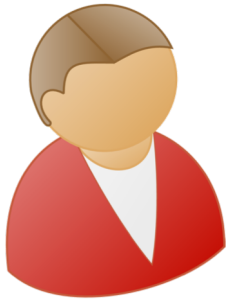
Round-Optimal Secure Multiparty Computation with Honest Majority

Prabhanjan Ananth Arka Rai Choudhuri **Aarushi Goel** Abhishek Jain

CRYPTO 2018

Secure Multiparty Computation

x_2



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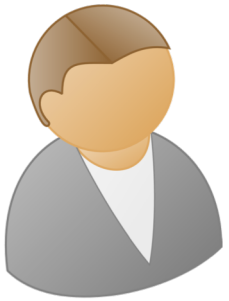

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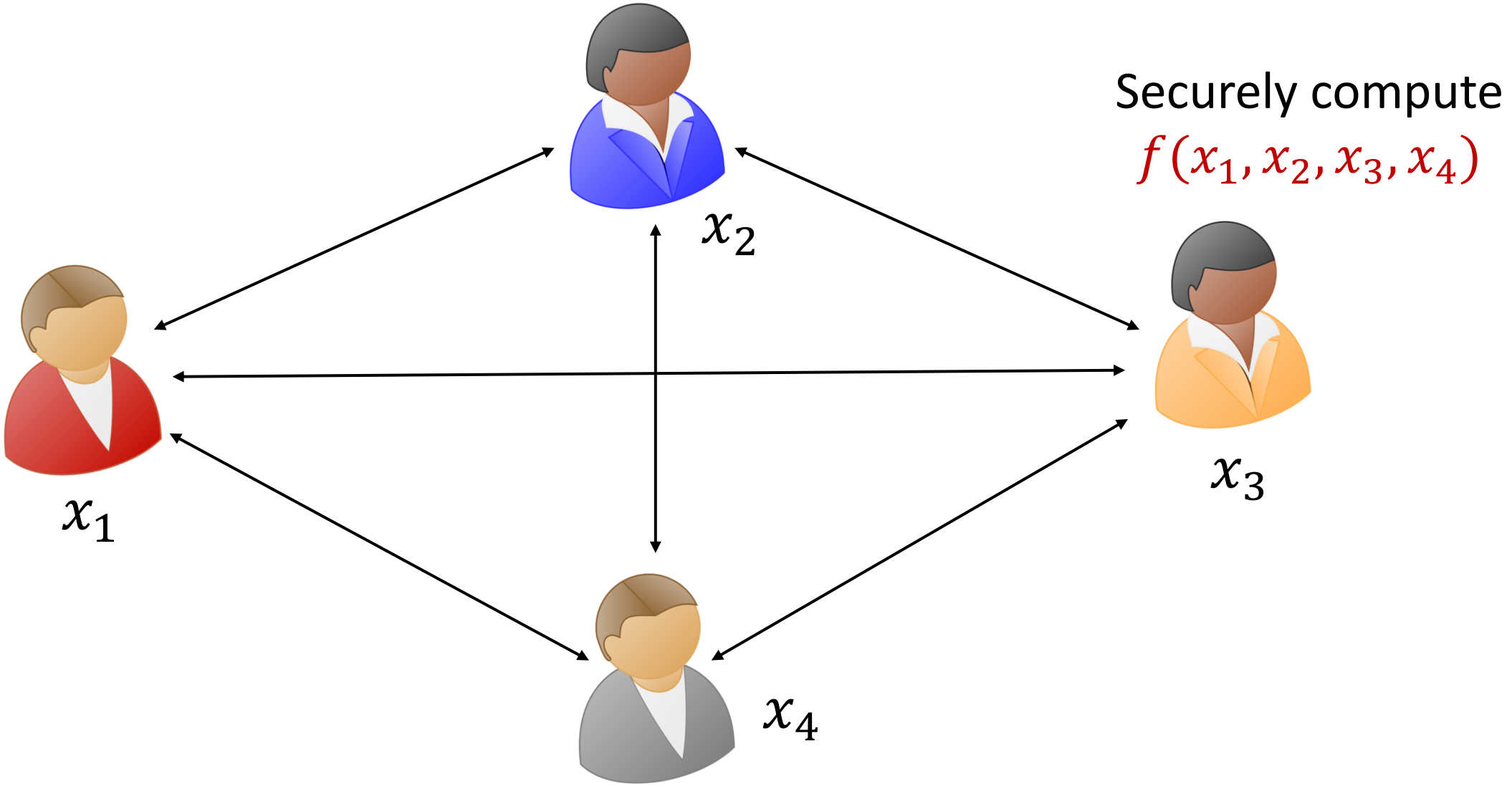
Secure Multiparty Computation



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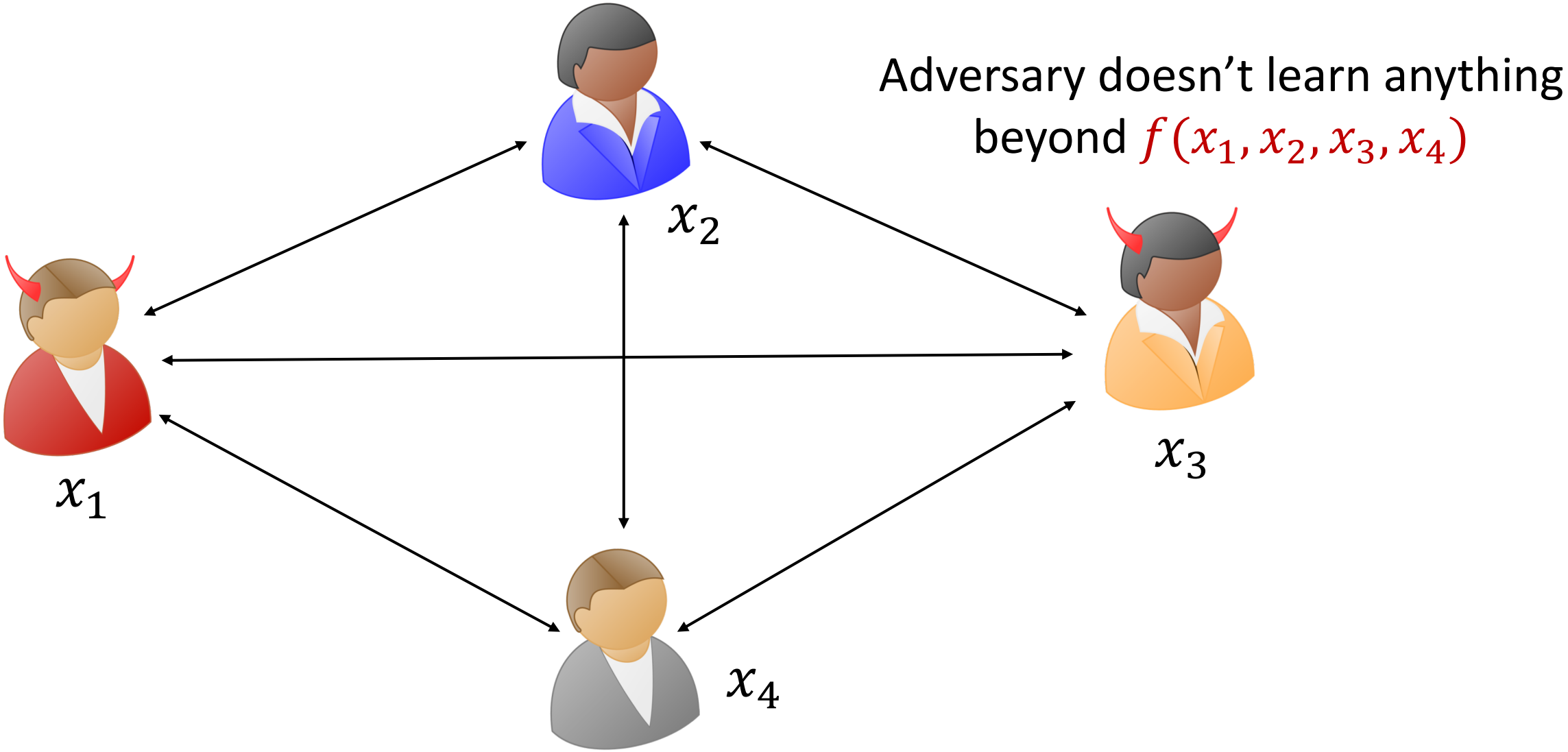

Honest Majority MPC

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- Round complexity lower bounds of dishonest majority do not apply.

  4 rounds necessary for dishonest majority in the plain model [Garg-Mukherjee-Pandey-Polychroniadou16]

Problem Statement

What is the exact round complexity of honest majority MPC in the plain model?

Honest Majority MPC: Security Notions

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Goal: Develop round optimal protocols in these settings.

Brief History: Security with Abort

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- [Benhomouda-Lin17, Garg-Srinivasan17]: $t < N$ semi-honest corruptions based on OT. Malicious corruptions in the CRS model.

Question: Security with Abort

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Open even in semi-honest case from assumptions weaker than OT.

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Does there exist a two round MPC protocol secure against $t < N/2$ fail-stop corruptions in the plain model?

Does there exist a three round MPC protocol secure against $t < N/2$ malicious corruptions in the plain model?

Both questions open regardless of assumptions.

Our Results: Security with Abort

Two round MPC for general functionalities in the plain model, assuming one-way functions.

Our Results: Guaranteed Output Delivery

Fail-Stop Corruptions: Two round MPC for general functions:

Broadcast channel protocol in the bare-public-key model, assuming PKE.

Point-to-point channel protocol in the plain model, assuming OT.

Our Results: Guaranteed Output Delivery

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Three round MPC from one-way functions in the plain model.

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Fail-Stop Corruptions: Two round MPC for general functions:

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Point-to-point channel protocol in the plain model, assuming OT.

Malicious Corruptions: Three round MPC for general functions:

Broadcast channel protocol in the plain model, assuming Zaps and PKE.

Security with Abort against Malicious Adversaries

[Garg-Srinivasan17]

A compiler from any polynomial round MPC protocol to a two round protocol using two round UC secure OT.

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Starting Idea: Leverage honest majority to remove OT.

[Garg-Srinivasan17]

Use of OT in [GS17]

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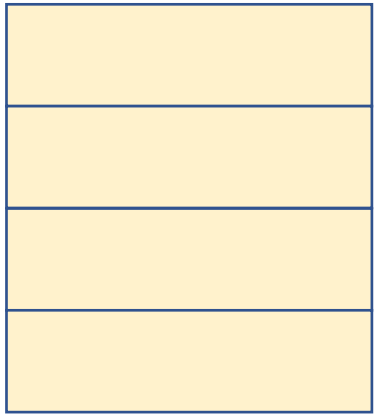
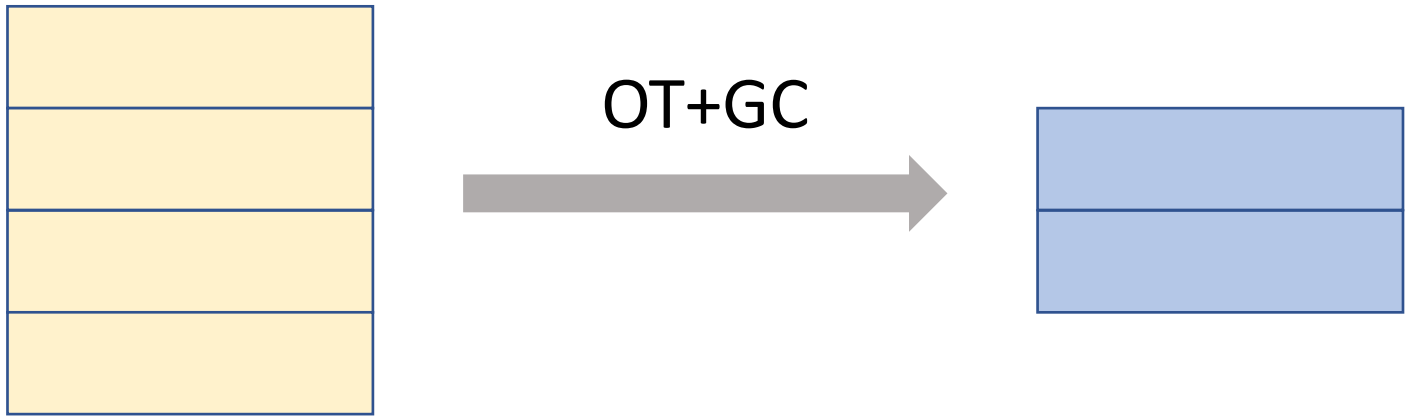


Any polynomial round MPC Protocol

Use of OT in [GS17]
Start with any dishonest majority protocol based on OT over broadcast channels

[Garg-Srinivasan17]



Any polynomial round MPC Protocol

Two-round MPC Protocol

Use of OT in [GS17]
Start with any dishonest majority protocol based on OT over broadcast channels
Compile it into a 2 round protocol using OT and Garbled circuits

Our Strategy

	Use of OT in [GS17]	Our approach
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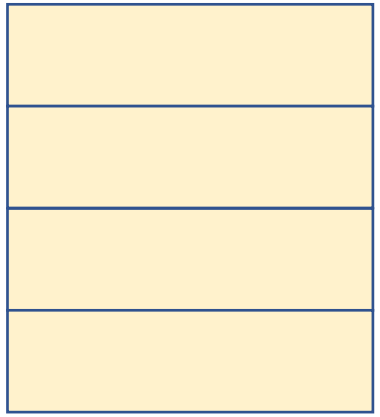
Recap of [Garg-Srinivasan17]



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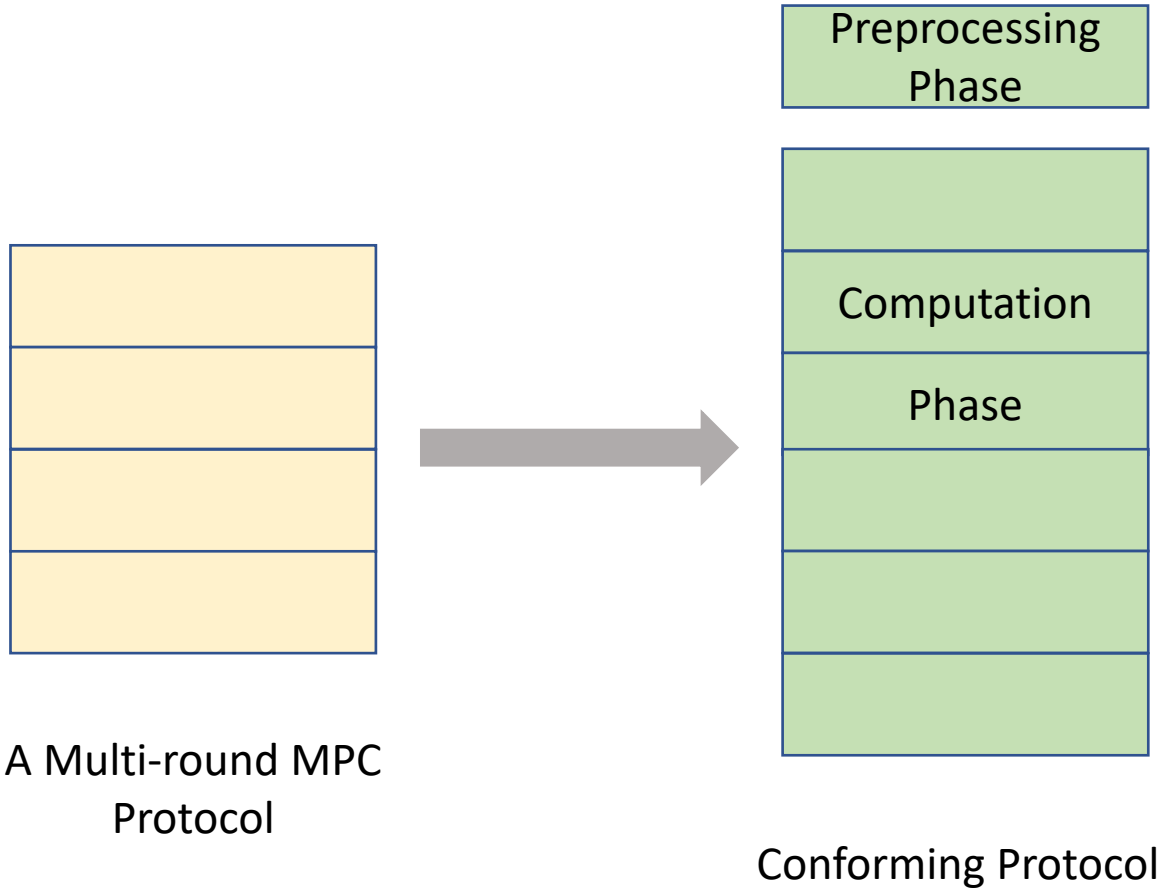

A Multi-round MPC Protocol

Conforming Protocol

Transform into a "conforming protocol" with a specific syntactic structure.

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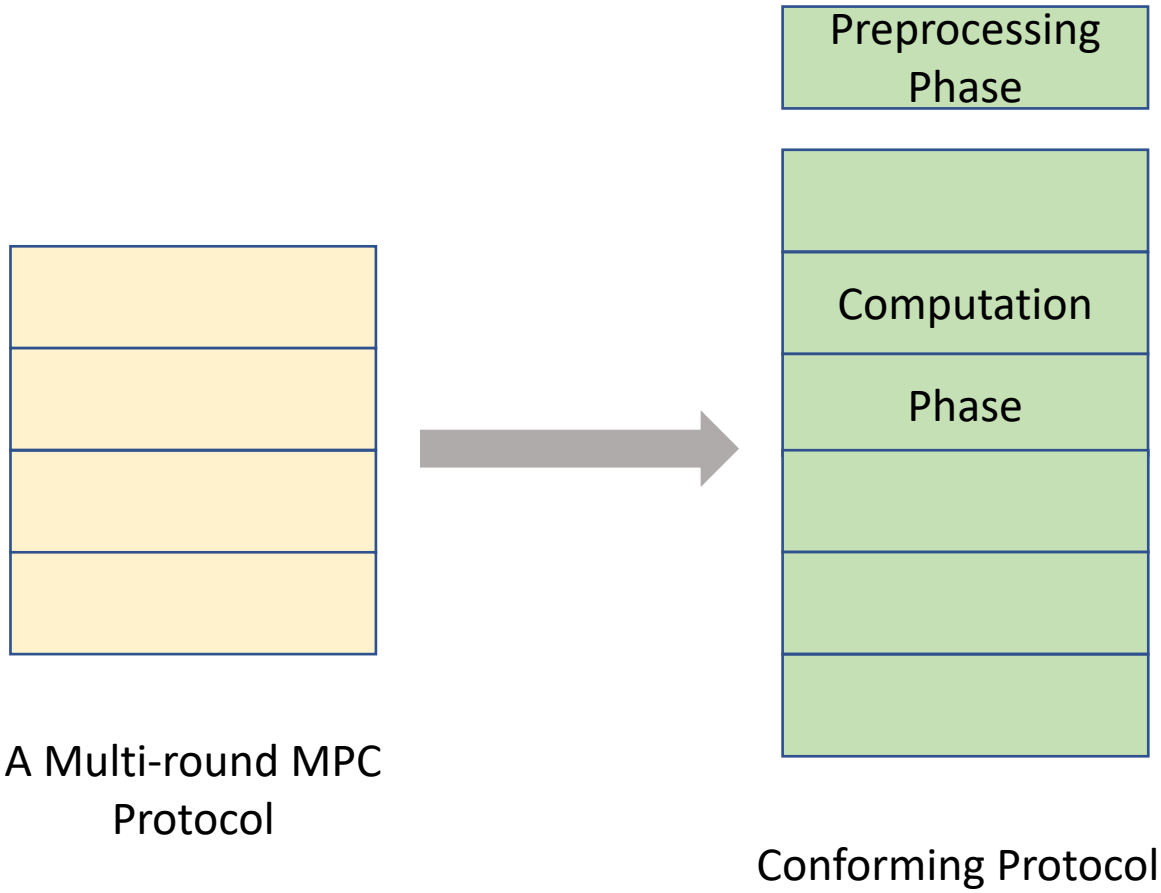

A Multi-round MPC Protocol

Conforming Protocol

Computation Phase:

Only a single bit is broadcasted by a single party (speaker) in each round.

All other parties are listeners for that round.

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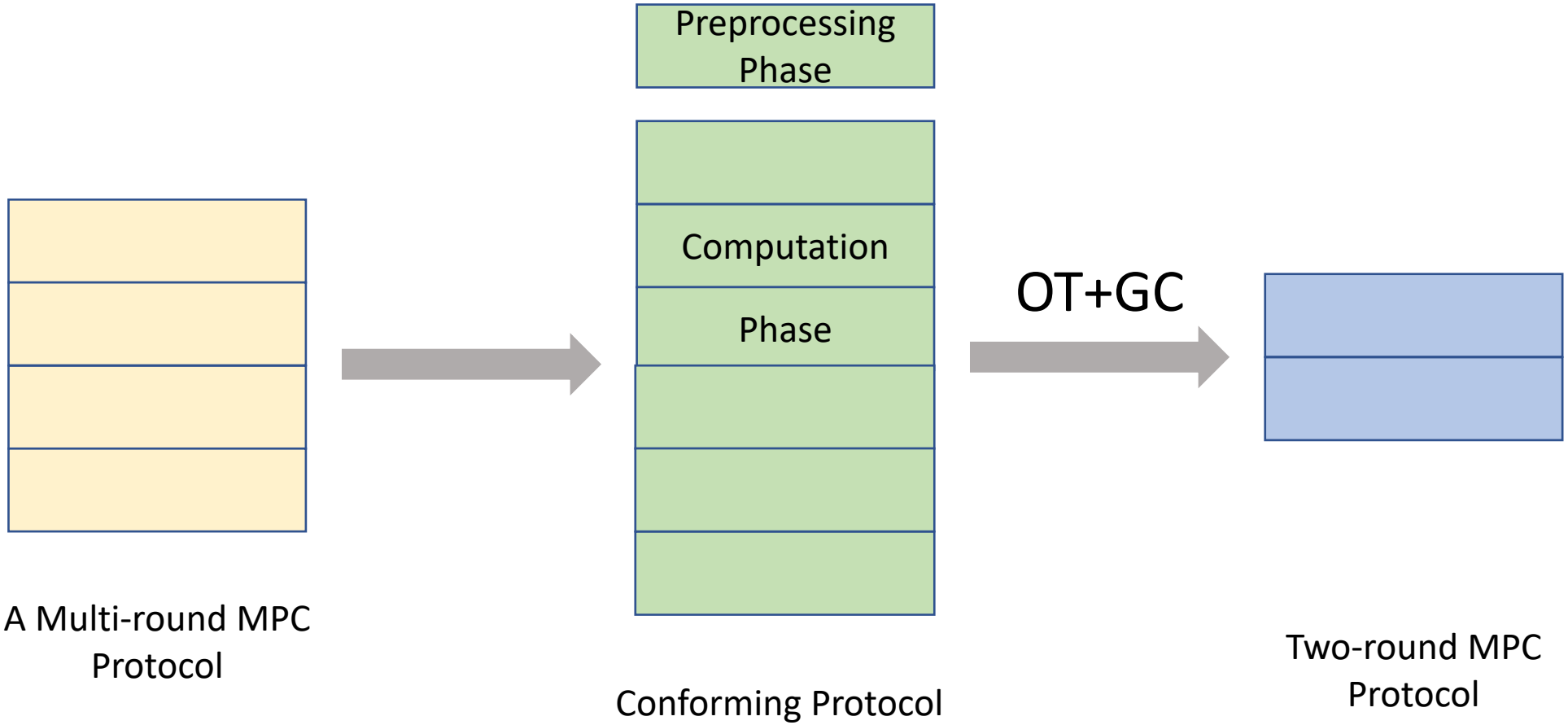

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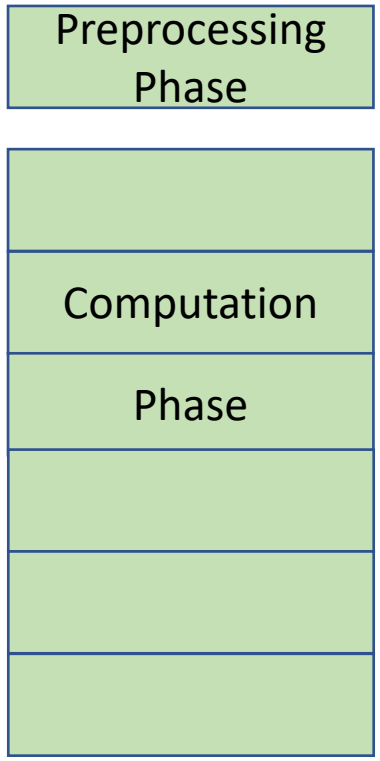
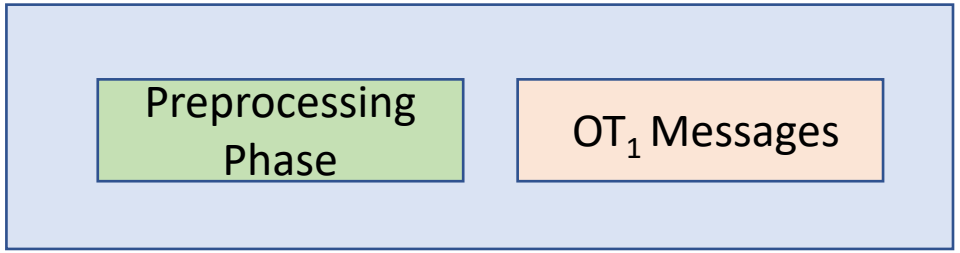


Conforming Protocol

Two-round UC secure OT + Garbled Circuits

Round 1



- Each party sends OT receiver messages for the rounds in which it speaks.
- These messages commit to all its actions in the computation phase of the conforming protocol.

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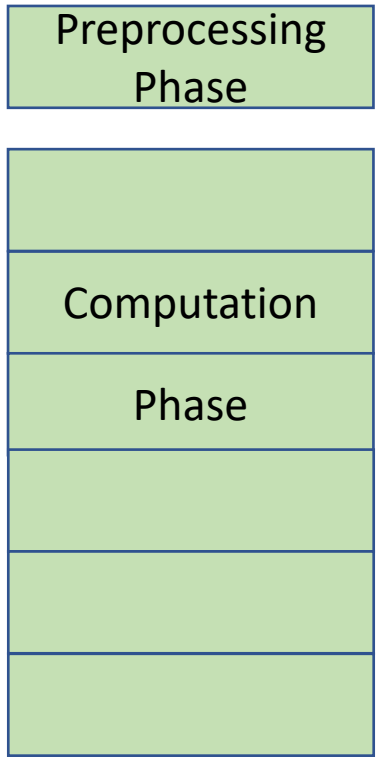

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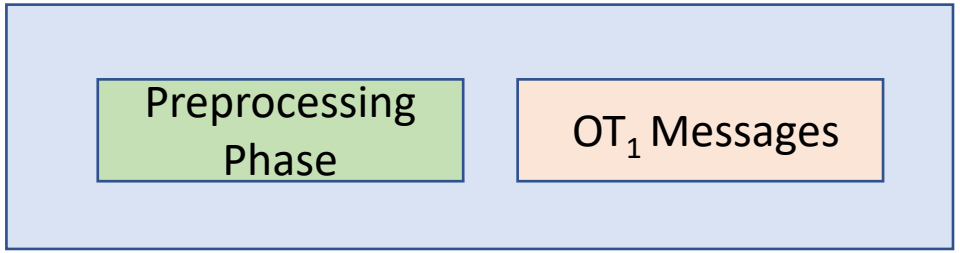
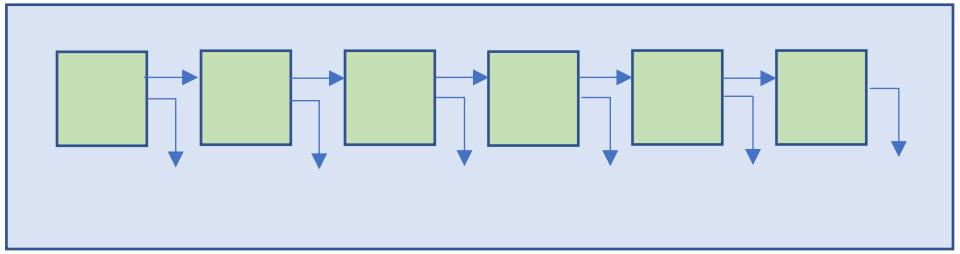


Round 2



Each party sends garbled circuits corresponding to each round in the computation phase.

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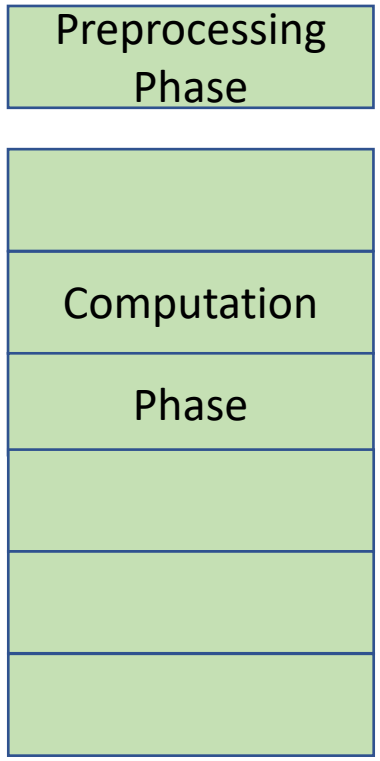

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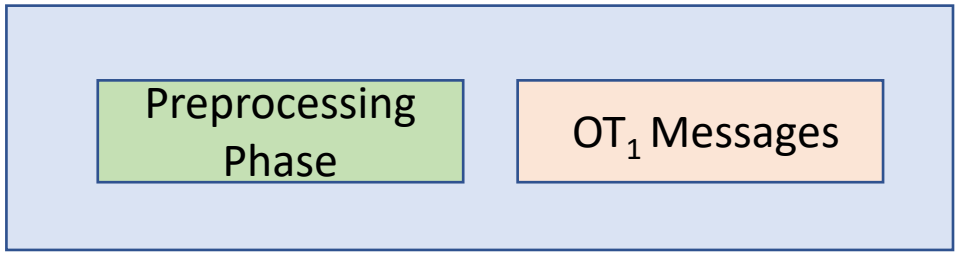

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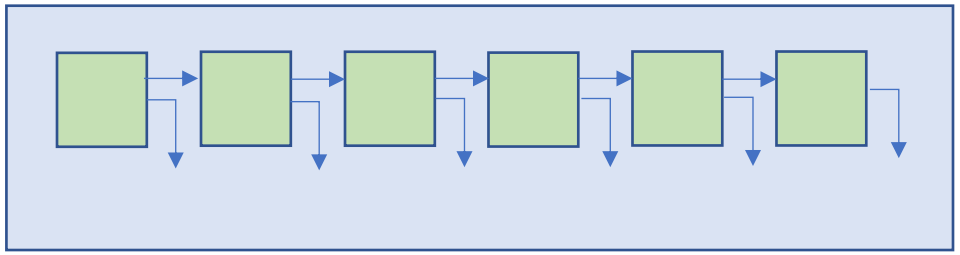

GCs output the OT sender messages.

Goal of these OTs is to deliver wire labels of GC.

Our Strategy: Challenge 2

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$$m_b = m_0(1 + b) + m_1(b)$$

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Later: How to implement

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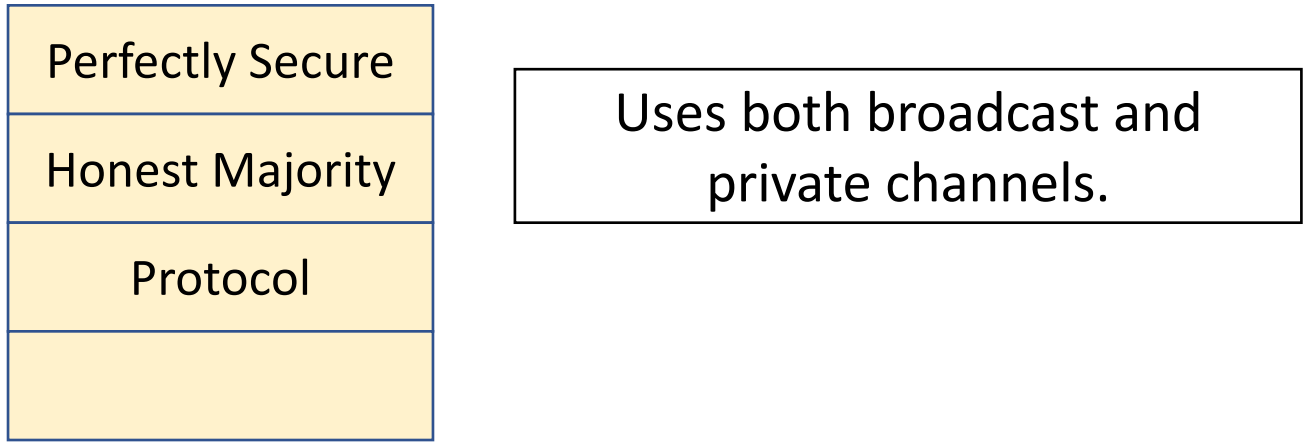

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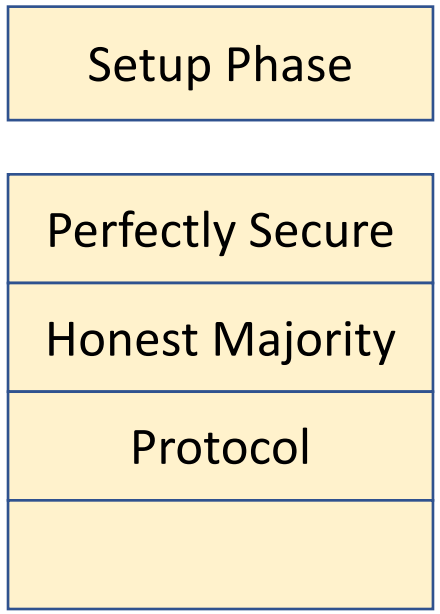

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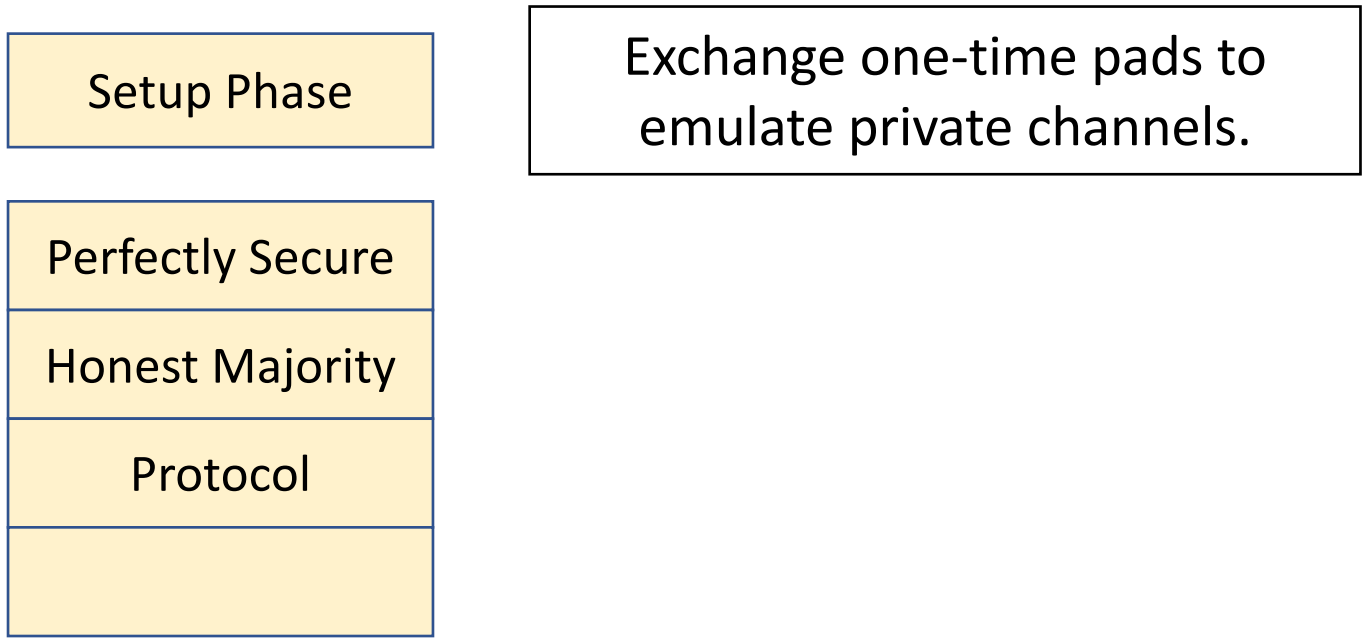

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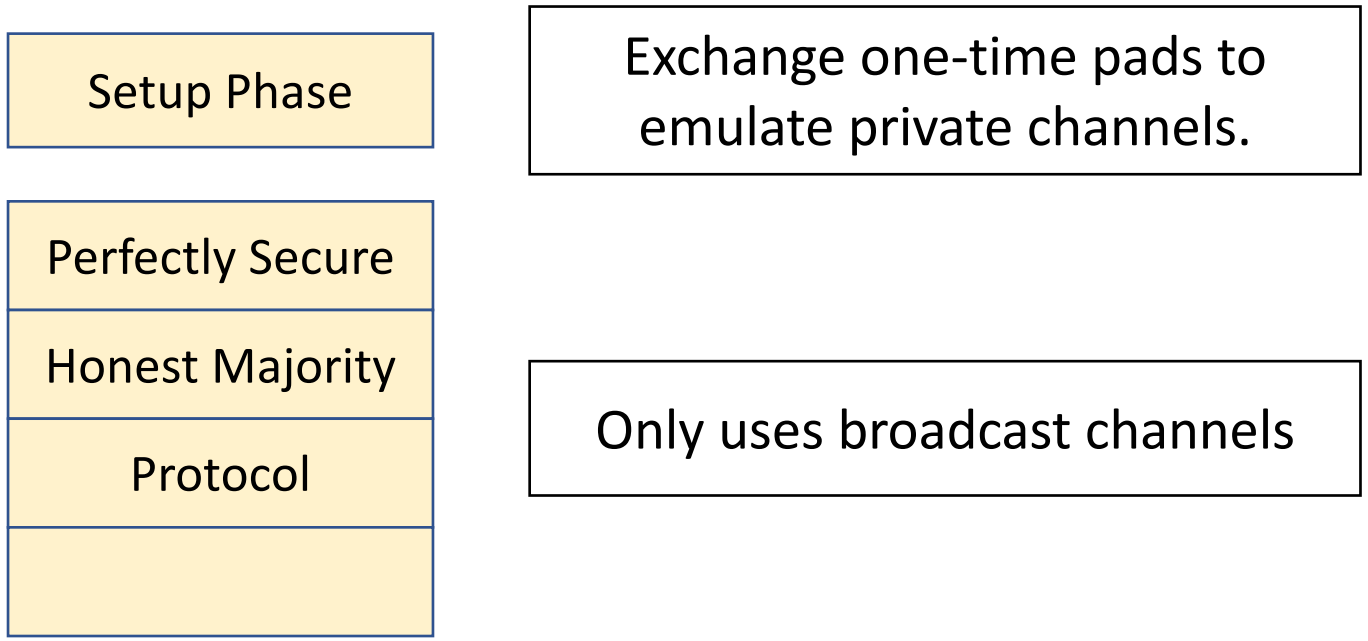

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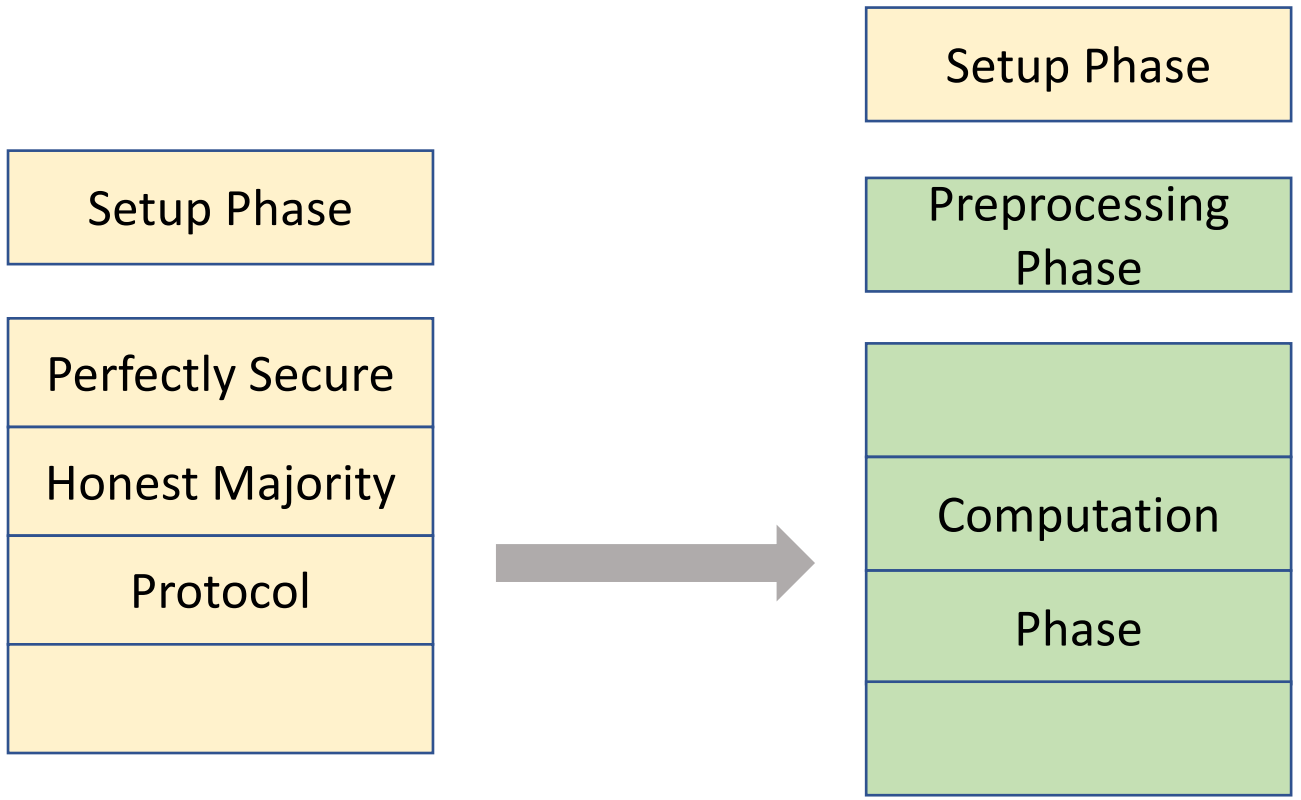
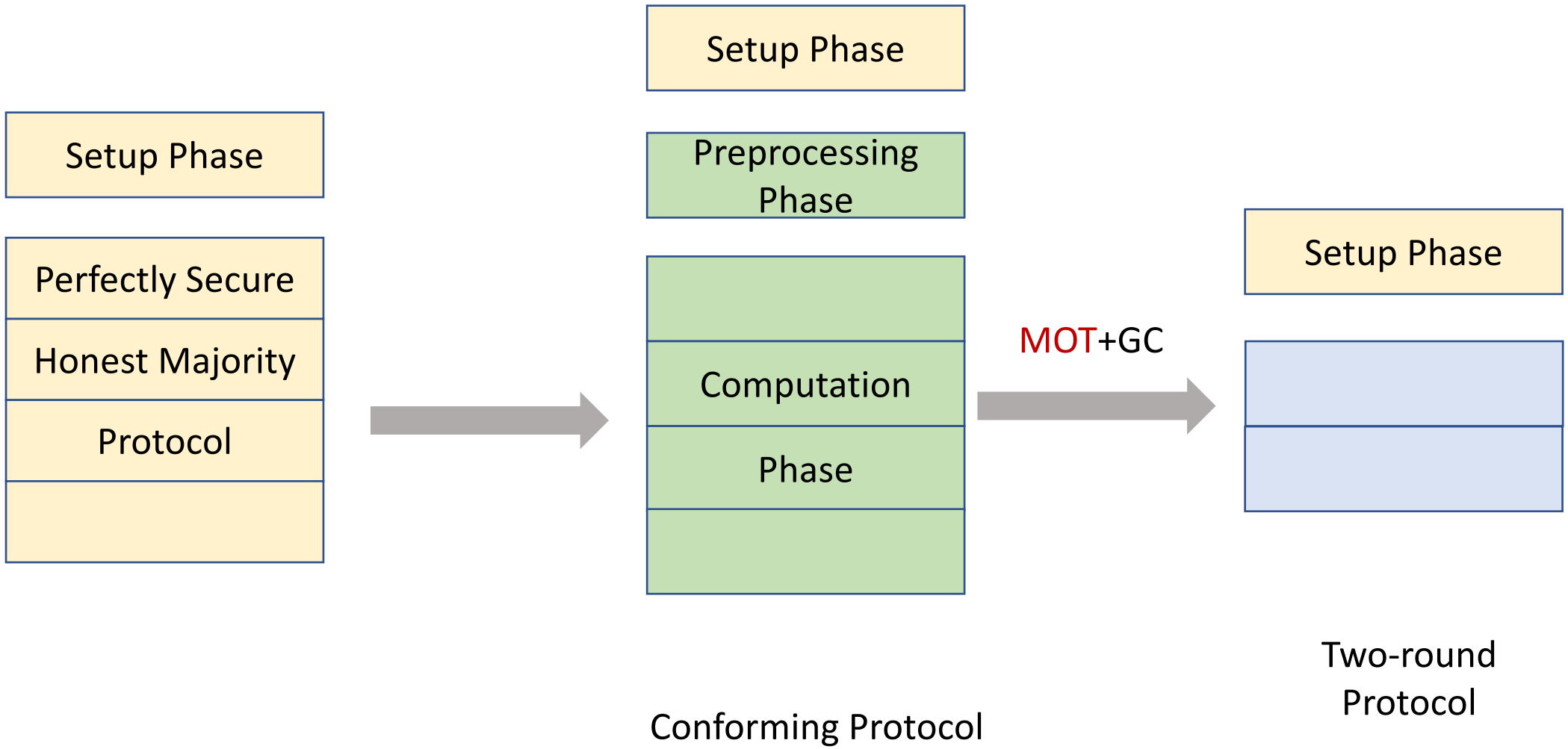


Transform to a conforming protocol with a setup phase

Conforming Protocol

Compressing Private Channel Protocols



Compressing Private Channel Protocols

Can we parallelize the first round with the setup phase?

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Conforming Protocol with setup

Setup Phase

Listener of round t

R

Speaker of round t

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Conforming Protocol with setup

Setup Phase

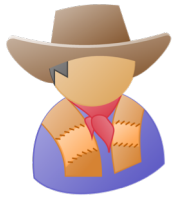
Listener of round t

R

Speaker of round t

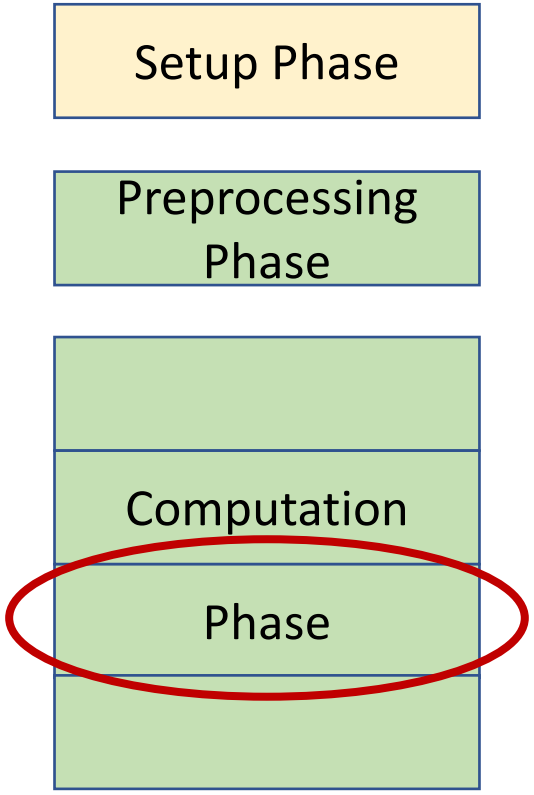
Round t

(computation phase)



Speaker of round t

$Broadcasts\ (m \oplus R)$



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2 Round Protocol with setup

Setup Phase

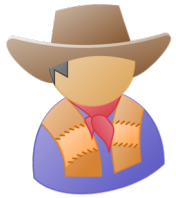
Listener of round t

R

Speaker of round t

Setup Phase

Round 1



Speaker of round t

$Broadcasts\ OT_1\ messages$

Round 1

Round 2

Can we parallelize the first round with the setup phase?

2 Round Protocol with setup

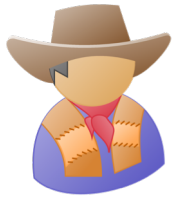
Setup Phase

Listener of round t

R

Speaker of round t

Round 1



Speaker of round t

$Broadcasts\ OT_1\ messages$

OT_1 messages commit to all actions in the first round.

Can we parallelize the first round with the setup phase?

2 Round Protocol with setup

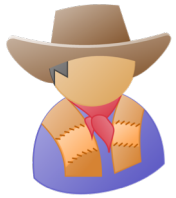
Setup Phase

Listener of round t

R

Speaker of round t

Round 1



Speaker of round t

$Broadcasts\ OT_1\ messages$

OT_1 messages depend on R which is not known before setup.

Can we parallelize the first round with the setup phase?

2 Round Protocol with setup

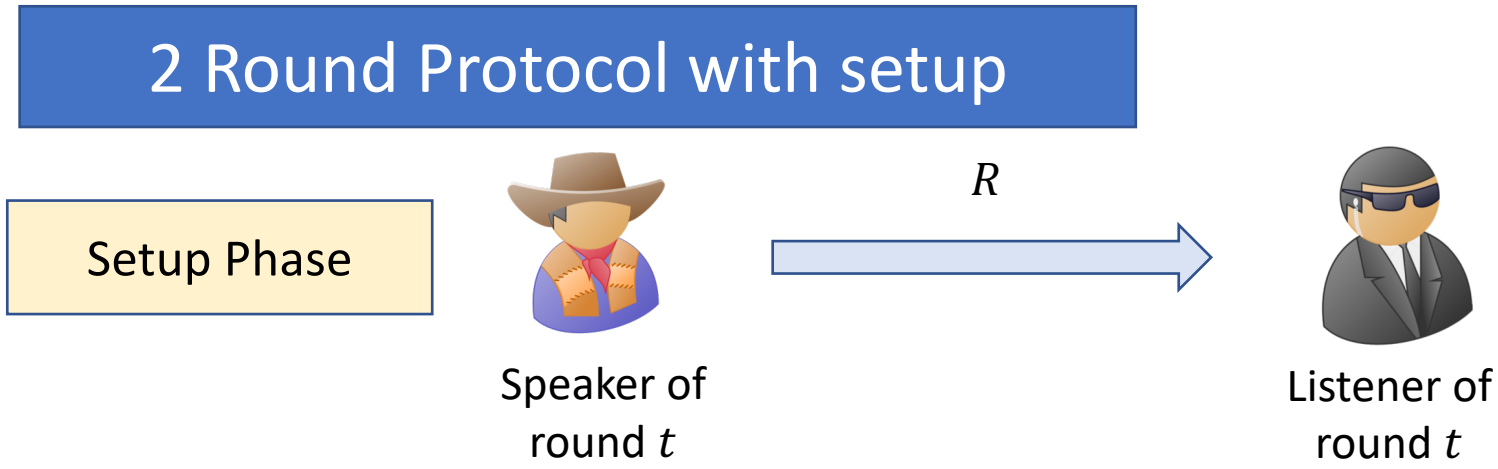
Setup Phase

Speaker of round t

R

Listener of round t

Can we parallelize the first round with the setup phase?



- Similar problem arises.
- Transfers the problem to another round.

Can we parallelize the first round with the setup phase?

2 Round Protocol with setup

Setup Phase

R

Speaker of round 2

Listener of round 2

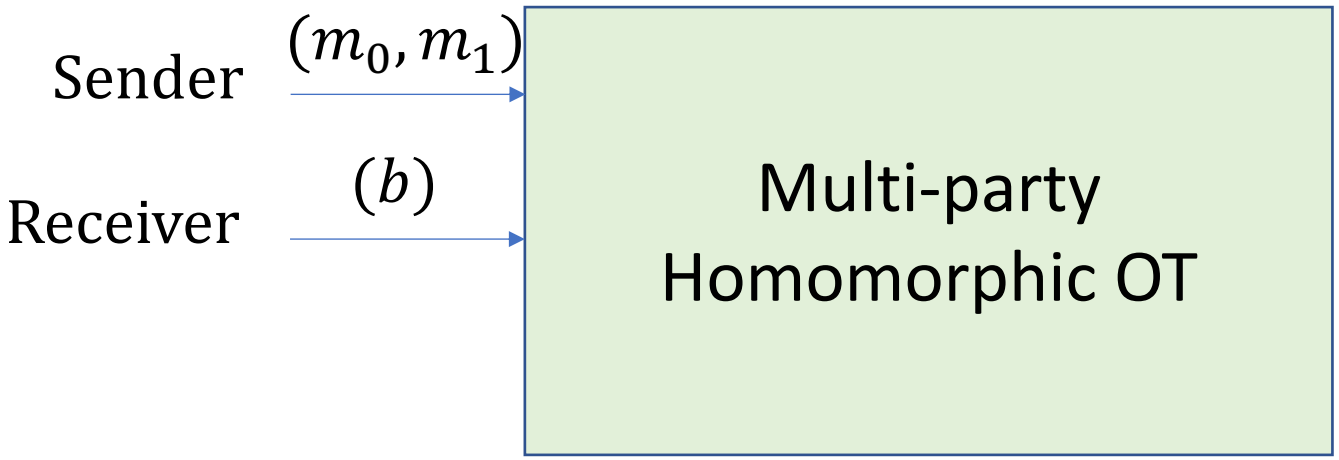
This approach doesn't seem to work!

- Similar problem arises.
- Transfers the problem to another round.

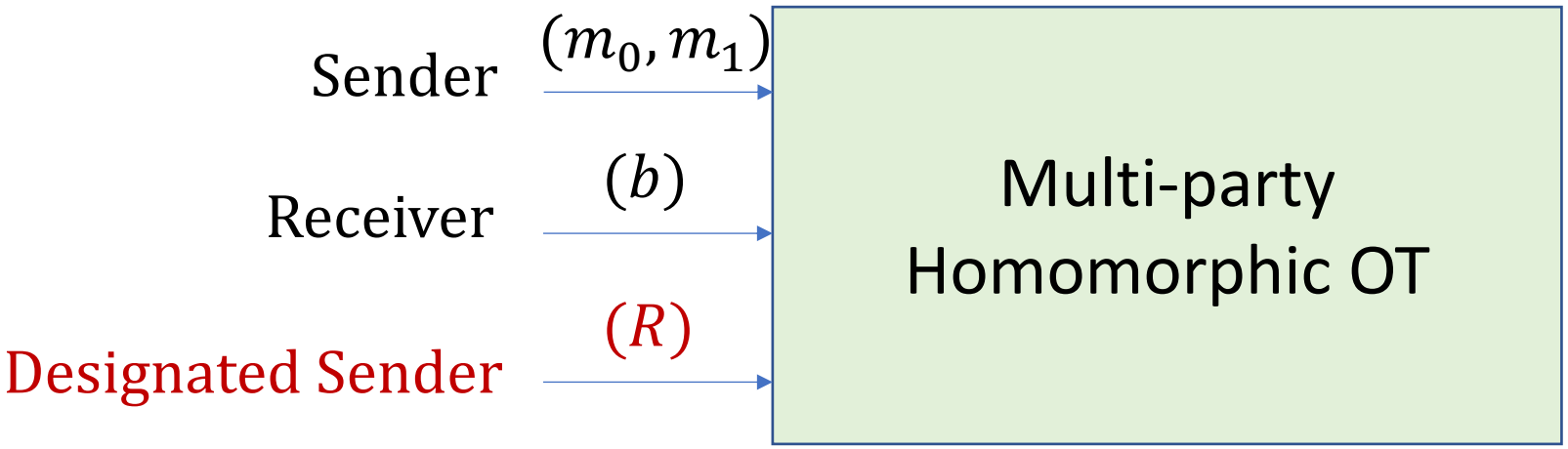
Multi-party Homomorphic OT

- Multi-party protocol.
- Only 3 parties have inputs, others have no input.
- Every party receives the output.

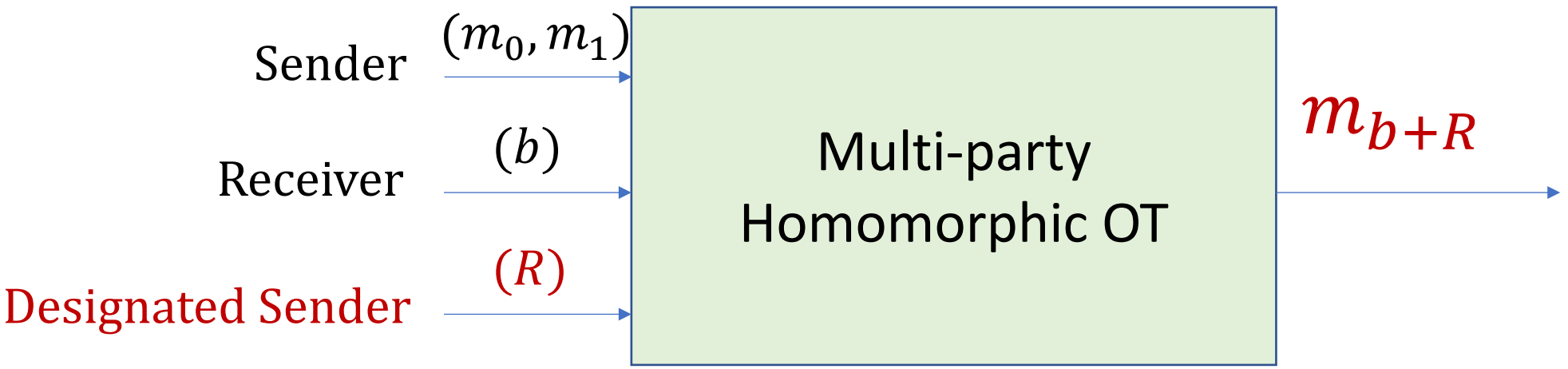
Multi-party Homomorphic OT



Multi-party Homomorphic OT



Multi-party Homomorphic OT



Multi-party Homomorphic OT

- The homomorphic OT functionality with sender inputs (m_0, m_1), receiver input (b) and designated sender input (R) can be represented as degree 2 polynomial in $\mathbb{F}_2$.

$$m_{b+R} = m_0(1 + b + R) + m_1(b + R)$$

Parallelizing using MHOT

2 Round Protocol with setup

Listener of round t

R

Speaker of round t

Setup Phase

Speaker of round t

$Broadcasts\ OT_1\ messages$

Round 1

Parallelizing using MHOT

2 Round Protocol with setup

Listener of round t

R

Speaker of round t

Setup Phase

Speaker of round t

$Broadcasts\ OT_1\ messages$

Round 1

Listener of round t

$Broadcasts\ OT_1\ message\ using\ input\ R$

Parallelizing using MHOT

2 Round Protocol with setup parallelized

Listener of round t

R

Speaker of round t

Setup Phase

Round 1

Speaker of round t

$Broadcasts\ OT_1\ messages$

Listener of round t

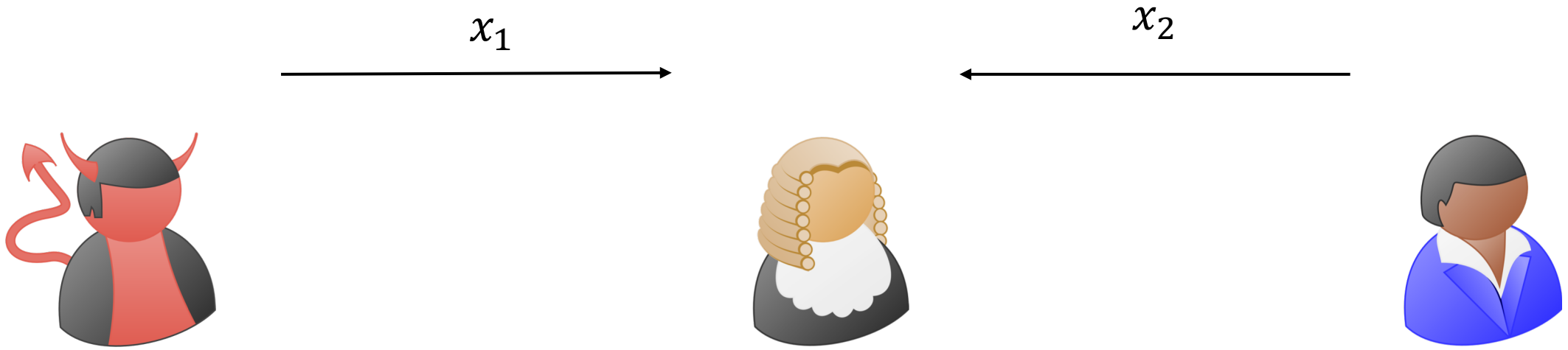
$Broadcasts\ OT_1\ message\ using\ input\ R$

The homomorphism property of the multi-party OT allows us to parallelize

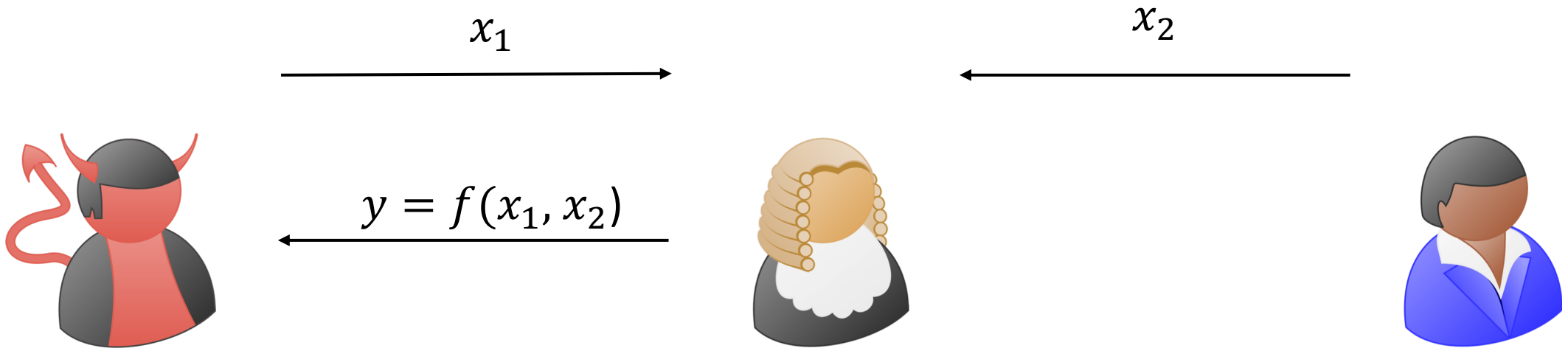
Instantiating Multi-party Homomorphic OT

- [Ishai-Kushilevitz-Paskin10] give a construction for such a degree 2 polynomial computation protocol that satisfies statistical t-privacy with knowledge of outputs.

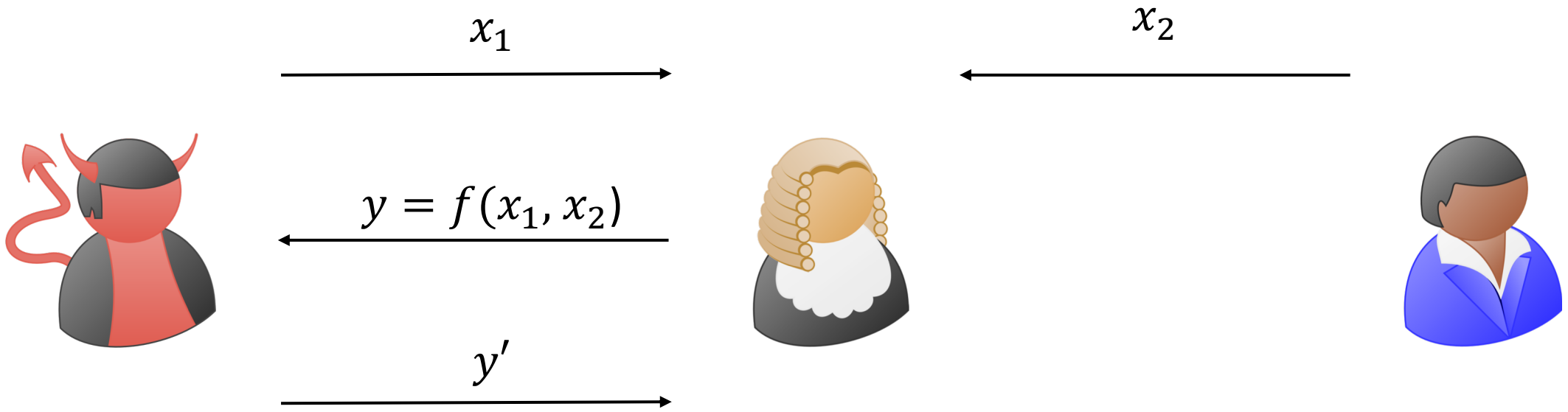
Ideal World: Privacy with Knowledge of Outputs



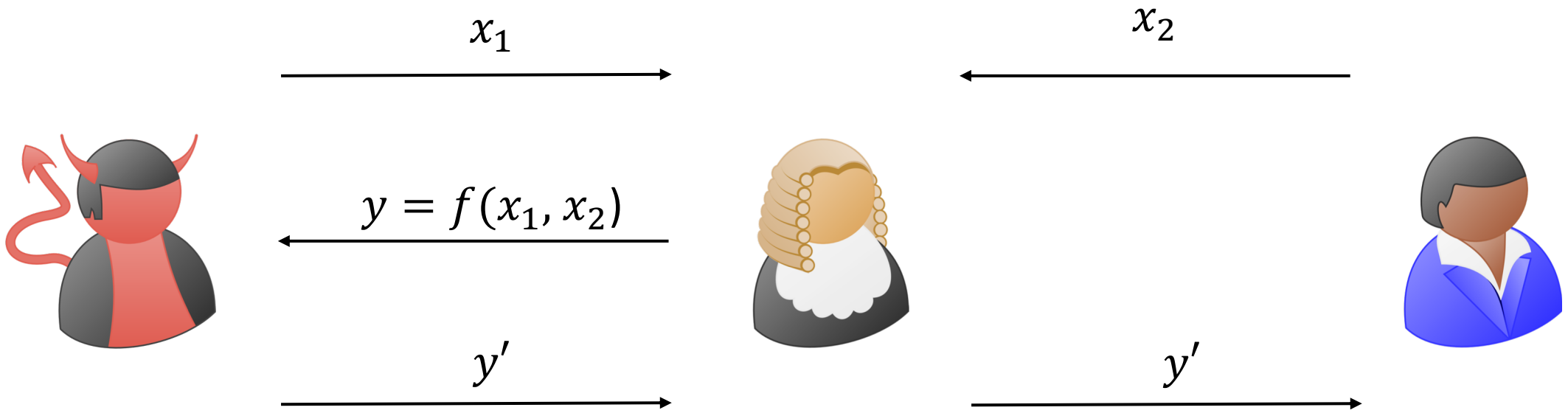
Ideal World: Privacy with Knowledge of Outputs



Ideal World: Privacy with Knowledge of Outputs



Ideal World: Privacy with Knowledge of Outputs



Instantiating Multi-party Homomorphic OT

- [Ishai-Kushilevitz-Paskin10] give a construction for such a degree 2 polynomial computation protocol that satisfies statistical t-privacy with knowledge of outputs.

Privacy with knowledge of outputs: A weaker notion than security with abort that does not guarantee correctness of output of the honest parties.

Instantiating Multi-party Homomorphic OT

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Challenge: How to ensure correctness of honest party outputs?

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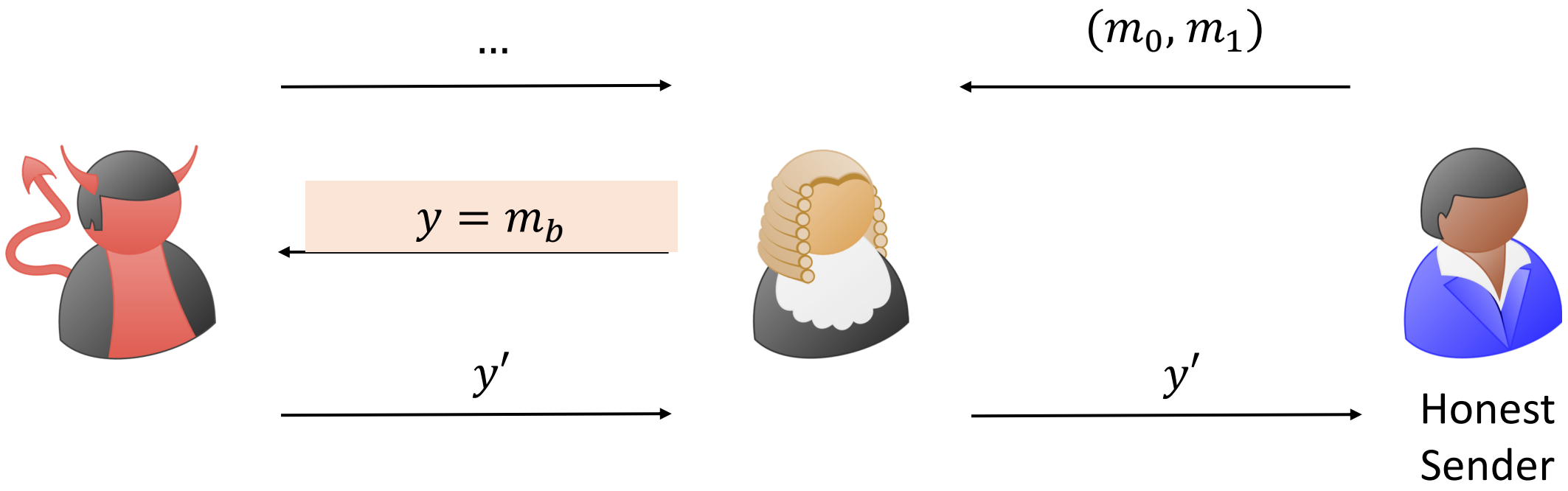
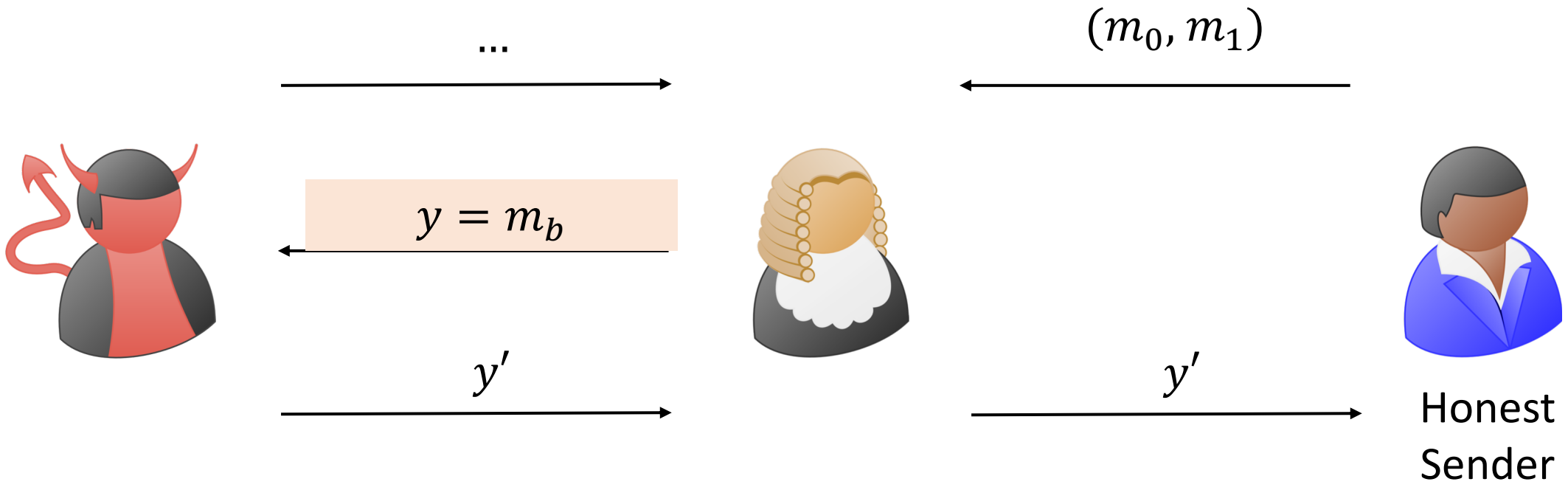


Challenge: How to ensure correctness of honest party outputs?



y' does not depend on m_{1-b}

Challenge: How to ensure correctness of honest party outputs?

- OT functionality transmits wire labels for GC.
- Unless valid labels are transmitted, GC remains private.

https://eprint.iacr.org/2018/572

Thank You.

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