The Broadcast Message Complexity of Secure Multiparty Computation

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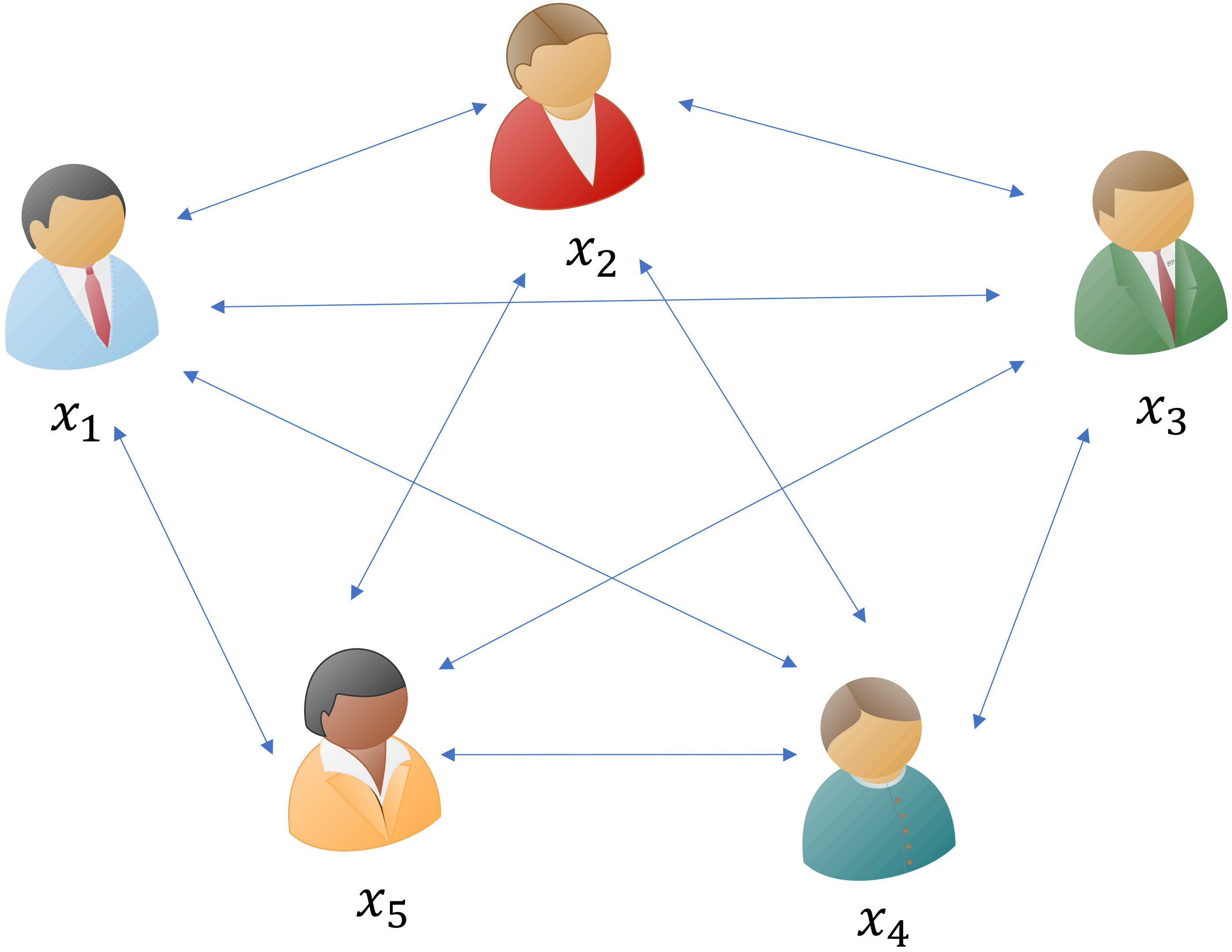
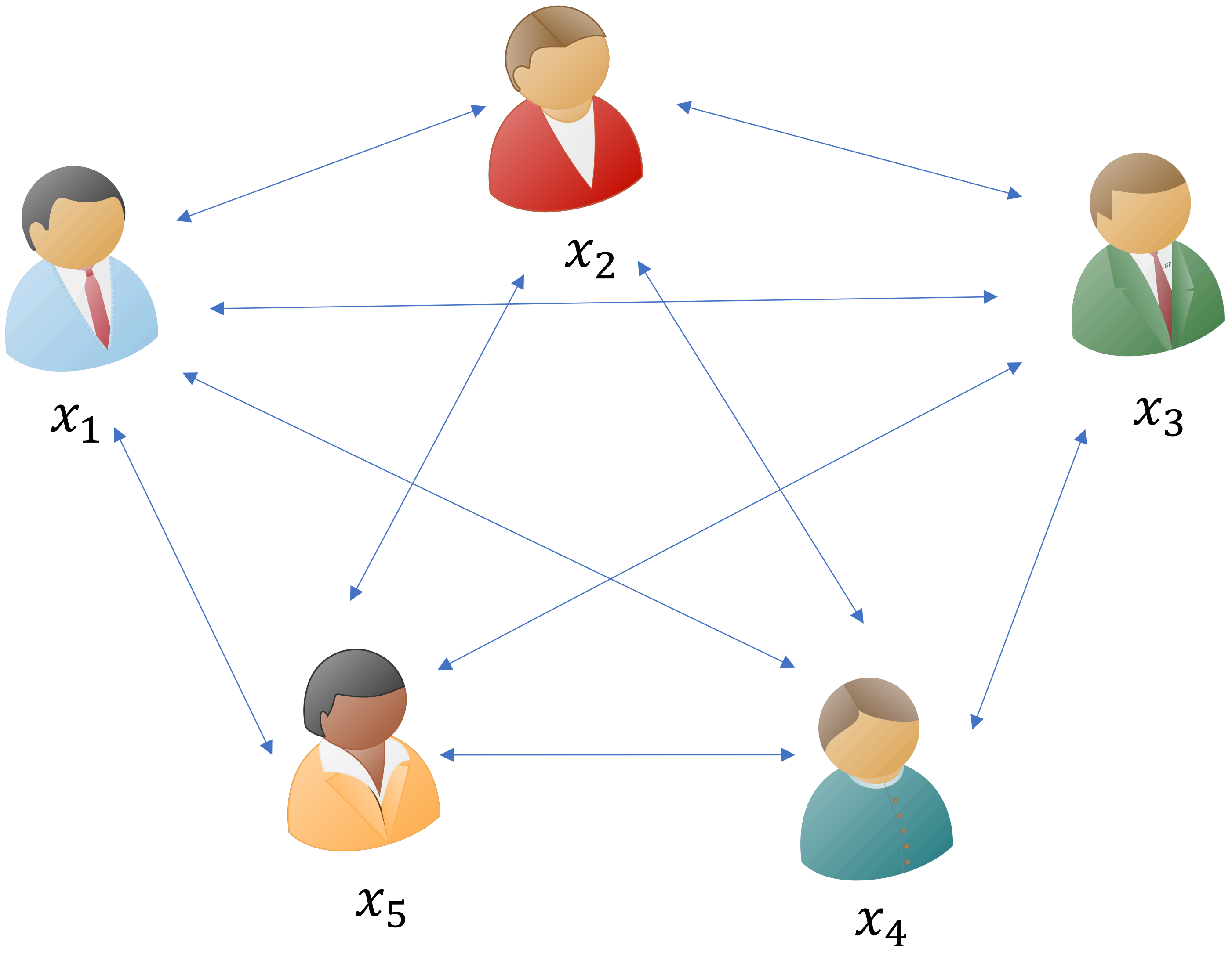
ASIACRYPT 2019

Secure Multiparty Computation



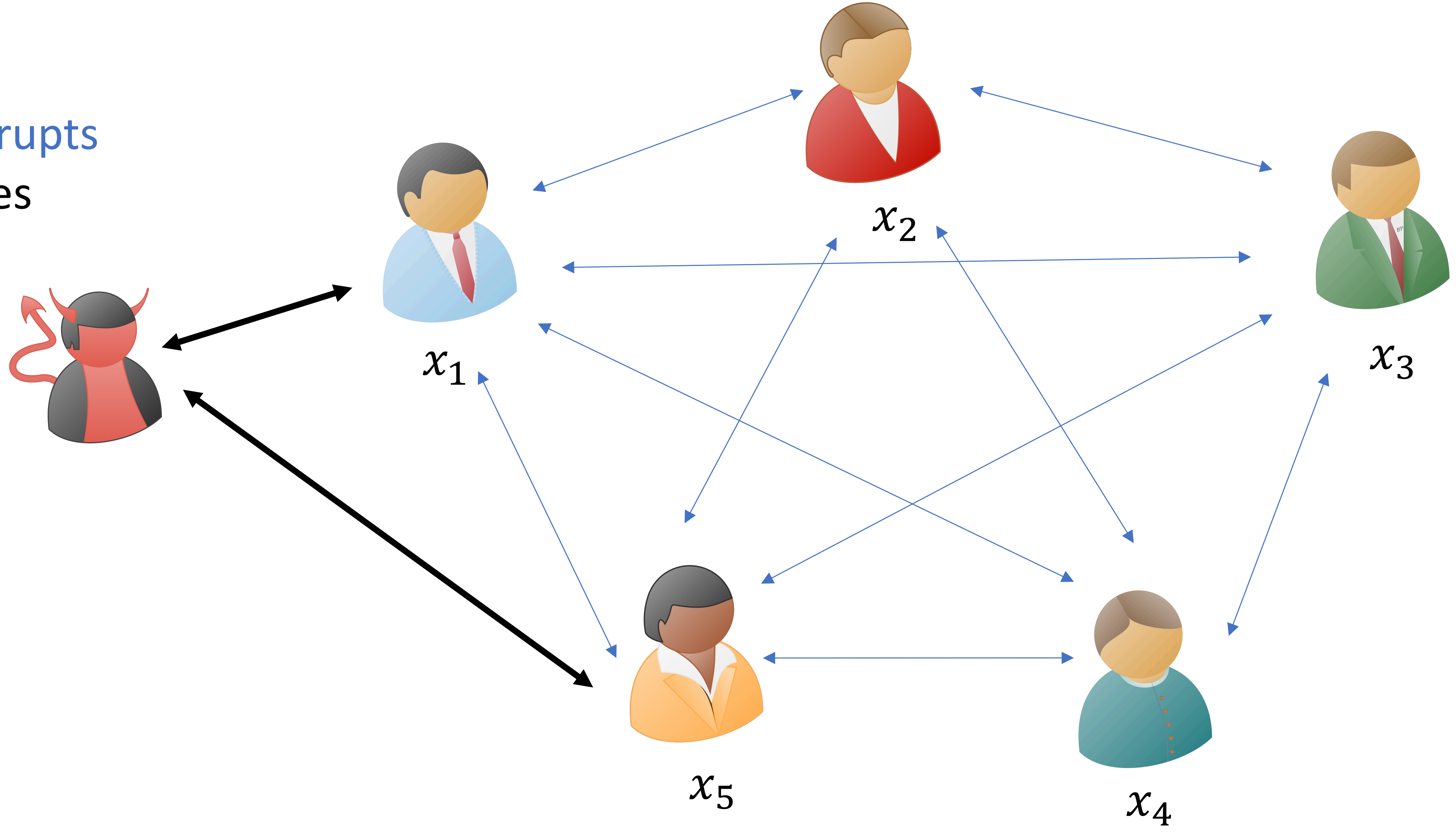
Secure Multiparty Computation

Compute
$f(x_1, x_2, x_3, x_4, x_5)$



Secure Multiparty Computation

Adversary corrupts
t< n parties



Secure Multiparty Computation

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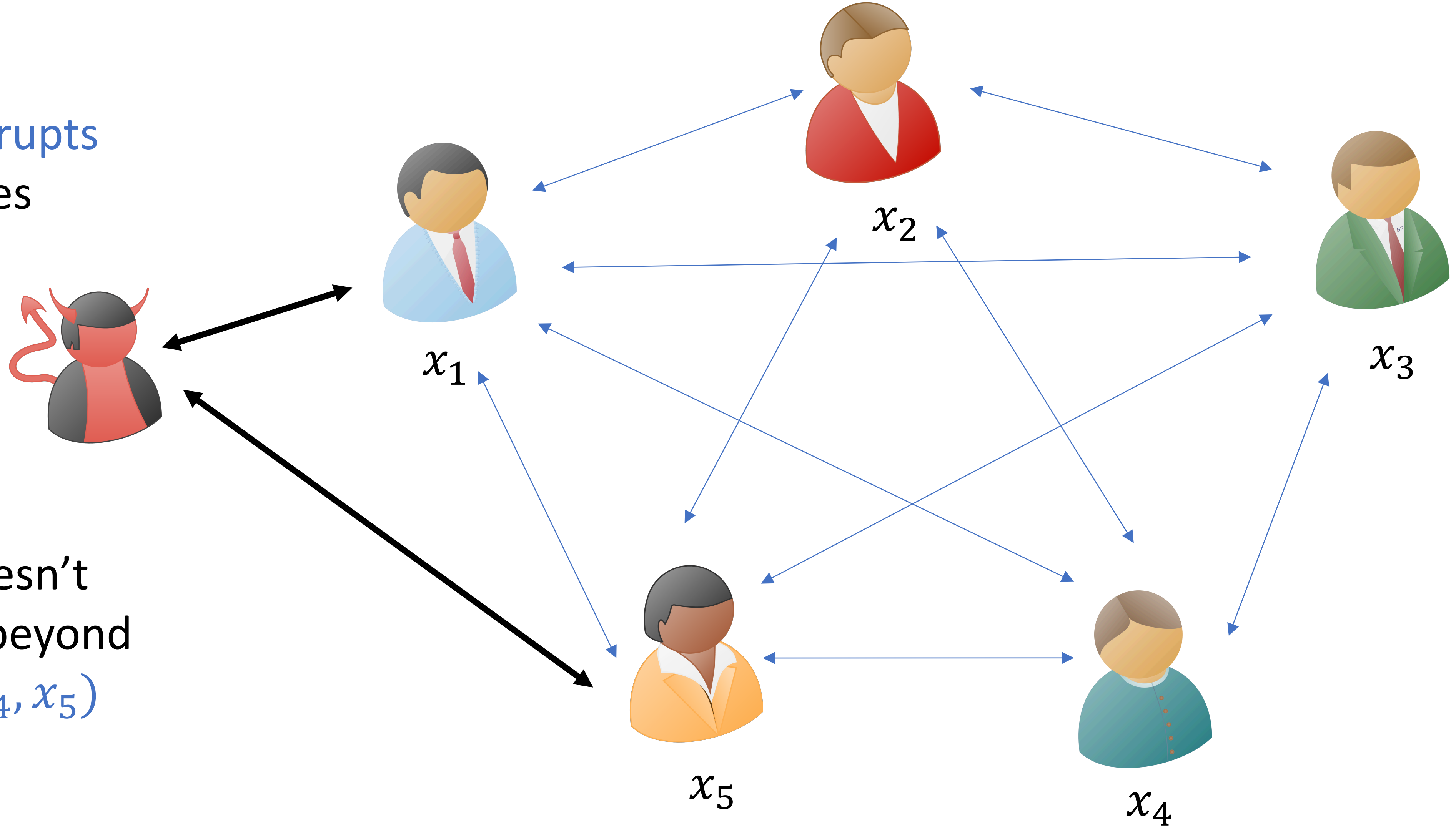

Adversary doesn't
learn anything beyond
$f(x_1, x_2, x_3, x_4, x_5)$

Communication Models

- Point to Point (P2P) Model
- Broadcast Model
- Hybrid Model (P2P + Broadcast)

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Communication Model: Broadcast Model

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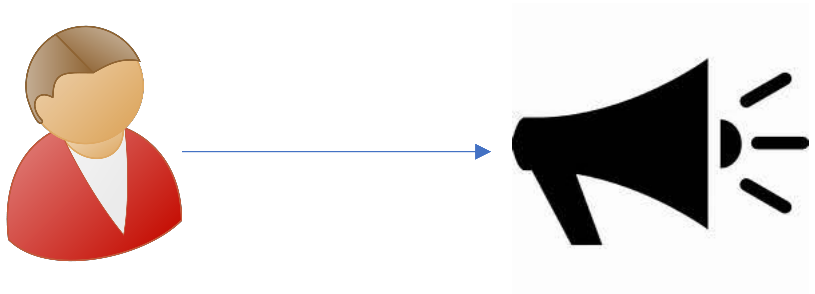
Authenticated
Broadcast Channel

Communication Model: Broadcast Model



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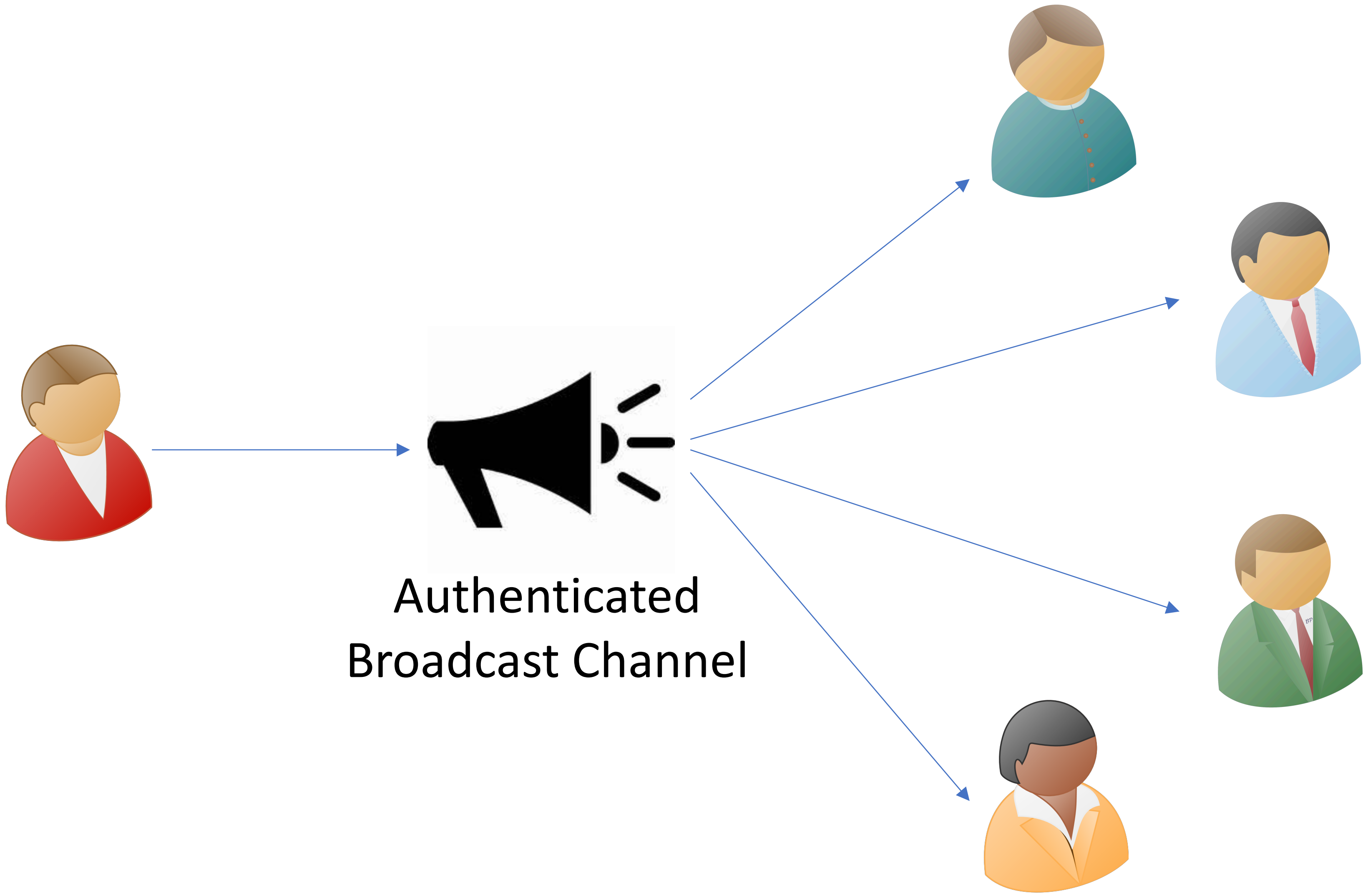
Communication Model: Broadcast Model



Problem Statement

What is the broadcast message complexity of secure multiparty computation in the presence of $t < n$ semi-honest corruptions?

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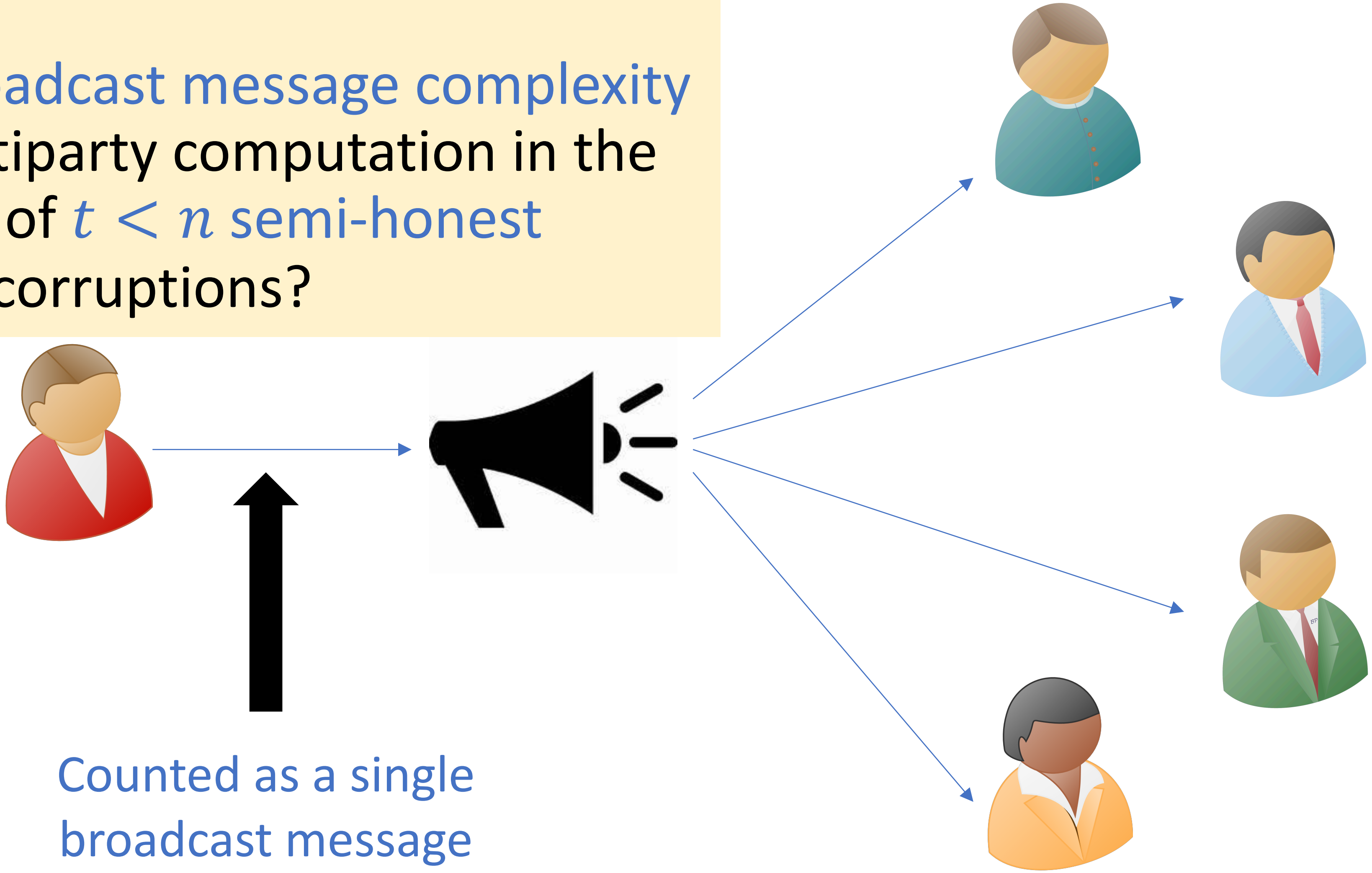

Related Work: P2P Message Complexity

$t = n - 1$ [Ishai, Mittal, Ostrovsky 18]

$t < n$ [Mittal 18]

Simultaneous Broadcast Model

Every party
broadcasts a message
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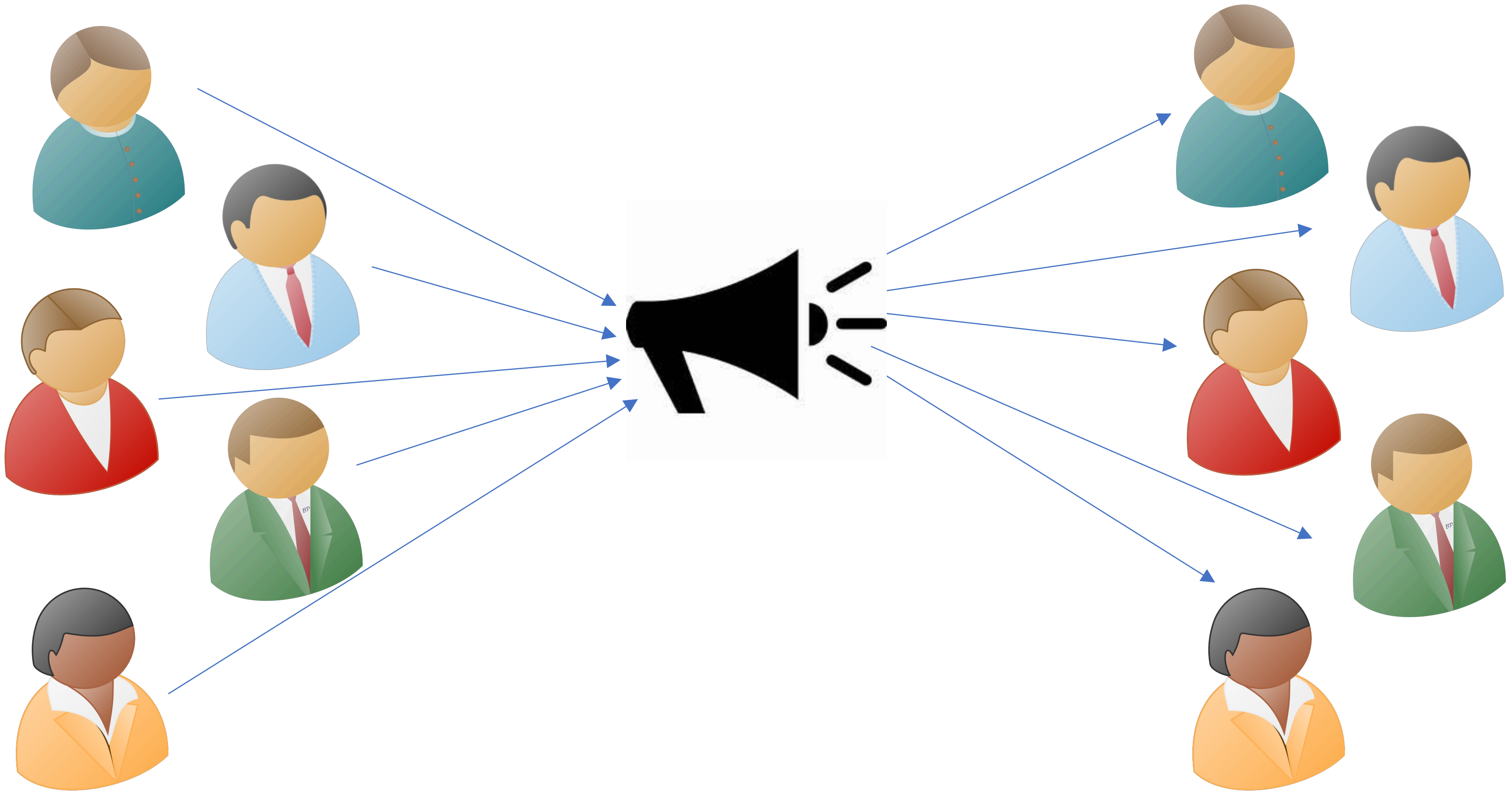


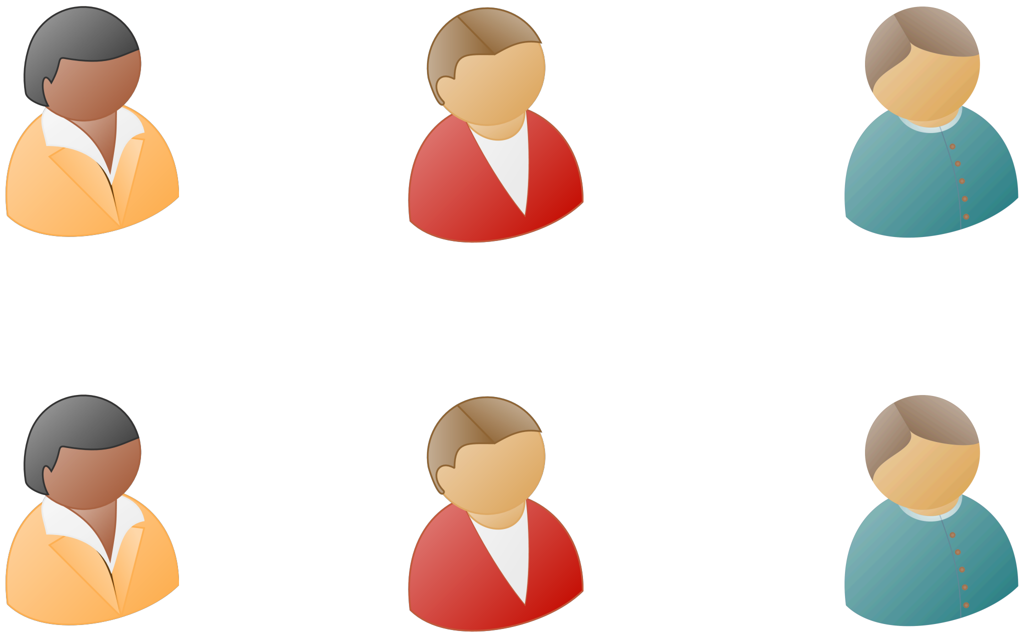
Simultaneous Broadcast Model

2 rounds are necessary for semi-honest secure computation [HLP11].

Simultaneous Broadcast Model

Round 1

Round 2



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Simultaneous Broadcast Model

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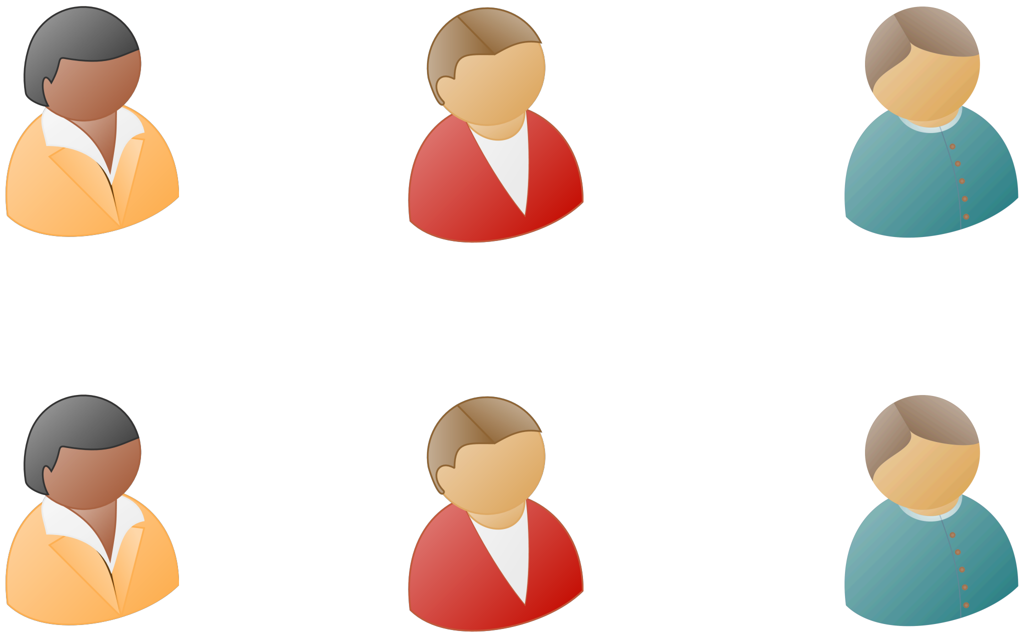


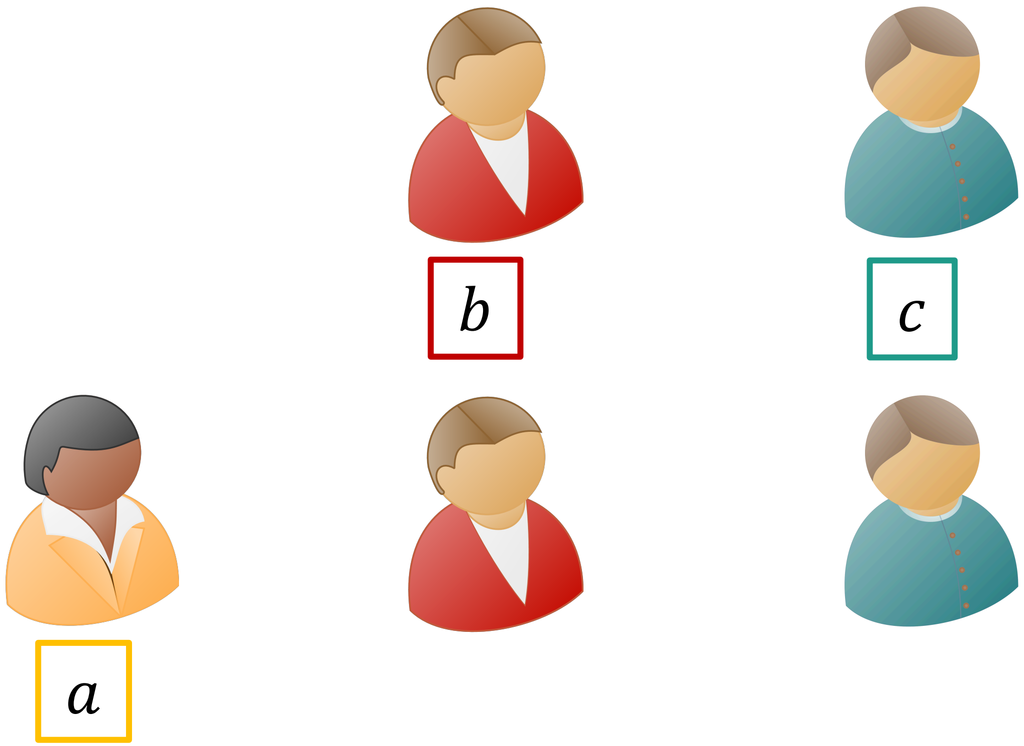
2 rounds are necessary for semi-honest secure computation.

Is the Broadcast Message Complexity $2n$?

Seems Inherent? (Scenario 1)

Round 1

Round 2



- Alice doesn't broadcast a message in the first round

Seems Inherent? (Scenario 1)

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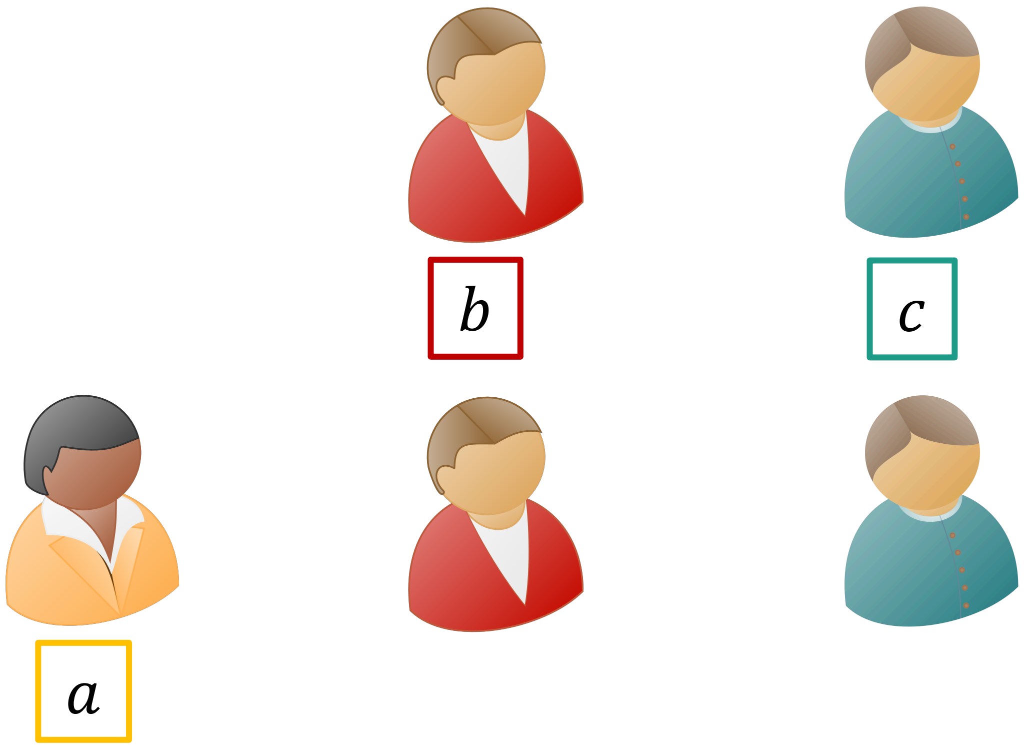
Round 2



- Alice doesn't broadcast a message in the first round
- In a given round, honest parties broadcast messages at the same time.

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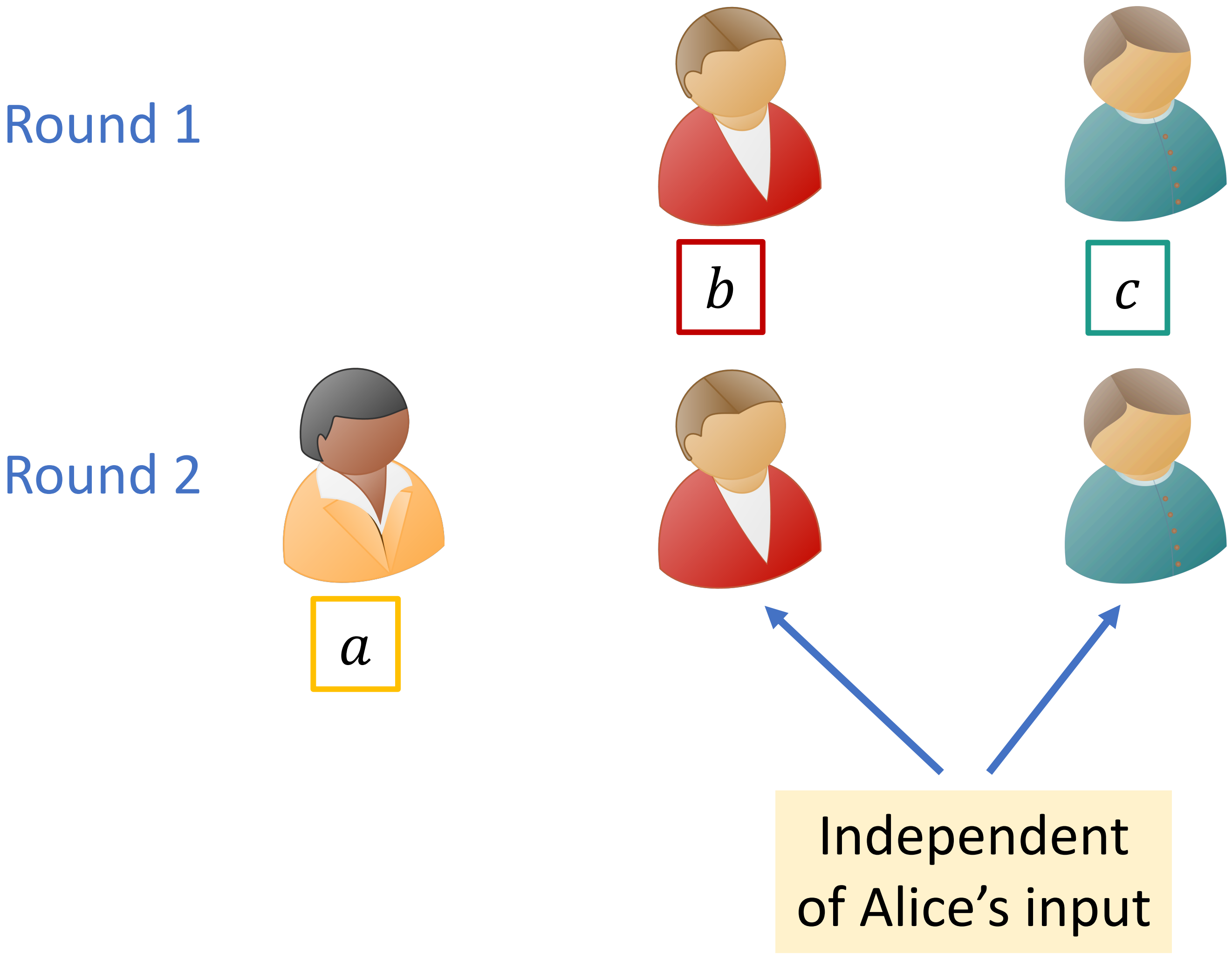

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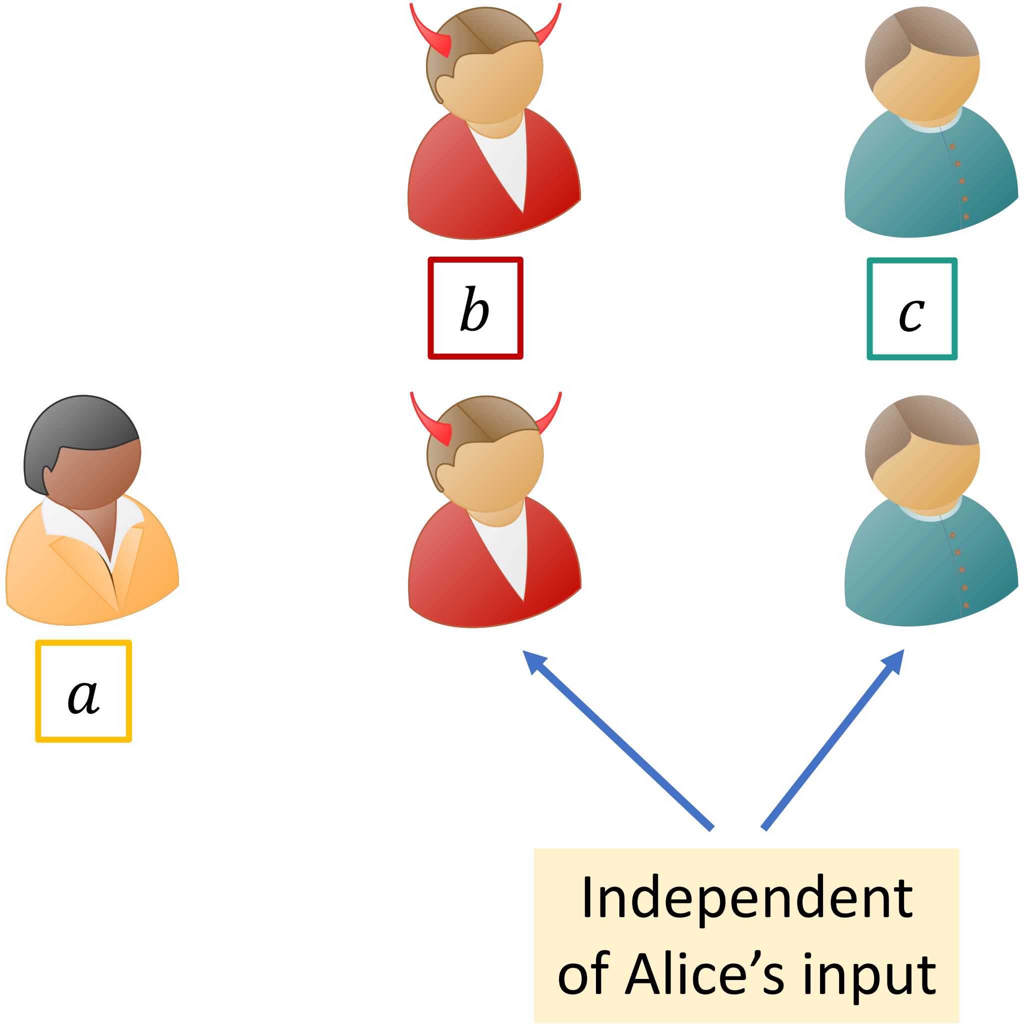
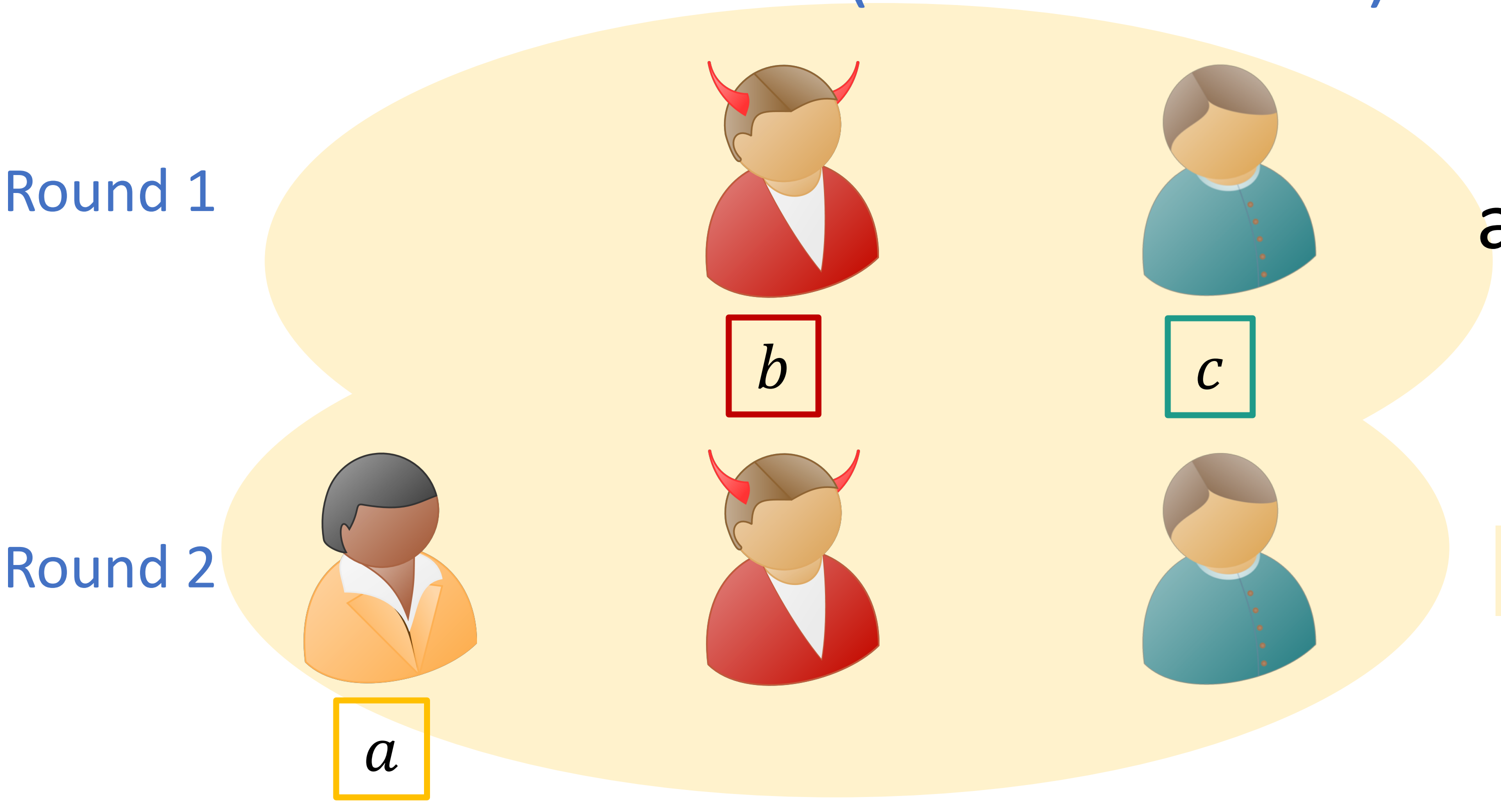


Corrupt Bob can launch an offline spoofing attack

Seems Inherent? (Scenario 1)



Corrupt Bob can launch an offline spoofing attack

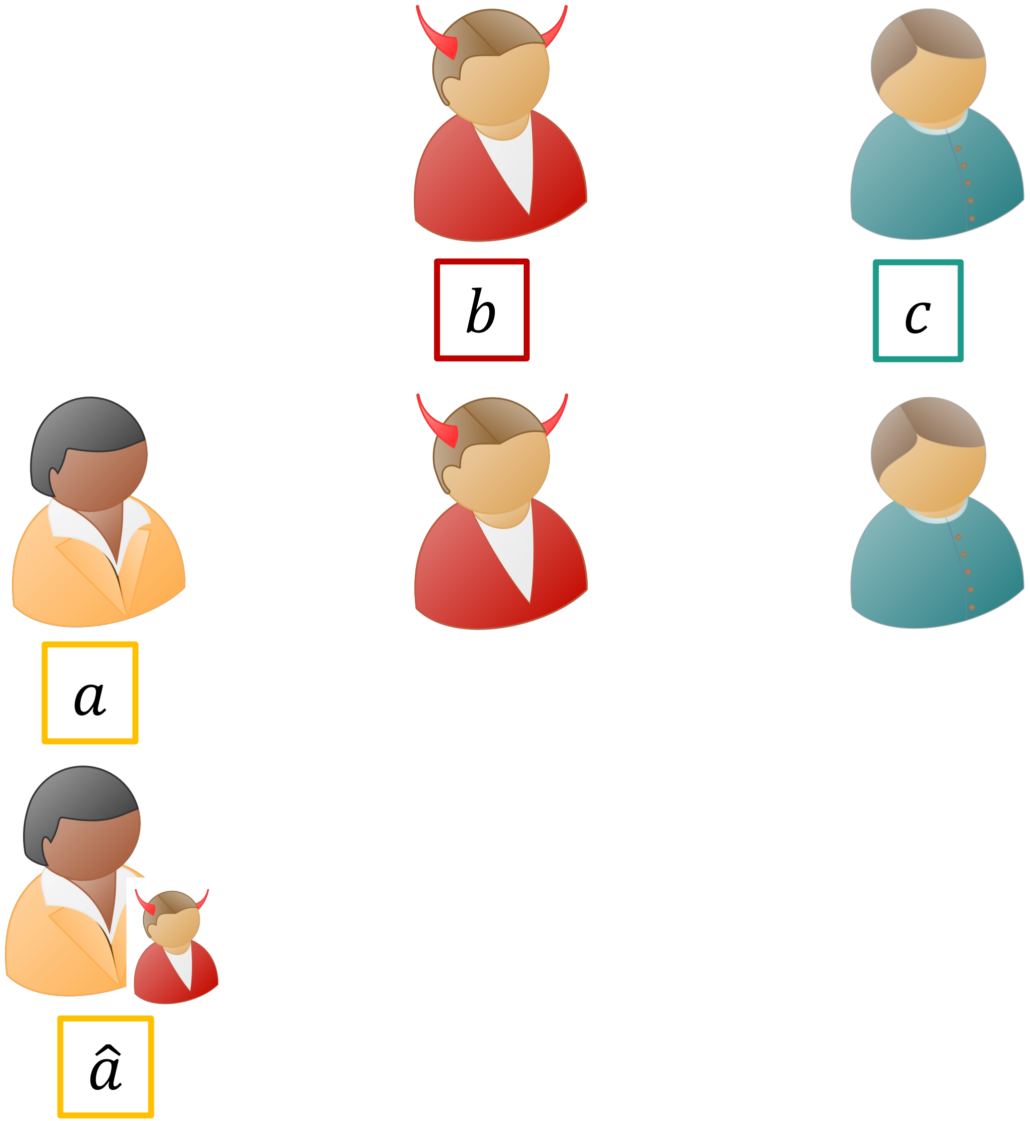
Output: $y = f(a, b, c)$

Seems Inherent? (Scenario 1)

Round 1

Round 2

Offline Computation



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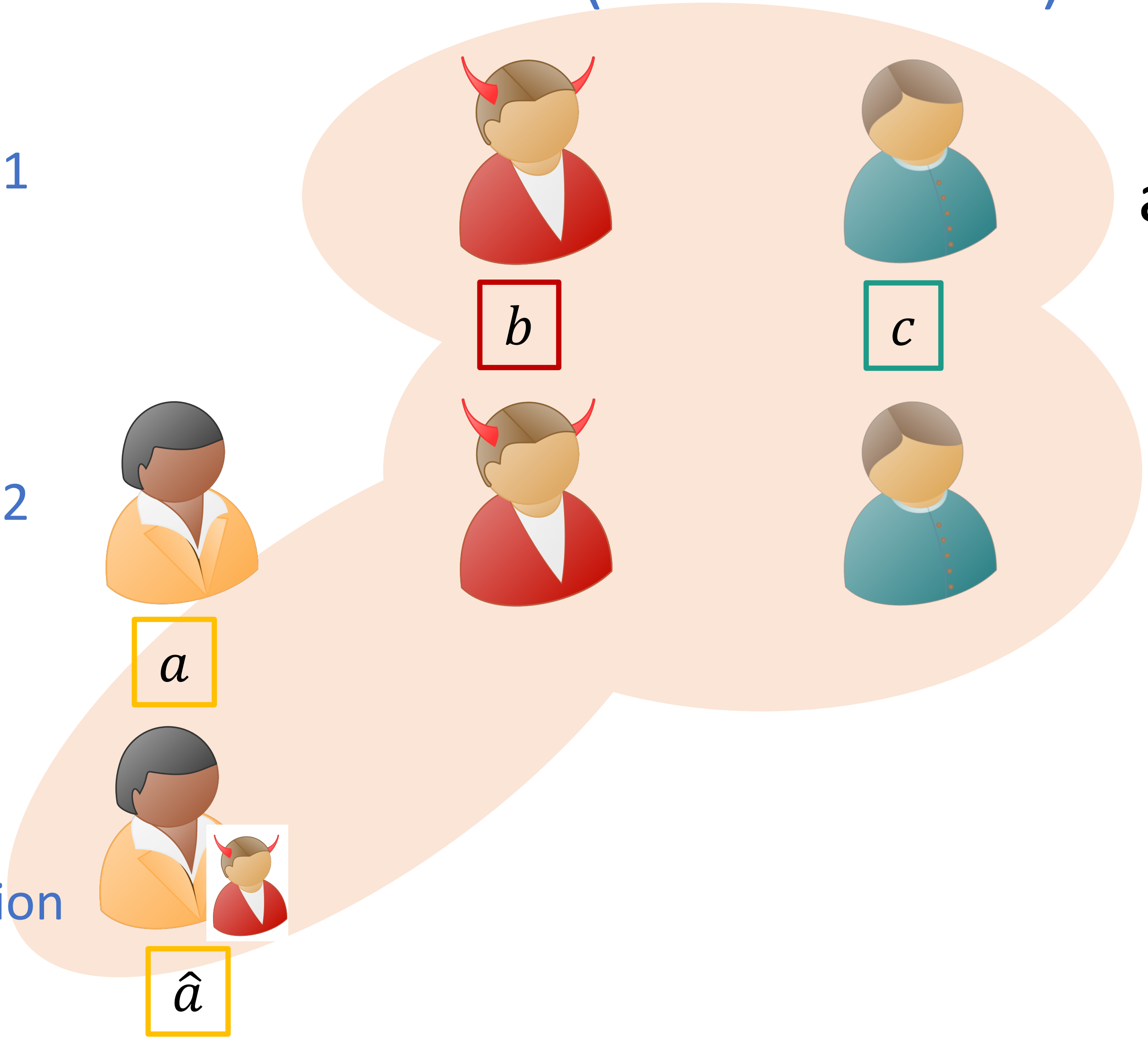

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Output: $\hat{y} = f(\hat{a}, b, c)$

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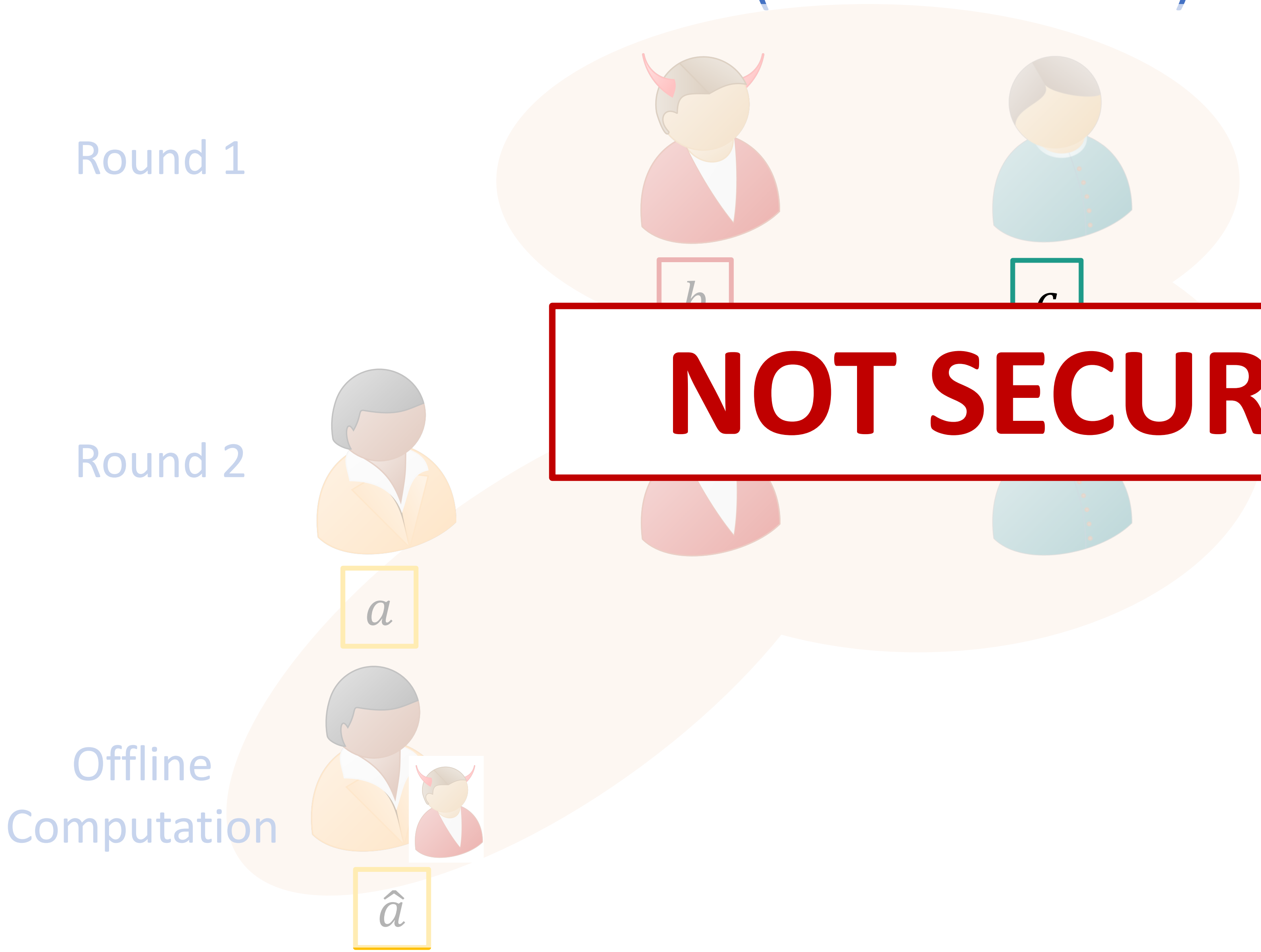

Corrupt Bob can launch an offline spoofing attack

NOT SECURE!!

Output: $y = f(a, b, c)$

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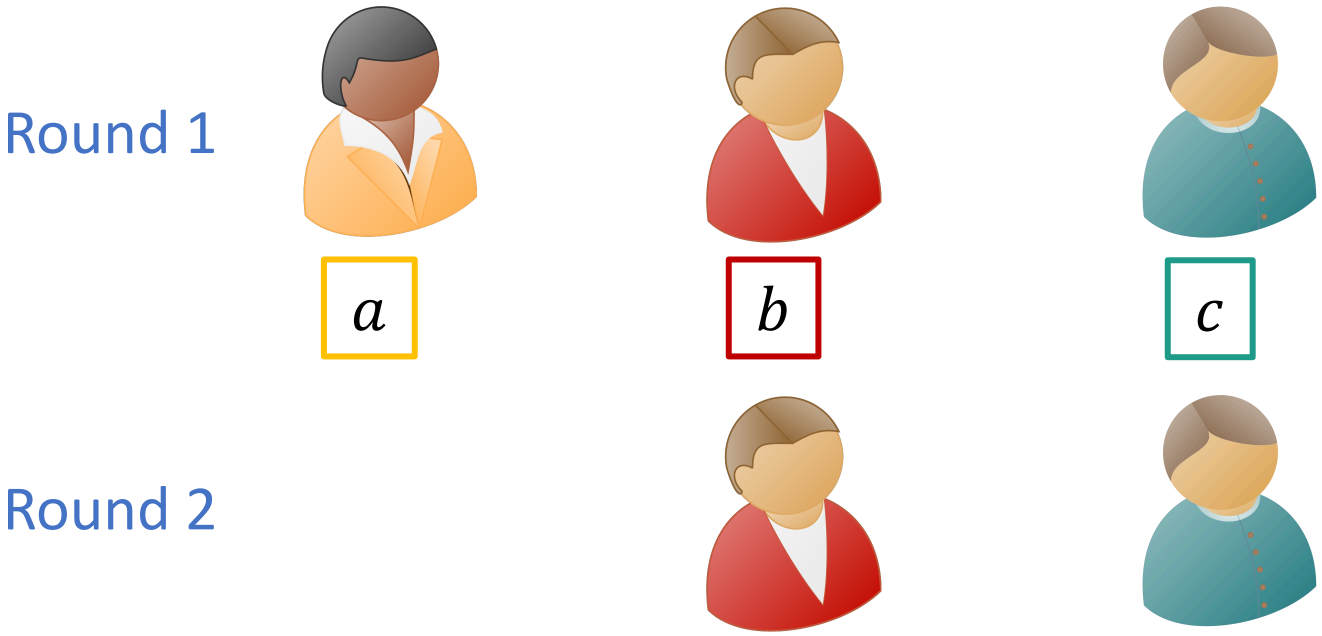

- Alice doesn’t broadcast a message in the second round

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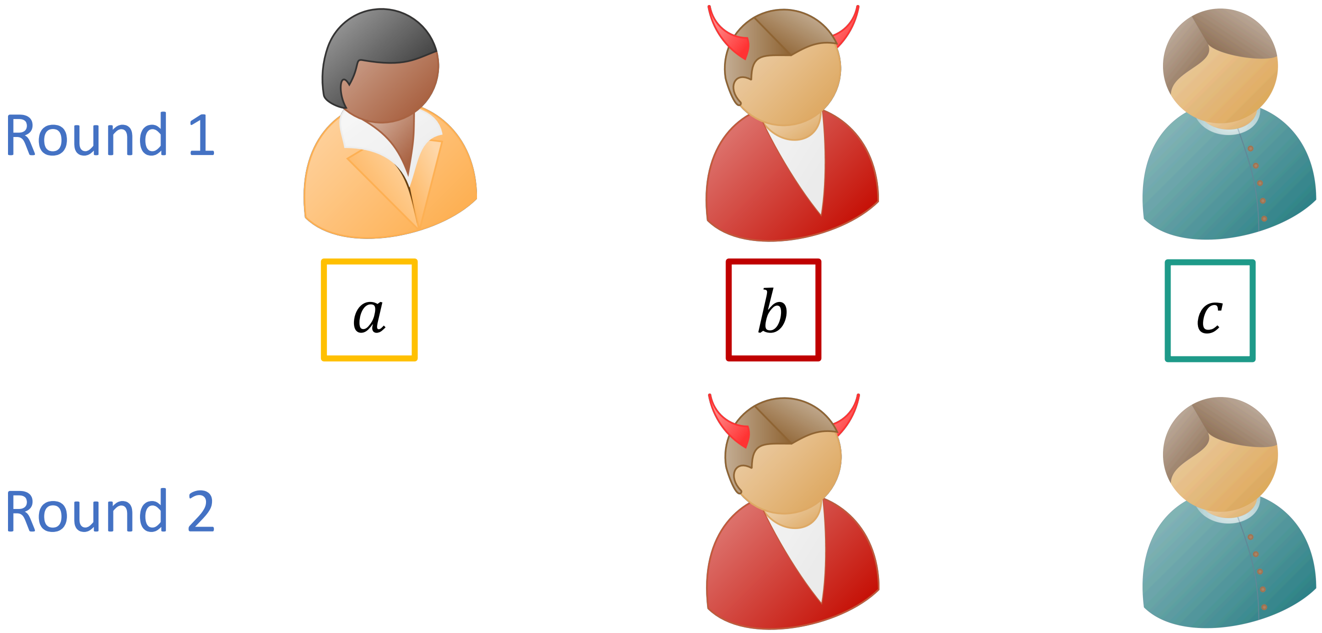

Corrupt Bob can launch an offline residual function attack

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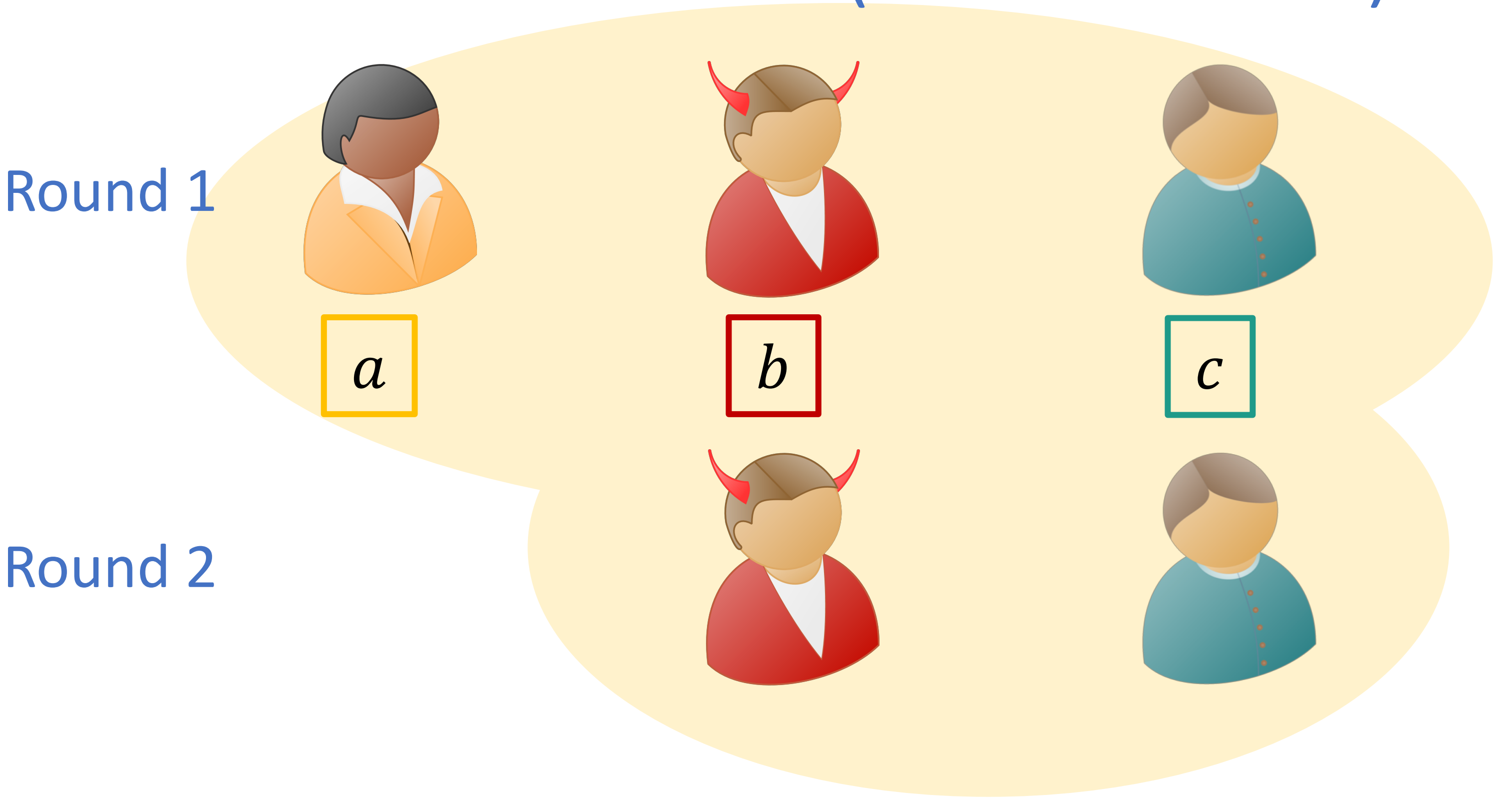

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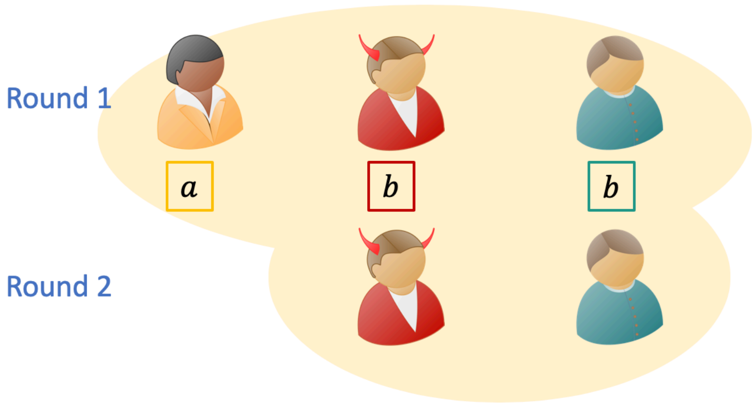

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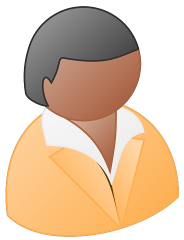

a

Offline Computation

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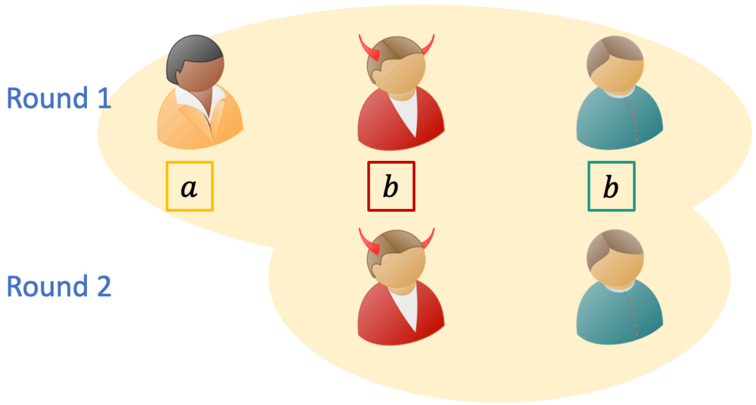

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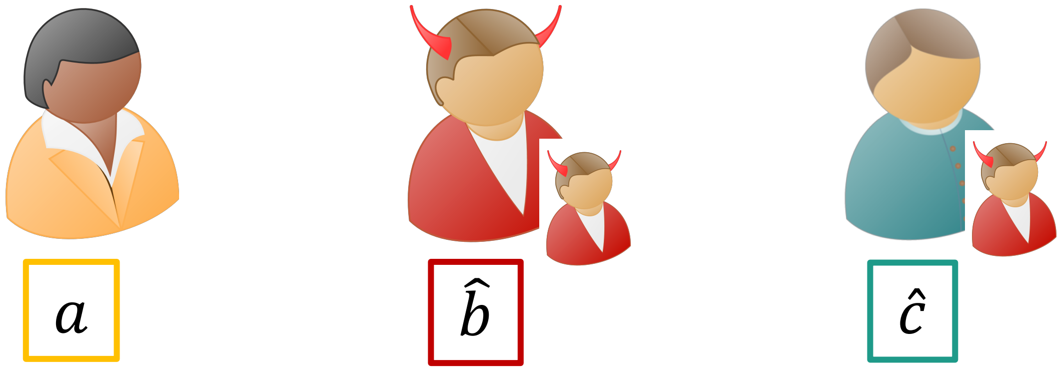

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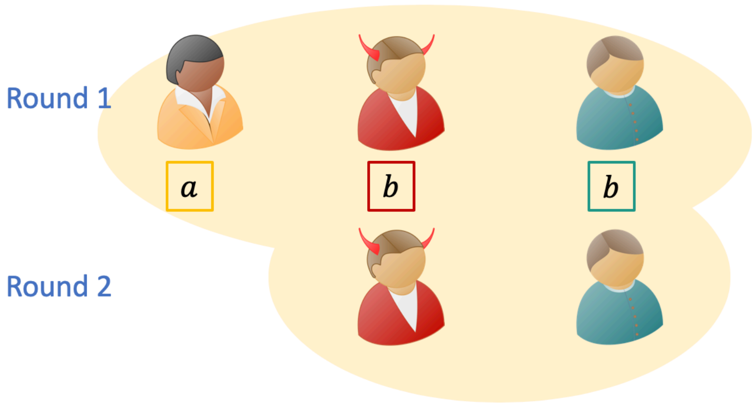

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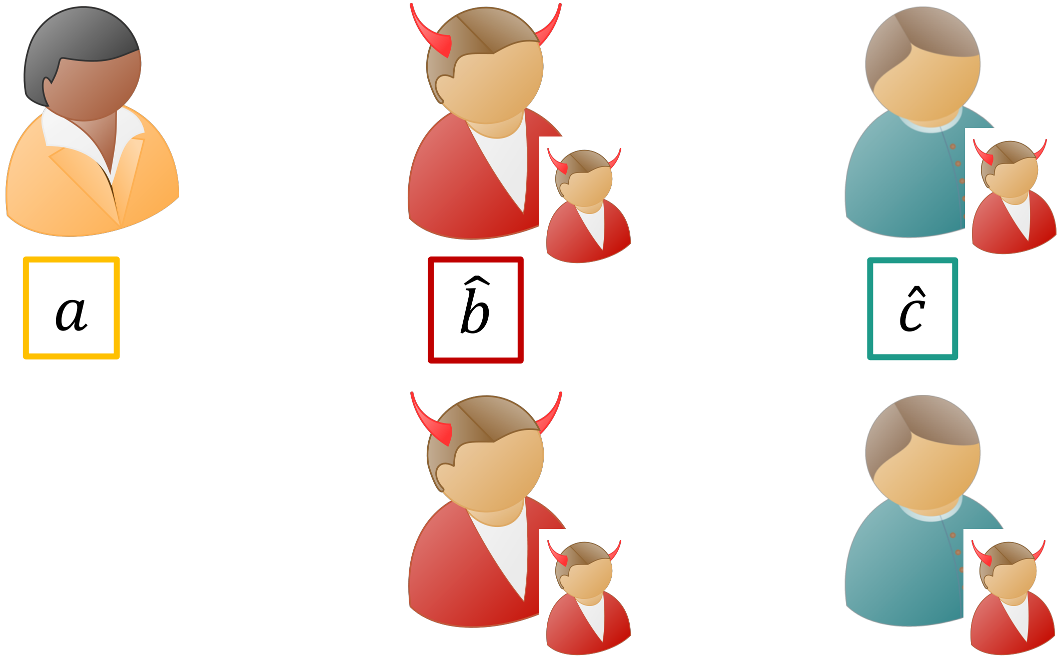

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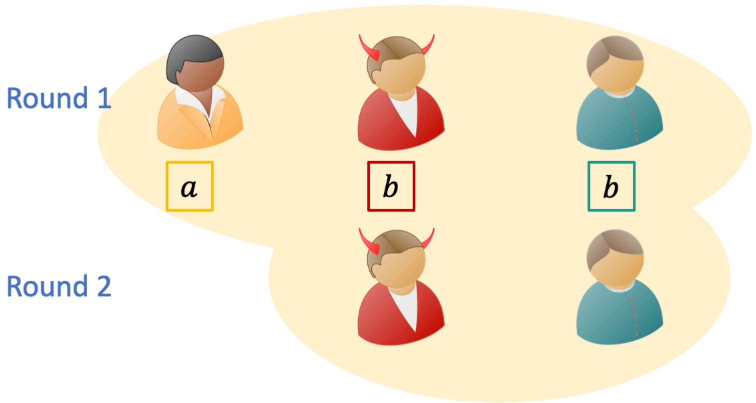

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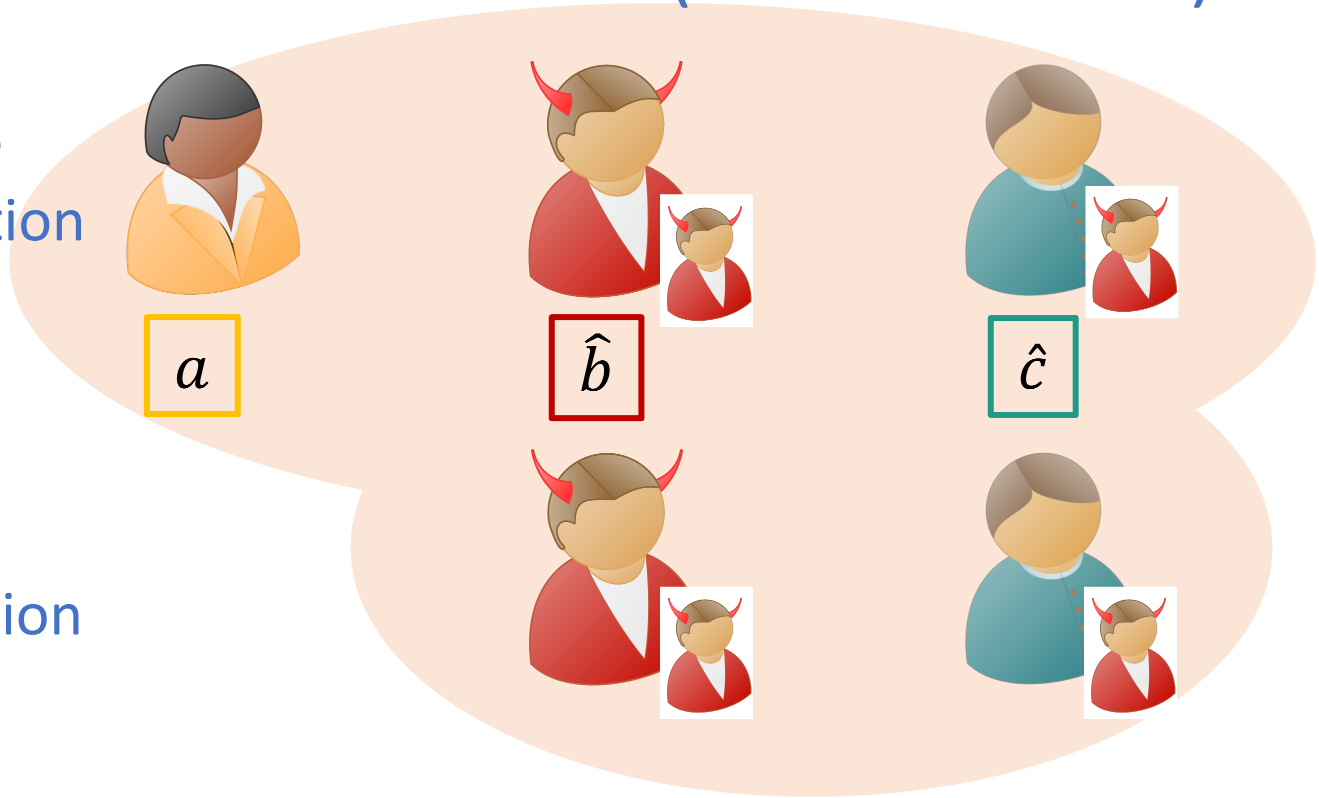
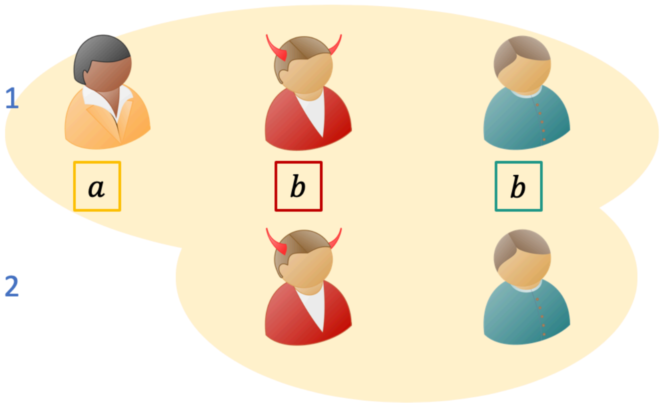


Output: $y = f(a, \hat{b}, c)$

Corrupt Bob can launch an offline residual function attack

Round 1

Round 2



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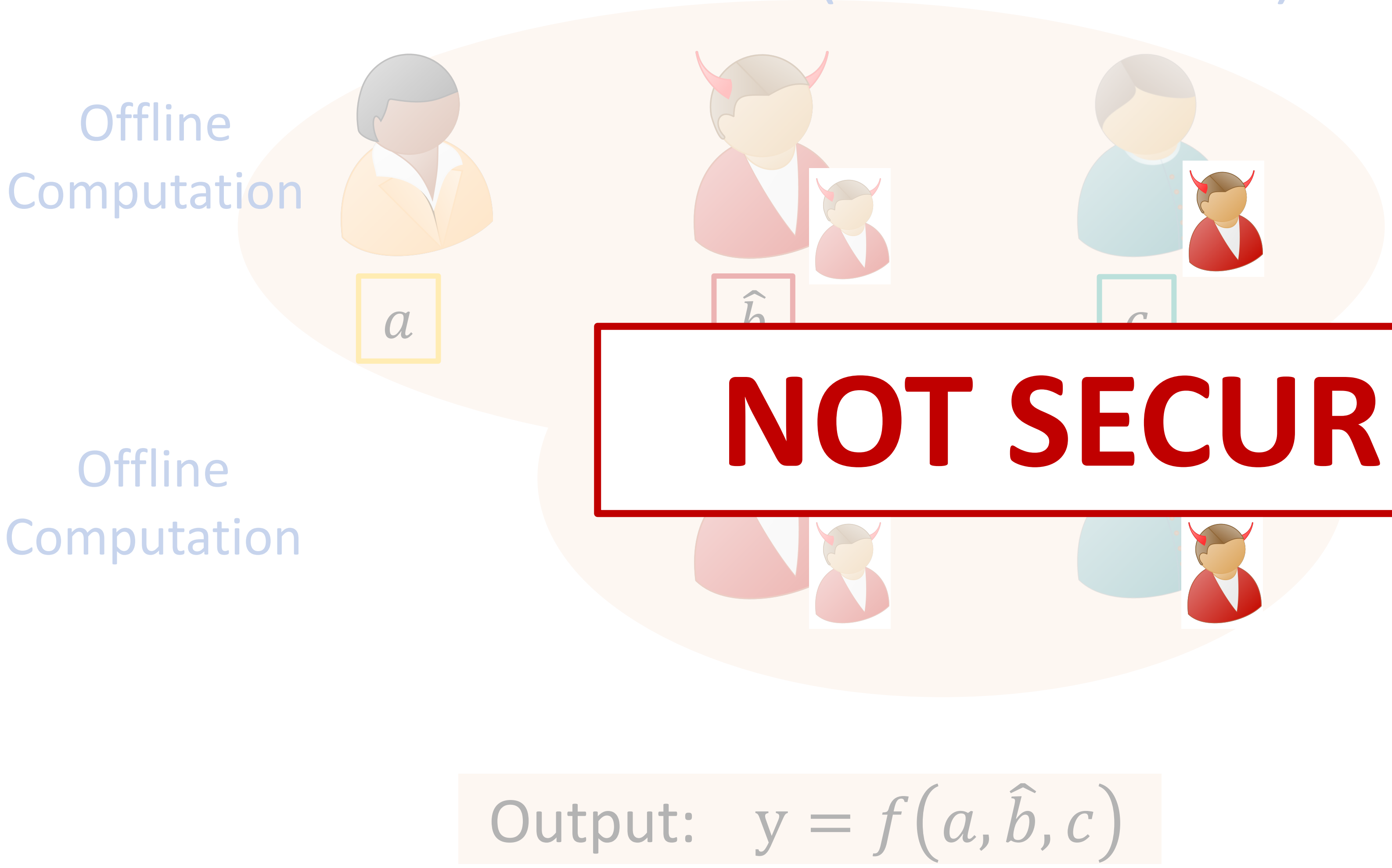
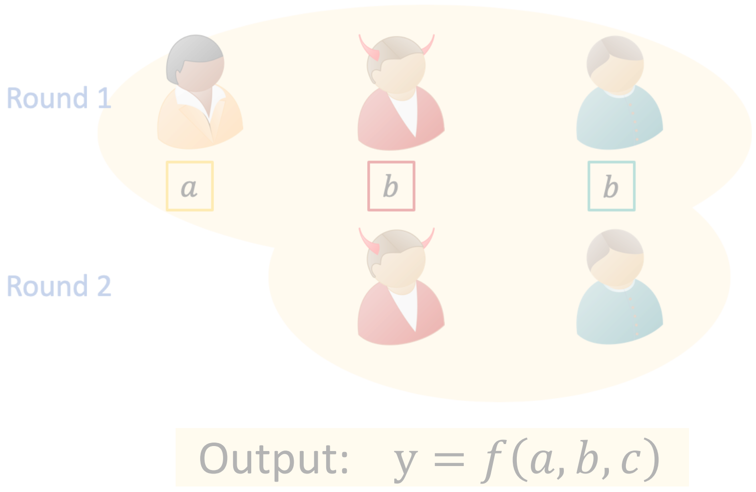


NOT SECURE!!

Corrupt Bob can launch an offline residual function attack



Our Observation

Increasing round complexity

can

decrease broadcast message complexity

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Increasing round complexity

can

decrease broadcast message complexity

Simultaneity is wasteful

Our Results

Model	Corruptions	Rounds	Output Parties	Broadcasts
Plain/CRS	$t < n - 1$		> 1	$n + t + 1$
			$= 1$	$n + t$

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			$= 1$	$n + t$
Plain/CRS	$t = n - 1$		> 1	$2n - 1$
			$= 1$	$2n - 2$

Our Results

Model	Corruptions	Rounds	Output Parties	Broadcasts
Plain	$t < n - 1$		> 1	$n + t + 1$
			$= 1$	$n + t$
Plain	$t = n - 1$		> 1	$2n - 1$
			$= 1$	$2n - 2$
PKI	$t < n$		$> n - t$	$n + t$
			$\leq n - t$	$n + t - 1$

Our Results

Model	Corruptions	Rounds	Output Parties	Broadcasts
Plain/CRS	$t < n - 1$	3	> 1	$n + t + 1$
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			$= 1$	$2n - 2$
PKI	$t < n$	3	$> n - t$	$n + t$
			$\leq n - t$	$n + t - 1$

3 rounds are necessary and sufficient for optimal broadcast message complexity

Our Results

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PKI	$t < n$	3	$> n - t$	$n + t$
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Broadcast message complexity is much lower than $2n$.

This Talk: Lower Bounds

Model	Corruptions	Rounds	Output Parties	Broadcasts
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PKI/CRS	$t < n$	3	$> n - t$	$n + t$
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Message Complexity in the Plain/CRS Model

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Obsv 1

At least t+1 parties must broadcast at least two messages each

Message Complexity in the Plain/CRS Model

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Obsv 2

All parties must broadcast at least one message

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$\boxed{n = 5}$ $\boxed{t = 2}$

At least t+1 parties must broadcast at least two messages each

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Assume only $t = 2$ parties broadcast at least two messages

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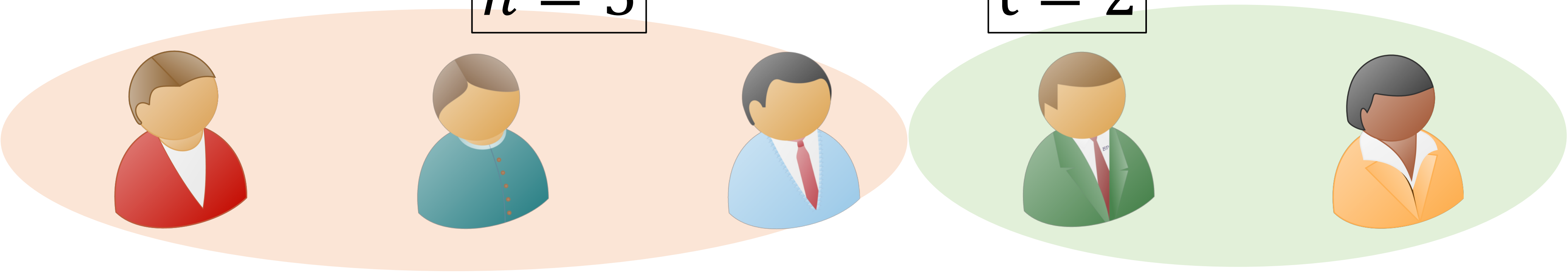
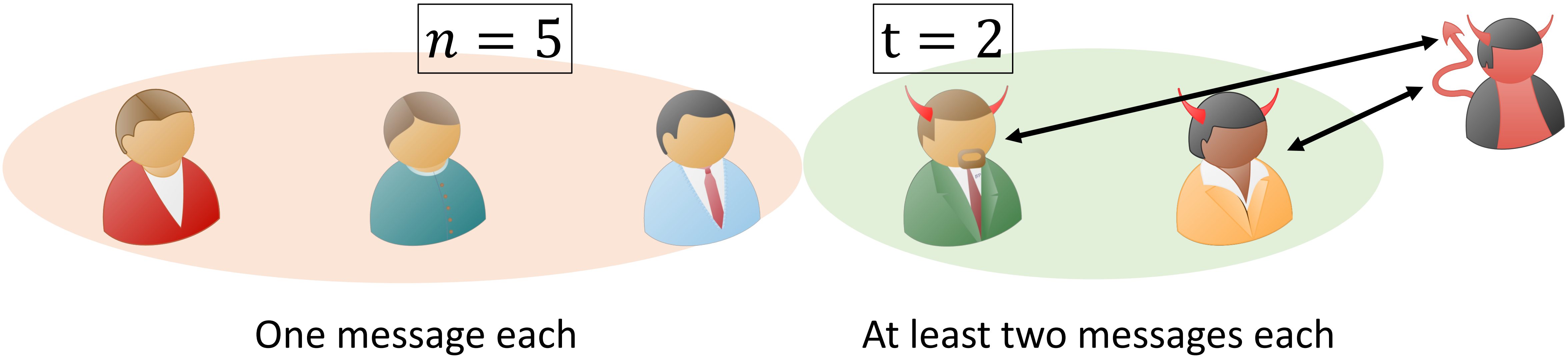


One message each

At least two messages each

Assume only $t = 2$ parties broadcast at least two messages

At least t+1 parties must broadcast at least two messages each



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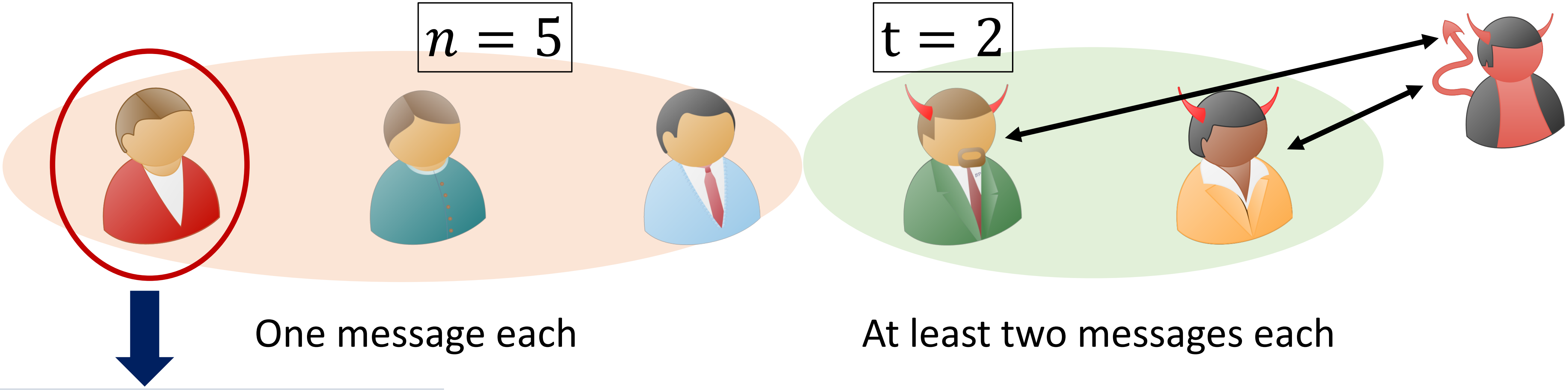


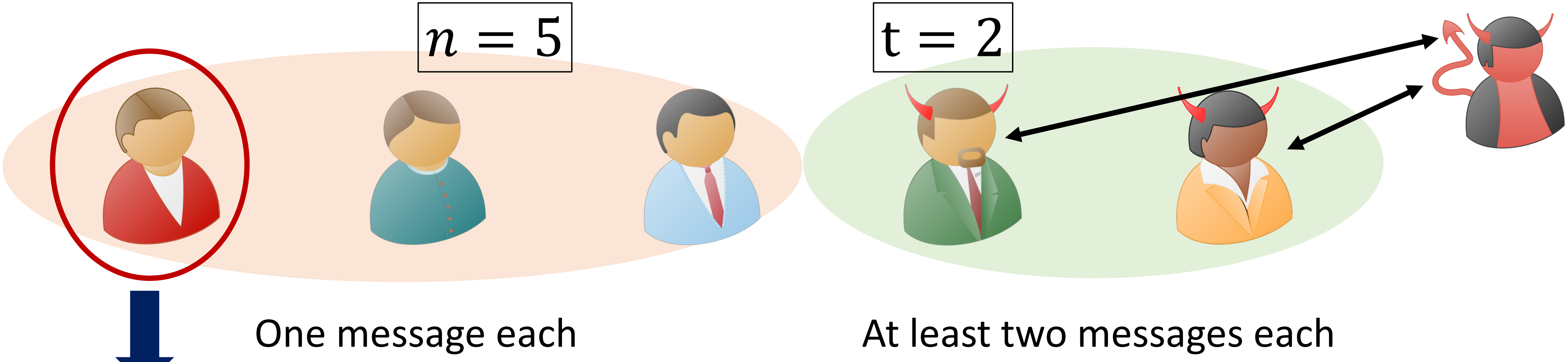
One message each

At least two messages each

First party in the orange set

Assume only $t = 2$ parties broadcast at least two messages

At least t+1 parties must broadcast at least two messages each

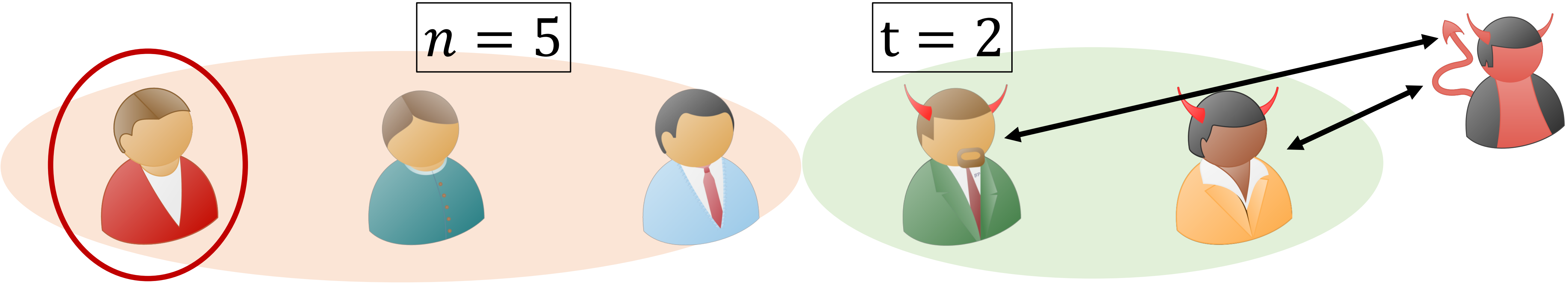


First party in the orange set

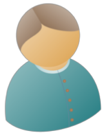
His message is independent of the inputs of other parties in the orange set

Assume only $t = 2$ parties broadcast at least two messages

At least t+1 parties must broadcast at least two messages each

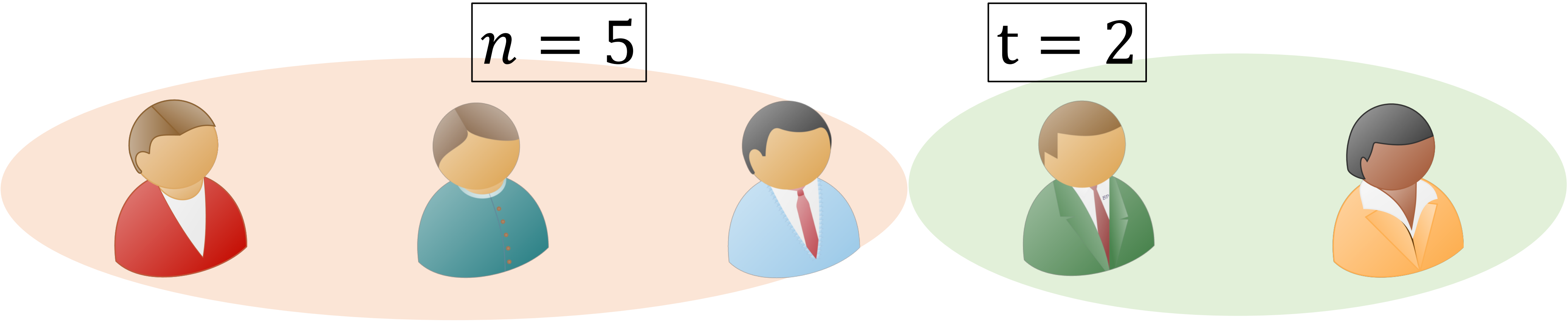


Residual Function Attack by Spoofing

 can recompute messages of  and  on different inputs by spoofing as them.

Assume only $t = 2$ parties broadcast at least two messages

At least t+1 parties must broadcast at least two messages each



One message each

At least two messages each

$\boxed{\text{Not Secure !!}}$

Assume only $t = 2$ parties broadcast at least two messages

Message Complexity in the Plain/CRS Model

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Important for considering their inputs.

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Message Complexity in the Plain/CRS Model

Obsv 1

At least t+1 parties must broadcast at least two messages each

$2\times(t+1)$ messages

Obsv 2

All parties must broadcast at least one message

$1\times(n-(t+1))$ messages

$2\times(t+1)+1\times(n-(t+1))=n+t+1$ messages

Communication Pattern in the Plain/CRS Model

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Minimum Round Complexity: 3

Communication Pattern in the Plain/CRS Model

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There is a unique communication pattern.

Communication Pattern in the Plain/CRS Model

Minimum Round Complexity: 3

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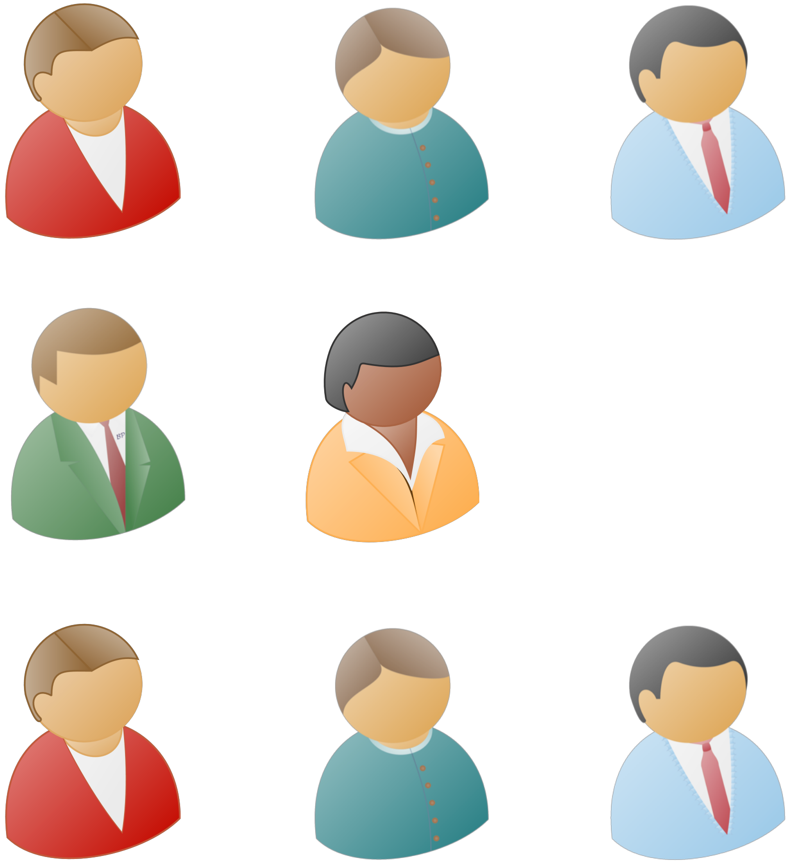
Round 1

Round 2

Round 3



Communication Pattern in the Plain/CRS Model

Message Complexity in the PKI Model

Obsv 1

At least t parties must broadcast at least two messages each

Message Complexity in the PKI Model

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At least t parties must broadcast at least two messages each

This is in contrast to the requirement in the plain model

Spoofing attacks are not possible in the PKI model

Message Complexity in the PKI Model

Obsv 1

At least t parties must broadcast at least two messages each

Obsv 2

All parties must broadcast at least one message

Message Complexity in the PKI Model

Obsv 1	At least t parties must broadcast at least two messages each
Obsv 2	All parties must broadcast at least one message

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Assume only $t - 1 = 1$ parties broadcast at least two messages

At least t parties must broadcast at least two messages each

$n = 5$ $\quad$ $t = 2$

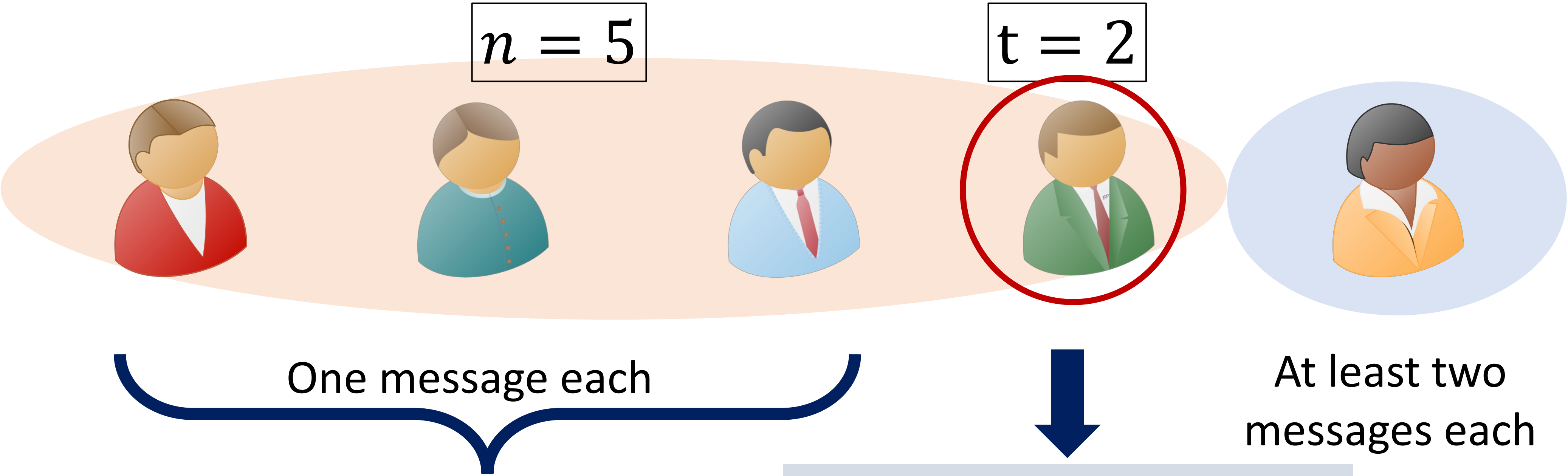
One message each

At least two messages each

Last party in the orange set

Assume only $t - 1 = 1$ parties broadcast at least two messages

At least t parties must broadcast at least two messages each



Messages of these parties are independent of the last party's input

Last party in the orange set

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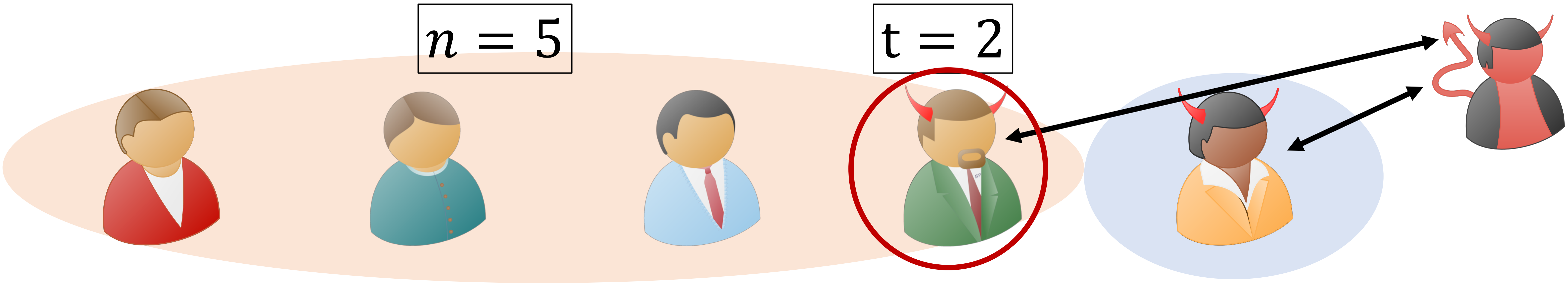
At least t parties must broadcast at least two messages each



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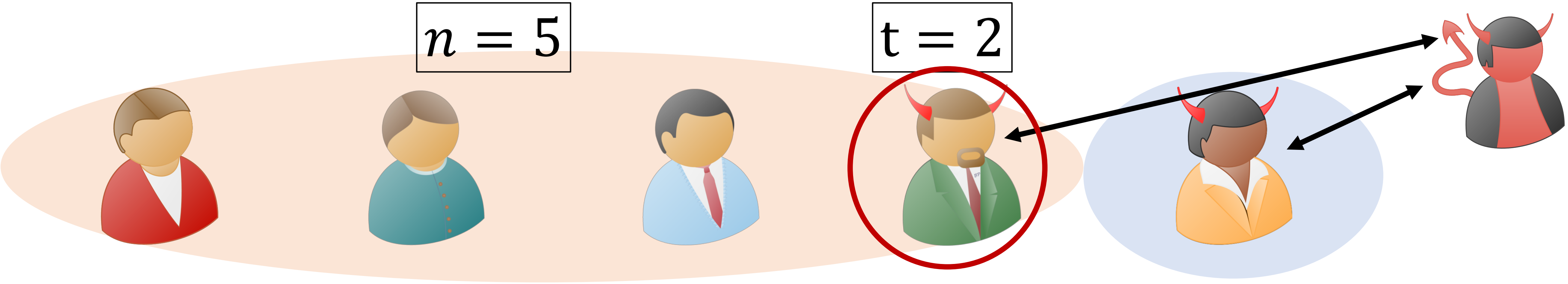

Residual Function Attack without Spoofing

Re-compute the message of  on different inputs.

Assume only $t - 1 = 1$ parties broadcast at least two messages

At least t parties must broadcast at least two messages each

$n = 5$ $\quad$ $t = 2$

Not Secure !!

Assume only $t - 1 = 1$ parties broadcast at least two messages

Message Complexity in the PKI Model

STEP 1

At least t parties must broadcast at least two messages each

STEP 2

All parties must broadcast at least one message

Message Complexity in the PKI Model

STEP 1

At least t parties must broadcast at least two messages each

$2 \times t$ messages

STEP 2

All parties must broadcast at least one message

$1 \times (n - t)$ messages

$(2 \times t) + (1 \times (n - t)) = n + t$ messages

Communication Pattern in the PKI Model

Minimum Round Complexity: 3

There is a restricted class of admissible communication patterns.

Summary

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- Provide tight bounds for semi-honest corruptions in the PKI, plain and CRS models.
- Show that 3 rounds are necessary and sufficient for optimal message complexity.
- Show which communication patterns are feasible for achieving optimal message complexity.

Thank You.

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