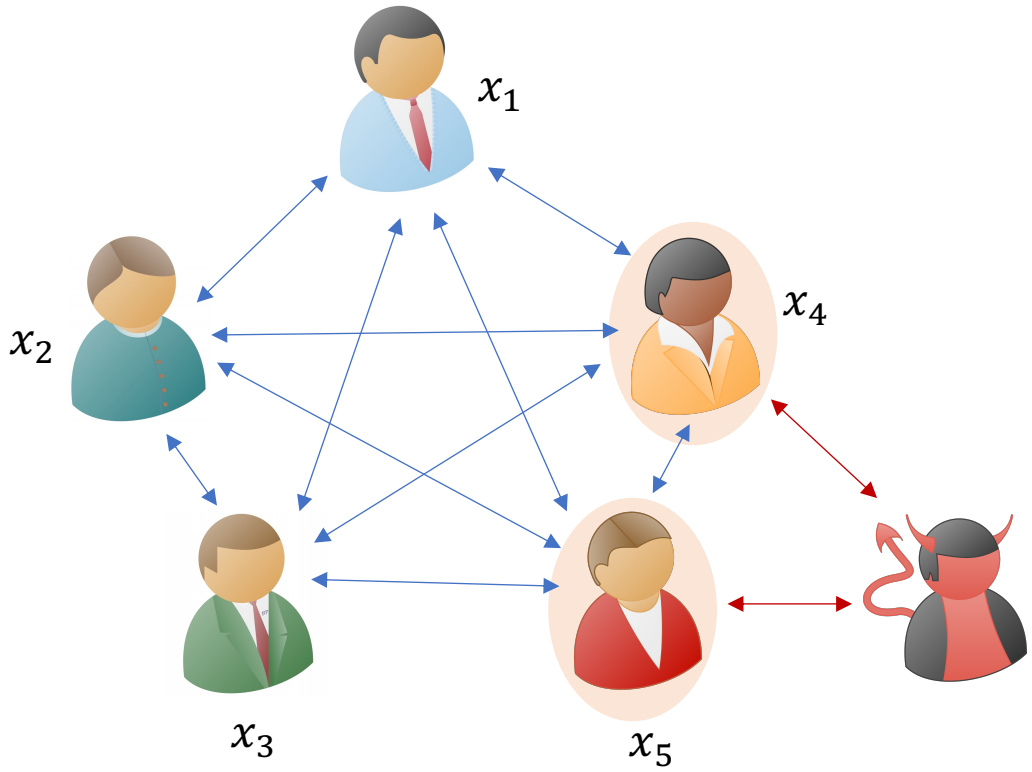
On Communication Models and Best-Achievable Security in Two-Round MPC

Aarushi Goel Abhishek Jain Manoj Prabhakaran Rajeev Raghunath

TCC 2021

Secure Multiparty Computation (MPC)

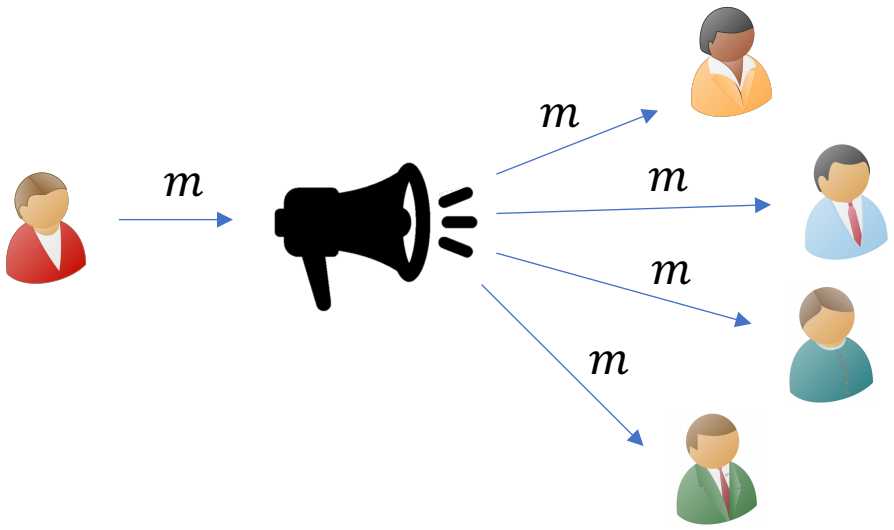


Adversary learns nothing beyond the output y

MPC protocol for computing $y = f(x_1, x_2, x_3, x_4, x_5)$

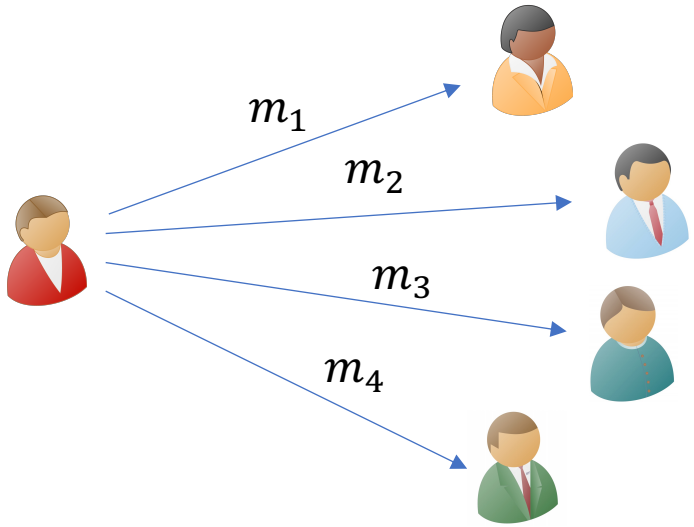
Communication Models

Broadcast Channel



Necessary for achieving security against $t > n/3$ corruptions

Private Point-to-Point (P2P) Channels



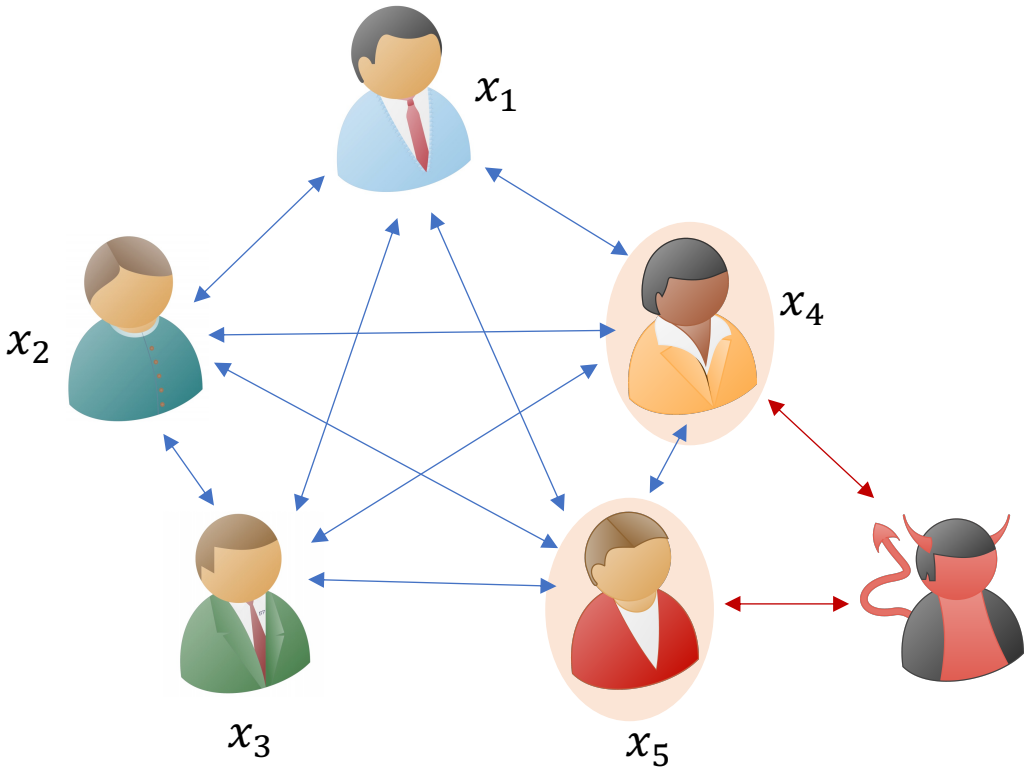
Necessary for achieving information theoretic security

Our Setting: Two-Rounds

Minimal Rounds, since one-round MPC is impossible [HLP'11]

A lot of advancement in recent years
[GS'18, BL'18, PR18, ACGJ'18, ABT'18, GIS'18, ACGJ'19, ABT'19]

Our Setting: Honest Majority [BGW88]



Adversary corrupts a minority of the parties

Advantages

Enables stronger security guarantees

Can be designed using only symmetric-key primitives

Can be designed in fewer Rounds

Often holds up in practice

Main Question

In two-round honest-majority MPC, in the different communication models involving broadcast and P2P channels:

- What levels of security are achievable for general computation?
- Under what assumptions?

In this work we focus on the plain model (no setup) and sometimes augment it to use a bare public-key infrastructure (bare PKI)

Different Security Notions

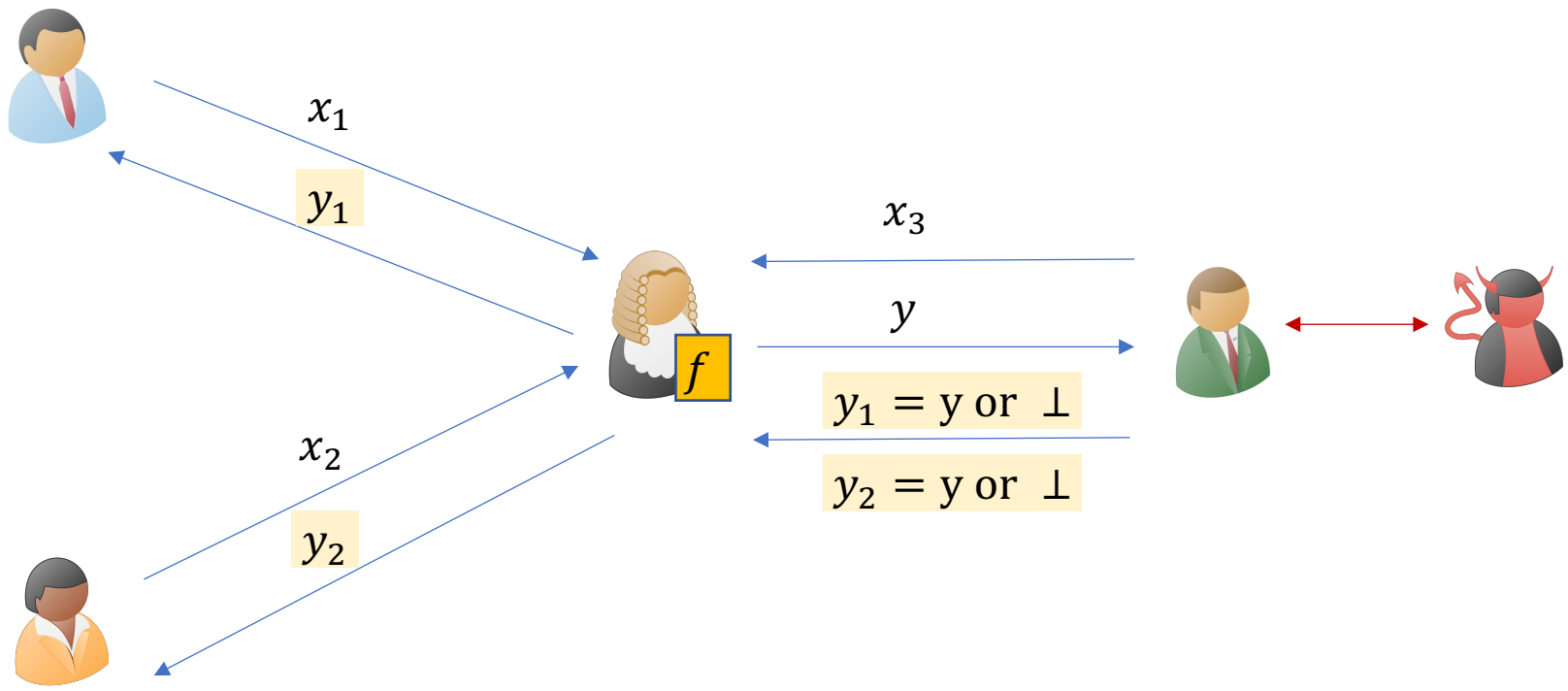
Privacy against semi-honest adversaries

Different Security Notions

Privacy against semi-honest adversaries

Security with (Selective/Unanimous/Identifiable) abort against malicious adversaries

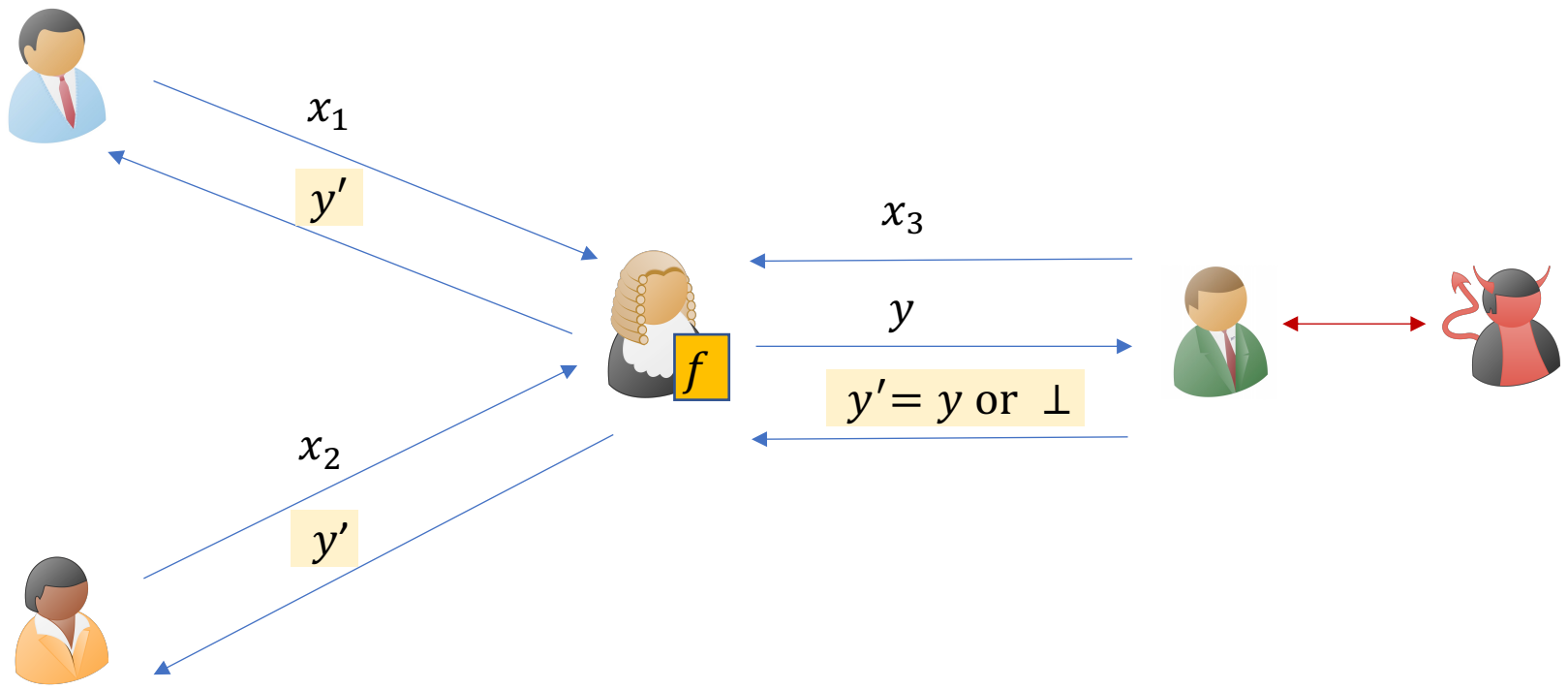
Security with Selective Abort



Honest Parties

Corrupt Party

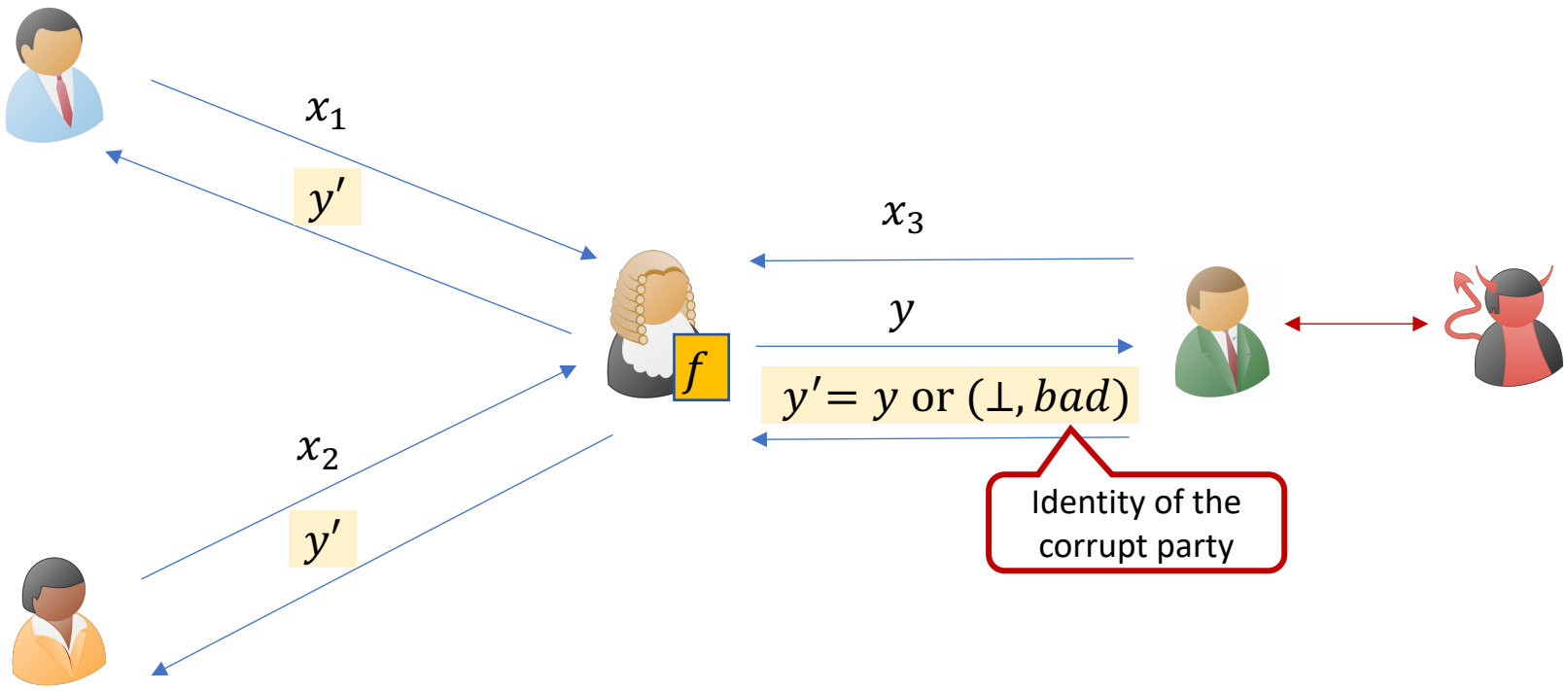
Security with Unanimous Abort



Honest Parties

Corrupt Party

Security with Identifiable Abort



Honest Parties

Corrupt Party

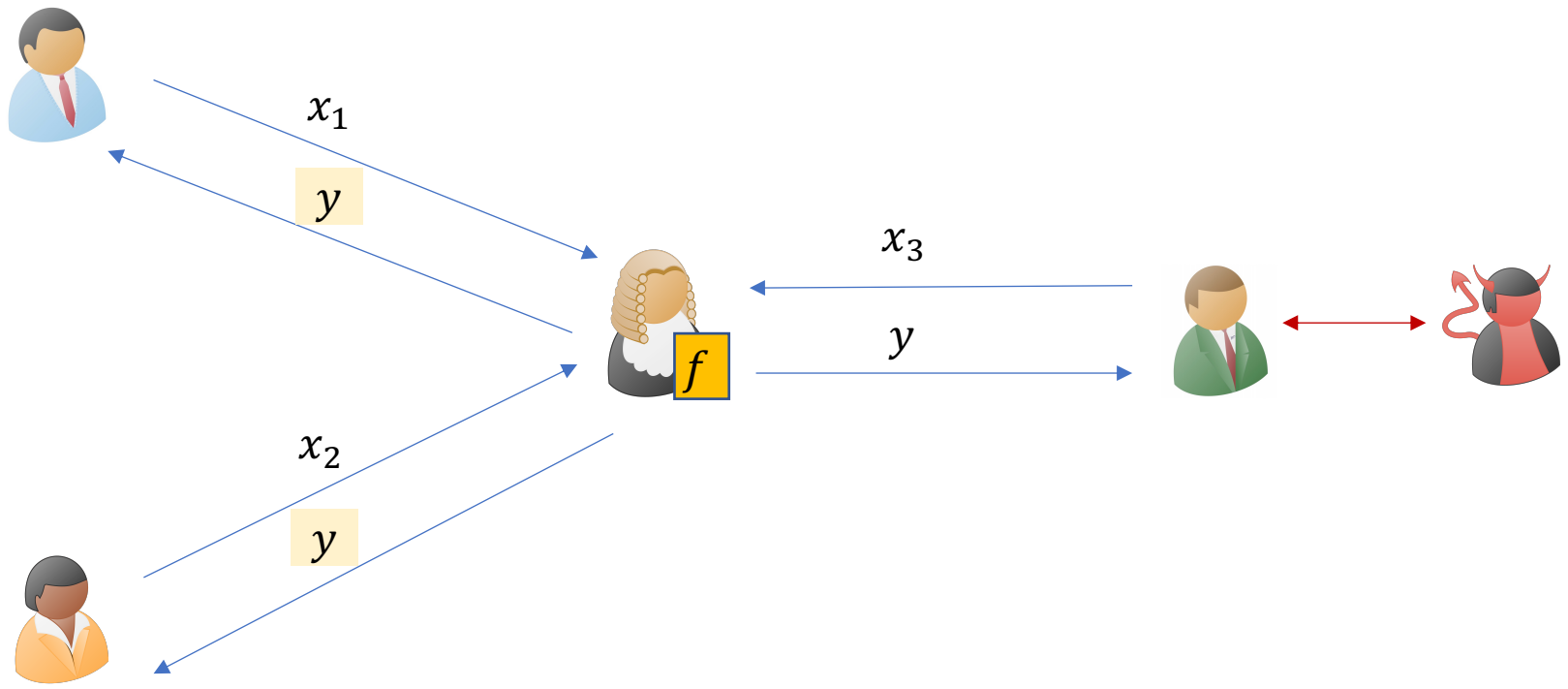
Different Security Notions

Privacy against semi-honest adversaries

Security with (Selective/Unanimous/Identifiable) abort against malicious adversaries

Guaranteed output delivery against (Malicious/Fail-stop) adversaries

Guaranteed Output Delivery

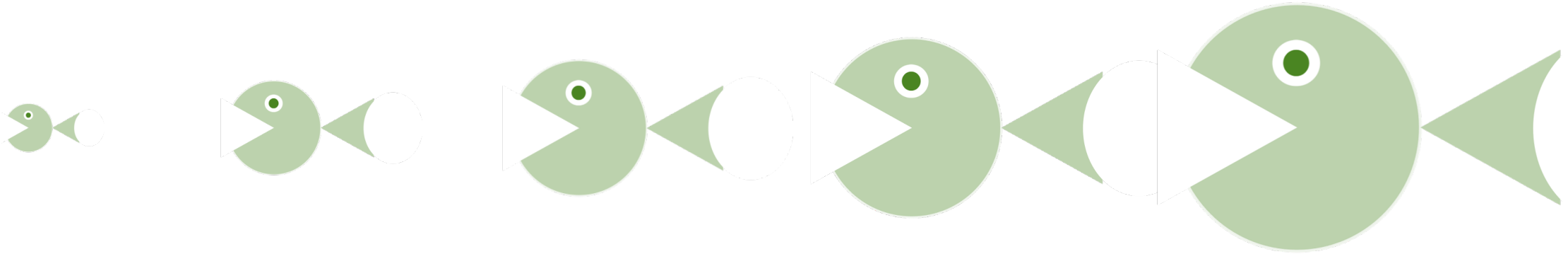


Honest Parties

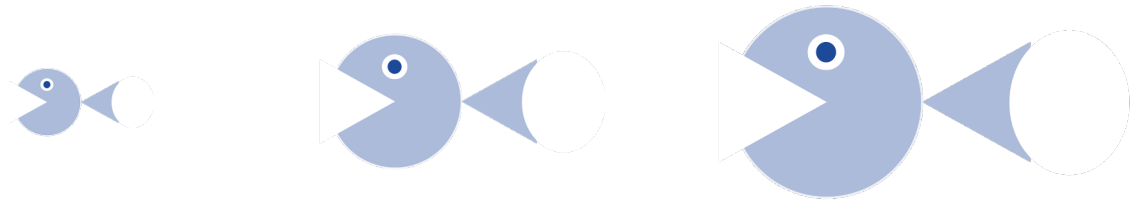
Corrupt Party

Adversary is either malicious or fail-stop

Hierarchy of Security Notions

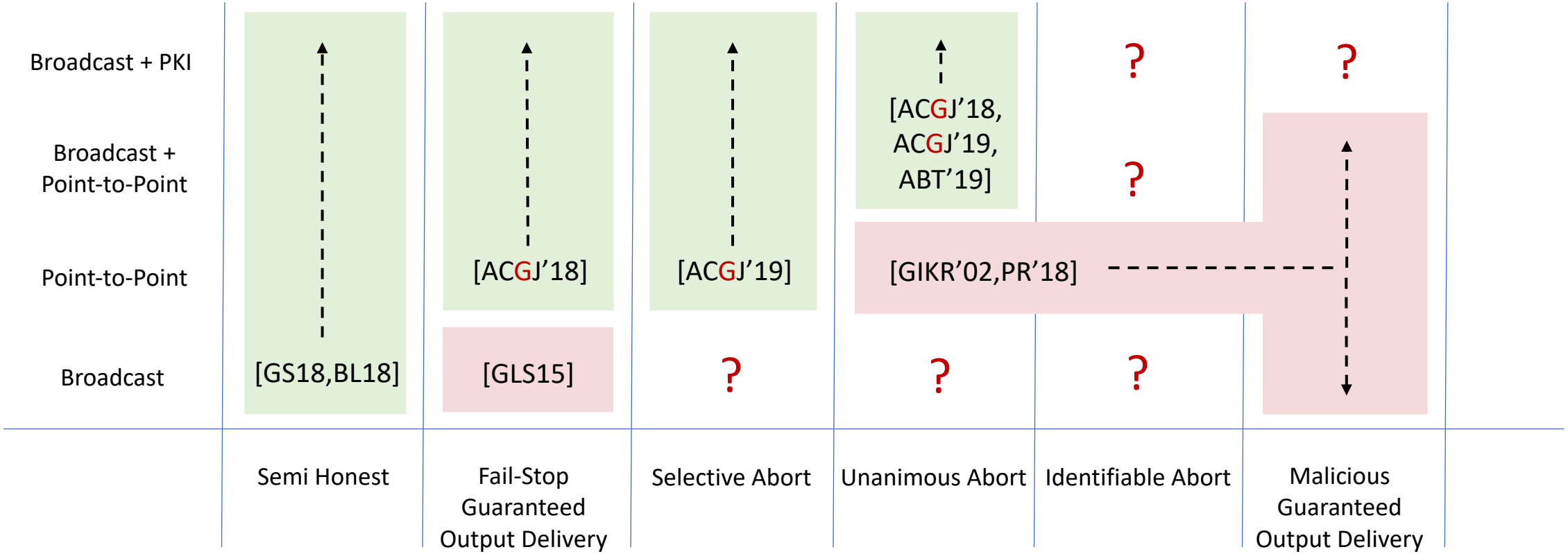


Semi Honest | Selective Abort | Unanimous Abort | Identifiable Abort | Guaranteed Output Delivery

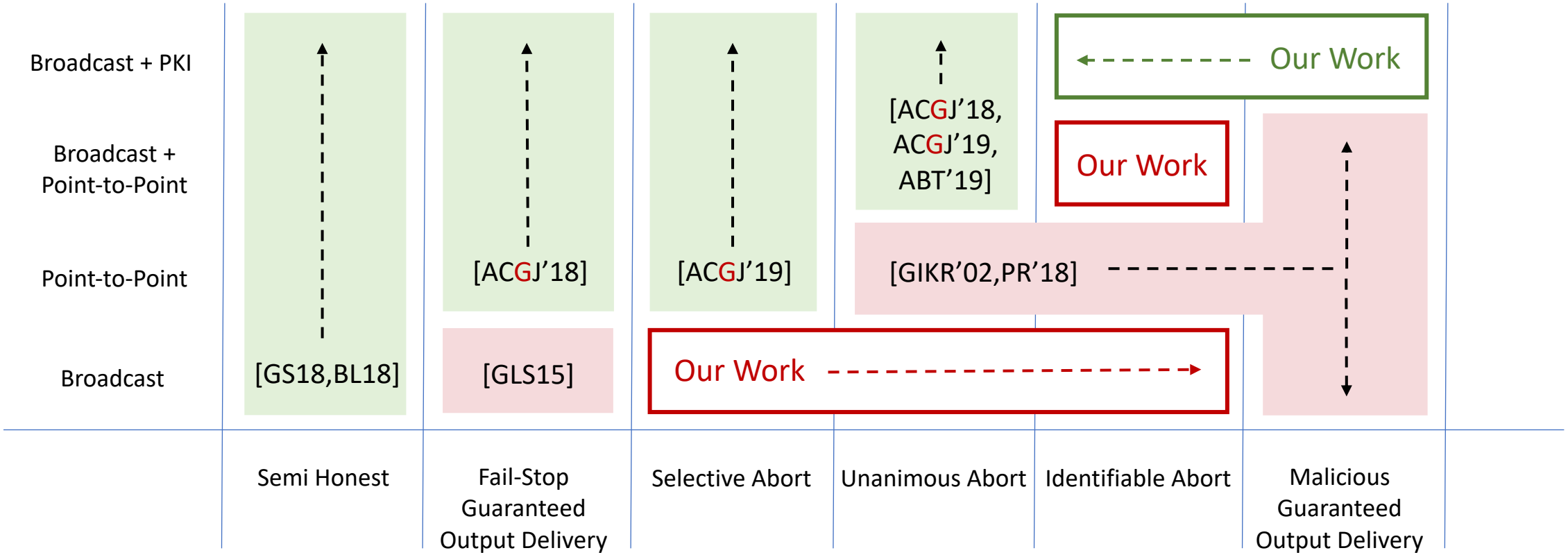


Semi Honest | Fail-stop guaranteed output delivery | Malicious guaranteed output delivery

Two-Round MPC

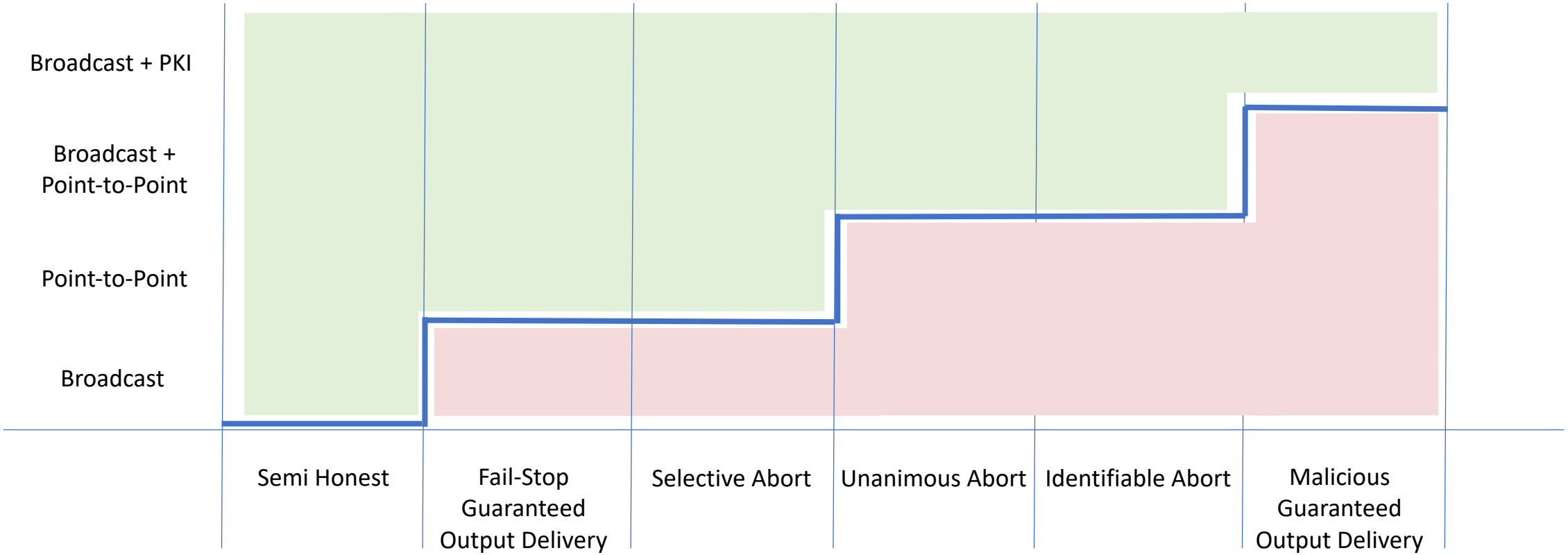


Two-Round MPC (Completing the Picture)

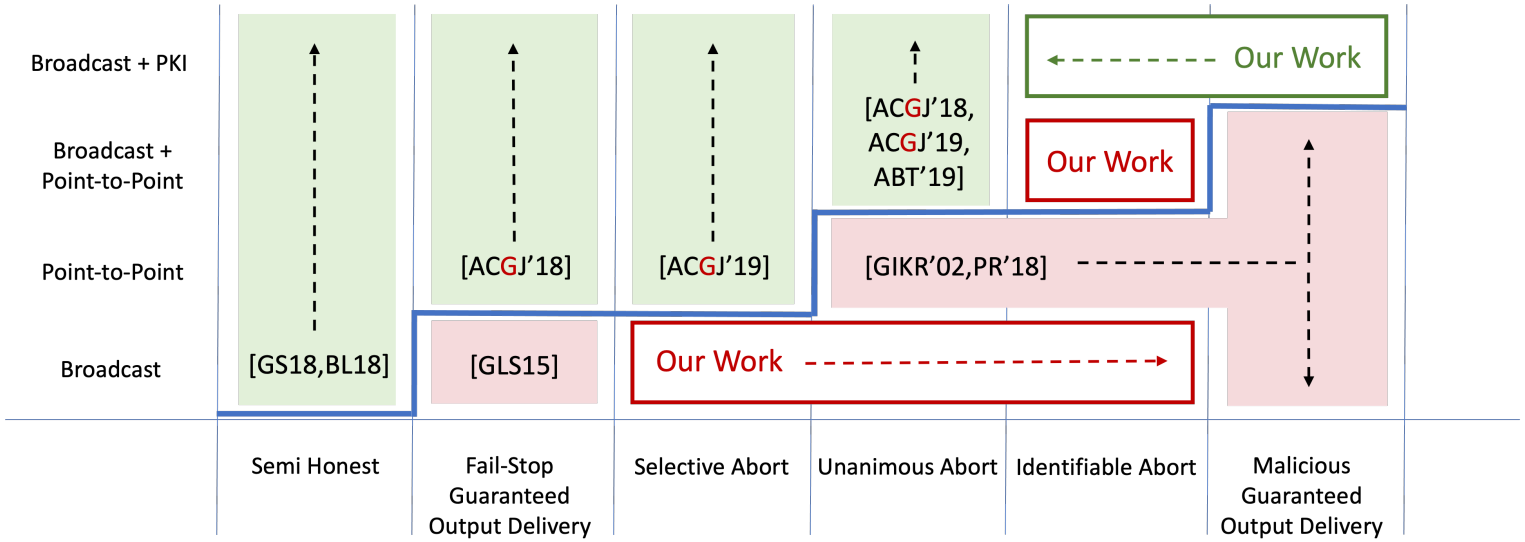


Hierarchy of Communication Models

Broadcast < Point-to-Point < Broadcast + Point-to-Point < Broadcast + PKI



Our Contributions



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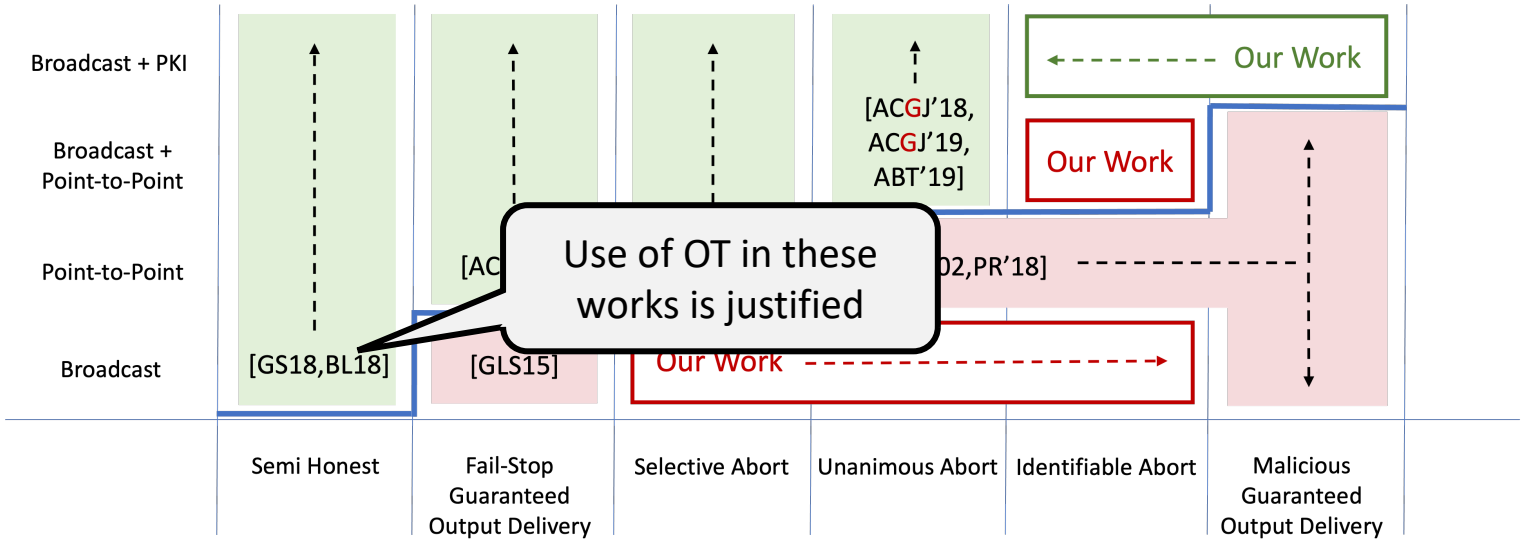
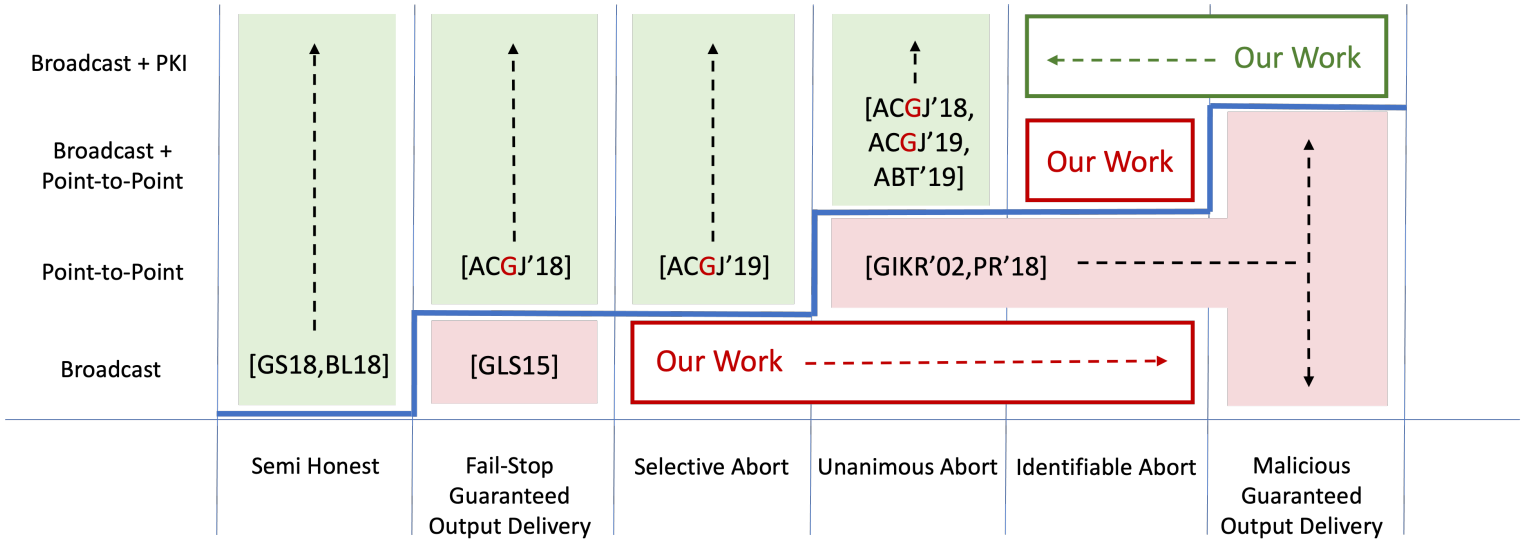


Two-round honest-majority semi-honest/malicious MPC over broadcast channels
⇒ semi-honest/malicious two-message OT

This implication holds both in the plain and in the CRS model

Our Contributions



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Two-message malicious OT is impossible in the plain model

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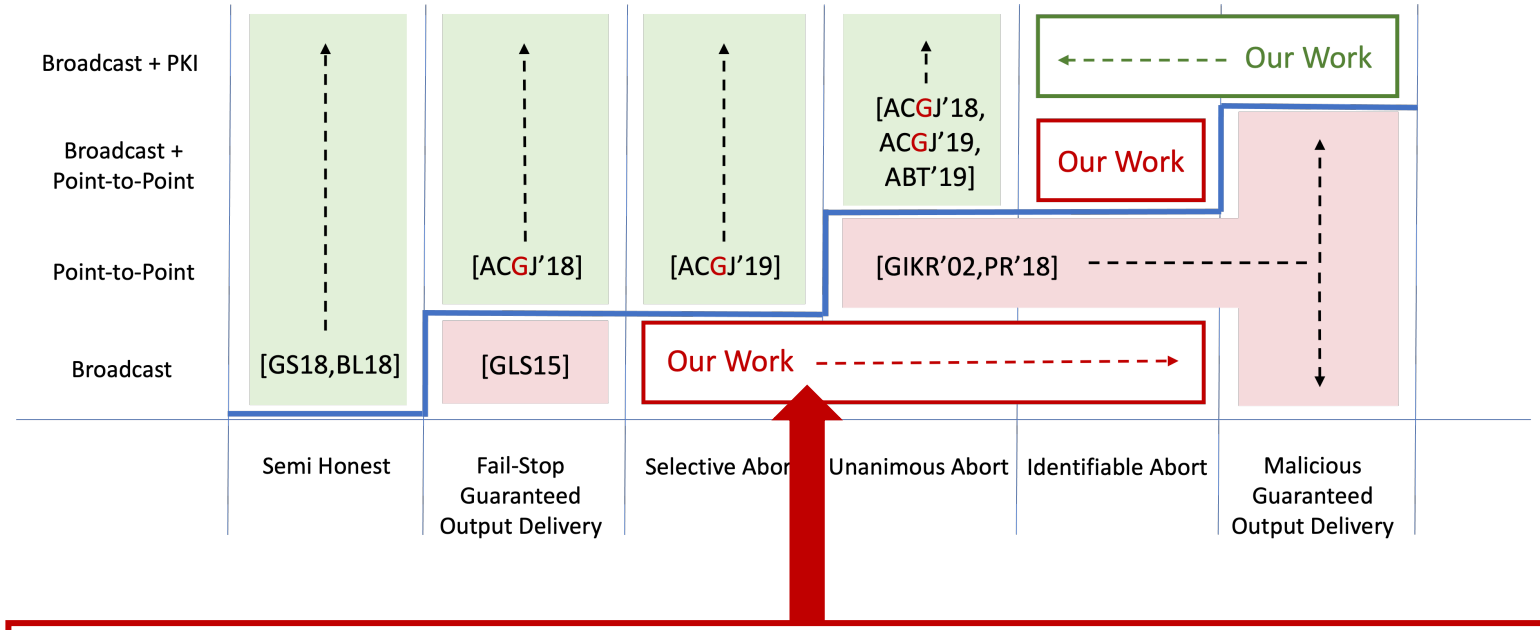

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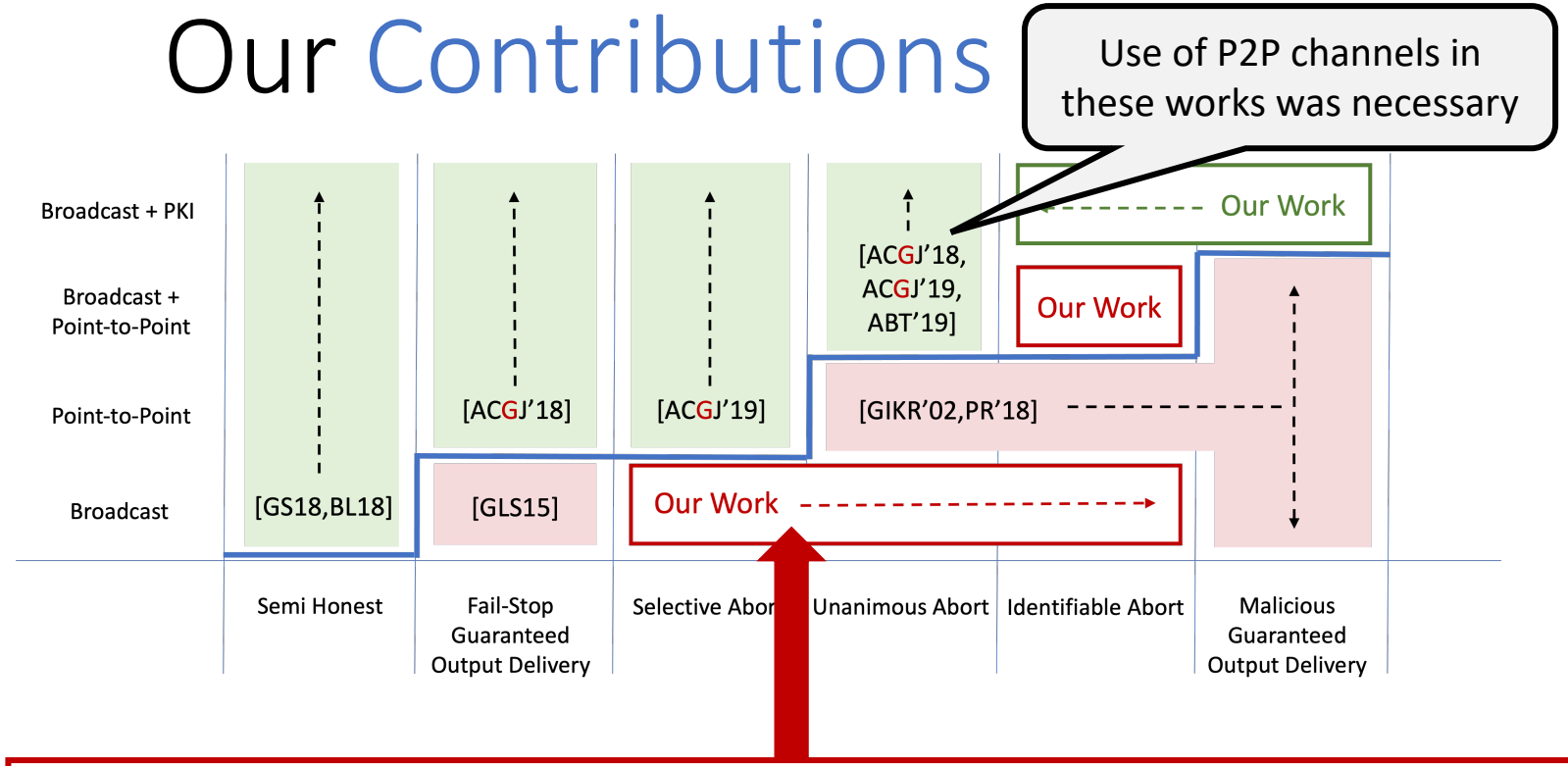

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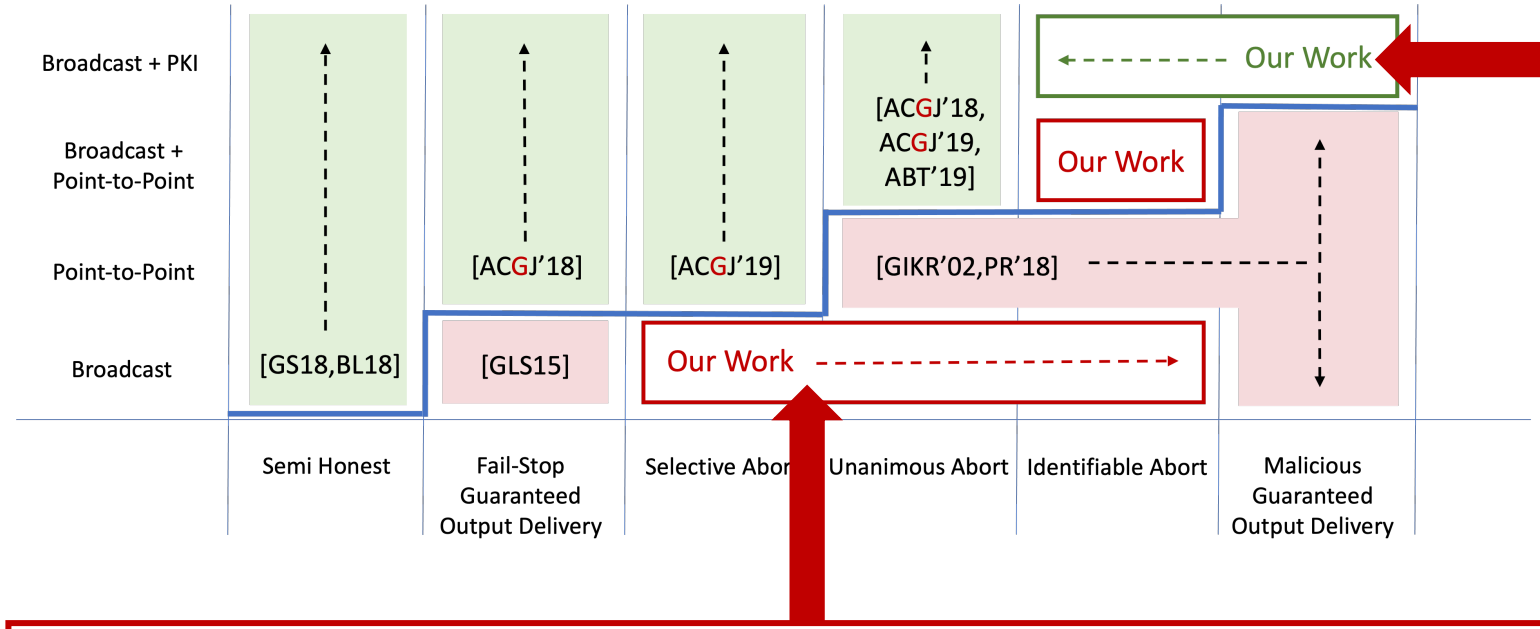
Establishes equivalence of honest majority and dishonest majority in this setting

Our Contributions



A two-round guaranteed output delivery protocol using PKE and multi-CRS NIZKs in broadcast + PKI setting for $t < n/2$

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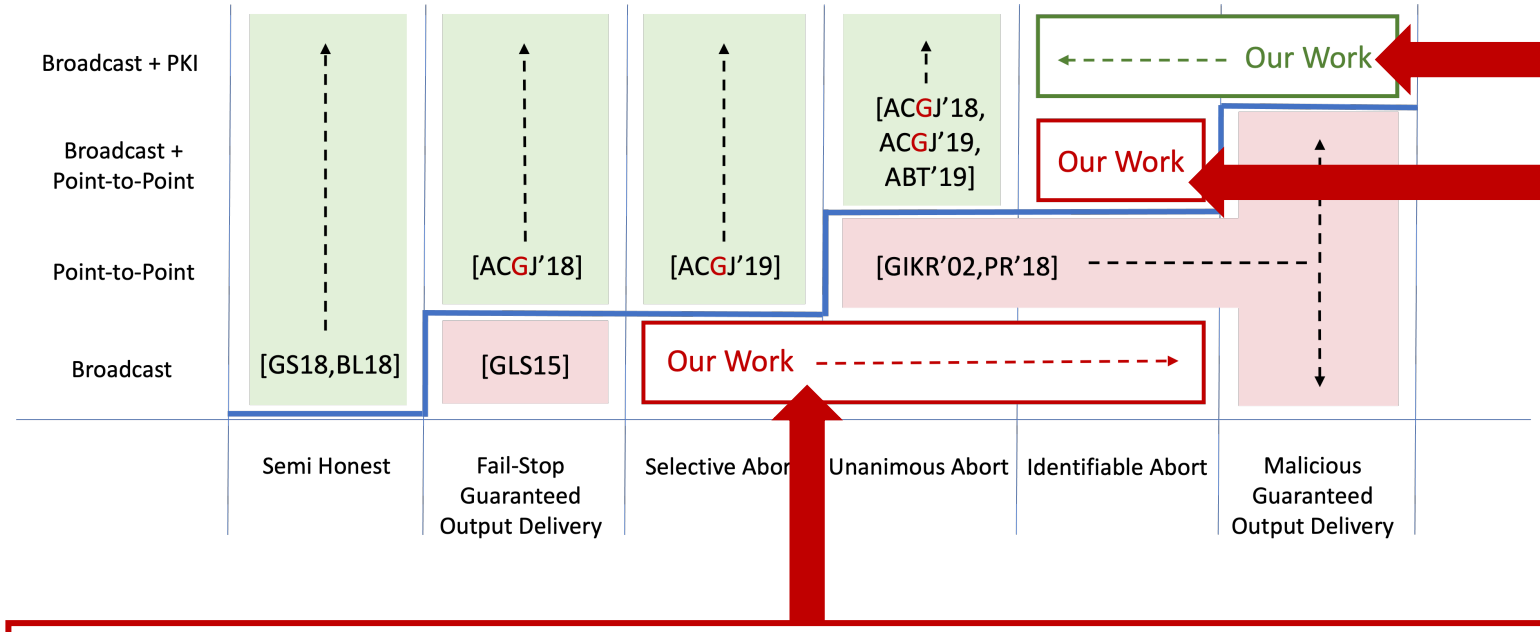

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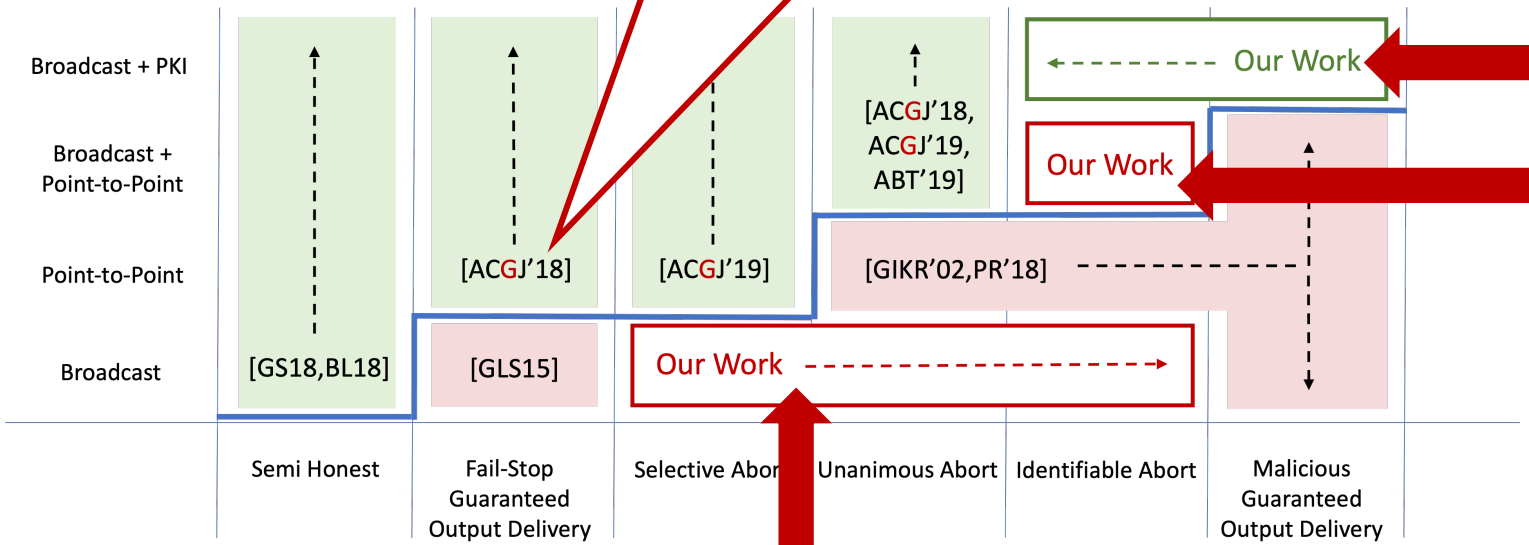
Two-message malicious OT is impossible in the plain model

Our Con

We also show that for $\frac{n}{3} < t < \frac{n}{2}$, fail-stop guaranteed output delivery implies OT!



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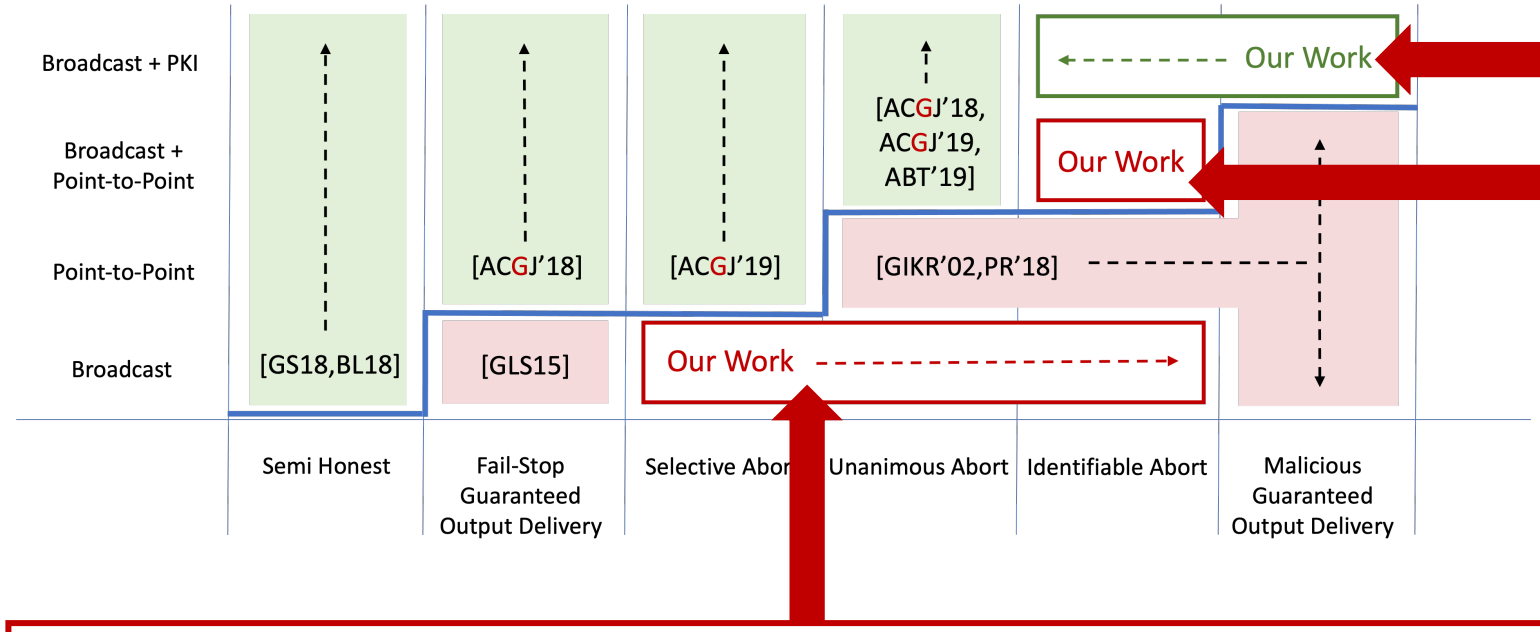

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⇒ semi-honest/malicious two-message OT

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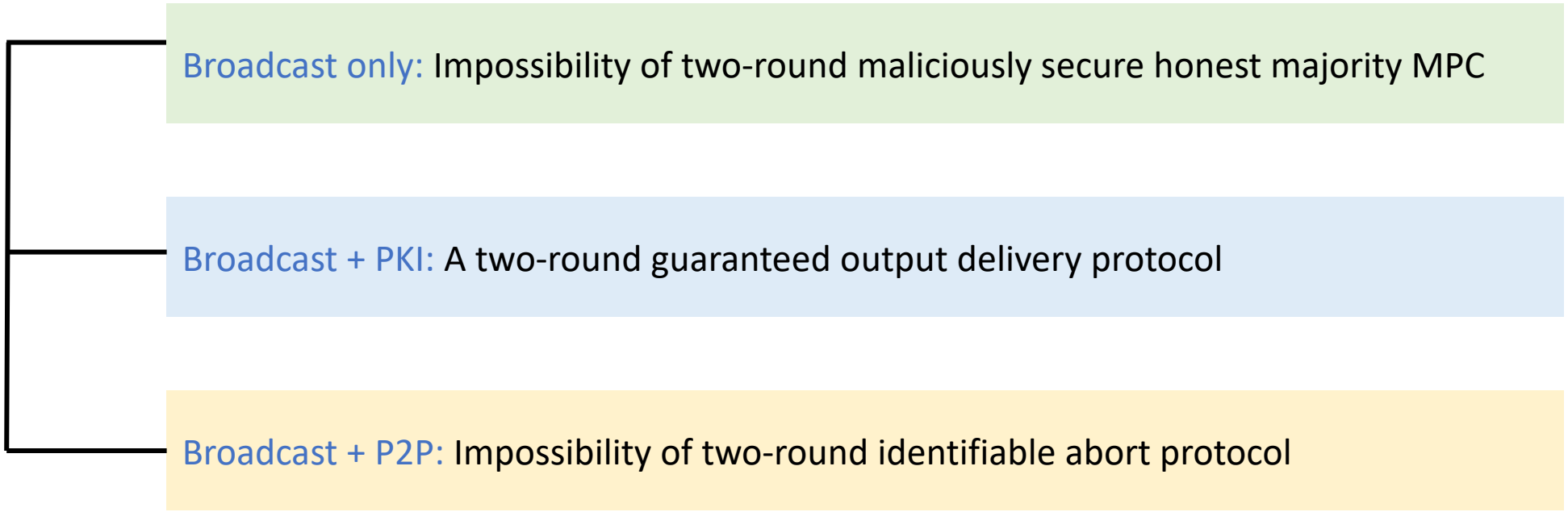
Two-message malicious OT is impossible in the plain model

Our Main Ideas

Talk Outline



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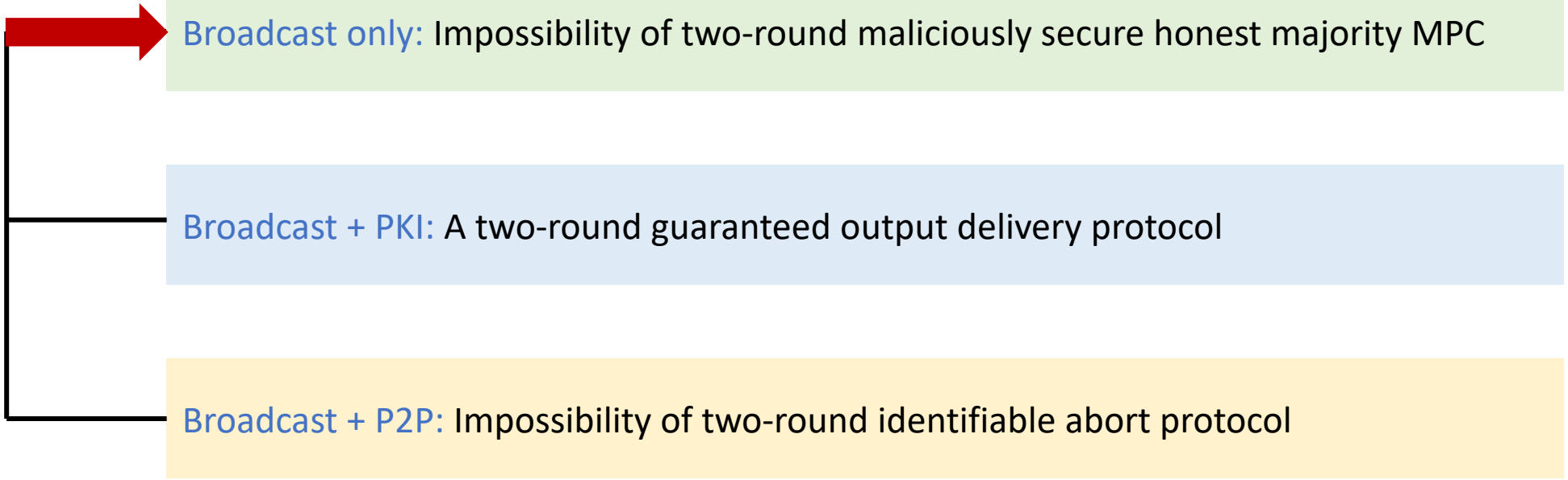
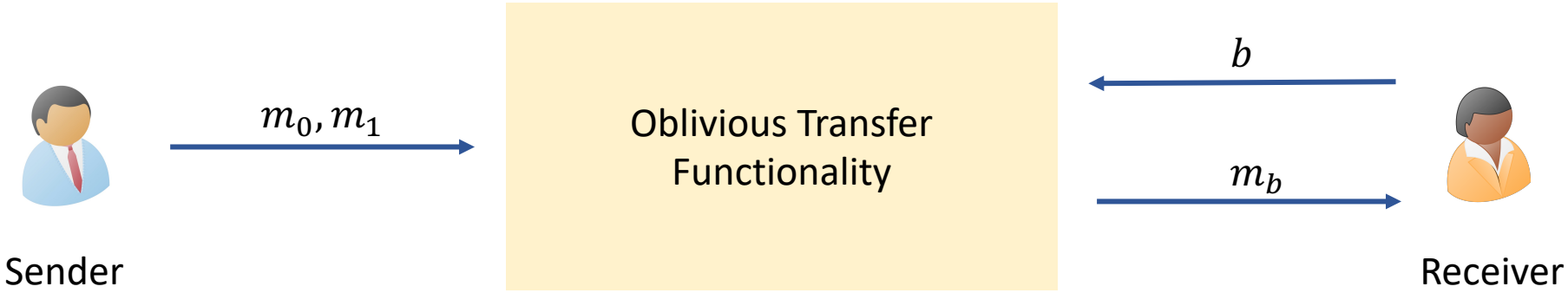
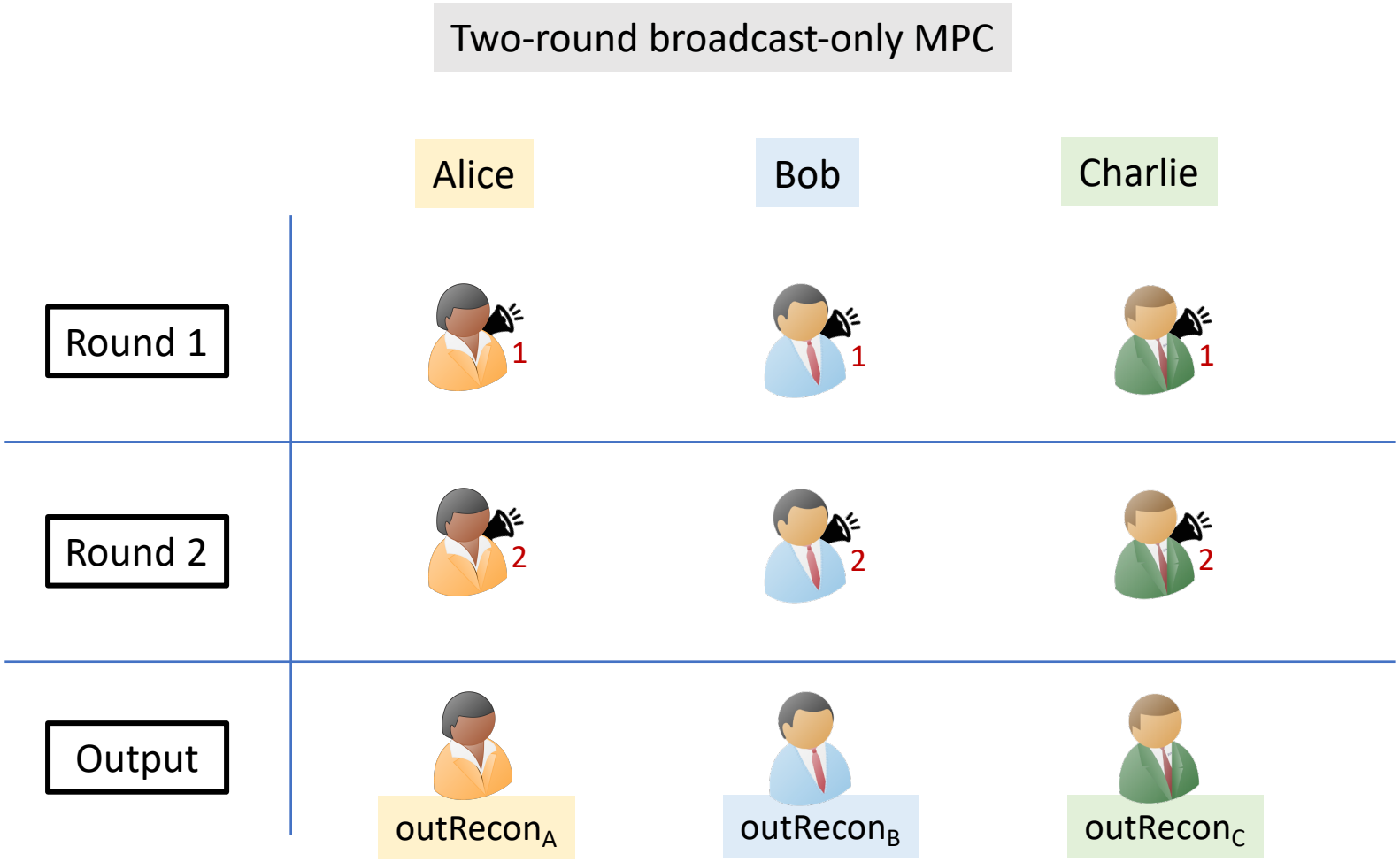


Oblivious Transfer



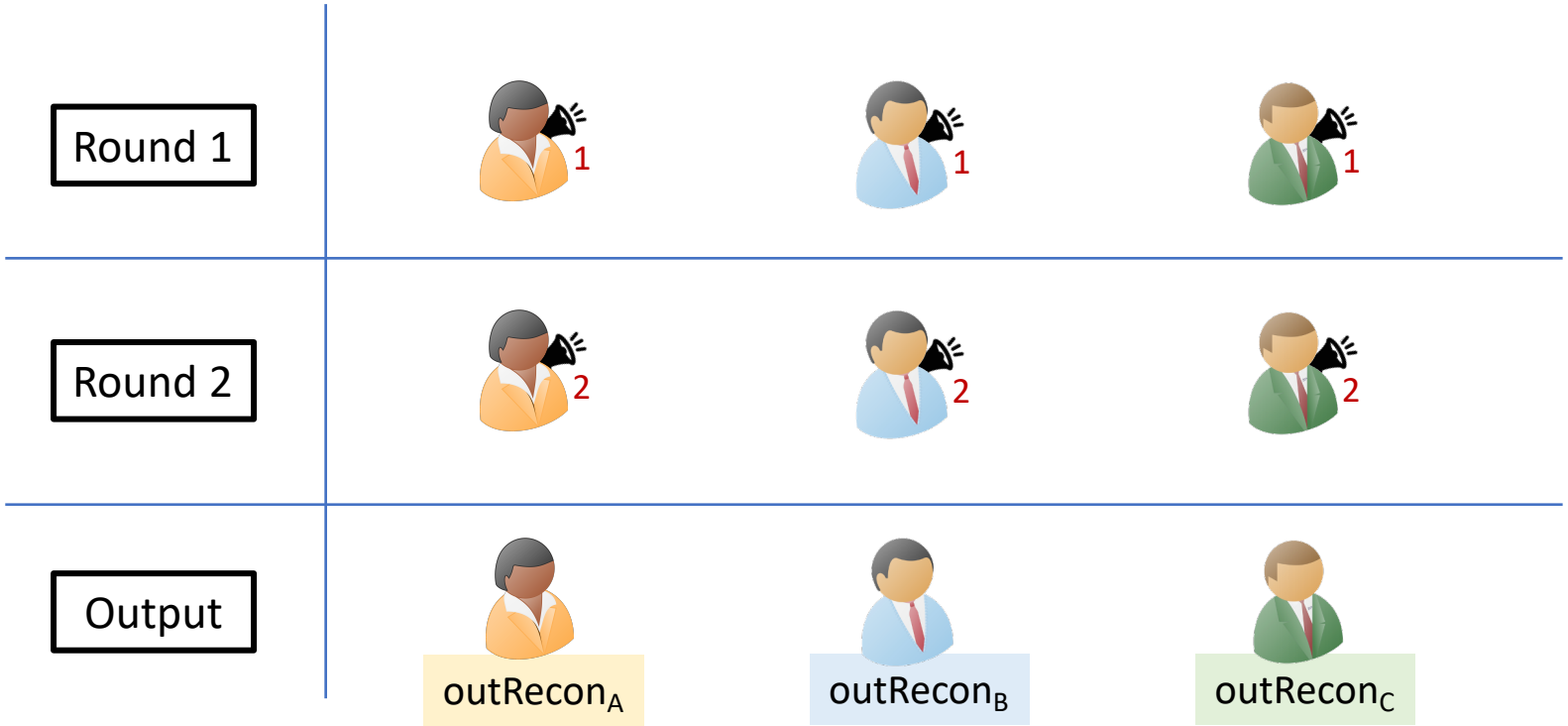
Broadcast-Only: Two-Round MPC implies OT



Broadcast-Only: Two-Round MPC implies OT

Two-round broadcast-only MPC for

$F(b, m_0, m_1, \perp) = (m_b, \perp, \perp)$

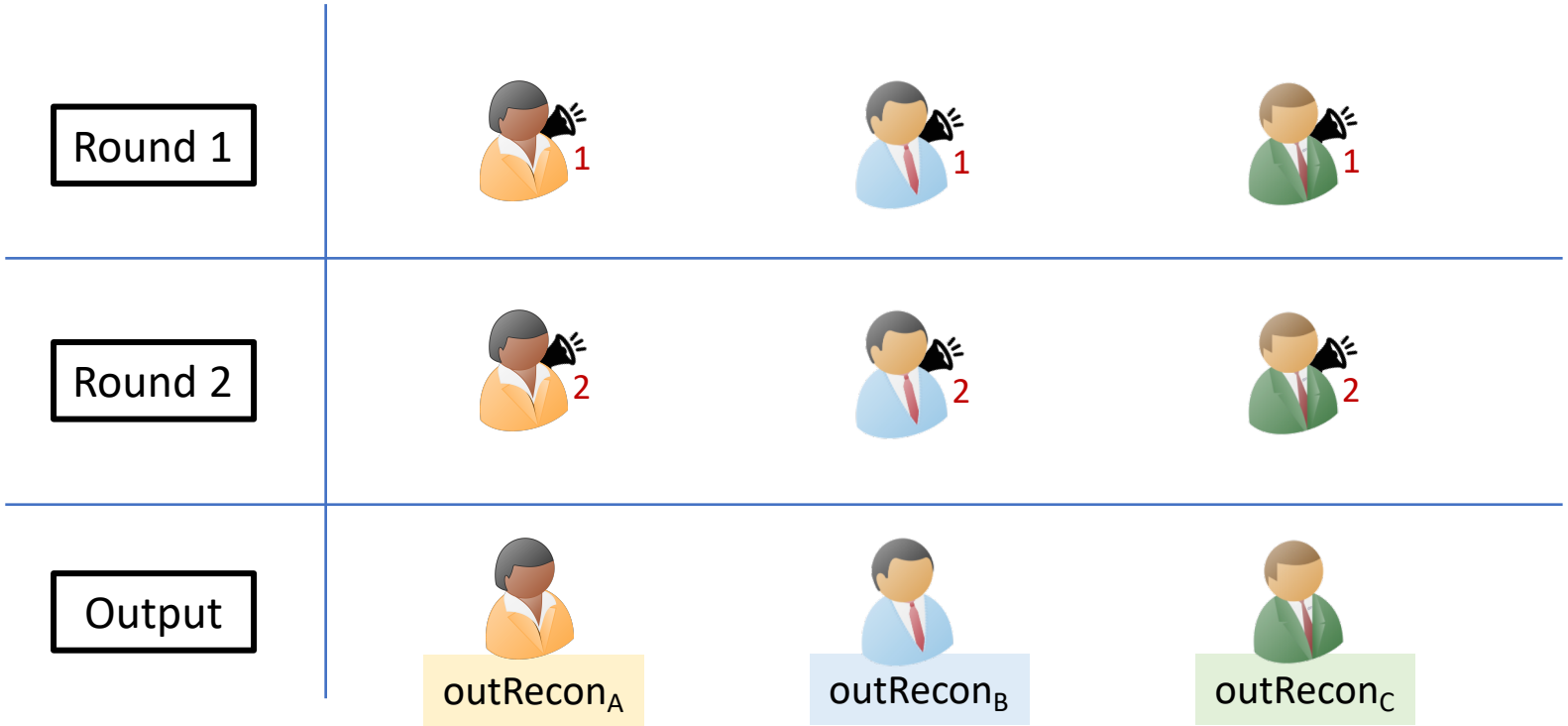


Broadcast-Only: Two-Round MPC implies OT

Receiver Sender Helper

Two-Round Broadcast-only MPC for

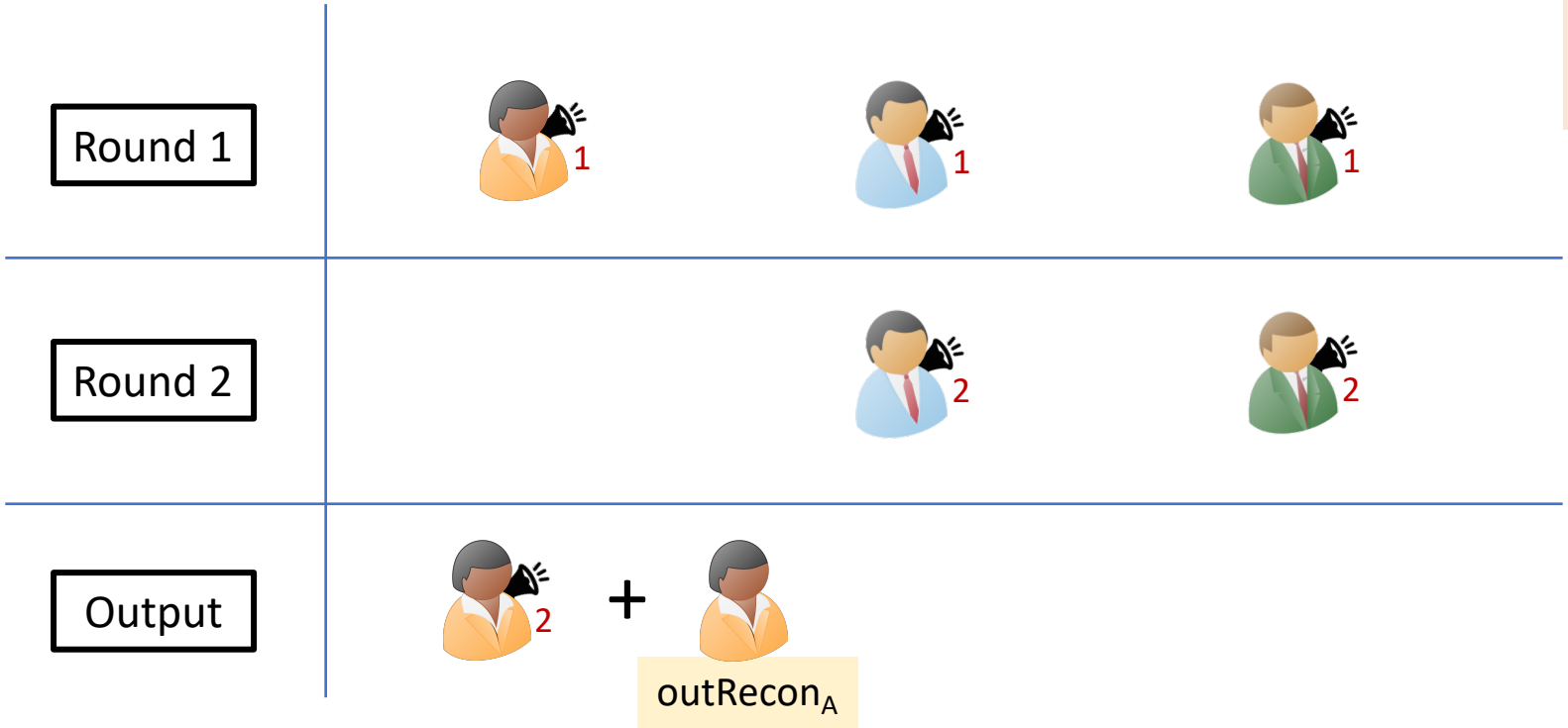
$F(b, m_0, m_1, \perp) = (m_b, \perp, \perp)$



Broadcast-Only: Two-Round MPC implies OT

Two-round broadcast-only MPC for

$F(b, m_0, m_1, \perp) = (\perp, m_b, \perp)$



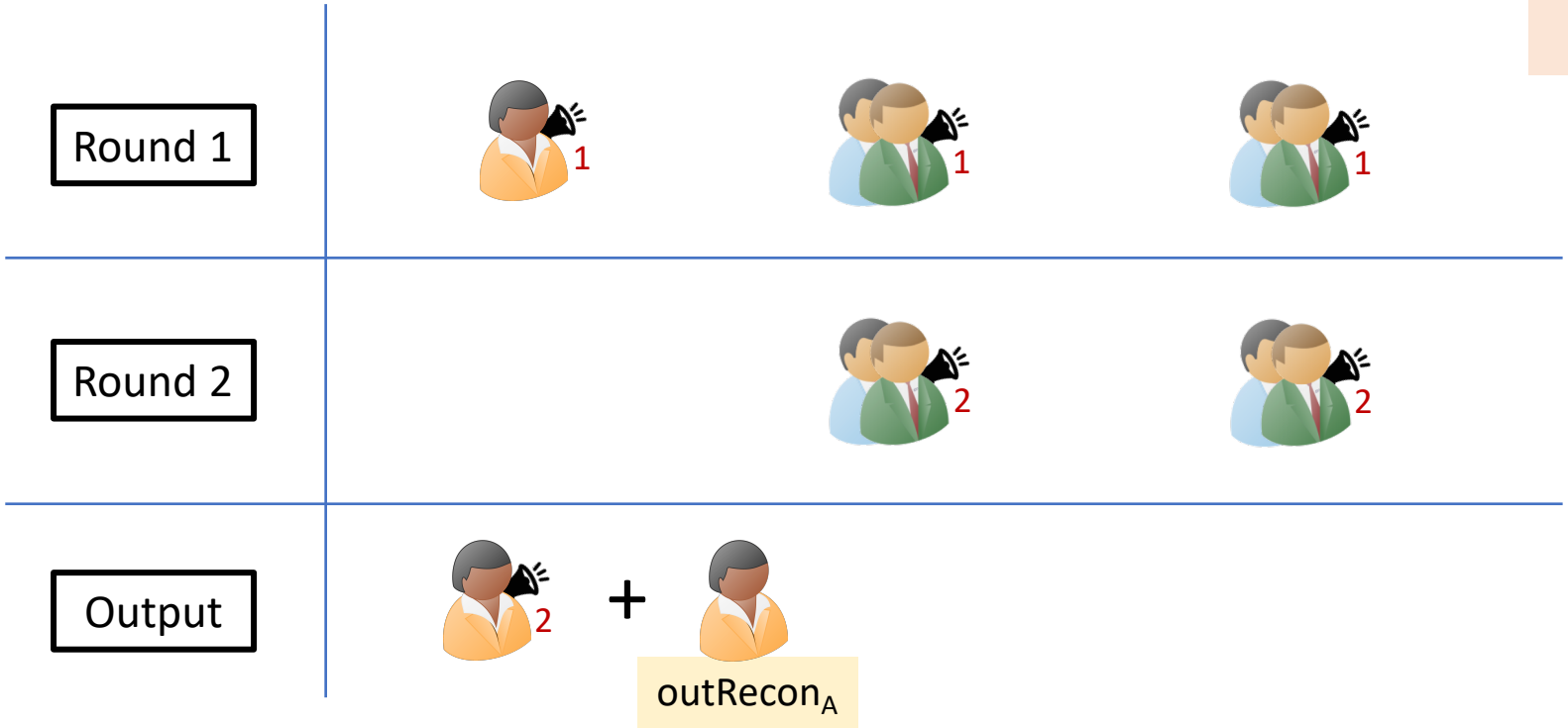
Since Alice is the only ''output-party'', it does not need to broadcast its second-round message

Broadcast-Only: Two-Round MPC implies OT

Two-round broadcast-only MPC for

$$F(b, m_0, m_1) = (m_b, \perp)$$

Modification: Bob and Charlie operate as a single party.



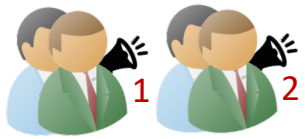
Two-Message OT

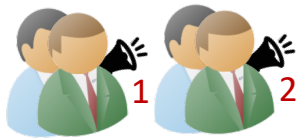
$$F(b, m_0, m_1) = (m_b, \perp)$$

Alice/Receiver Bob/Sender + Charlie/Helper

Round 1

Round 2





Output

+

outRecon_A

If Bob + Charlie are a single entity, they can broadcast all their messages together in the second round.

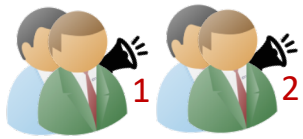
Two-Message OT: Security against Receiver

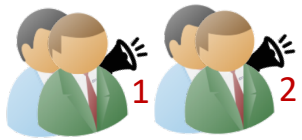
$$F(b, m_0, m_1) = (m_b, \perp)$$

Alice/Receiver Bob/Sender + Charlie/Helper

Round 1

Round 2





Output

+

outRecon_A

Security against receiver follows from security of the original two-round MPC

If the original MPC protocol was semi-honest/malicious, we get security against semi-honest/malicious receiver

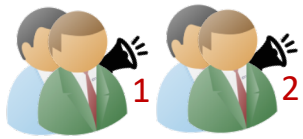
Two-Message OT: Security against Sender

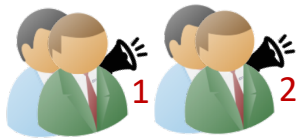
$$F(b, m_0, m_1) = (m_b, \perp)$$

Alice/Receiver | Bob/Sender + Charlie/Helper

Round 1

Round 2





Output

+

outRecon_A

Charlie did not have an input in the original function

If the adversary only corrupts Bob in the original protocol, it can obtain the same view as in this transformed 2-party protocol, by internally simulating Charlie.

We get security against semi-honest sender

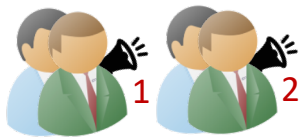
Two-Message OT

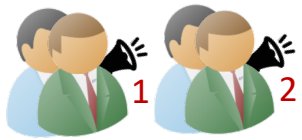
$$F(b, m_0, m_1) = (m_b, \perp)$$

Alice/Receiver Bob/Sender + Charlie/Helper

Round 1

Round 2





Output

+

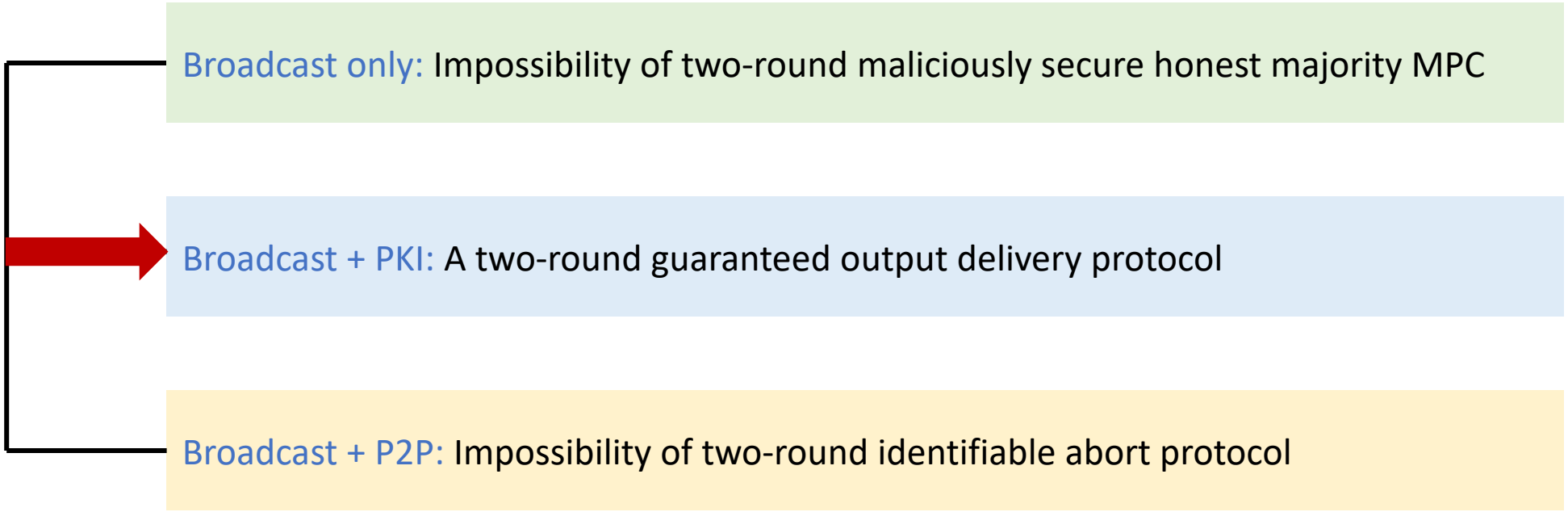
outRecon$_A$

A maliciously secure broadcast-only two-round MPC
⇒ Two-message malicious receiver OT

We show that a two-message malicious receiver OT is impossible

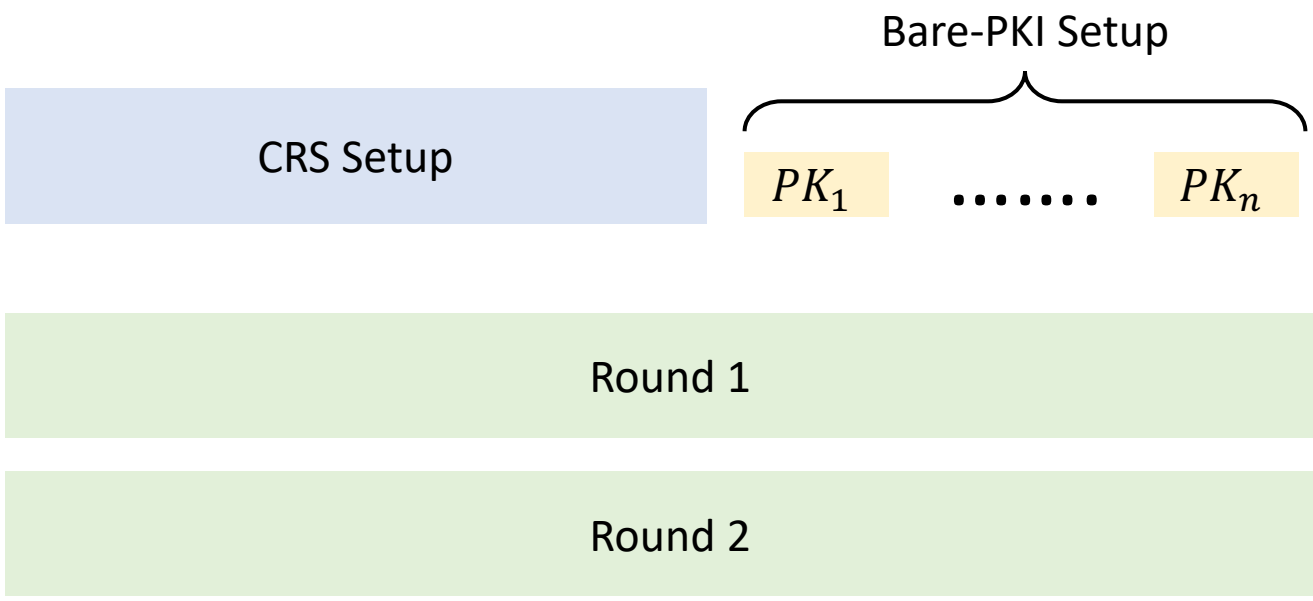
Hence, a maliciously secure broadcast-only two-round MPC is impossible!

Talk Outline



Broadcast + PKI: Guaranteed Output Delivery

Existing guaranteed output delivery protocols (e.g. [GLS'18]) in the broadcast + PKI setting, rely on a trusted CRS setup



CRS in these protocols is only used for NIZK proofs

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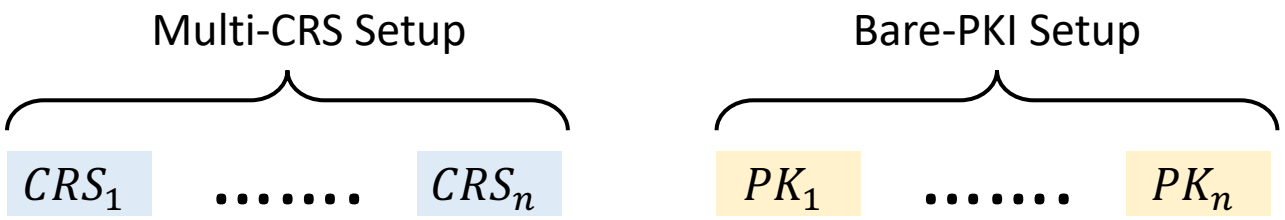


Round 1

Round 2

CRS in these protocols is only used for NIZK proofs

NIZKs in the honest majority setting can be replaced with multi-CRS NIZKs [GO'07]

Broadcast + PKI: Guaranteed Output Delivery

Existing guaranteed output delivery protocols (e.g. [GLS'18]) in the broadcast + PKI setting, rely on a trusted CRS setup

PK'_1 CRS_1 + PK_1 ..... PK'_n CRS_n + PK_n

Round 1

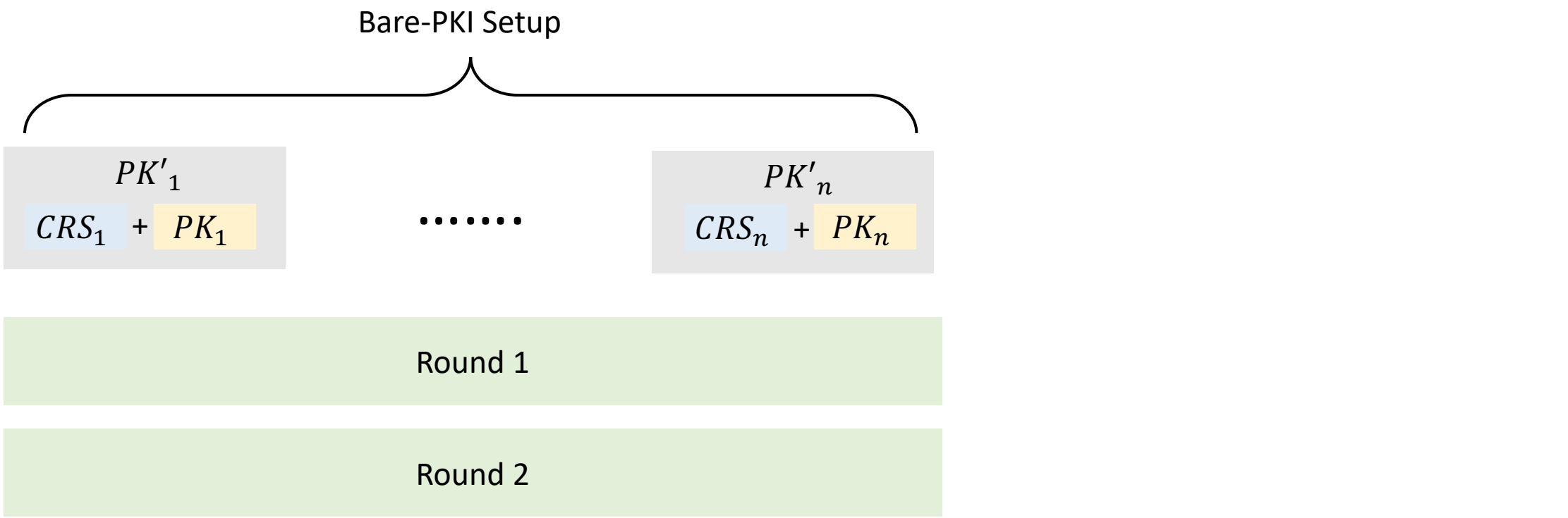
Round 2

CRS in these protocols is only used for NIZK proofs

NIZKs in the honest majority setting can be replaced with multi-CRS NIZKs [GO'07]

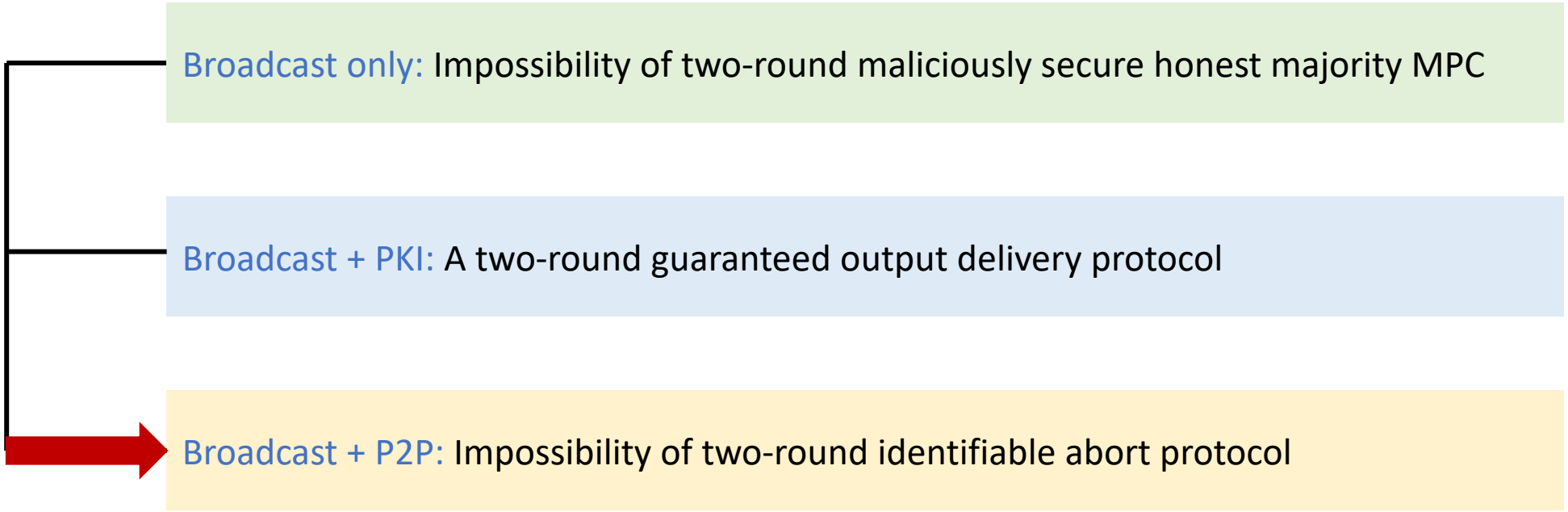
Multi-CRS can be embedded inside the bare-PKI setup

Broadcast + PKI: Guaranteed Output Delivery



This gives us a two-round guaranteed output delivery protocol without CRS!

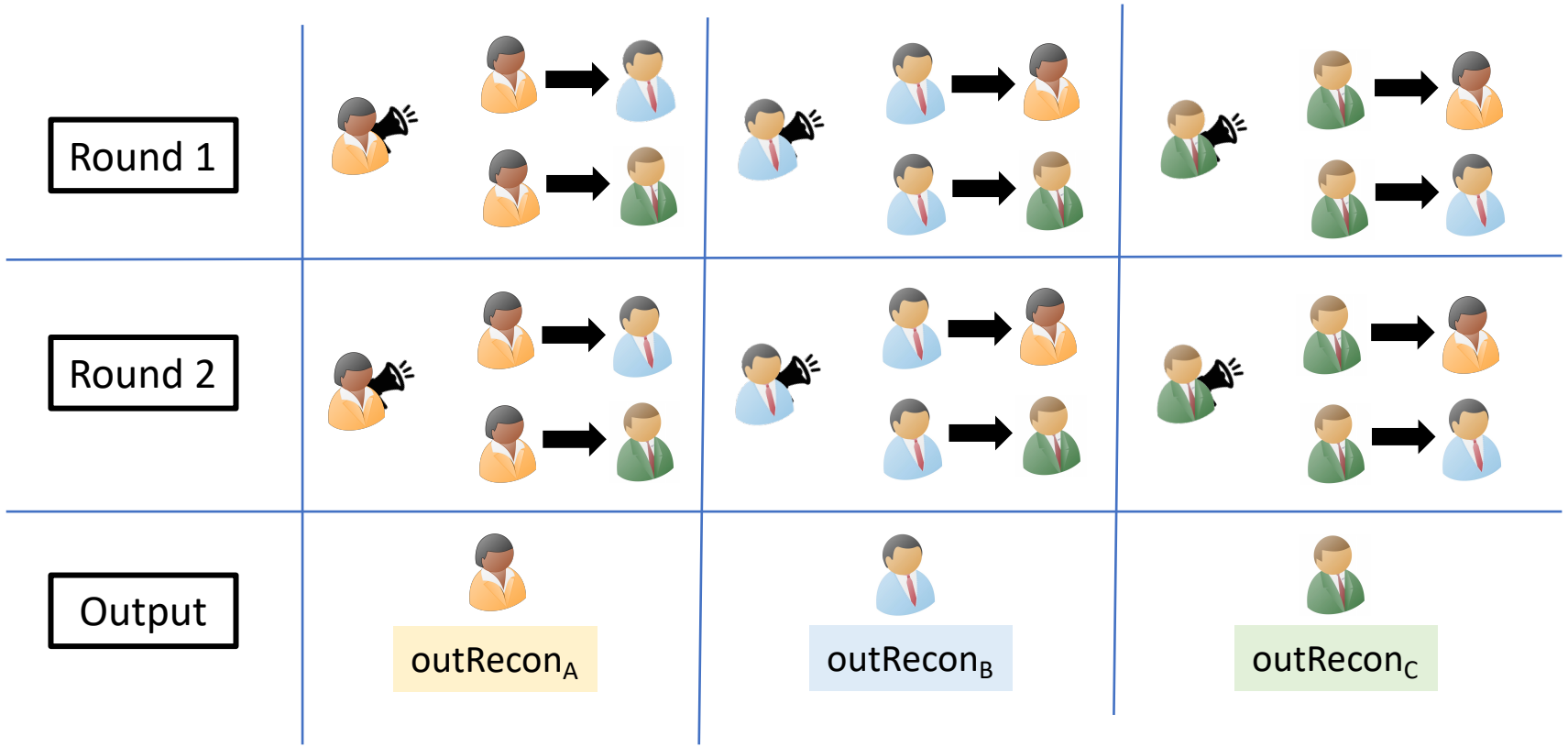
Talk Outline



Broadcast + P2P: Identifiable Abort is Impossible

Assume FSOC, ∃ a two-round identifiable abort protocol for

$$F(b, m_0, m_1, \perp) = (\perp, \perp, m_b)$$



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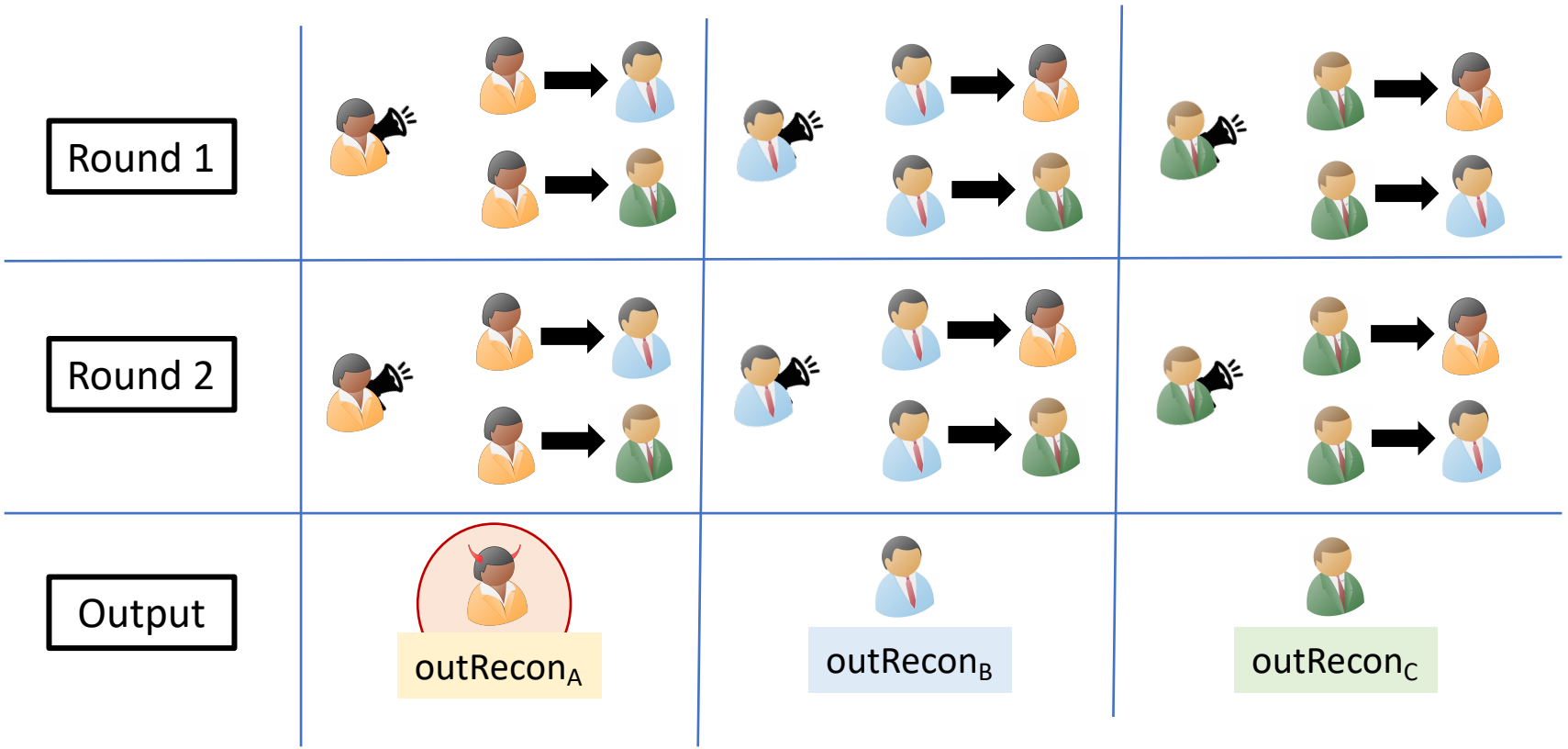

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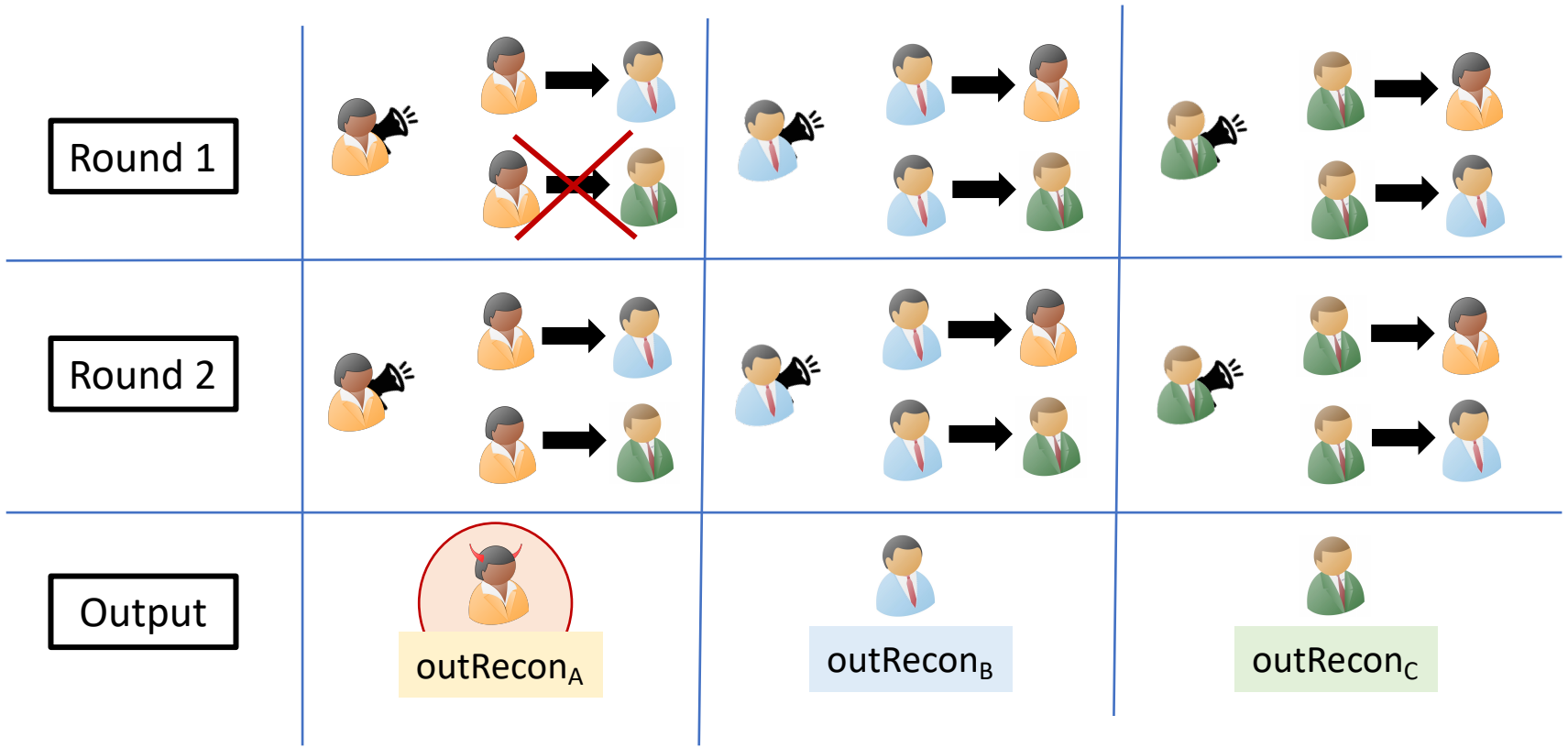

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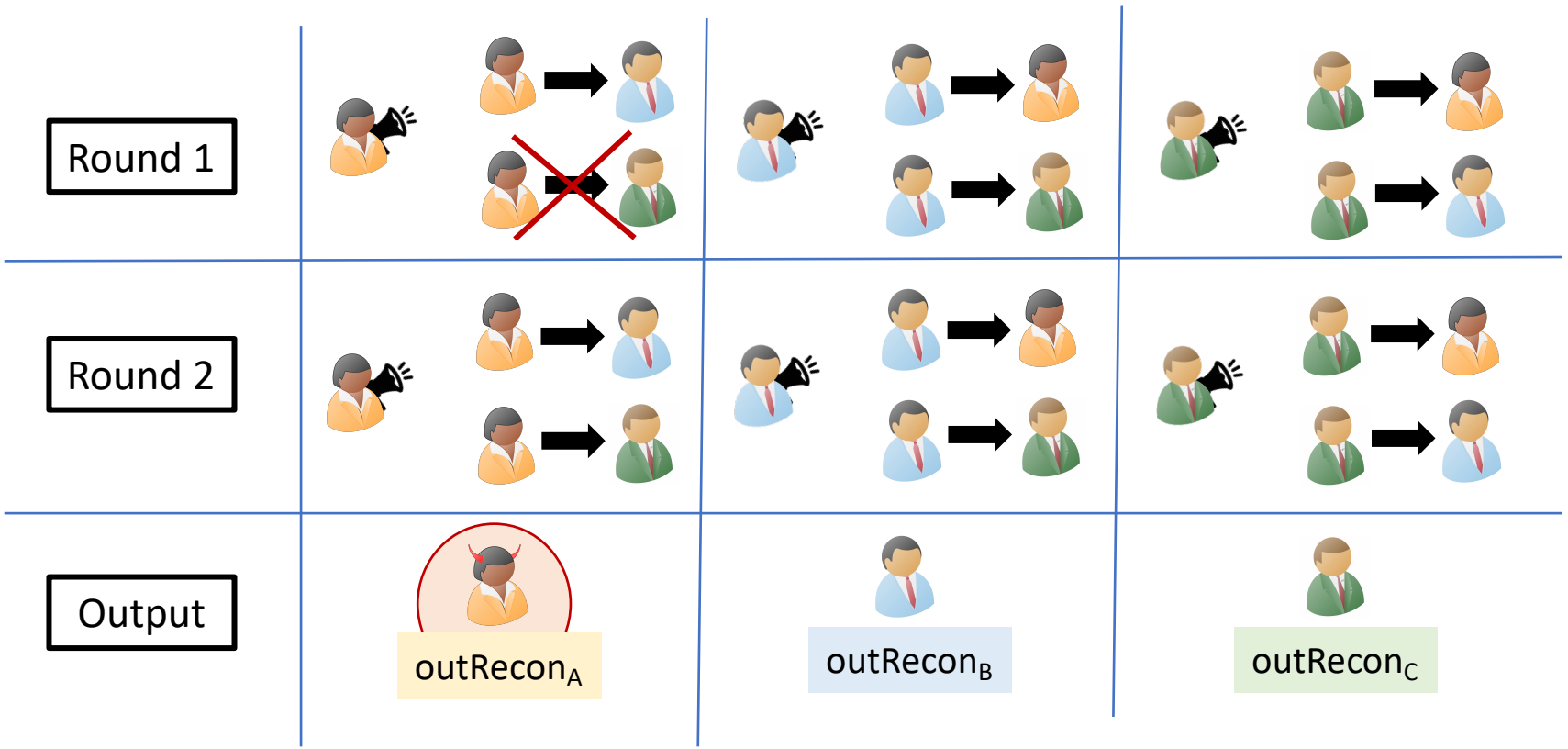

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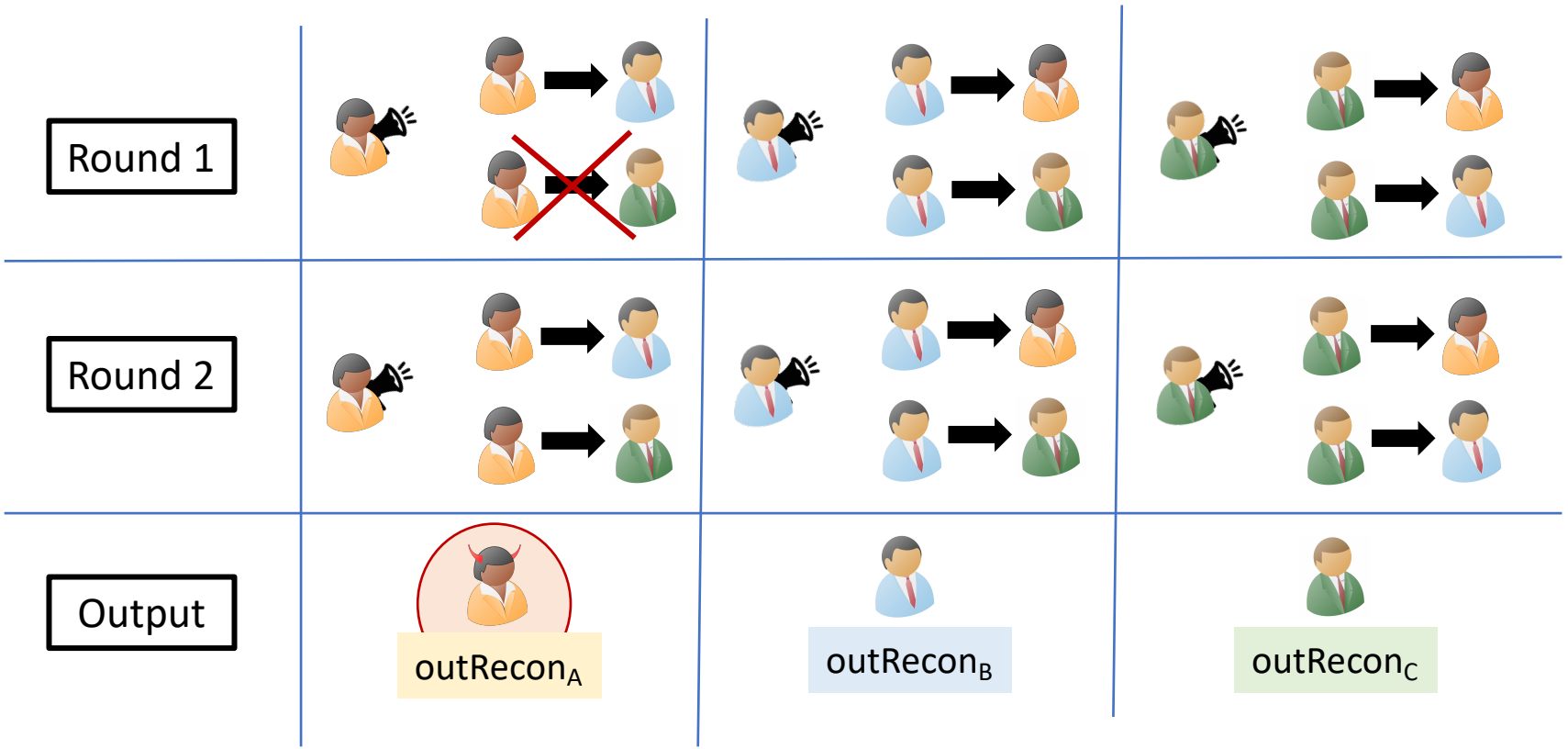

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If outputs ⊥, then all honest parties should identify as corrupt.

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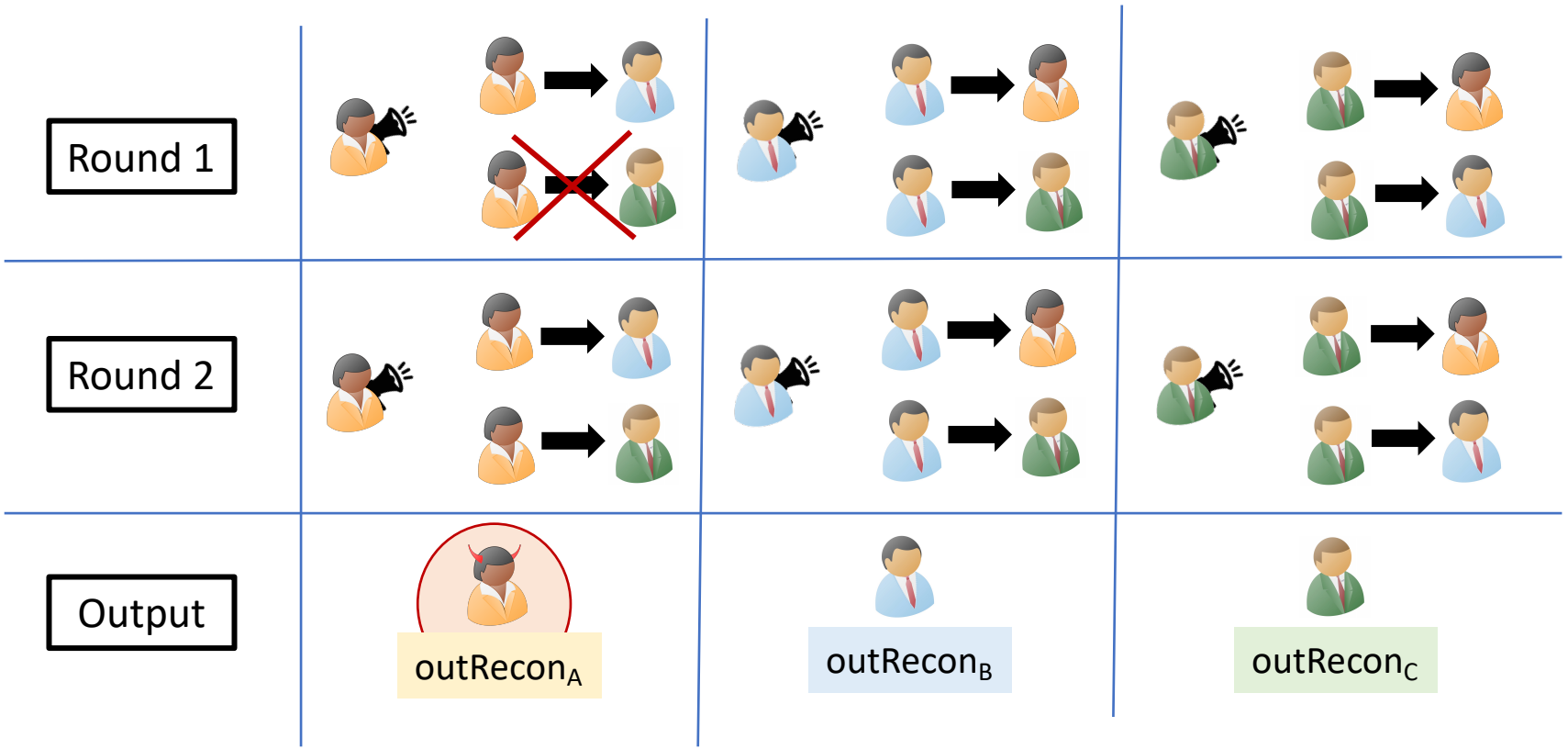

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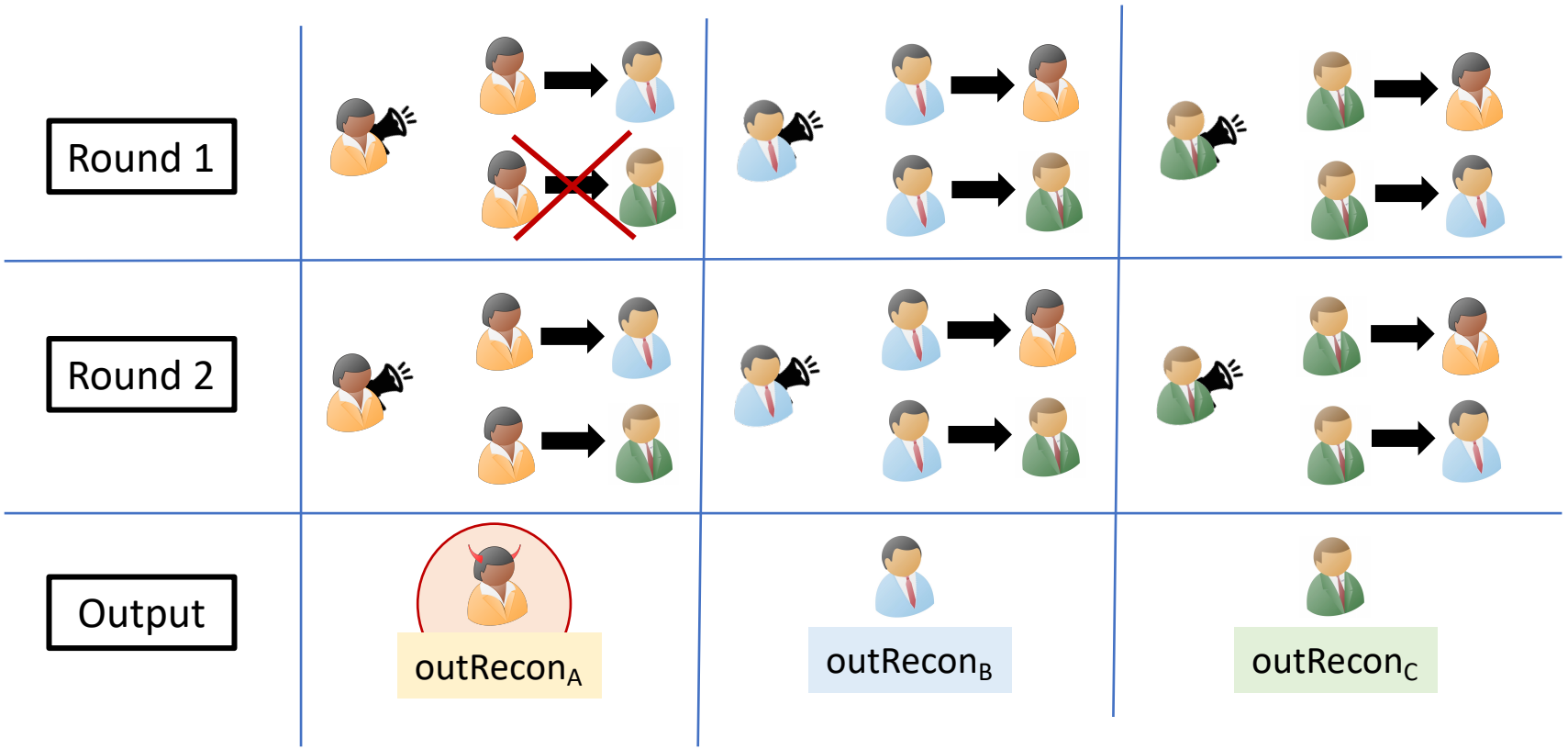

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1. The simulator extracts b as ‘s input.

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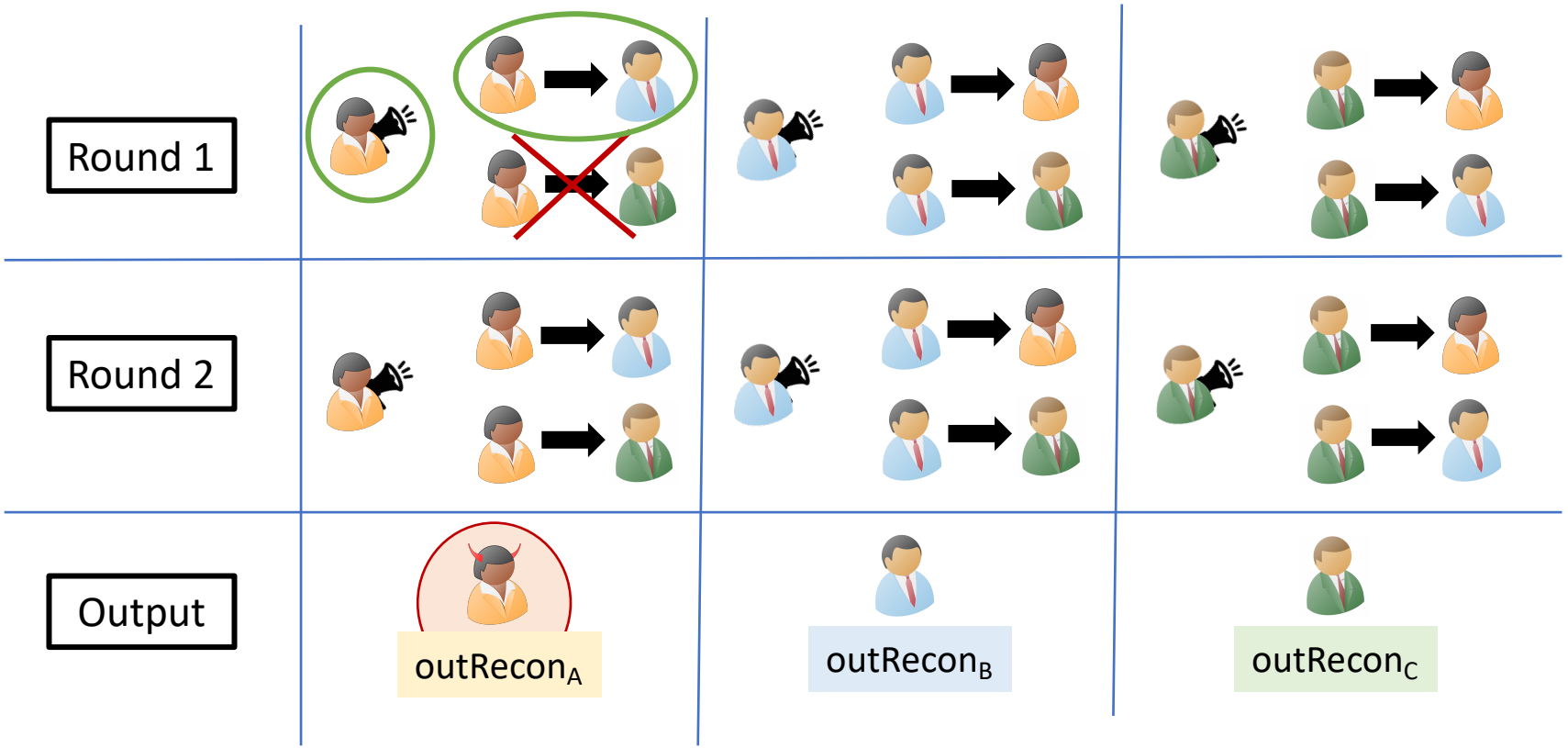

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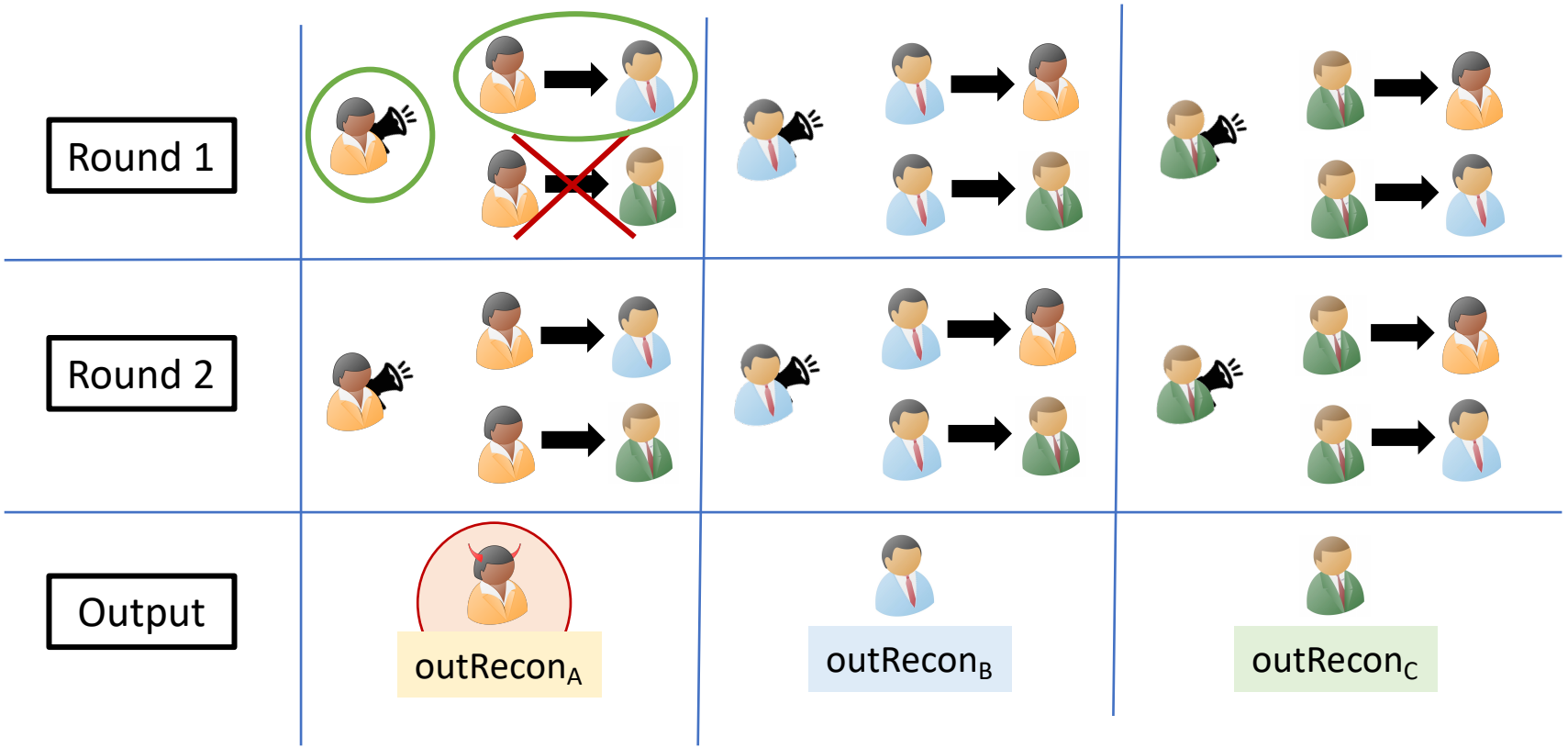

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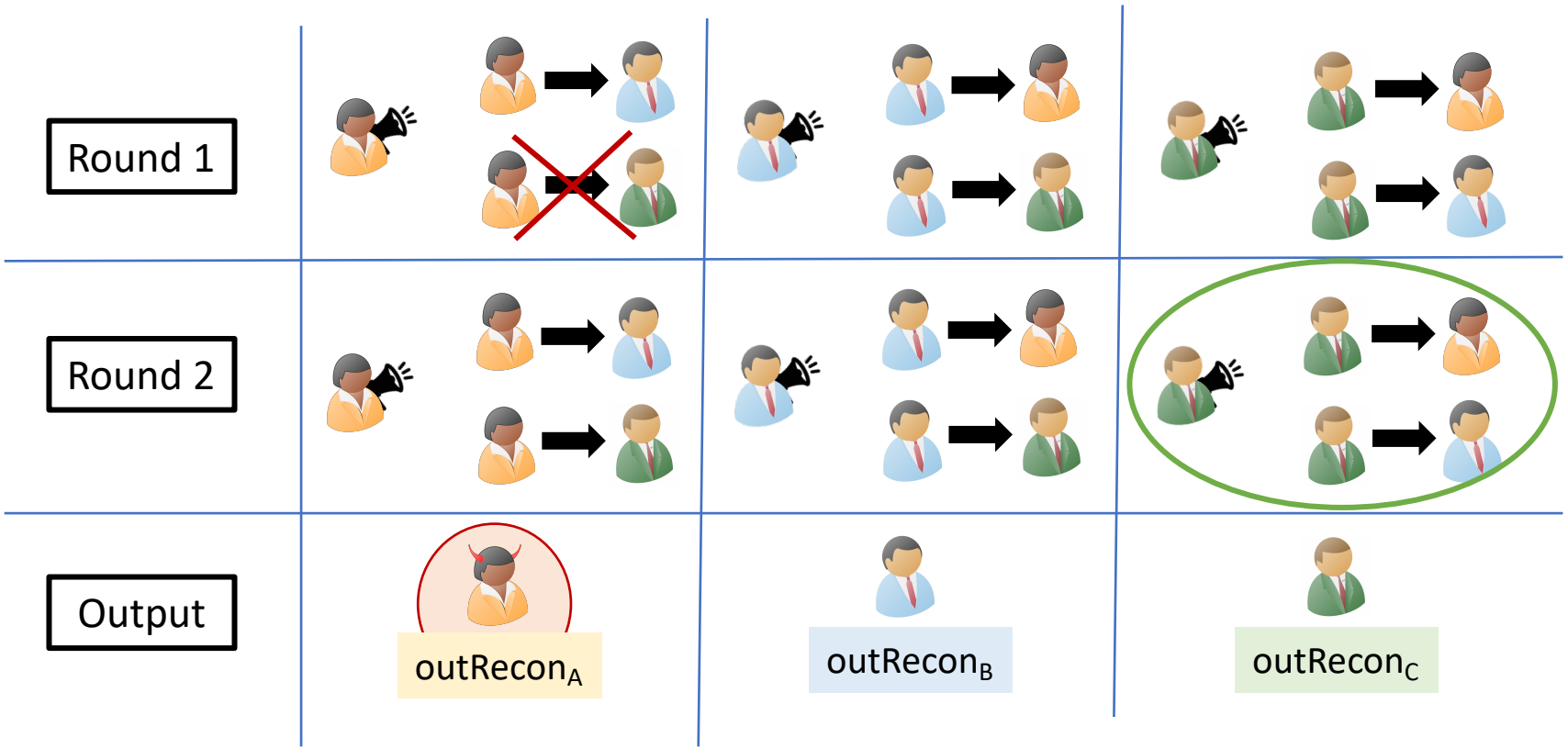

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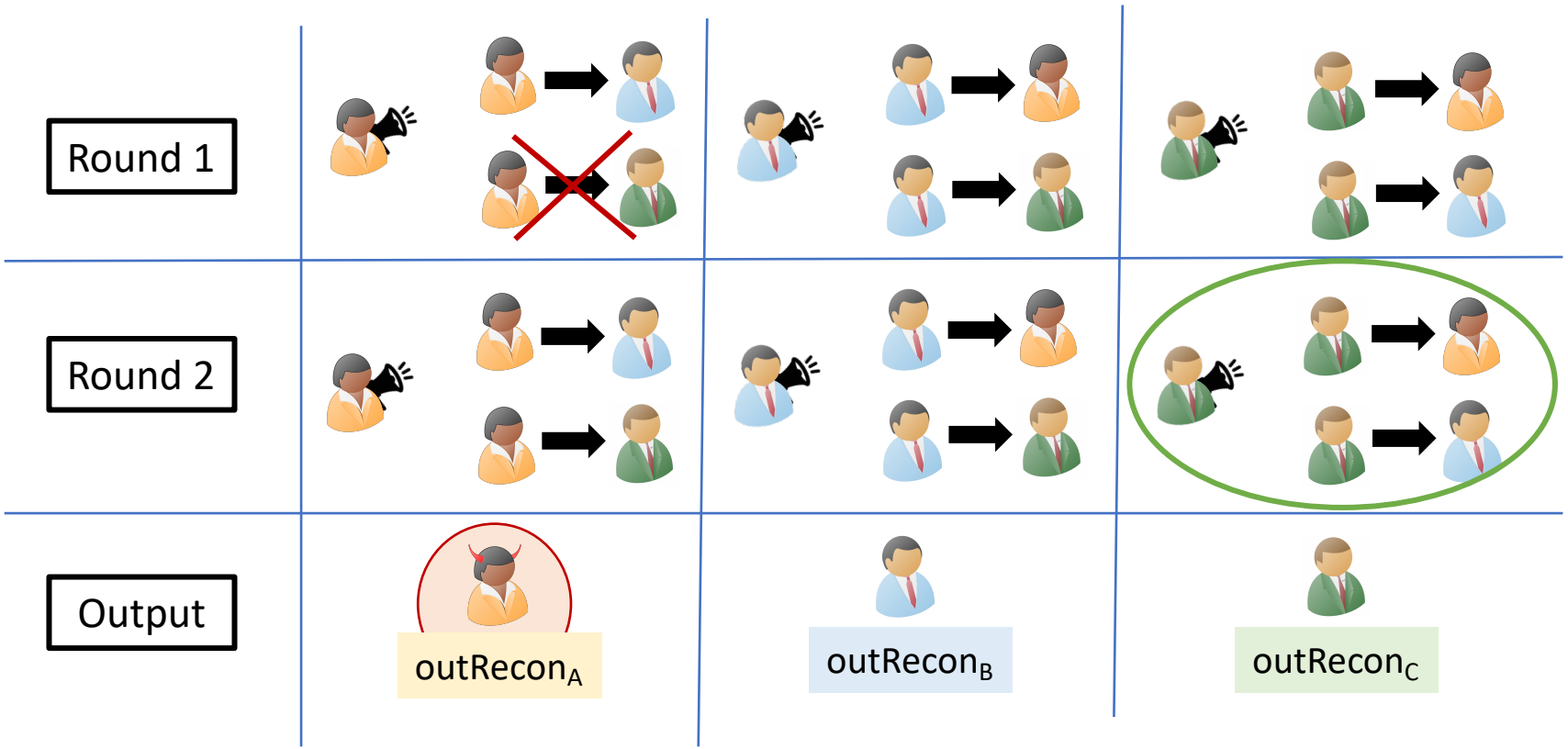

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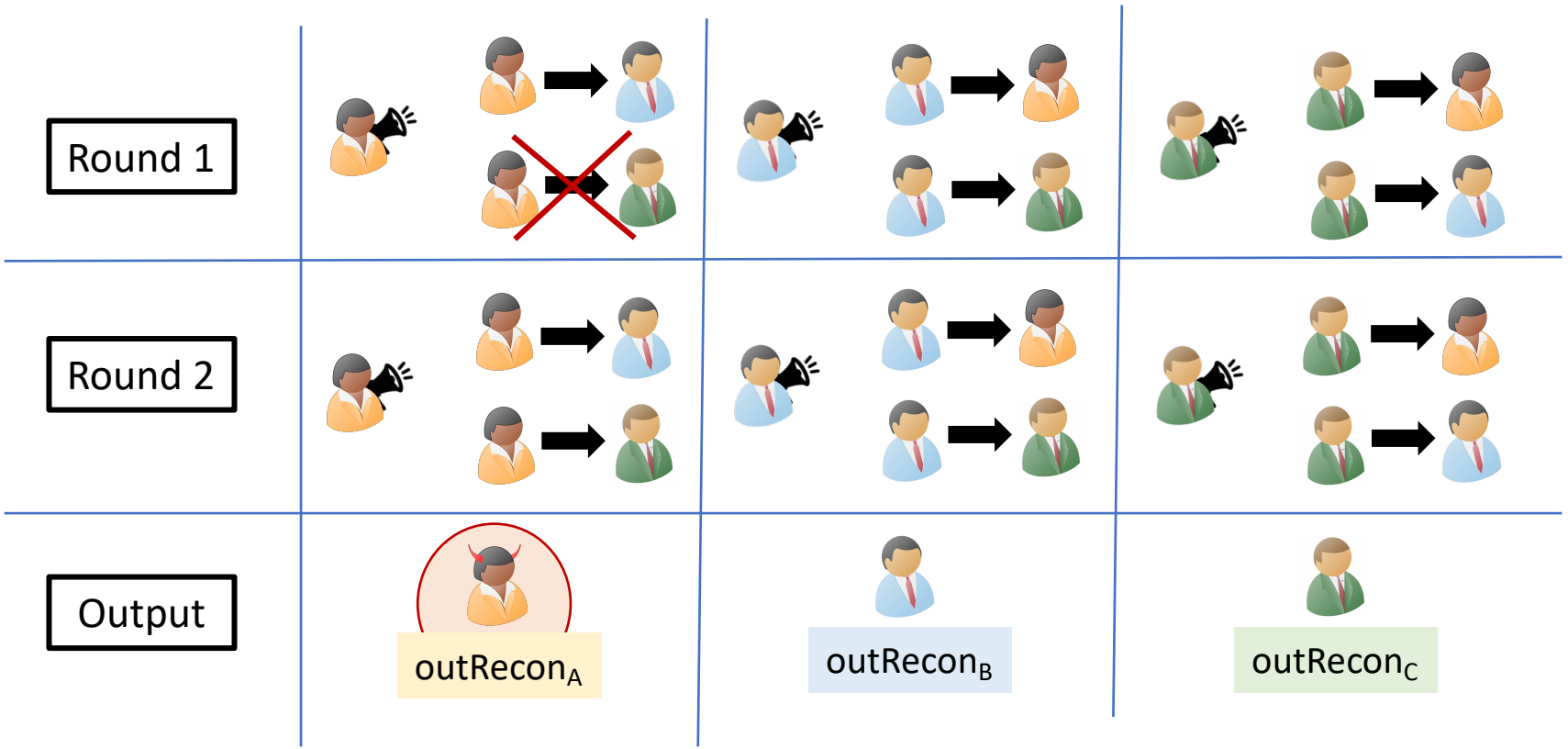

Adversary corrupts Alice

Alice doesn't send private message to Charlie

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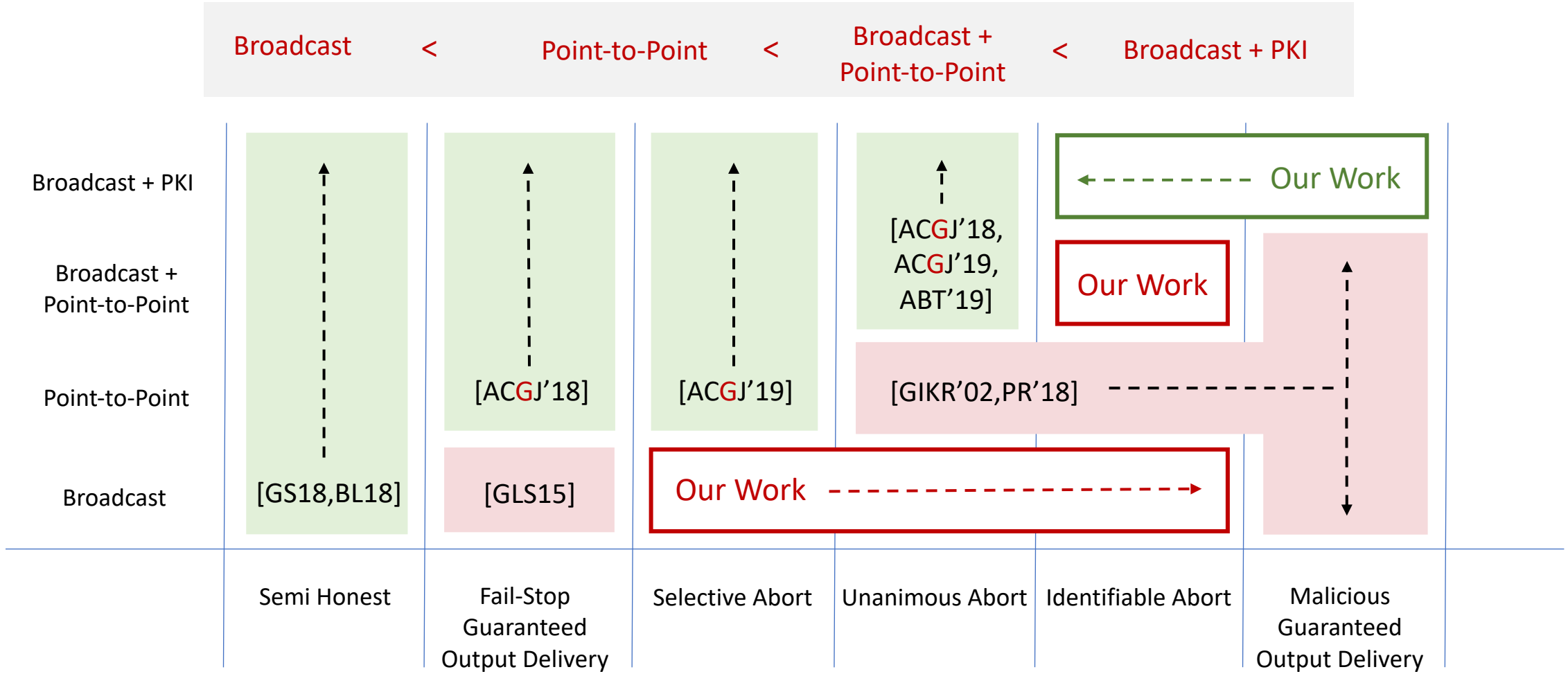
Neither of these cases are true!

No such identifiable abort protocol exists!

Conclusion: Two-Round MPC



https://eprint.iacr.org/2021/690

Thank You!