rangle \rfloor_2 = \begin{cases} 0 & \text{authorized} \\ 1 & \text{unauthorized} \end{cases}$$

Solution: use many constrained PRFs!

OT Extension using CPRF + BIPSW weak PRF

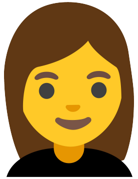


Alice



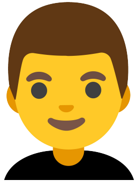
Bob

OT Extension using CPRF + BIPSW weak PRF



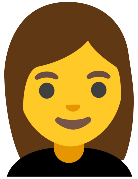
Alice

Trusted Setup



Bob

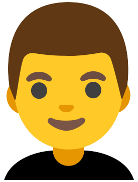
OT Extension using CPRF + BIPSW weak PRF



Alice

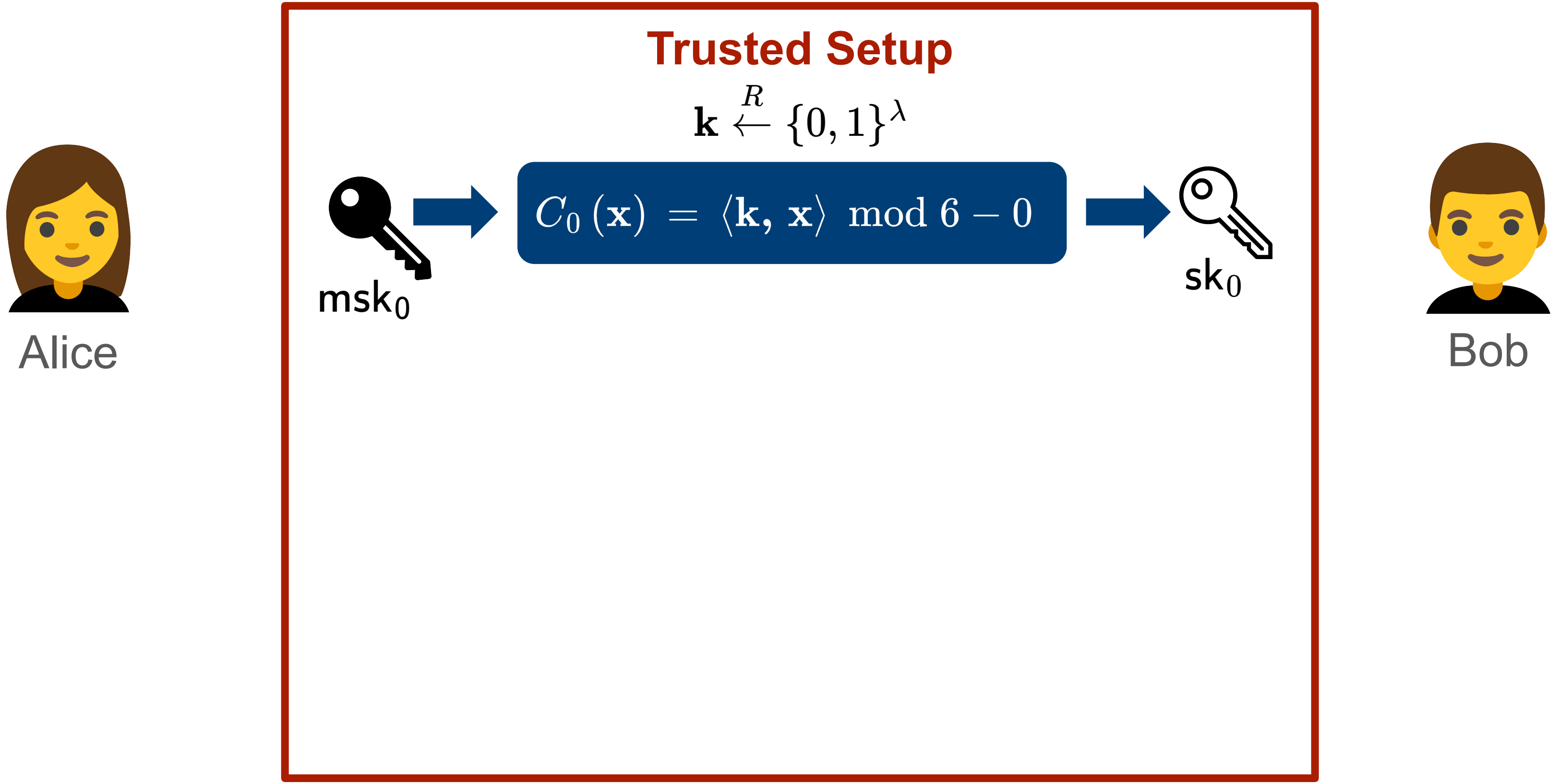
Trusted Setup

$$\mathbf{k} \xleftarrow{R} \{0,1\}^{\lambda}$$



Bob

OT Extension using CPRF + BIPSW weak PRF

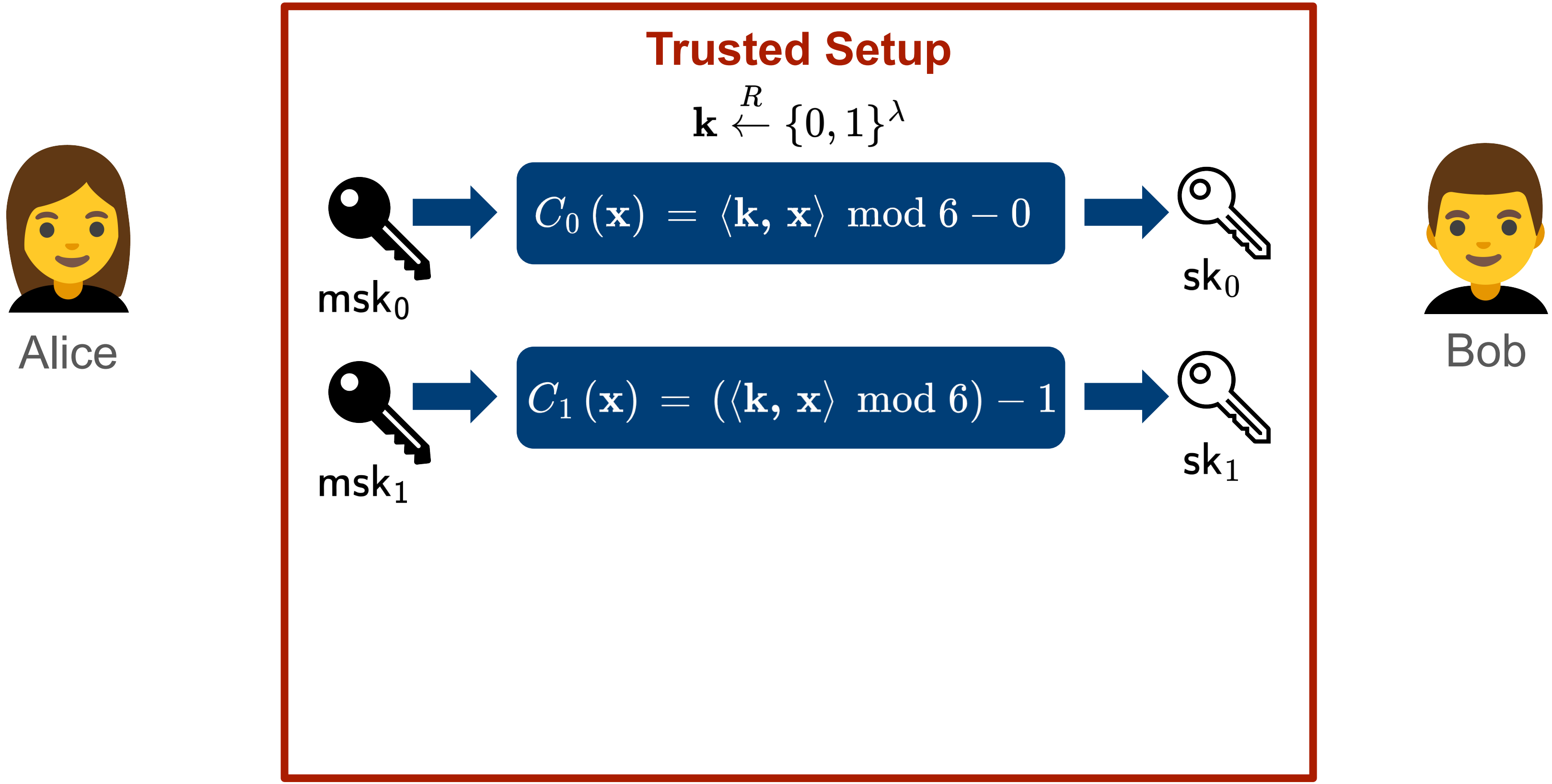


Trusted Setup

$$\mathbf{k} \xleftarrow{R} \{0,1\}^\lambda$$

$$C_0\left(\mathbf{x}\right) = \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 - 0$$

OT Extension using CPRF + BIPSW weak PRF



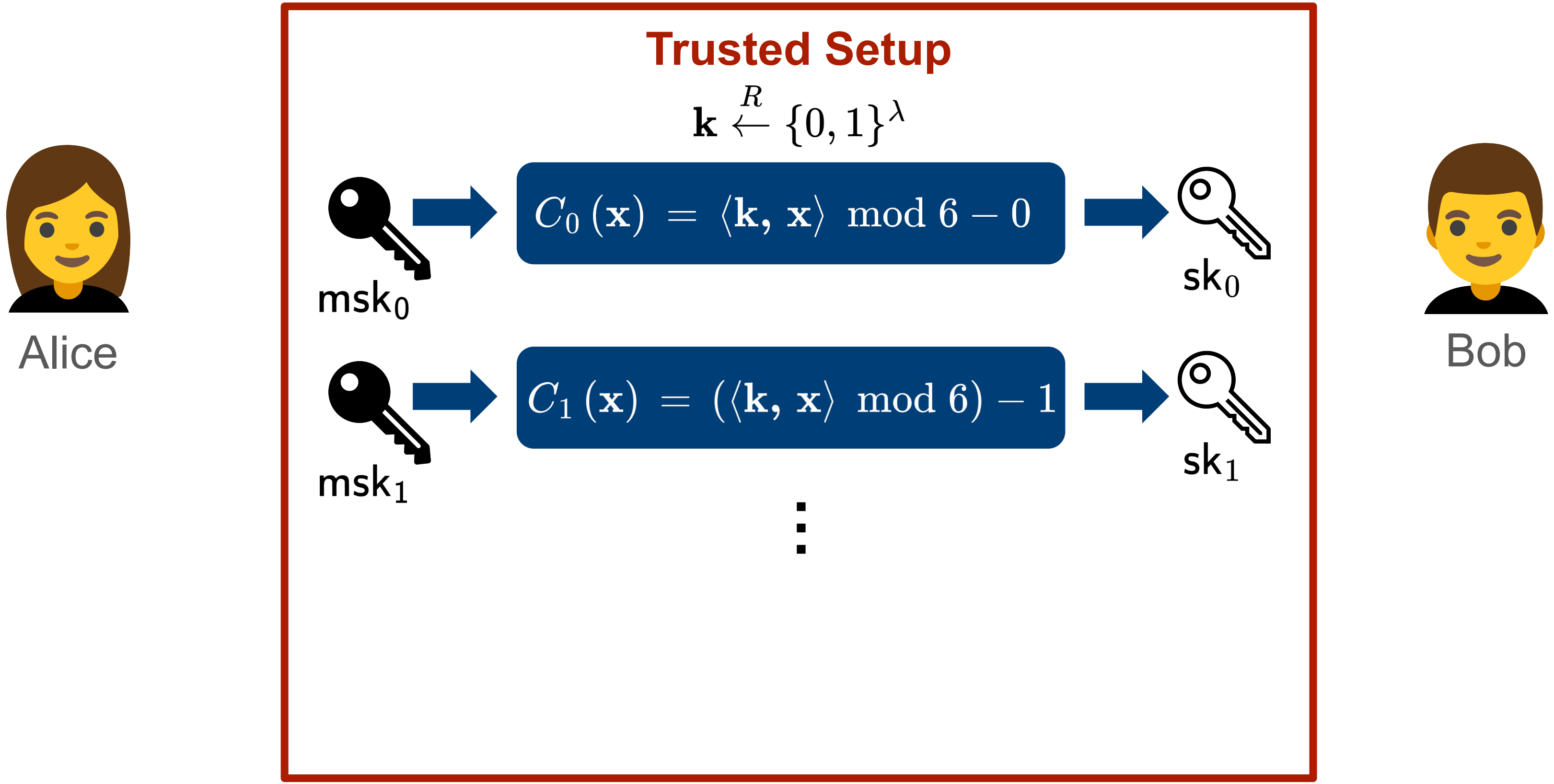
Trusted Setup

$$\mathbf{k} \xleftarrow{R} \{0,1\}^\lambda$$

$$C_0\left(\mathbf{x}\right) = \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 - 0$$

$$C_1\left(\mathbf{x}\right) = \left(\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6\right) - 1$$

OT Extension using CPRF + BIPSW weak PRF



Trusted Setup

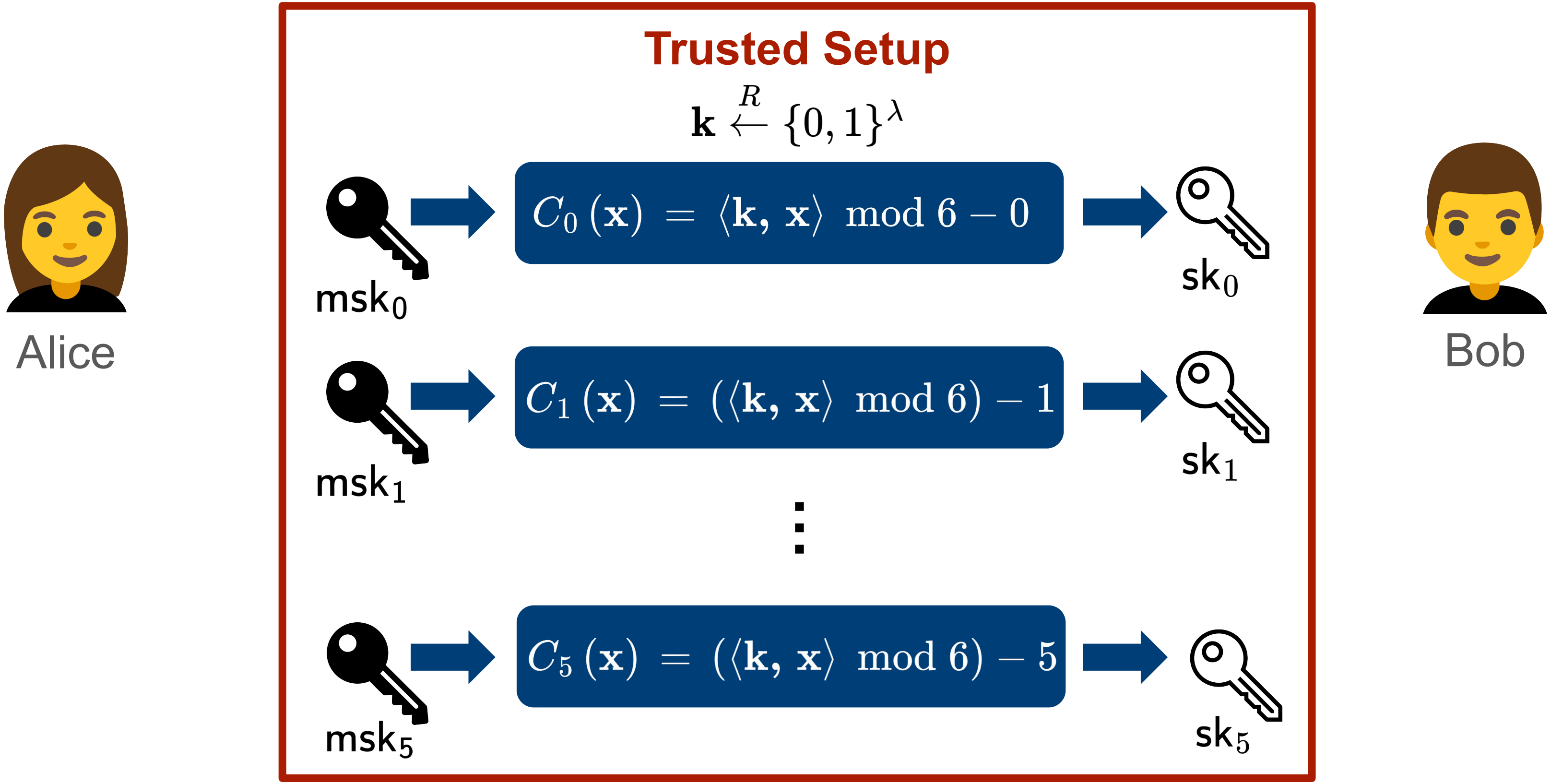
$$\mathbf{k} \xleftarrow{R} \{0,1\}^{\lambda}$$

$$C_0(\mathbf{x}) = \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 - 0$$

$$C_1(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 1$$

$$\vdots$$

OT Extension using CPRF + BIPSW weak PRF



Alice

Trusted Setup

$\mathbf{k} \xleftarrow{R} \{0,1\}^{\lambda}$

msk_0

$C_0\left(\mathbf{x}\right) = \langle \mathbf{k}, \mathbf{x} \rangle \mod 6 - 0$

sk_0

msk_1

$C_1\left(\mathbf{x}\right) = \left(\langle \mathbf{k}, \mathbf{x} \rangle \mod 6\right) - 1$

sk_1

⋮

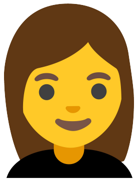
msk_5

$C_5\left(\mathbf{x}\right) = \left(\langle \mathbf{k}, \mathbf{x} \rangle \mod 6\right) - 5$

sk_5

Bob

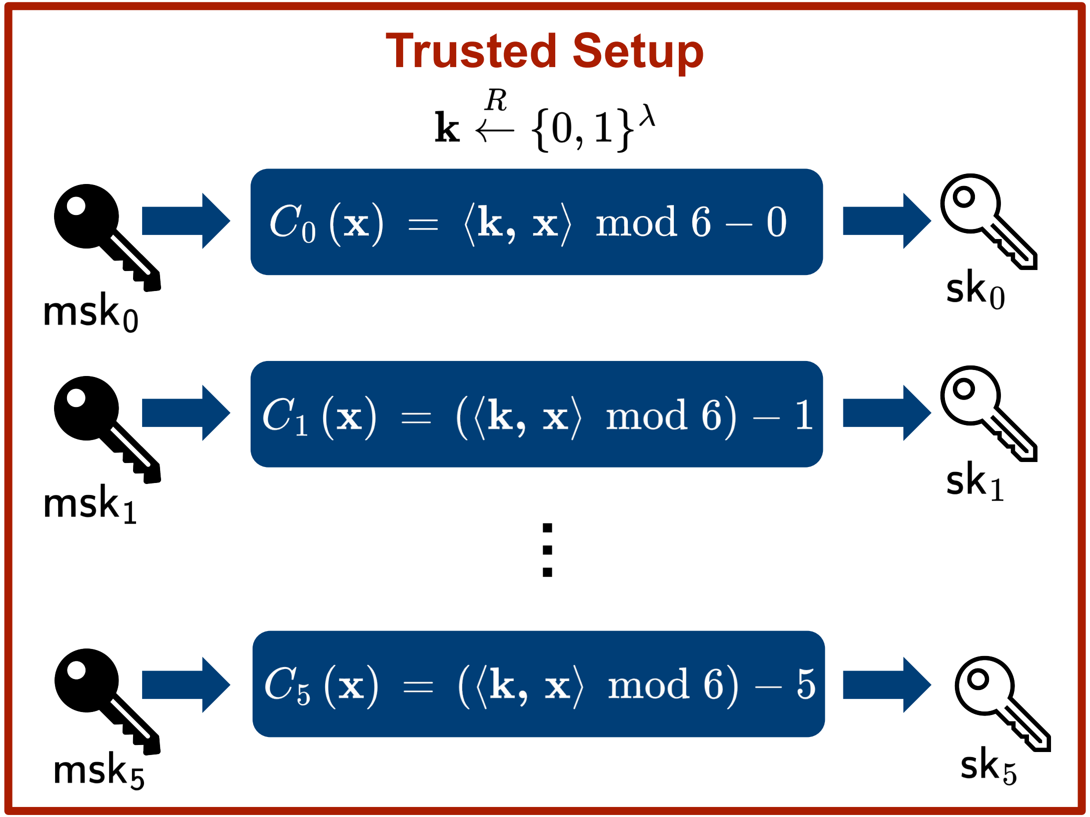
OT Extension using CPRF + BIPSW weak PRF



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$



Trusted Setup

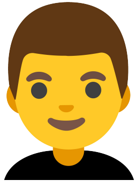
$$\mathbf{k} \overset{R}{\leftarrow} \{0,1\}^\lambda$$

msk_0 → $C_0(\mathbf{x}) = \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 - 0$ → sk_0

msk_1 → $C_1(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 1$ → sk_1

⋮

msk_5 → $C_5(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 5$ → sk_5



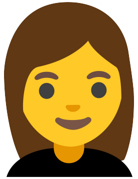
Bob

$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

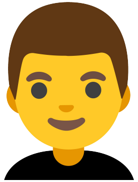
OT Extension using CPRF + BIPSW weak PRF



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$



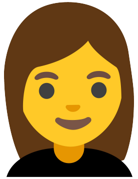
Bob

BIPSW weak PRF Key → $\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

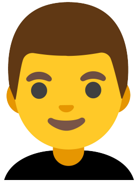


Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

Constrained CPRF keys for each possible inner product value {0,1,2,3,4,5} →



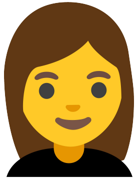
Bob

$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

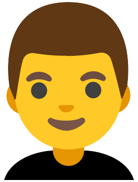


Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

← **Master CPRF keys**



Bob

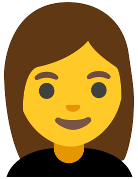
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

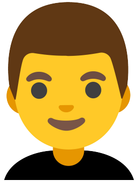
For a public, random input $\mathbf{x}$:



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$



Bob

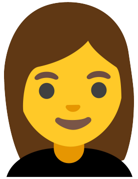
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:

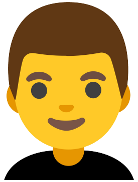


Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\,(\mathsf{msk}_0,\ \mathbf{x})$$
$$a_1 := \mathsf{PRF}\,(\mathsf{msk}_1,\ \mathbf{x})$$
$$a_2 := \mathsf{PRF}\,(\mathsf{msk}_2,\ \mathbf{x})$$
$$a_3 := \mathsf{PRF}\,(\mathsf{msk}_3,\ \mathbf{x})$$
$$a_4 := \mathsf{PRF}\,(\mathsf{msk}_4,\ \mathbf{x})$$
$$a_5 := \mathsf{PRF}\,(\mathsf{msk}_5,\ \mathbf{x})$$



Bob

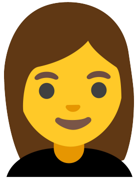
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:



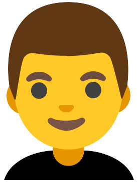
Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\,(\mathsf{msk}_0,\ \mathbf{x})$$
$$a_1 := \mathsf{PRF}\,(\mathsf{msk}_1,\ \mathbf{x})$$
$$a_2 := \mathsf{PRF}\,(\mathsf{msk}_2,\ \mathbf{x})$$
$$a_3 := \mathsf{PRF}\,(\mathsf{msk}_3,\ \mathbf{x})$$
$$a_4 := \mathsf{PRF}\,(\mathsf{msk}_4,\ \mathbf{x})$$
$$a_5 := \mathsf{PRF}\,(\mathsf{msk}_5,\ \mathbf{x})$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \;=\; 4$$



Bob

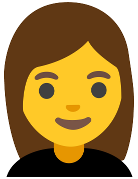
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\left(\mathsf{msk}_0,\ \mathbf{x}\right)$$

$$a_1 := \mathsf{PRF}\left(\mathsf{msk}_1,\ \mathbf{x}\right)$$

$$a_2 := \mathsf{PRF}\left(\mathsf{msk}_2,\ \mathbf{x}\right)$$

$$a_3 := \mathsf{PRF}\left(\mathsf{msk}_3,\ \mathbf{x}\right)$$

$$a_4 := \mathsf{PRF}\left(\mathsf{msk}_4,\ \mathbf{x}\right)$$

$$a_5 := \mathsf{PRF}\left(\mathsf{msk}_5,\ \mathbf{x}\right)$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \ = \ 4$$

$$a_4 := \mathsf{PRF}\left(\mathsf{sk}_4,\ \mathbf{x}\right)$$

Bob

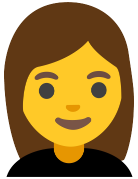
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:



Alice

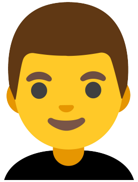
$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\,(\mathsf{msk}_0,\ \mathbf{x})$$
$$a_1 := \mathsf{PRF}\,(\mathsf{msk}_1,\ \mathbf{x})$$
$$a_2 := \mathsf{PRF}\,(\mathsf{msk}_2,\ \mathbf{x})$$
$$a_3 := \mathsf{PRF}\,(\mathsf{msk}_3,\ \mathbf{x})$$
$$a_4 := \mathsf{PRF}\,(\mathsf{msk}_4,\ \mathbf{x})$$
$$a_5 := \mathsf{PRF}\,(\mathsf{msk}_5,\ \mathbf{x})$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \ = \ 4$$

$$a_4 := \mathsf{PRF}\,(\mathsf{sk}_4,\ \mathbf{x})$$



Bob

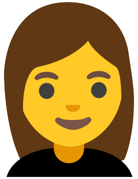
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:



Alice

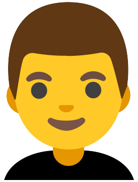
$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\,(\mathsf{msk}_0,\ \mathbf{x})$$
$$a_1 := \mathsf{PRF}\,(\mathsf{msk}_1,\ \mathbf{x})$$
$$a_2 := \mathsf{PRF}\,(\mathsf{msk}_2,\ \mathbf{x})$$
$$a_3 := \mathsf{PRF}\,(\mathsf{msk}_3,\ \mathbf{x})$$
$$a_4 := \mathsf{PRF}\,(\mathsf{msk}_4,\ \mathbf{x})$$
$$a_5 := \mathsf{PRF}\,(\mathsf{msk}_5,\ \mathbf{x})$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 = 1$$

$$a_1 := \mathsf{PRF}\,(\mathsf{sk}_1,\ \mathbf{x})$$



Bob

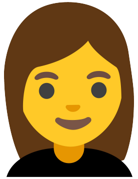
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\left(\mathsf{msk}_0,\ \mathbf{x}\right)$$

$$a_1 := \mathsf{PRF}\left(\mathsf{msk}_1,\ \mathbf{x}\right)$$

$$a_2 := \mathsf{PRF}\left(\mathsf{msk}_2,\ \mathbf{x}\right)$$

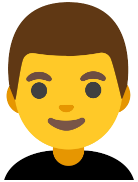
$$a_3 := \mathsf{PRF}\left(\mathsf{msk}_3,\ \mathbf{x}\right)$$

$$a_4 := \mathsf{PRF}\left(\mathsf{msk}_4,\ \mathbf{x}\right)$$

$$a_5 := \mathsf{PRF}\left(\mathsf{msk}_5,\ \mathbf{x}\right)$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6\ =\ 1$$

$$a_1 := \mathsf{PRF}\left(\mathsf{sk}_1,\ \mathbf{x}\right)$$



Bob

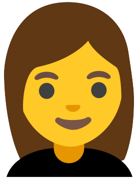
$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:



Alice

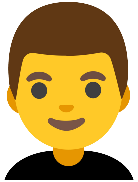
$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\left(\mathsf{msk}_0,\ \mathbf{x}\right)$$
$$a_1 := \mathsf{PRF}\left(\mathsf{msk}_1,\ \mathbf{x}\right)$$
$$a_2 := \mathsf{PRF}\left(\mathsf{msk}_2,\ \mathbf{x}\right)$$
$$a_3 := \mathsf{PRF}\left(\mathsf{msk}_3,\ \mathbf{x}\right)$$
$$a_4 := \mathsf{PRF}\left(\mathsf{msk}_4,\ \mathbf{x}\right)$$
$$a_5 := \mathsf{PRF}\left(\mathsf{msk}_5,\ \mathbf{x}\right)$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 = 2$$

$$a_2 := \mathsf{PRF}\left(\mathsf{sk}_2,\ \mathbf{x}\right)$$



Bob

$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

OT Extension using CPRF + BIPSW weak PRF

For a public, random input $\mathbf{x}$:

Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

$$a_0 := \mathsf{PRF}\left(\mathsf{msk}_0,\ \mathbf{x}\right)$$
$$a_1 := \mathsf{PRF}\left(\mathsf{msk}_1,\ \mathbf{x}\right)$$
$$a_2 := \mathsf{PRF}\left(\mathsf{msk}_2,\ \mathbf{x}\right)$$
$$a_3 := \mathsf{PRF}\left(\mathsf{msk}_3,\ \mathbf{x}\right)$$
$$a_4 := \mathsf{PRF}\left(\mathsf{msk}_4,\ \mathbf{x}\right)$$
$$a_5 := \mathsf{PRF}\left(\mathsf{msk}_5,\ \mathbf{x}\right)$$

$$\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 \ = \ 2$$

$$a_2 := \mathsf{PRF}\left(\mathsf{sk}_2,\ \mathbf{x}\right)$$

Bob

$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

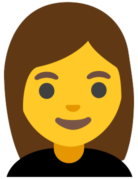
Random-bit OT

Random-bit OT

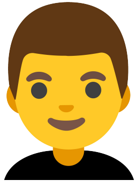
Theorem [Beaver'96]: If there exists a *random-bit* OT protocol with R rounds, then there exists a *chosen-bit* OT protocol with R rounds.

Getting random-bit OT

In random-bit OT, Bob does not get to set the “choice bit” b



Alice

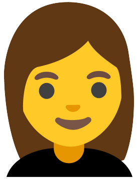


Bob

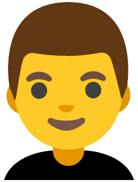
(m_0, m_1)

Getting random-bit OT

In random-bit OT, Bob does not get to set the “choice bit” b



Alice



Bob

(m_0, m_1)

(a_0, a_1, a_2)
(a_3, a_4, a_5) ← **Computed using the CPRFs** → (c, a_c)

Getting random-bit OT

In random-bit OT, Bob does not get to set the “choice bit” b

Alice

Bob

$$(a_0 \oplus m_0, a_1 \oplus m_0, a_2 \oplus m_0)$$

$$(a_3 \oplus m_1, a_4 \oplus m_1, a_5 \oplus m_1)$$

$$(m_0,\ m_1)$$

$$(a_0, a_1, a_2)$$

$$(a_3, a_4, a_5)$$

$$(c,\ a_c)$$

Getting random-bit OT

In random-bit OT, Bob does not get to set the "choice bit" b

Alice

(m_0, m_1)

(a_0, a_1, a_2)
(a_3, a_4, a_5)

$$\xrightarrow{\substack{(a_0 \oplus m_0, a_1 \oplus m_0, a_2 \oplus m_0) \\ (a_3 \oplus m_1, a_4 \oplus m_1, a_5 \oplus m_1)}}$$

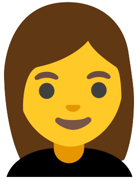
Bob

(c, a_c)

$$m_b := (m_b \oplus a_c) \oplus a_c$$

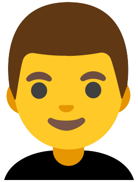
Getting random-bit OT

In random-bit OT, Bob does not get to set the "choice bit" b



Alice

$$(a_0 \oplus m_0, a_1 \oplus m_0, a_2 \oplus m_0)$$
$$(a_3 \oplus m_1, a_4 \oplus m_1, a_5 \oplus m_1)$$
$$\xrightarrow{\hspace{6cm}}$$



Bob

$$(m_0, m_1)$$

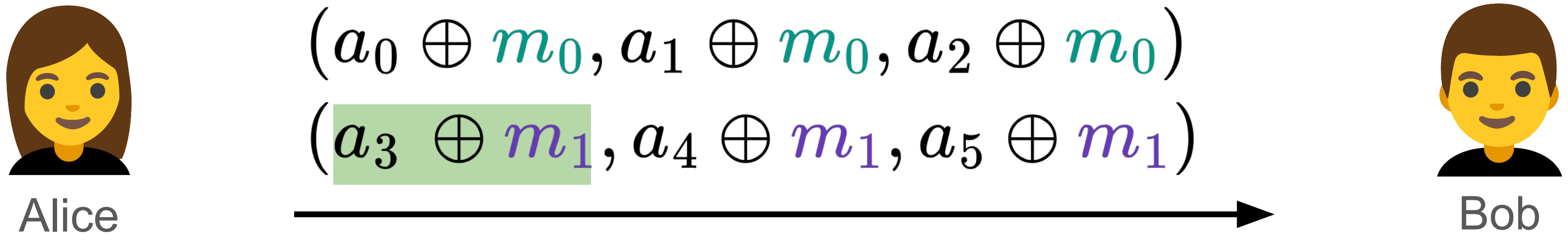
$$(a_0, a_1, a_2)$$
$$(a_3, a_4, a_5)$$

$$(2, a_2)$$

$$m_0 := (m_0 \oplus a_2) \oplus a_2$$

Getting random-bit OT

In random-bit OT, Bob does not get to set the "choice bit" b



$$(a_0 \oplus m_0, a_1 \oplus m_0, a_2 \oplus m_0)$$

$$(a_3 \oplus m_1, a_4 \oplus m_1, a_5 \oplus m_1)$$

$$(m_0, m_1)$$

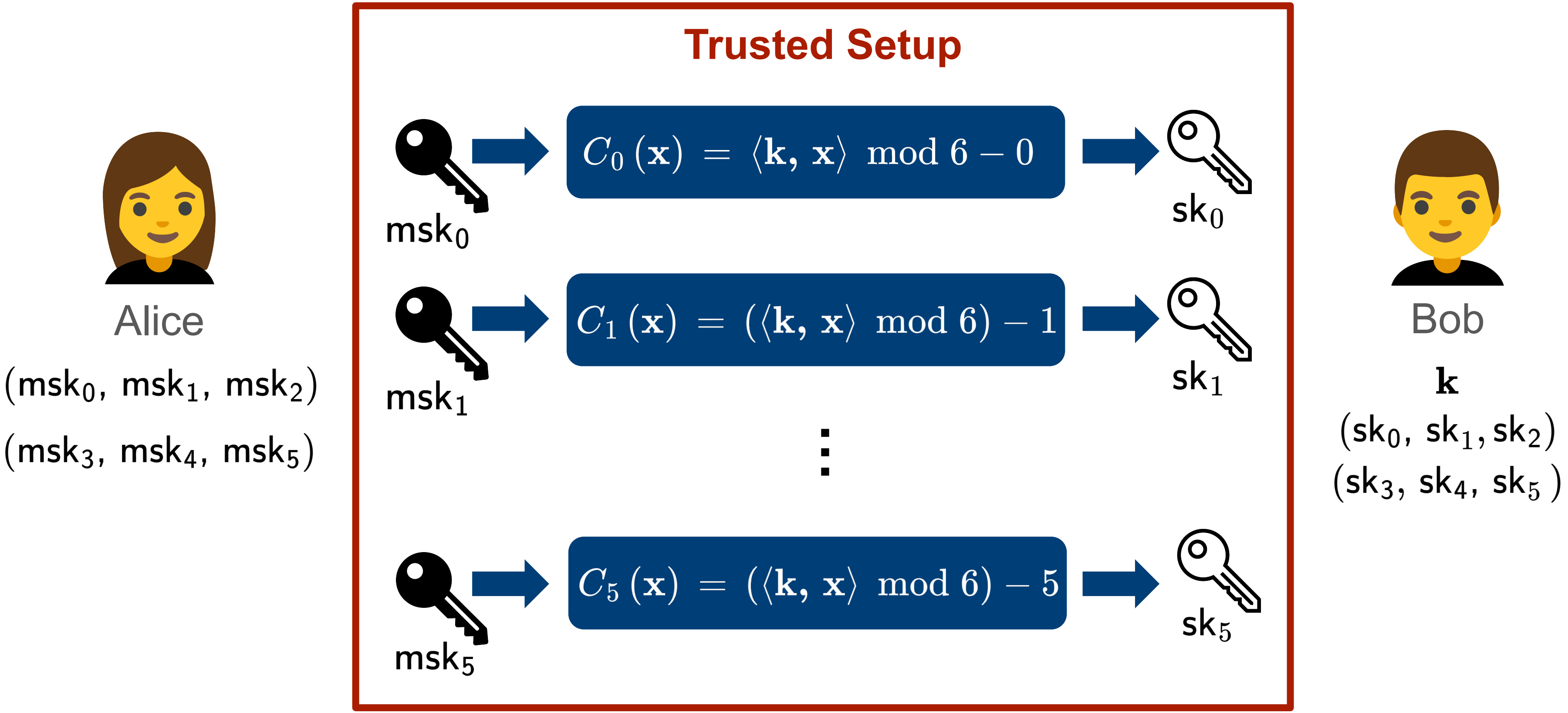
$$(a_0, a_1, a_2)$$
$$(a_3, a_4, a_5)$$

$$(3, a_3)$$

$$m_1 := (m_1 \oplus a_3) \oplus a_3$$

Public-key Setup

Obtaining a public-key setup



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$

Trusted Setup

msk_0 → $C_0(\mathbf{x}) = \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 - 0$ → sk_0

msk_1 → $C_1(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 1$ → sk_1

⋮

msk_5 → $C_5(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 5$ → sk_5

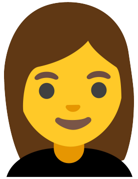
Bob

$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

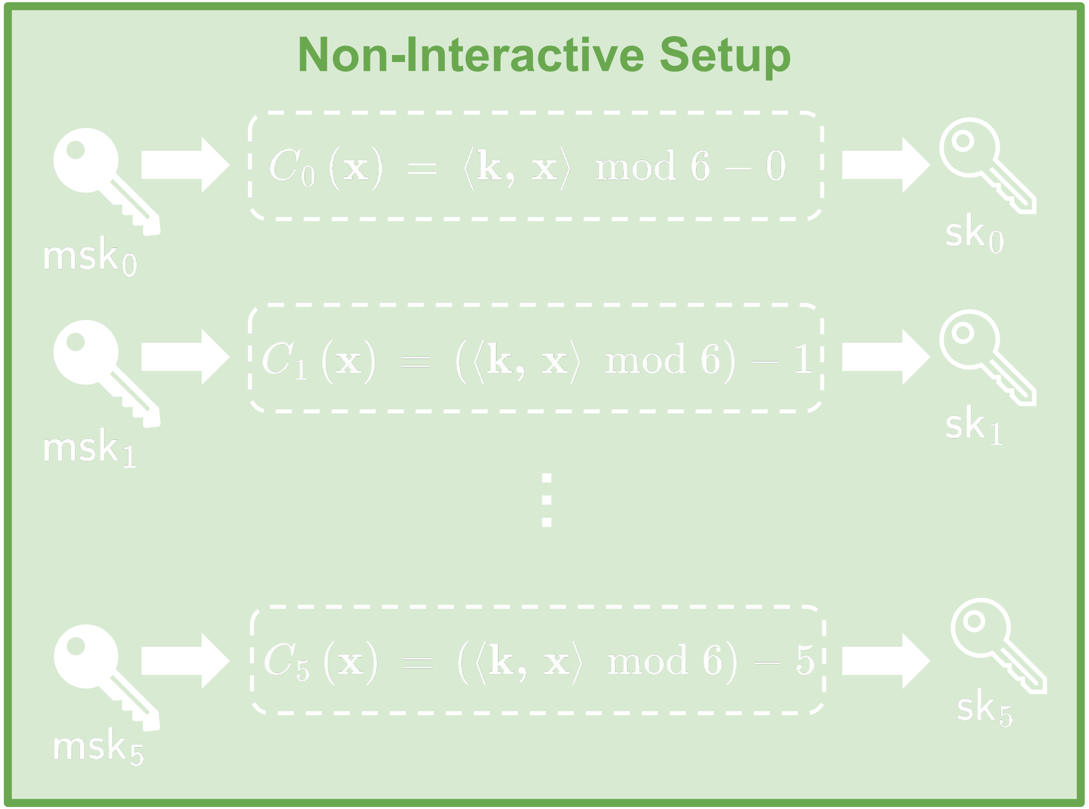
Obtaining a public-key setup



Alice

$(\mathsf{msk}_0,\ \mathsf{msk}_1,\ \mathsf{msk}_2)$

$(\mathsf{msk}_3,\ \mathsf{msk}_4,\ \mathsf{msk}_5)$



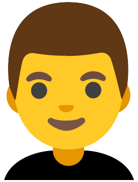
Non-Interactive Setup

msk_0 → $C_0(\mathbf{x}) = \langle \mathbf{k}, \mathbf{x} \rangle \bmod 6 - 0$ → sk_0

msk_1 → $C_1(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 1$ → sk_1

$\vdots$

msk_5 → $C_5(\mathbf{x}) = (\langle \mathbf{k}, \mathbf{x} \rangle \bmod 6) - 5$ → sk_5



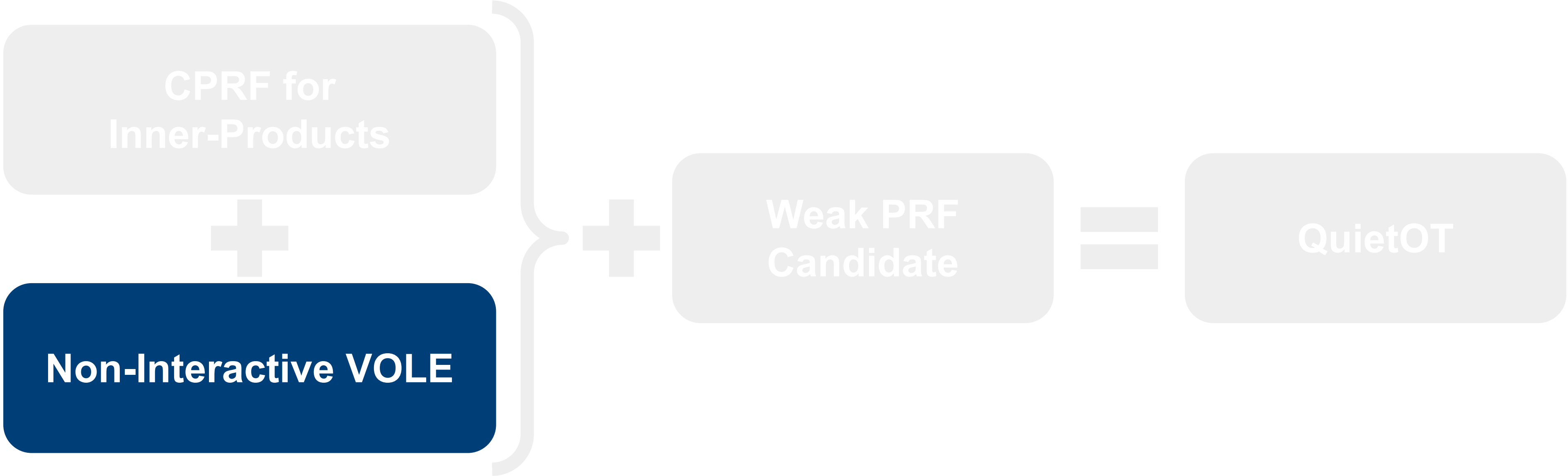
Bob

$\mathbf{k}$

$(\mathsf{sk}_0,\ \mathsf{sk}_1, \mathsf{sk}_2)$

$(\mathsf{sk}_3,\ \mathsf{sk}_4,\ \mathsf{sk}_5\ )$

Obtaining a public-key setup



CPRF for Inner-Products

+

Non-Interactive VOLE

+

Weak PRF Candidate

=

QuietOT

Obtaining a public-key setup

Constrained PRF for Inner-Product Predicates [S'24]

Let $H : \mathcal{R} \times \mathcal{R}^\ell \to \mathcal{Y}$ be a random oracle (RO).

Obtaining a public-key setup

Constrained PRF for Inner-Product Predicates [S'24]

Let $H : \mathcal{R} \times \mathcal{R}^{\ell} \to \mathcal{Y}$ be a random oracle (RO).

```
KeyGen( $1^{\lambda}$ ):
    1. $\mathbf{z_0} \overset{R}{\leftarrow} \mathcal{R}^{\ell}$
    2. Return msk $:= \mathbf{z_0}$
```

```
Constrain( msk, $\mathbf{k}$ ):
    1. $\Delta \overset{R}{\leftarrow} \mathcal{R}$
    2. $\mathbf{z_1} := \mathbf{z_0} - \Delta\mathbf{k}$
    3. Return sk$_{\mathbf{z}}$ $:= \mathbf{z_1}$
```

```
Eval( msk, $\mathbf{x}$ ):
    1. $k := \langle \mathbf{z_0}, \mathbf{x} \rangle$
    2. Return $H(k, \mathbf{x})$
```

```
CEval( sk$_{\mathbf{z}}$, $\mathbf{x}$ ):
    1. $k := \langle \mathbf{z_1}, \mathbf{x} \rangle$
    2. Output $H(k, \mathbf{x})$
```

Obtaining a public-key setup

Constrained PRF for Inner-Product Predicates [S'24]

Let $H : \mathcal{R} \times \mathcal{R}^{\ell} \rightarrow \mathcal{Y}$ be a random oracle (RO).

KeyGen(1^{λ}):

1. $\mathbf{z_0} \overset{R}{\leftarrow} \mathcal{R}^{\ell}$
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Constrain(msk , $\mathbf{k}$):

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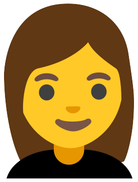

Alice

$\Delta \overset{\boldsymbol{R}}{\leftarrow} \mathcal{R}$

Bob

$\mathbf{k} \in \mathcal{R}^{\ell}$

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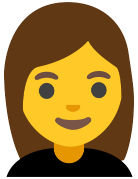

Alice

```
KeyGen( $1^\lambda$ ):
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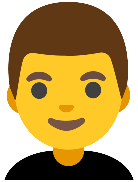

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Non-Interactive VOLE

$\mathbf{k} \in \mathcal{R}^\ell$

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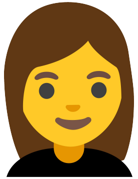

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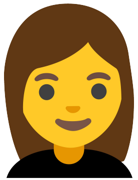

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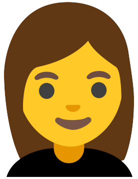

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Non-Interactive VOLE

$\mathbf{k} \in \mathcal{R}^\ell$

$\mathbf{z}_1$

$$\mathbf{z}_0 - \mathbf{z}_1 = \Delta \cdot \mathbf{k}$$

Obtaining a public-key setup

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KeyGen(

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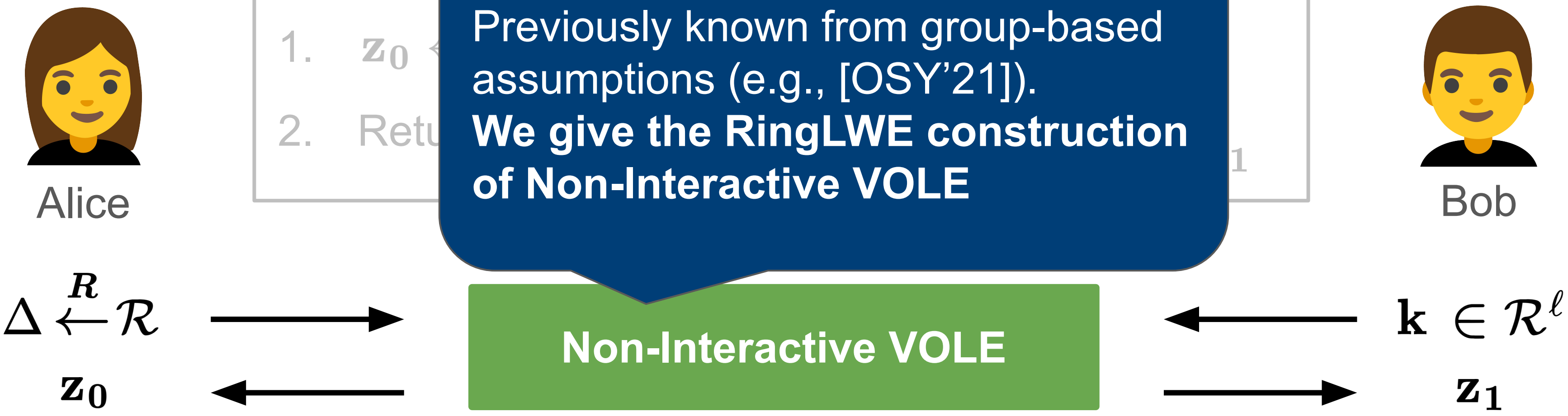
2. Retu

Previously known from group-based assumptions (e.g., [OSY’21]).
We give the RingLWE construction of Non-Interactive VOLE



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Implementation and Evaluation

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Artifact Badges: Available, Functional, and Reproduced.

https://github.com/sachaservan/QuietOT

Protocol	OT/s	Bits/OT

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SoftSpokenOT	44,443,000	32

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<table>
<tr><th>Protocol</th><th>OT/s</th><th>Bits/OT</th><th>Sender PK Size</th><th>Receiver PK Size</th></tr>
<tr><td>SoftSpokenOT</td><td>44,443,000</td><td>32</td><td colspan="2" rowspan="4">No Public Key Setup</td></tr>
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OSY	1	3	50 KB	1 KB

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For context, average website is 2MB in size

A lot more in the paper!

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Open questions:

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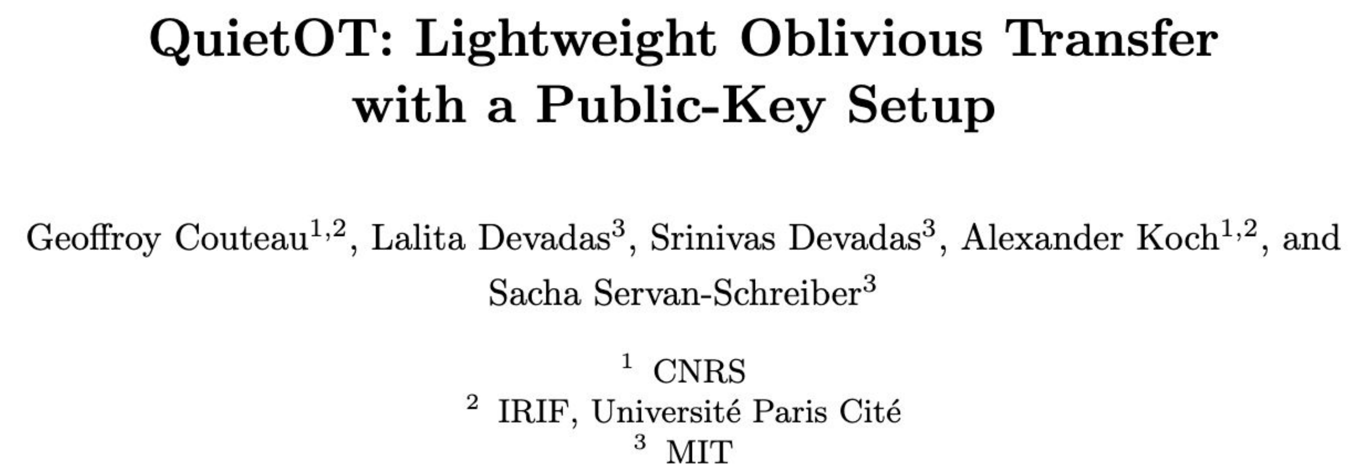
Open questions:

- Malicious security?
- Can we reach 50,000,000 OT/s with a public key setup?

Thank you!

Email: 3s@mit.edu
ePrint: ia.cr/**2024/1079**



QuietOT: Lightweight Oblivious Transfer with a Public-Key Setup

Geoffroy Couteau[1,2], Lalita Devadas[3], Srinivas Devadas[3], Alexander Koch[1,2], and Sacha Servan-Schreiber[3]

[1] CNRS
[2] IRIF, Université Paris Cité
[3] MIT

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