Round-Optimal Black-Box Protocol Compilers

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Eurocrypt 2022

Secure Multiparty Computation

[Yao 86, Goldreich-Micali-Wigderson 87]

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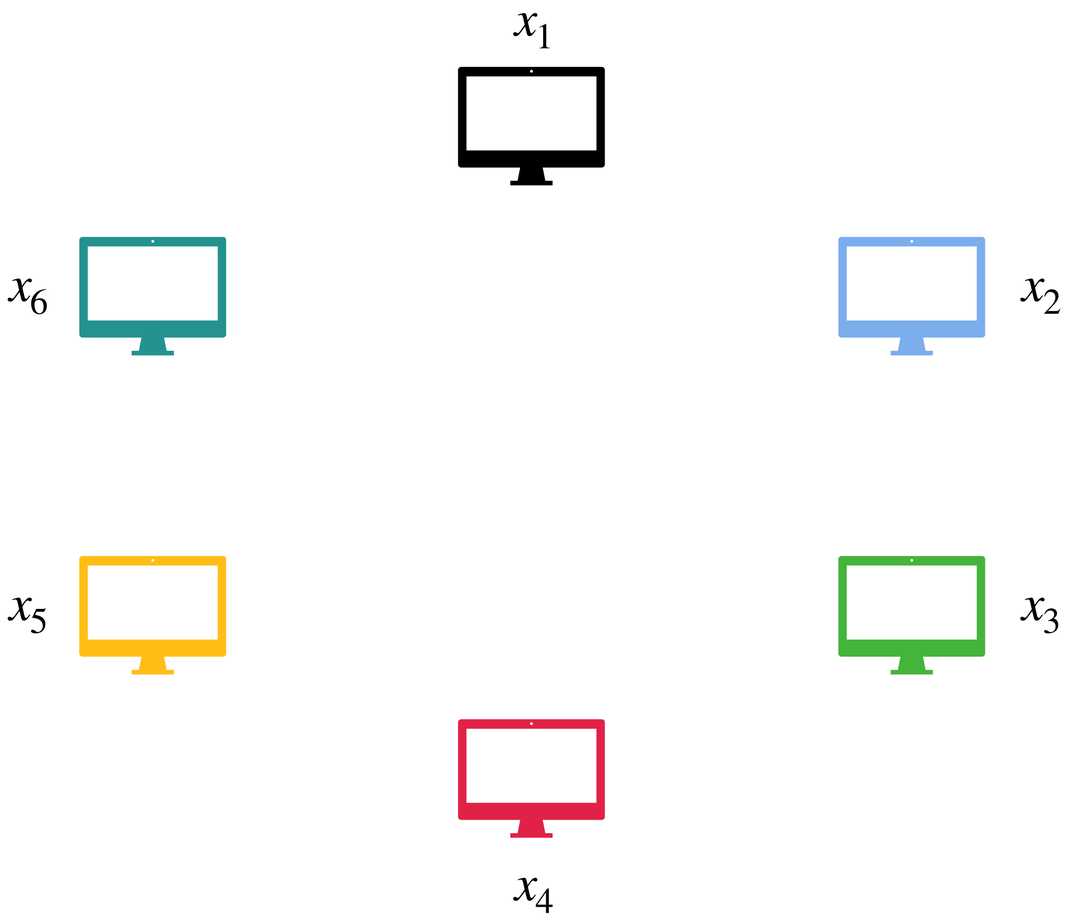

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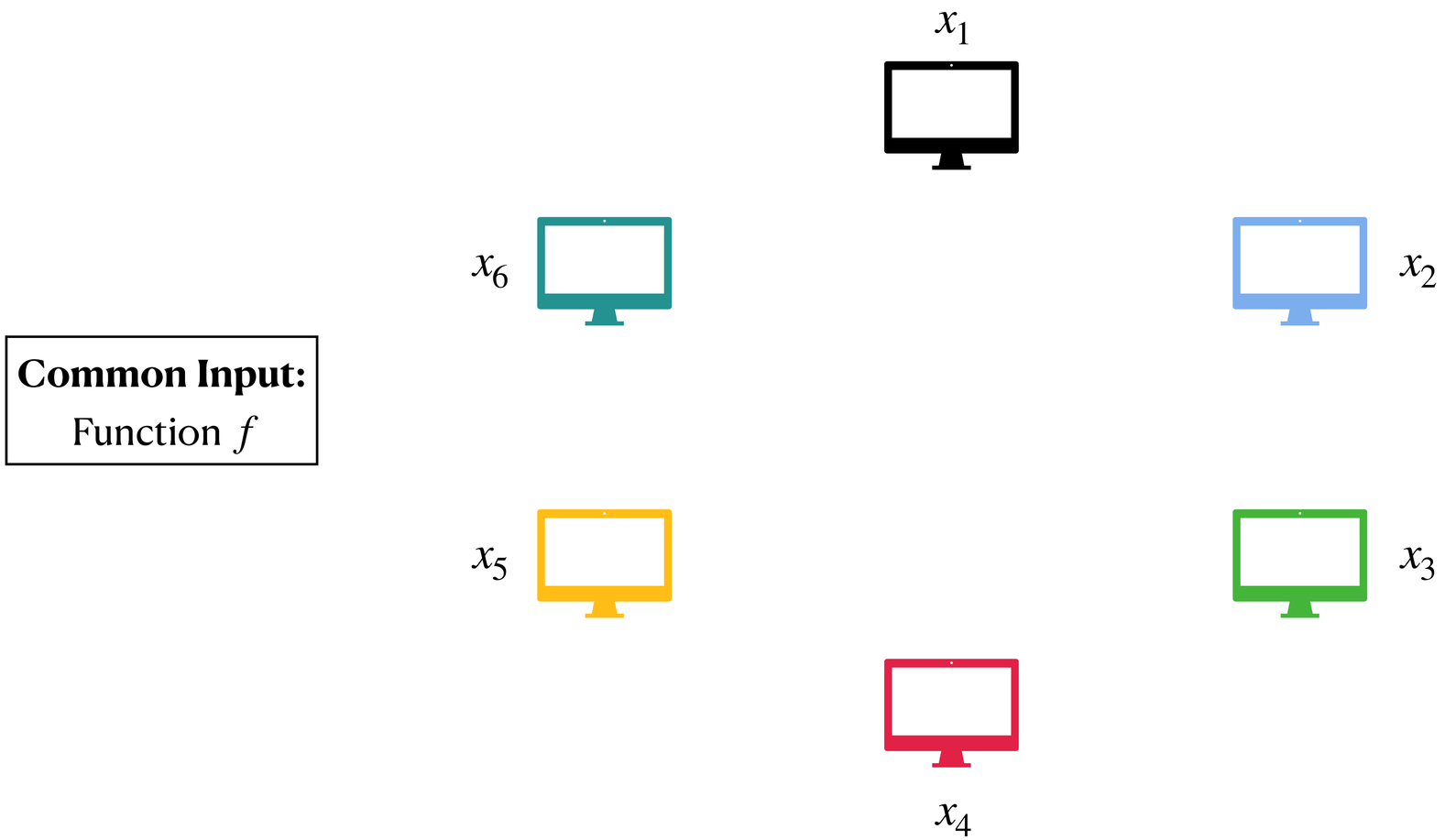

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Function f

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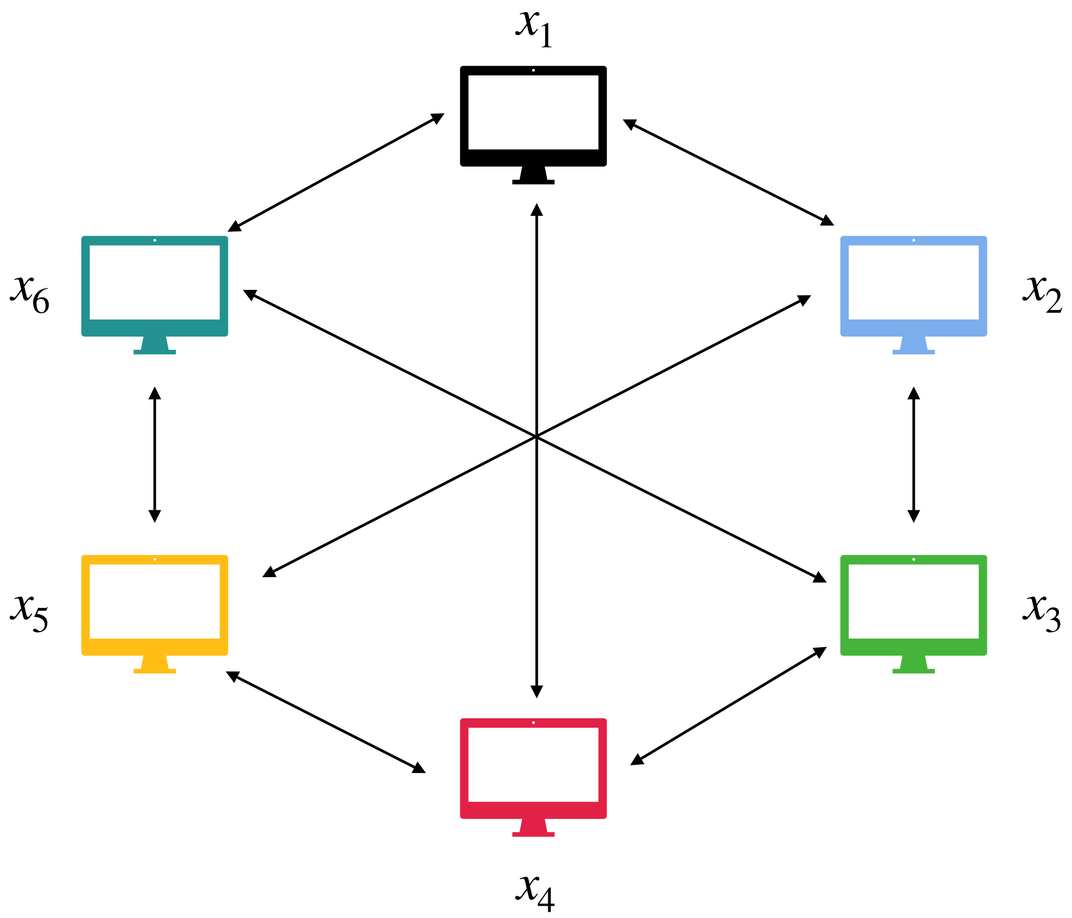

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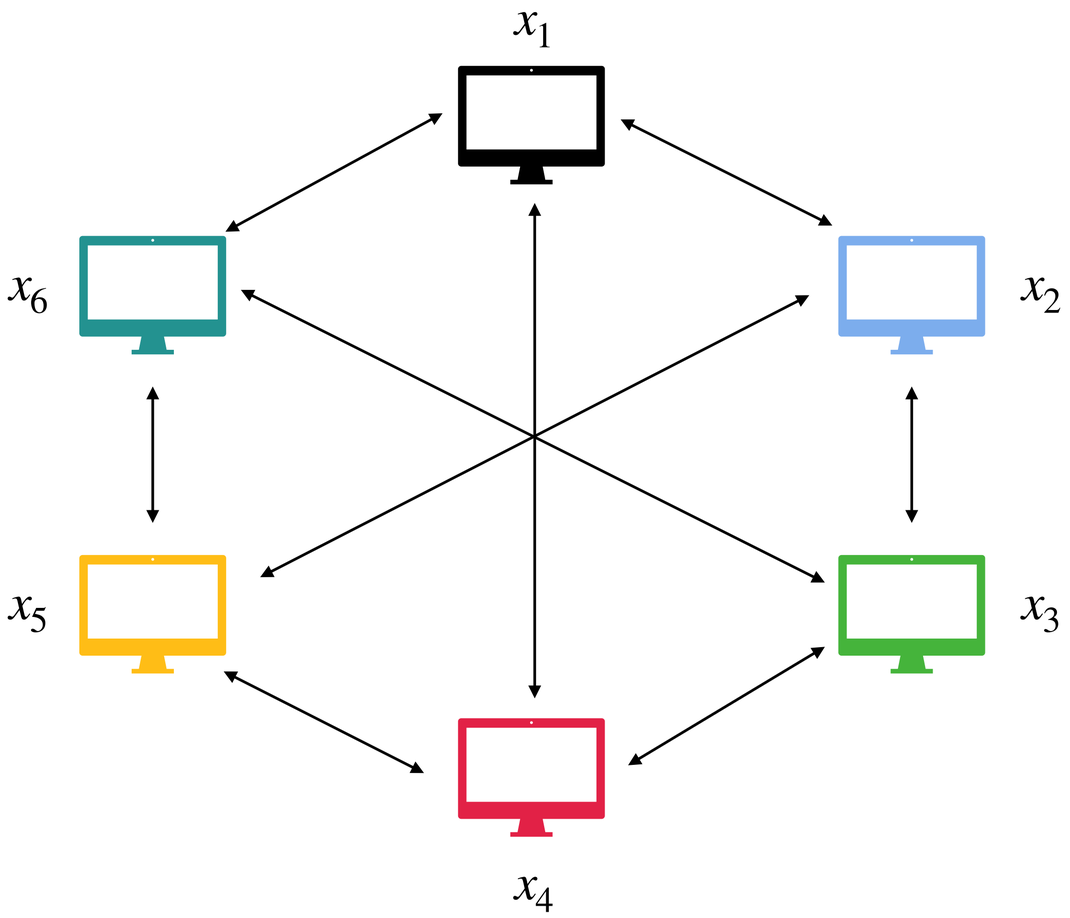

Correctness

Secure Multiparty Computation

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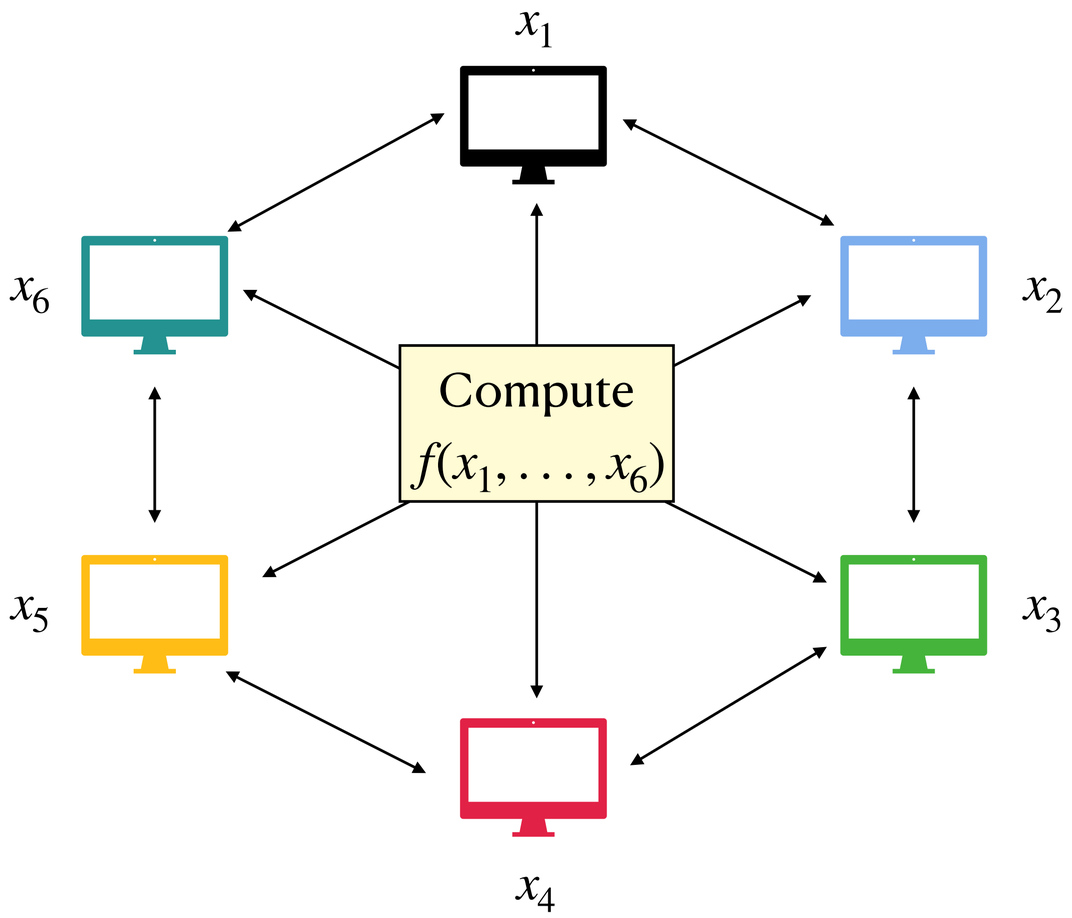

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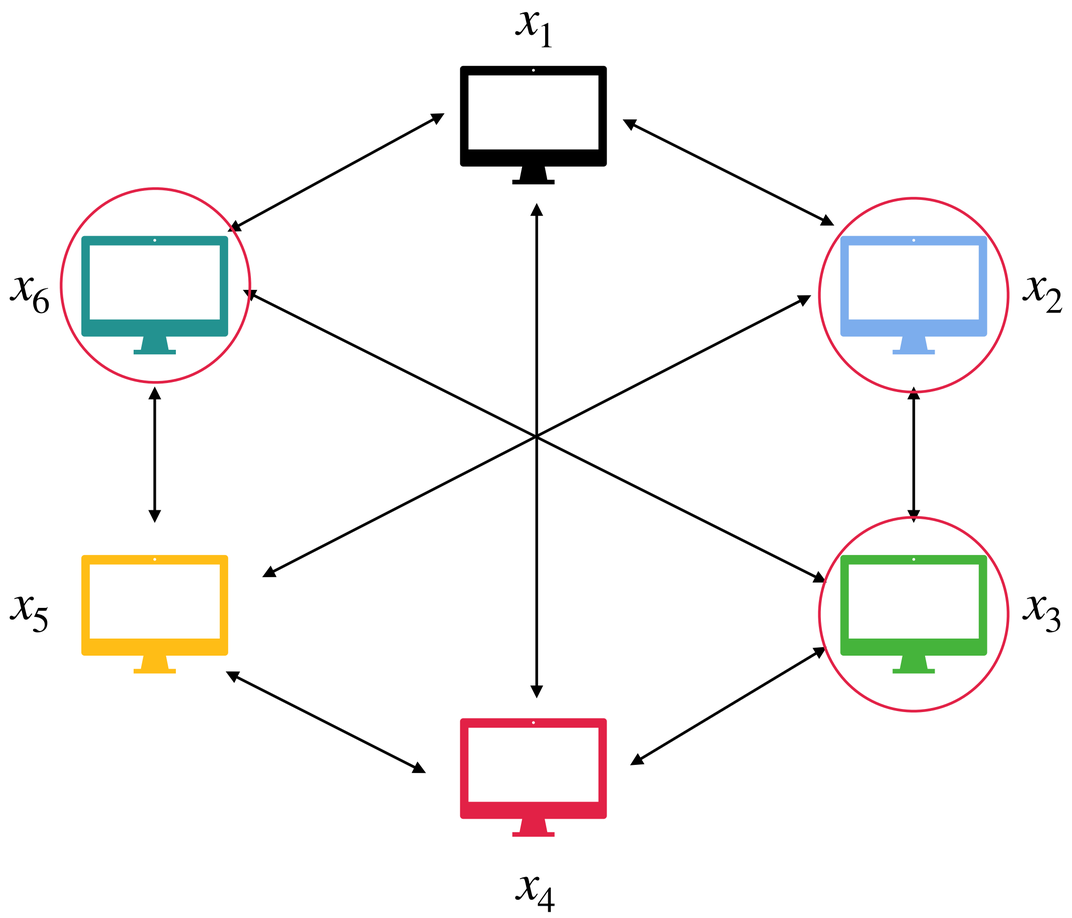

Security

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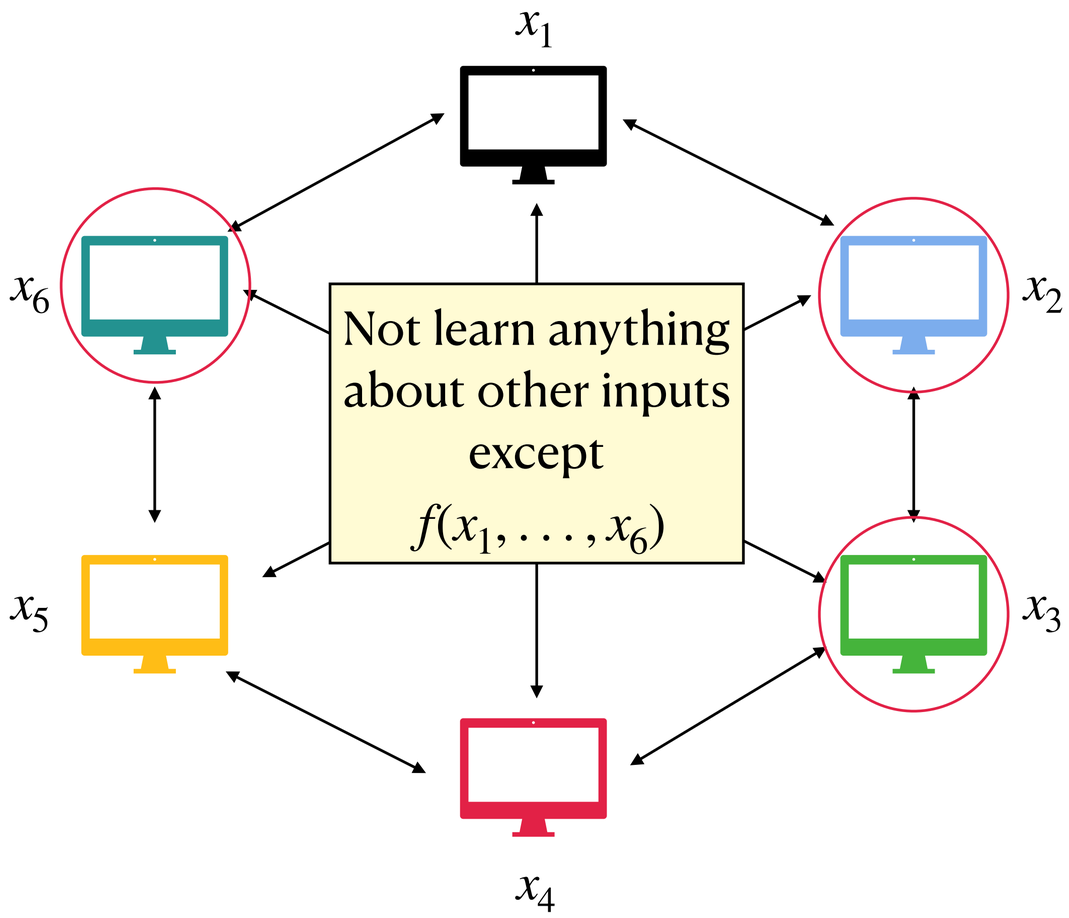

Security

Types of Adversary

Types of Adversary

Semi-Honest Adversary

Types of Adversary

- Follow the protocol specification but try to learn additional information.

Semi-Honest Adversary

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- Easier to protect against.

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Malicious Adversary

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- Could deviate from the protocol specification and break security.

Malicious Adversary

Types of Adversary

- Follow the protocol specification but try to learn additional information.
- Easier to protect against.

Semi-Honest Adversary

- Could deviate from the protocol specification and break security.
- Harder to protect against.

Malicious Adversary

Protocol Compilers

Protocol Compilers

Protocol for computing f' with security against Semi-Honest Adversary

Protocol Compiler

Protocol for computing f with security against Malicious adversary

Protocol Compilers

For every f, $\exists f'$.

Protocol Compiler

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Protocol for computing f' with security against Semi-Honest Adversary

Protocol Compiler

Protocol for computing f with security against Malicious adversary

Goal: Construct "**efficient**" Protocol Compilers.

How to measure efficiency?

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- **Preserve round complexity**

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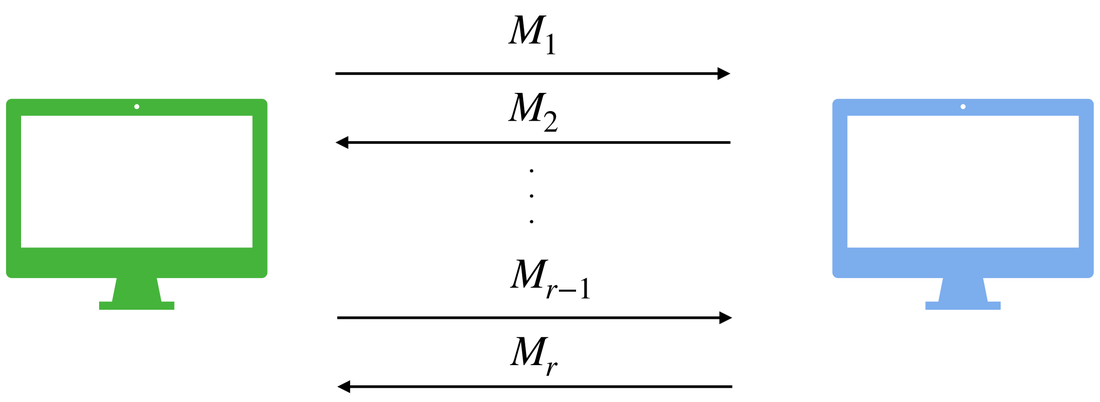
  - The compiled protocol has the same number of rounds as the initial protocol.
- **Black-Box use**
  - The compiled protocol makes black-box use of the initial protocol.
- **Making use of simple tools**
  - The compiler avoids sophisticated and less efficient cryptographic tools.

Prior Approaches

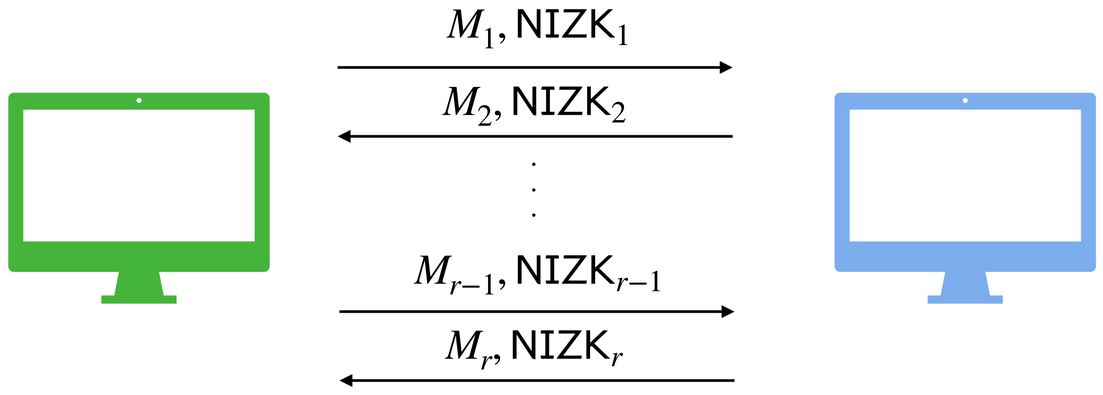
GMW Compiler

Prior Approaches

GMW Compiler



Semi-Honest Secure Protocol



Malicious Secure Protocol

Prior Approaches

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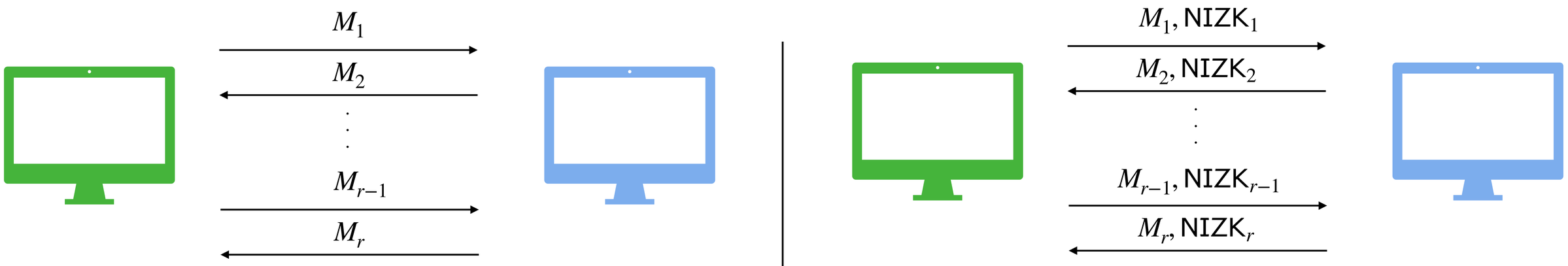

Semi-Honest Secure Protocol

Malicious Secure Protocol

Non-Black-Box use

Prior Approaches

IPS Compiler

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Prior Approaches

IPS Compiler

- A black-box protocol compiler.
- Resulted in an increase in round-complexity.
- Required stronger cryptographic tools such as malicious secure oblivious transfer.
- Required the semi-honest secure protocol to satisfy stronger security property, namely, adaptive security with erasures.

Our Results

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- A protocol compiler that is:

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  - Round-Optimal, i.e., transforms round-optimal semi-honest secure protocol to round-optimal malicious secure protocol.

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- A protocol compiler that is:
  - Round-Optimal, i.e., transforms round-optimal semi-honest secure protocol to round-optimal malicious secure protocol.
  - Black-Box.
  - Makes use of simple cryptographic tools/setup: ROM/1-out-2 OT correlations.

Applications

2PC

Applications

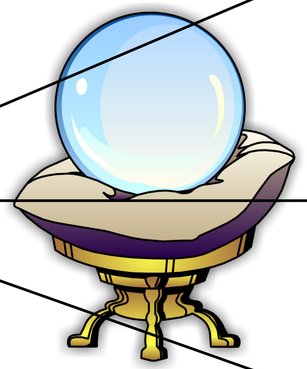
2PC

Two-round
Semi-Honest
2PC

Applications

2PC

Two-round Semi-Honest 2PC



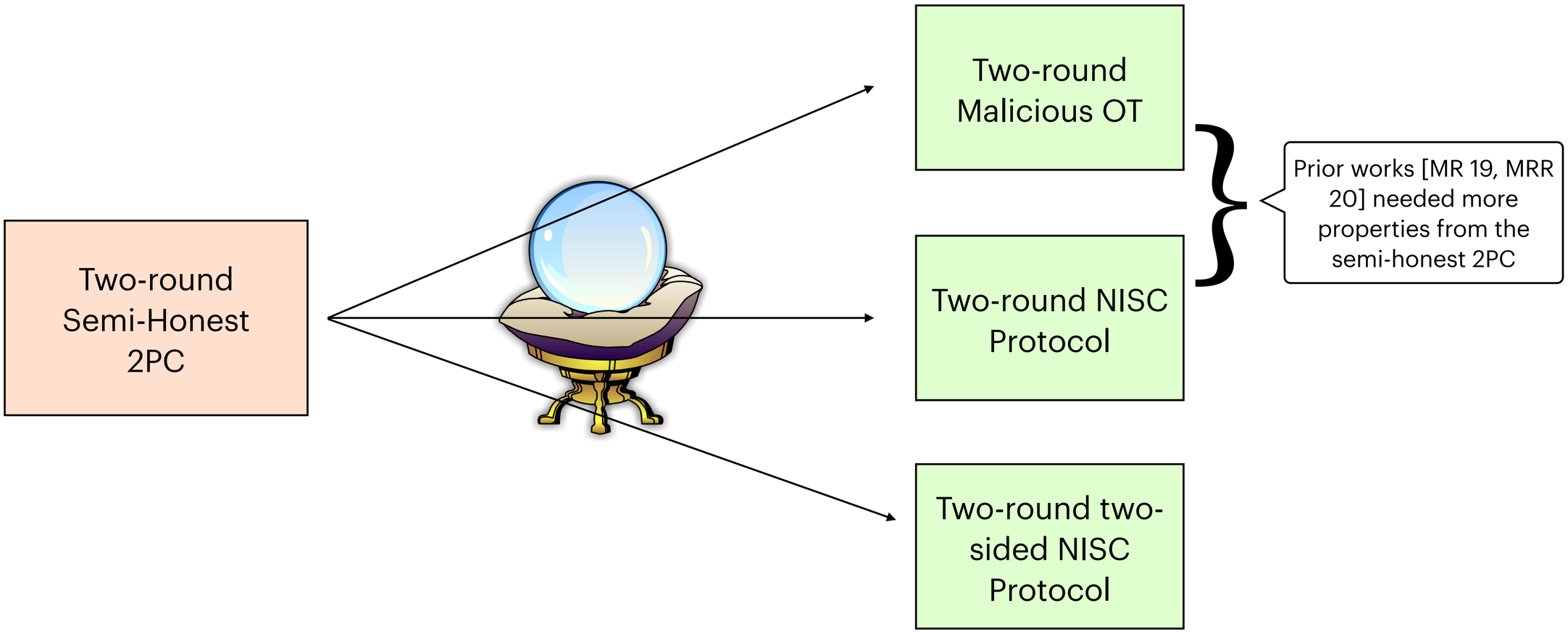
Two-round Malicious OT

Two-round NISC Protocol

Two-round two-sided NISC Protocol

Applications

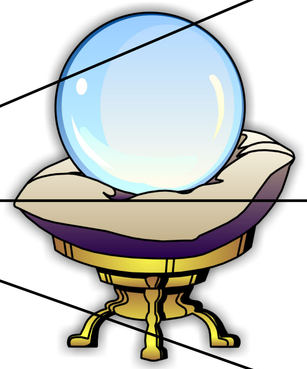
2PC



Applications

2PC

Two-round Semi-Honest 2PC



Two-round Malicious OT

Two-round NISC Protocol

Two-round two-sided NISC Protocol

Prior works [MR 19, MRR 20] needed more properties from the semi-honest 2PC

ROM can be replaced with fixed poly sized OT correlations if we start with semi-malicious 2PC

Applications

MPC

Applications

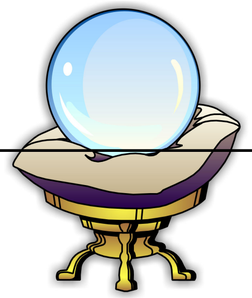
MPC

Two-round
Semi-Honest
OT

Applications

MPC

Two-round Semi-Honest OT

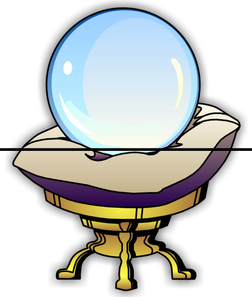


Three-round malicious MPC

Applications

MPC

Two-round Semi-Honest OT



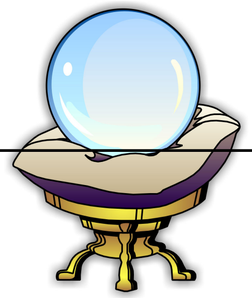
Three-round malicious MPC

Round-Optimality follows from [ABGIS 20]

Applications

MPC

Two-round Semi-Honest OT



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Two-round Semi-Malicious* MPC

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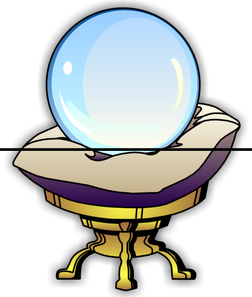

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OT Correlations

Two-round malicious MPC

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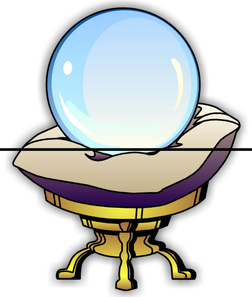


Three-round malicious MPC

Round-Optimality follows from [ABGIS 20]

Two-round Semi-Malicious* MPC

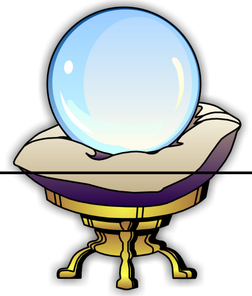
OT Correlations

Two-round malicious MPC

Prior work [IKSS 21] required complex multiparty correlations.

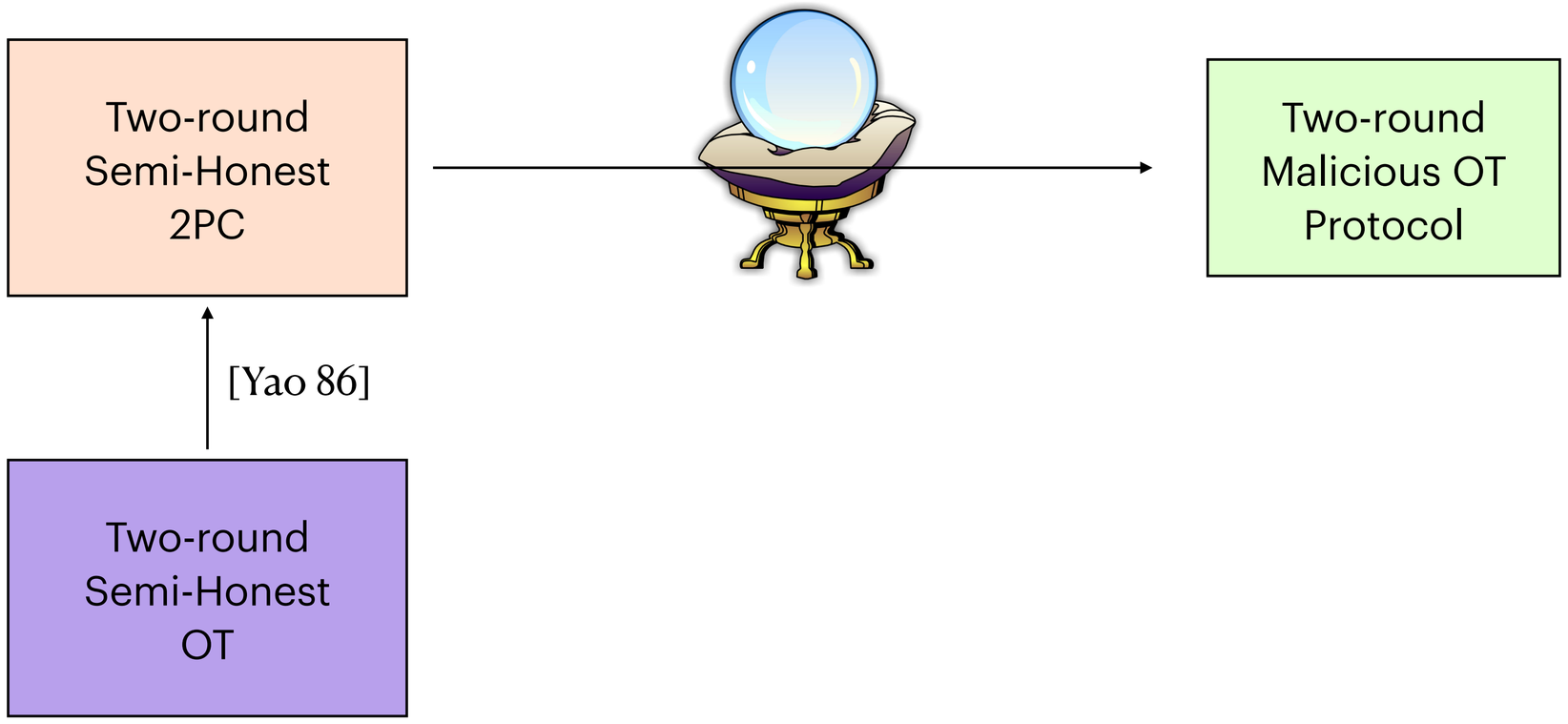
In this talk

Two-round
Semi-Honest
2PC



Two-round
Malicious OT
Protocol

In this talk


Two-round
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[Yao 86]
Two-round
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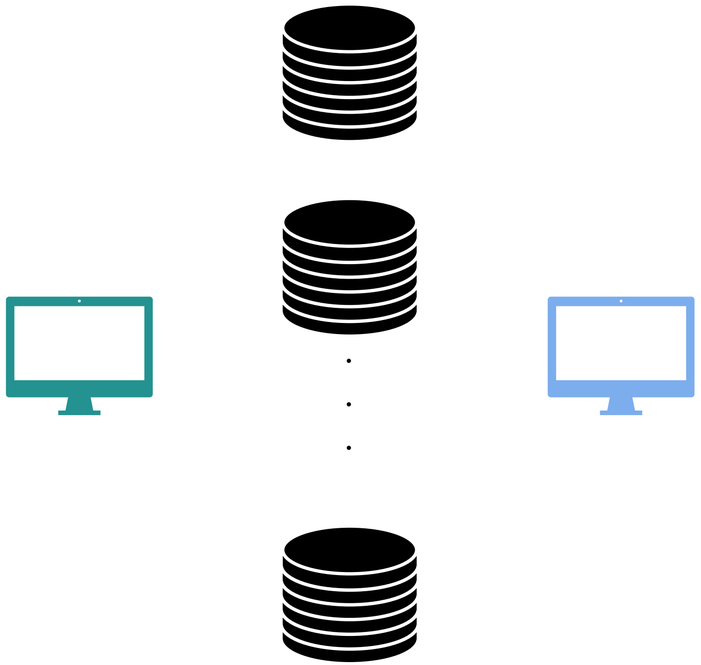

Outer Protocol

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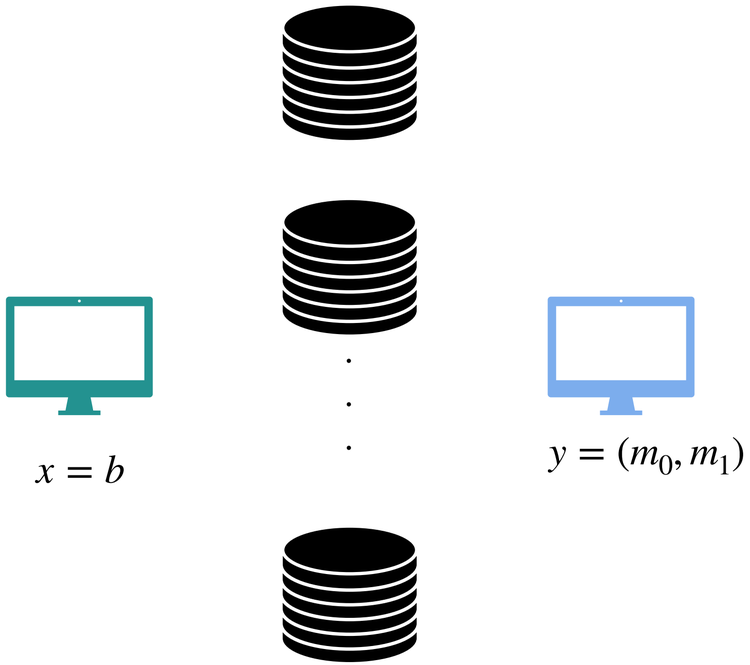

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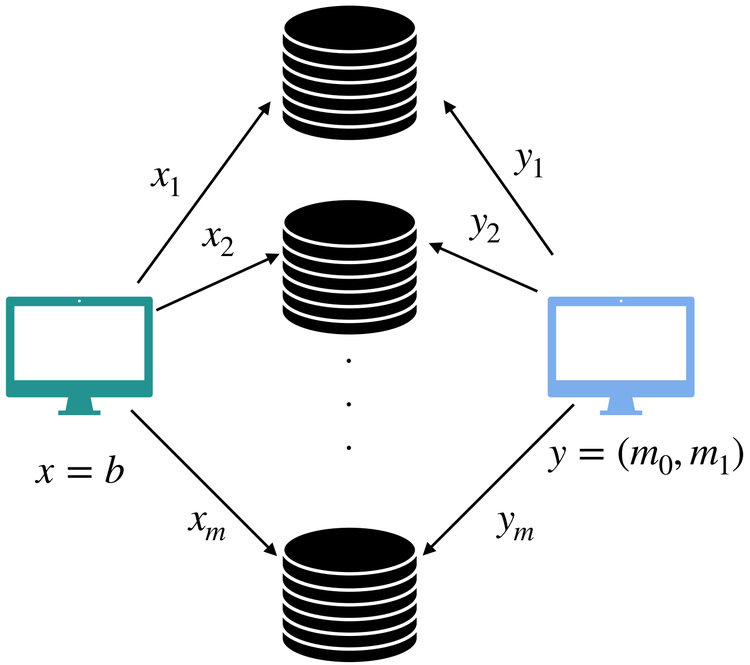

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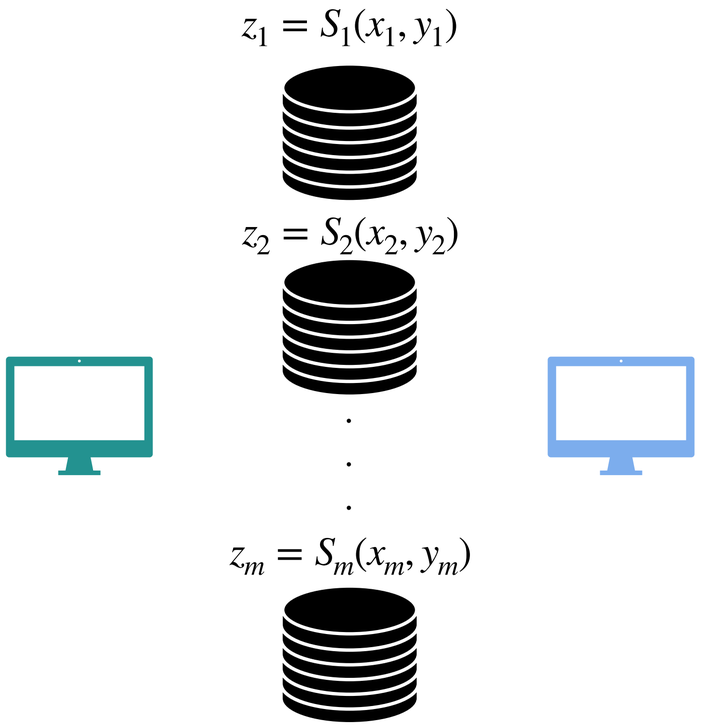

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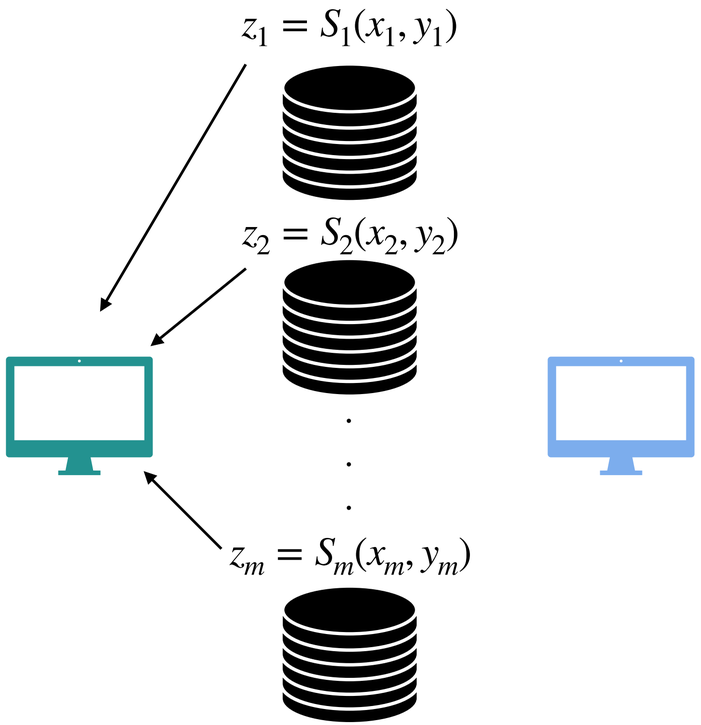

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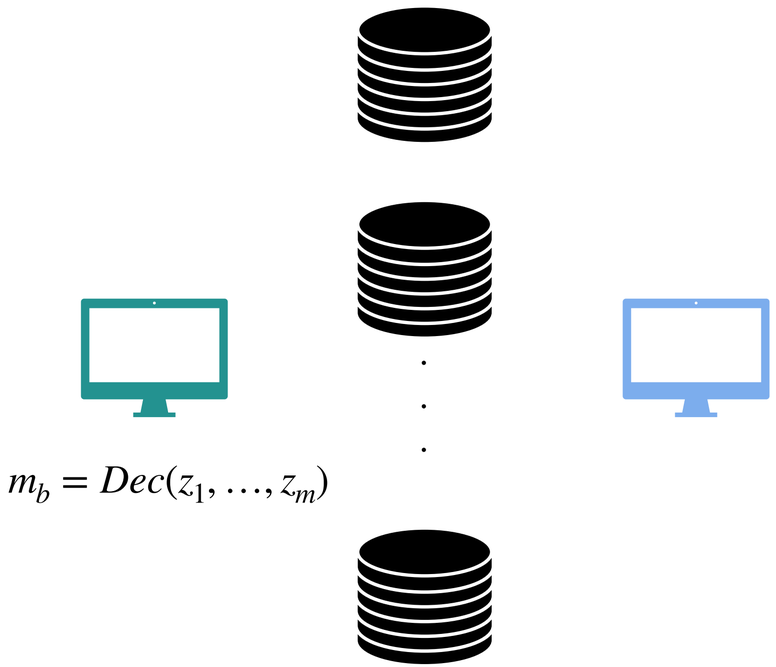

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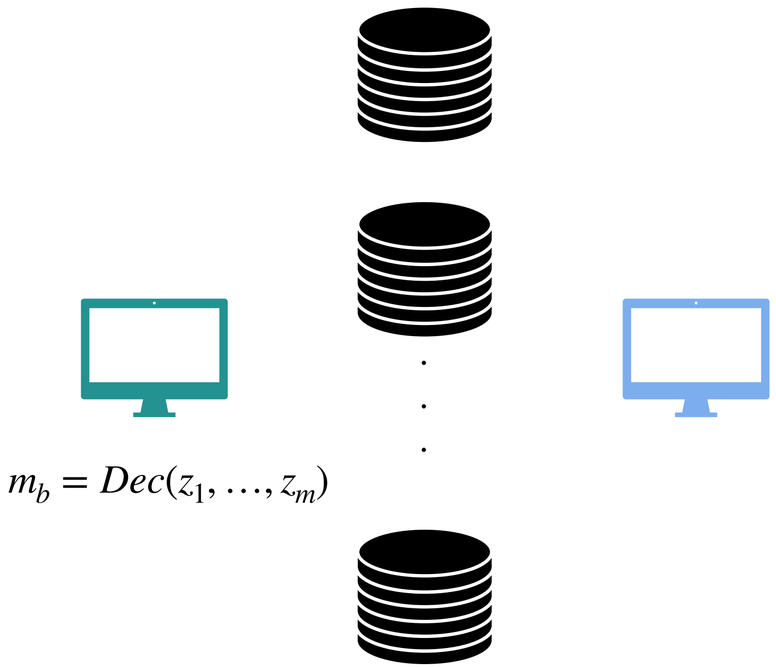

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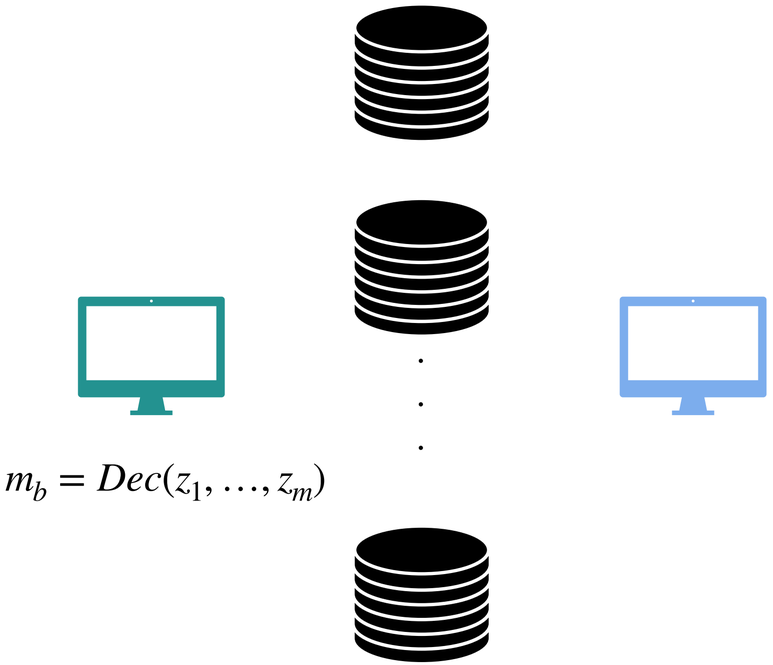

Outer Protocol

Two-round Semi-Honest* 2PC for $S_1(\cdot, \cdot)$

Two-round Semi-Honest* 2PC for $S_2(\cdot, \cdot)$

.
.
.

Two-round Semi-Honest* 2PC for $S_m(\cdot, \cdot)$

Inner Protocol

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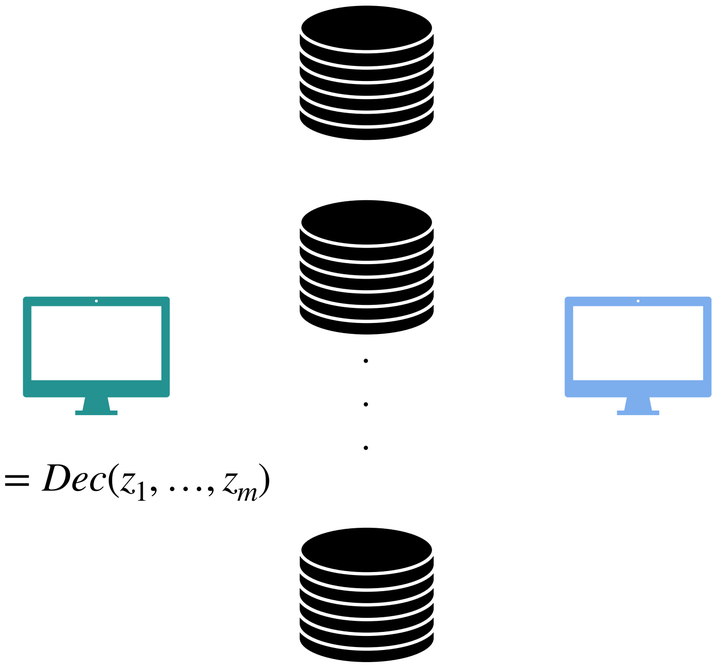

$m_b = Dec(z_1, \ldots, z_m)$

Outer Protocol

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Two-round Semi-Honest* 2PC for $S_m(\cdot, \cdot)$

Inner Protocol

Watchlist Protocol

The IPS Compiled Protocol

The IPS Compiled Protocol

$x = b$

$y = (m_0, m_1)$

The IPS Compiled Protocol

$(x_1, \ldots, x_m)$

$x = b$

$(y_1, \ldots, y_m)$

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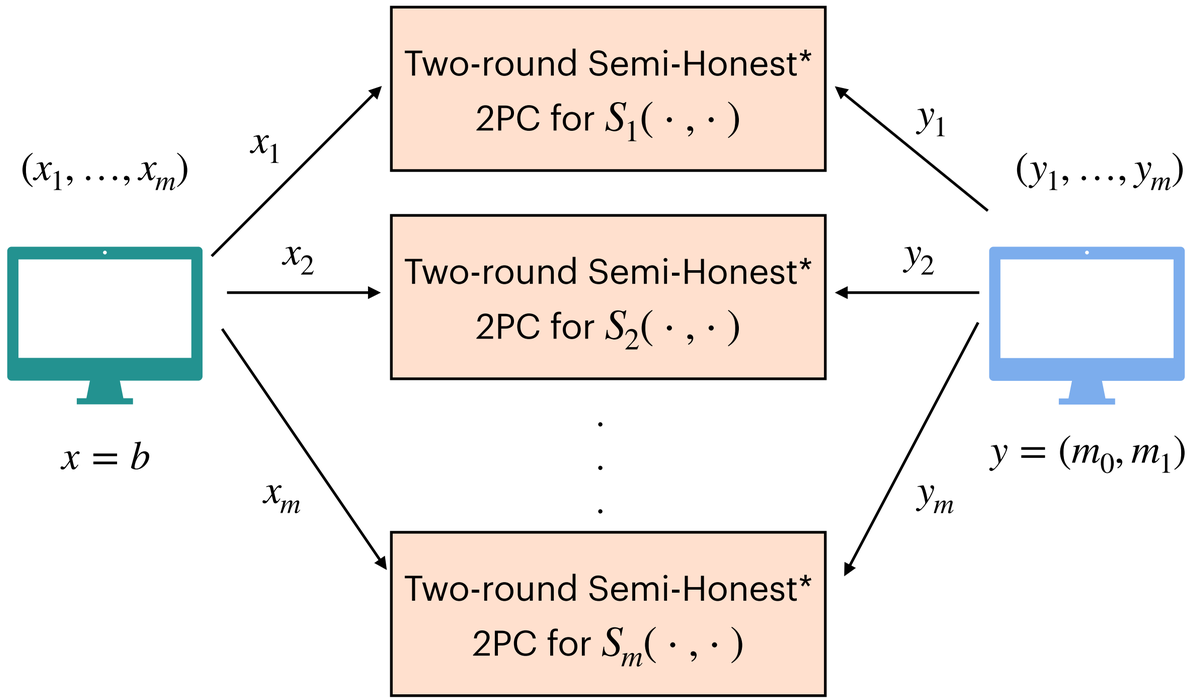
The IPS Compiled Protocol



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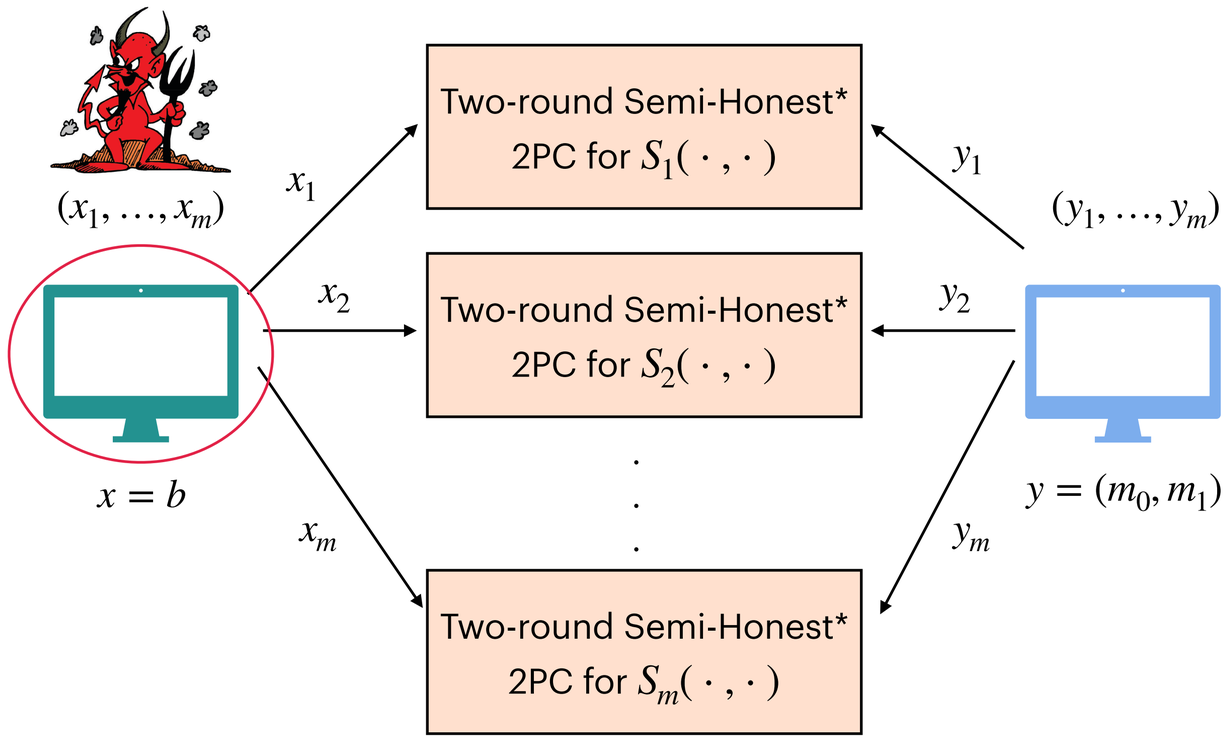

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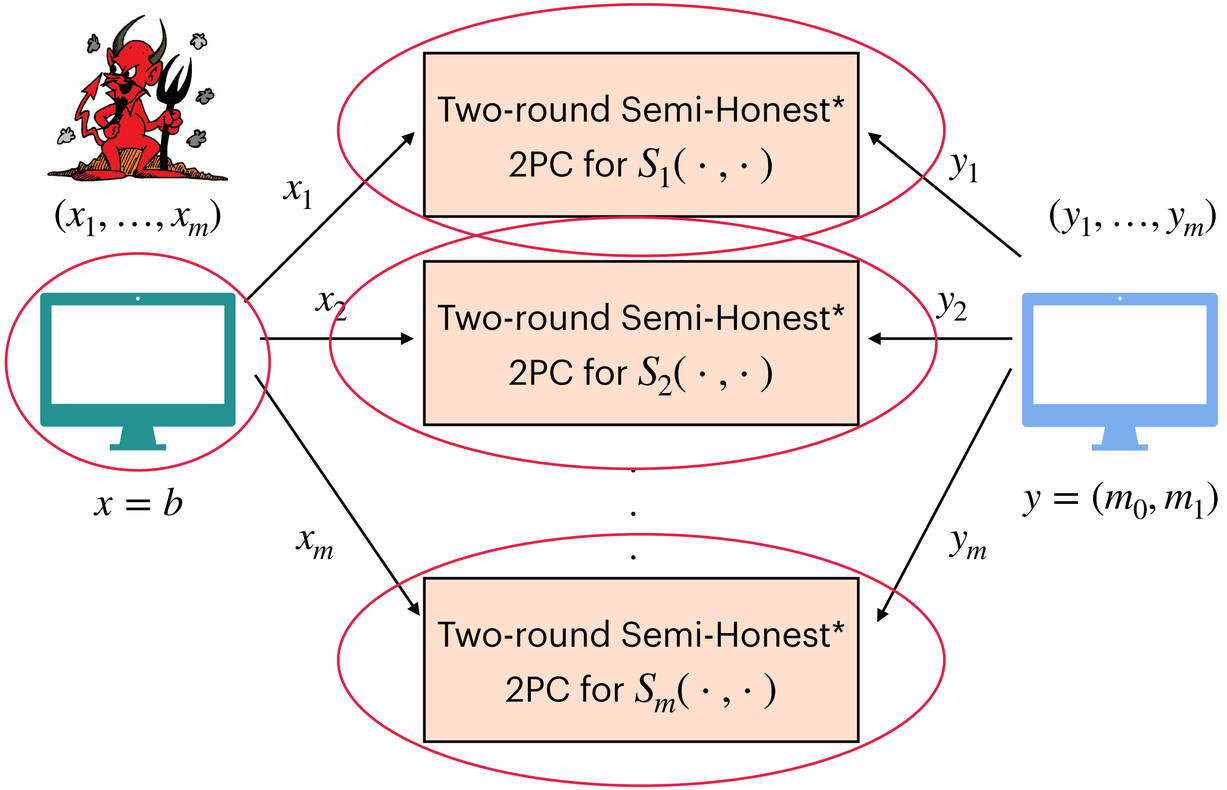

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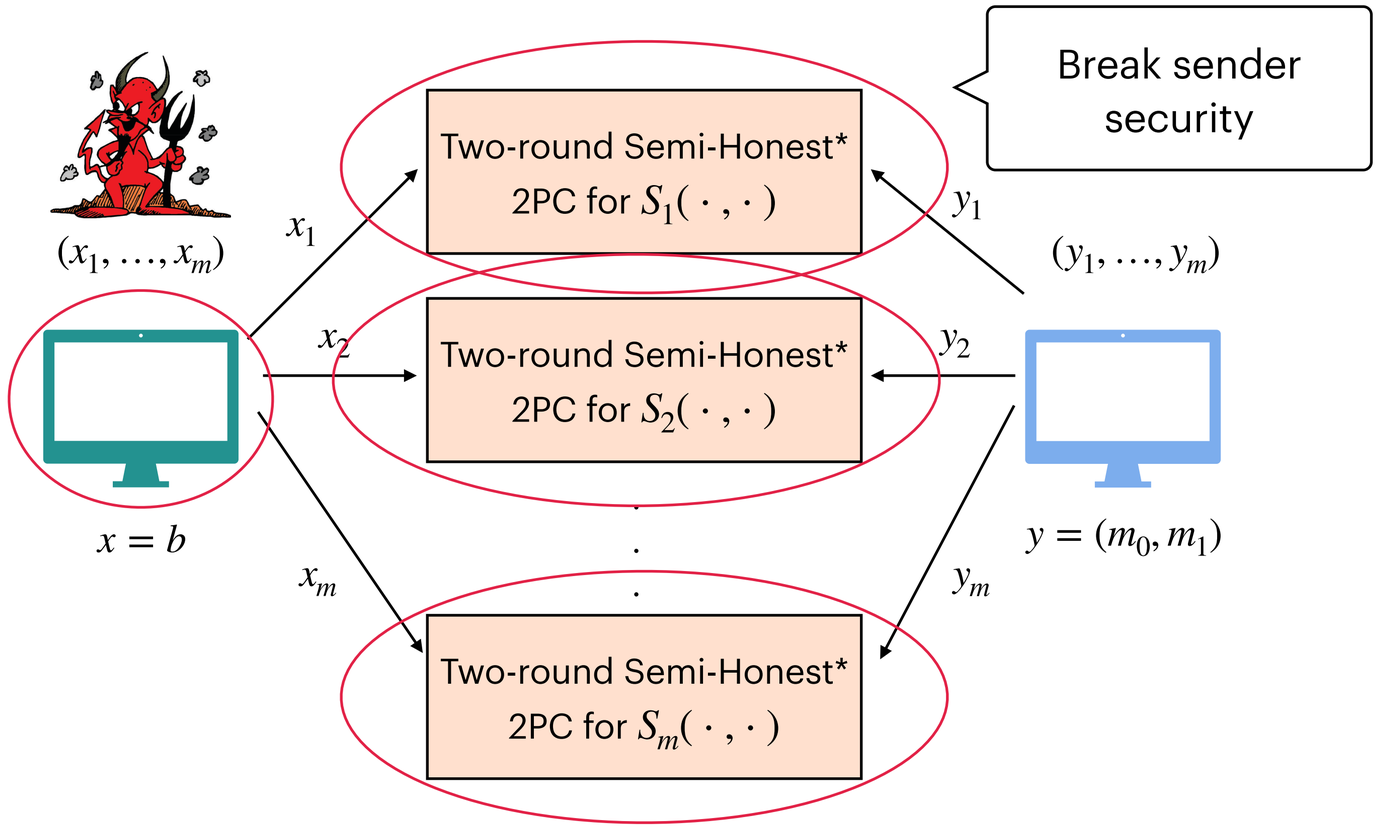

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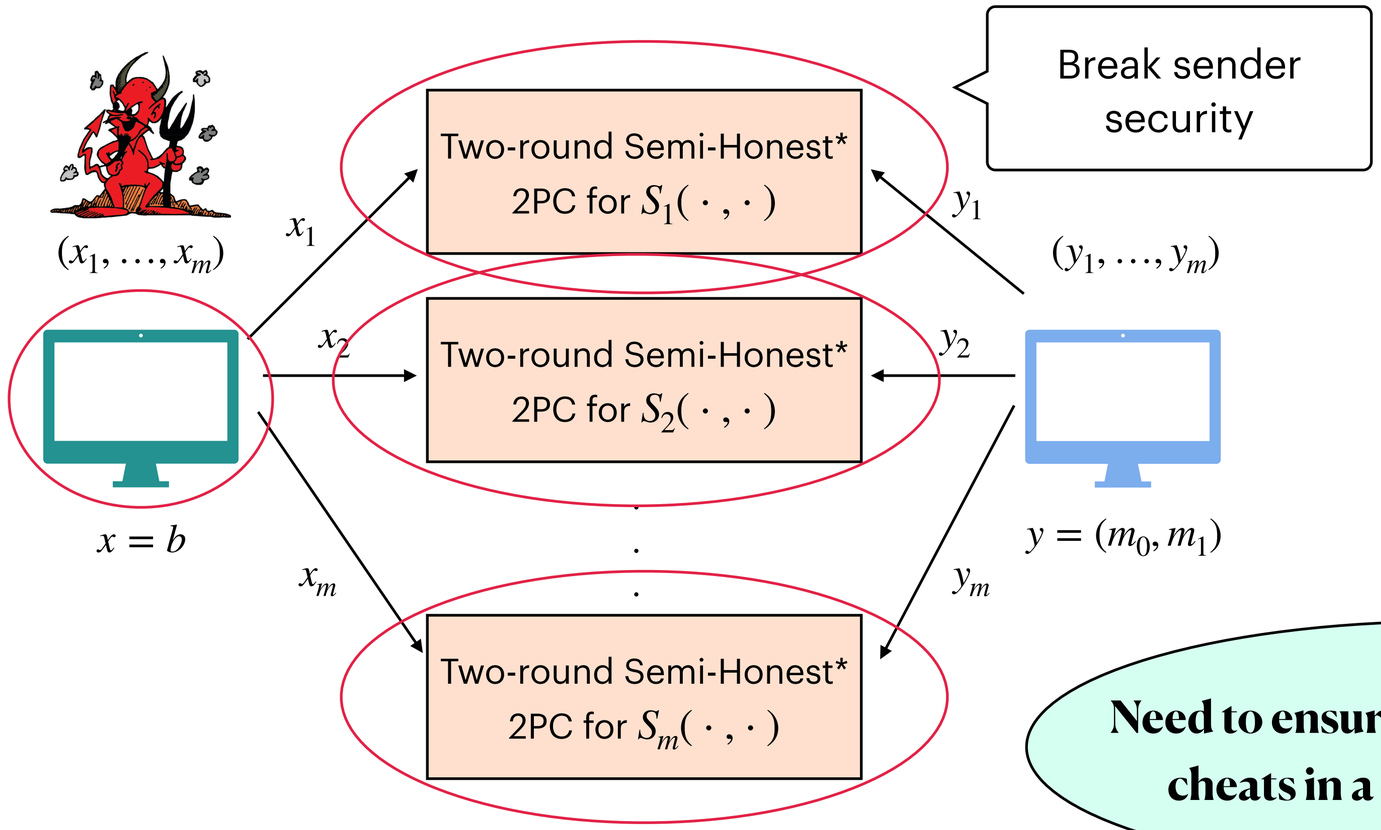
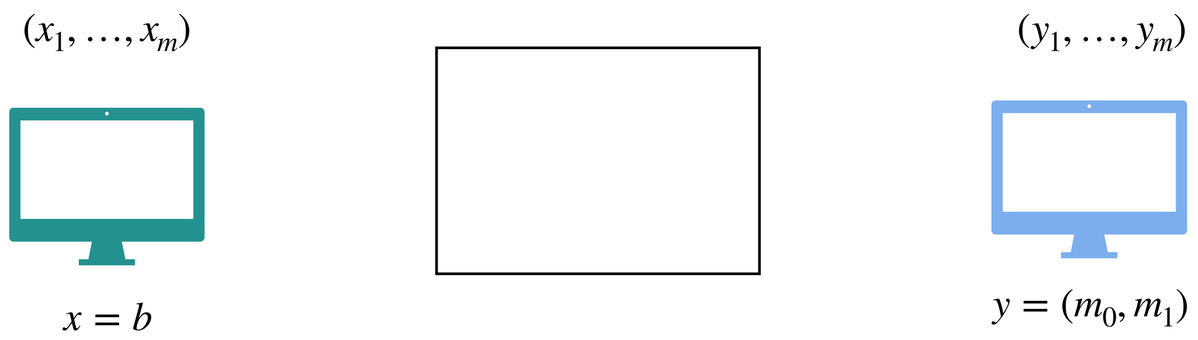


Need to ensure that adversary only cheats in a constant fraction

Role of Watchlist Protocol



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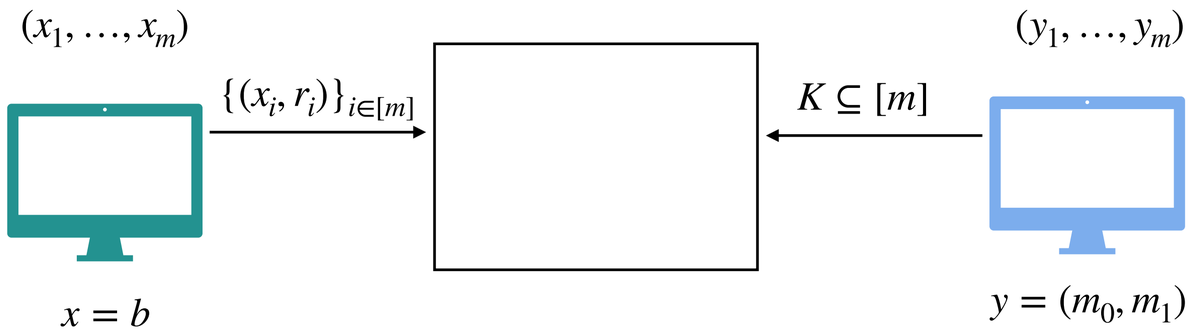

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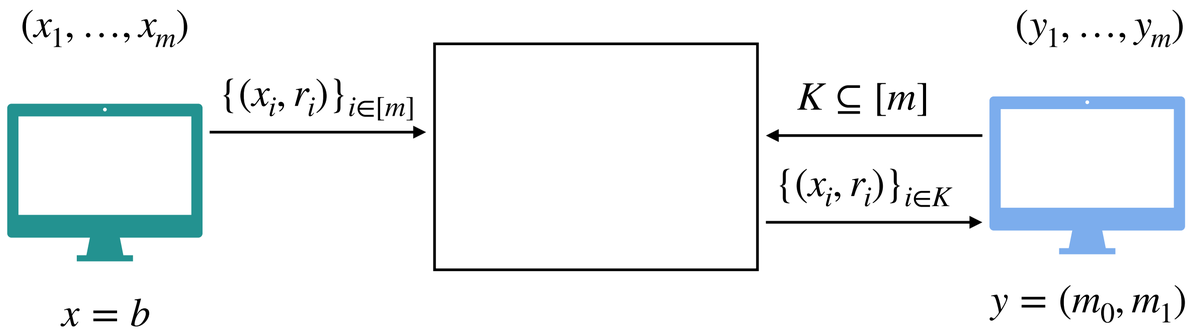

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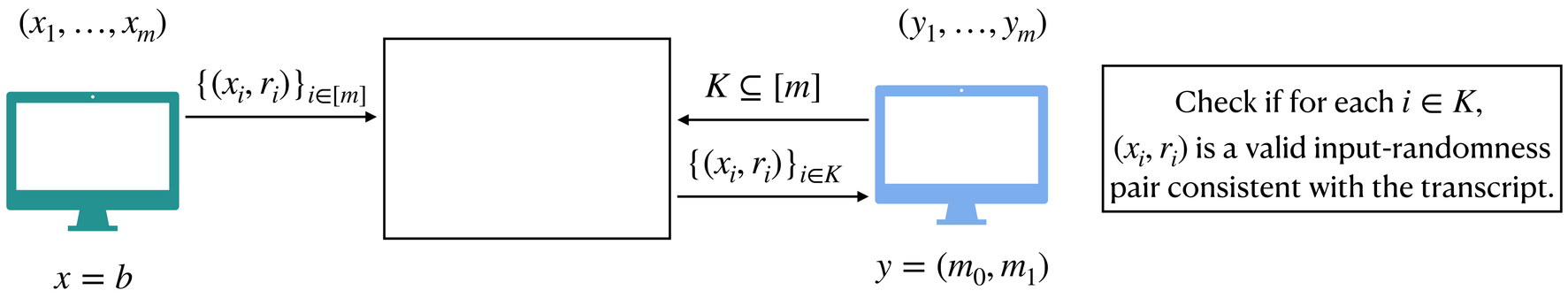

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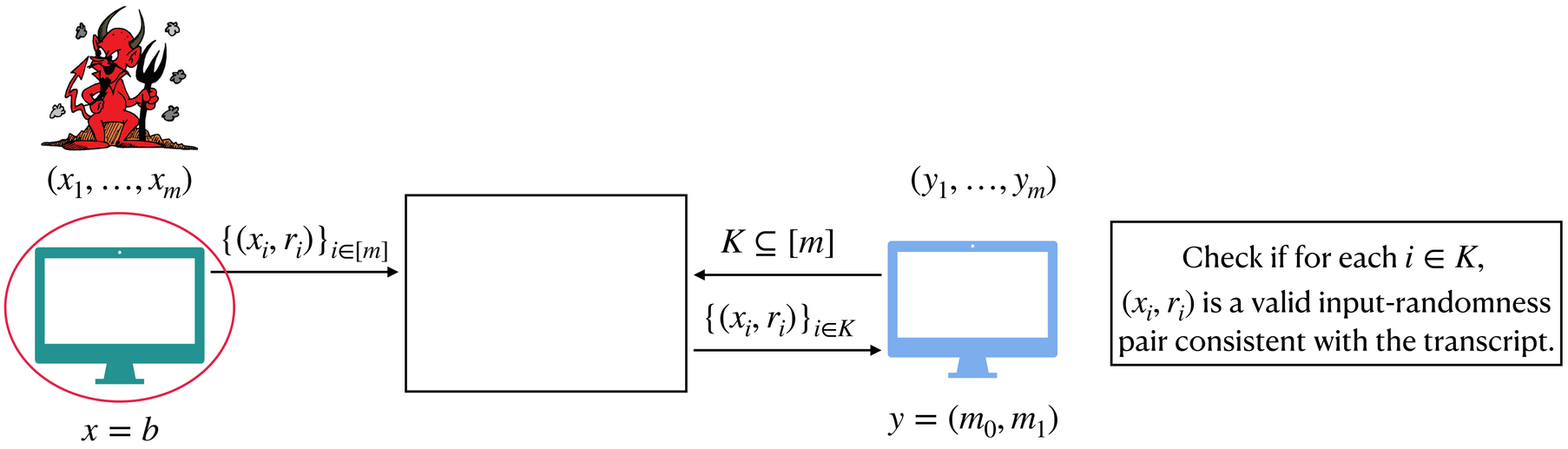

Watchlist Protocol

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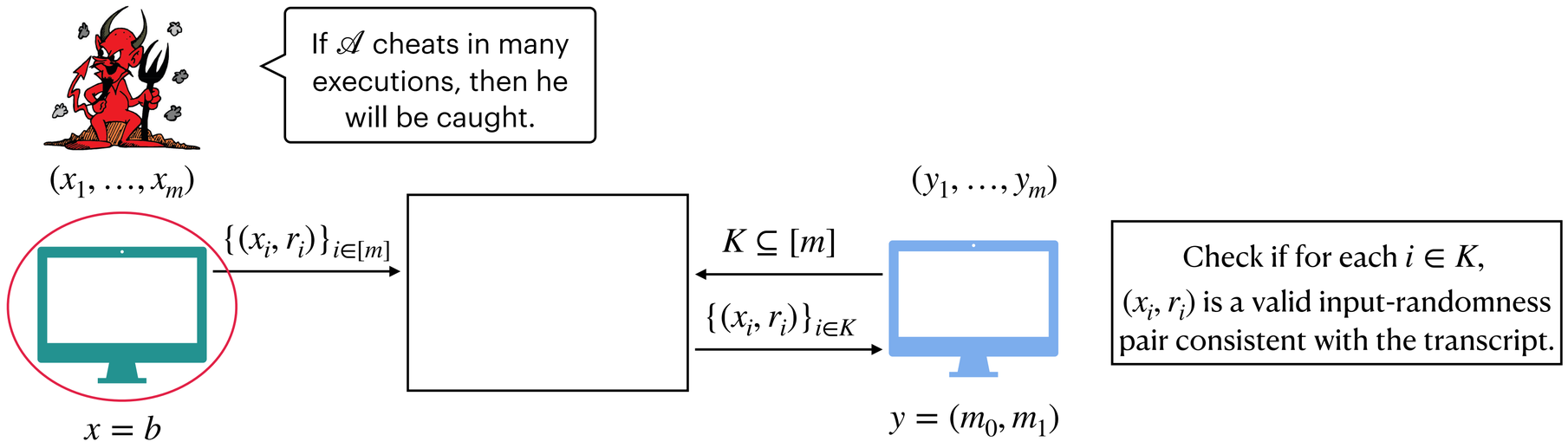

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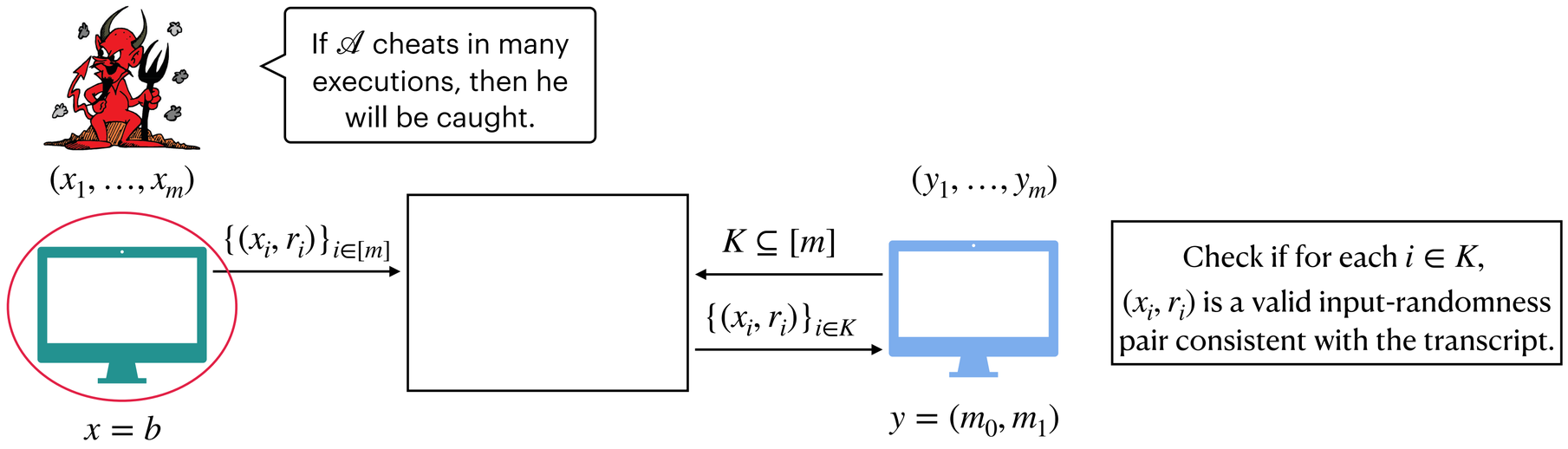

Watchlist Protocol

Construction of watchlist protocol requires malicious OT

Our Solution

K need not be kept secret but needs to be randomly chosen after the receiver message.

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$(x_1, \ldots, x_m)$

$x = b$

$(y_1, \ldots, y_m)$

$y = (m_0, m_1)$

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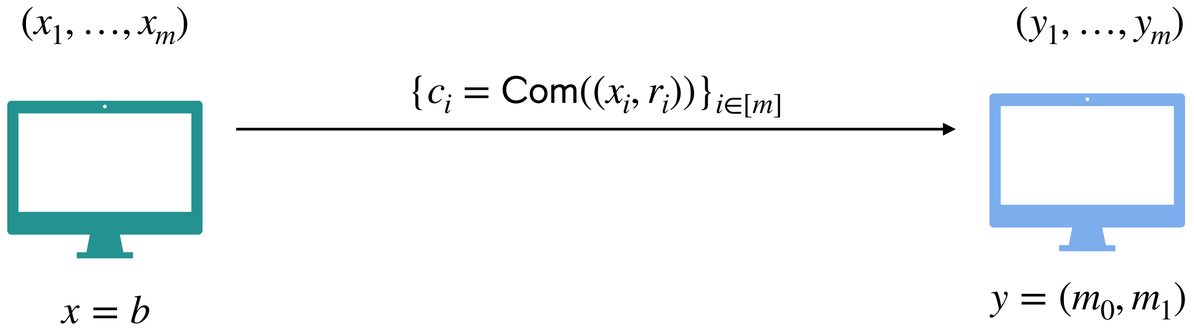

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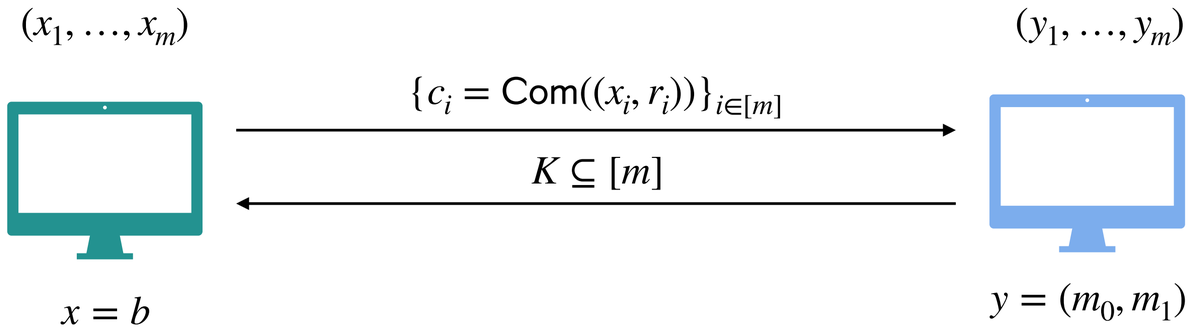

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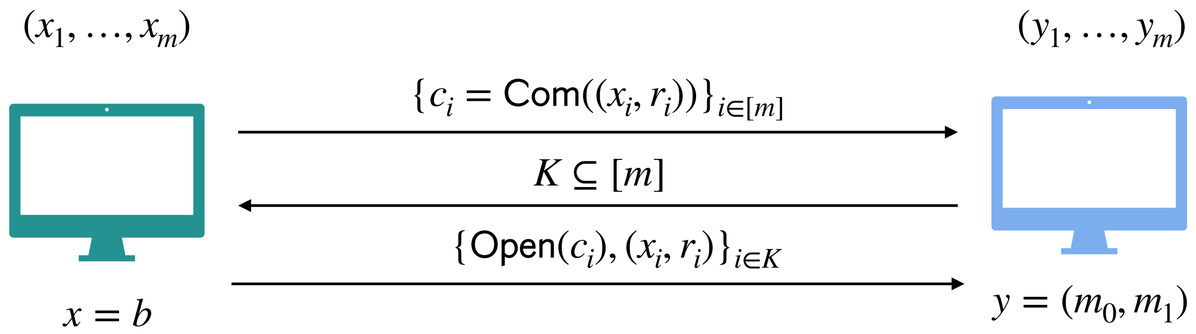

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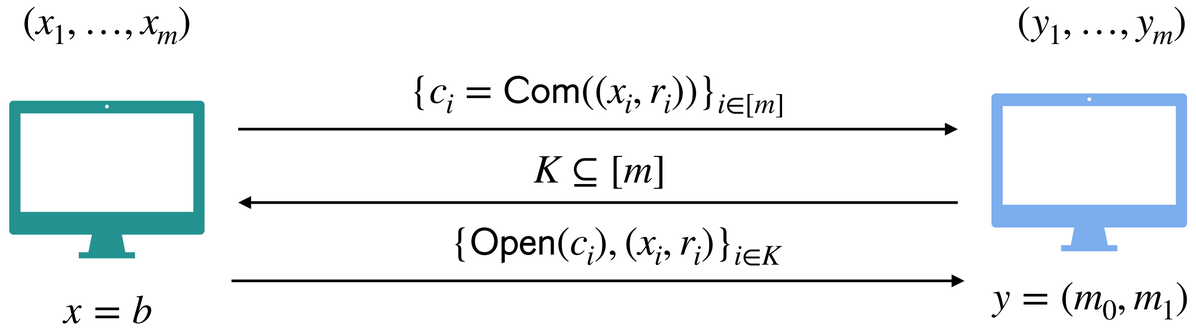

Check if for each $i \in K$, (x_i, r_i) is a valid input-randomness pair consistent with the transcript.

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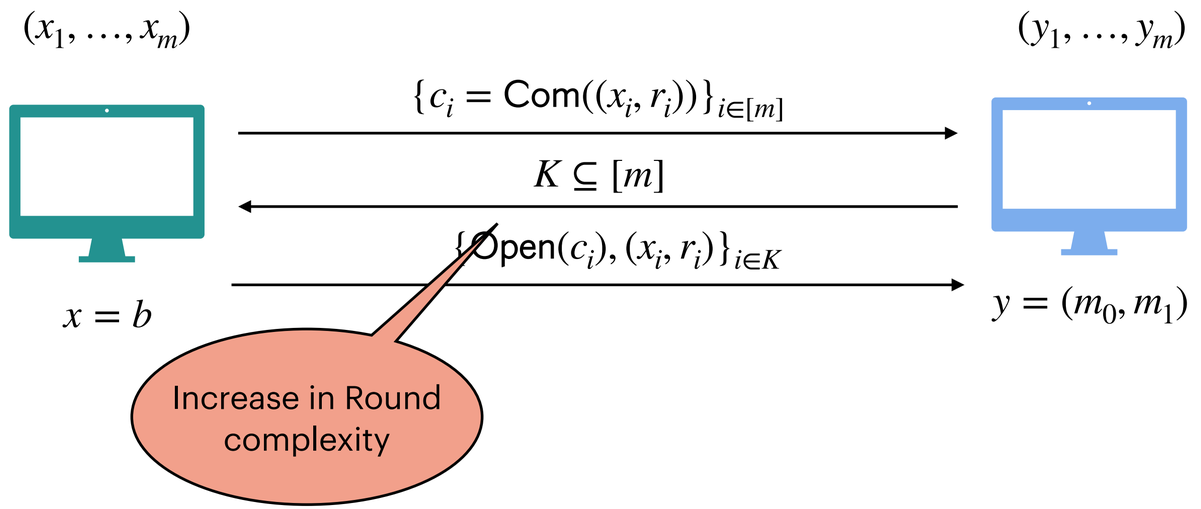

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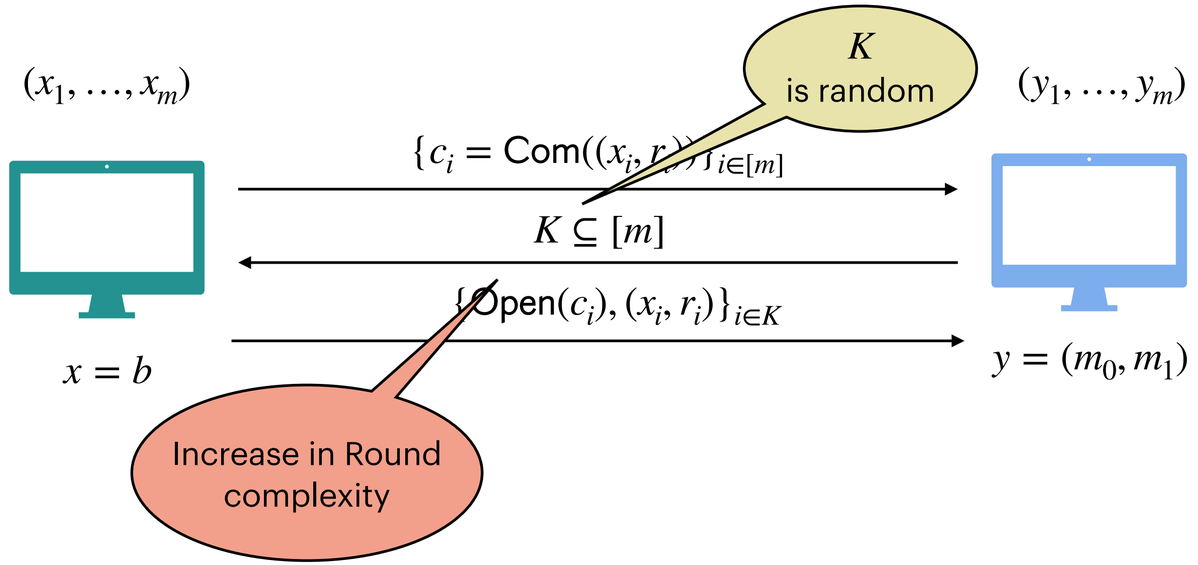

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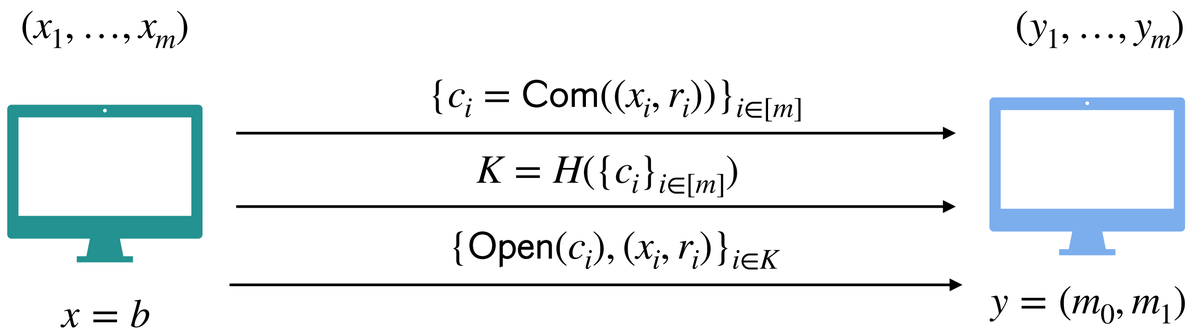
Fiat-Shamir paradigm



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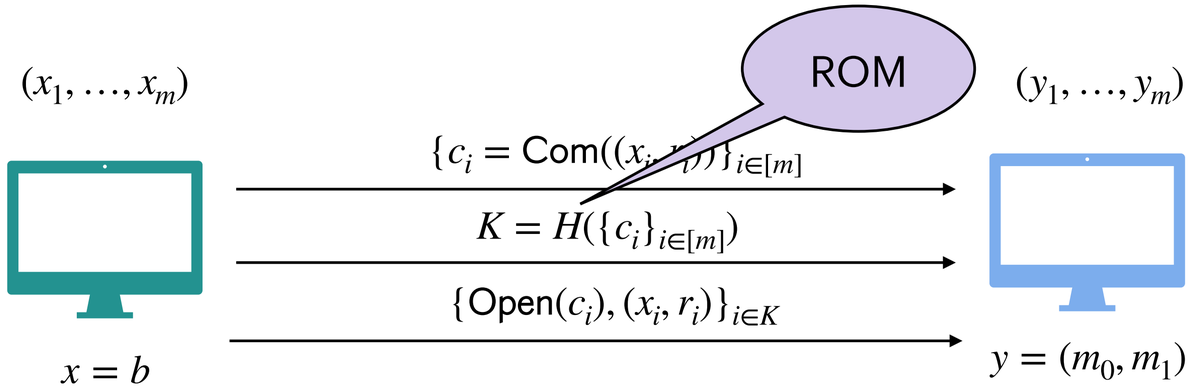
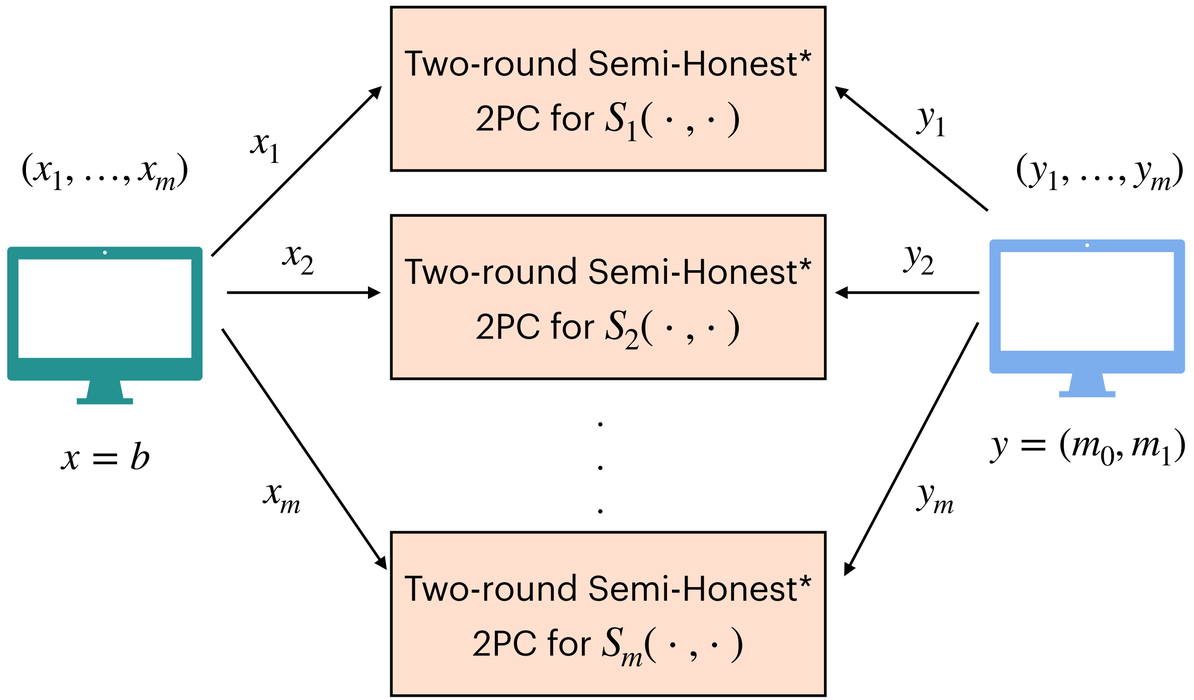


Dealing with Adaptive Security with Erasures



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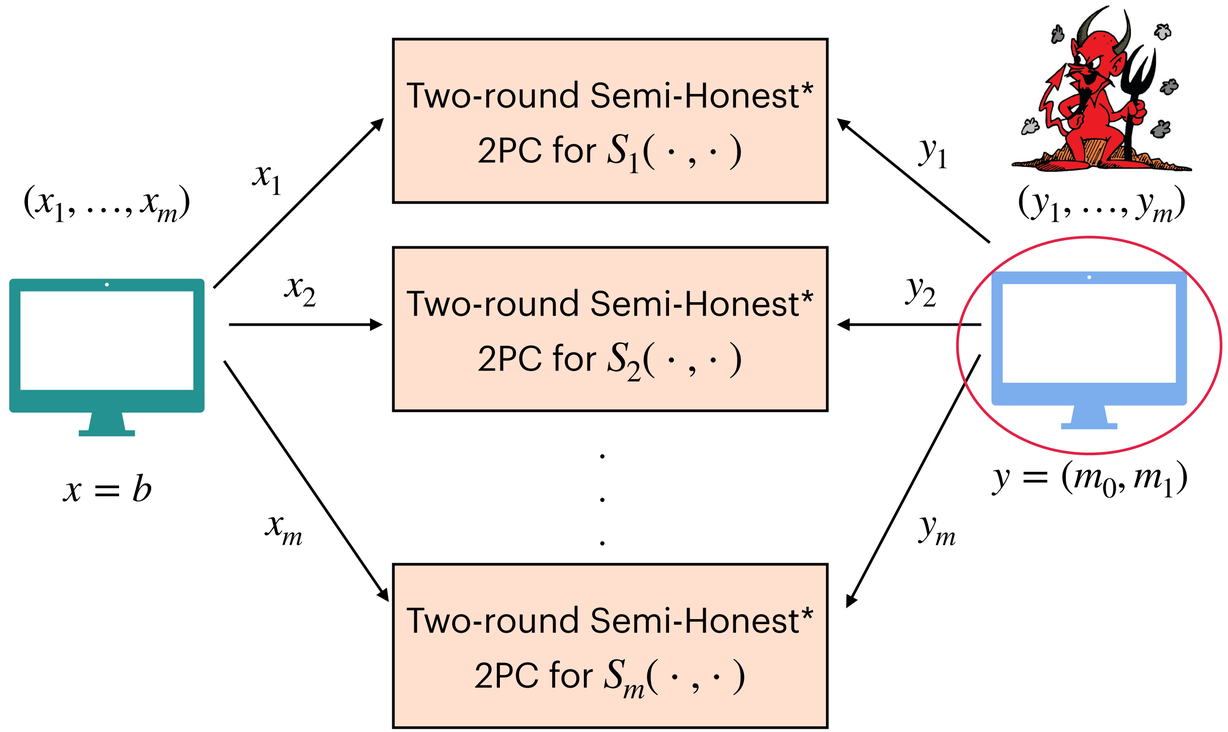

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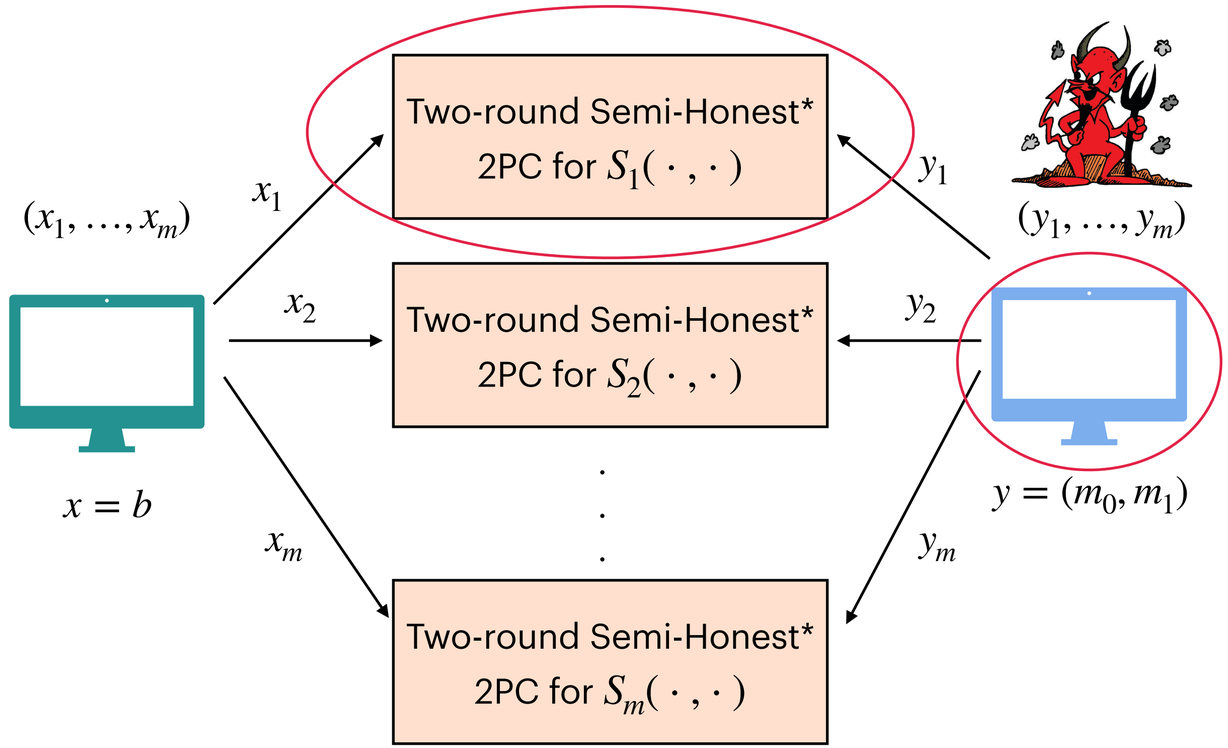

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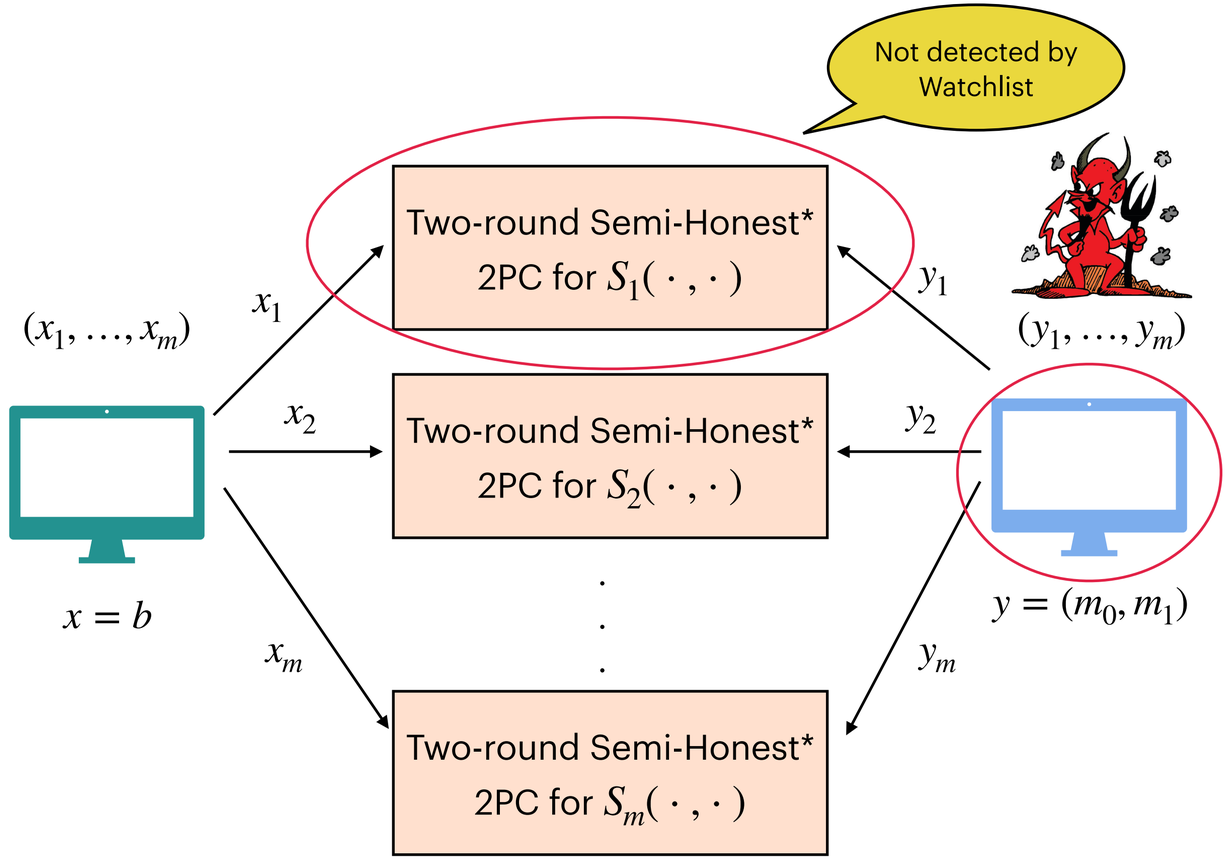

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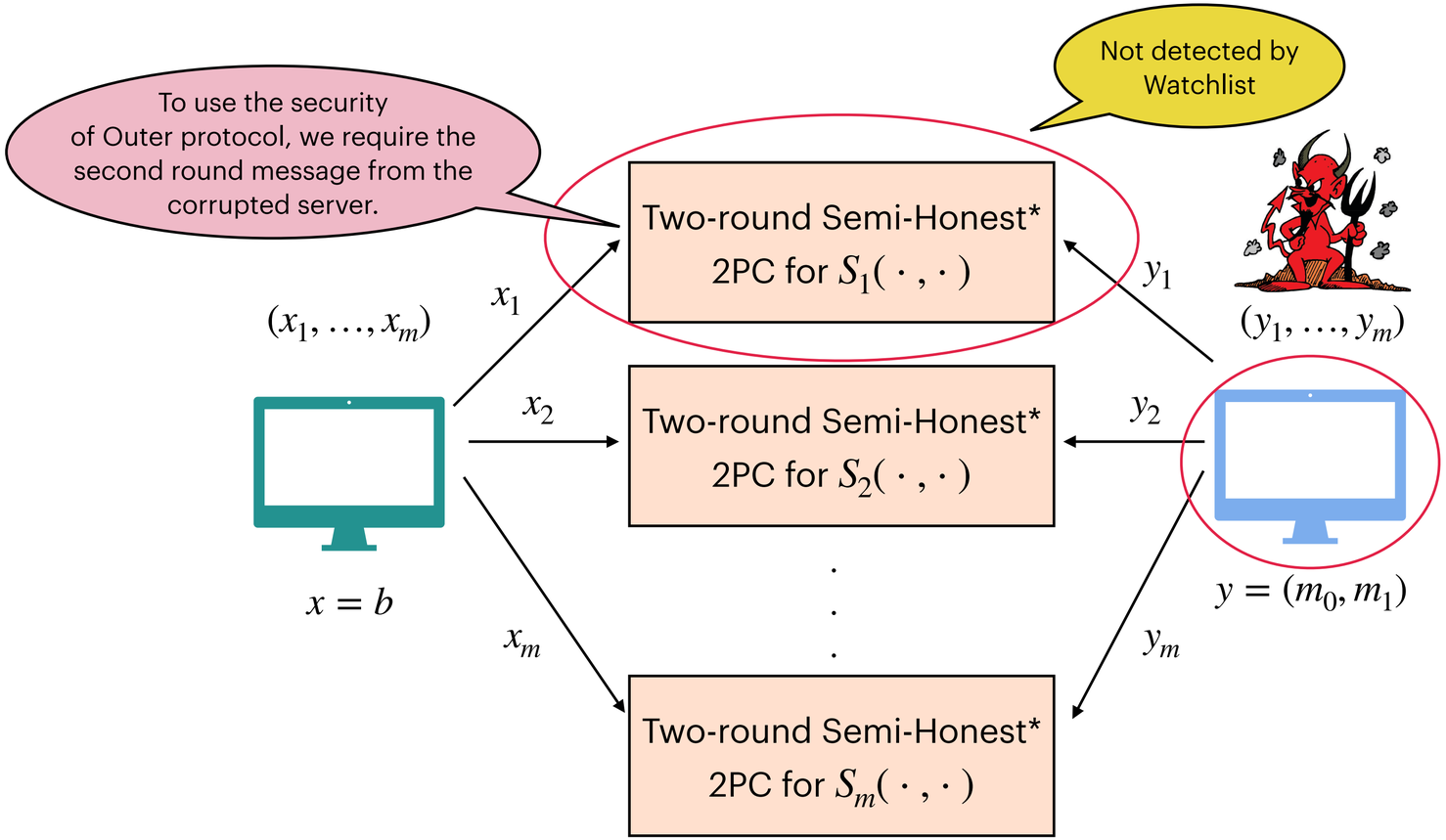

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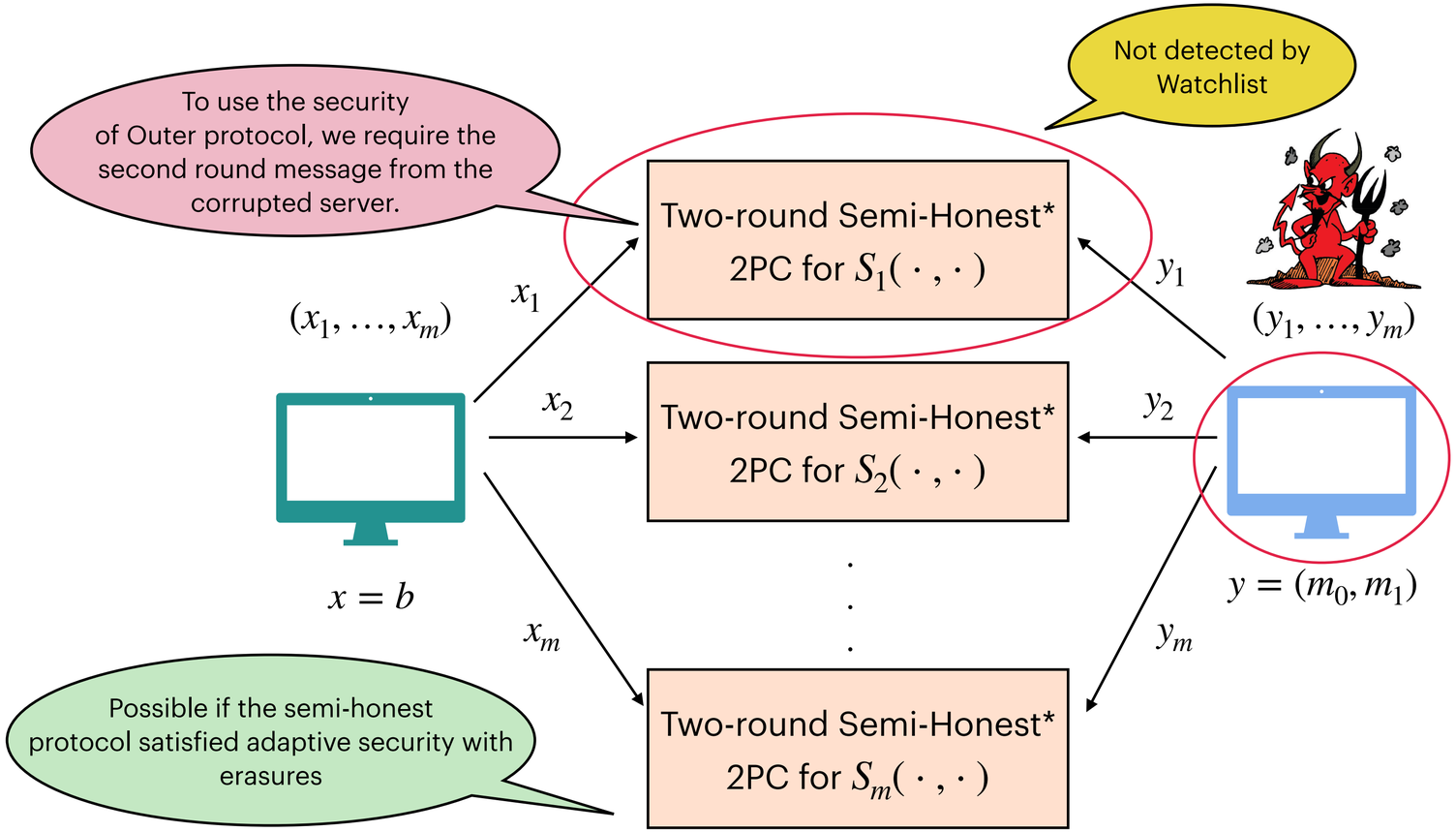
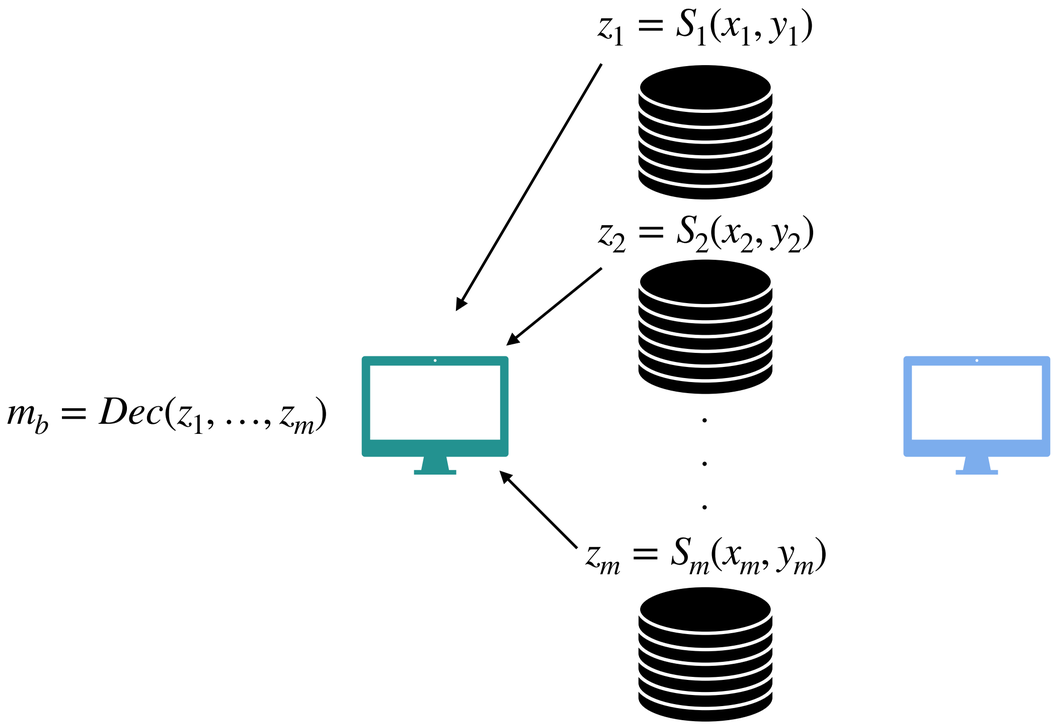


Stronger Outer Protocol



Outer Protocol

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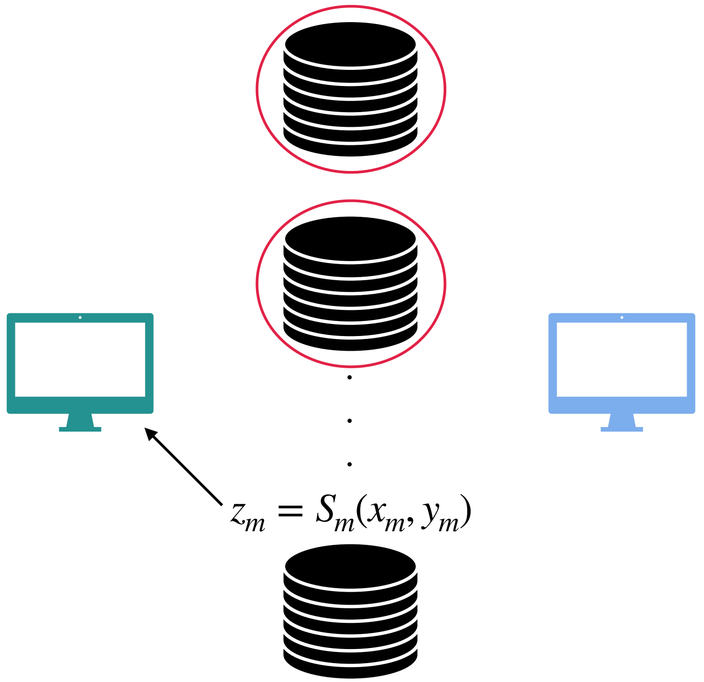

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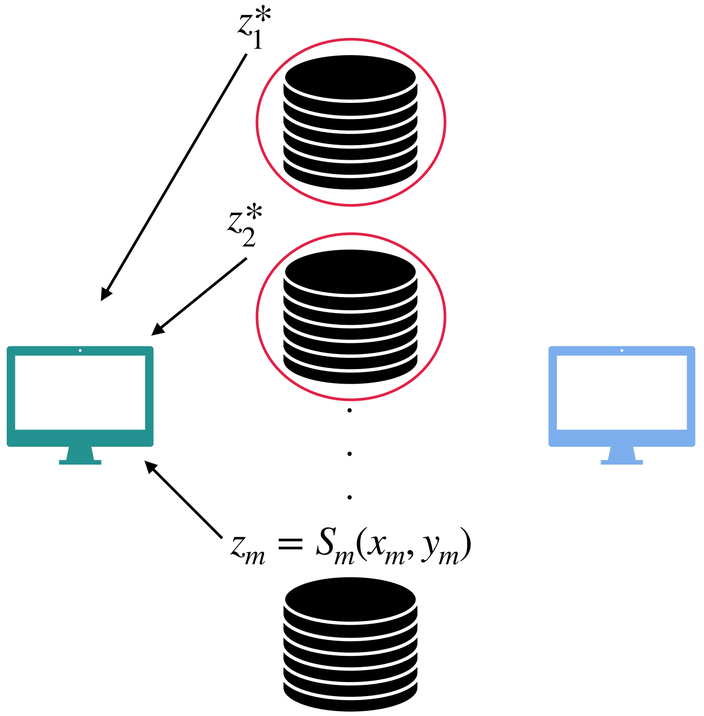

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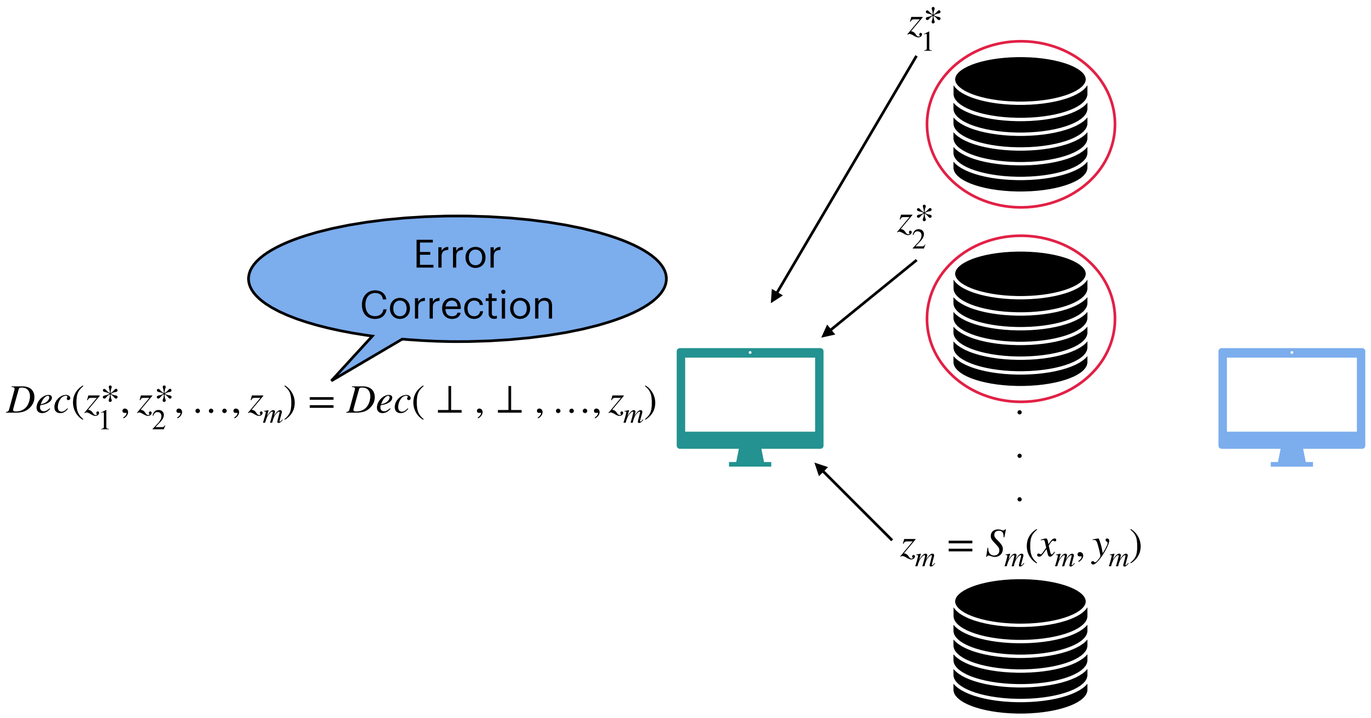

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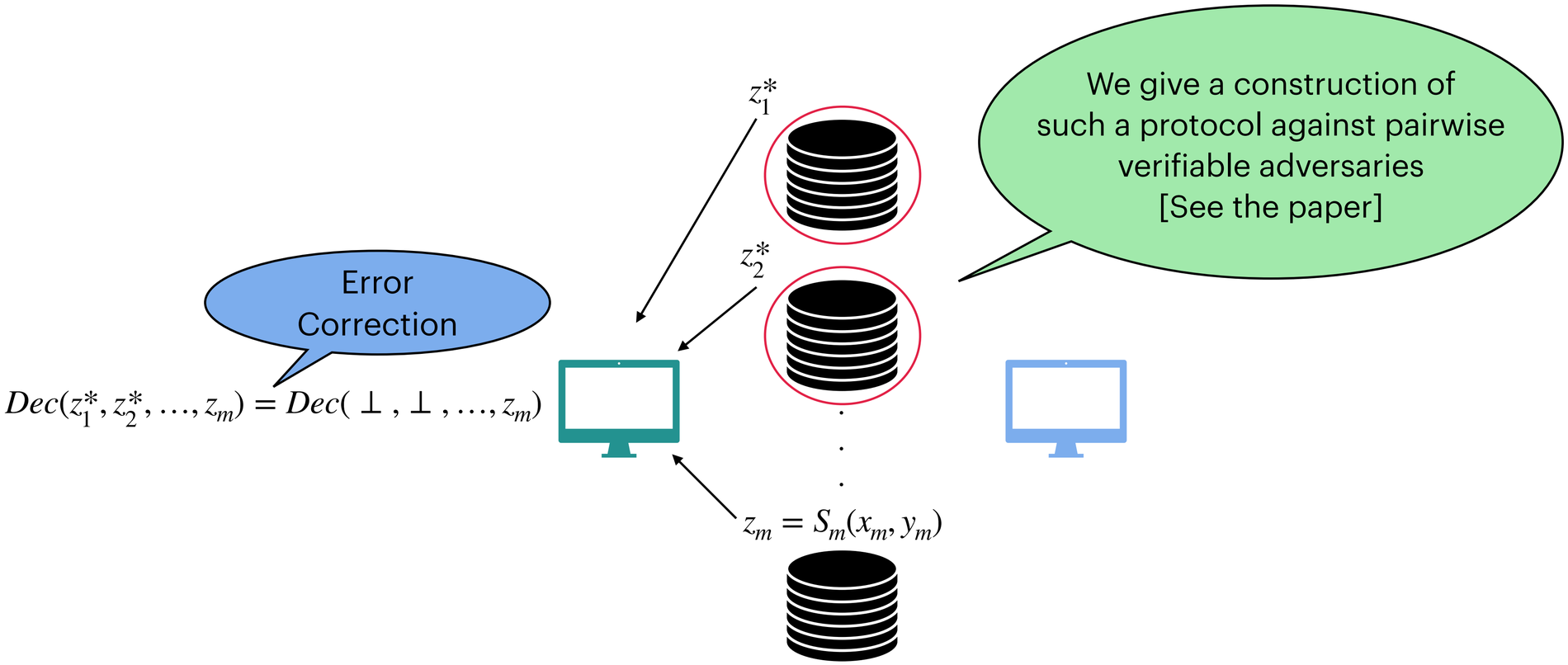

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Thank you!