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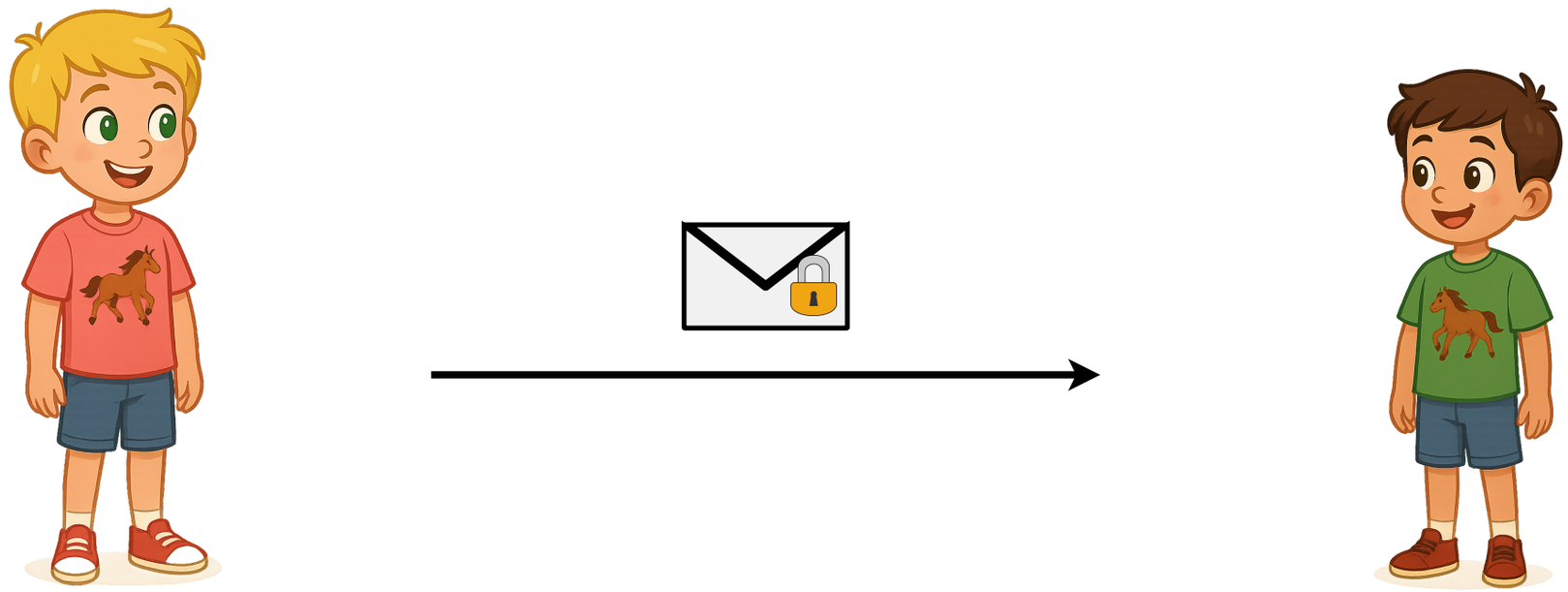
Design and Analysis of Secure Cryptographic Implementations in the Random Probing Model

Sonia Belaïd

Journées Nationales 2026 du GDR SI
June 10, 2026

Introduction

Side-Channel Attacks



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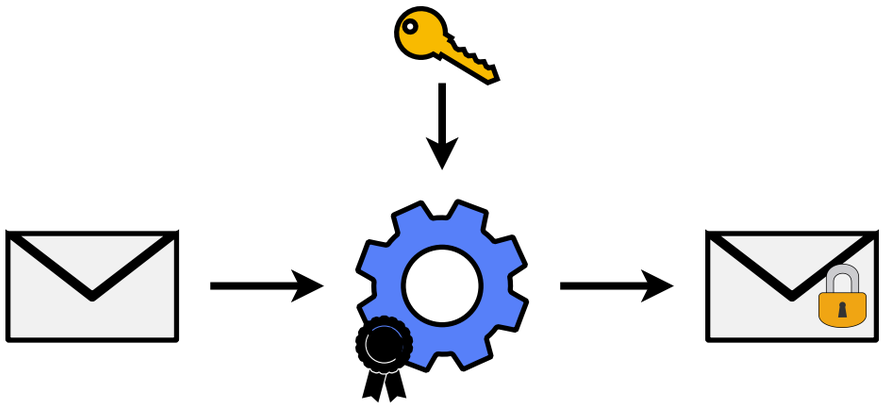
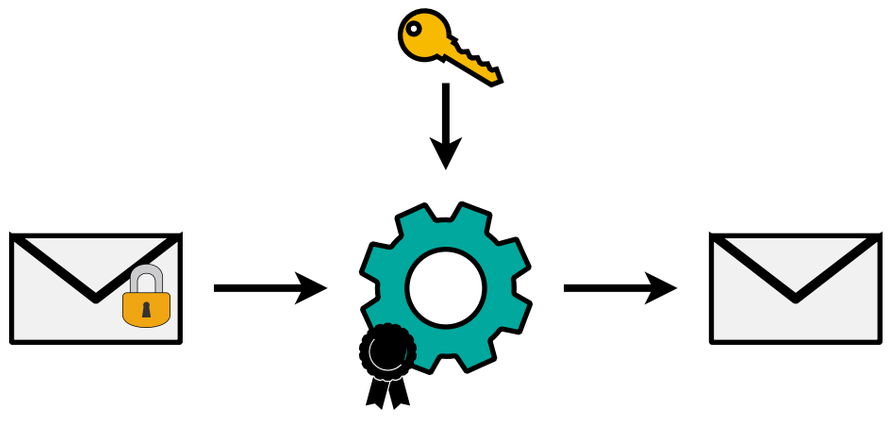


Mathis



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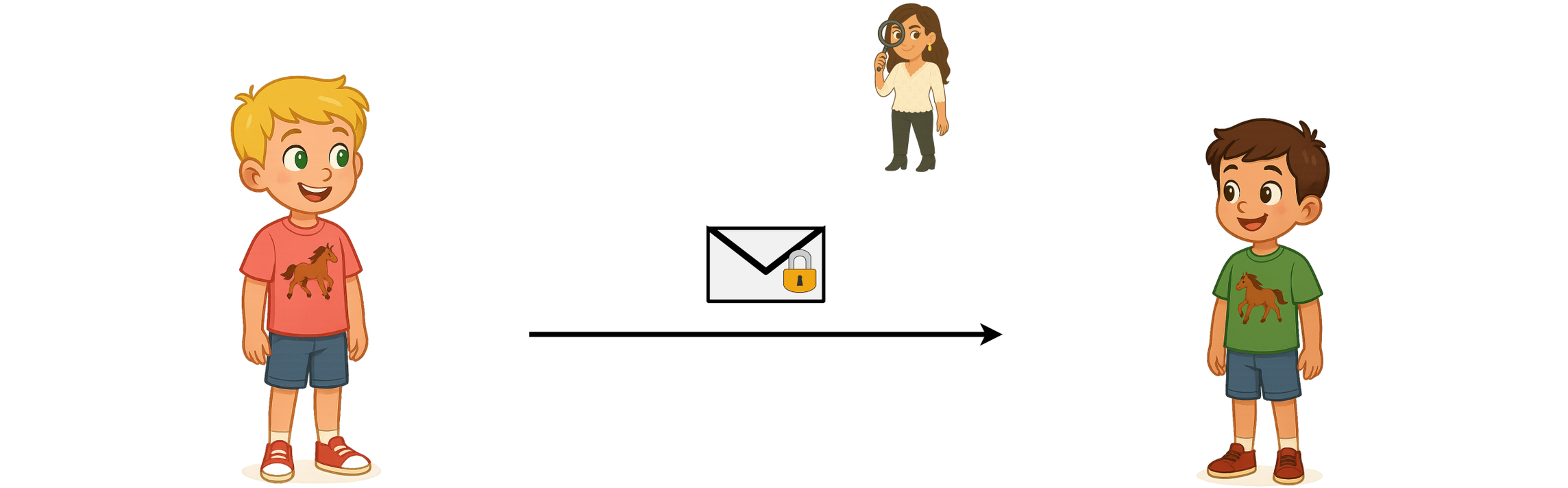

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Mathis

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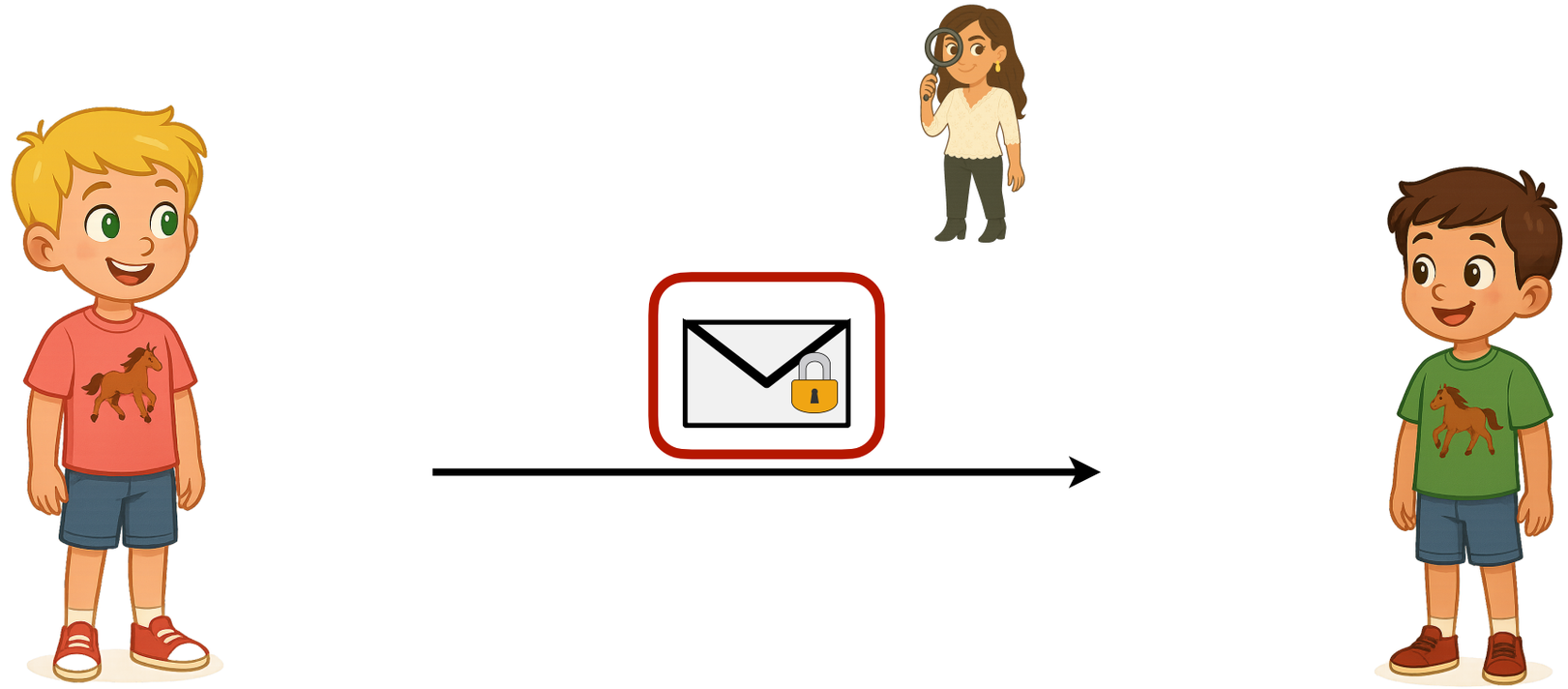

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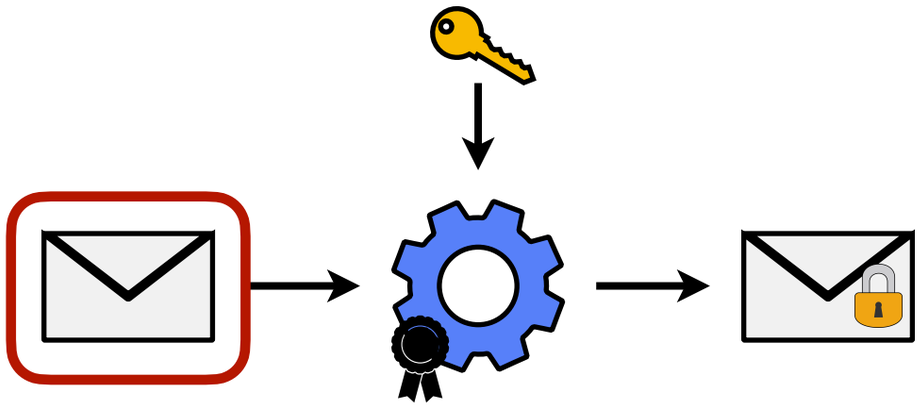

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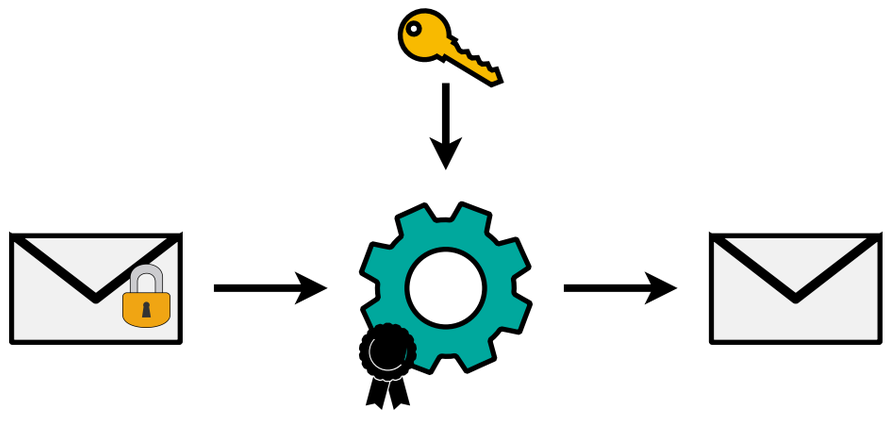
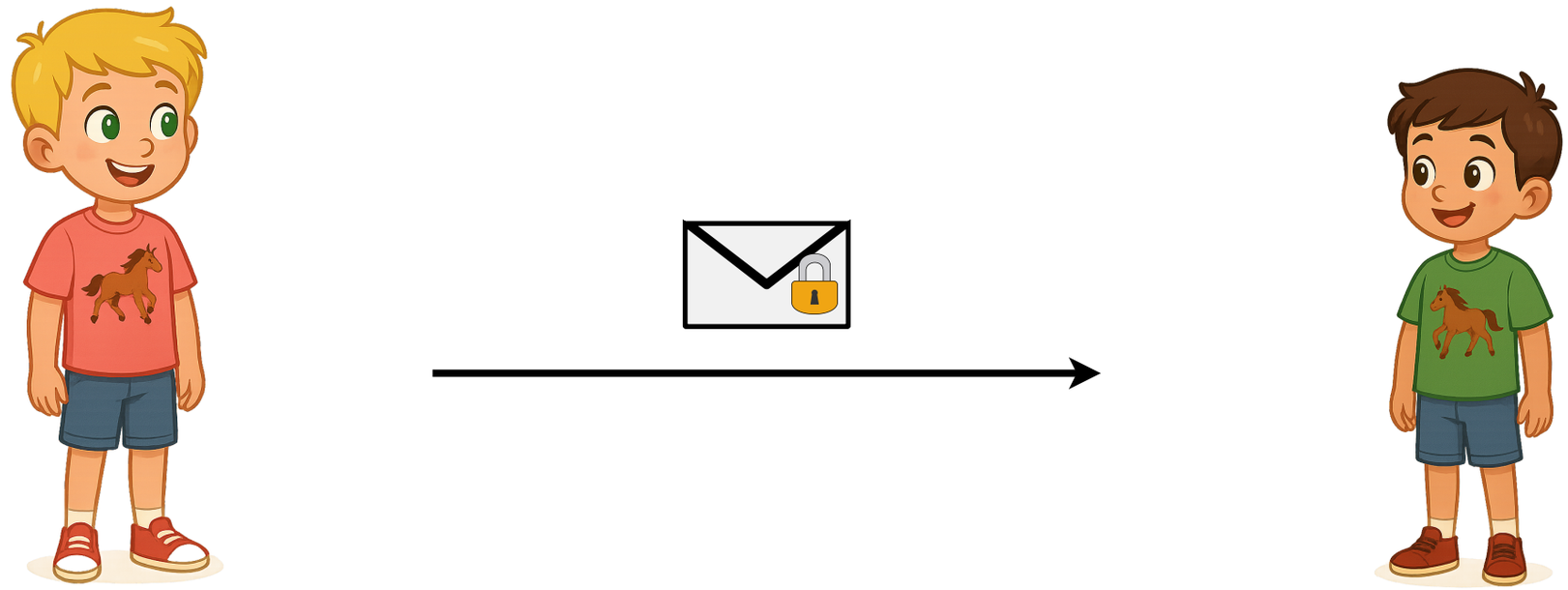


Side-Channel Attacks

Kocher • Jaffe • Jun

CRYPTO 1999



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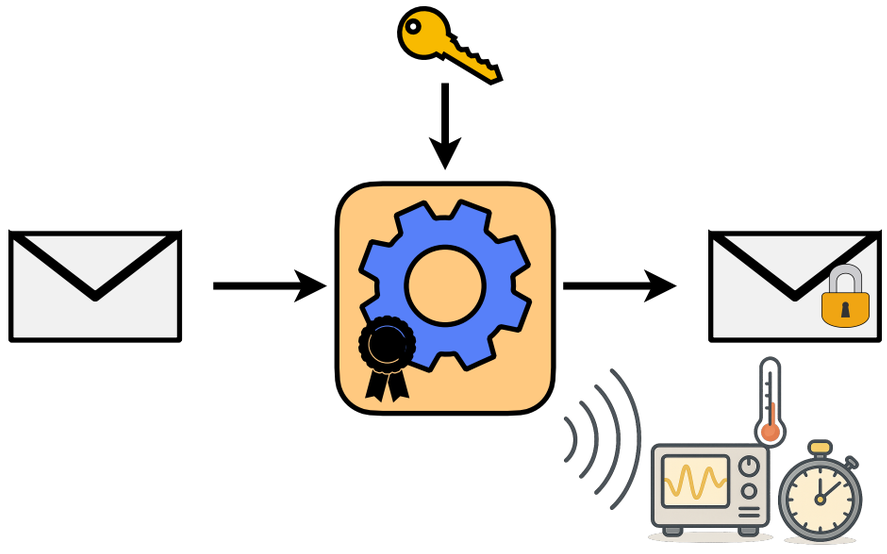

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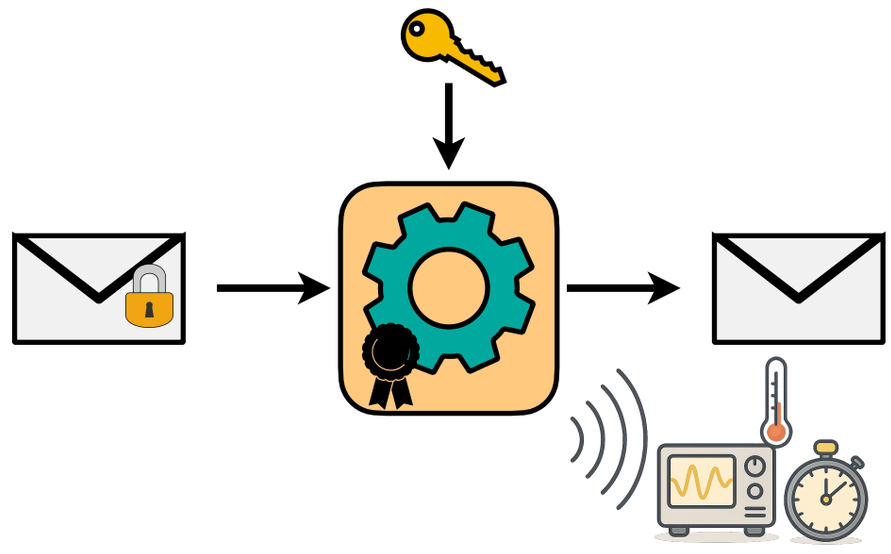

Masking

Chari • Jutla • Rao • Rohatgi

CRYPTO 1999

Goubin • Patarin

CHES, 1999

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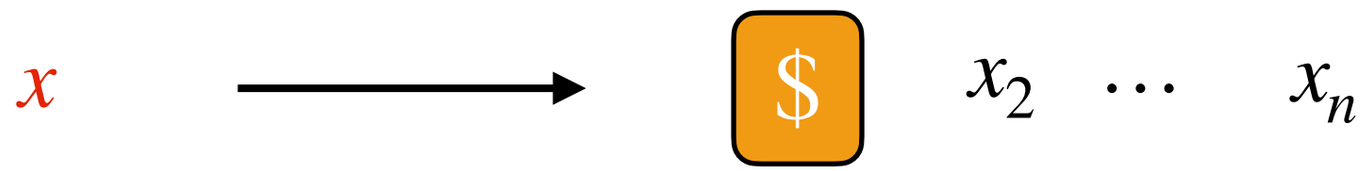

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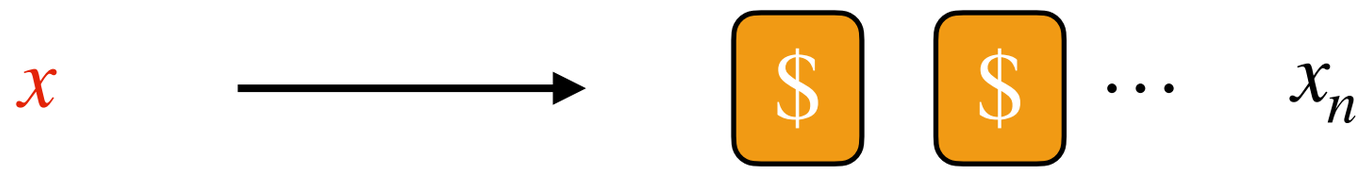

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CHES, 1999

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CHES, 1999

x $\quad\quad$ $x_1 \quad x_2 \quad \cdots \quad x_n$

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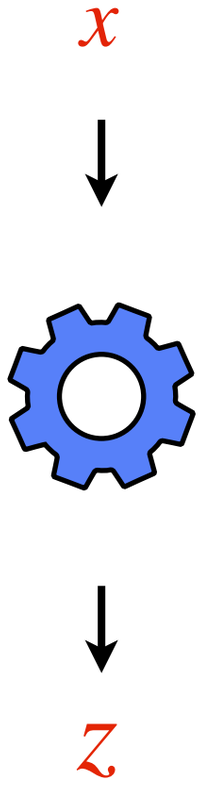

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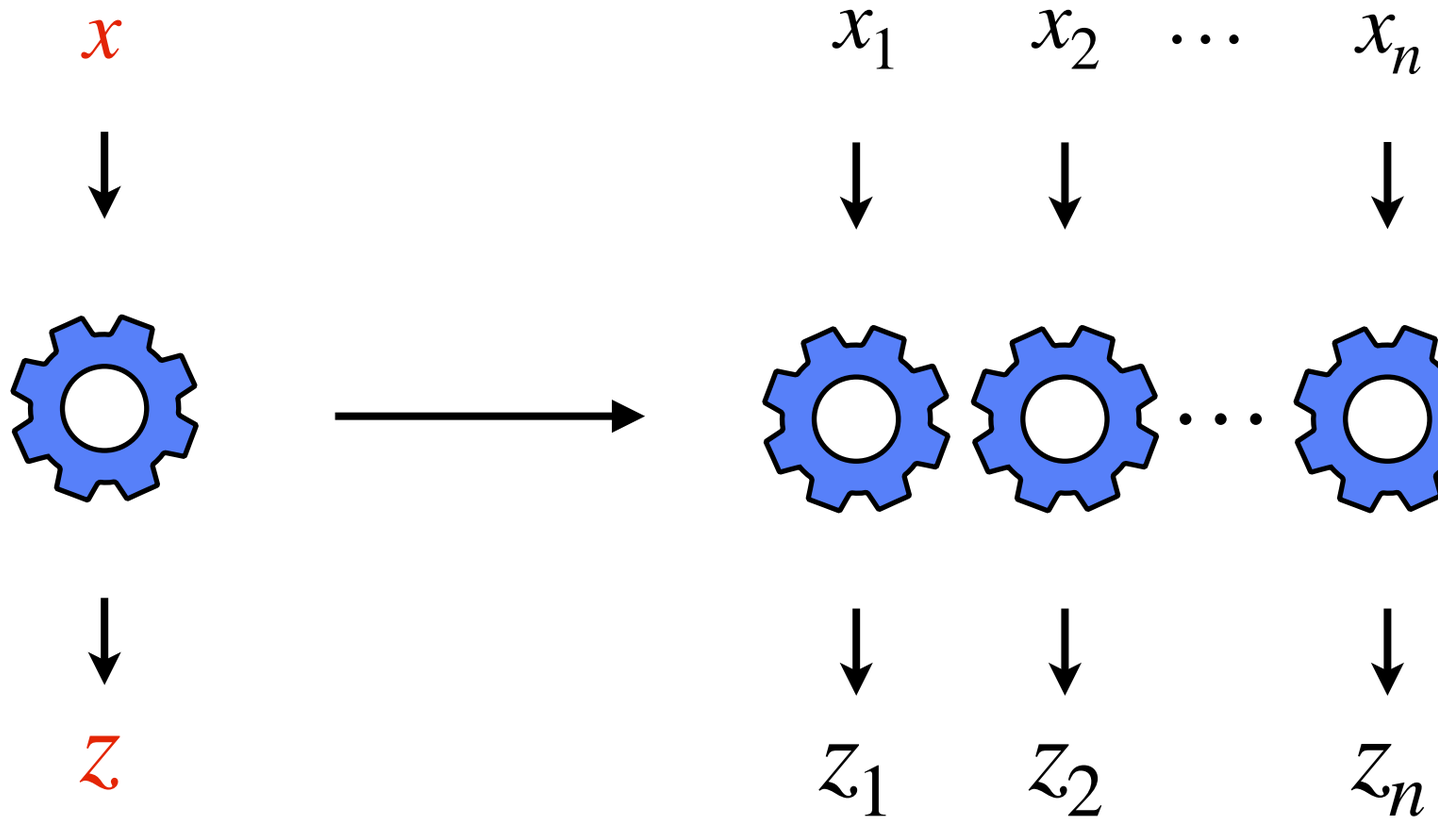

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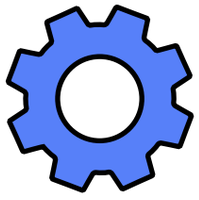
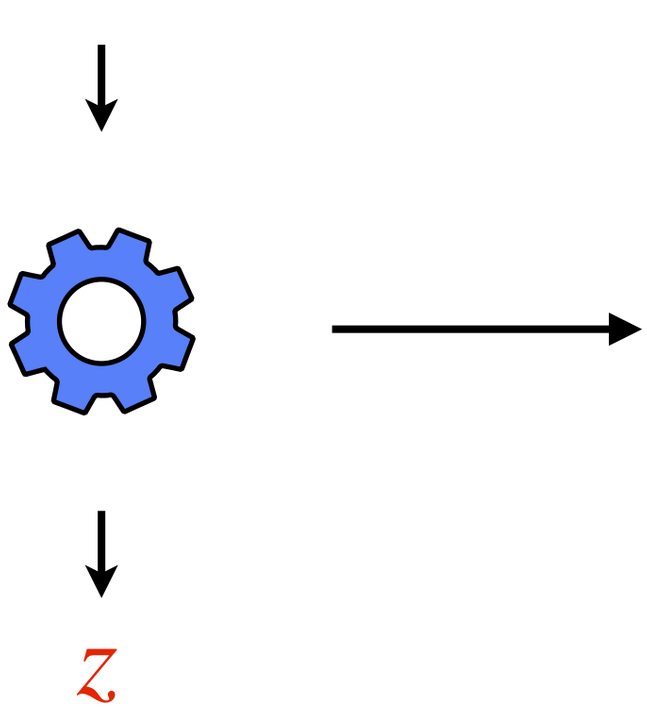


non-linear function

x

$x_1 \quad x_2 \quad \cdots \quad x_n$



z

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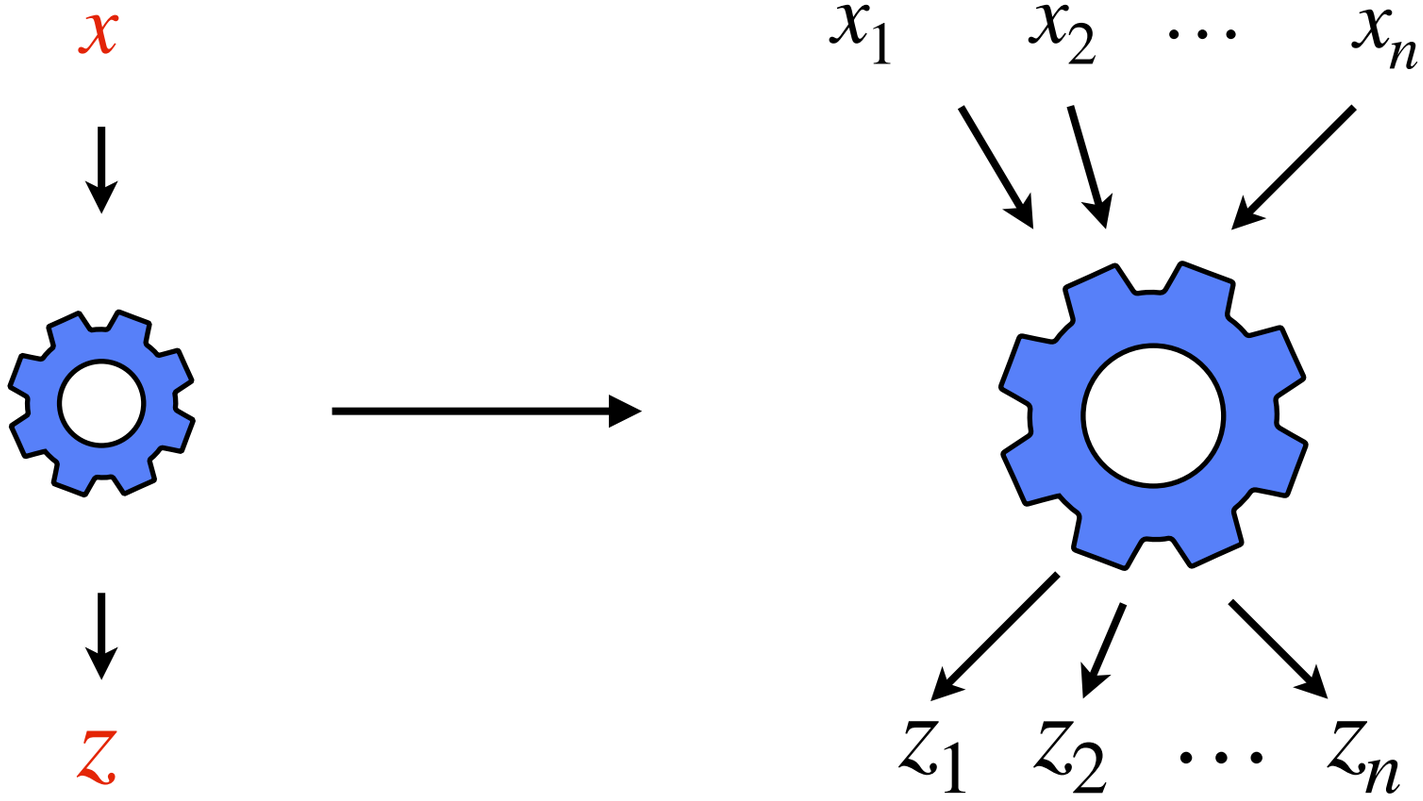

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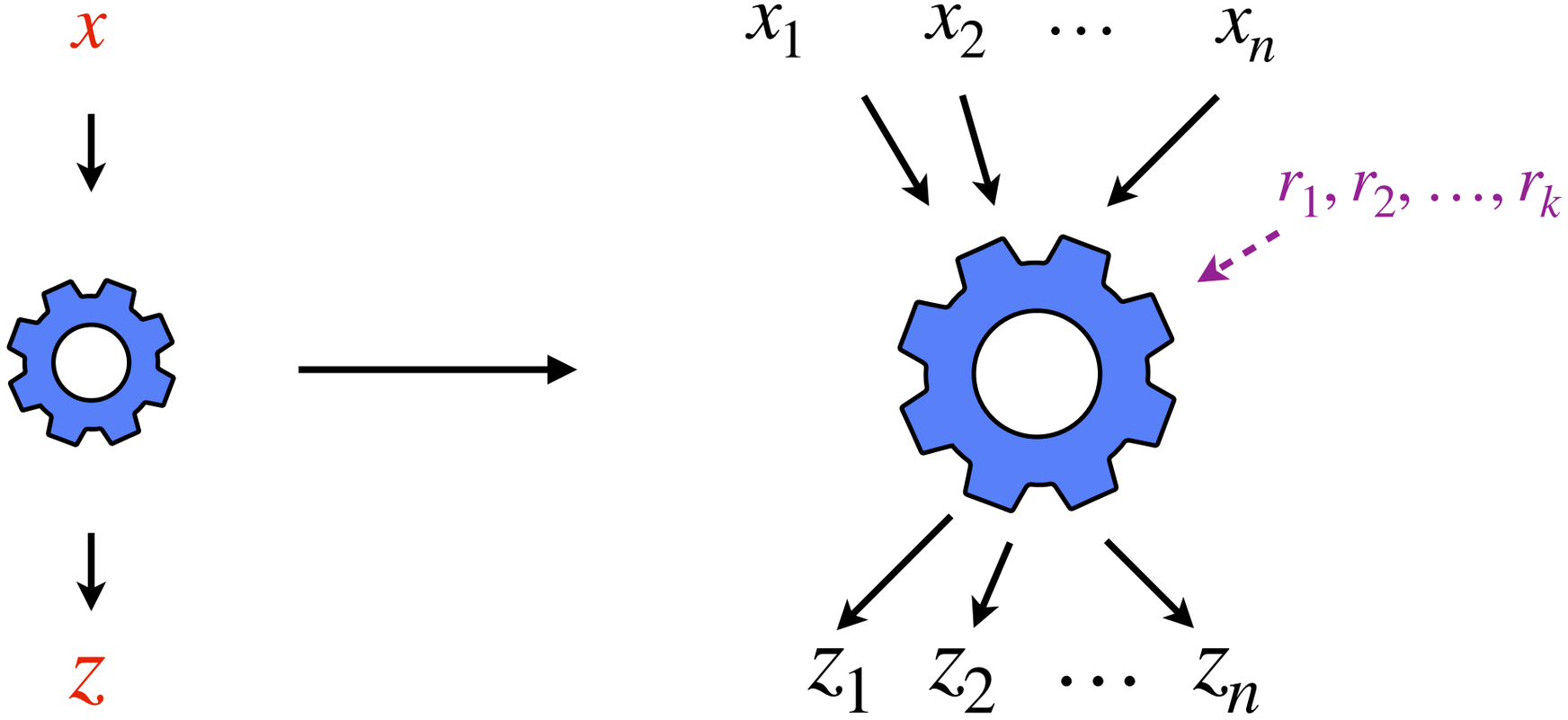

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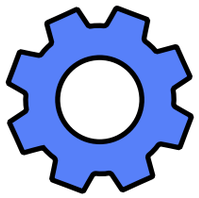

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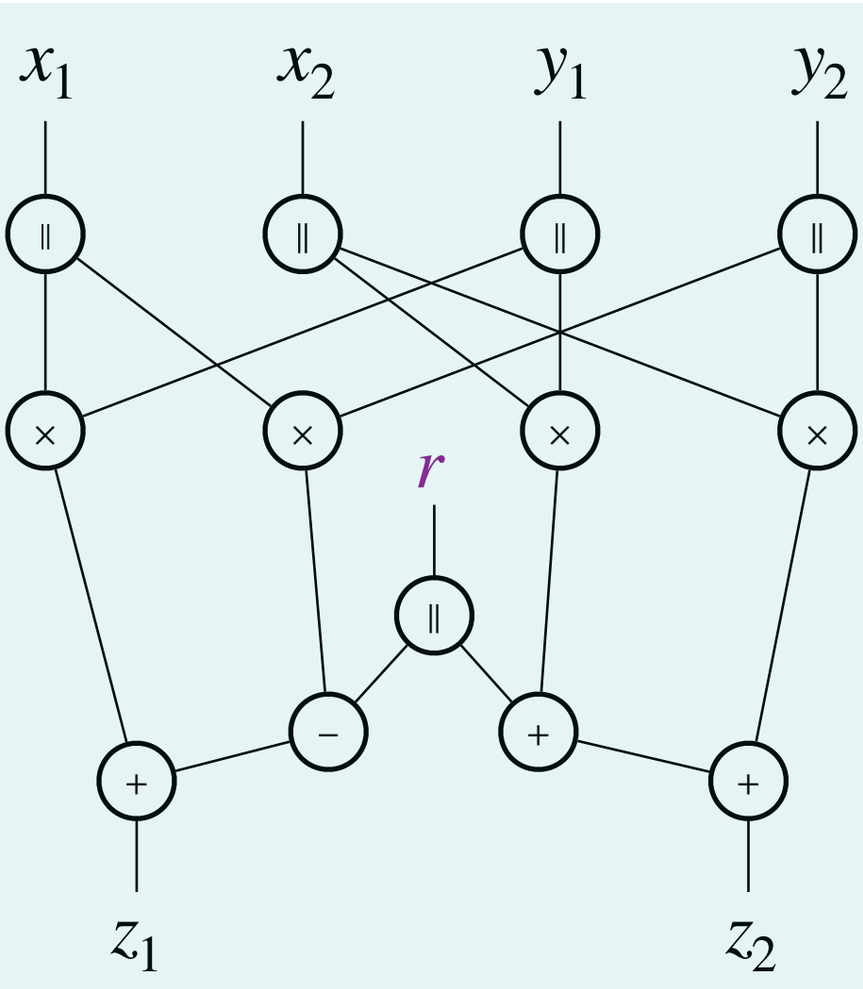


Example

Masking

Chari • Jutla • Rao • Rohatgi

CRYPTO 1999

Goubin • Patarin

CHES, 1999

non-linear function

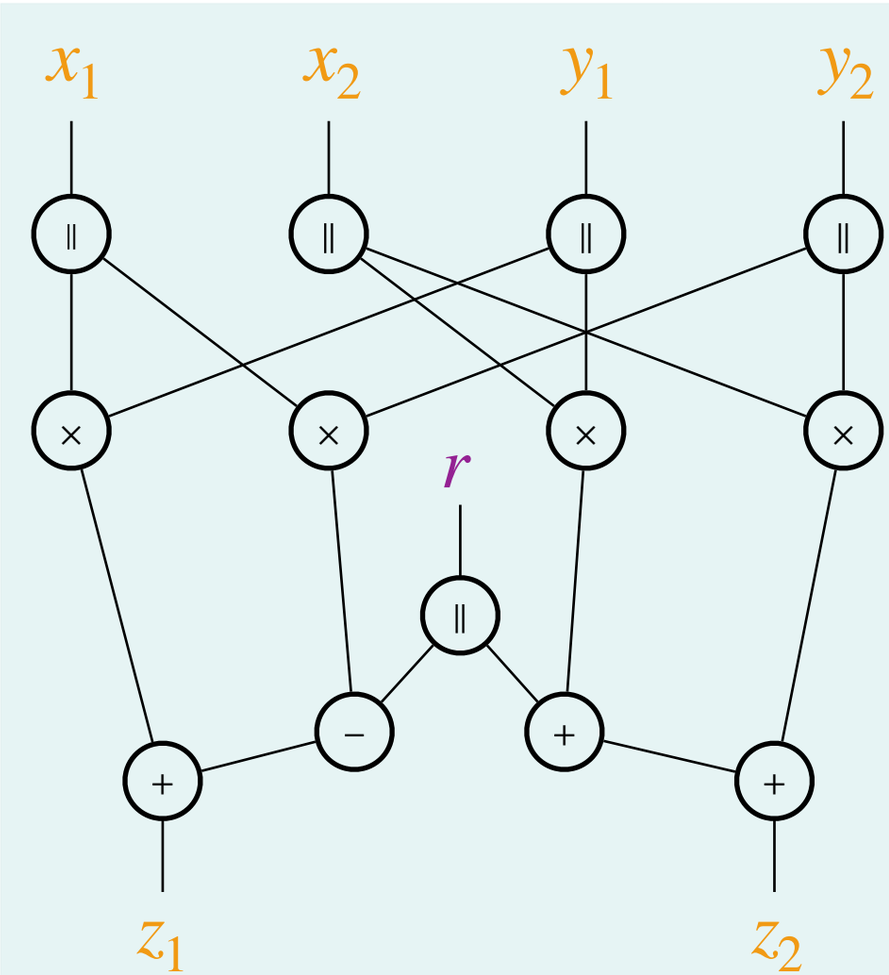
Inputs:

$$x = x_1 + x_2$$

$$y = y_1 + y_2$$

Output:

$$z = z_1 + z_2 = x \cdot y$$



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CRYPTO 1999

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CHES, 1999

non-linear function

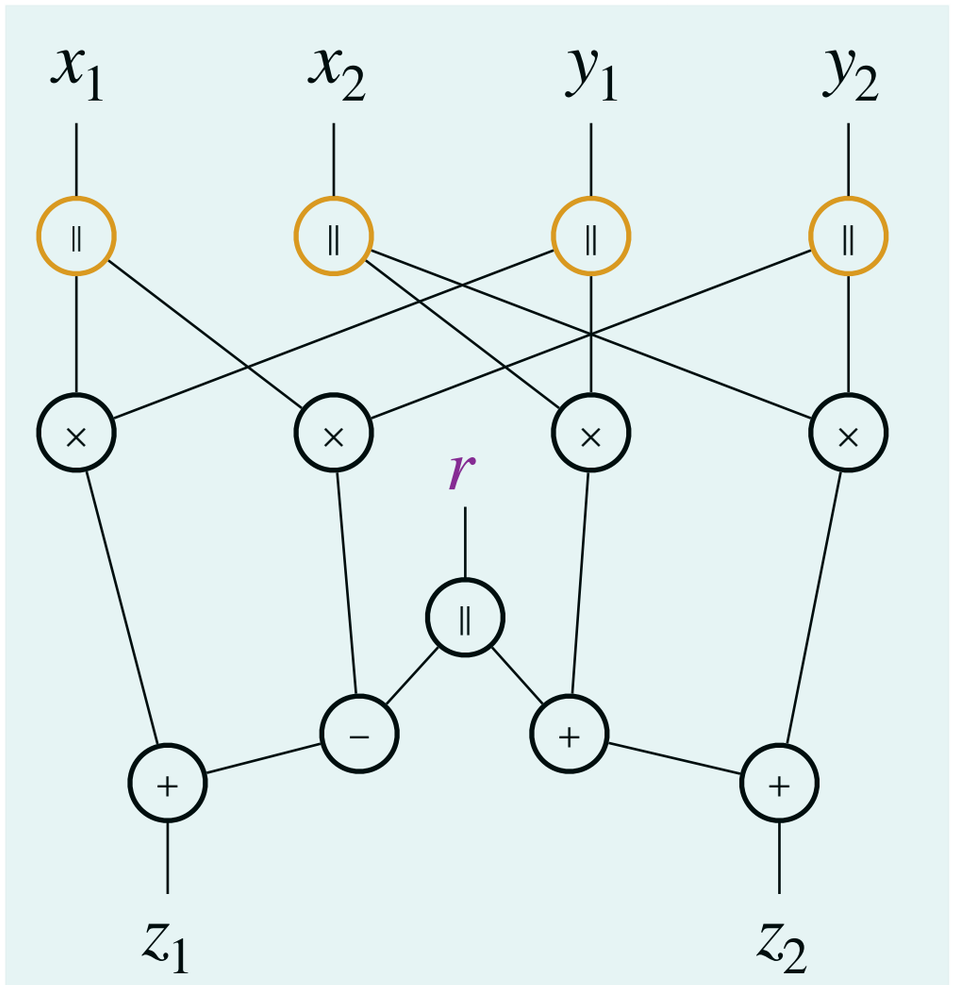
Copies:

$$x_1 \to (x_1^1, x_1^2)$$

$$x_2 \to (x_2^1, x_2^2)$$

$$y_1 \to (y_1^1, y_1^2)$$

$$y_2 \to (y_2^1, y_2^2)$$



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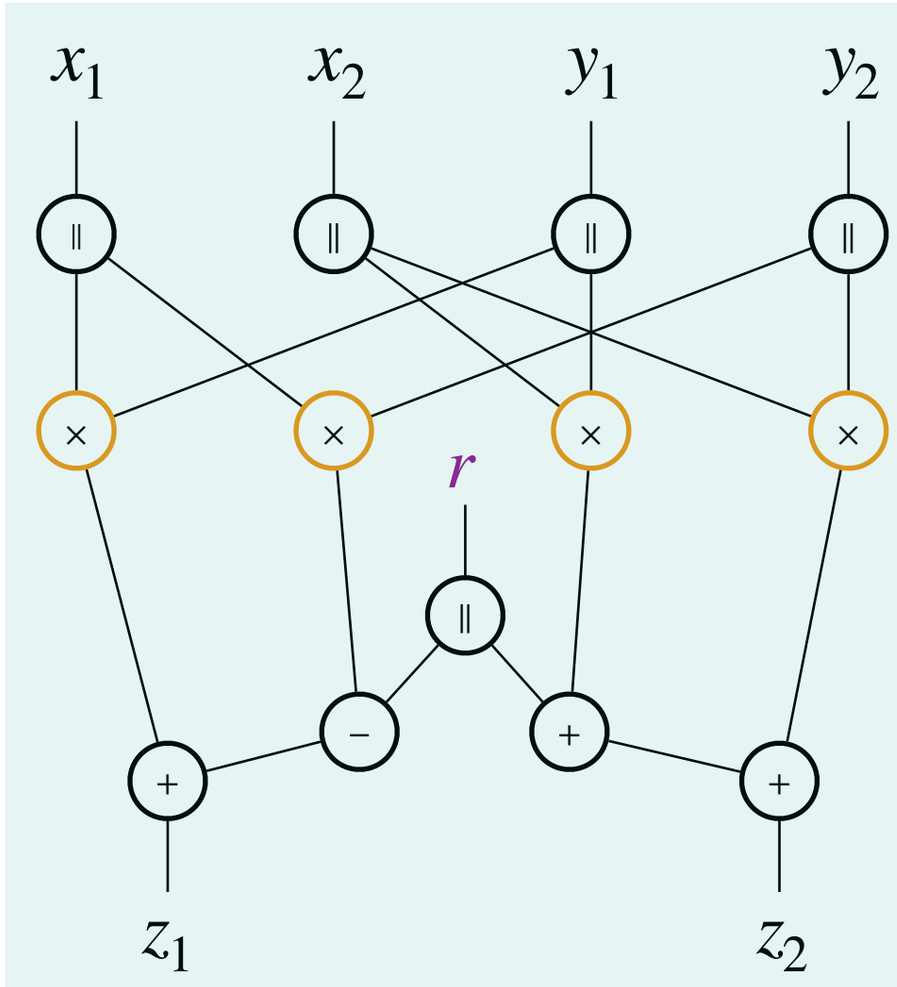
non-linear function

Cross-products:

$x_1^2 \cdot y_2^1$ $\quad$ $x_1^1 \cdot y_1^1$

$x_2^2 \cdot y_2^2$ $\quad$ $x_2^1 \cdot y_1^2$



Example

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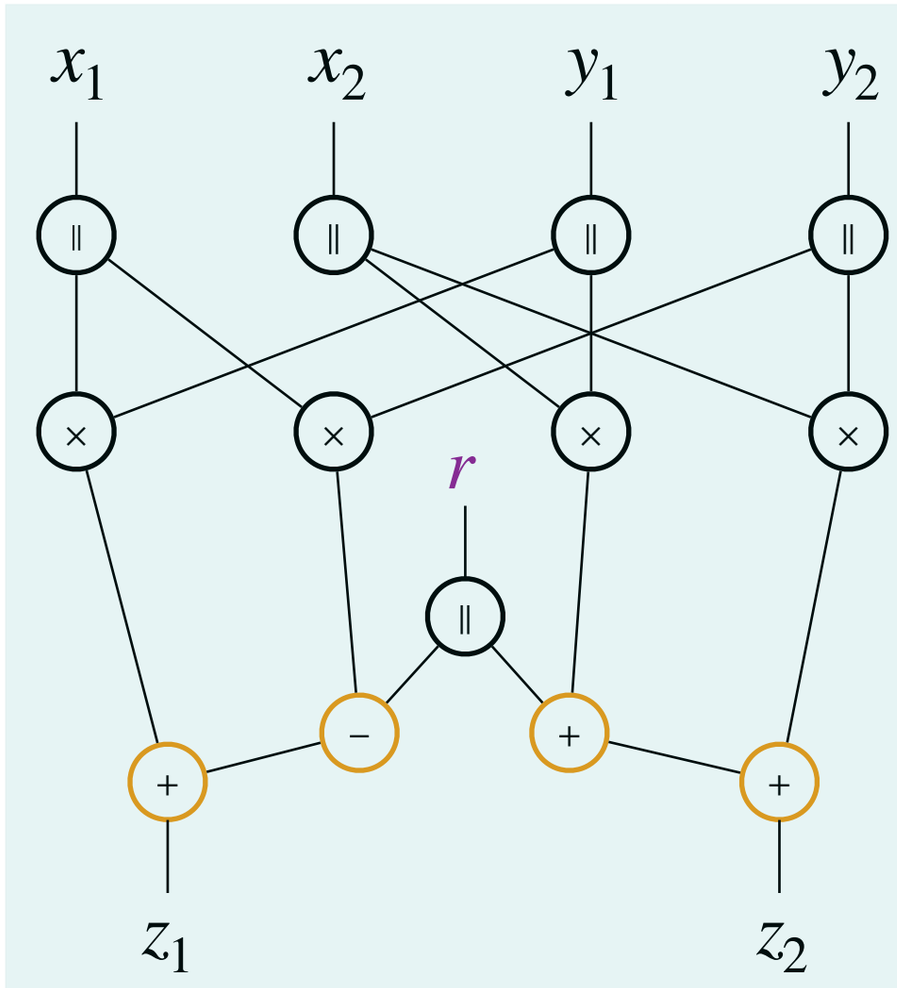
non-linear function

Final sums:

$$x_1^2 \cdot y_2^1 - r + x_1^1 \cdot y_1^1$$
$$x_2^2 \cdot y_2^2 + r + x_2^1 \cdot y_1^2$$



Example

Leakage Models

Chari • Jutla • Rao • Rohatgi

CRYPTO 1999

Prouff • Rivain

EUROCRYPT 2013

δ-noisy leakage model

Most realistic

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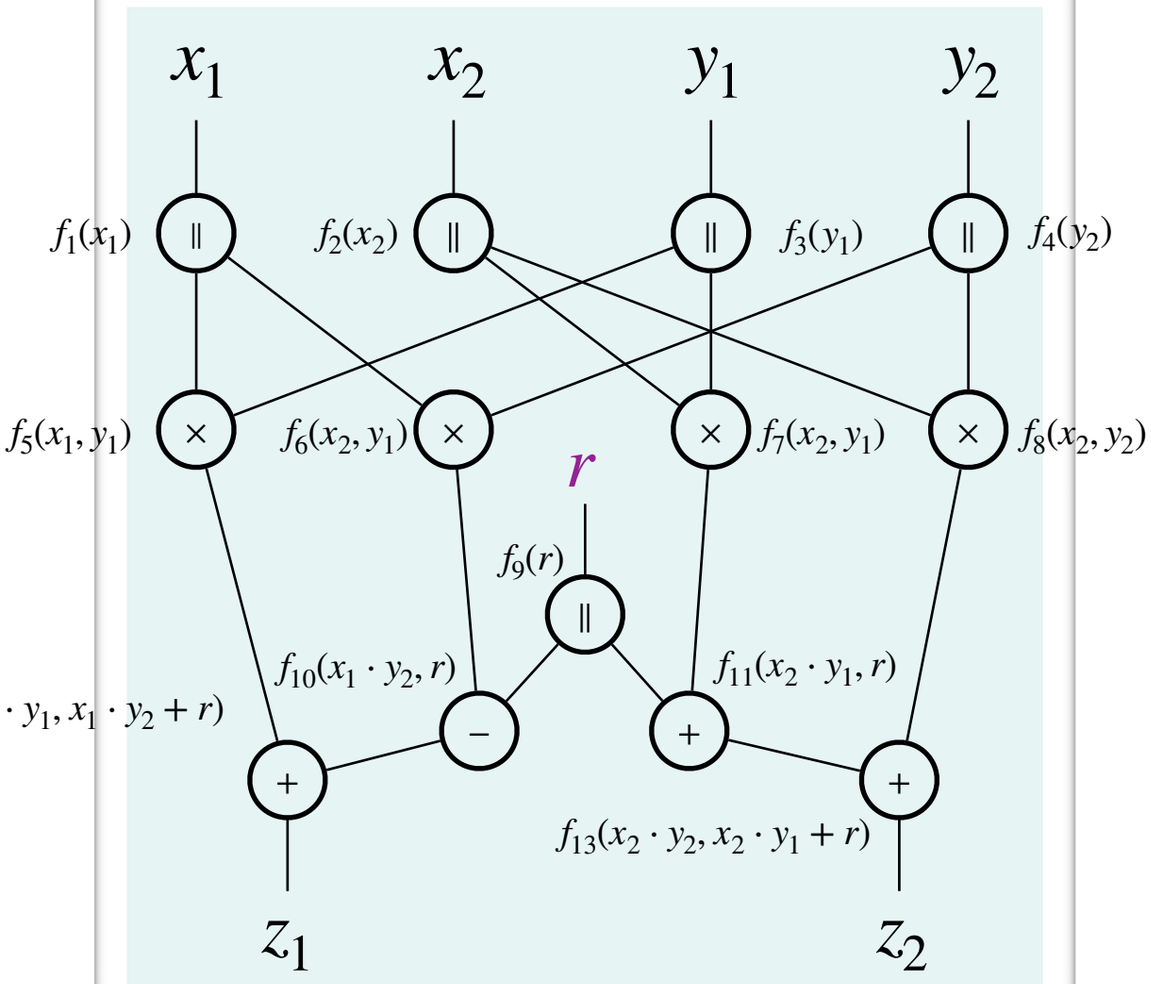

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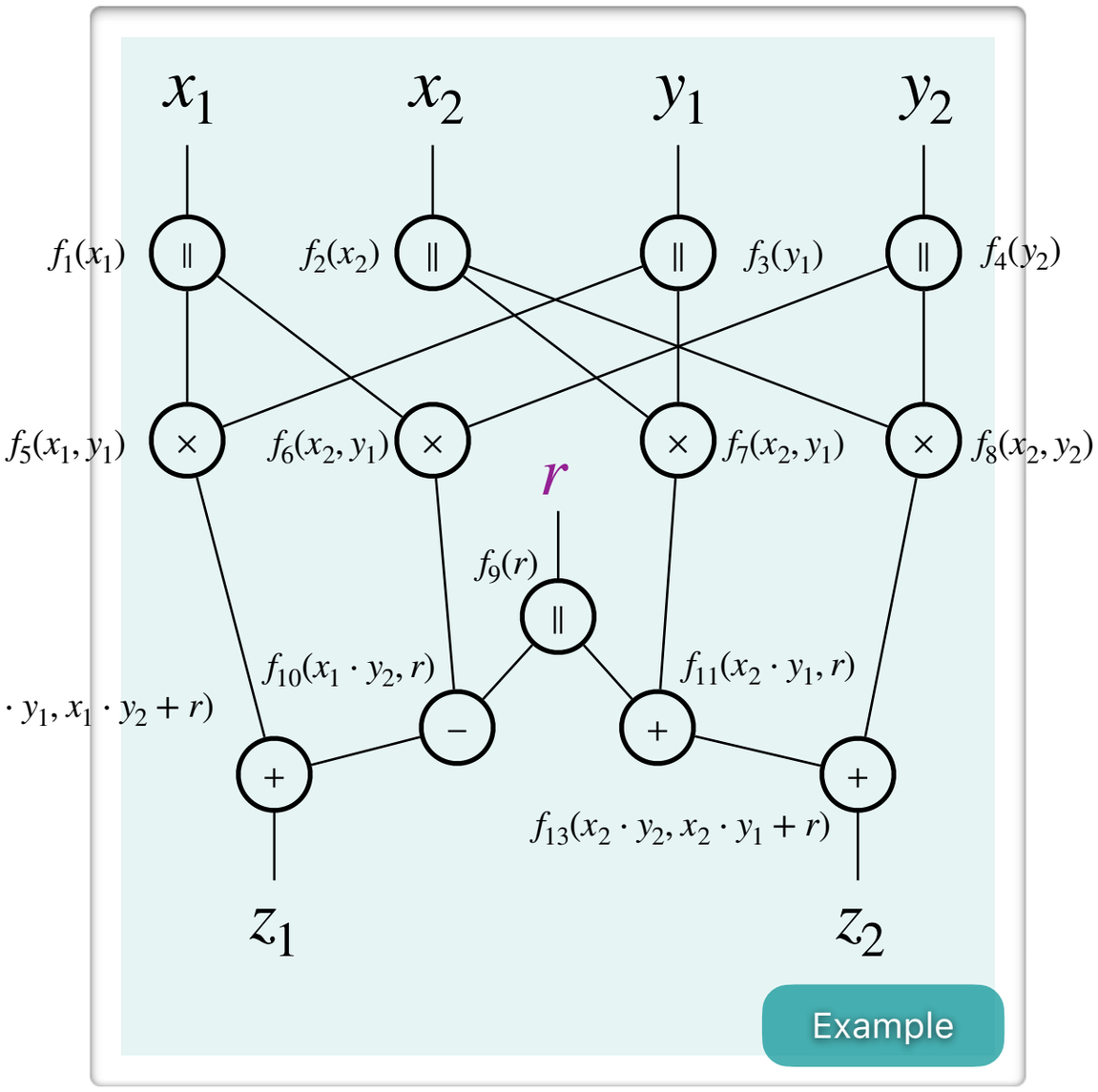

δ-noisy leakage model

Most realistic

$$\beta_{\Delta}(X \mid f_i(X)) = \mathbb{E}_y\left[\Delta(X; X \mid f_i(X) = y)\right] \leq \delta$$

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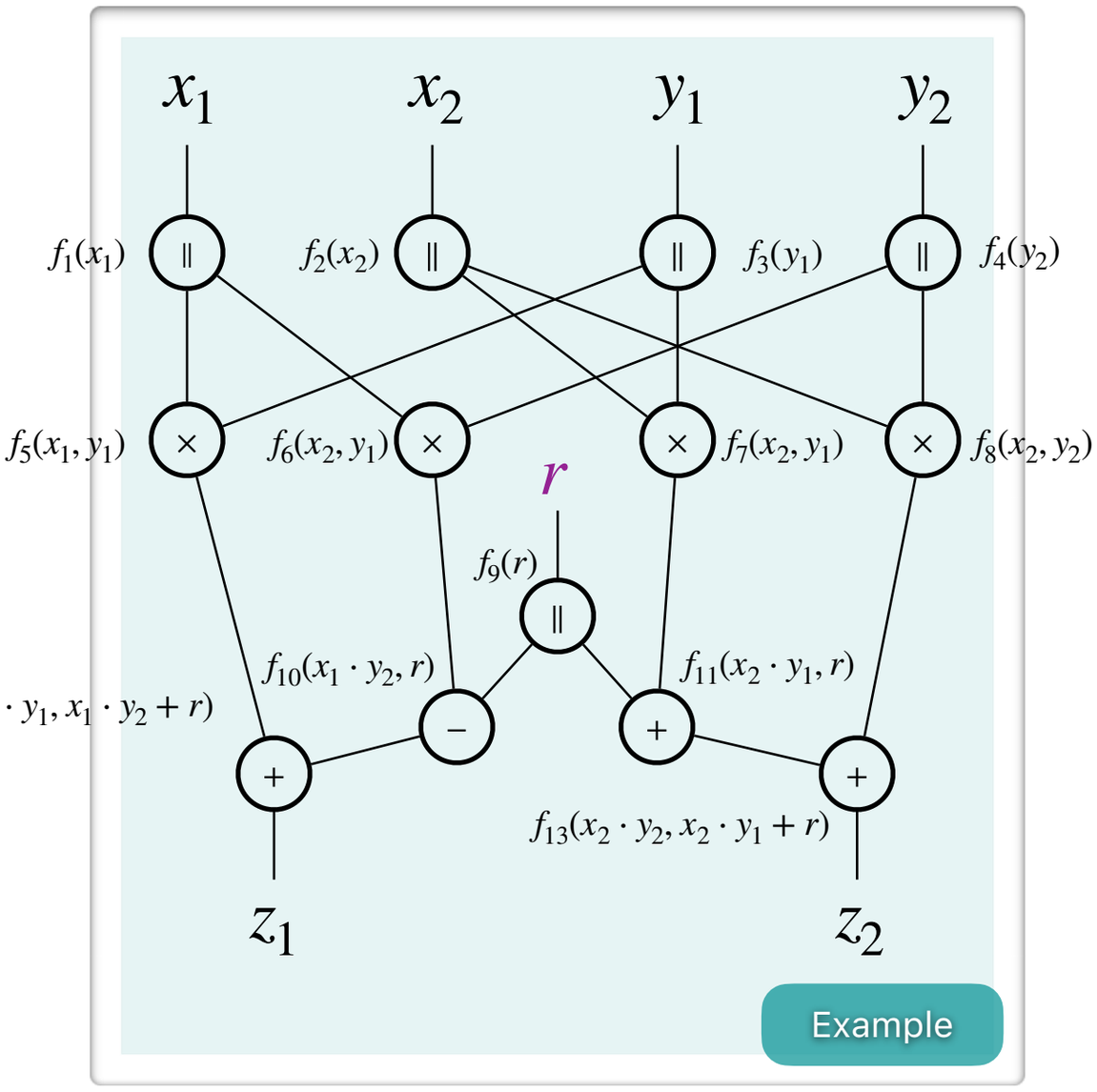

δ-noisy leakage model

Most realistic

$$\beta_{\Delta}(X \,|\, f_1(X), f_2(X), \ldots, f_{13}(X)) \;\leq\; \varepsilon$$

Leakage Models

Ishai • Sahai • Wagner
CRYPTO 2003

t-probing model

Most convenient

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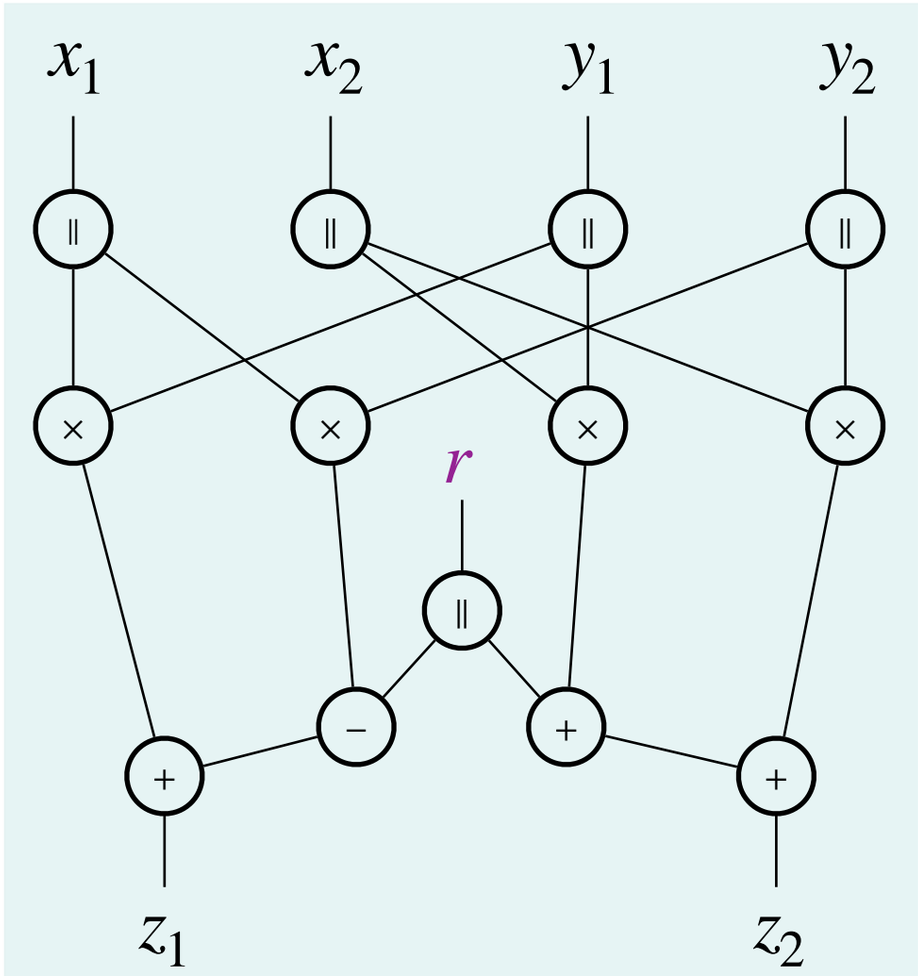

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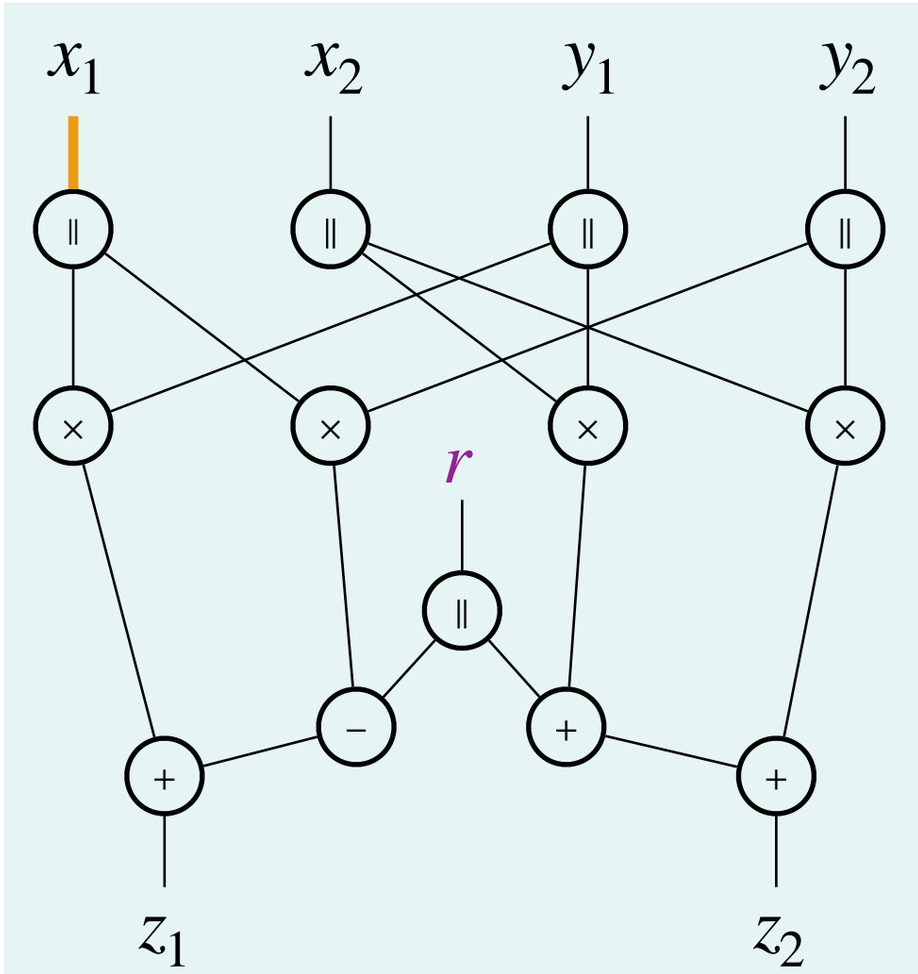

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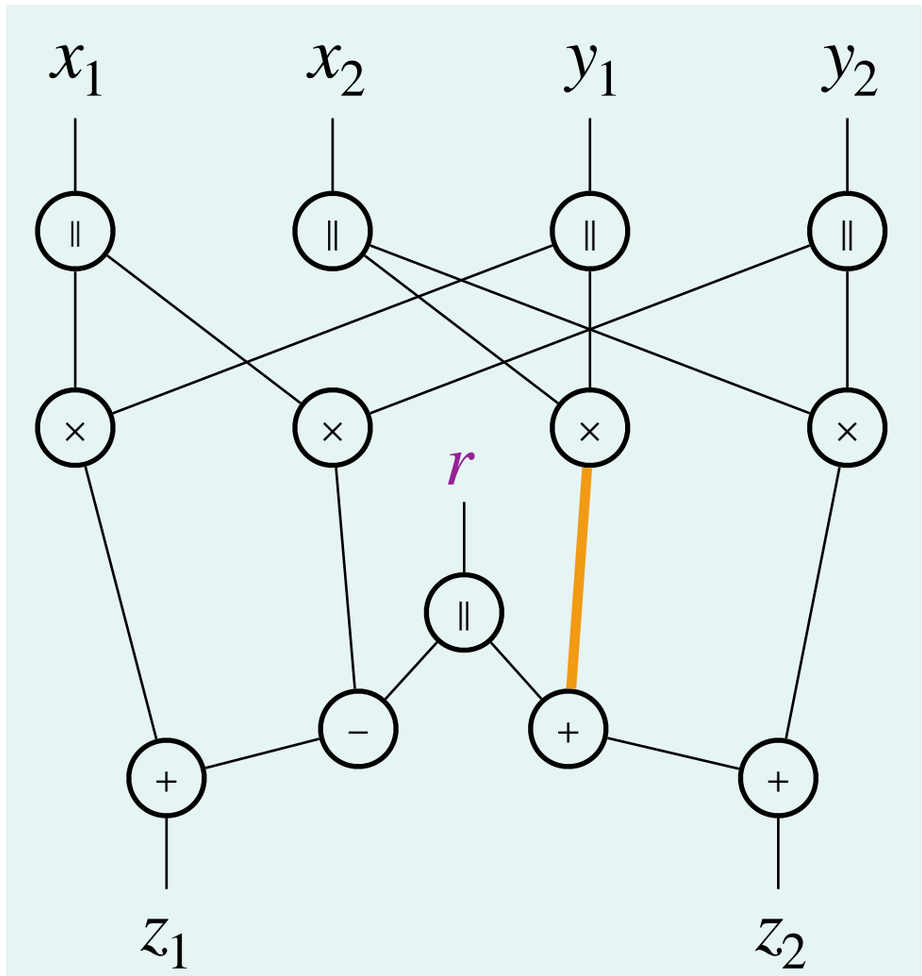

Example

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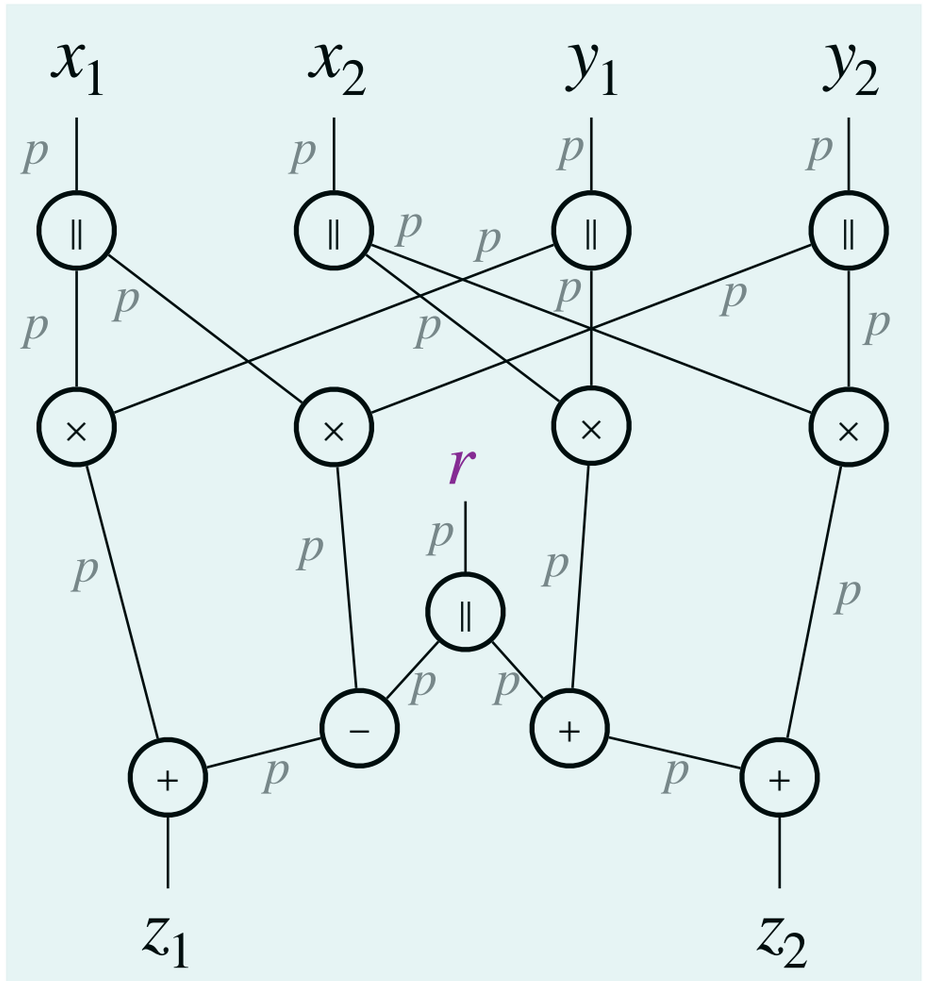

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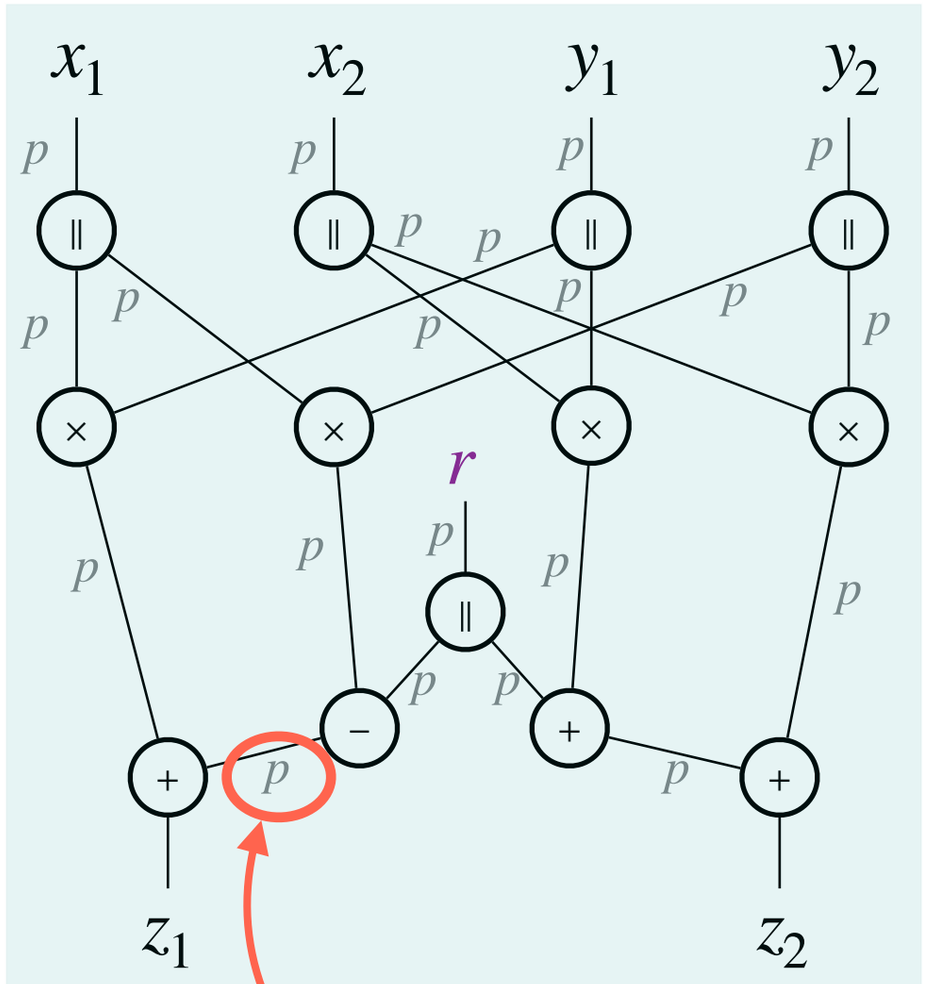

leakage rate

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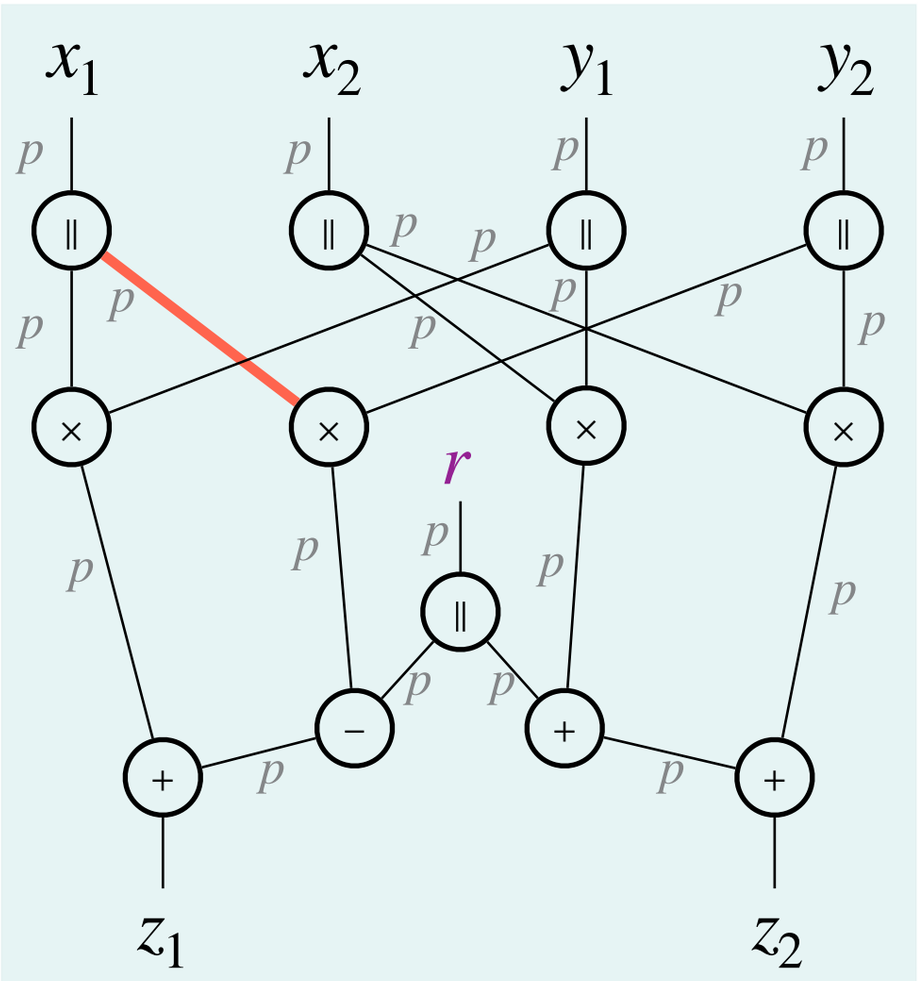

Example

DDF Reduction

t-probing security

Most convenient

p-random probing security

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δ-noisy leakage security

Most realistic

with $\delta = \Theta(p)$

Duc • Dziembowski • Faust

EUROCRYPT 2014

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Duc • Dziembowski • Faust

EUROCRYPT 2014

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with $p = \Theta\left(\frac{t}{|C|}\right)$

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Duc • Dziembowski • Faust

EUROCRYPT 2014

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EUROCRYPT 2014

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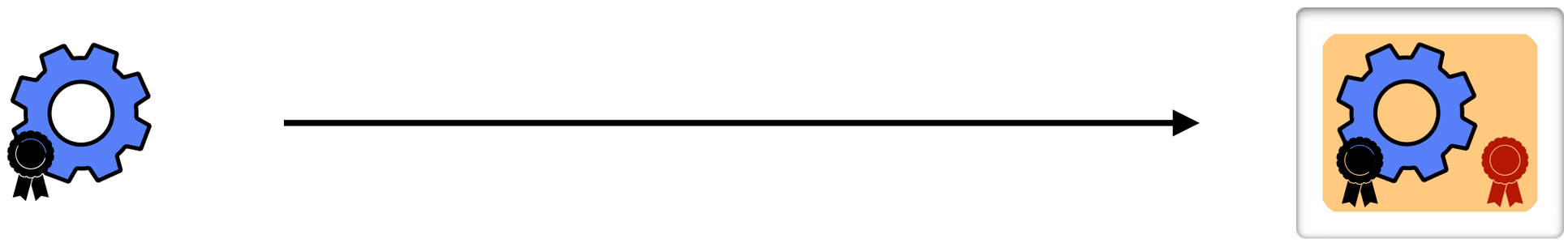
Duc • Dziembowski • Faust

EUROCRYPT 2014

Design and Analysis of Random Probing Secure Implementations

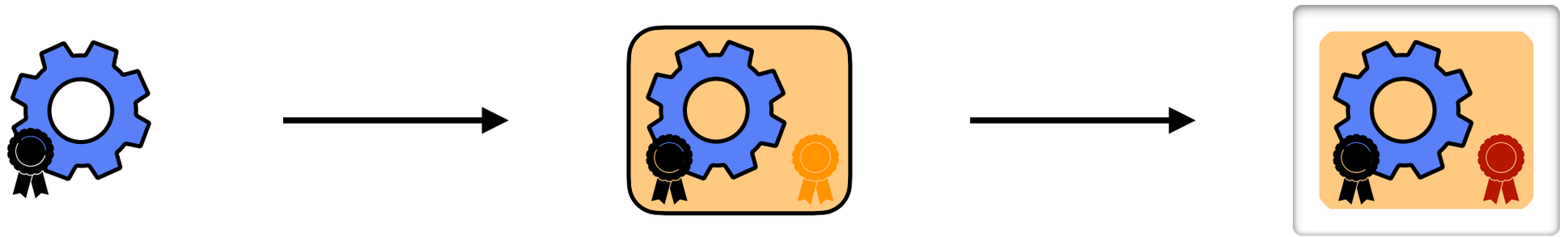
Main Goal



Black-box secure

Black-box and
physically secure

Main Goal



Black-box secure

Black-box and
random probing
secure

Black-box and
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Main Goal

Belaïd • Cassiers • Mutschler • Rivain • Roche • Standaert • Taleb

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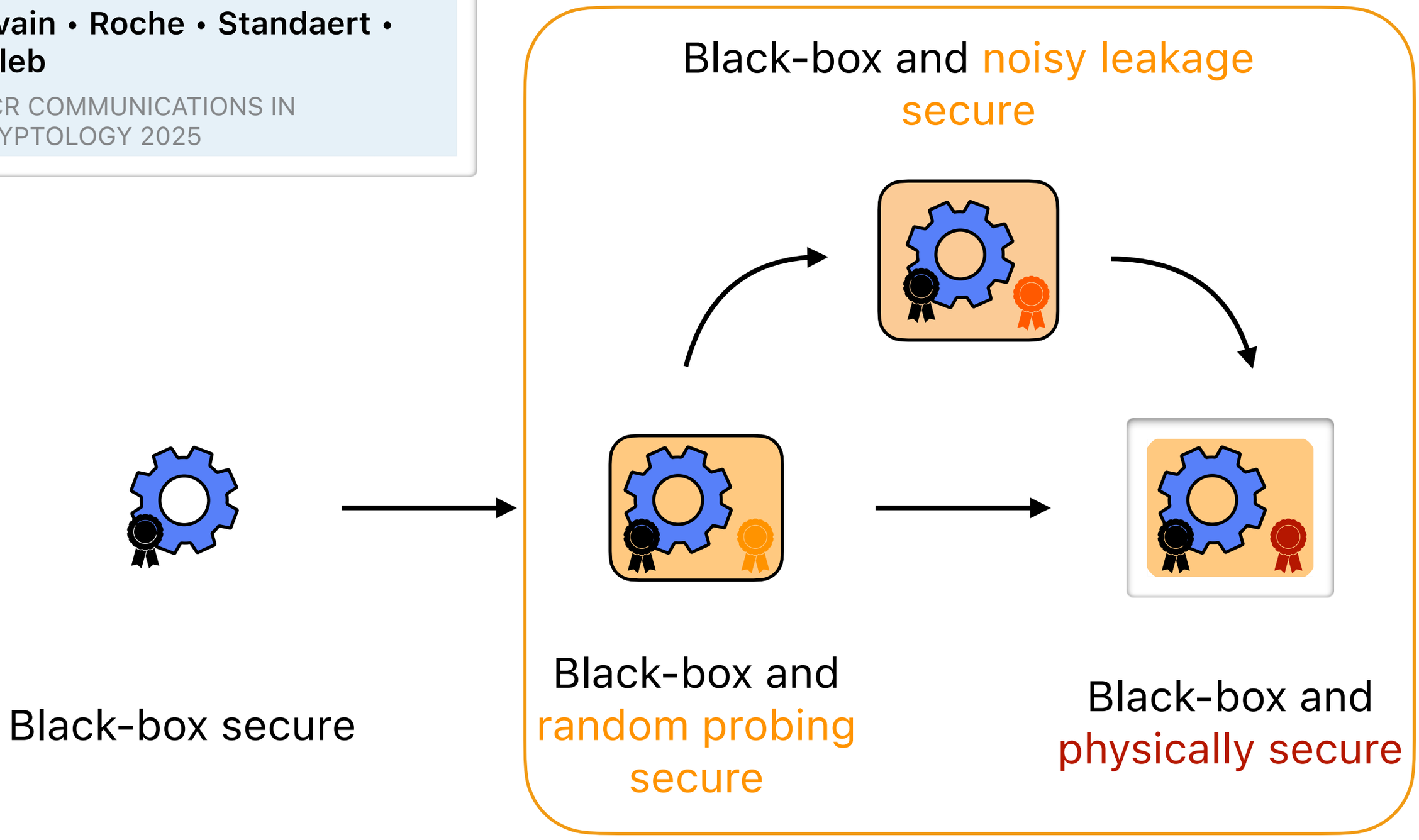

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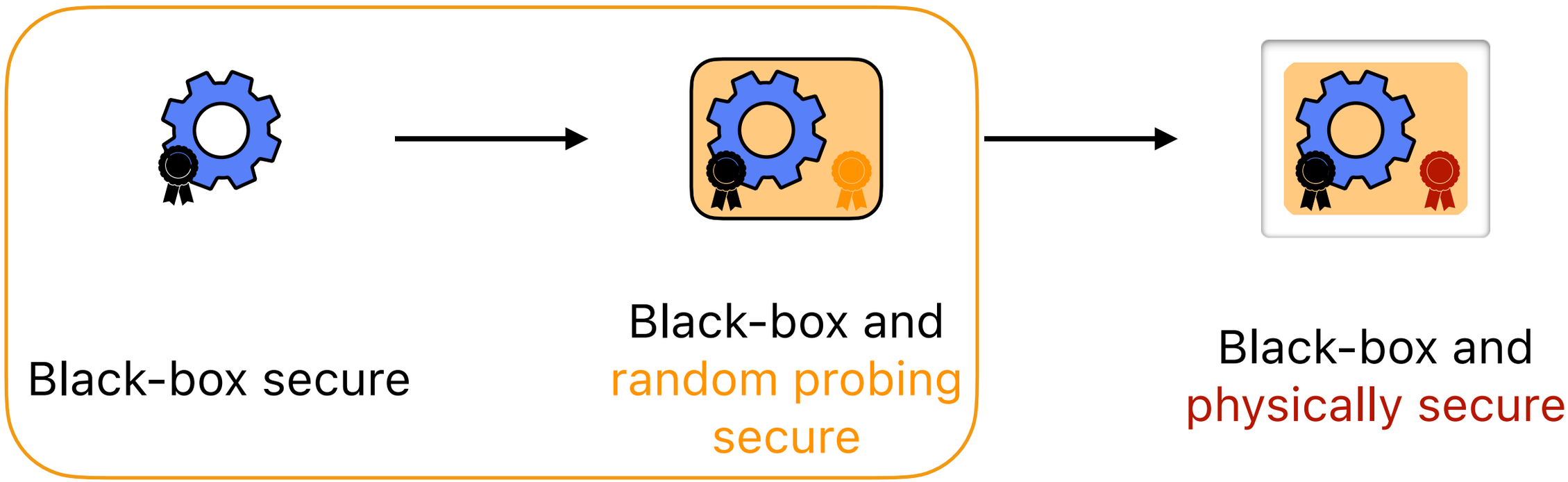

Black-box secure
Black-box and
random probing
secure
Black-box and
physically secure

Results

🔬 **Foundations**

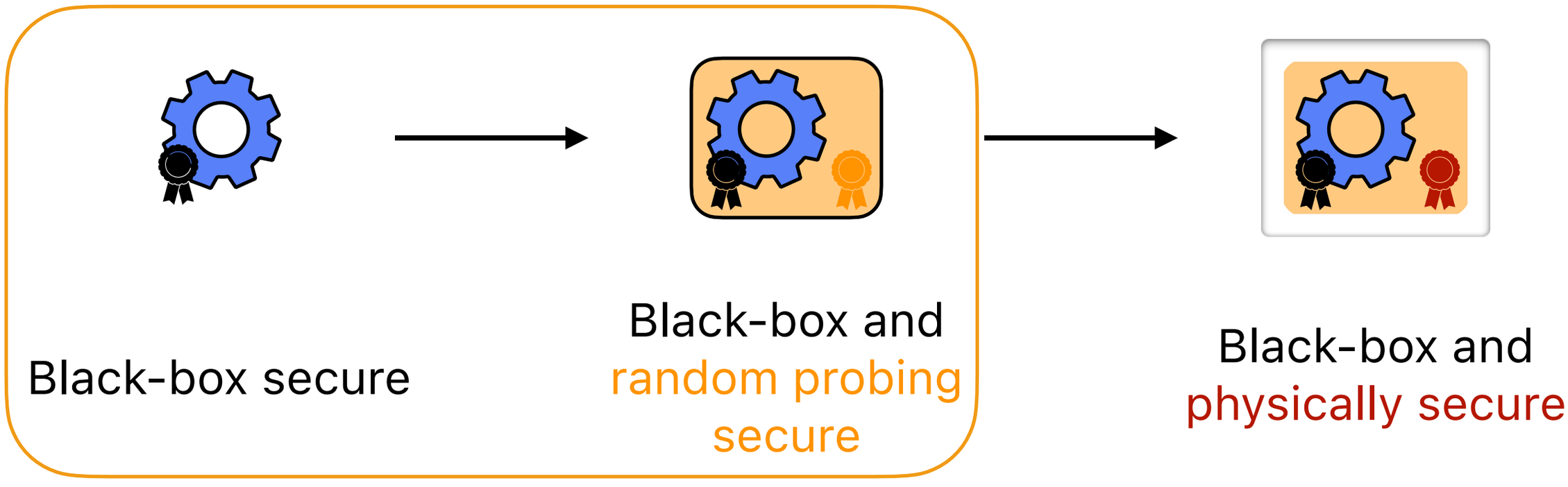
Random probing security & verification (small circuits)

🏗️ **Scaling up**

Composition frameworks (larger circuits)

🧩 **Building blocks**

Design of efficient gadgets



Results

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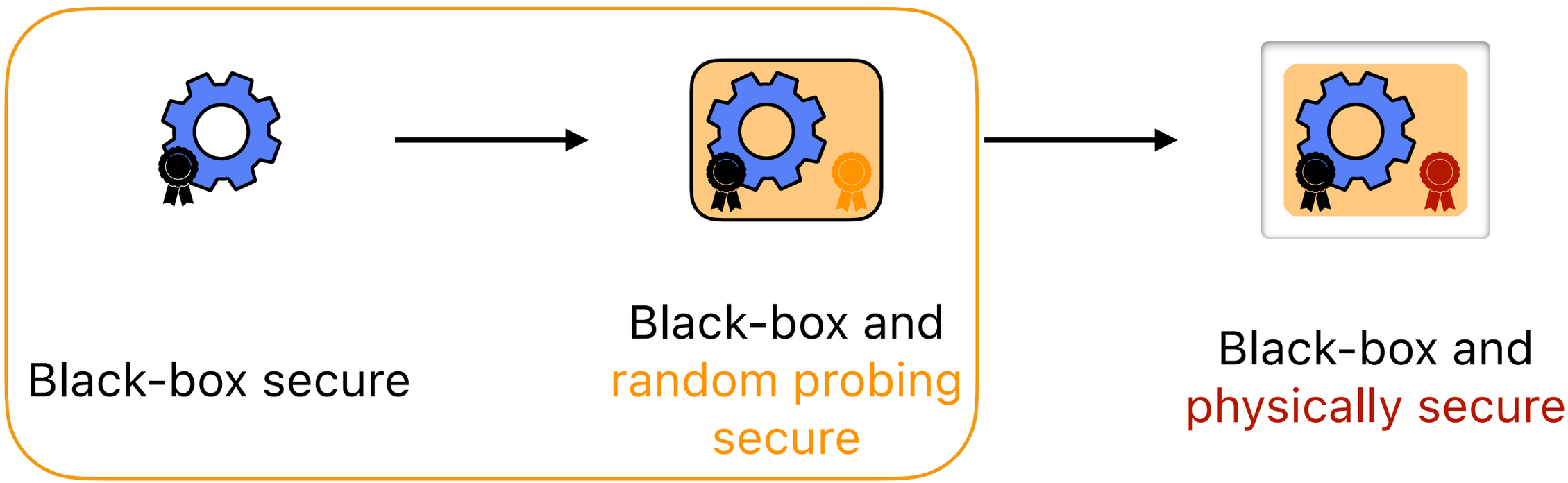
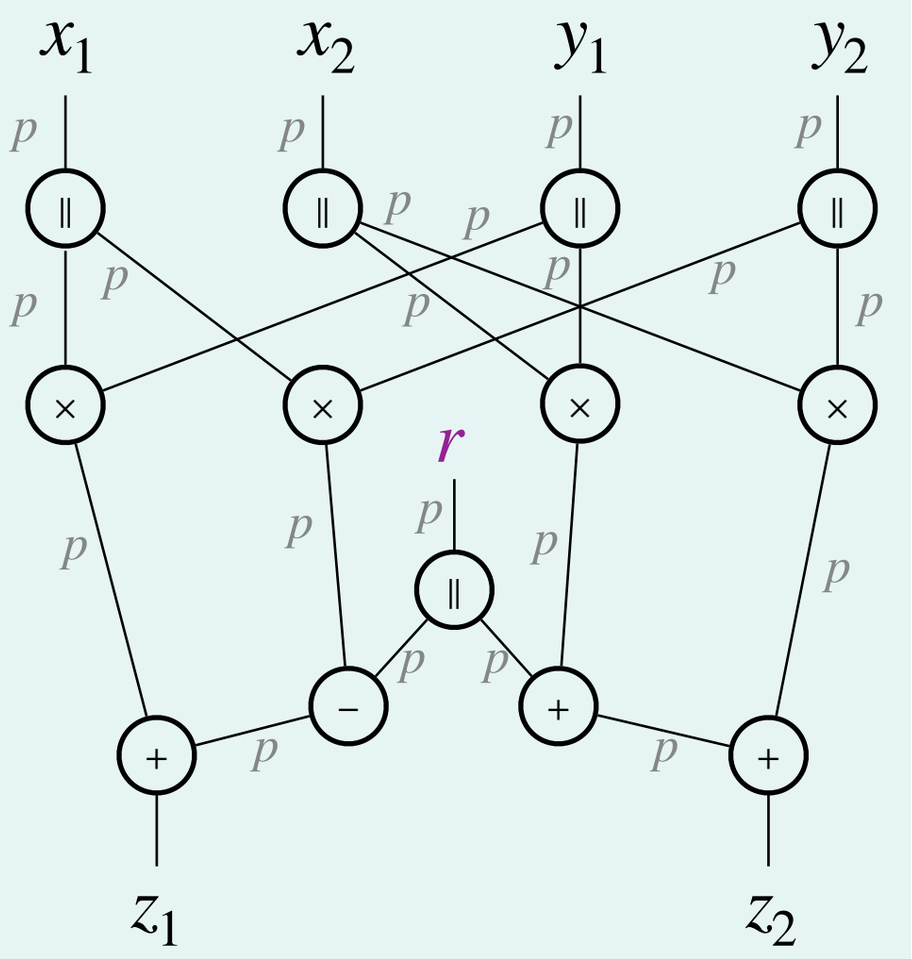


Random Probing Security

Ananth • Ishai • Sahai
CRYPTO 2018

Adversary's view



Example

Simulator

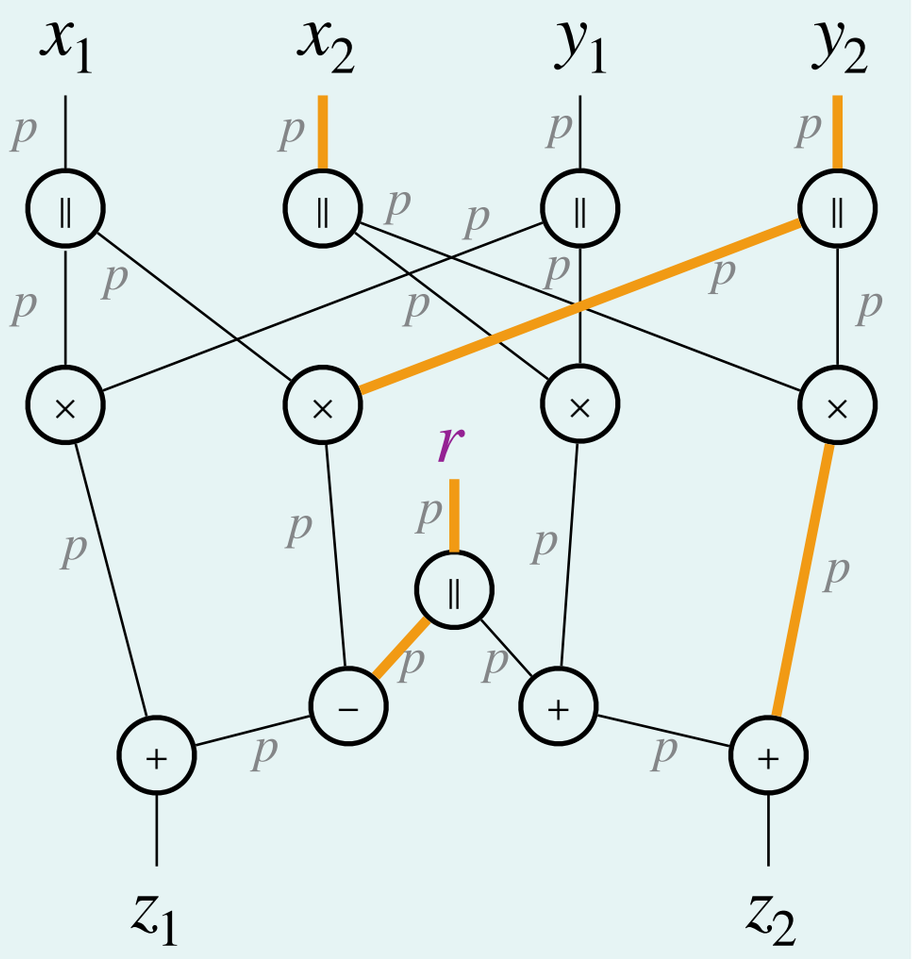
Example

A circuit is (p, ε)-random-probing secure if there exists a PPT simulator such that the distribution of the simulated leakage is ε-close to the one of the real leakage

Random Probing Security

Ananth • Ishai • Sahai
CRYPTO 2018

Adversary's view



Example

Simulator

Example

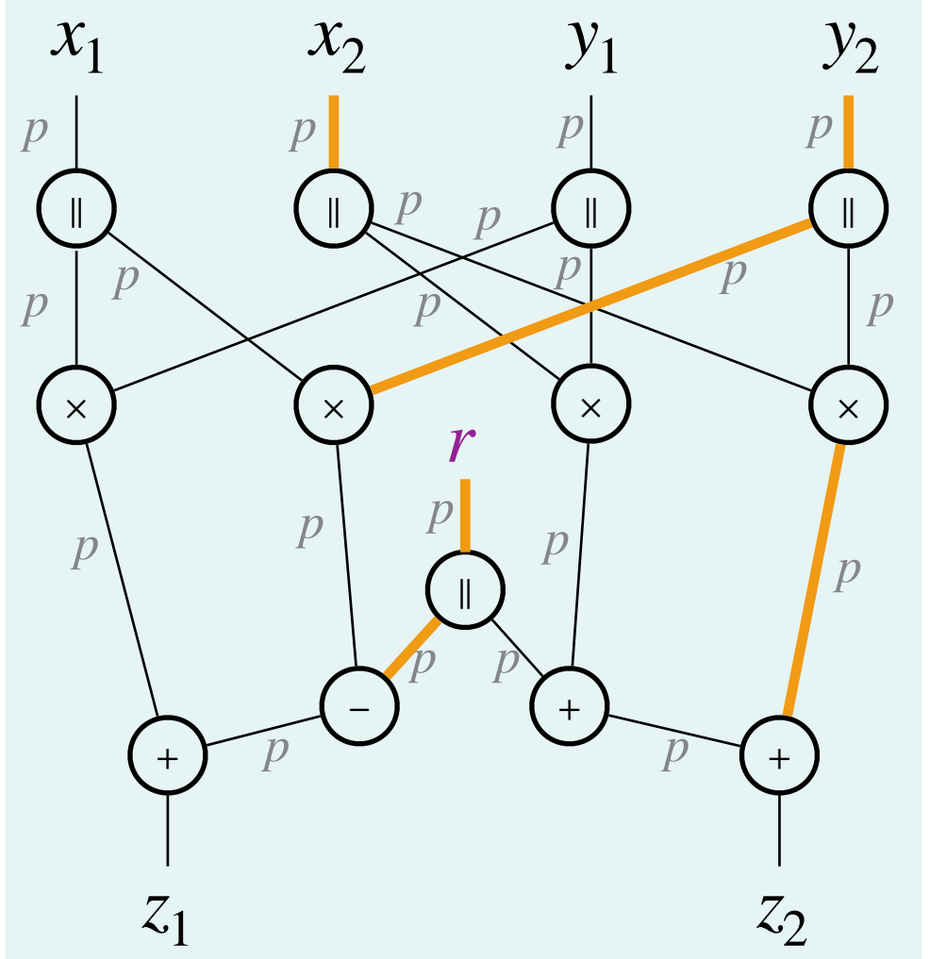
A circuit is (p, ε)-random-probing secure if there exists a PPT simulator such that the distribution of the simulated leakage is ε-close to the one of the real leakage

Random Probing Security

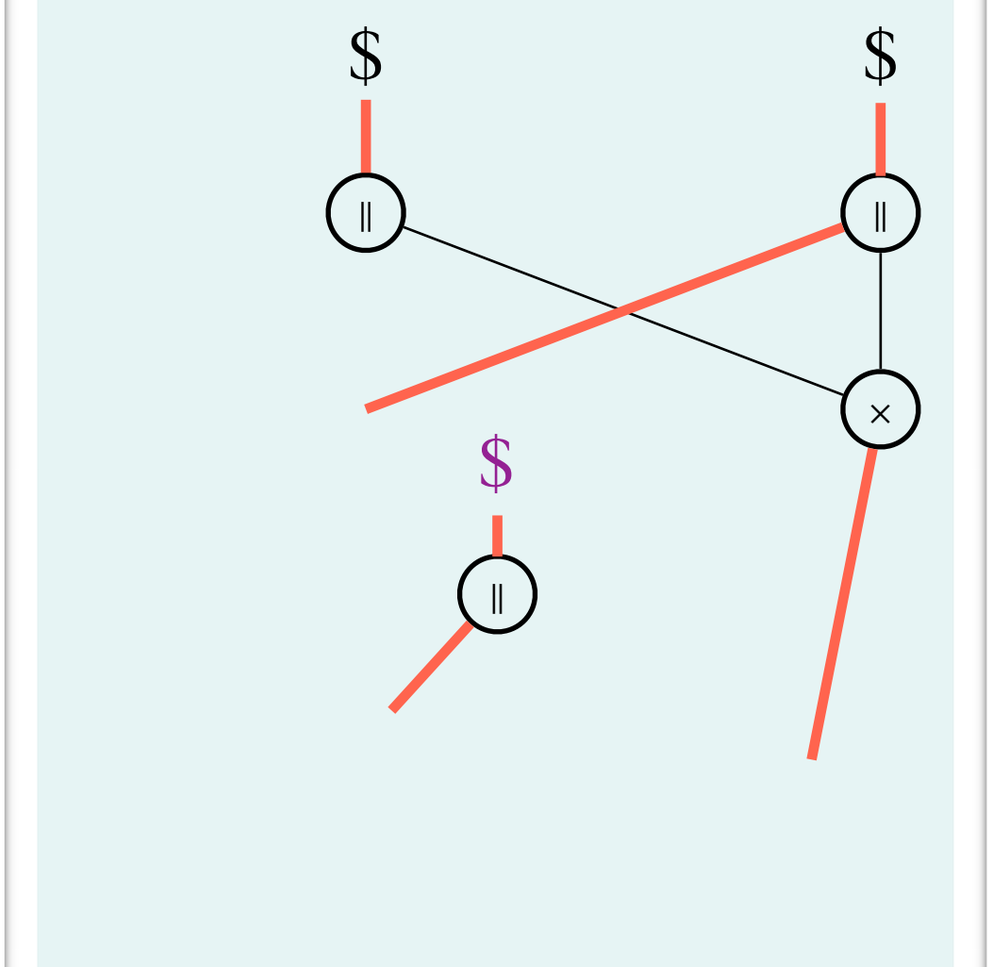
Ananth • Ishai • Sahai

CRYPTO 2018

Adversary's view



Simulator



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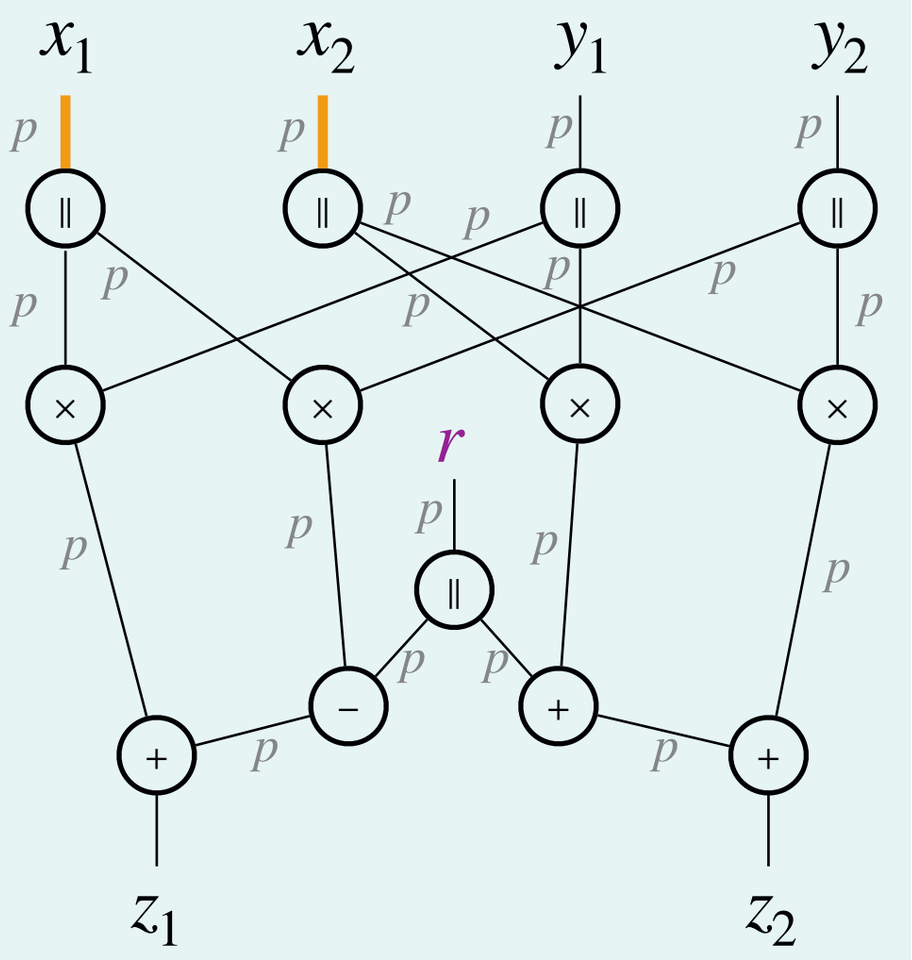

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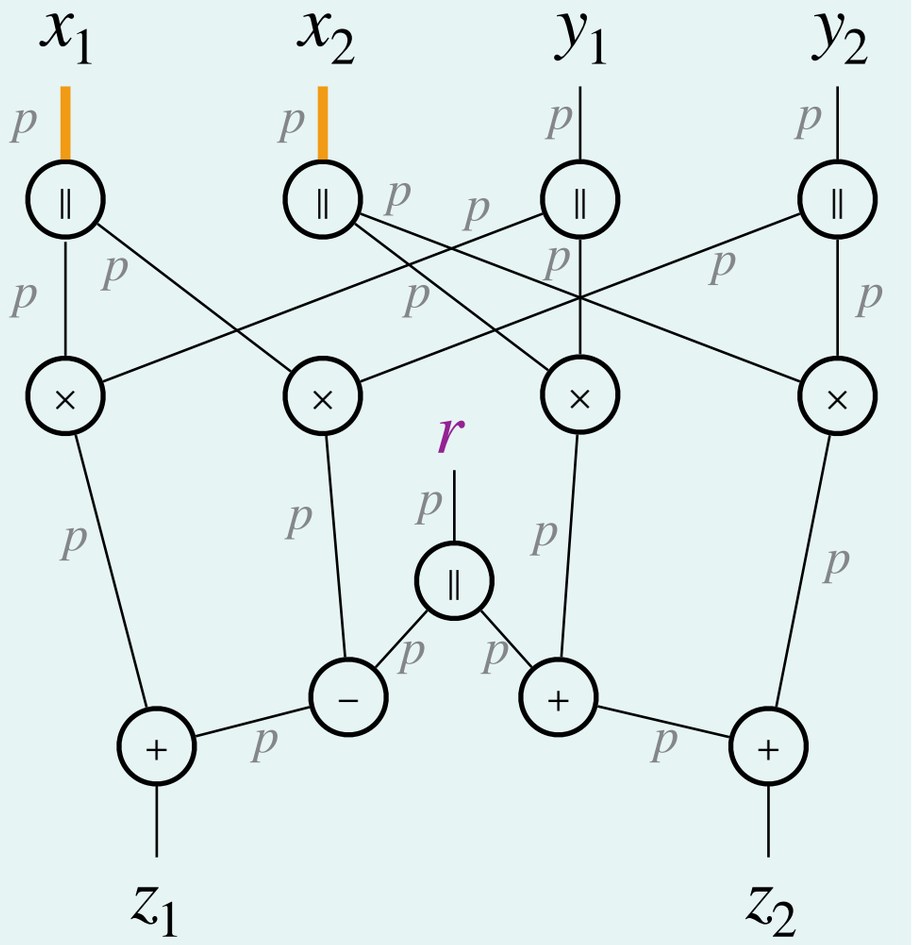

Example

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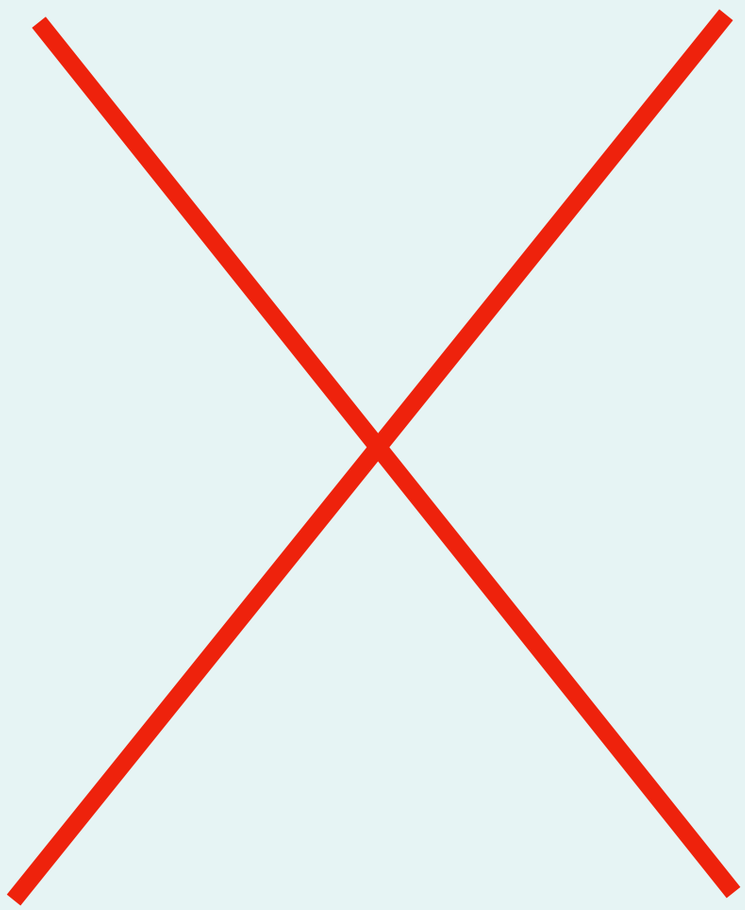

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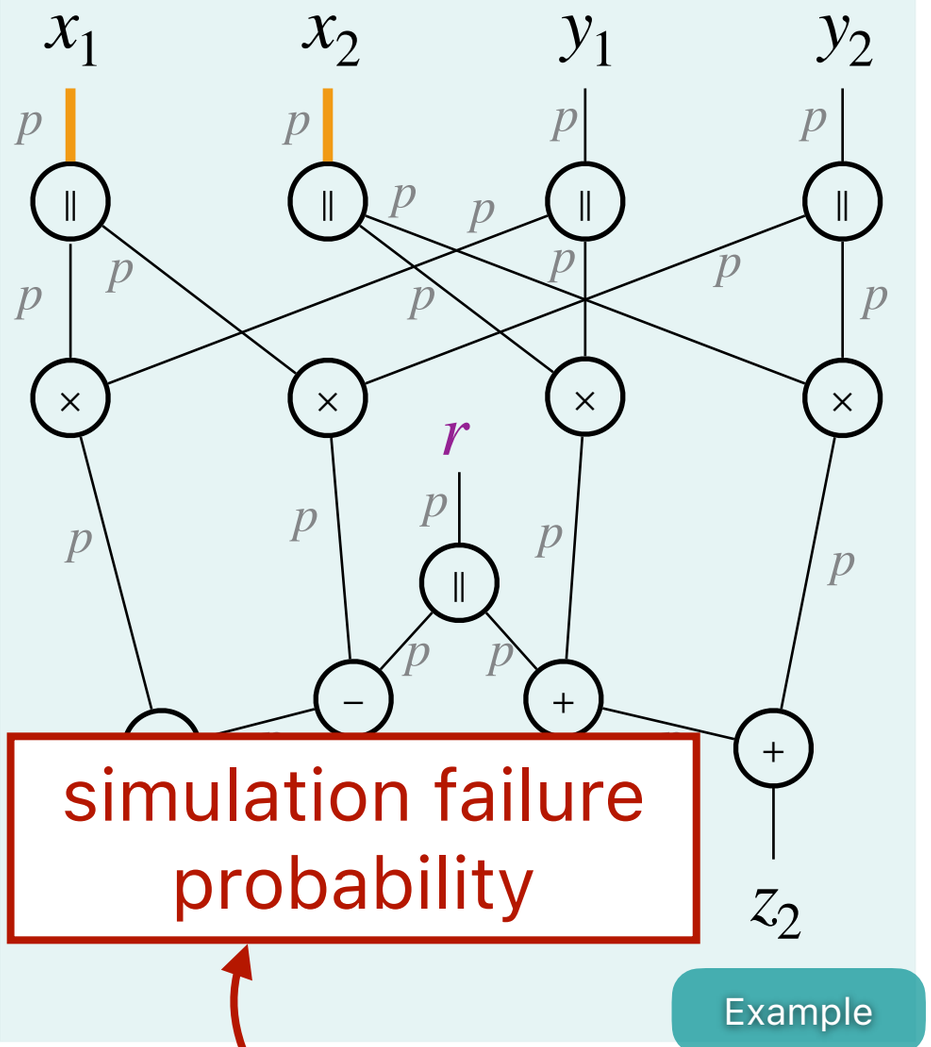

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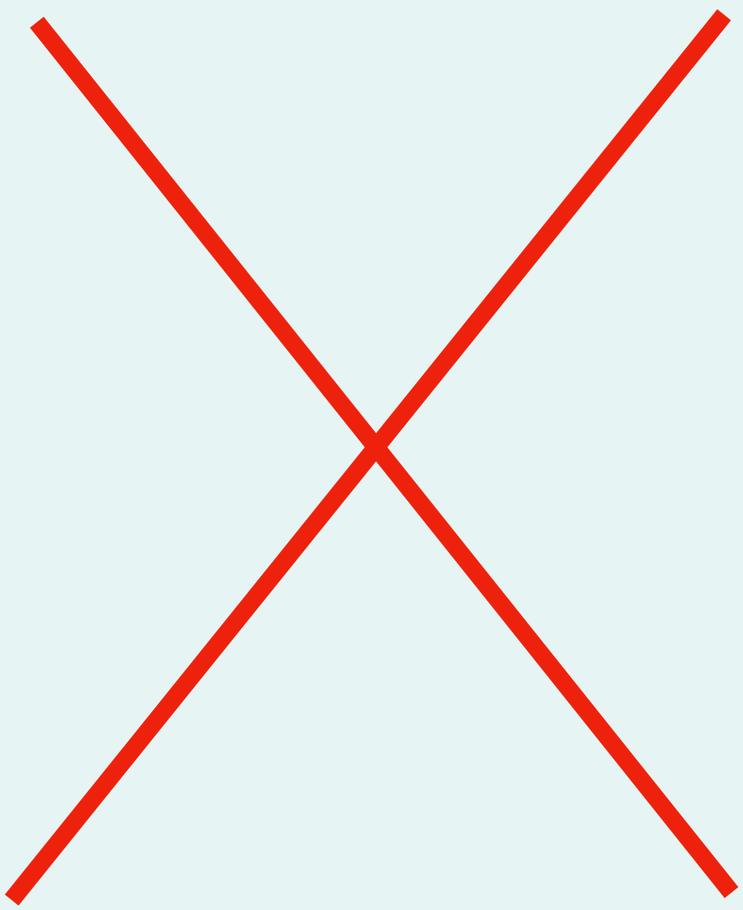

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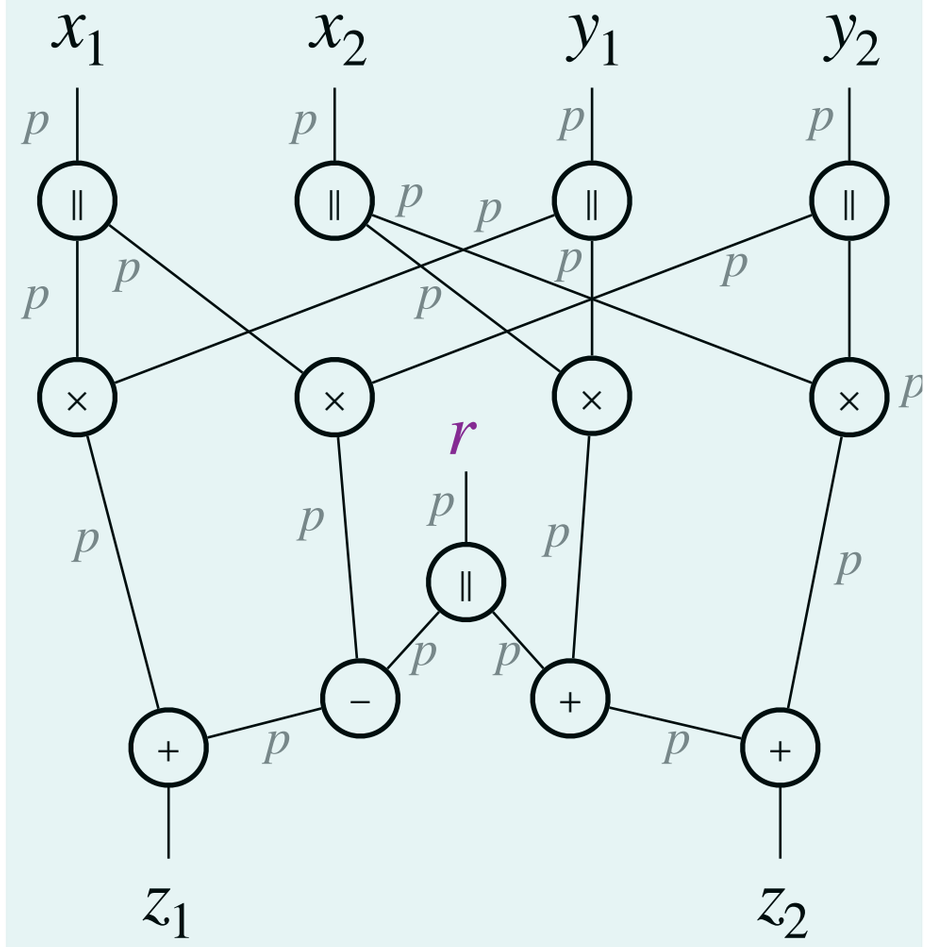
Random Probing Security

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

$\varepsilon = \mathbb{P}(\text{failure})$



Example

Random Probing Security

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

$$\varepsilon = \mathbb{P}(\text{failure})$$

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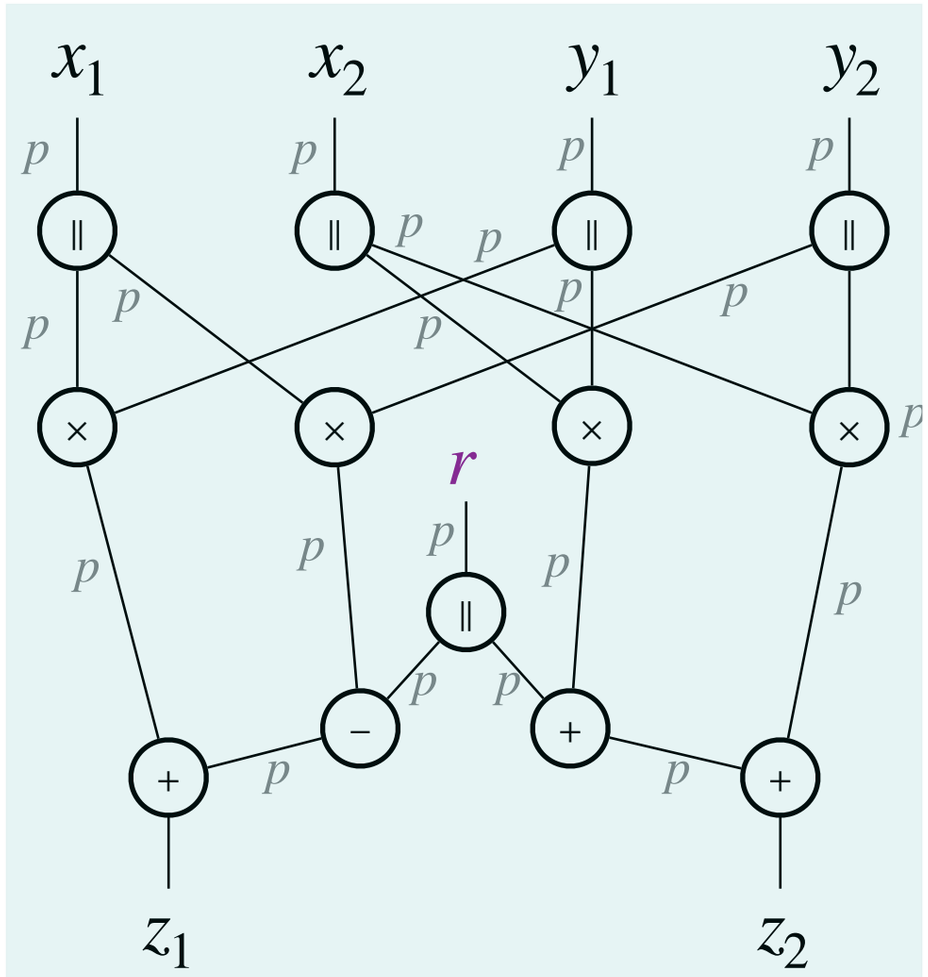

Example

Random Probing Security

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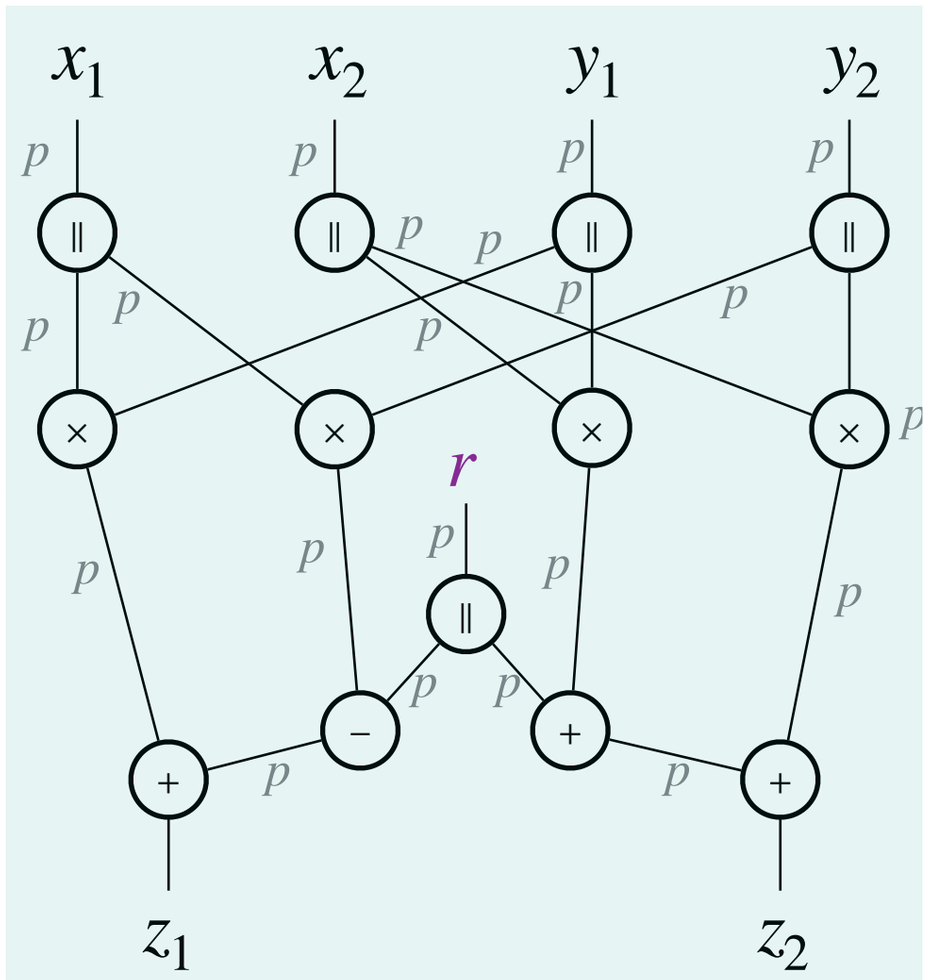

Example

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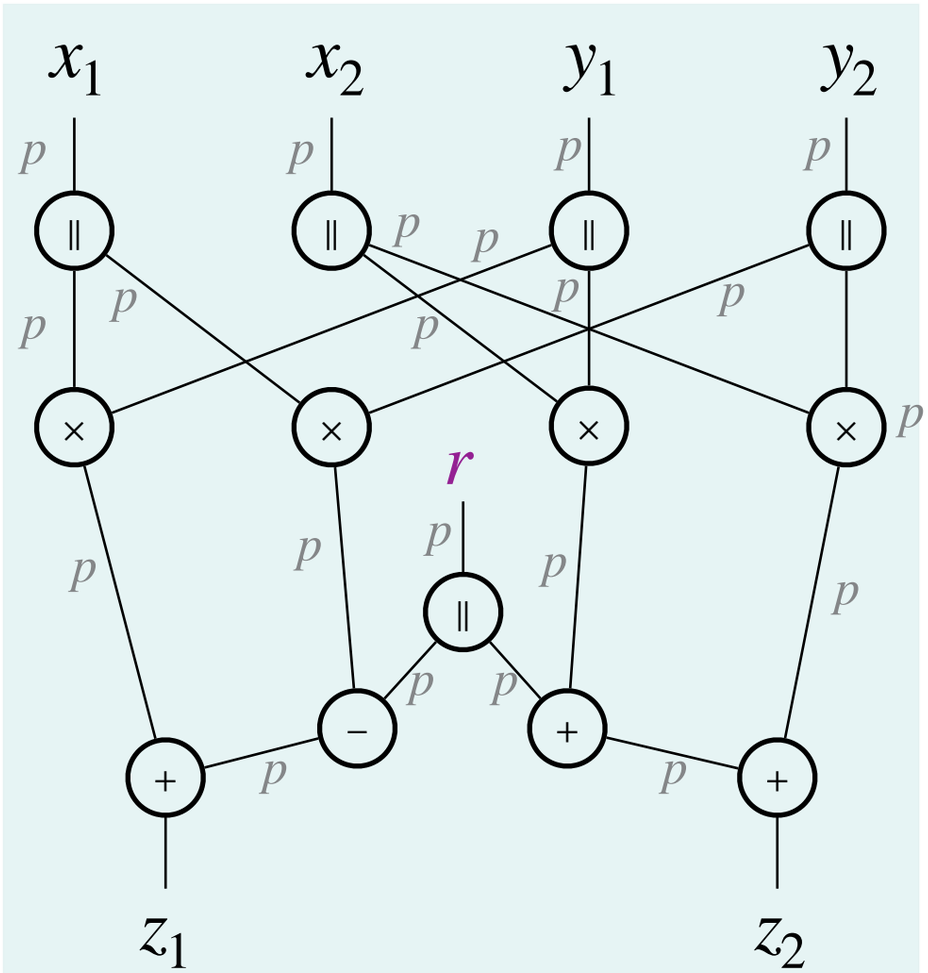

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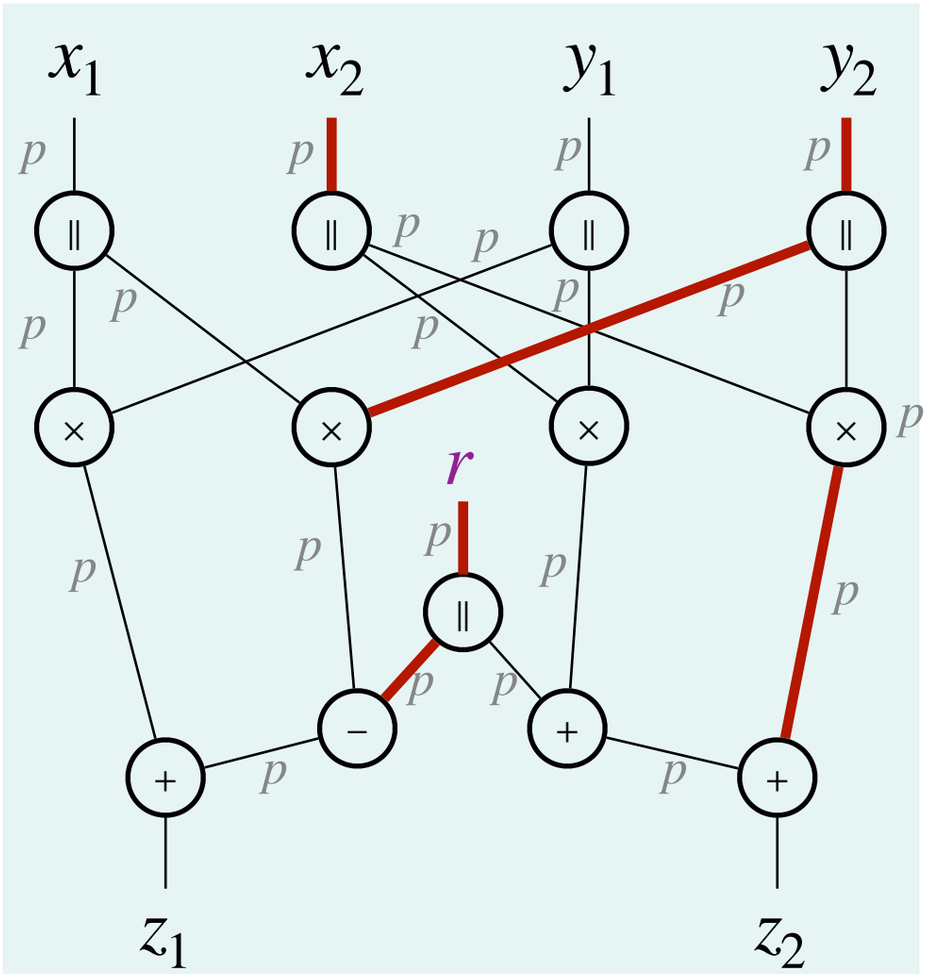

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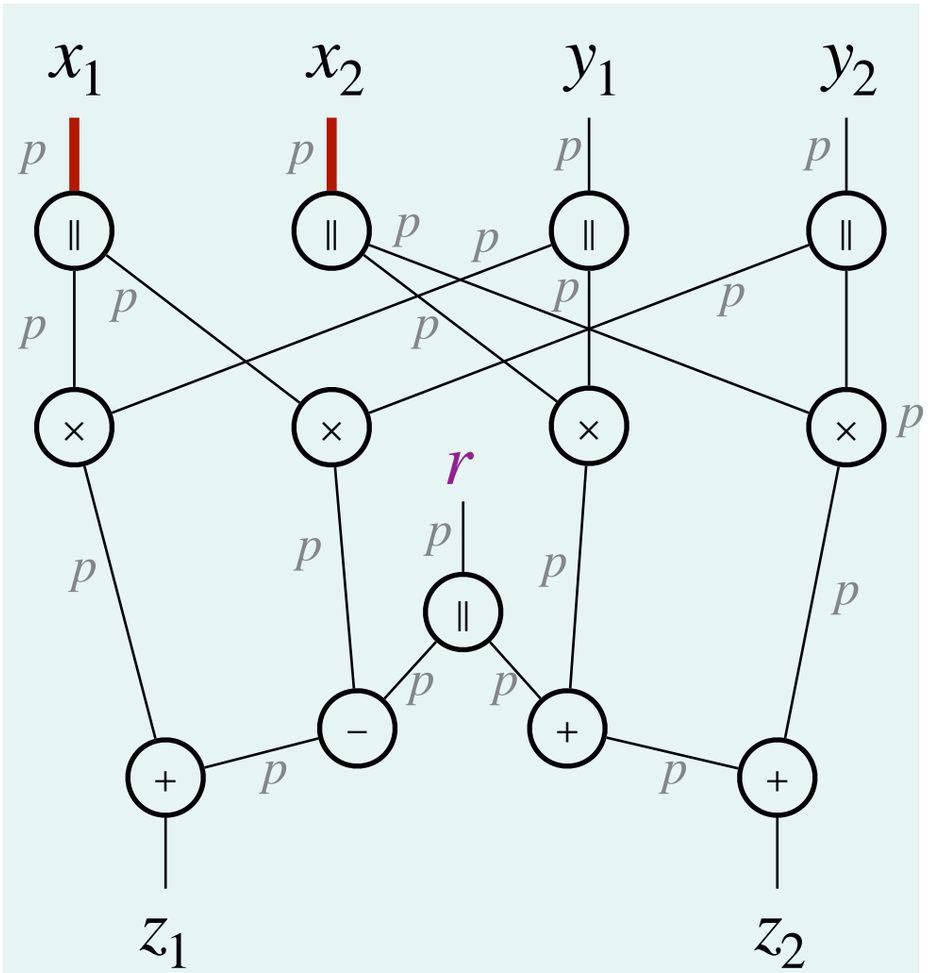

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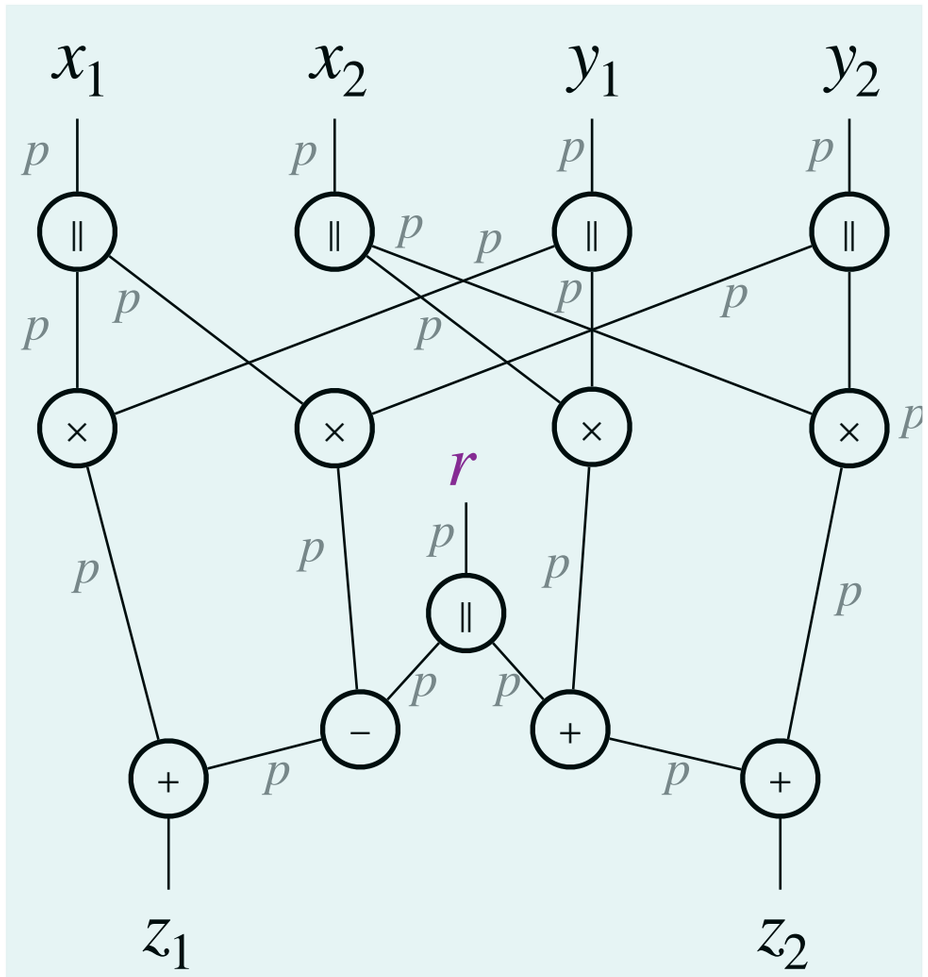

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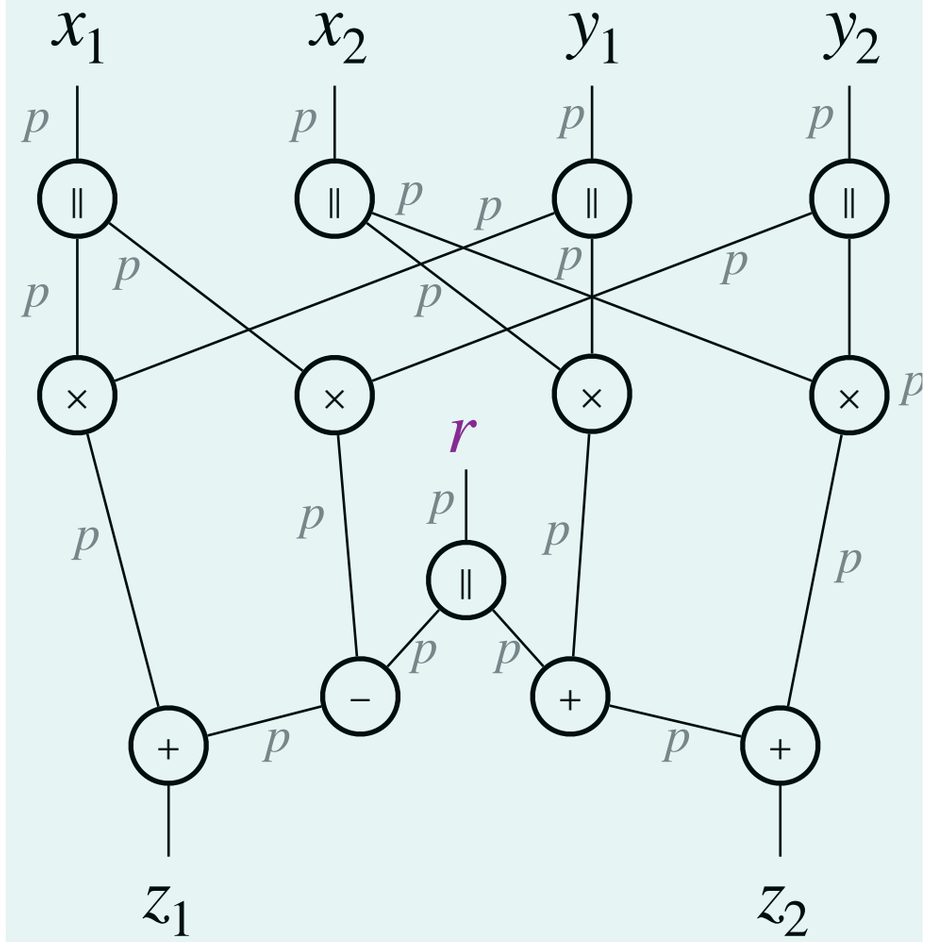
where $c_i = \sum_{\mathscr{W} \subseteq [s], |\mathscr{W}| = i} \delta_{\mathscr{W}}$



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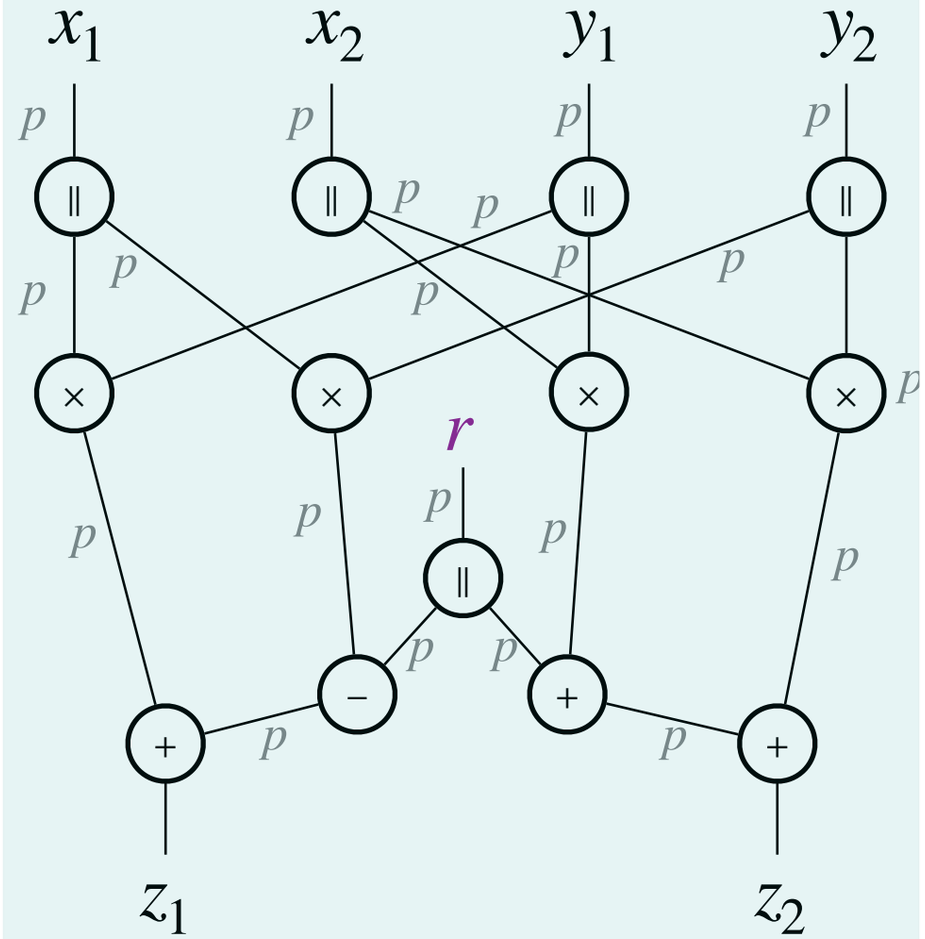
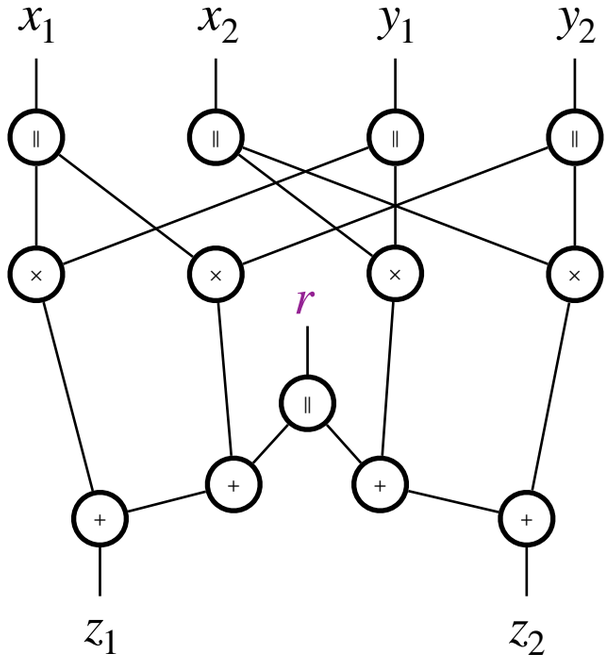
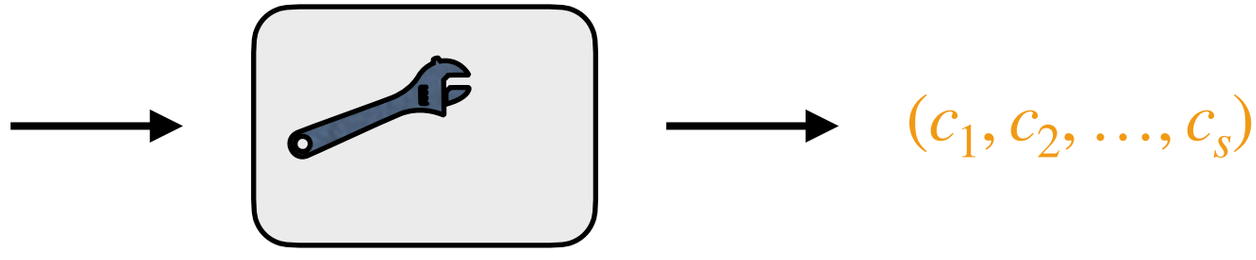


Verification Tools





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$(c_1, c_2, \ldots, c_s)$

2020

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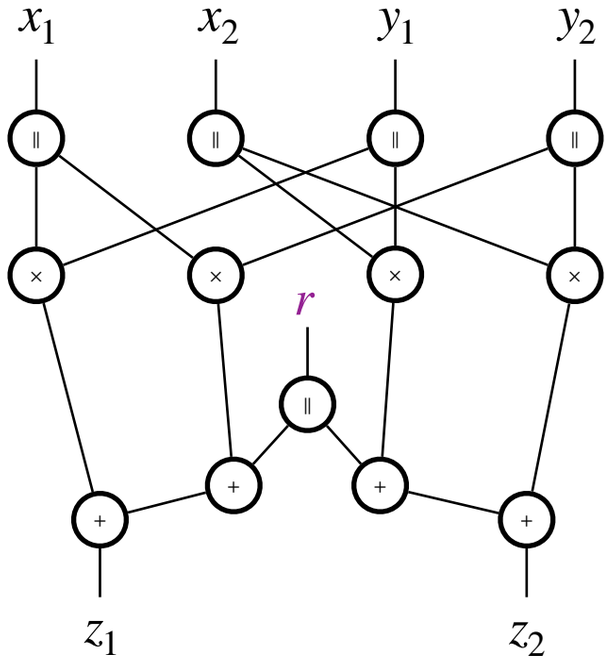
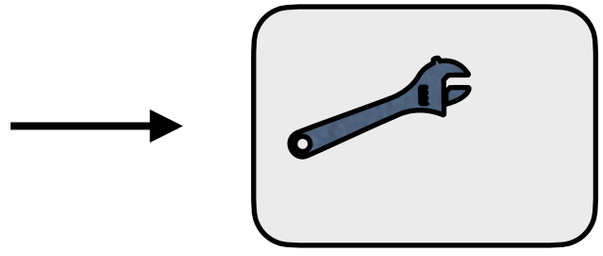
CRYPTO 2020 - VRAPS

Verification Tools





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$(c_1, c_2, \ldots, c_s)$

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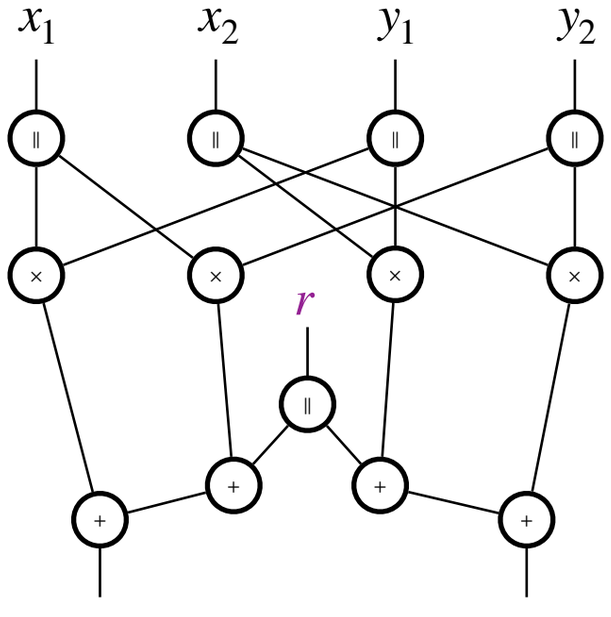
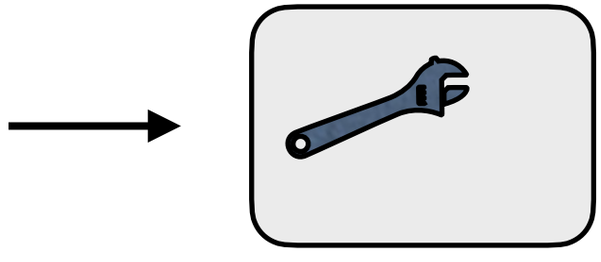
CRYPTO 2020 - VRAPS

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021 - STRAPS

Verification Tools





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2020 2021 2022

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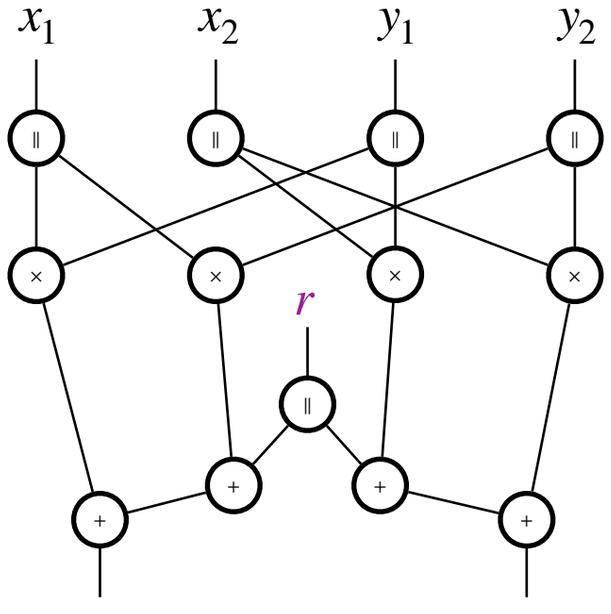
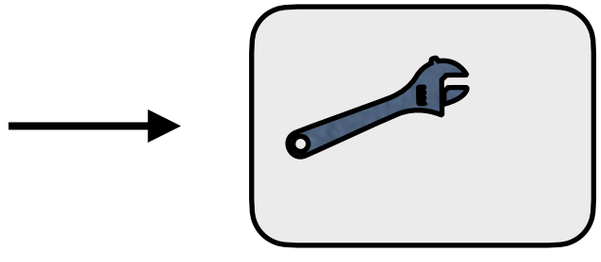
CRYPTO 2020 - VRAPS

Cassiers • Faust • Orlt • Standaert
CRYPTO 2021 - STRAPS

Belaïd • Mercadier • Rivain • Taleb
S&P 2022 - IronMask

Verification Tools





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2020 2021 2022 2024

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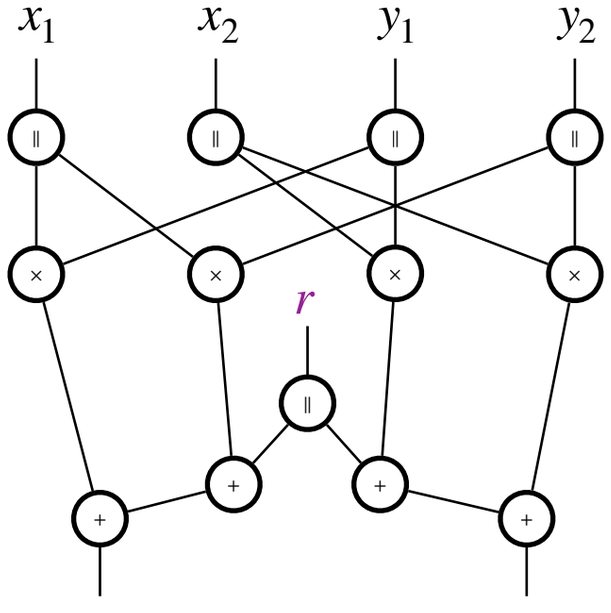
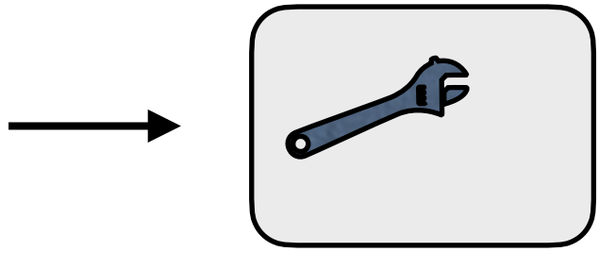
ASIACRYPT 2024 - IronMask+

Verification Tools





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2020 2021 2022 2024 2025

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CRYPTO 2020 - VRAPS

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CRYPTO 2021 - STRAPS

Belaïd • Mercadier • Rivain • Taleb
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ASIACRYPT 2024 - IronMask+

Beierle • Feldtkeller • Guinet • Güneysu • Leander • Richter-Brockmann • Sasdrich
EUROCRYPT 2025 - INDIANA

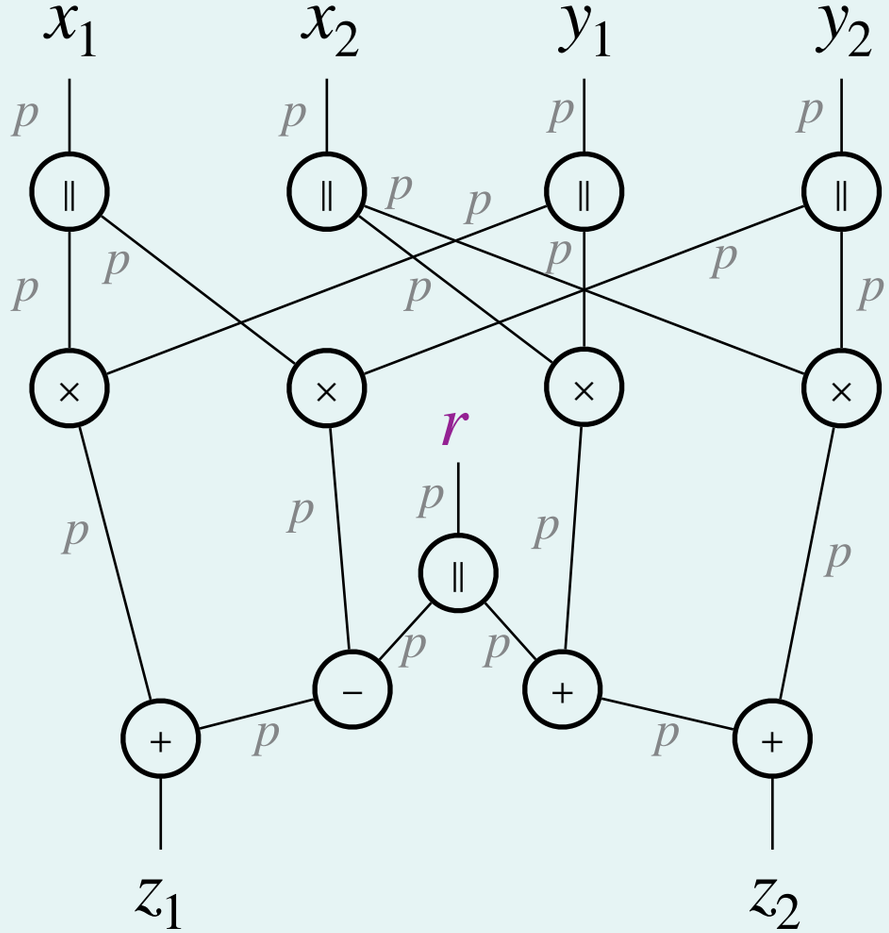
Verification of Small Circuits

$$\varepsilon = \sum_{i=1}^{s} c_i \cdot p^i \cdot (1-p)^{s-i}$$

with $s = 21$

2^{21} tuples to consider

⏳ $\leq$ 3 ms

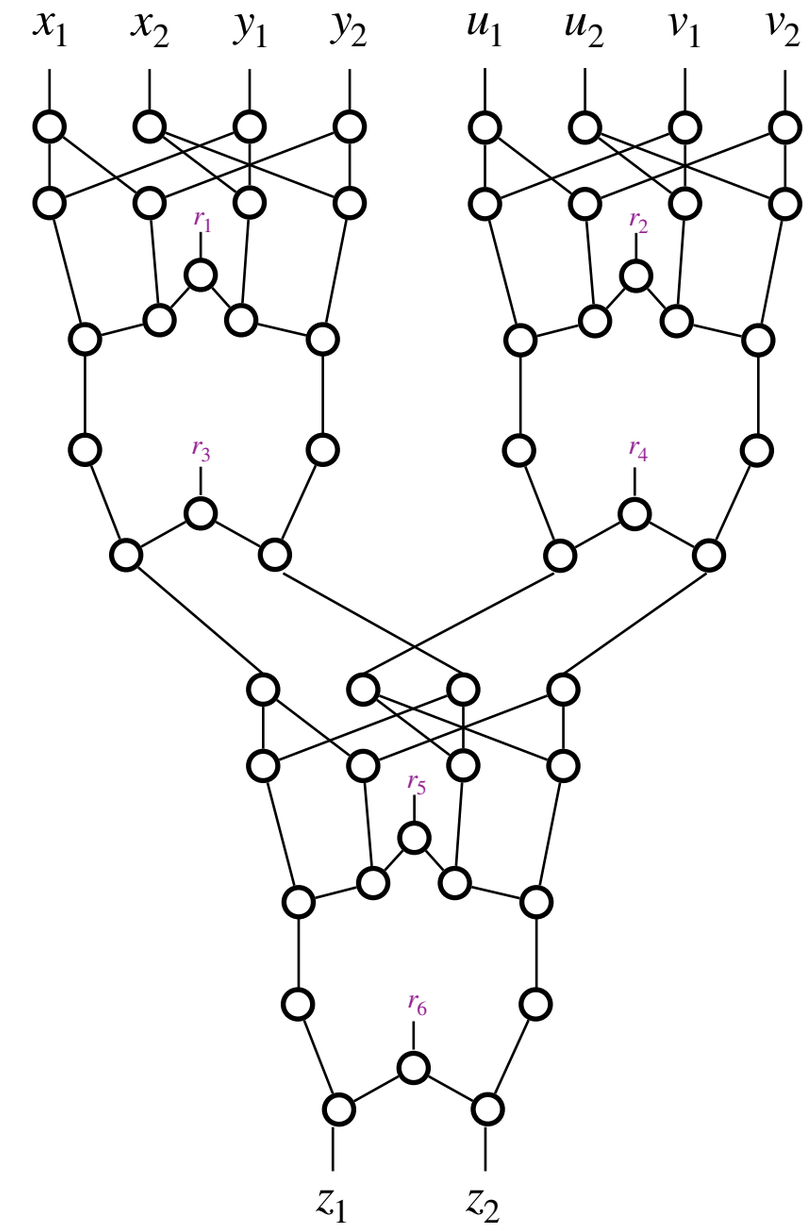


$(c_1, \cdots, c_{21}) =$
(0,49,737,4763,18735,52798,
115338,203064,293800,352692,
352714,293930,203490,116280,
54264,20349,5985,1330,210,21,1)

Example

Verification of Larger Circuits

$$\varepsilon = \sum_{i=1}^{s} c_i \cdot p^i \cdot (1-p)^{s-i}$$



impractical

Results

🔬 **Foundations**

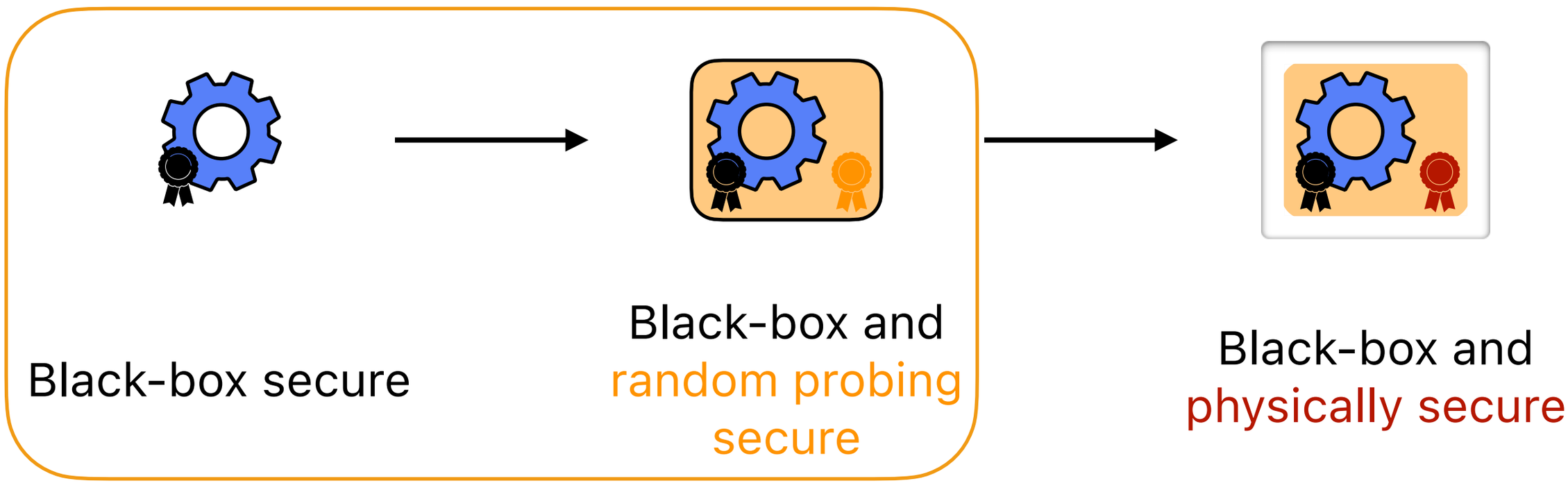
Random probing security & verification (small circuits)

🏗️ **Scaling up**

Composition frameworks (larger circuits)

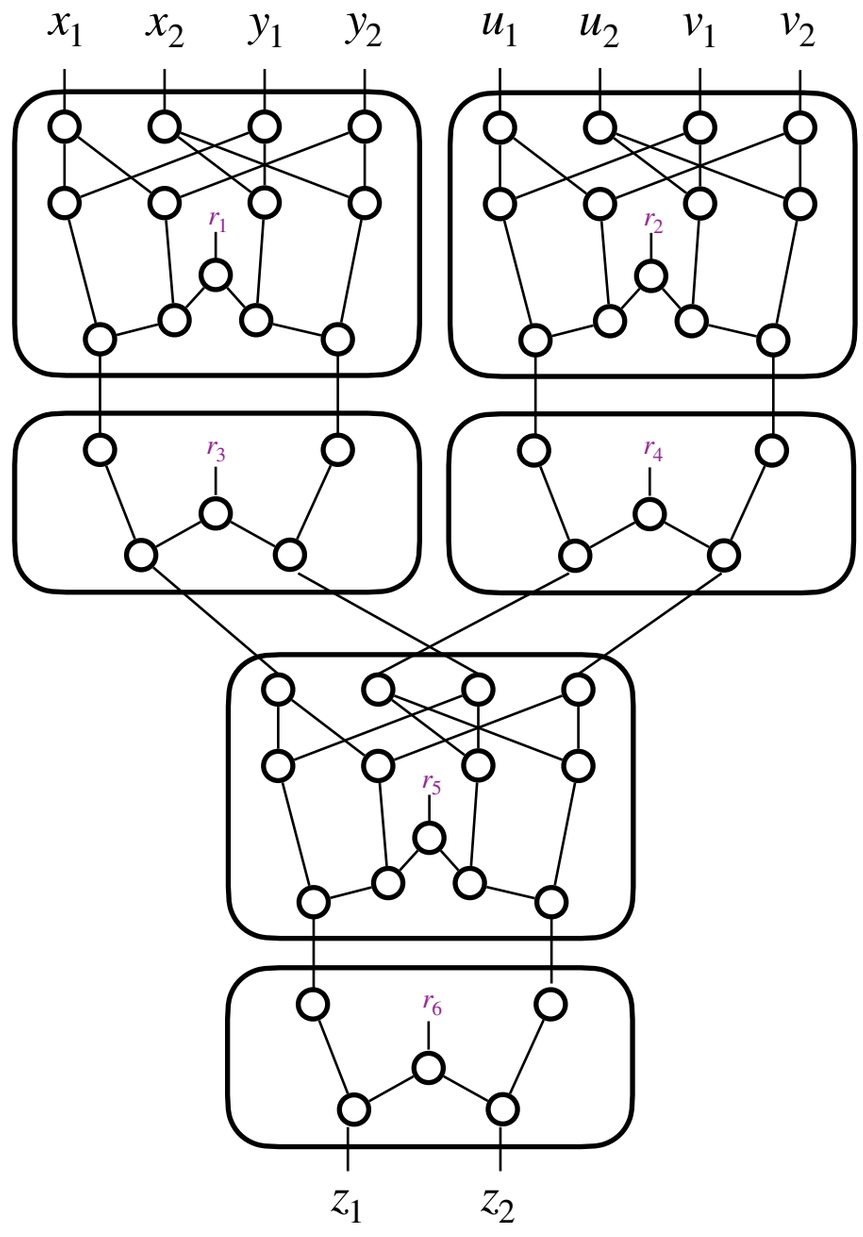
🧩 **Building blocks**

Design of efficient gadgets



Composition

$$\varepsilon = \sum_{i=1}^{s} c_i \cdot p^i \cdot (1-p)^{s-i}$$



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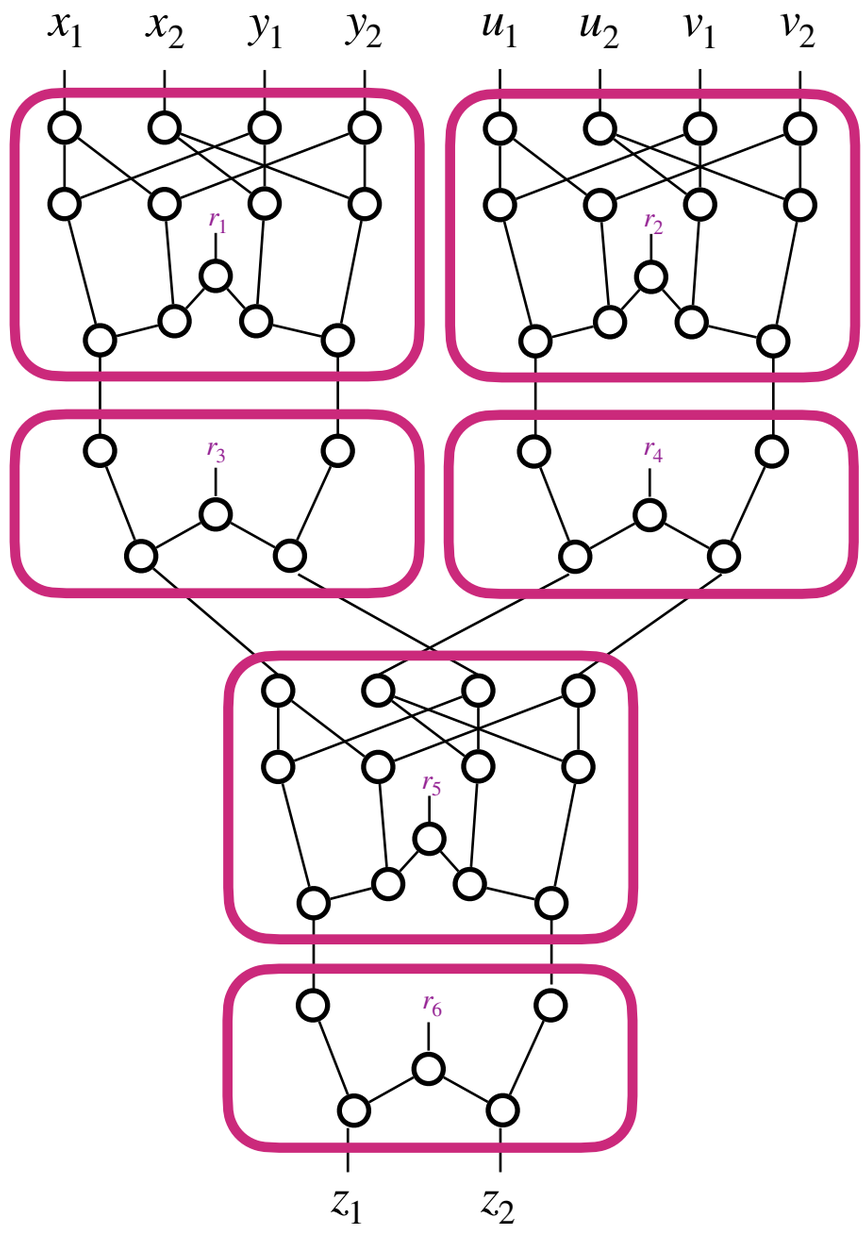
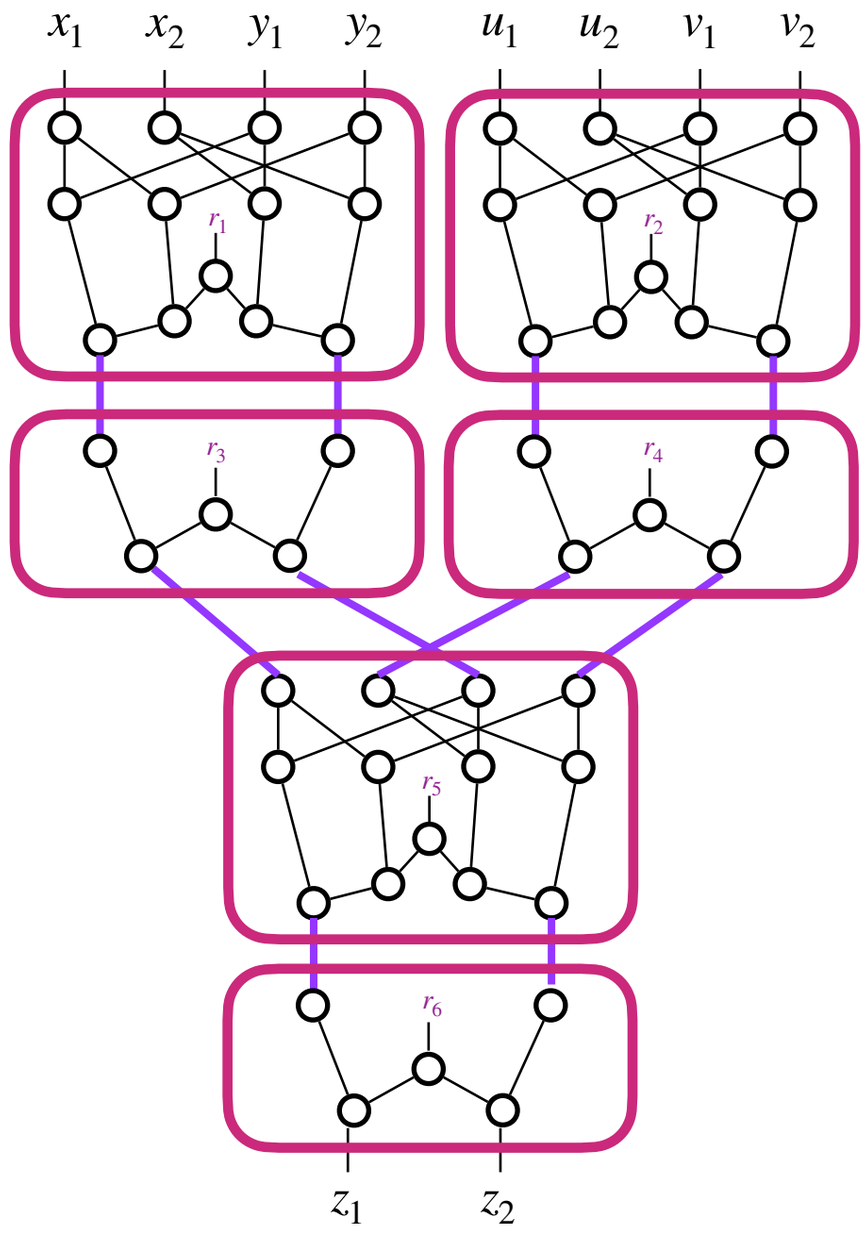


Local property

Composition

$$\varepsilon = \sum_{i=1}^{s} c_i \cdot p^i \cdot (1-p)^{s-i}$$

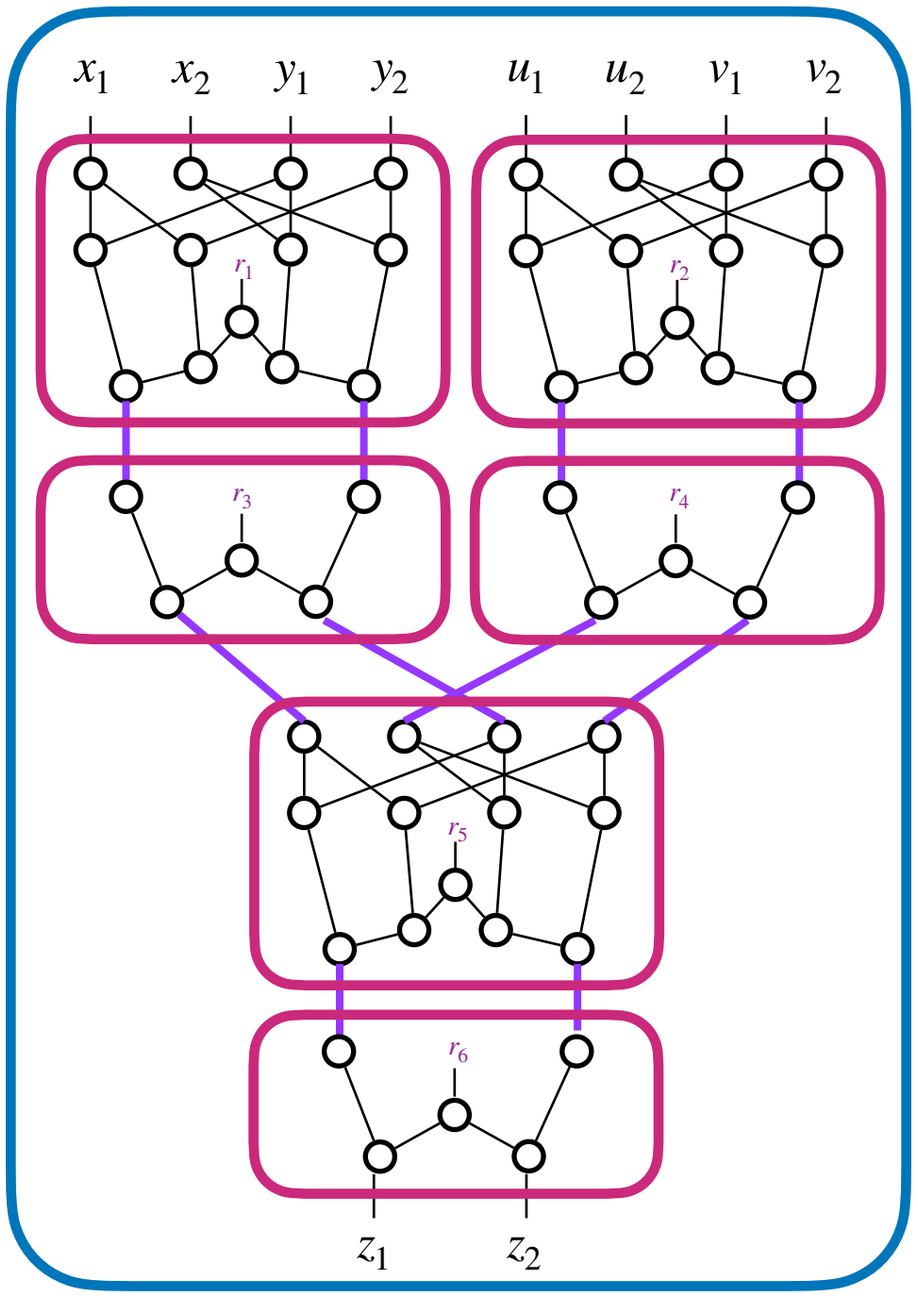


Local property

Composition

$$\varepsilon = \sum_{i=1}^{s} c_i \cdot p^i \cdot (1-p)^{s-i}$$

Global property



Local property

Composition

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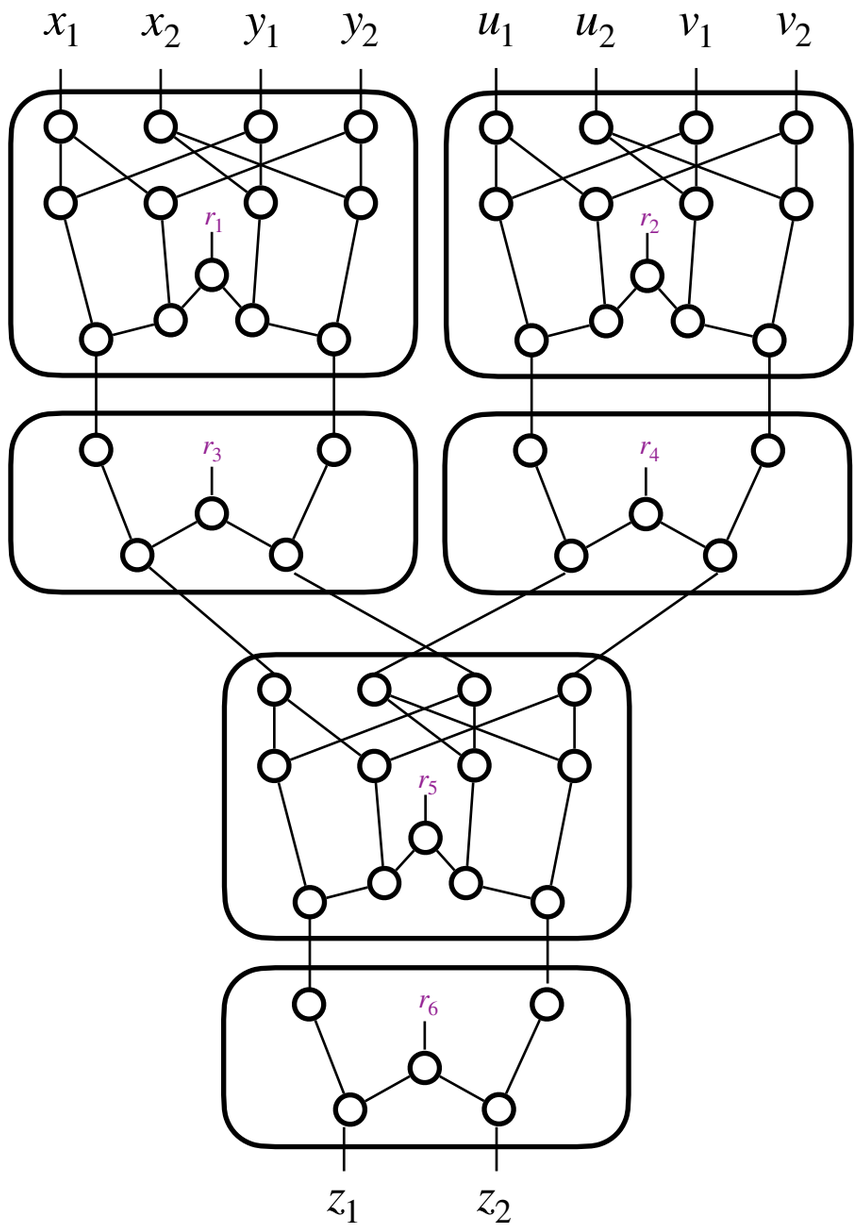
CRYPTO 2018

MPC-based construction with explicit and constant leakage rate



Composition

Ananth • Ishai • Sahai

CRYPTO 2018

MPC-based construction with explicit and constant leakage rate

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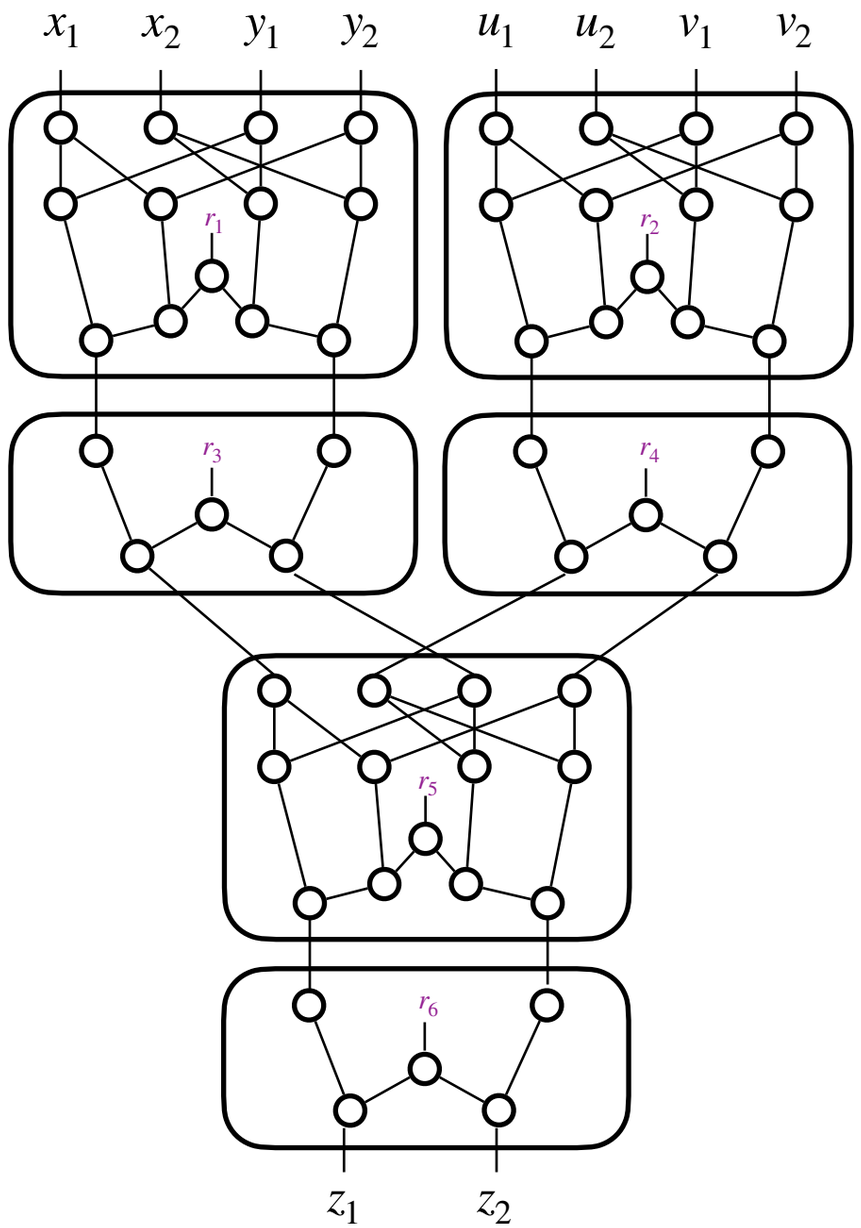
Threshold RPC



Threshold RPC

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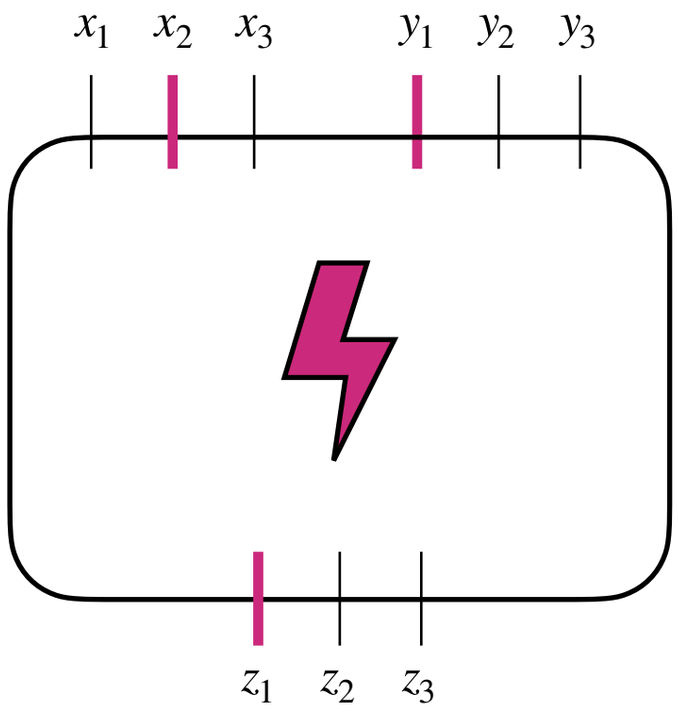
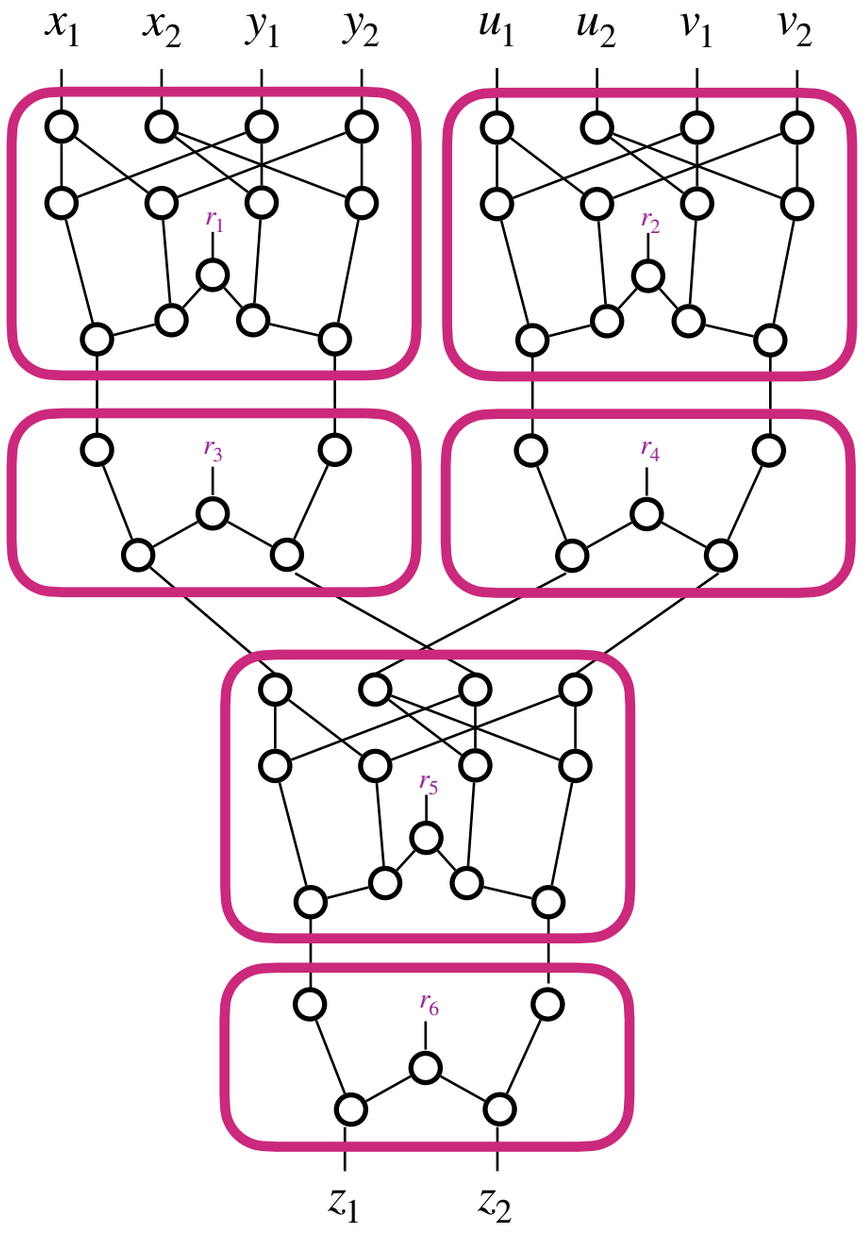
(p, t, ε)-threshold RPC:

Leakage and any t output shares can be perfectly simulated with at most t shares of each input, except with probability ε





Threshold RPC

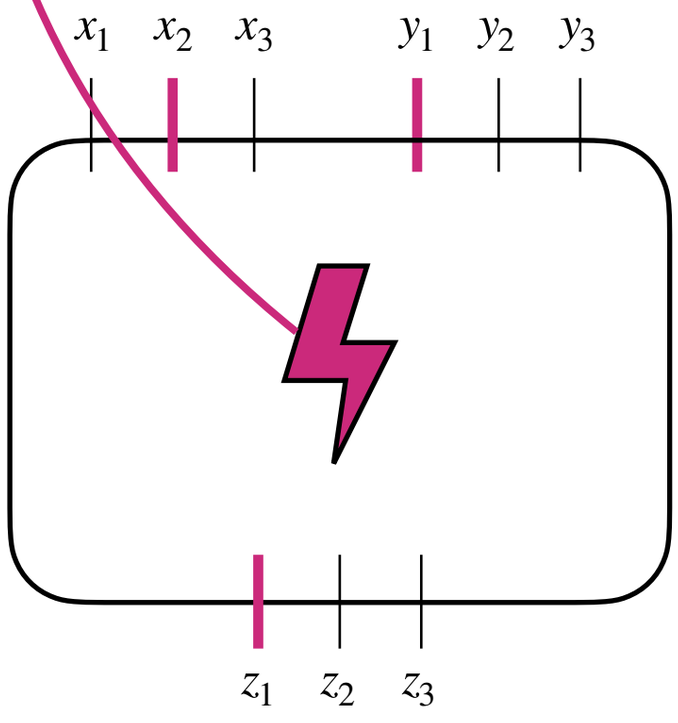
Threshold RPC

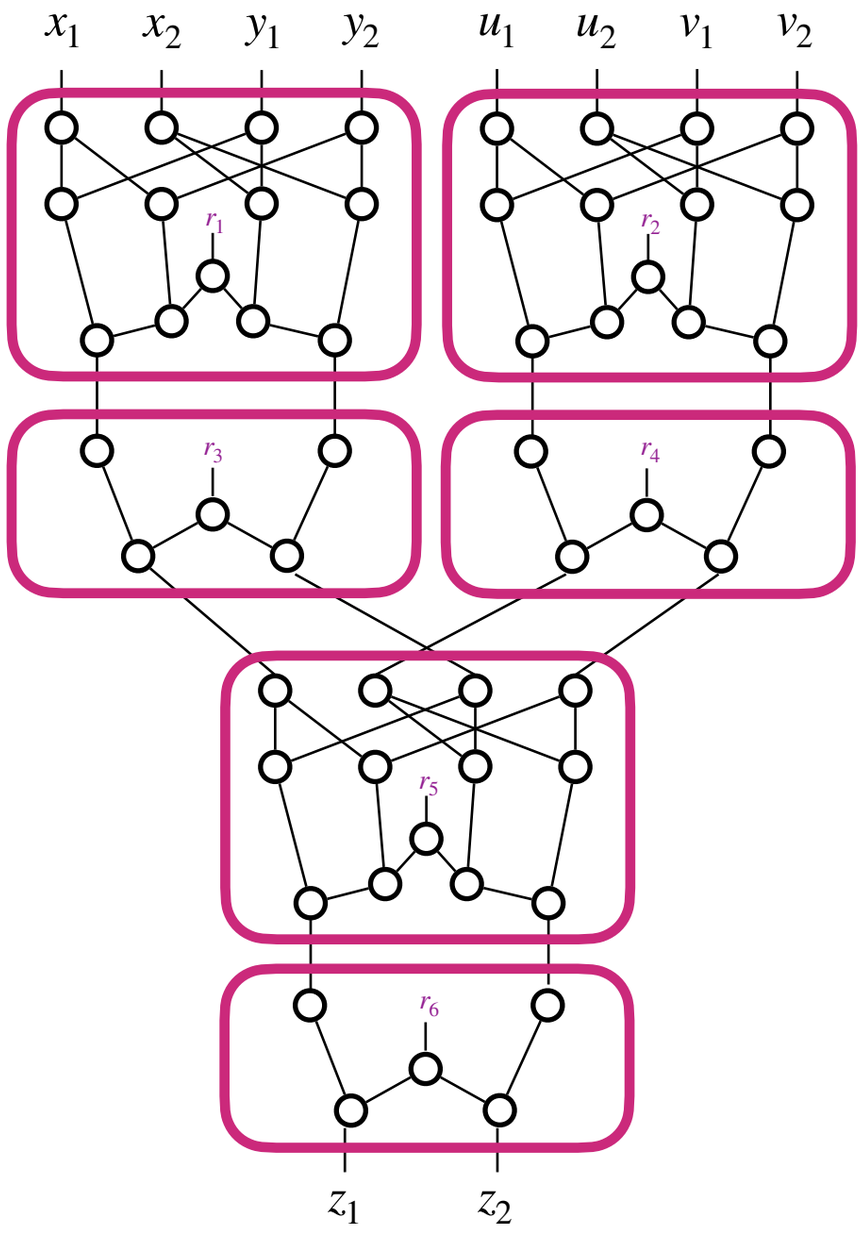
Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

(p, t, ε)-threshold RPC:

Leakage and any t output shares can be perfectly simulated with at most t shares of each input, except with probability ε





Threshold RPC

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

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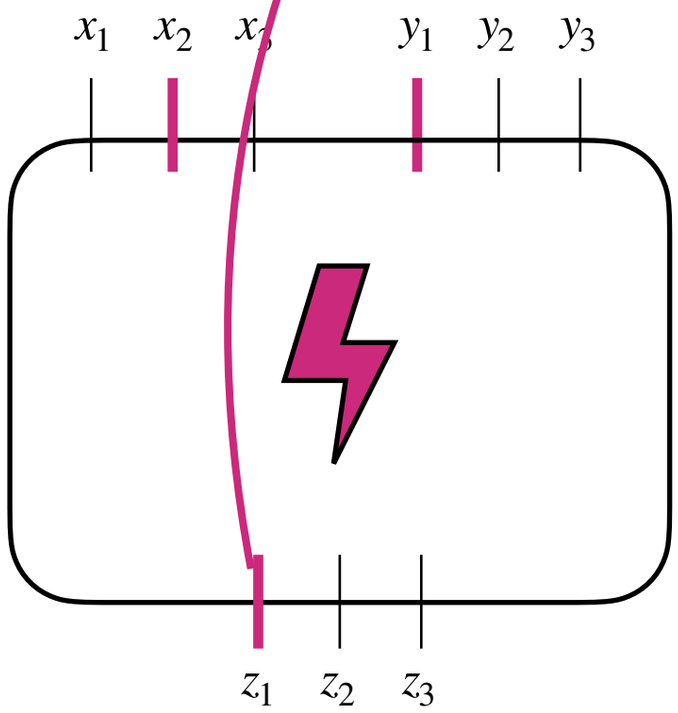

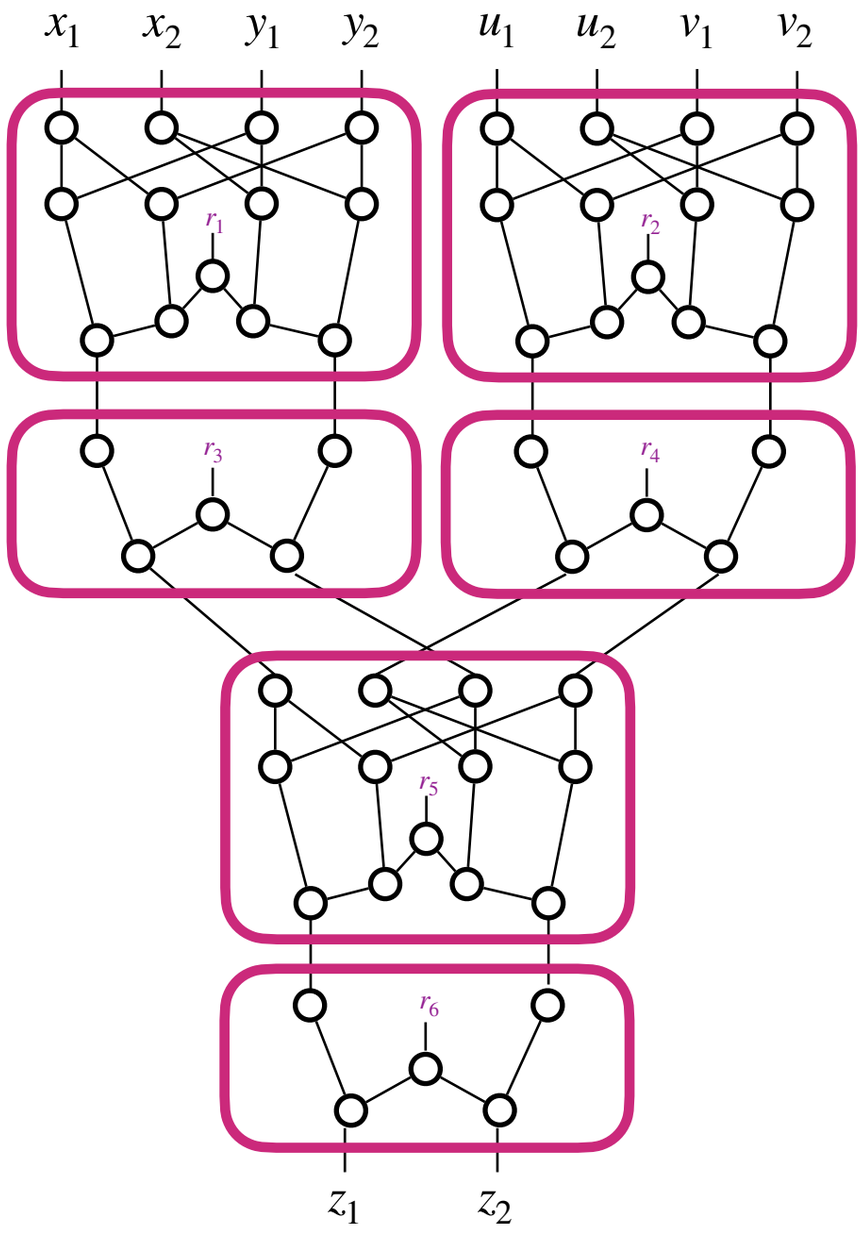

Threshold RPC

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

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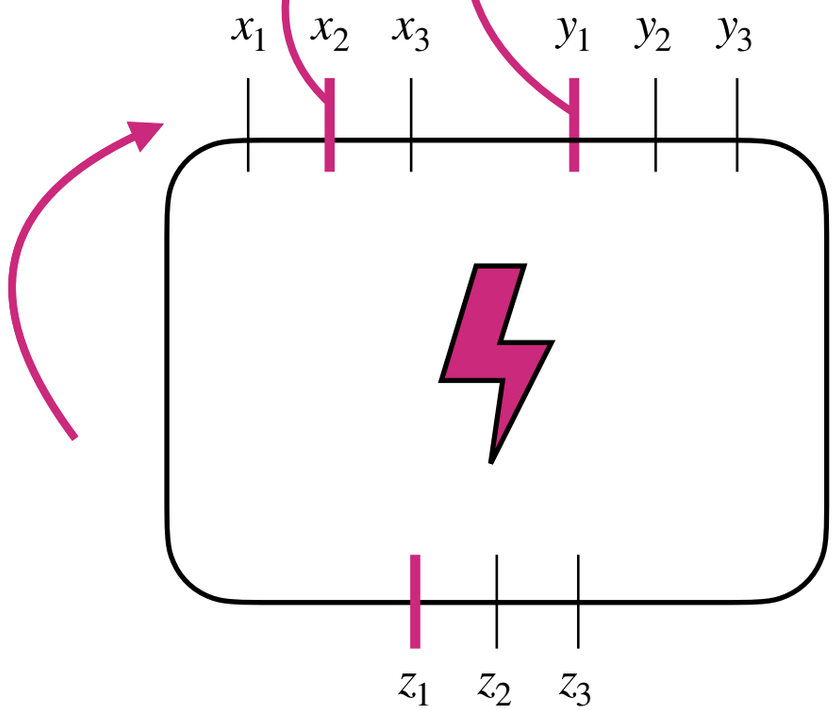

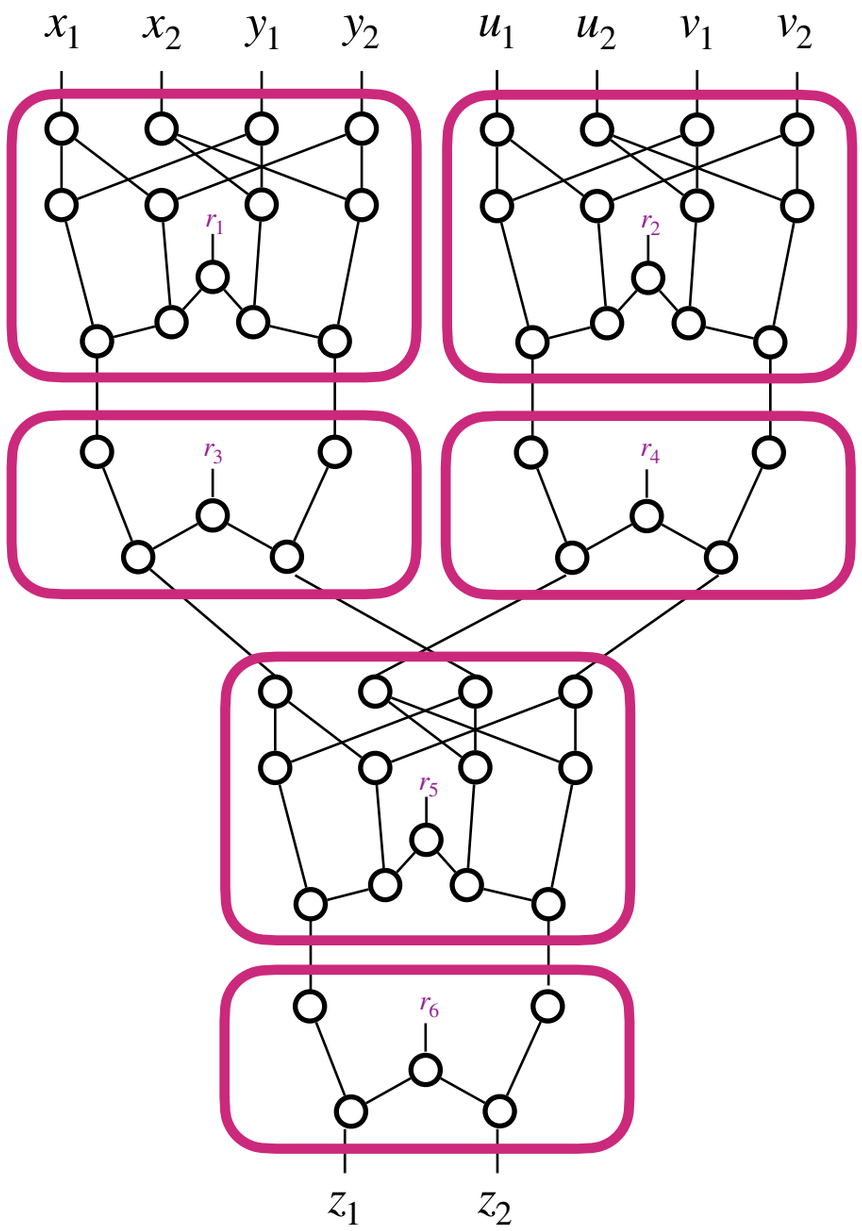

Threshold RPC

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

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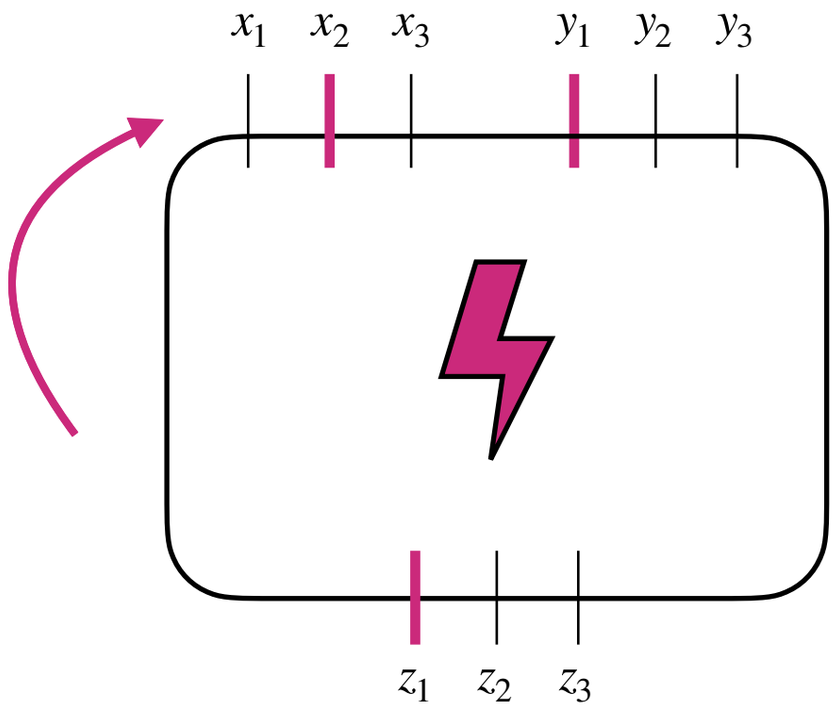
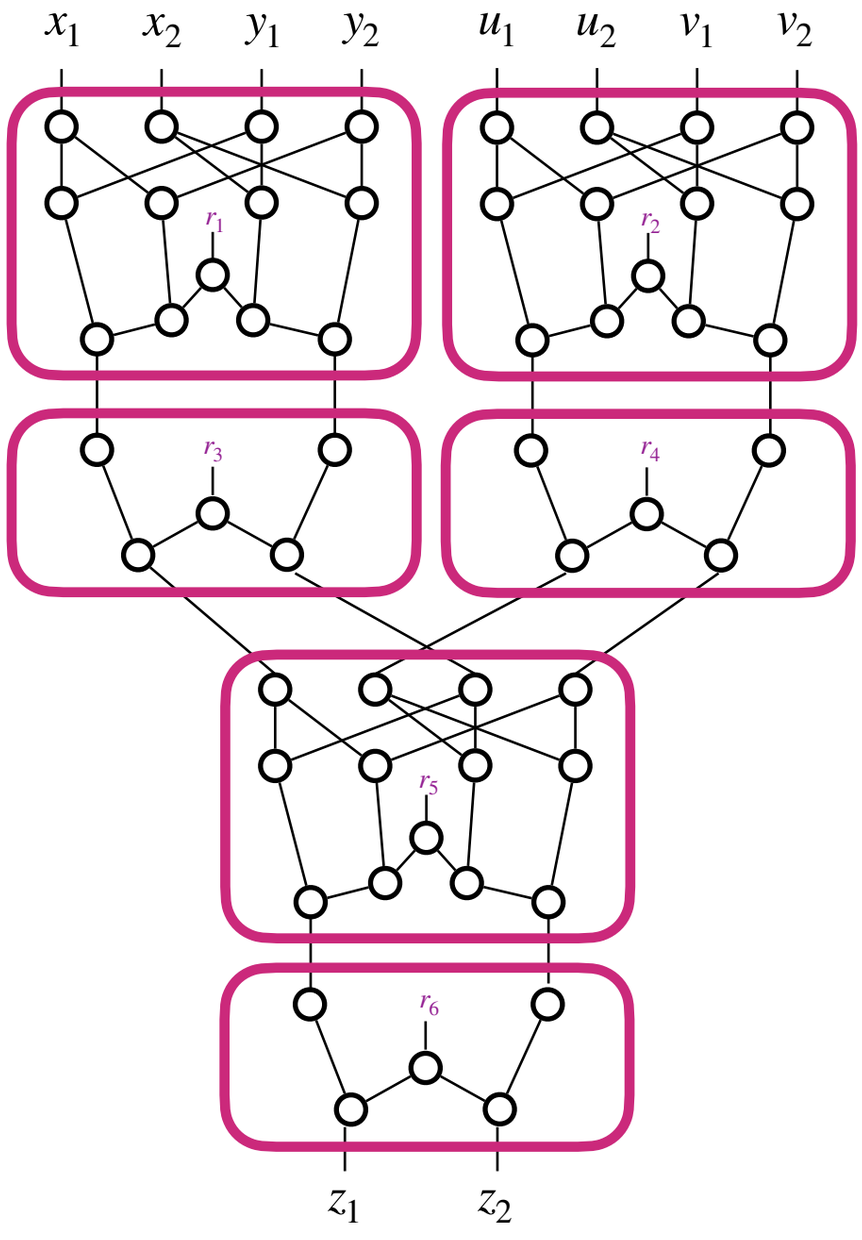




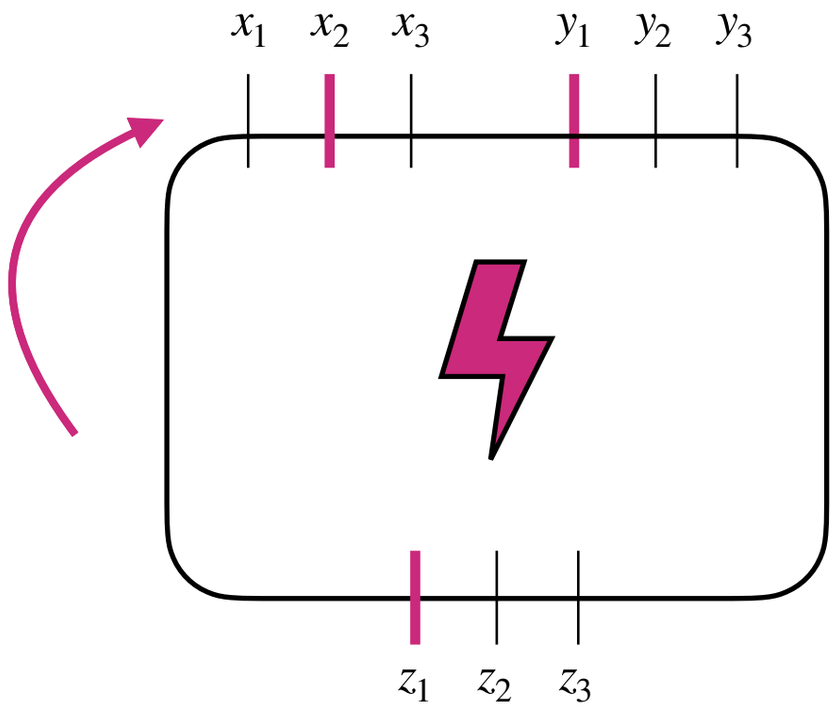
Threshold RPC

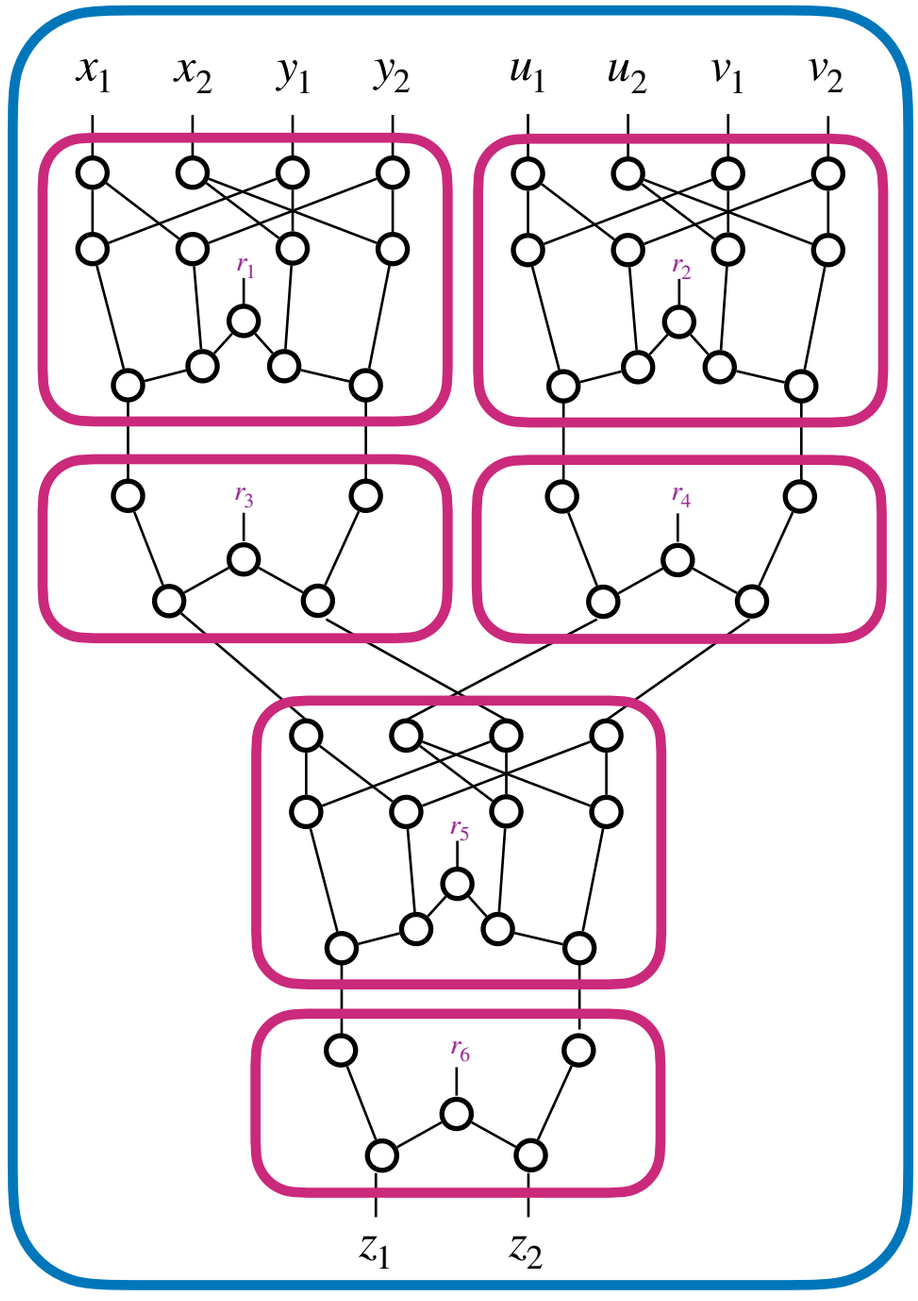
Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

Threshold RPC



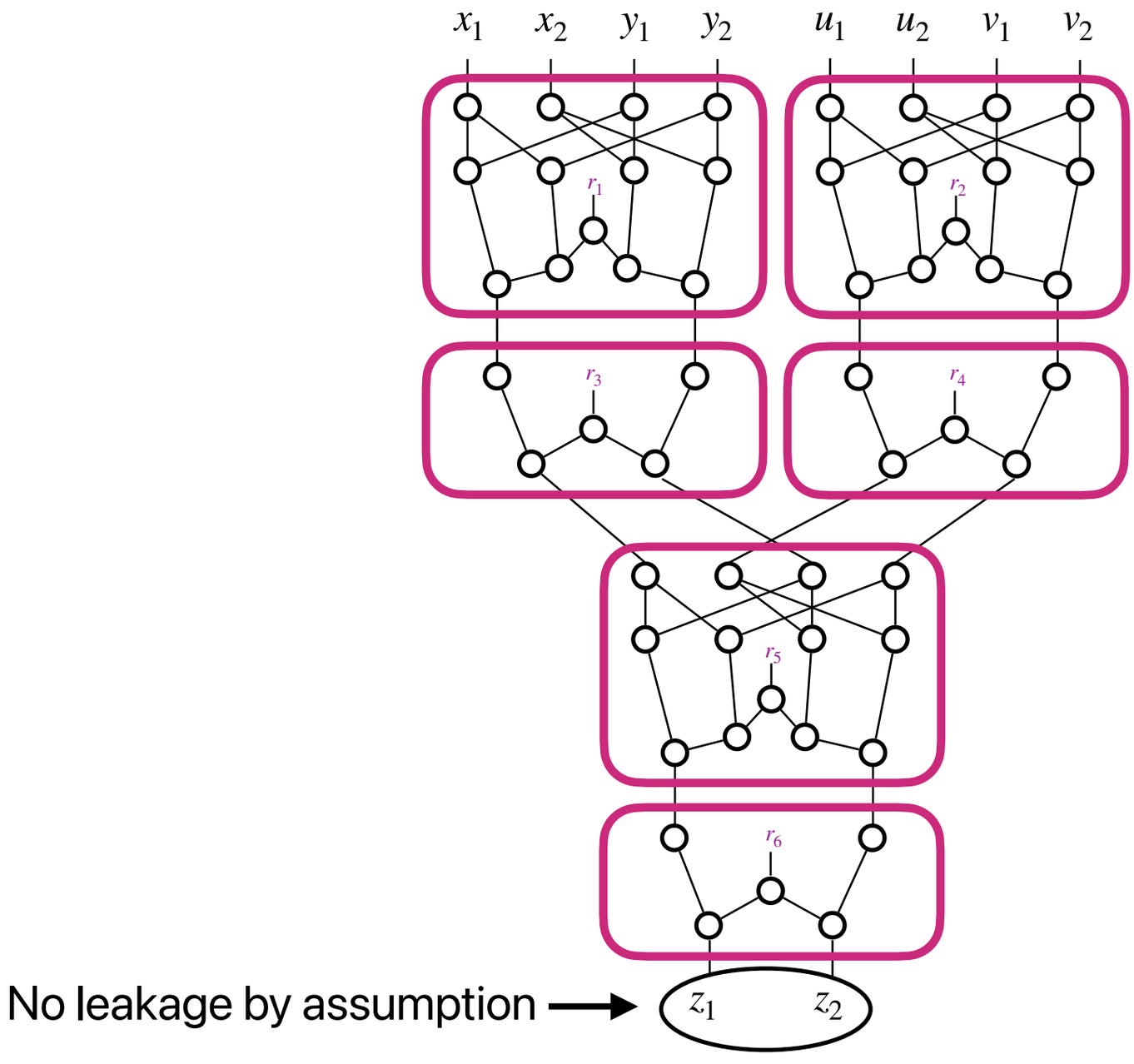


Threshold RPC

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

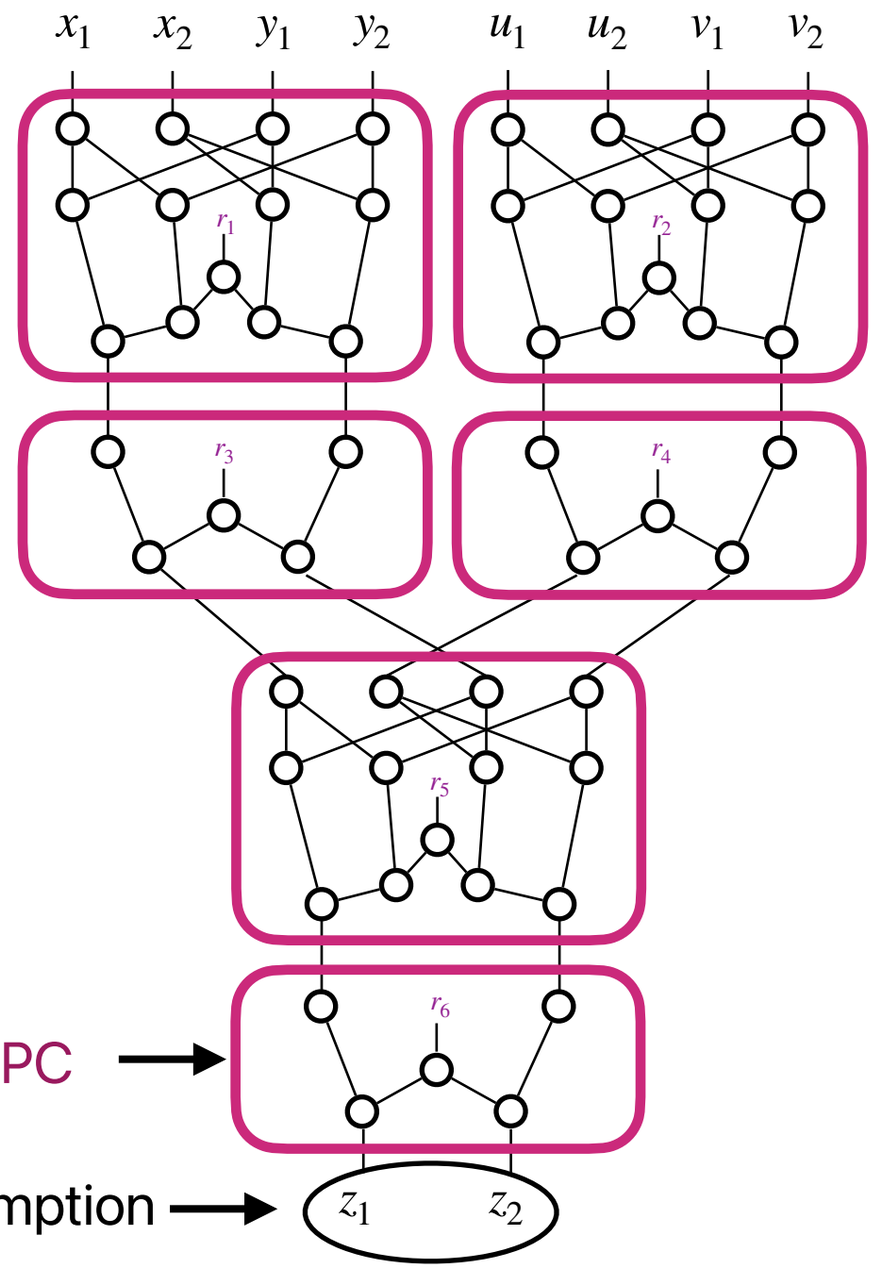
CRYPTO 2020



Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020



$(p,1,\varepsilon_b)$-threshold RPC →

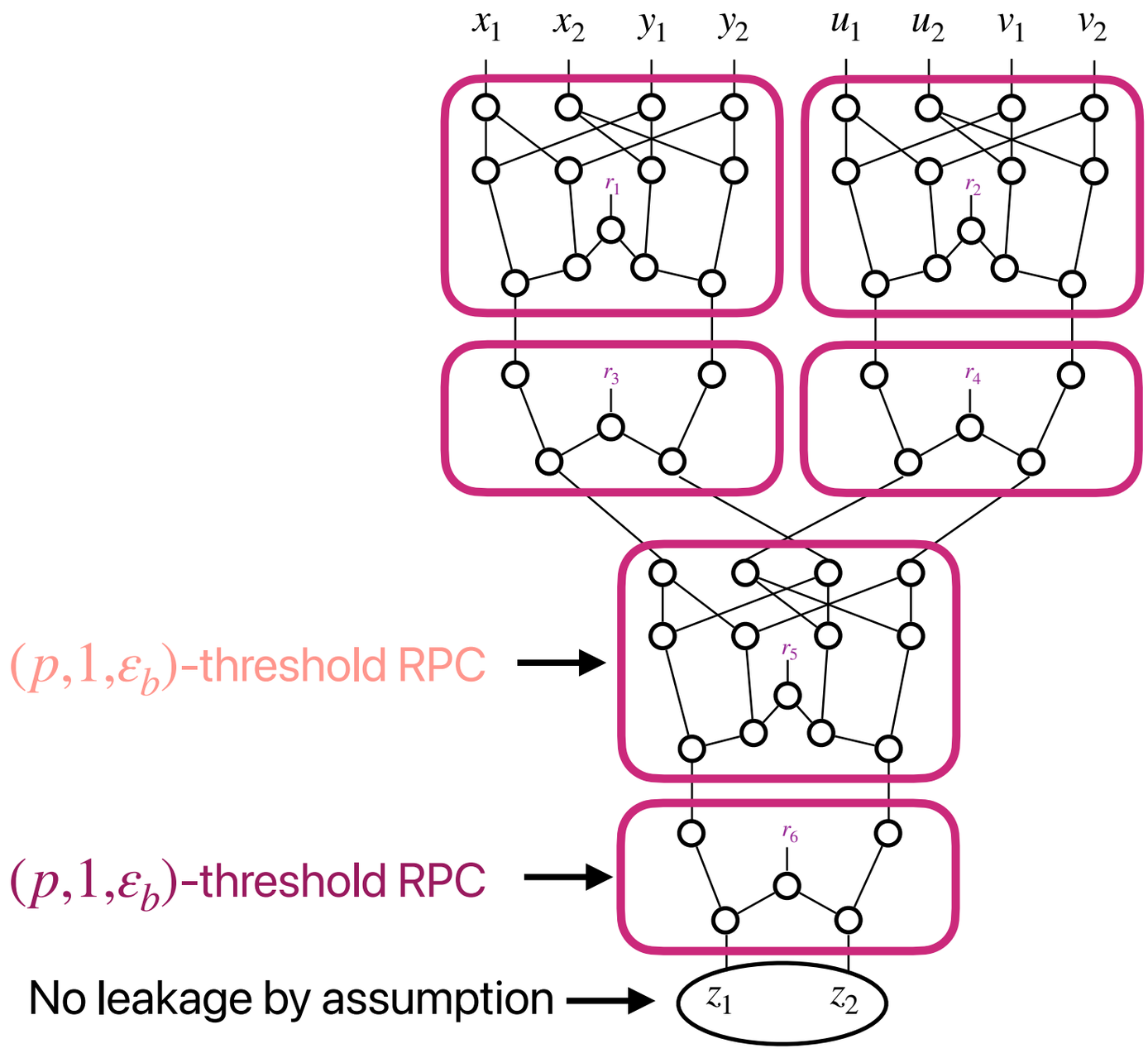
No leakage by assumption →

Simulation except with probability: $\varepsilon \leq \varepsilon_b$

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

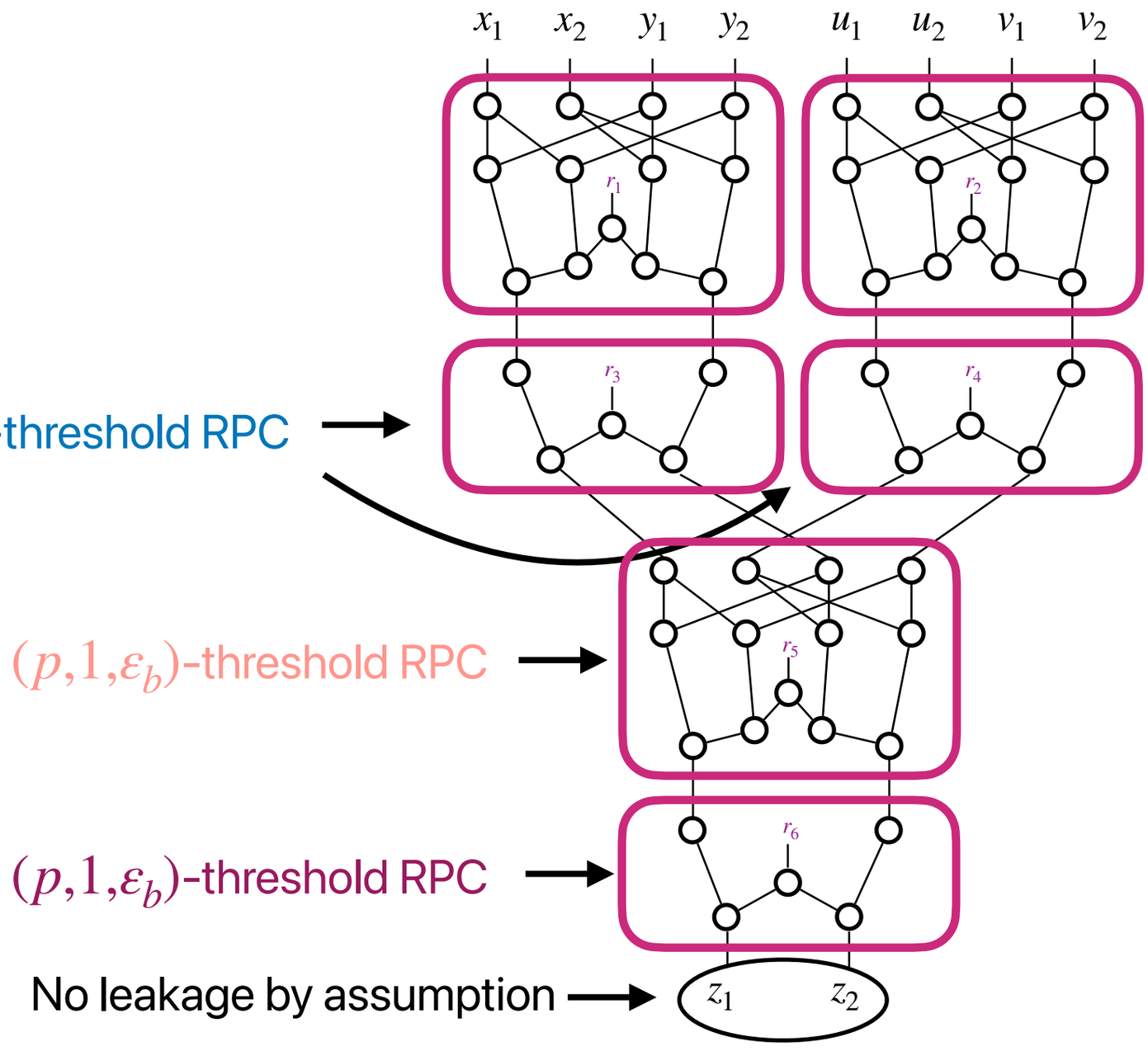


Simulation except with probability: $\varepsilon \leq 1 - (1 - \varepsilon_b)^2$

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

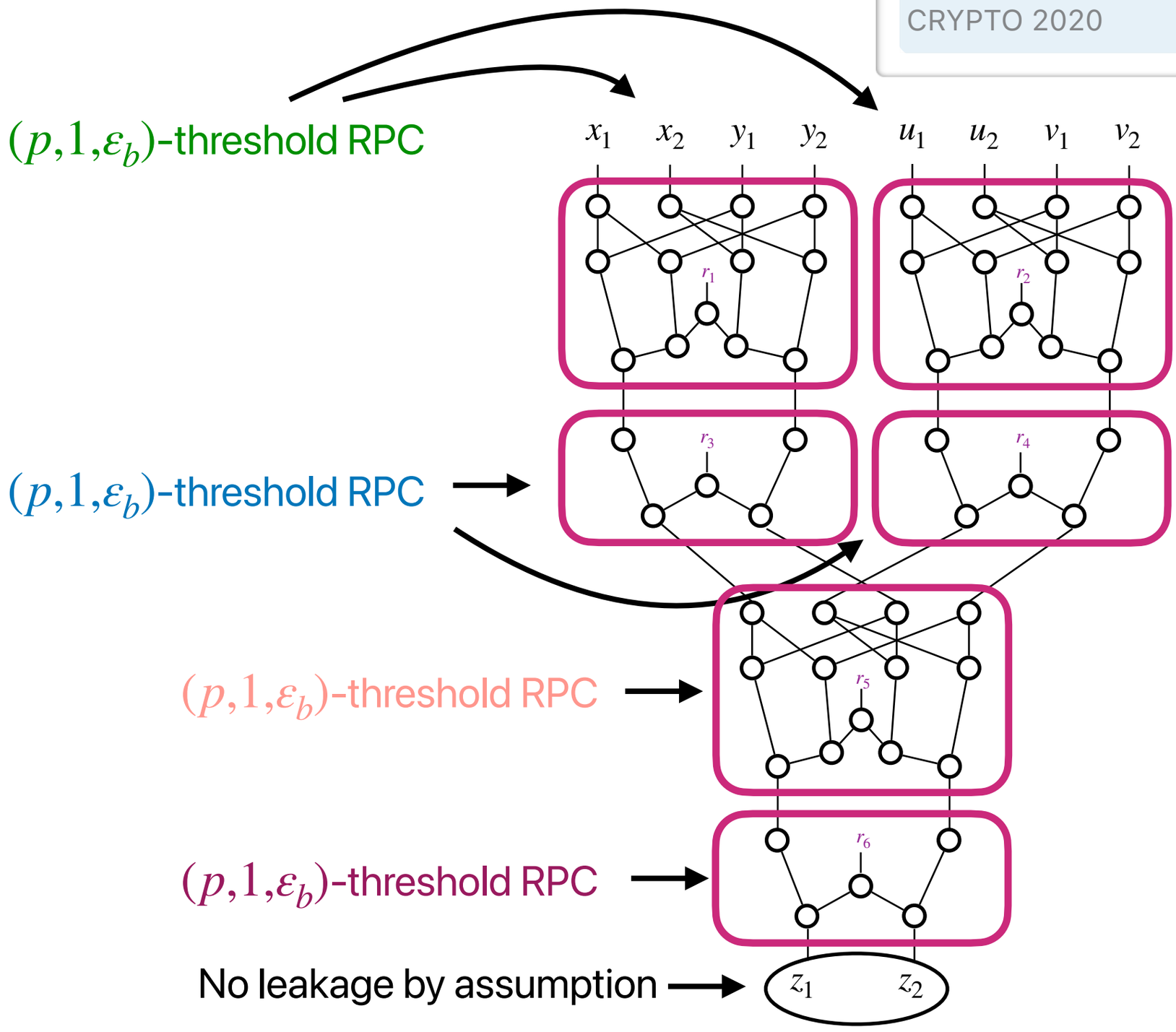


Simulation except with probability: $\varepsilon \leq 1 - (1 - \varepsilon_b)^4$

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

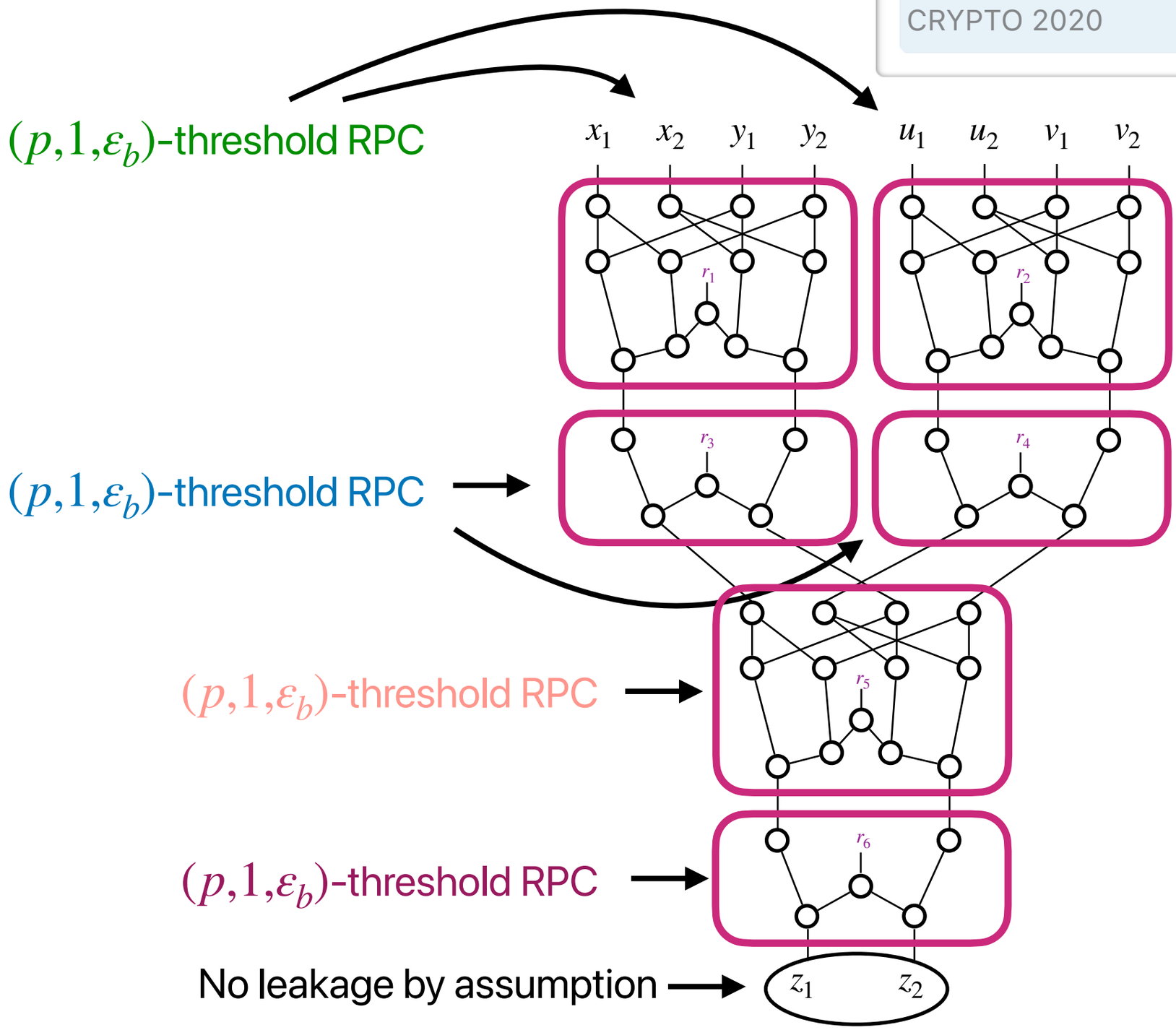


Simulation except with probability: $\varepsilon \leq 1 - (1 - \varepsilon_b)^6$

Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020



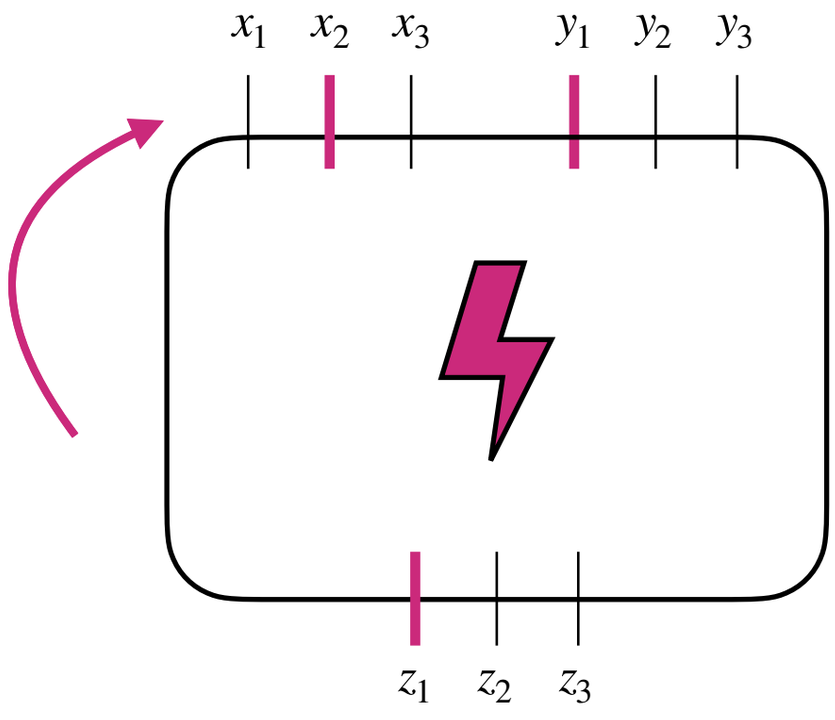
Simulation except with probability: $\varepsilon \leq 1 - (1 - \varepsilon_b)^6 \leq 6 \cdot \varepsilon_b$

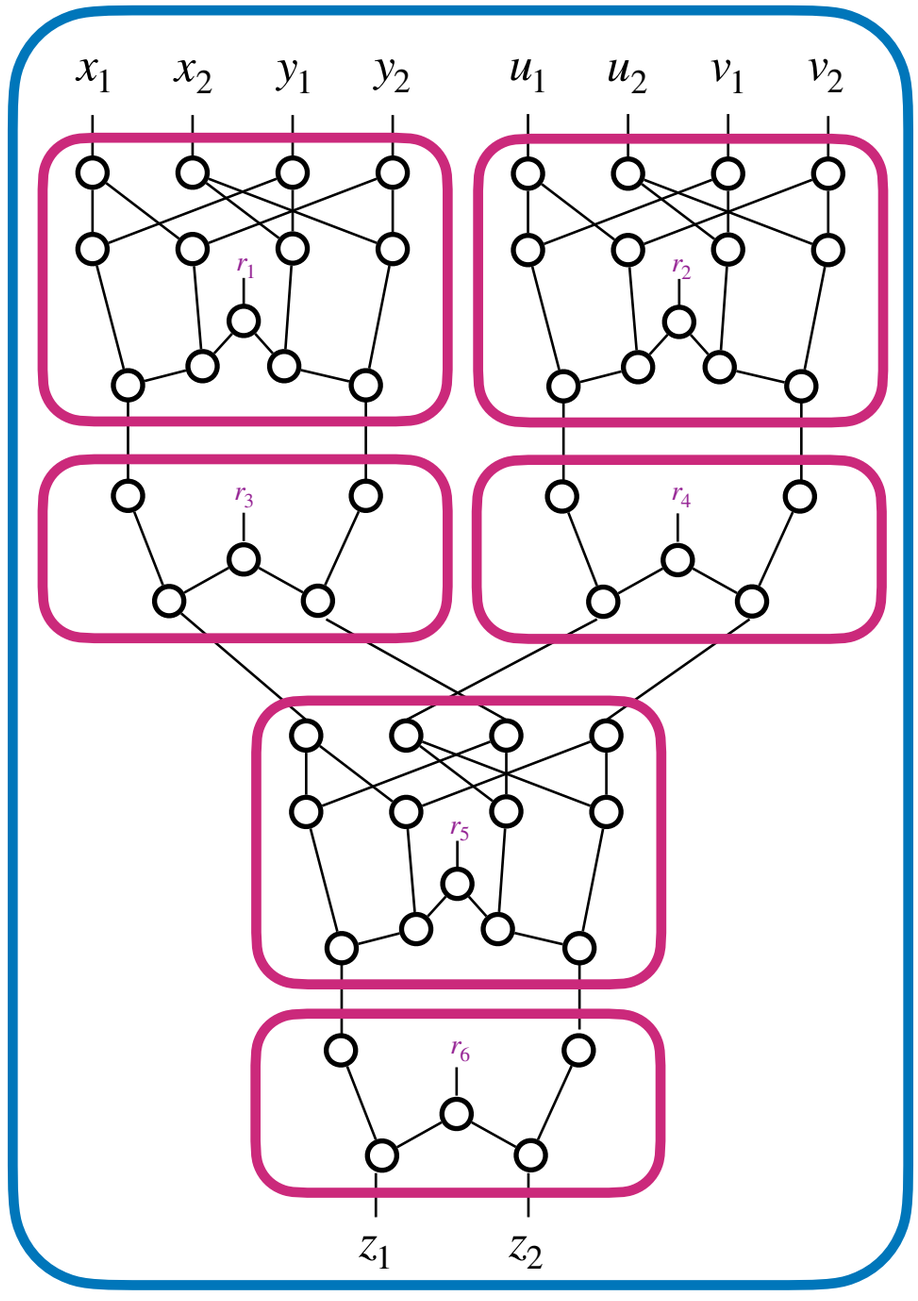
Threshold RPC

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

Threshold RPC





Threshold RPC

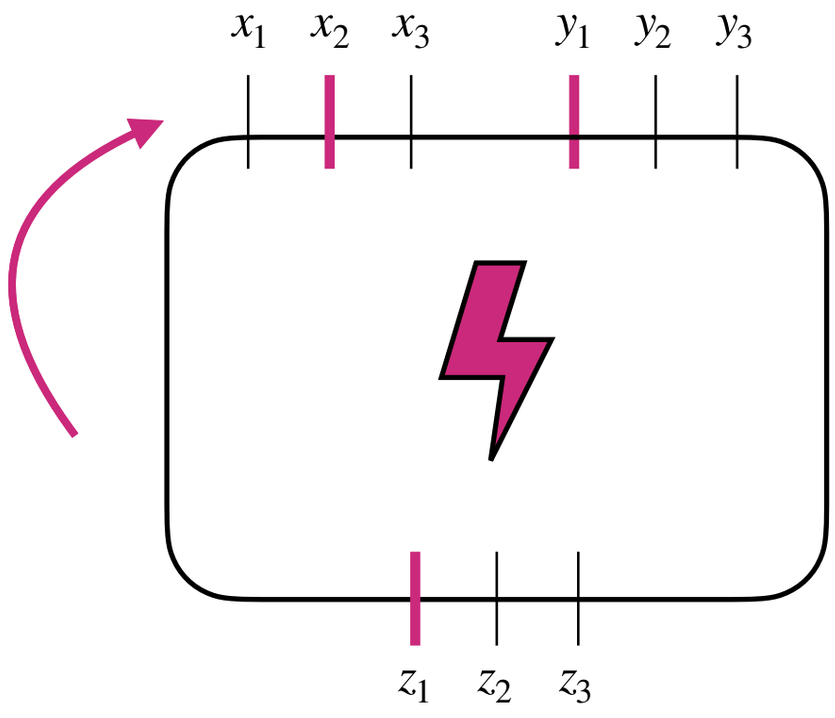
Threshold RPC

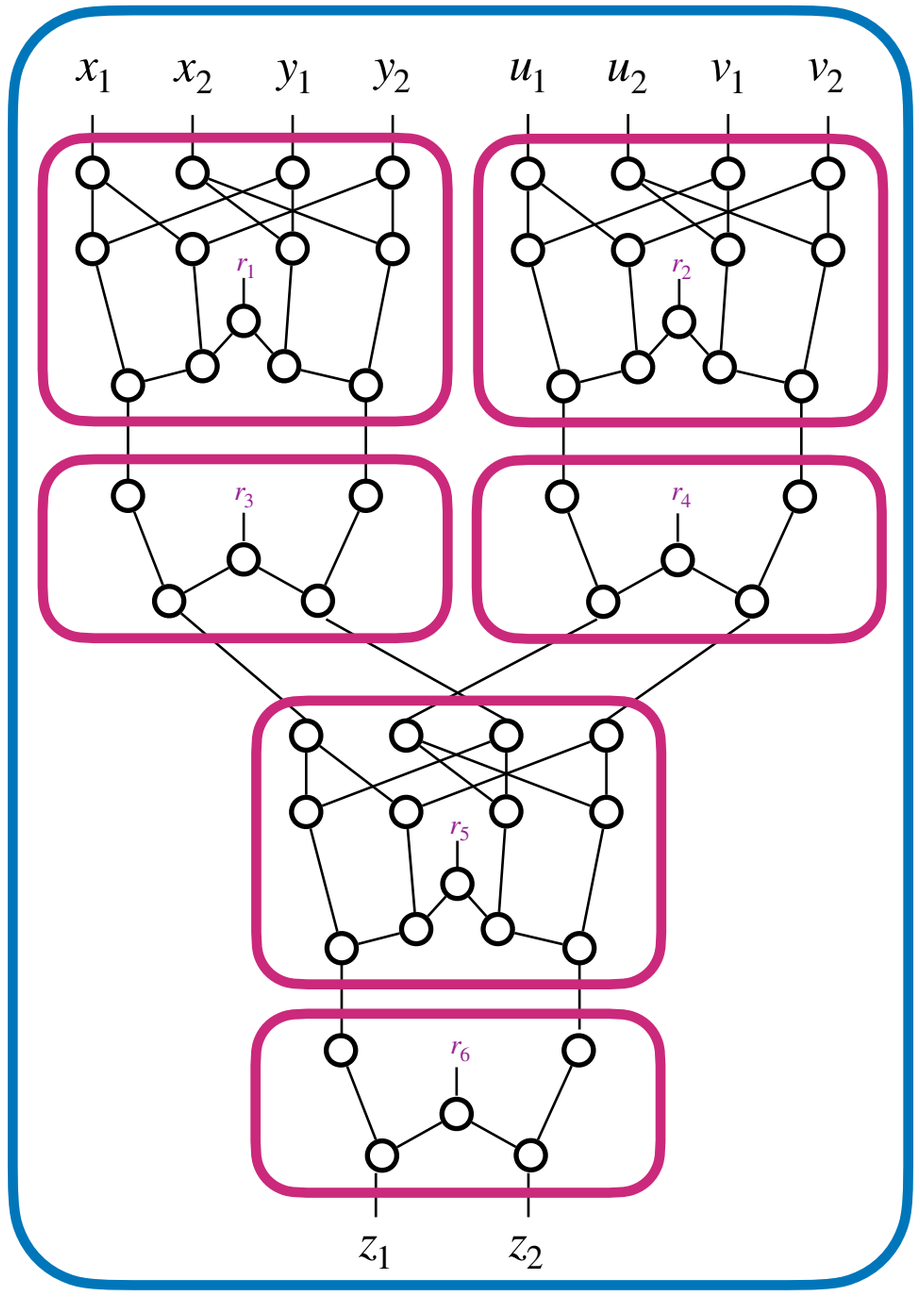
Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

Threshold RPC

⇒ Random Probing Security

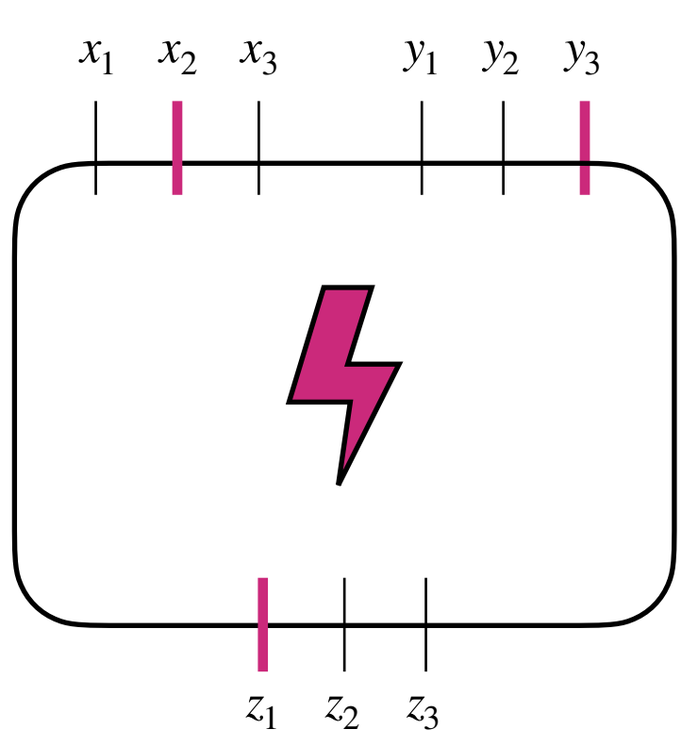




Threshold RPC

Threshold RPC

But not tight:
requiring more than t shares does not necessarily imply a failure



Threshold RPC

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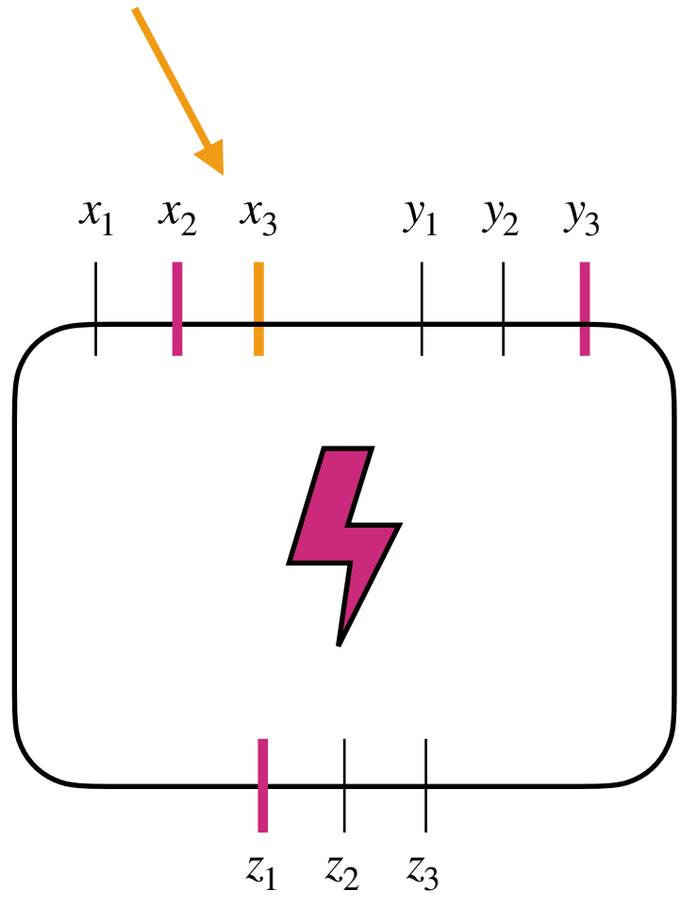

Threshold RPC

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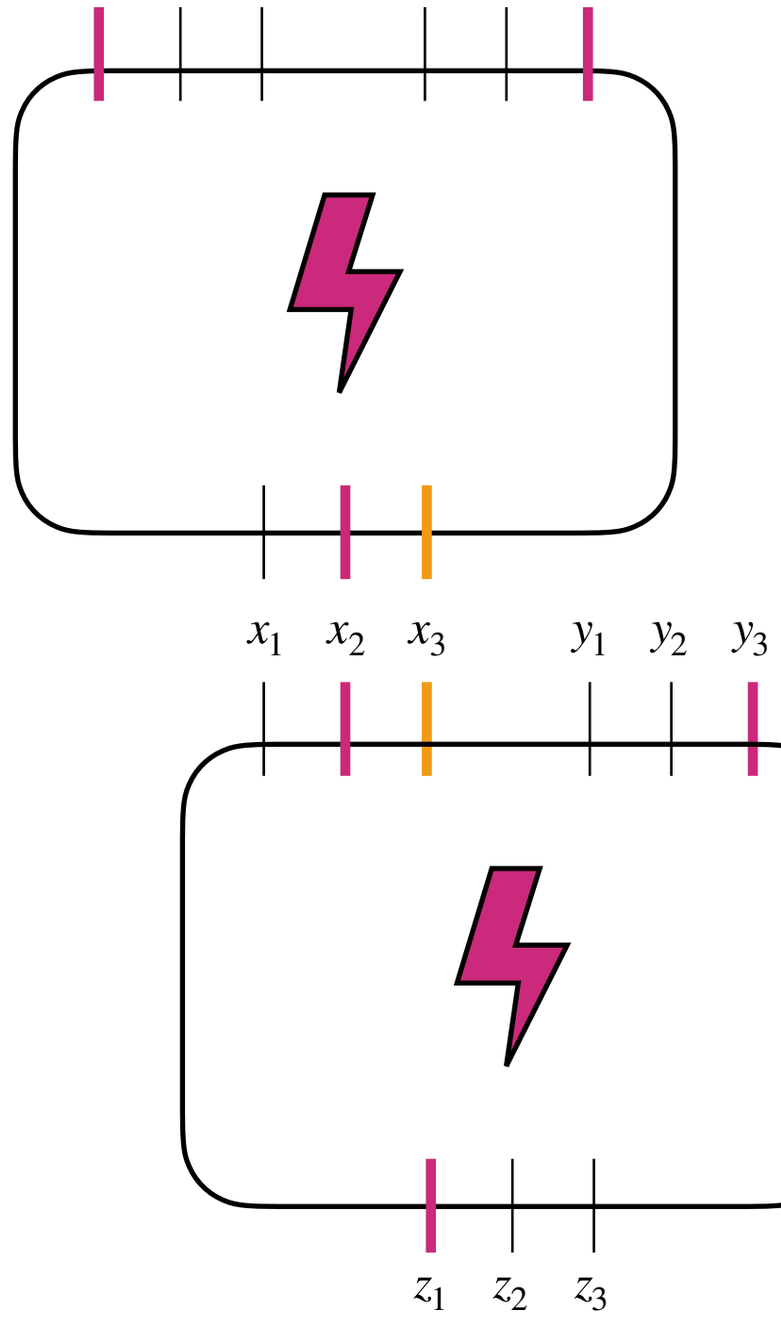


Composition

Ananth • Ishai • Sahai

CRYPTO 2018

MPC-based construction with explicit and constant leakage rate

Belaïd • Coron • Prouff • Rivain • Taleb

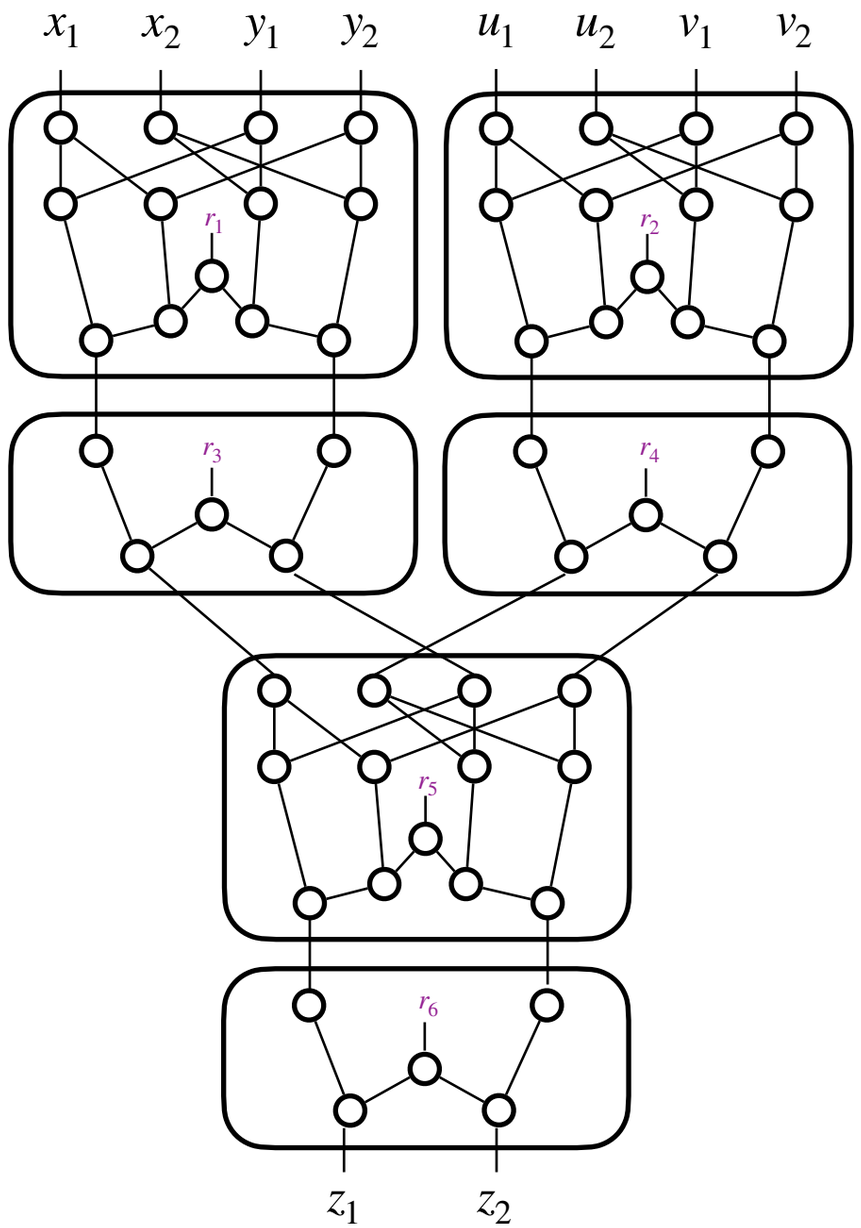
CRYPTO 2020

Threshold RPC

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

General RPC (Probe Distribution Tables)



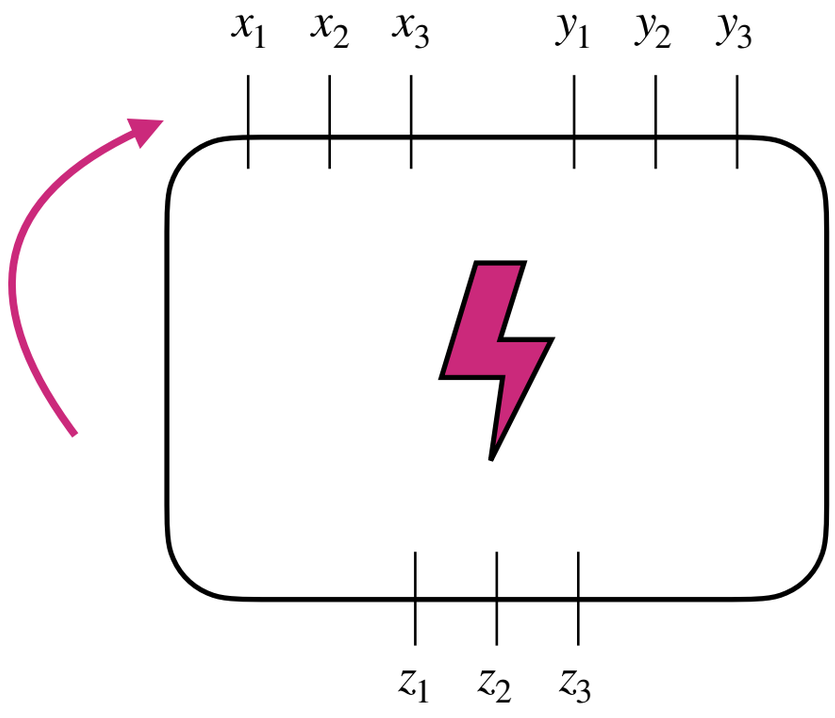
General RPC

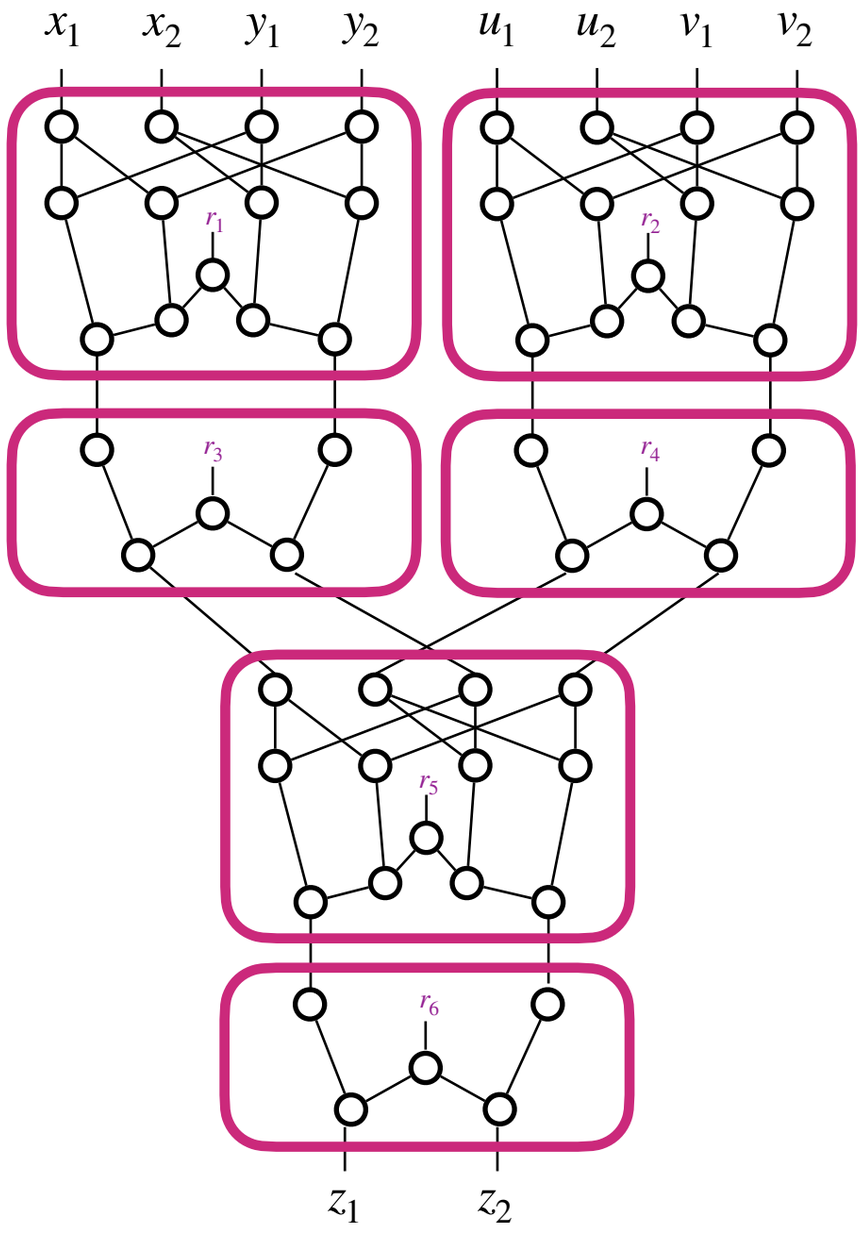
Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

$(p, \mathscr{E})$-general RPC:

For all $\mathscr{I}, \mathscr{O}$, leakage and the output shares $\mathscr{O}$ can be perfectly simulated with exactly the input shares $\mathscr{I}$ with probability $\leq \mathscr{E}_{\mathscr{O}}(\mathscr{I})$





General RPC

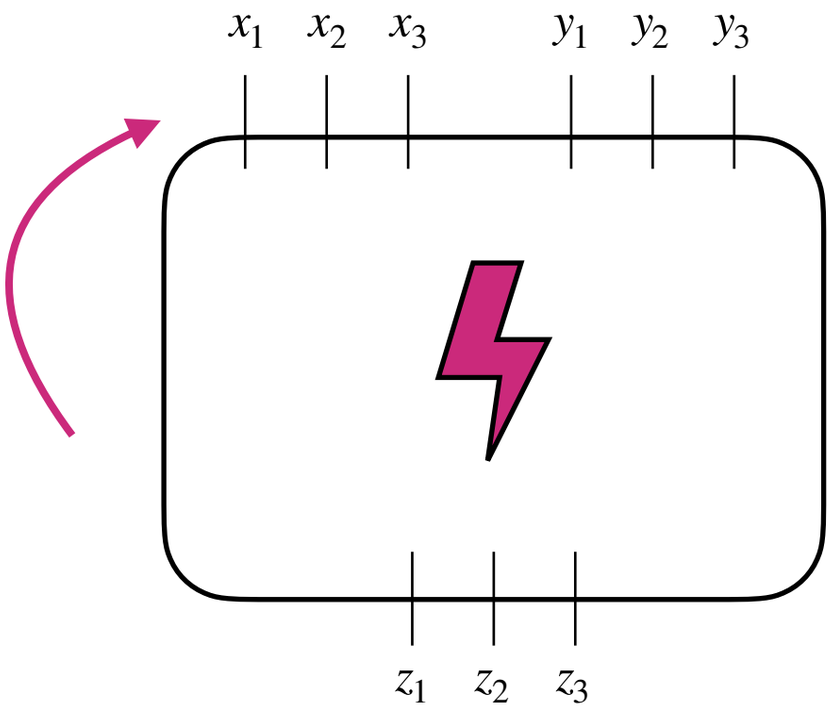
General RPC

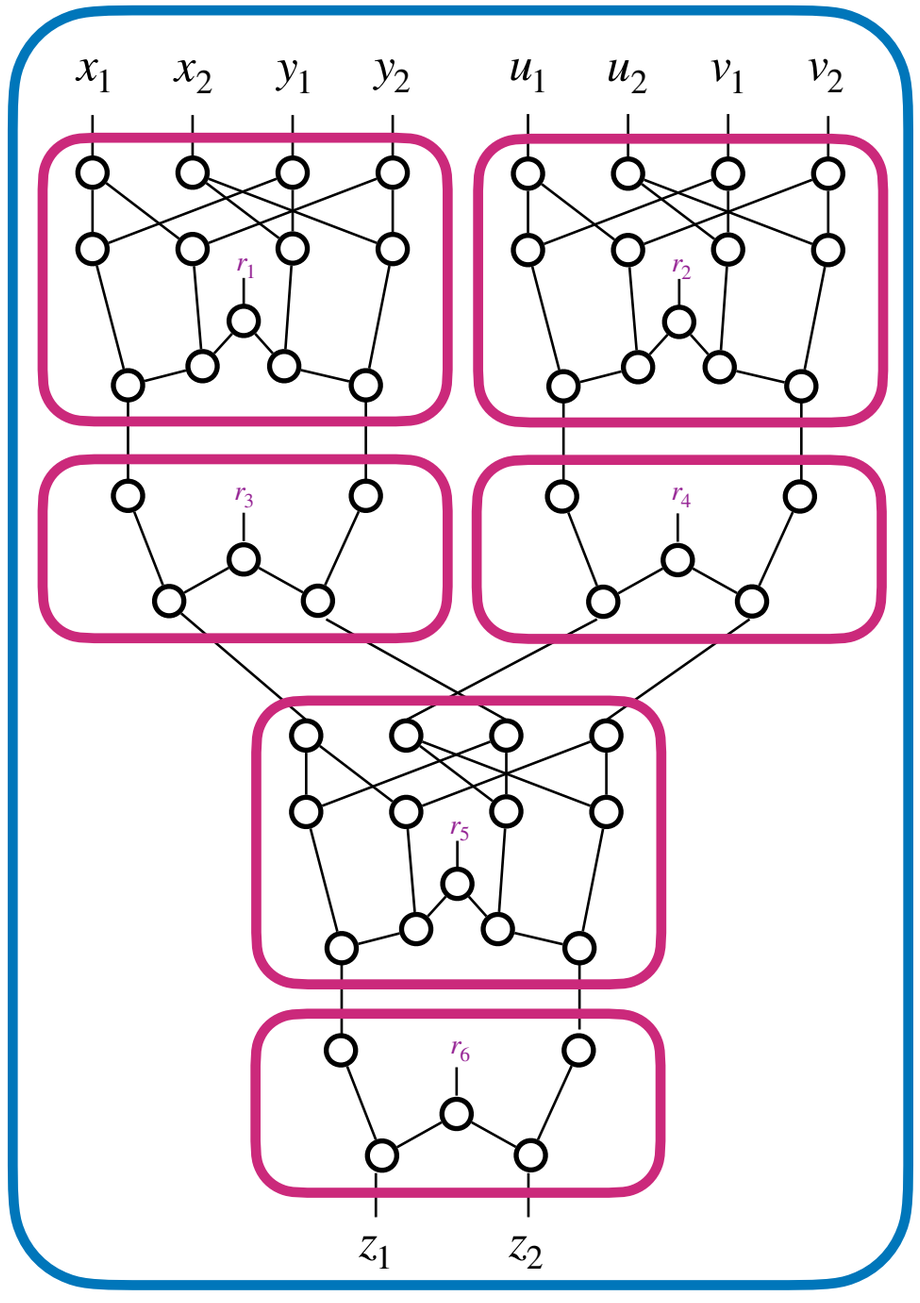
Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

General RPC

⇒ Random Probing Security





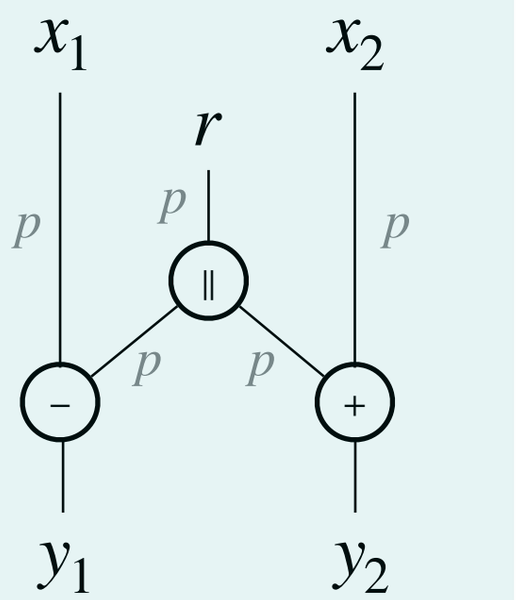
General RPC

General RPC

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

	$\varnothing$	y_1	y_2	(y_1, y_2)
$\varnothing$	$(1-p)^2$	$(1-p)^5$	$(1-p)^5$	0
x_1	$p(1-p)$	$(1-p)\cdot(1-(1-p)^4)$	$p(1-p)^4$	0
x_2	$p(1-p)$	$p(1-p)^4$	$(1-p)\cdot(1-(1-p)^4)$	0
(x_1, x_2)	p^2	$p\cdot(1-(1-p)^4)$	$p\cdot(1-(1-p)^4)$	1



Example

General RPC

	$\varnothing$	y_1	y_2	(y_1, y_2)
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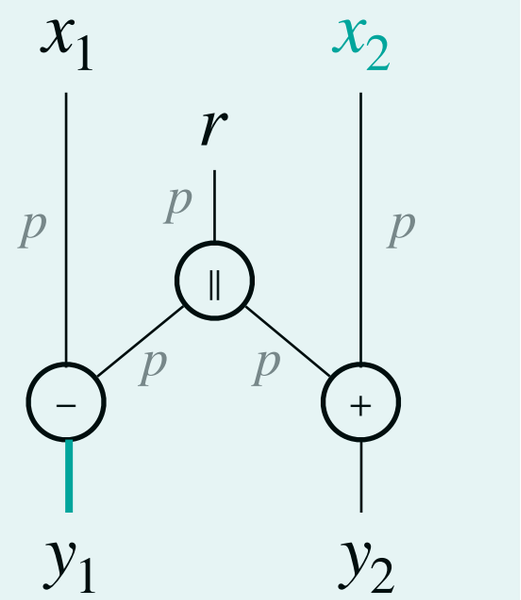
Cassiers • Faust • Orlt • Standaert

CRYPTO 2021



Example

General RPC

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

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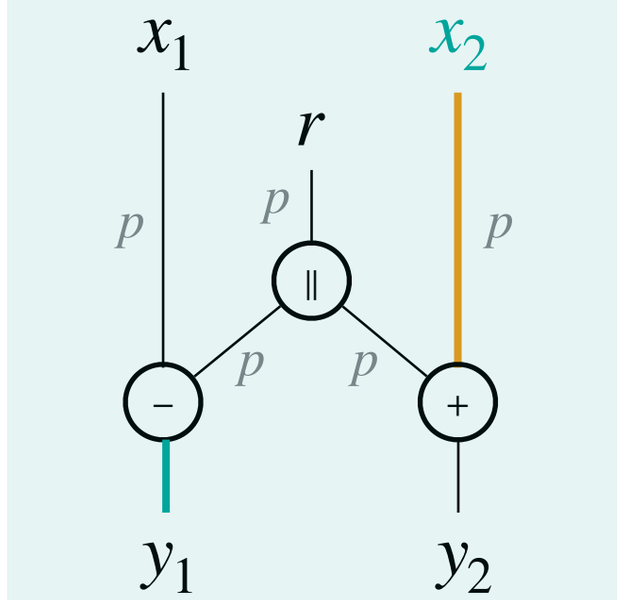
(x_1, x_2)	p^2	$p\cdot(1-(1-p)^4)$	$p\cdot(1-(1-p)^4)$	1



Example

General RPC

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

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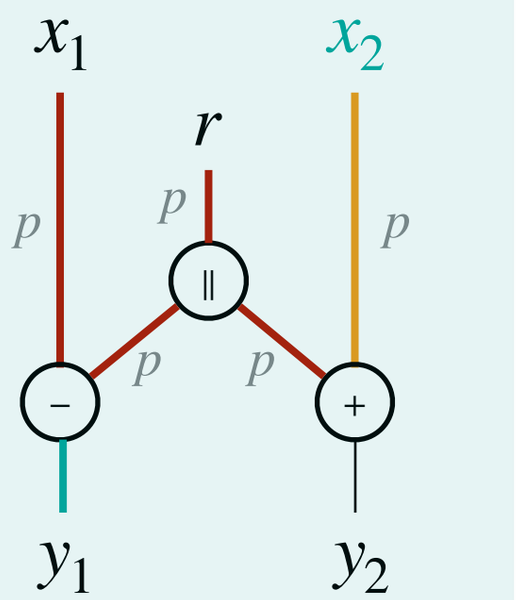
(x_1, x_2)	p^2	$p\cdot(1-(1-p)^4)$	$p\cdot(1-(1-p)^4)$	1



Example

General RPC

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

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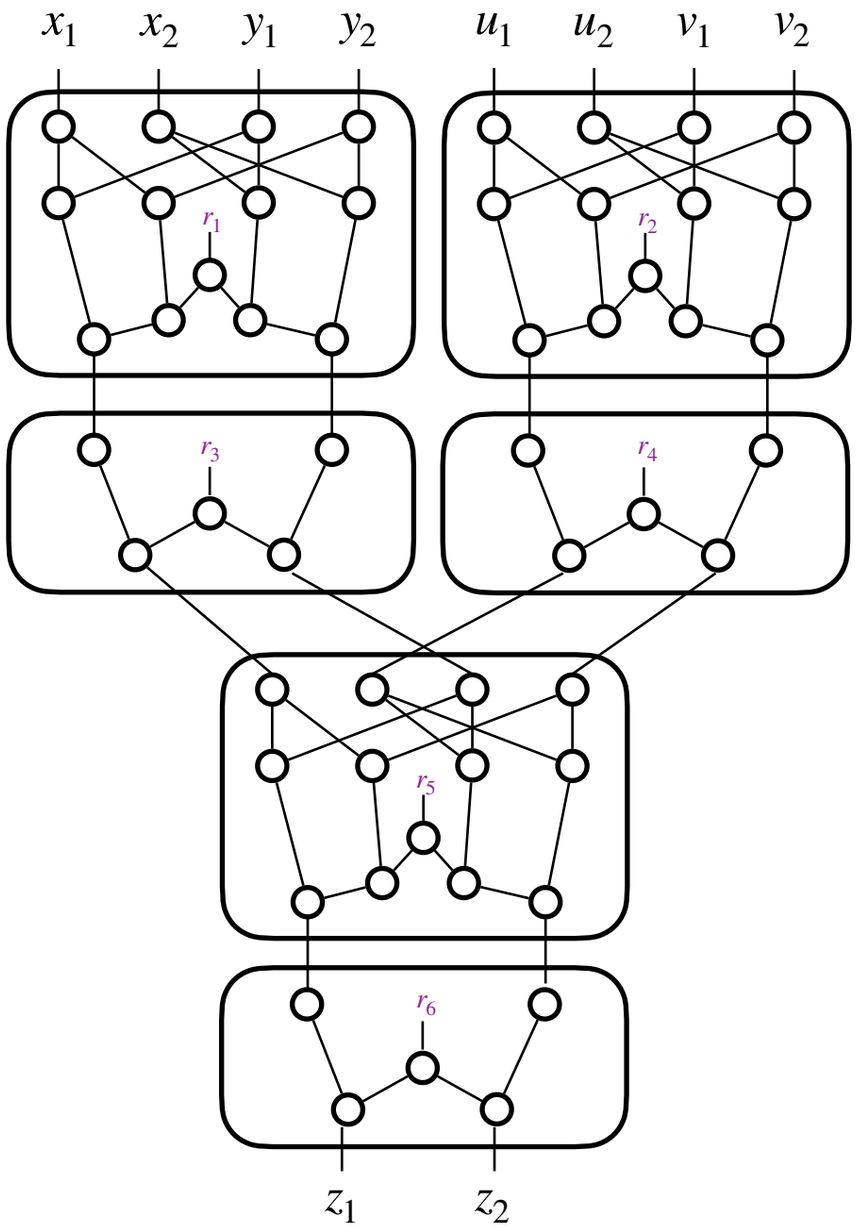


But to complex to evaluate large circuits > already 2^{10} cells

Composition

Ananth • Ishai • Sahai

CRYPTO 2018

MPC-based construction with explicit and constant leakage rate

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

Threshold RPC

Cassiers • Faust • Orlt • Standaert

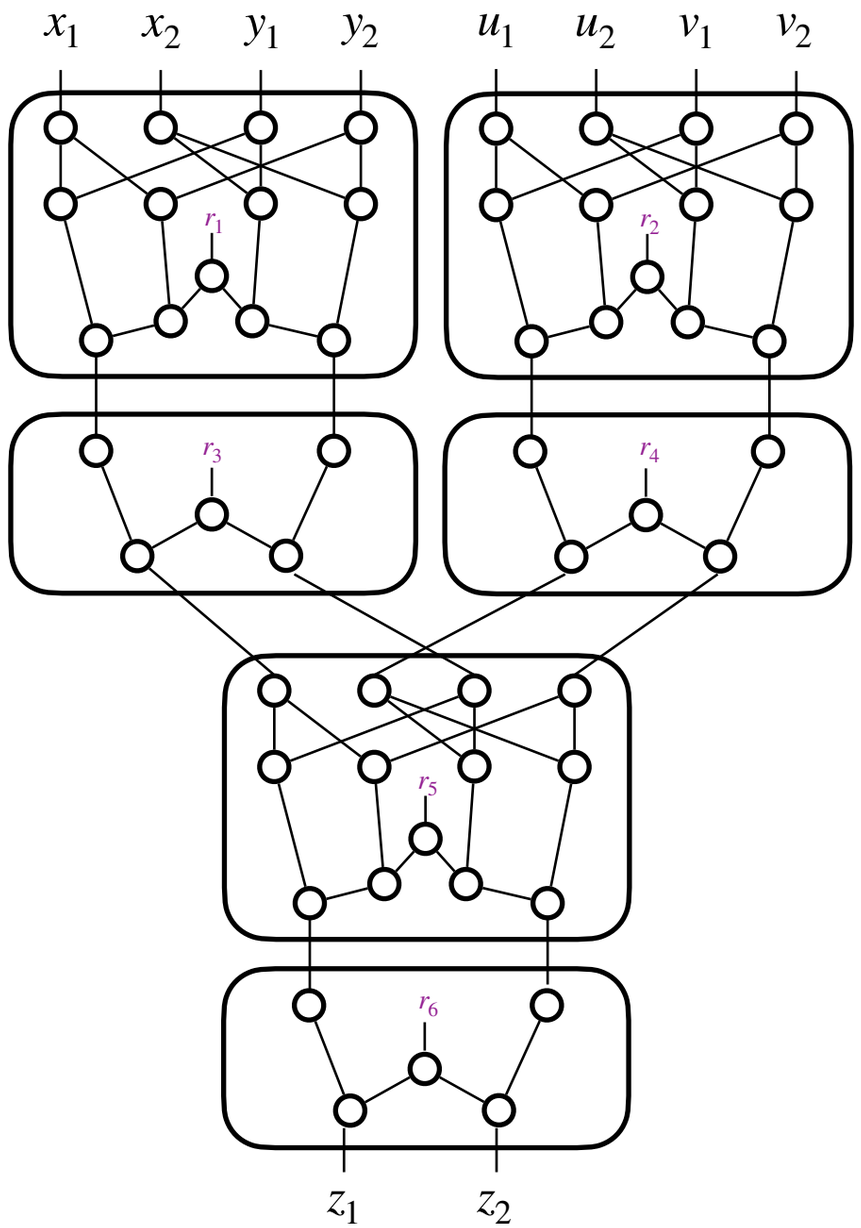
CRYPTO 2021

General RPC (Probe Distribution Tables)

Belaïd • Rivain • Rossi

EUROCRYPT 2025

Cardinal RPC



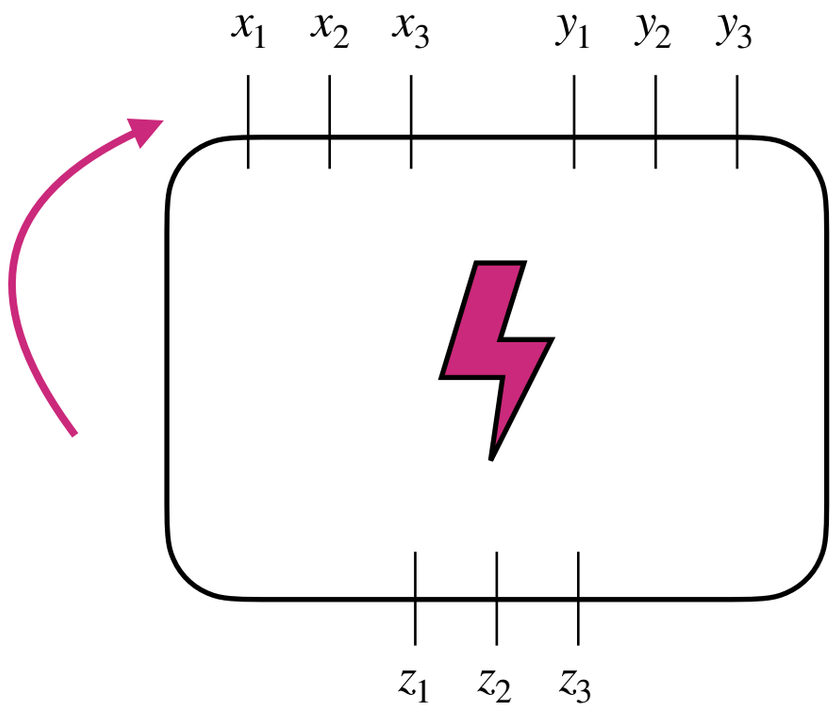
Cardinal RPC

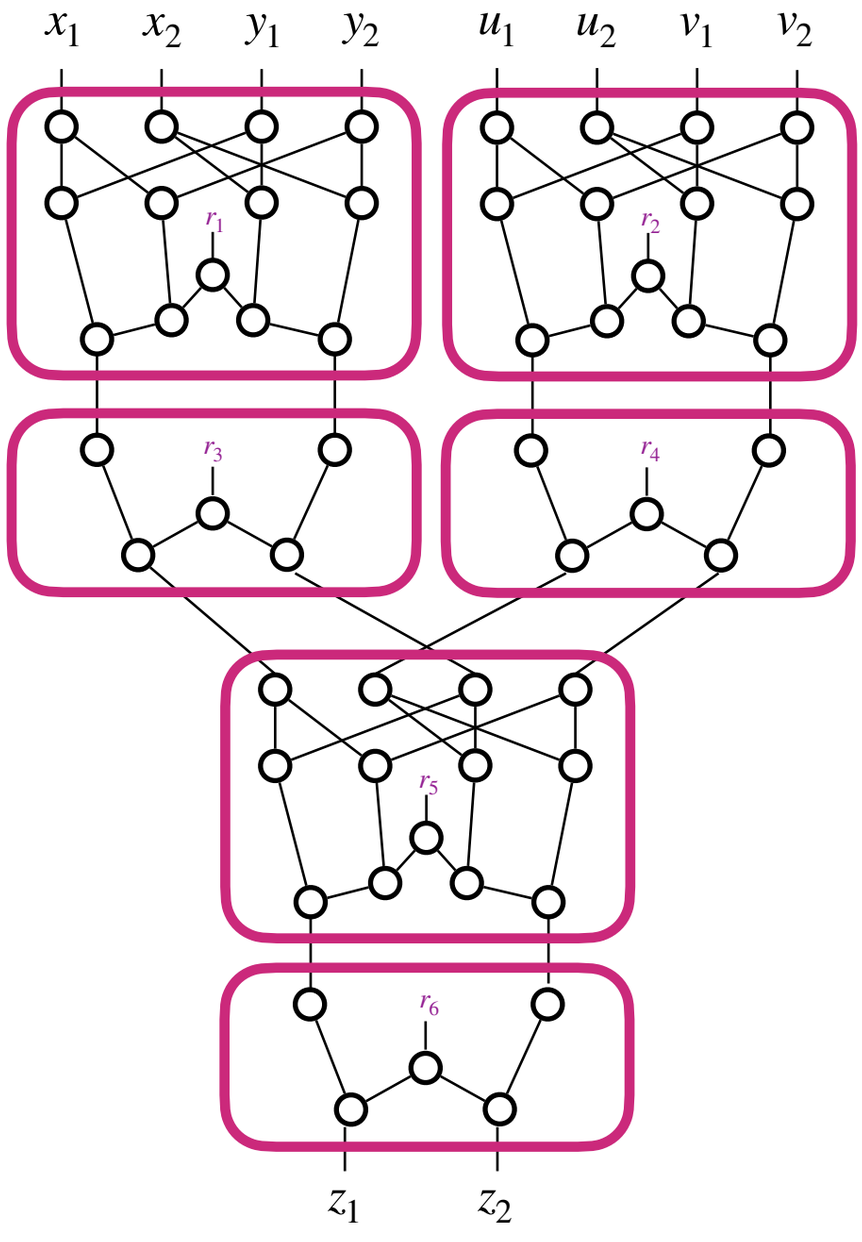
Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

$(p, \mathscr{E})$-cardinal RPC:

For all t^i, t^o, leakage and t^o output shares can be perfectly simulated with exactly t^i input shares with probability $\leq \mathscr{E}_{t^o}(t^i)$





Cardinal RPC

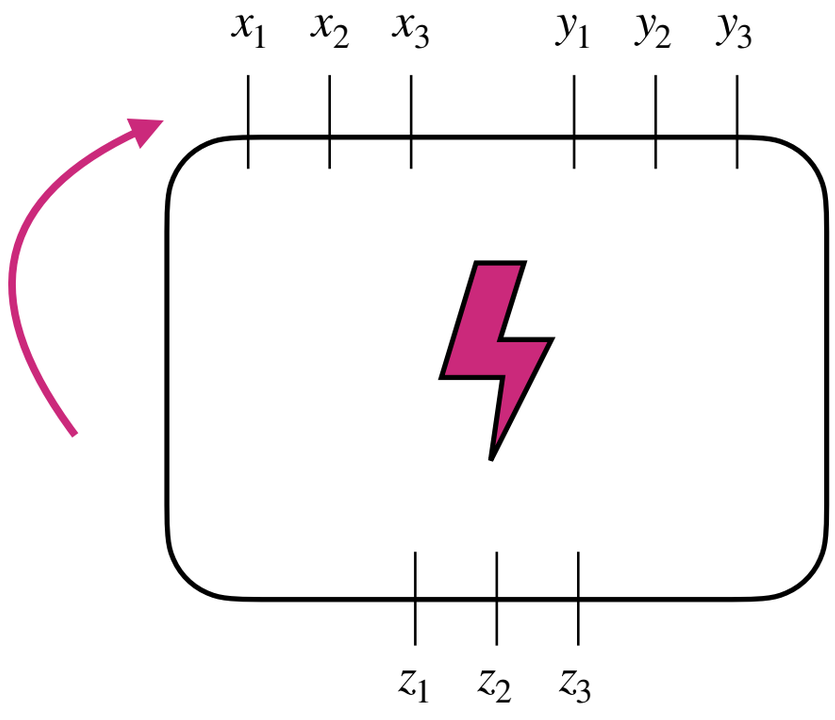
Cardinal RPC

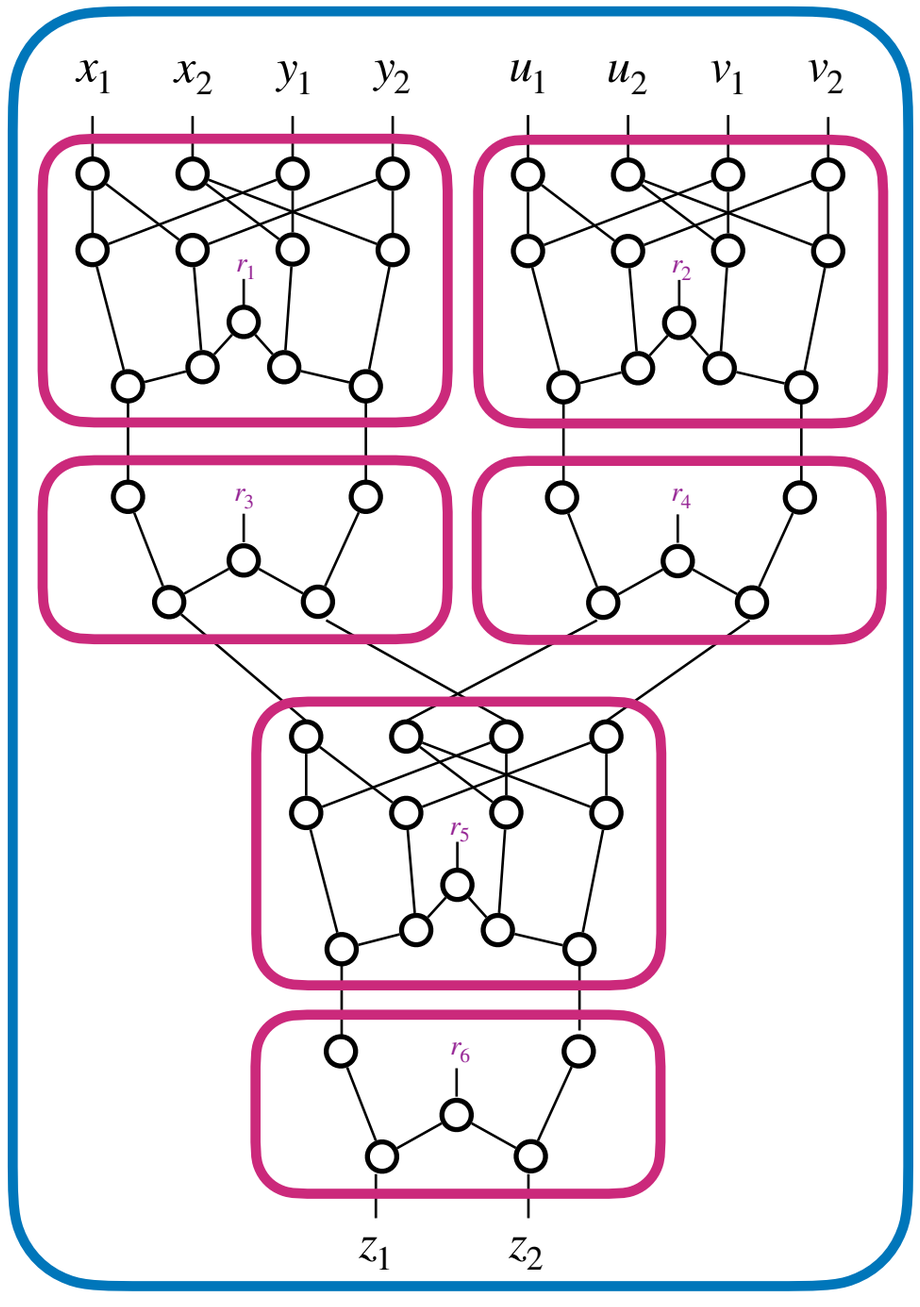
Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

Cardinal RPC

⇒ Random Probing Security





Cardinal RPC

Cardinal RPC

Belaïd • Rivain • Rossi

EUROCRYPT 2025

Cardinal RPC

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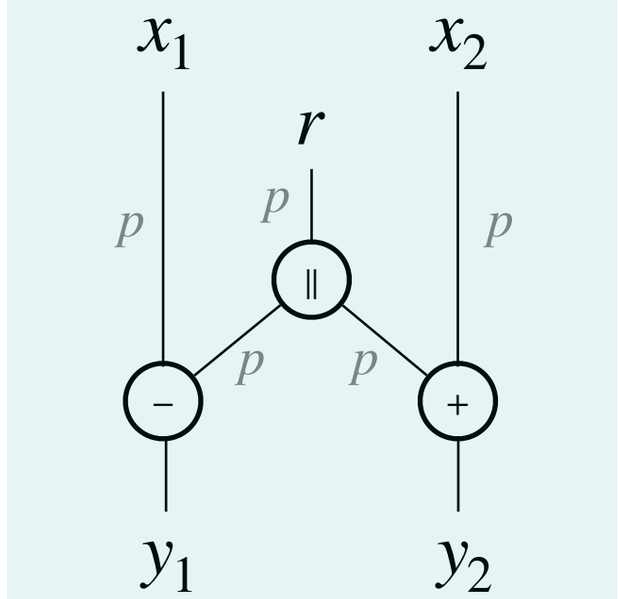
x_1	$p(1-p)$	$(1-p)\cdot(1-(1-p)^4)$	$p(1-p)^4$	0
x_2	$p(1-p)$	$p(1-p)^4$	$(1-p)\cdot(1-(1-p)^4)$	0
(x_1, x_2)	p^2	$p\cdot(1-(1-p)^4)$	$p\cdot(1-(1-p)^4)$	1

	0	1	2
0	$(1-p)^2$	$(1-p)^5$	0
1	$2p(1-p)$	$p(1-p)^4 + (1-p)\cdot(1-(1-p)^4)$	0
2	p^2	$p\cdot(1-(1-p)^4)$	1



Example

Uniformly Cardinal RPC

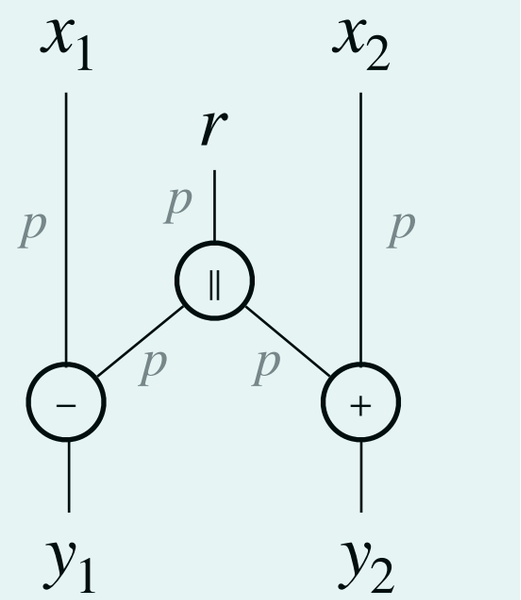
Belaïd • Normand • Rivain

ASIACRYPT 2025

Uniformly Cardinal RPC

	$\varnothing$	y_1	y_2	(y_1, y_2)
$\varnothing$	$(1-p)^2$	$(1-p)^5$	$(1-p)^5$	0
x_1	$p(1-p)$	$(1-p)\cdot(1-(1-p)^4)$	$p(1-p)^4$	0
x_2	$p(1-p)$	$p(1-p)^4$	$(1-p)\cdot(1-(1-p)^4)$	0
(x_1, x_2)	p^2	$p\cdot(1-(1-p)^4)$	$p\cdot(1-(1-p)^4)$	1

	0	1	2
0	$(1-p)^2$	$(1-p)^5$	0
1	$2p(1-p)$	$p(1-p)^4 + (1-p)\cdot(1-(1-p)^4)$	0
2	p^2	$p\cdot(1-(1-p)^4)$	1



Example

Uniformly Cardinal RPC

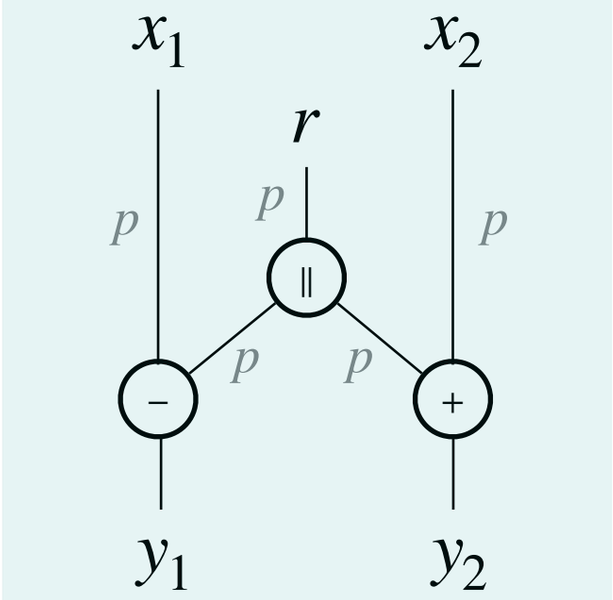
Belaïd • Normand • Rivain

ASIACRYPT 2025

Uniformly Cardinal RPC

	$\varnothing$	y_1	y_2	(y_1, y_2)
$\varnothing$	$(1-p)^2$	$(1-p)^5$	$(1-p)^5$	0
x_1	$p(1-p)$	$(1-p)\cdot(1-(1-p)^4)$	$p(1-p)^4$	0
x_2	$p(1-p)$	$p(1-p)^4$	$(1-p)\cdot(1-(1-p)^4)$	0
(x_1, x_2)	p^2	$p\cdot(1-(1-p)^4)$	$p\cdot(1-(1-p)^4)$	1

	0	1	2
0	$(1-p)^2$	$(1-p)^5$	0
1	$2p(1-p)$	$p(1-p)^4 + (1-p)\cdot(1-(1-p)^4)$	0
2	p^2	$p\cdot(1-(1-p)^4)$	1



Example

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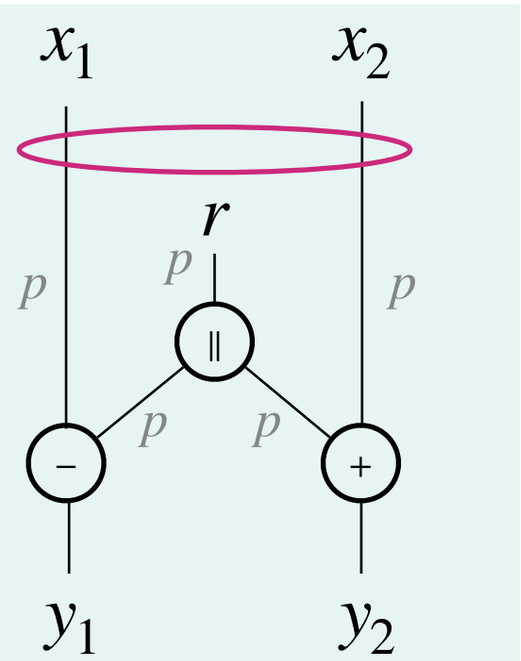
ASIACRYPT 2025

Uniformly Cardinal RPC

	$\varnothing$	y_1	y_2	(y_1, y_2)
$\varnothing$	$(1-p)^2$	$(1-p)^5$	$(1-p)^5$	0
x_1	$p(1-p)$	p'	p'	0
x_2	$p(1-p)$	p'	p'	0
(x_1, x_2)	p^2	$p \cdot (1-(1-p)^4)$	$p \cdot (1-(1-p)^4)$	1



Example

	0	1	2
0	$(1-p)^2$	$(1-p)^5$	0
1	$2p(1-p)$	$2 \cdot p'$	0
2	p^2	$p \cdot (1-(1-p)^4)$	1

$$p' = \frac{(1-p) \cdot (1-(1-p)^4) + p(1-p)^4}{2}$$

Uniformly cardinal RPC

Results

🔬 **Foundations**

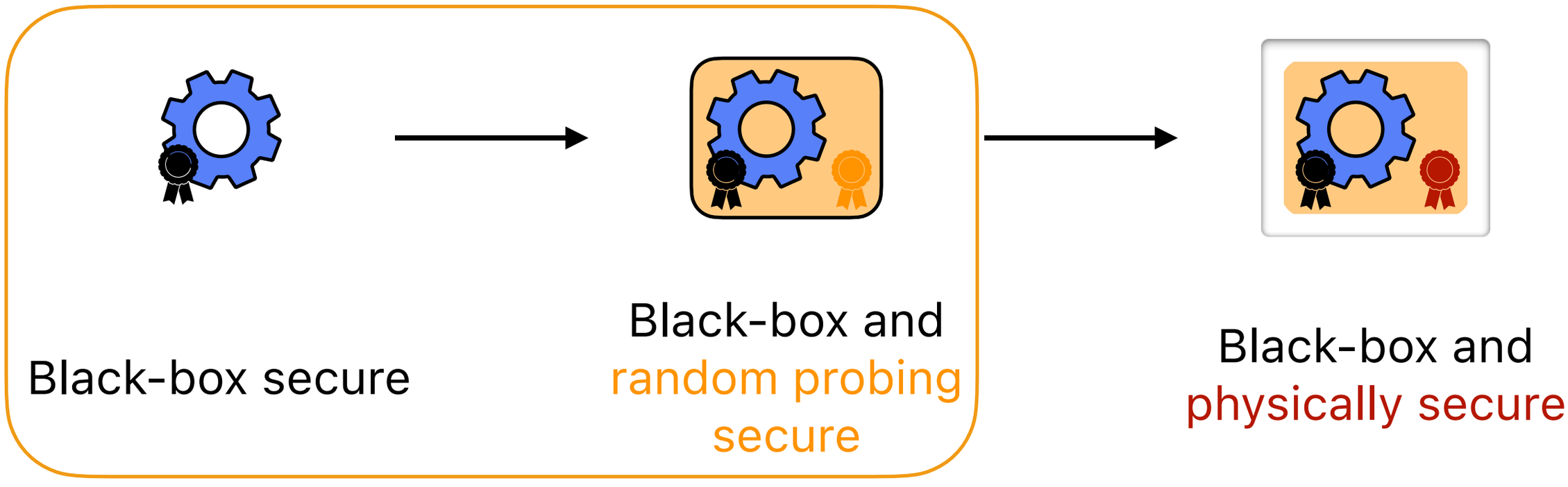
Random probing security & verification (small circuits)

🏗️ **Scaling up**

Composition frameworks (larger circuits)

🧩 **Building blocks**

Design of efficient gadgets



Composition

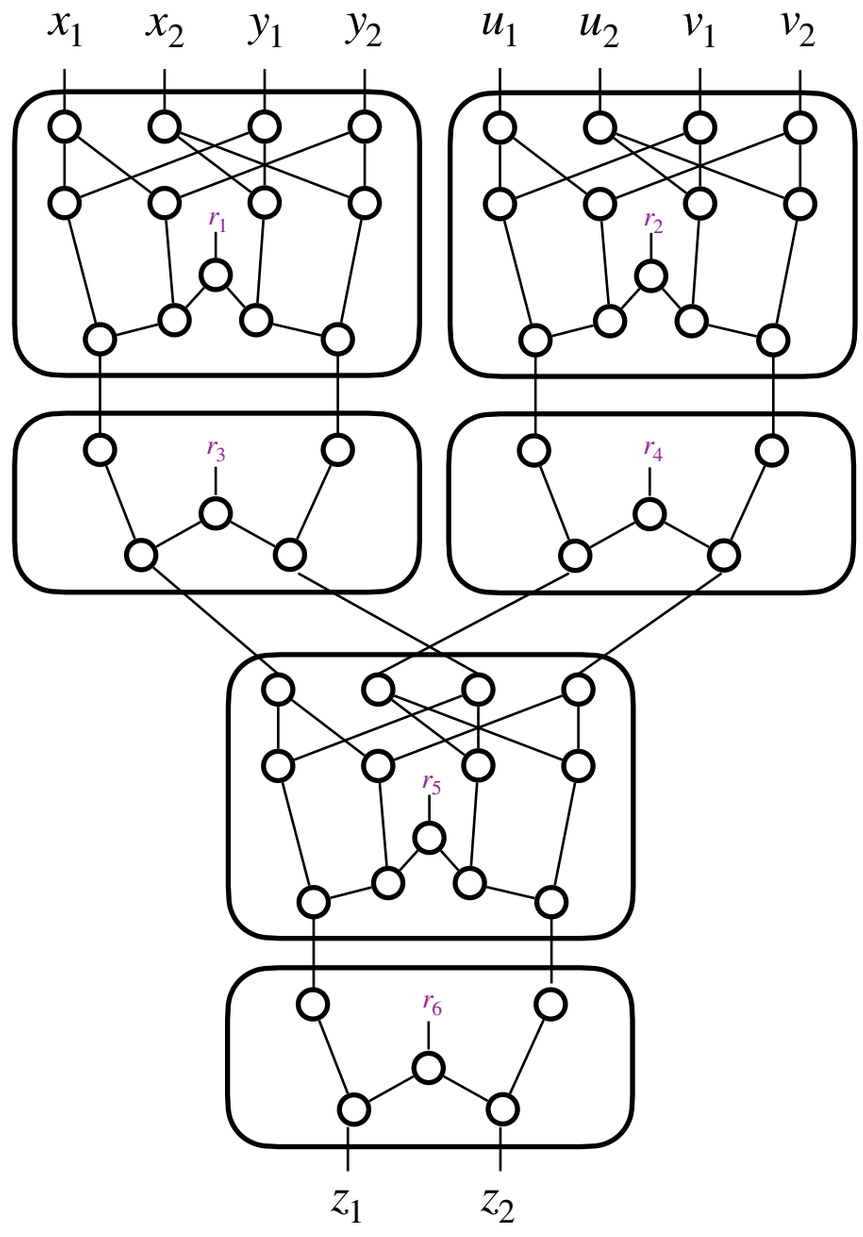
Belaïd • Rivain • Rossi

EUROCRYPT 2025

Belaïd • Normand • Rivain

ASIACRYPT 2025

(Uniformly) cardinal RPC
framework + gadgets



Toolbox:

- Linear gadgets
- Non-linear gadgets
- Refresh gadgets

Composition

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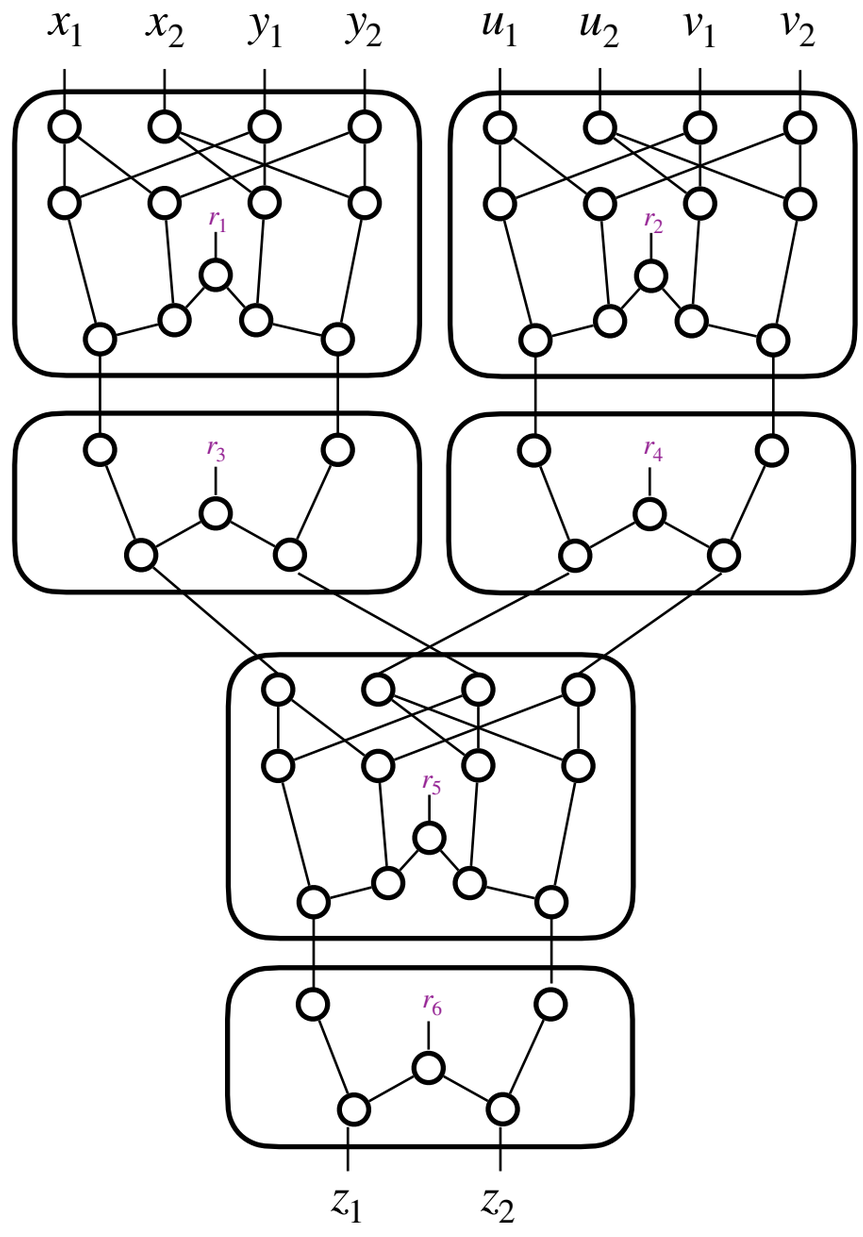

Toolbox:

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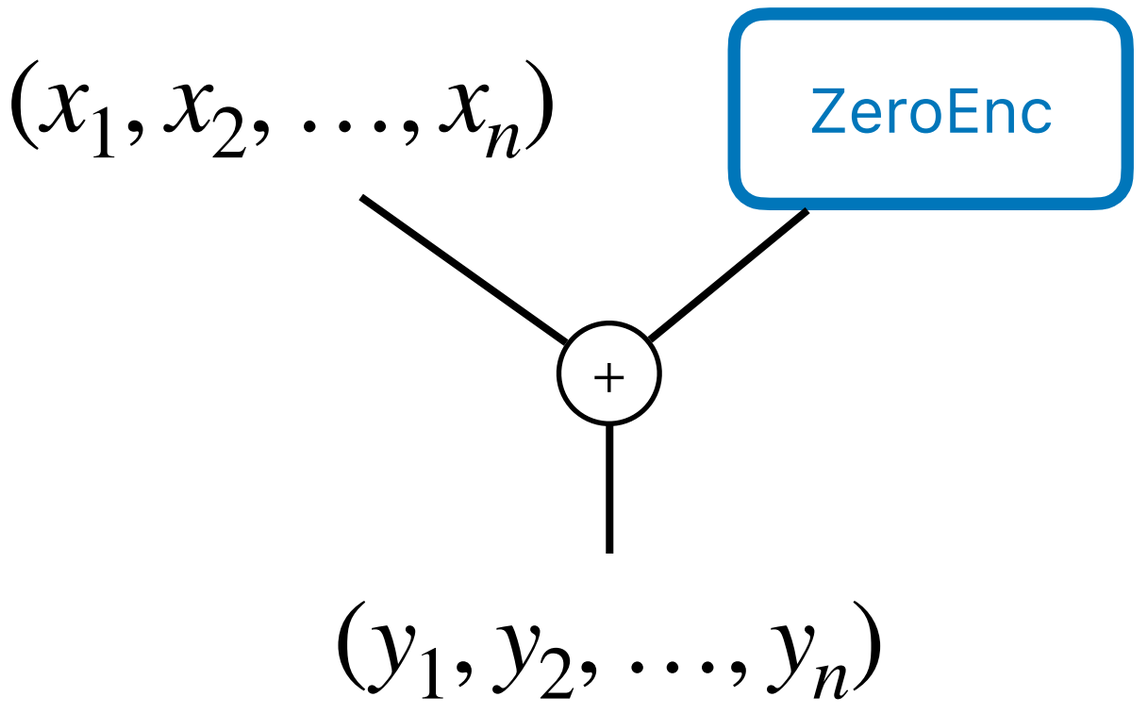
Refresh Gadget

Belaïd • Rivain • Rossi
EUROCRYPT 2025

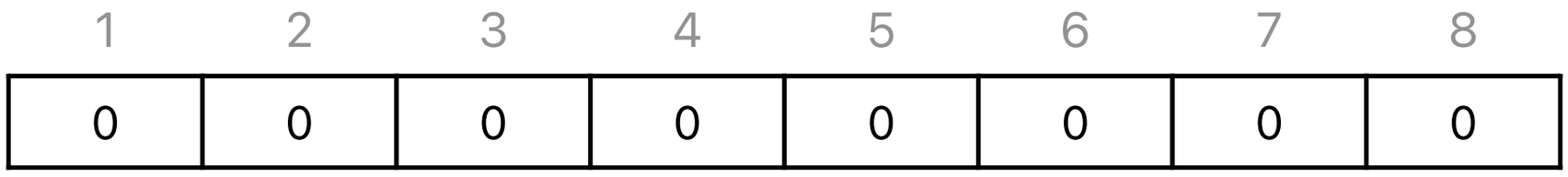


$$y_1 + y_2 + \ldots + y_n = x_1 + x_2 + \ldots + x_n$$

RPZeroEnc

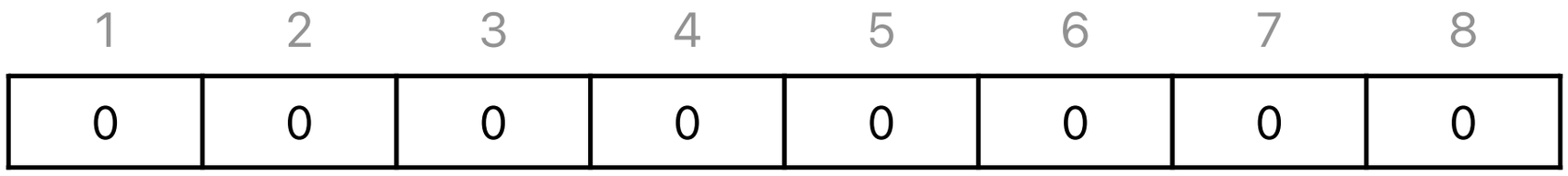
Belaïd • Rivain • Rossi

EUROCRYPT 2025



RPZeroEnc

Belaïd • Rivain • Rossi
EUROCRYPT 2025



1st iteration: $r_1 \leftarrow \$, \quad (i_1, j_1) \leftarrow \$$ (example : $i_1 = 3$, $j_1 = 7$)

RPZeroEnc

Belaïd • Rivain • Rossi
EUROCRYPT 2025

1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	0

1st iteration: $r_1 \leftarrow \$, \quad (i_1, j_1) \leftarrow \$$ (example : $i_1 = 3$, $j_1 = 7$)

1	2	3	4	5	6	7	8
0	0	r_1	0	0	0	$-r_1$	0

RPZeroEnc

Belaïd • Rivain • Rossi
EUROCRYPT 2025

1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	0

1st iteration: $r_1 \leftarrow \$, \quad (i_1, j_1) \leftarrow \$$ (example : $i_1 = 3$, $j_1 = 7$)

1	2	3	4	5	6	7	8
0	0	r_1	0	0	0	$-r_1$	0

2nd iteration: $r_2 \leftarrow \$, \quad (i_2, j_2) \leftarrow \$$ (example : $i_2 = 1$, $j_2 = 8$)

1	2	3	4	5	6	7	8
r_2	0	r_1	0	0	0	$-r_1$	$-r_2$

RPZeroEnc

Belaïd • Rivain • Rossi
EUROCRYPT 2025

1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	0

1st iteration: $r_1 \leftarrow \$, \quad (i_1, j_1) \leftarrow \$$ (example : $i_1 = 3$, $j_1 = 7$)

1	2	3	4	5	6	7	8
0	0	r_1	0	0	0	$-r_1$	0

2nd iteration: $r_2 \leftarrow \$, \quad (i_2, j_2) \leftarrow \$$ (example : $i_2 = 1$, $j_2 = 8$)

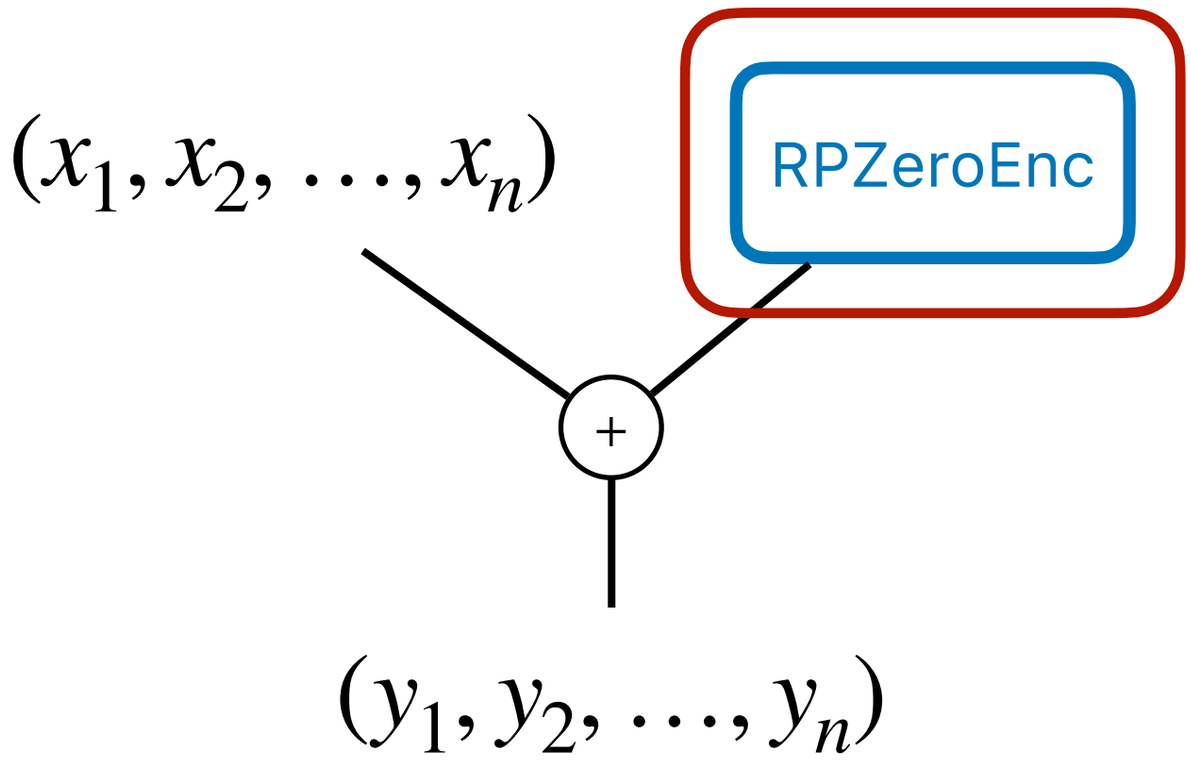
1	2	3	4	5	6	7	8
r_2	0	r_1	0	0	0	$-r_1$	$-r_2$

3rd iteration: $r_3 \leftarrow \$, \quad (i_3, j_3) \leftarrow \$$ (example : $i_3 = 2$, $j_3 = 3$)

1	2	3	4	5	6	7	8
r_2	r_3	$r_1 - r_3$	0	0	0	$-r_1$	$-r_2$

Refresh Gadget

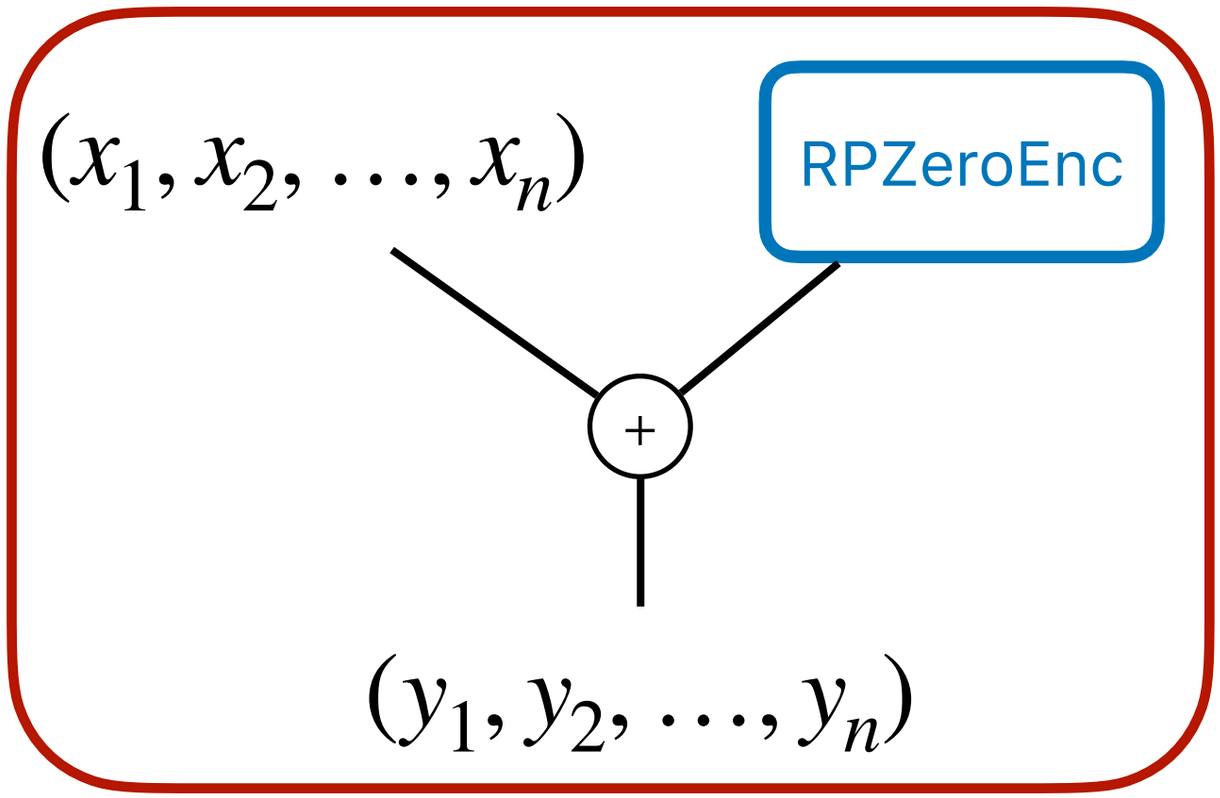
Belaïd • Rivain • Rossi
EUROCRYPT 2025



RPRefresh is cardinal RPC

Refresh Gadget

Belaïd • Rivain • Rossi
EUROCRYPT 2025



RPRefresh is cardinal RPC

Composition

Belaïd • Rivain • Rossi

EUROCRYPT 2025

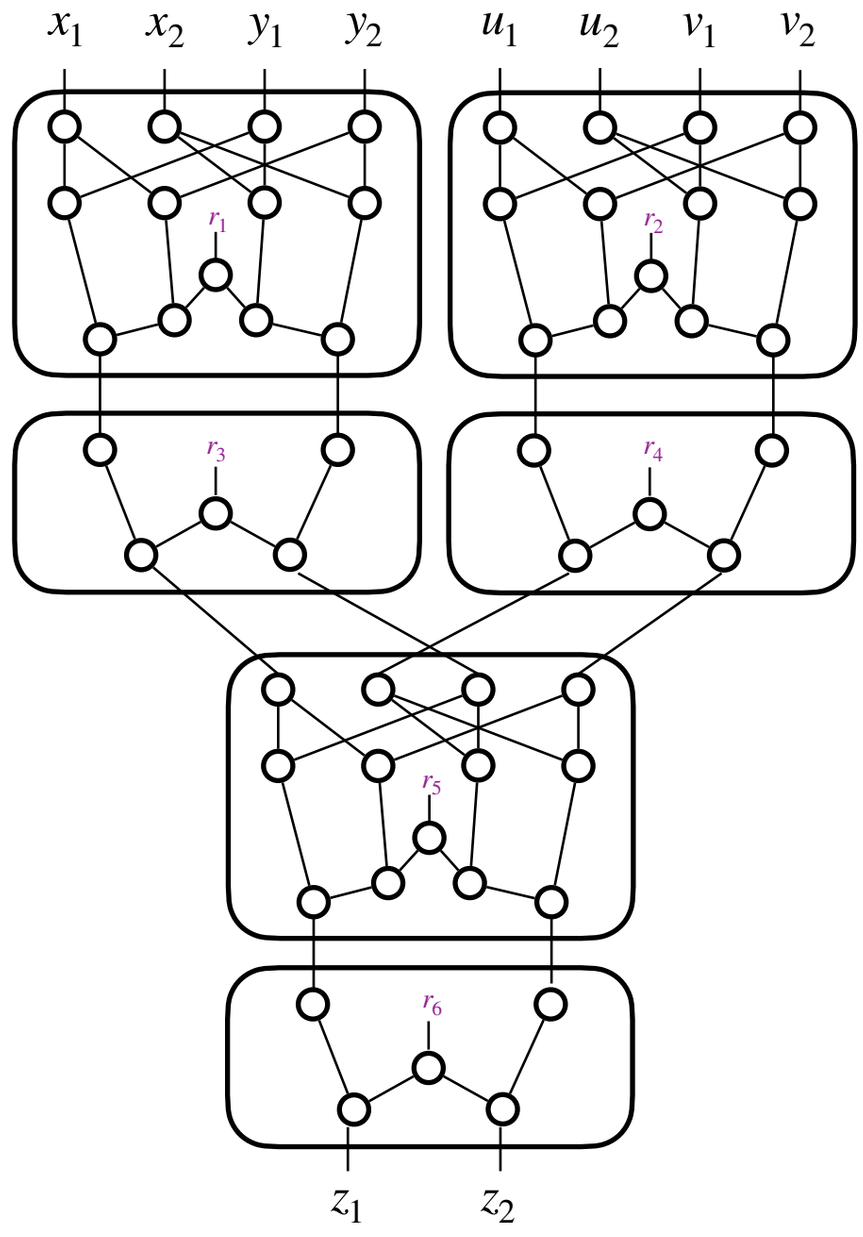
Belaïd • Normand • Rivain

ASIACRYPT 2025

(Uniformly) cardinal RPC
framework + gadgets

Toolbox:

- Linear gadgets
- Non-linear gadgets
- Refresh gadgets ✓



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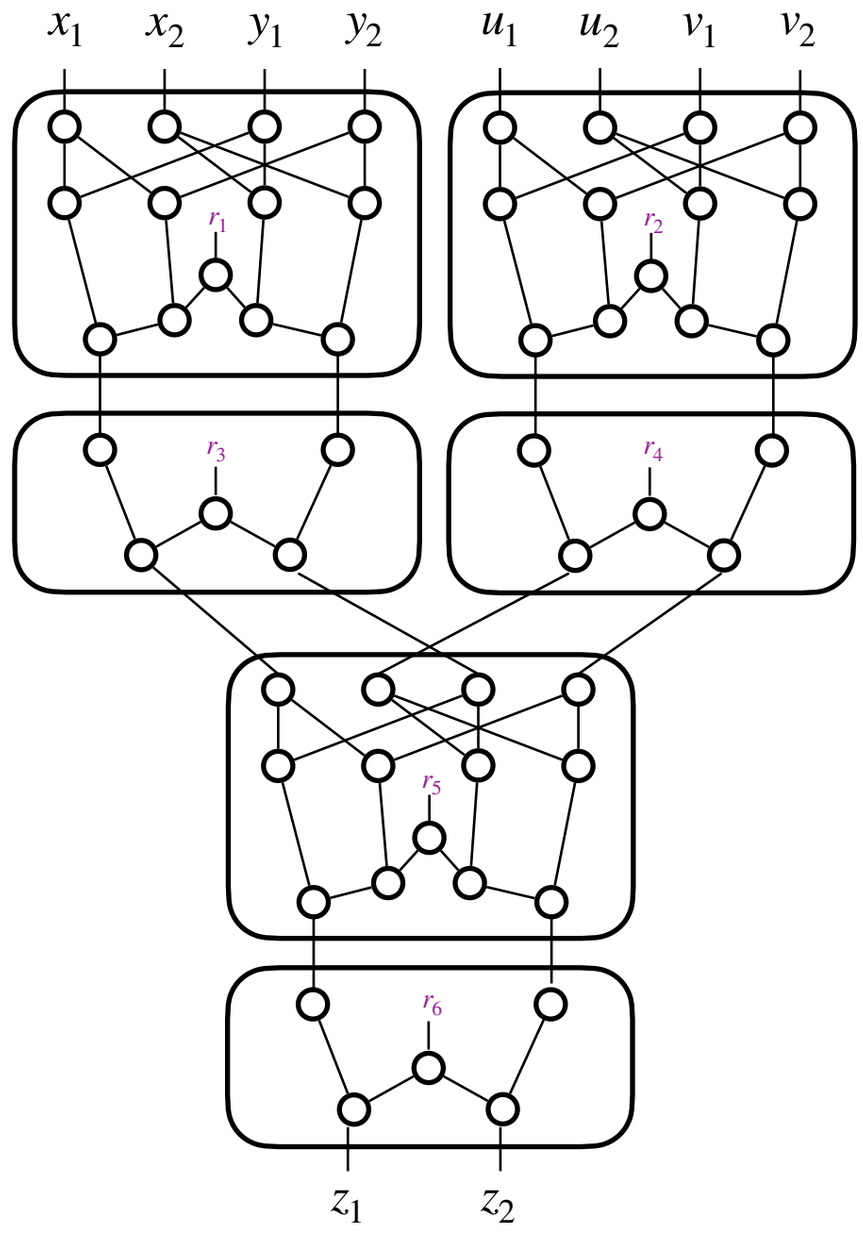

Toolbox:

- Linear gadgets ✓
- Non-linear gadgets ✓
- Refresh gadgets ✓

Composition

Ananth • Ishai • Sahai

CRYPTO 2018

Composition framework with explicit and constant leakage rate

Belaïd • Coron • Prouff • Rivain • Taleb

CRYPTO 2020

Threshold RPC

Cassiers • Faust • Orlt • Standaert

CRYPTO 2021

General RPC (Probe Distribution Tables)

Belaïd • Rivain • Rossi

EUROCRYPT 2025

Cardinal RPC

Belaïd • Normand • Rivain

ASIACRYPT 2025

Uniformly CRPC

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Berti • Faust • Orlt

TCHES 2023

Leakage diagrams

BFO23

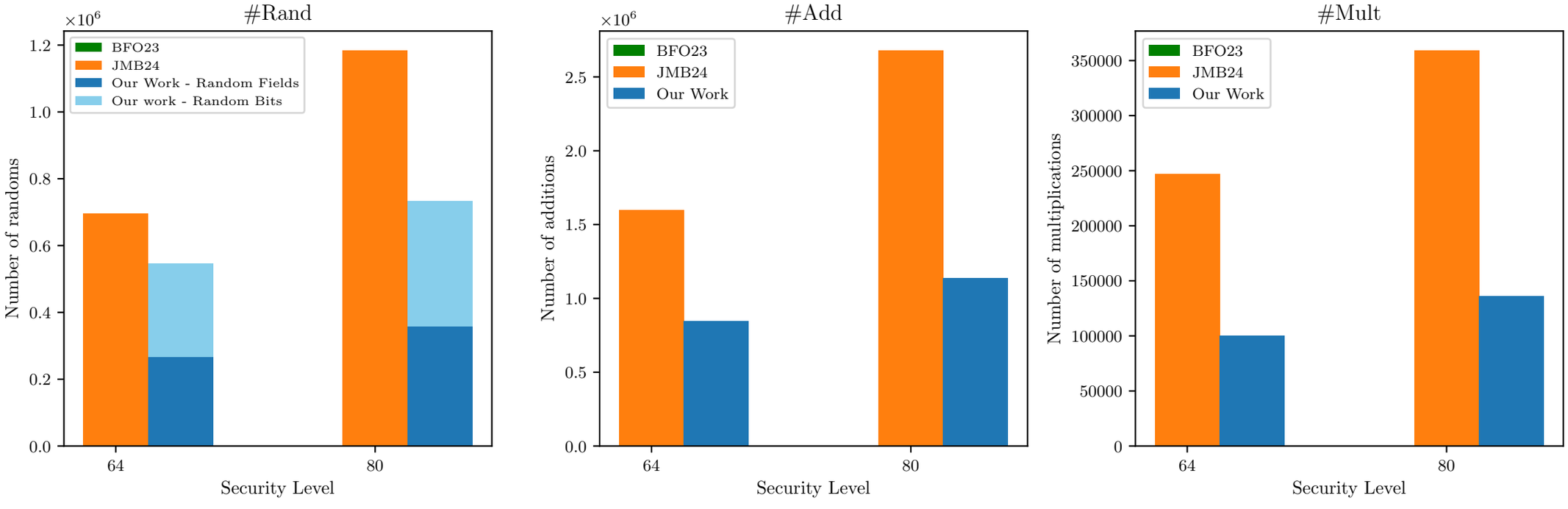
Jahandideh • Mennink • Batina

TCHES 2024

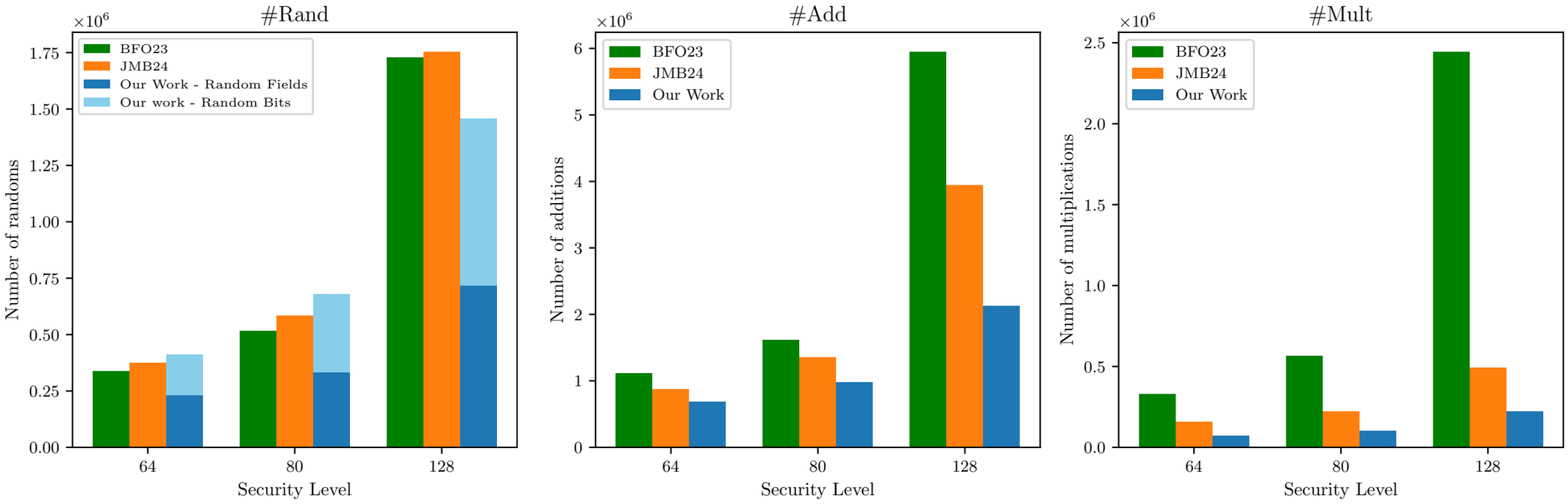
Mutual information

JMB24

Application on AES

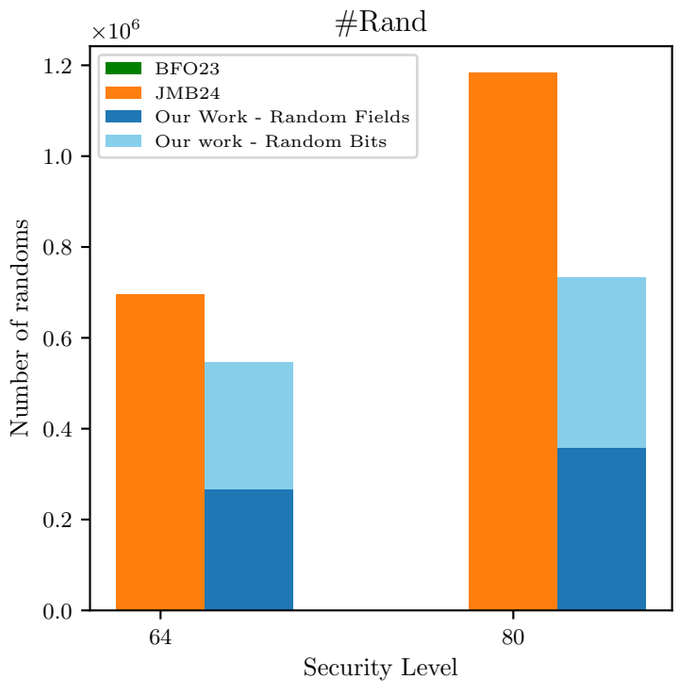


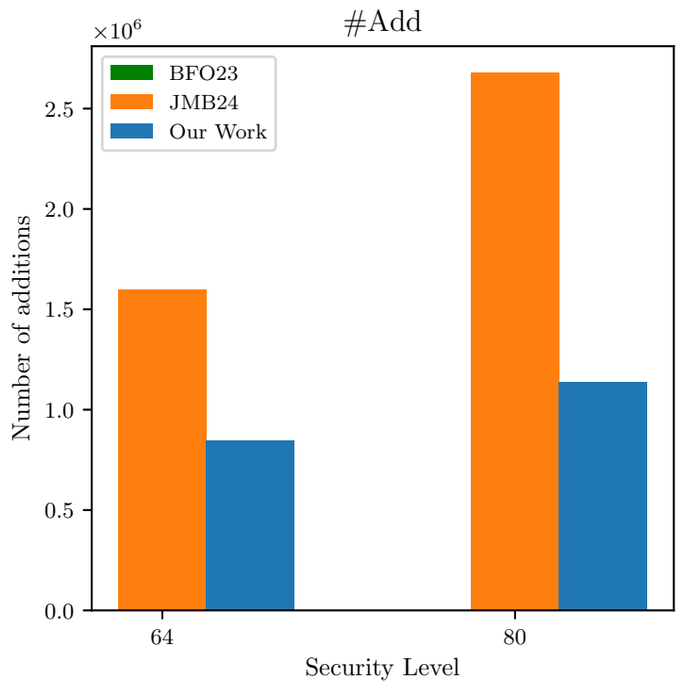
$p = 2^{-16}$

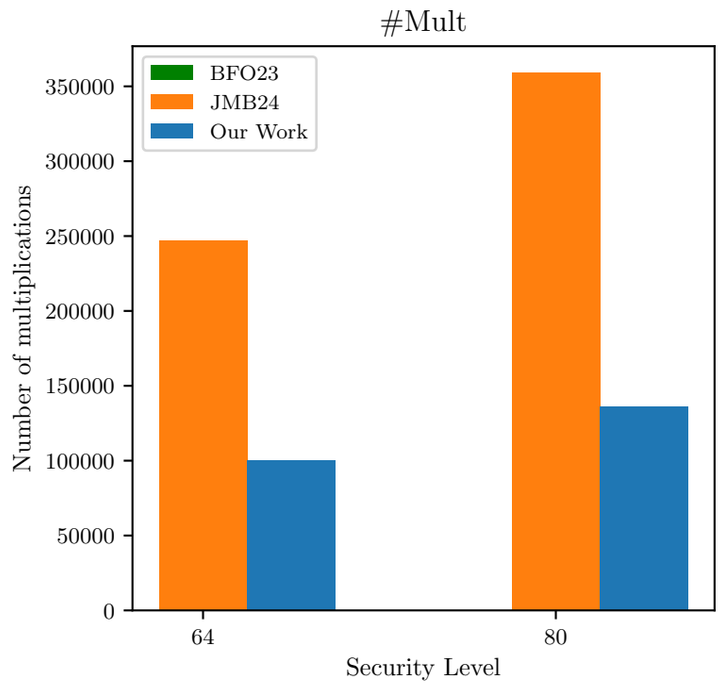


$p = 2^{-20}$

Application on AES







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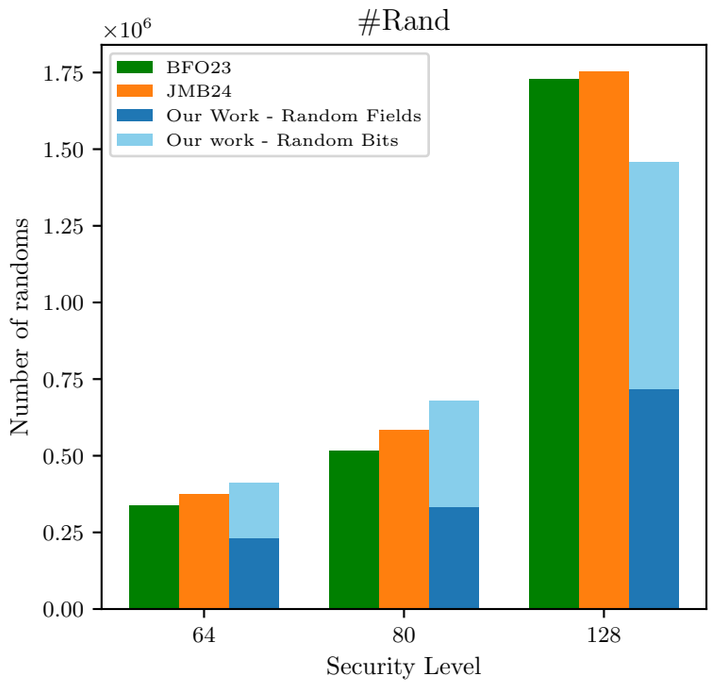

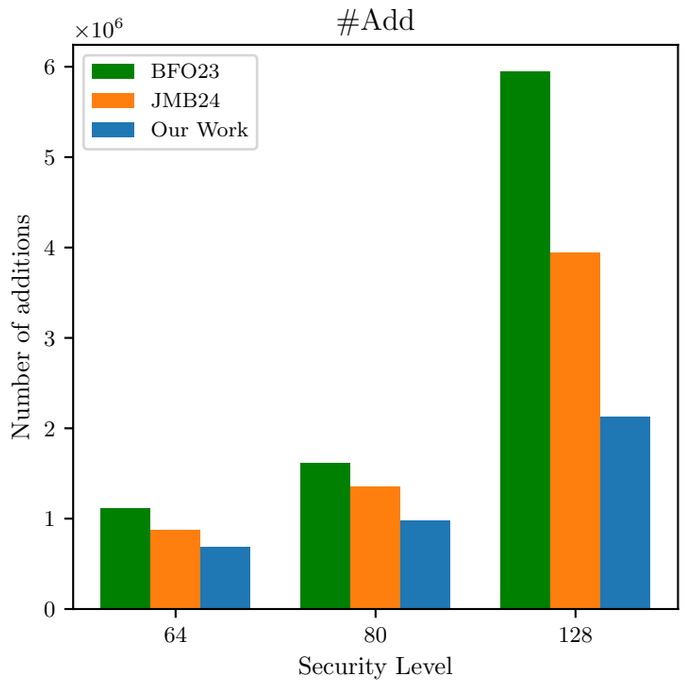

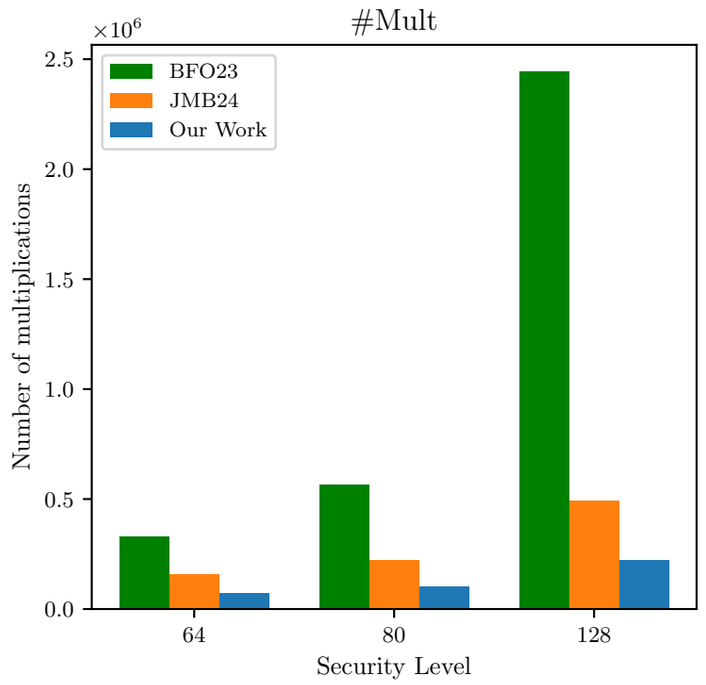

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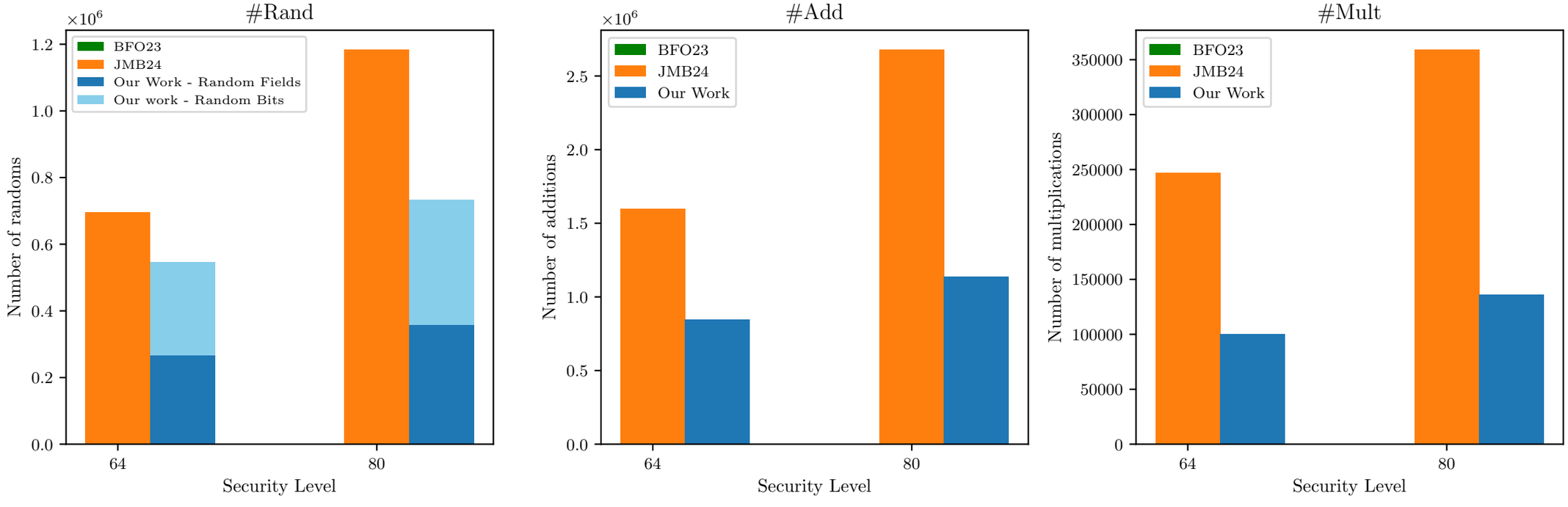
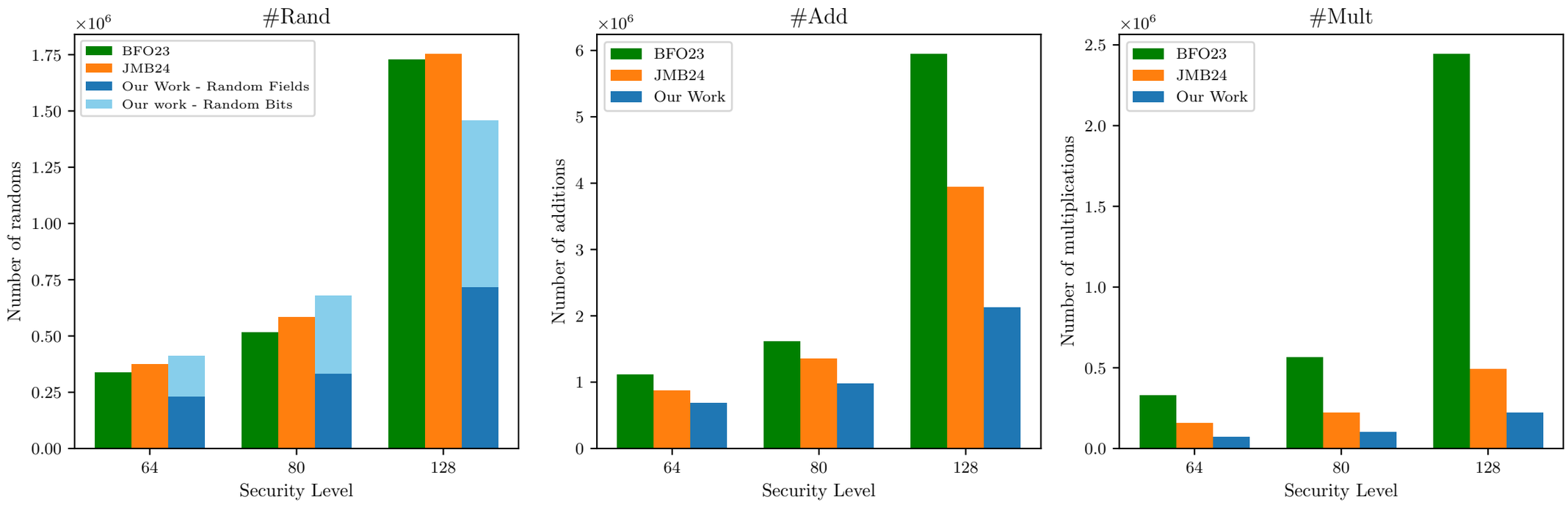
Application on AES



$p = 2^{-16}$



$p = 2^{-20}$

Conclusion

🔬 **Foundations**

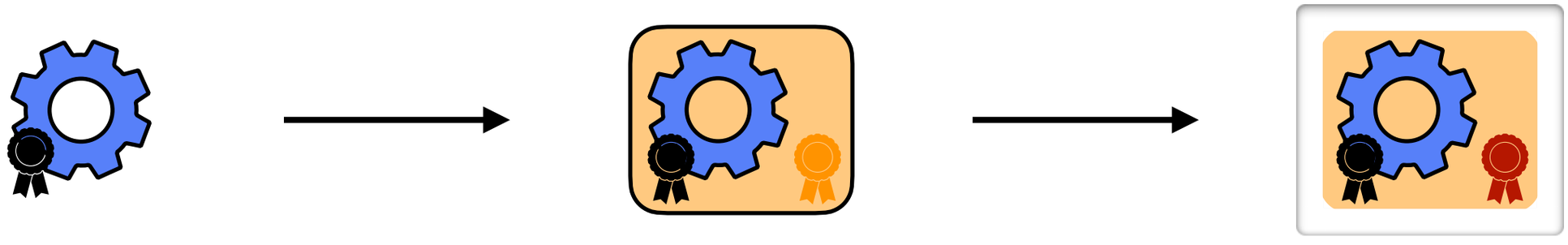
Random probing security & verification (small circuits)

🏗️ **Scaling up**

Composition frameworks (larger circuits)

🧩 **Building blocks**

Design of efficient gadgets



Black-box secure

Black-box and random probing secure

Black-box and physically secure

Conclusion

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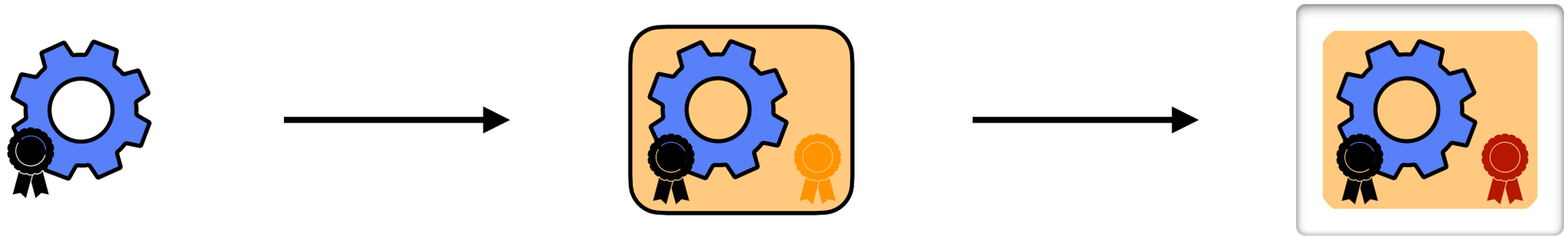

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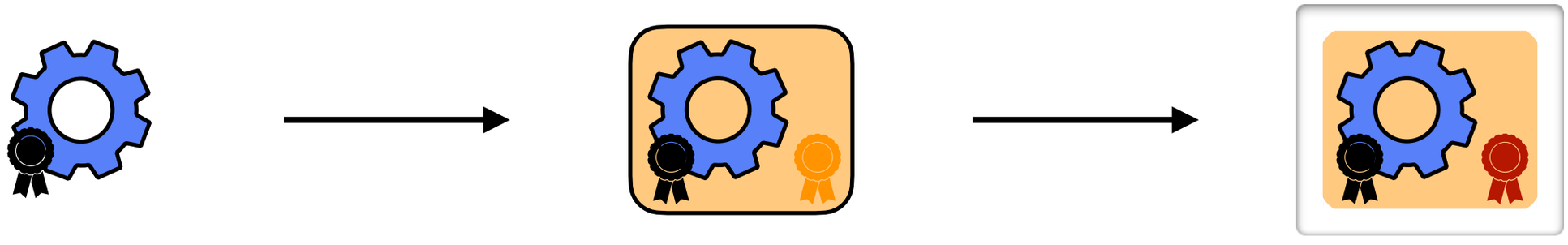

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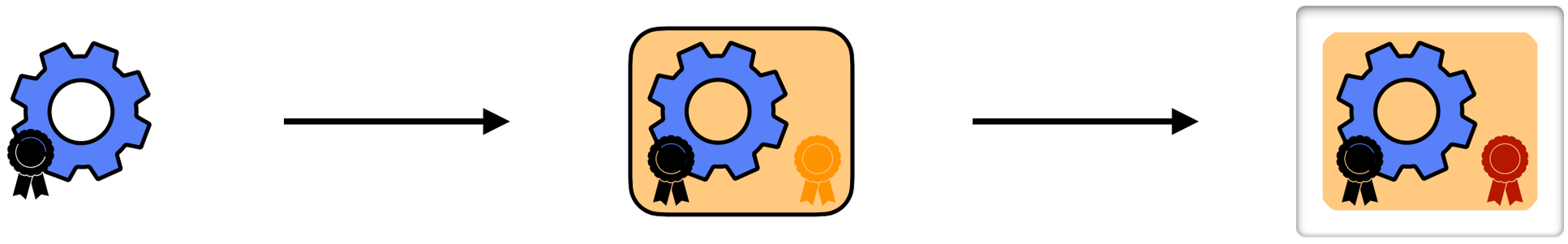

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Perspectives

🧩 **Design of more efficient gadgets**

Better trade-off complexity/security

⛑ **Design of masking friendly schemes**

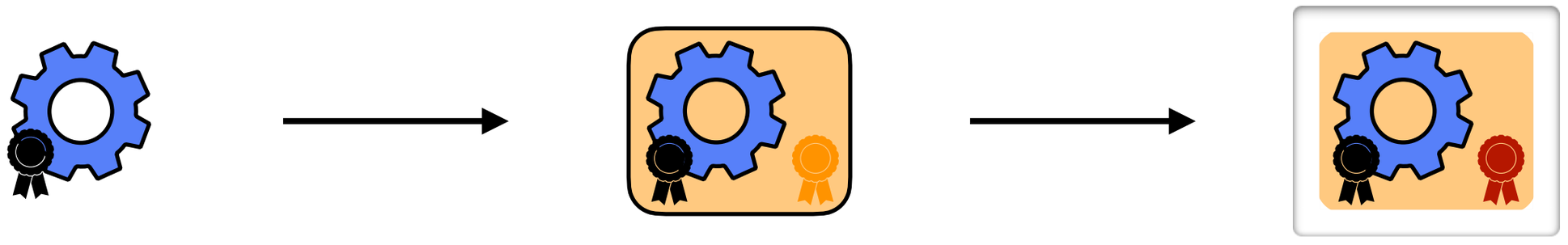
Better trade-off complexity/security

⊗ **Evaluation in the gate model**

Tighter reduction from physical security

🛠 **Development of advanced security tools**

Verification of customized implementations



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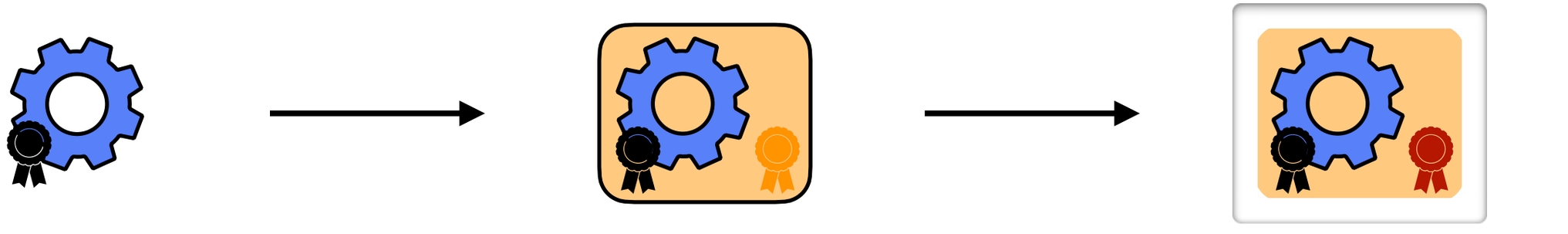

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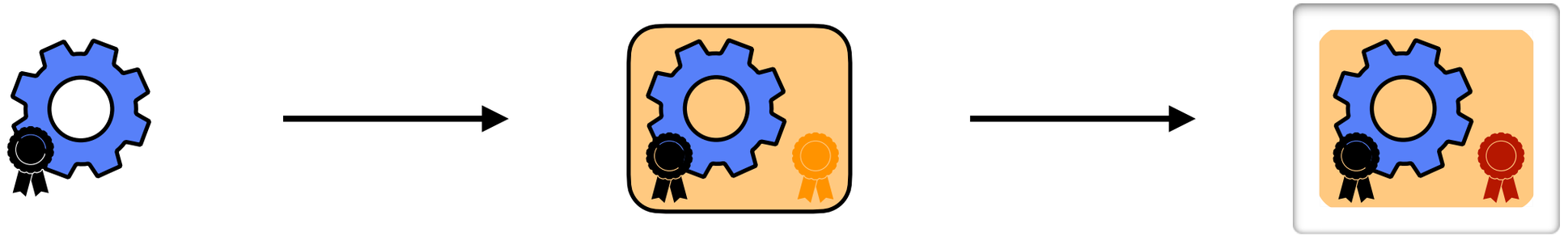

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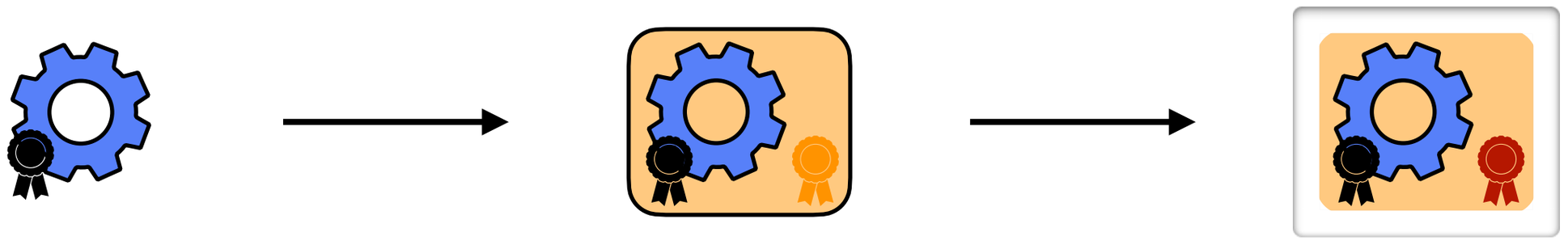
Verification of customized implementations

Questions?



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Black-box and
random probing
secure

Black-box and
physically secure