Two Round Information-Theoretic MPC with Malicious Security

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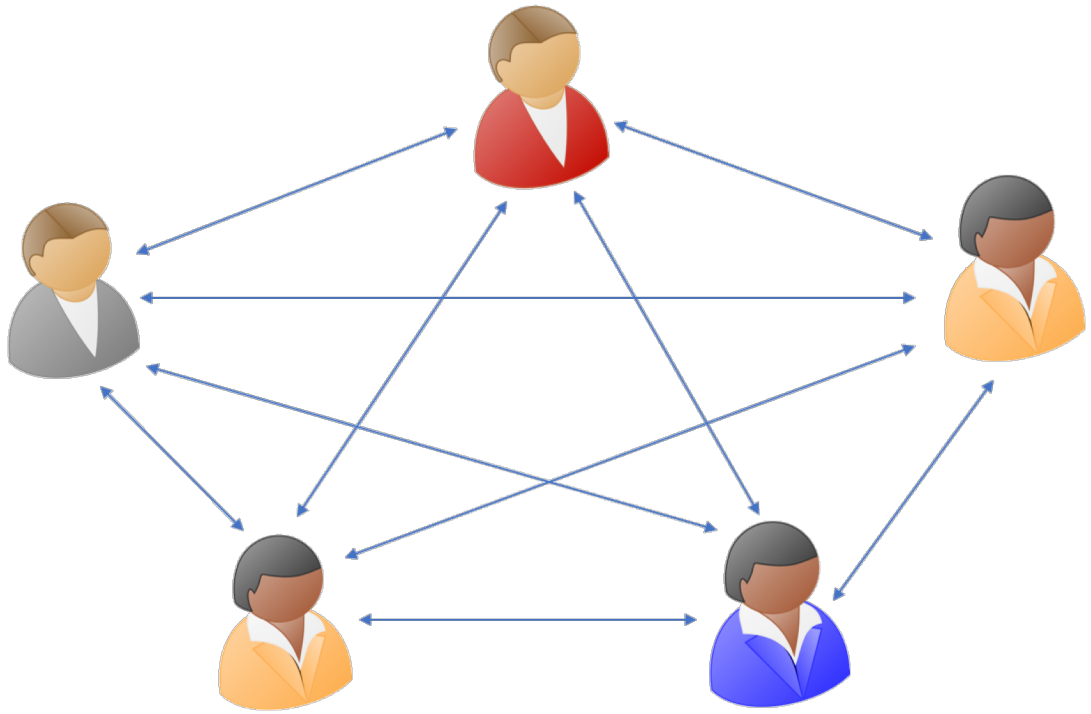
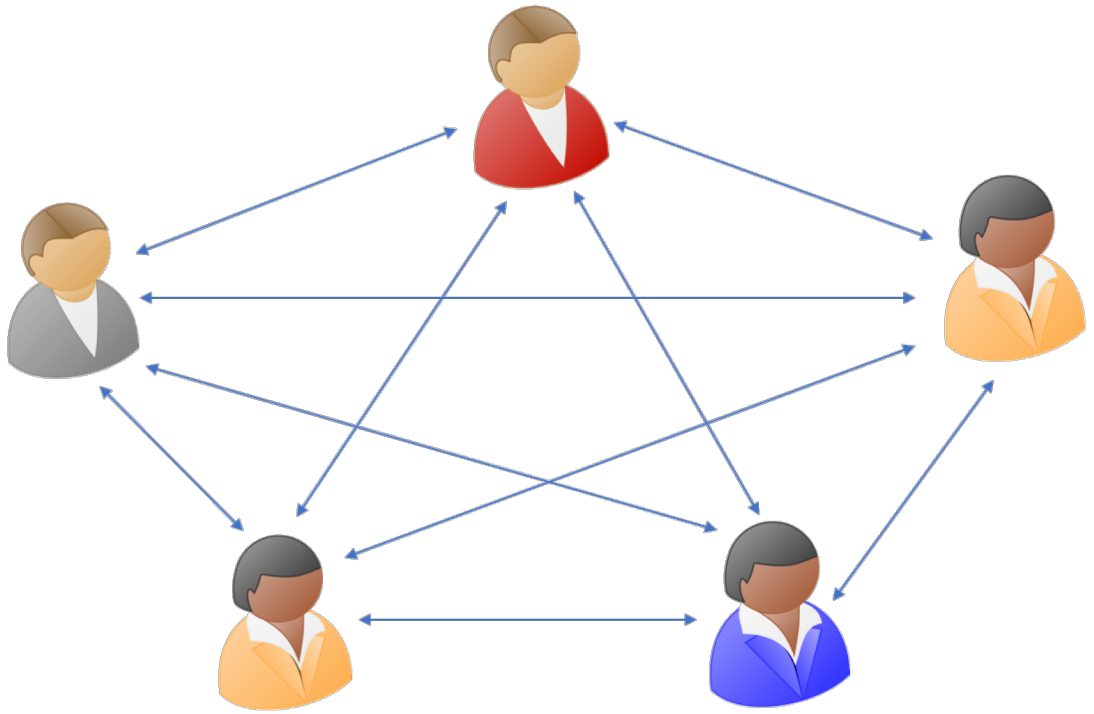
Adversarial Model



Adversarial Model

Malicious Adversary



Adversarial Model

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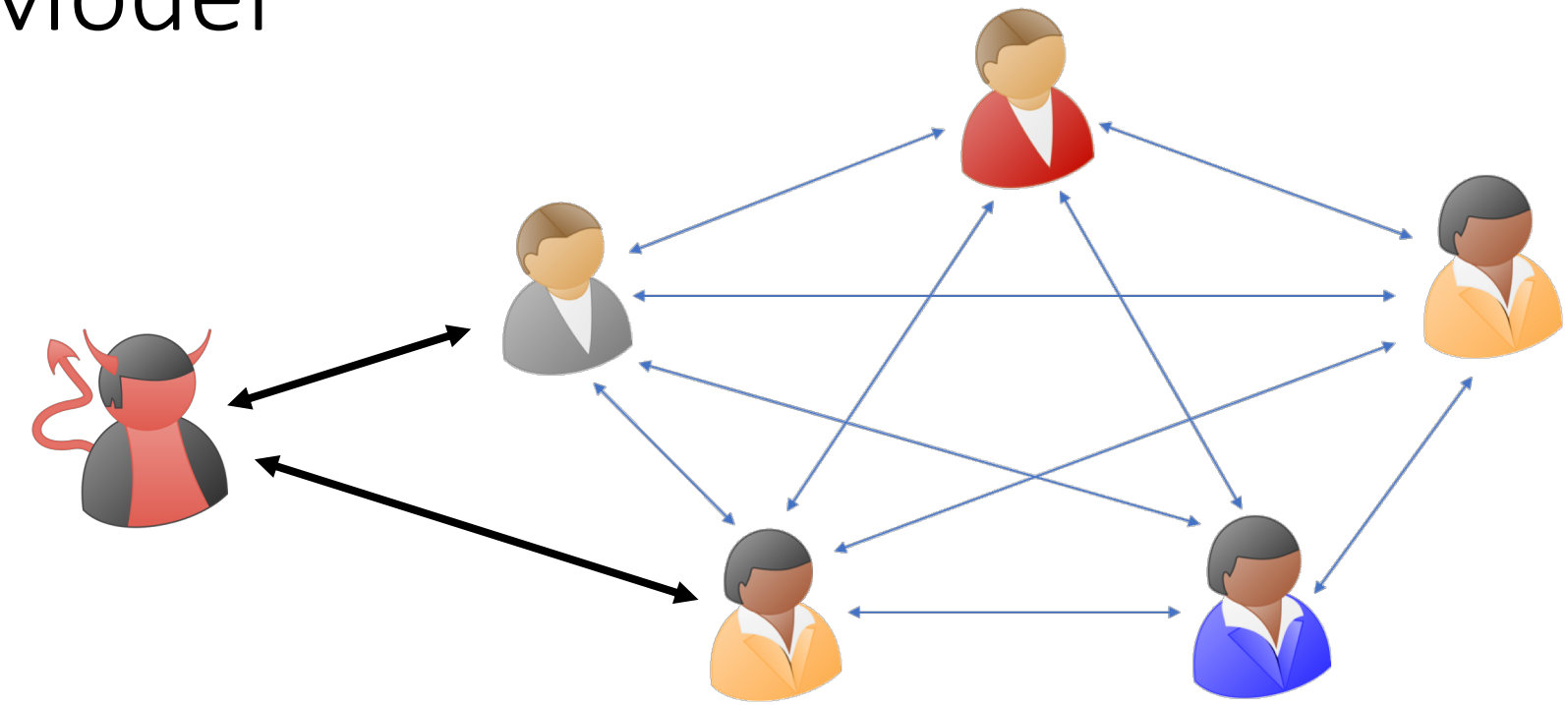

Corrupts $< n/2$ parties (Honest Majority)

Honest Majority MPC

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Information-Theoretic security is possible.

[Ben-Or, Goldwasser, Widgerson'88]

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Typically UC secure

Simulation proofs are typically straight-line

Honest Majority MPC

Information-Theoretic security is possible.

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Typically UC secure

Simulation proofs are typically straight-line

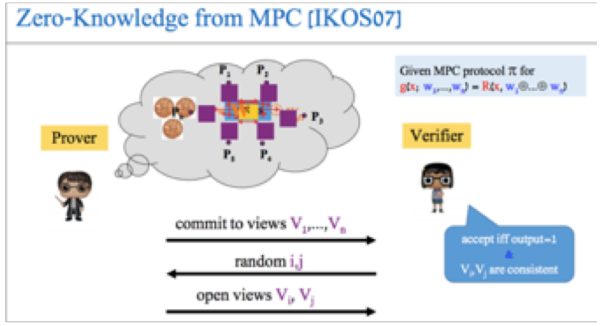
Round complexity lower bounds of dishonest majority do not apply.

4 rounds necessary for dishonest majority in the plain model

[Garg- Mukherjee-Pandey-Polychroniadou16]

Honest Majority MPC: Applications

Efficient Zero-Knowledge
[IKOS'07,…]

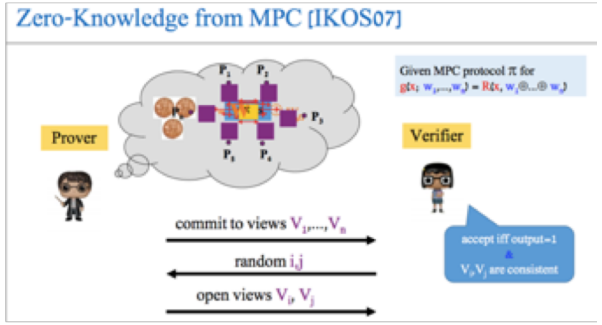


(Courtesy: Carmit Hazay's talk)

Useful for constructing efficient ZK-protocols.

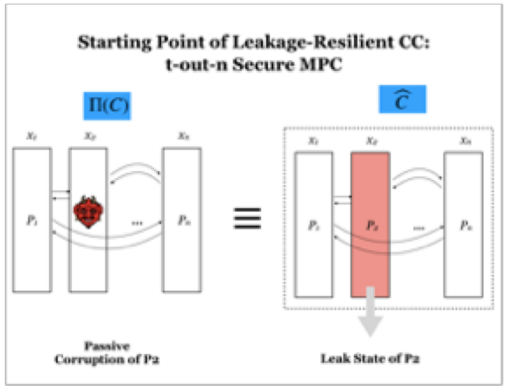
Honest Majority MPC: Applications

Efficient Zero-Knowledge
[IKOS'07,…]

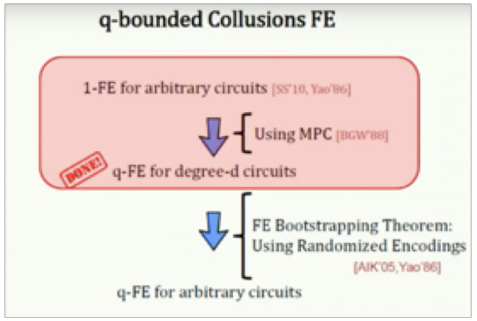


(Courtesy: Carmit Hazay's talk)

Leakage-Resilient Circuit Compilers
[ISW03,FKKNV10,AIS18]



Bounded-Key Functional Encryption
[GVW12,AV18]



(Courtesy: Sergey Gorbunov's talk)

History of IT-MPC

	Round Complexity	Class of Functions	Corruption Threshold	Adversary	
[BGW'88]	> # of multiplications	P/Poly	t<n/2	Malicious	
[BB'89, IK'00, AIK'06]	constant	NC^1	t<n/2	Malicious	
[IKP'10]	2	NC^1	t<n/3	Malicious	Security with selective abort
[GIS'18, ABT'18]	2	NC^1	t<n/2	Semi-honest	
[ABT'19]	2	NC^1	t<n/2	Malicious	Security with selective abort

Our Results

Round Complexity	Class of Functions	Corruption Threshold	Adversary
2	NC^1	$t<n/2$	Malicious

Security with Abort over
Broadcast + P2P

Security with Selective Abort over
P2P

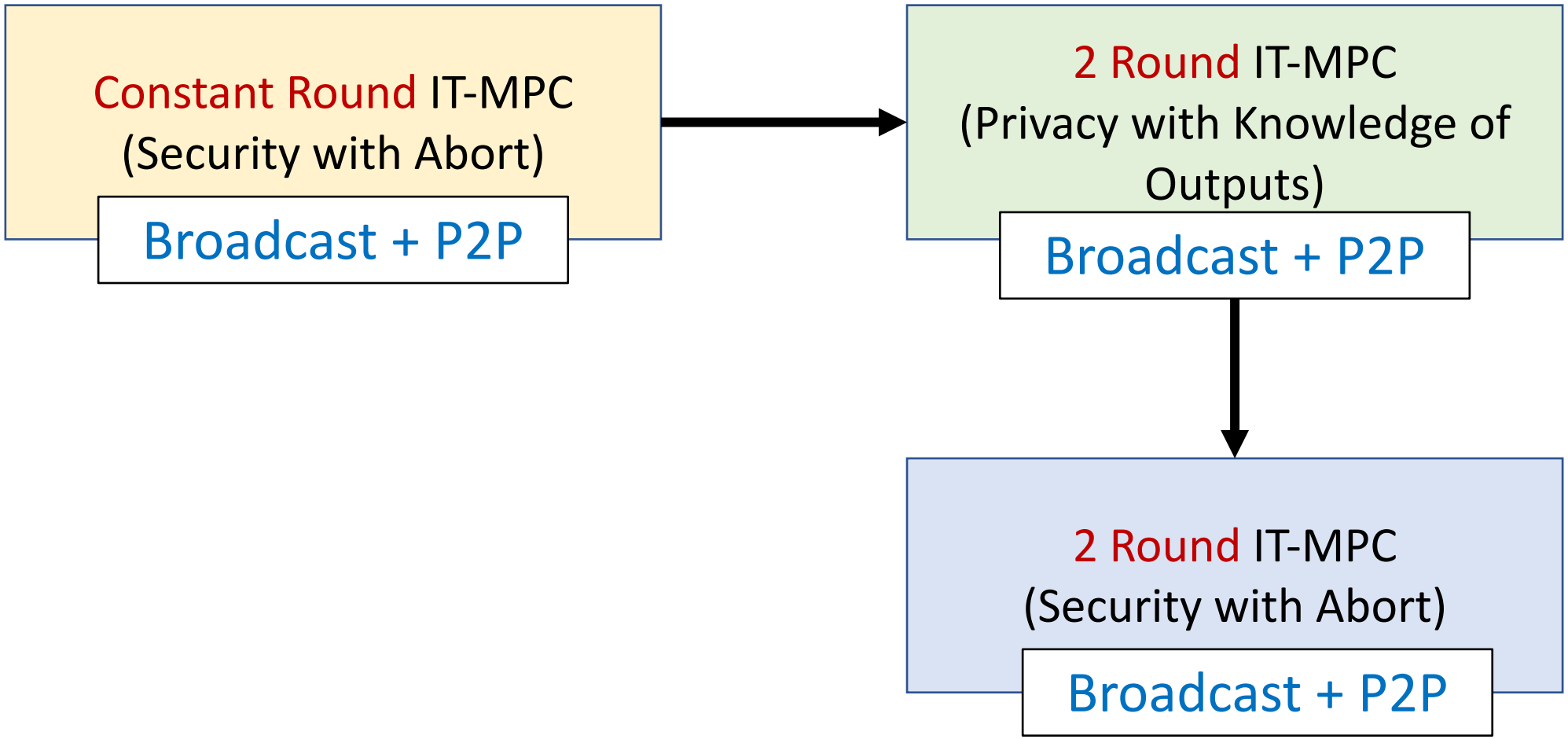
This Talk

Round Complexity	Class of Functions	Corruption Threshold	Adversary
2	NC^1	$t<n/2$	Malicious

Security with Abort over
Broadcast + P2P

Security with Selective Abort over
P2P

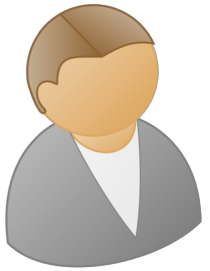
Our Strategy



Security with Abort

Party 1

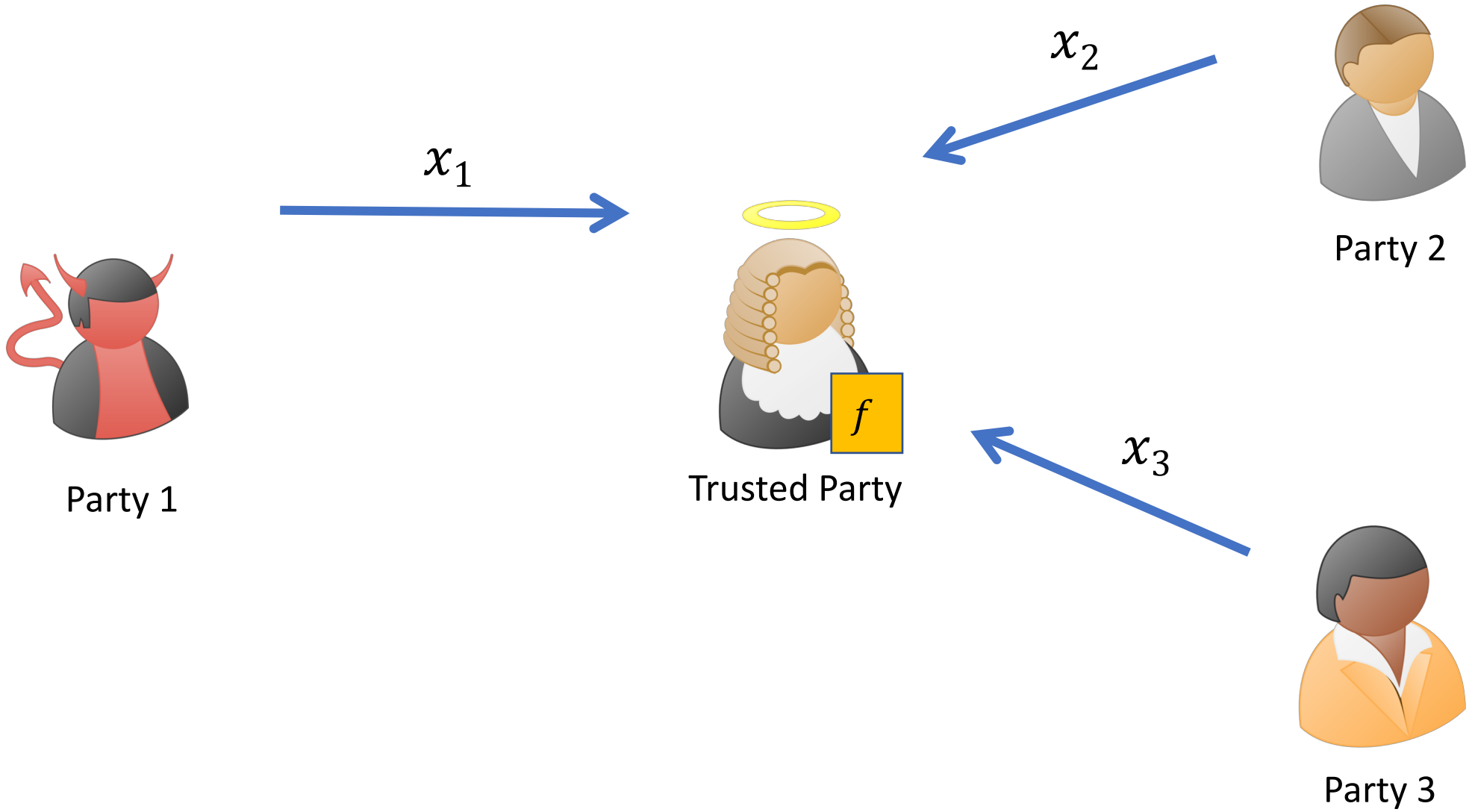
Trusted Party



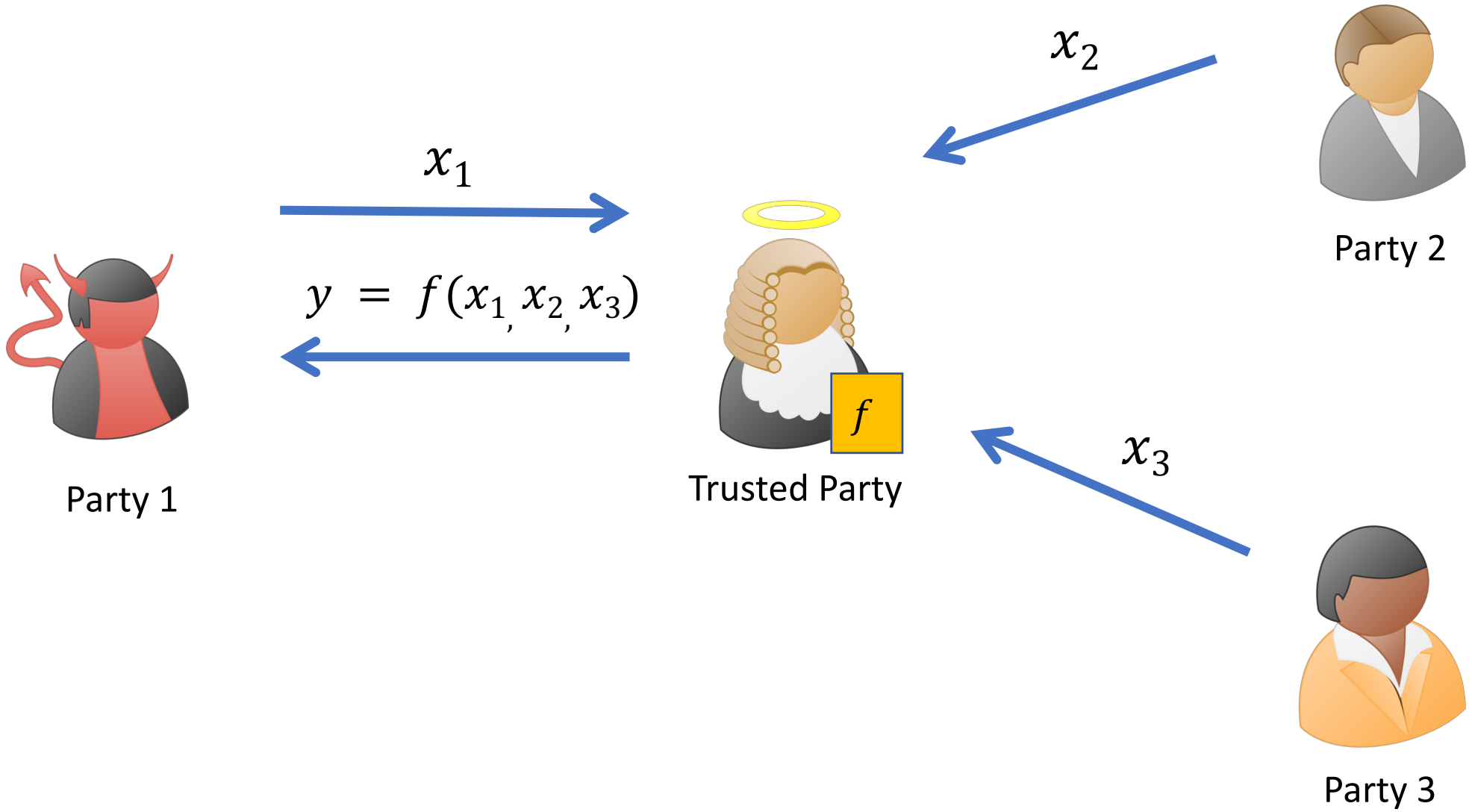
Party 2

Party 3

Security with Abort



Security with Abort



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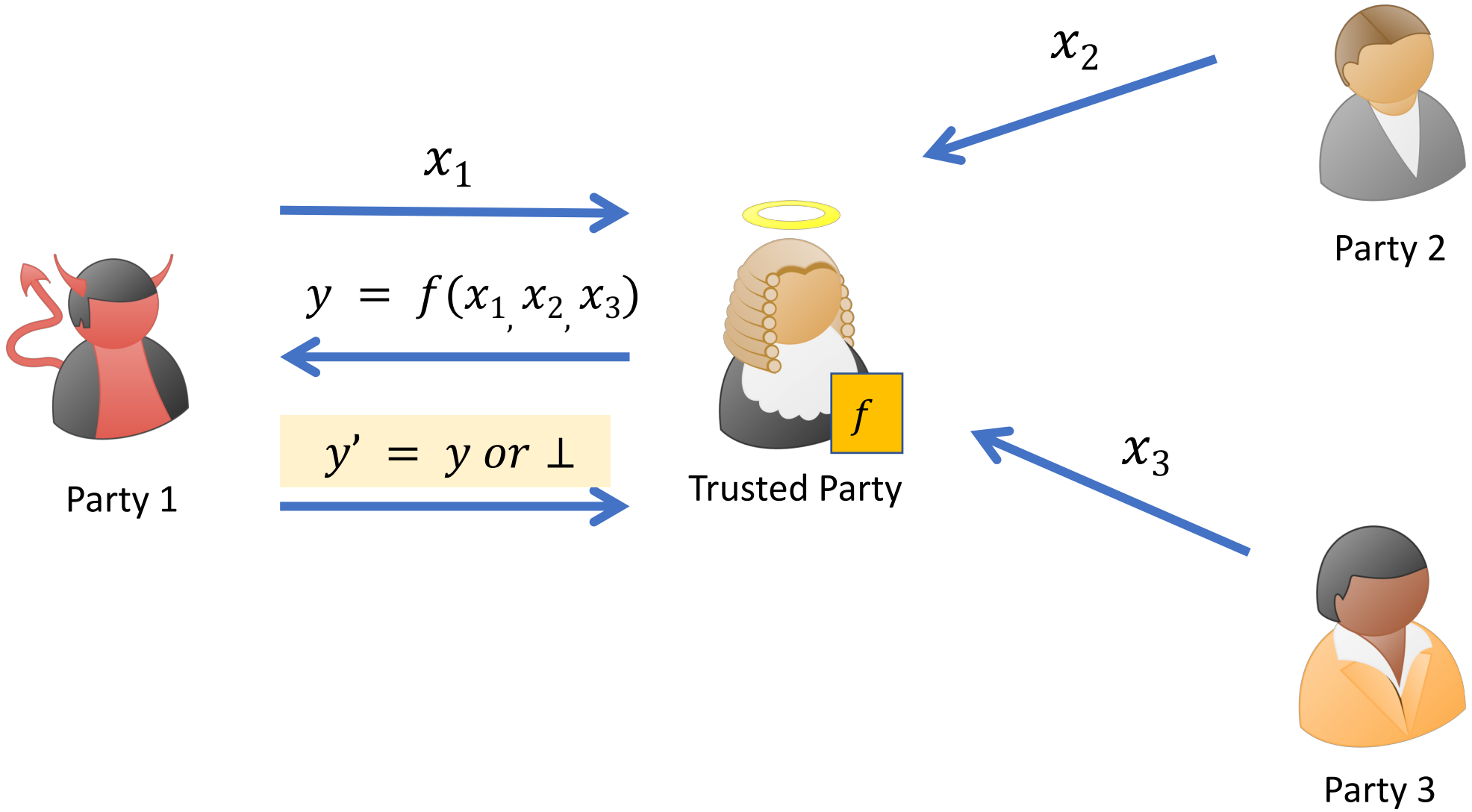
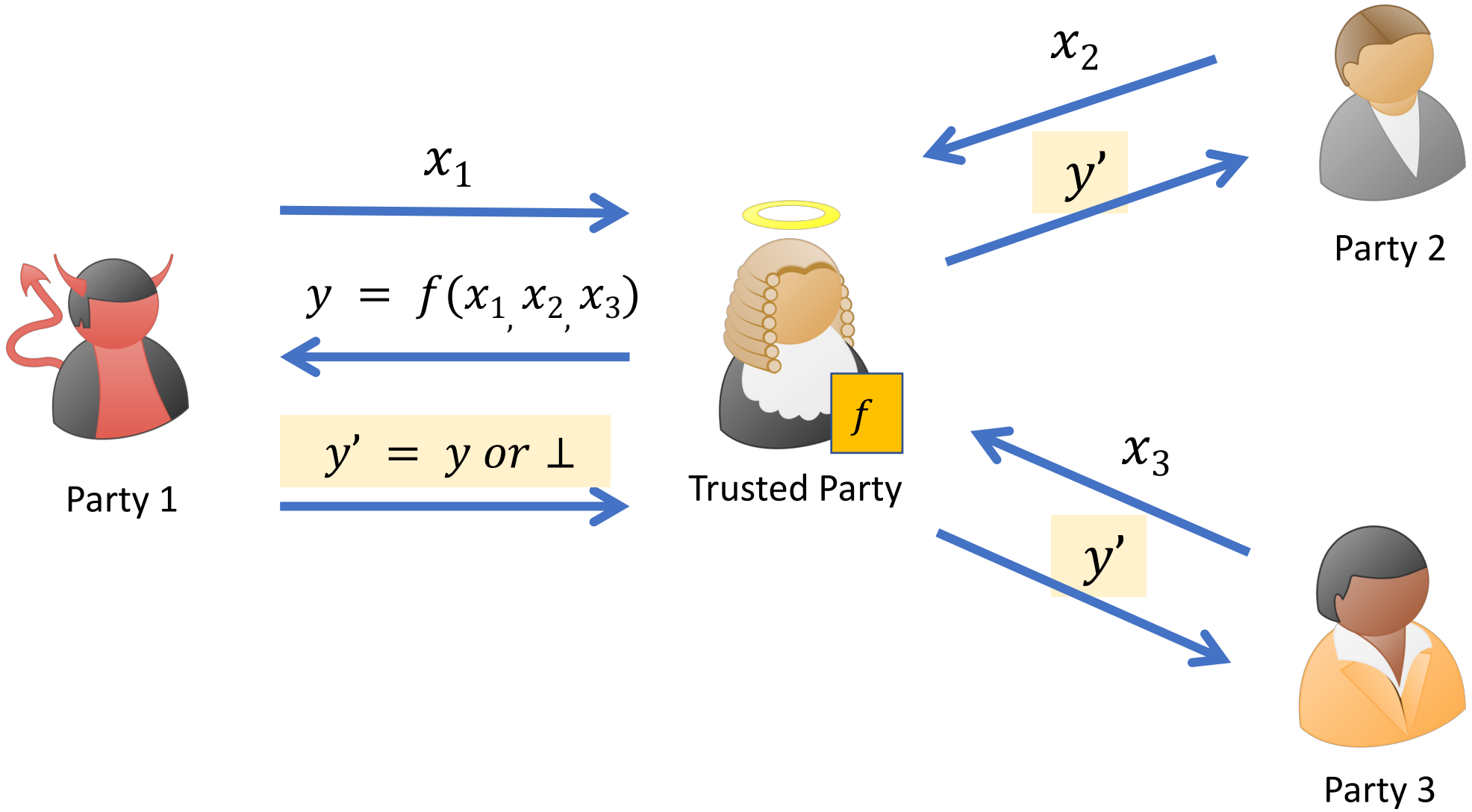


Security with Abort



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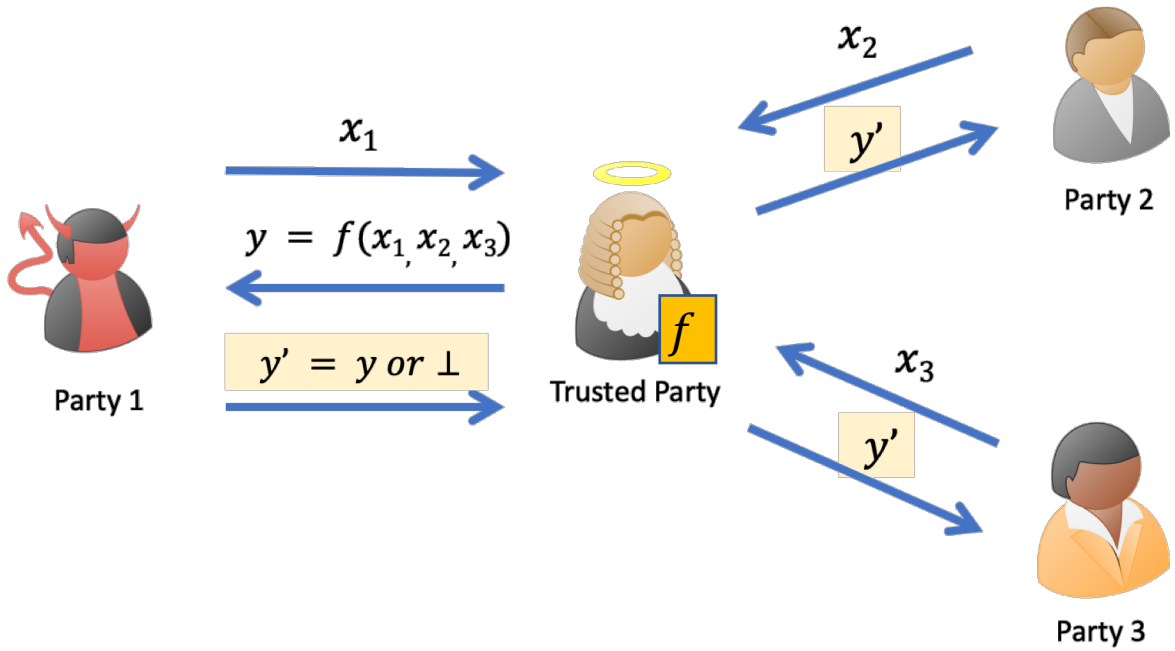
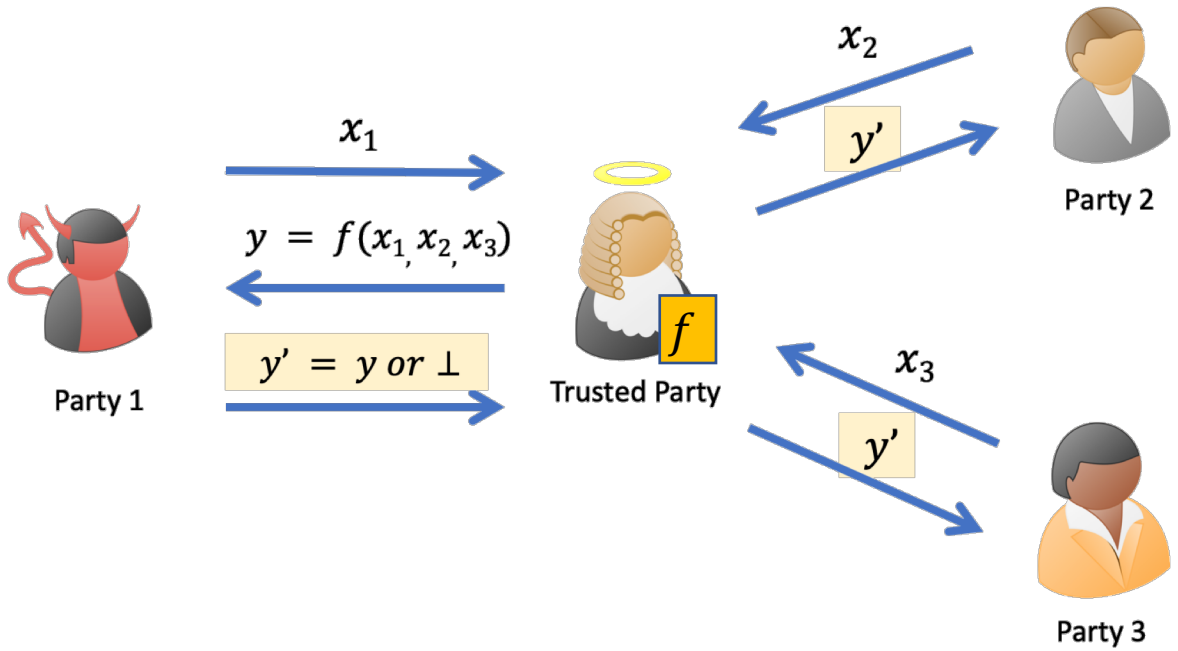


Privacy

x_2 and x_3 remain hidden

Security with Abort



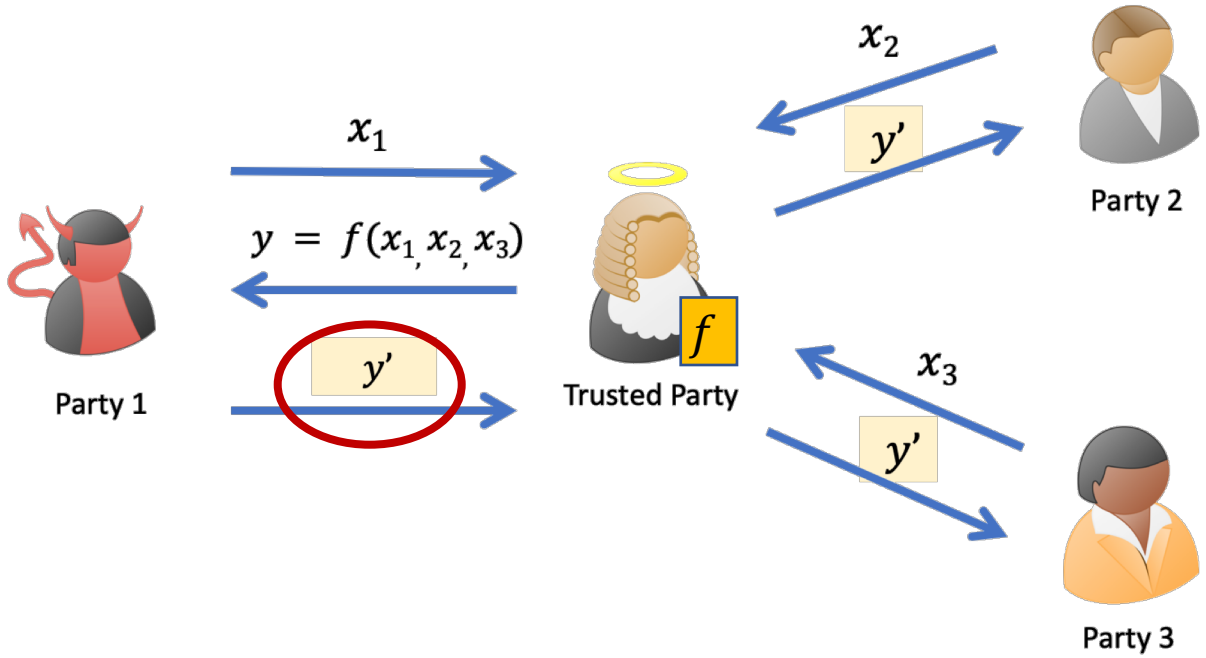
Privacy

x_2 and x_3 remain hidden

Output Correctness

Honest Parties either output $f(x_1, x_2, x_3)$ or $\perp$

Privacy with Knowledge of Outputs



Privacy

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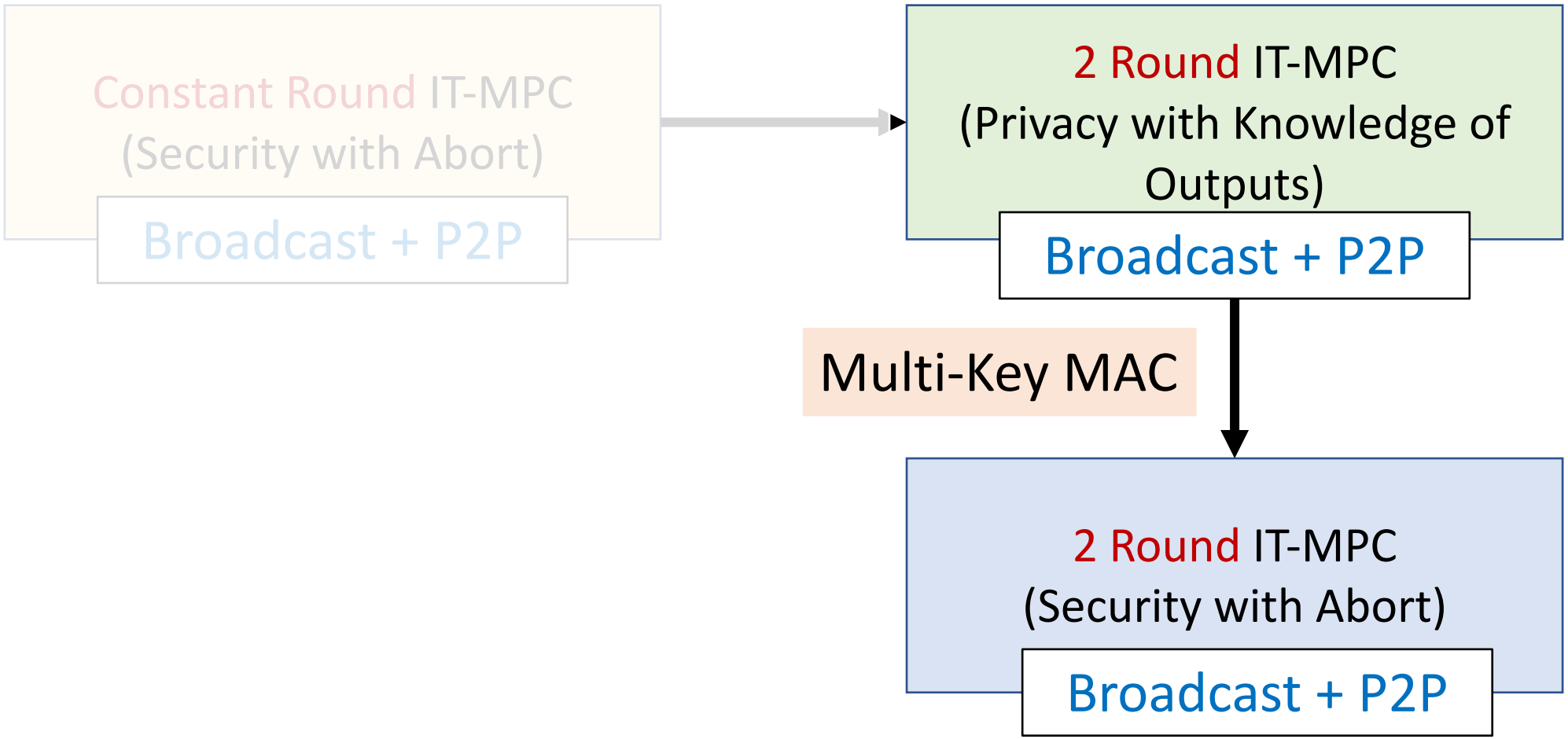
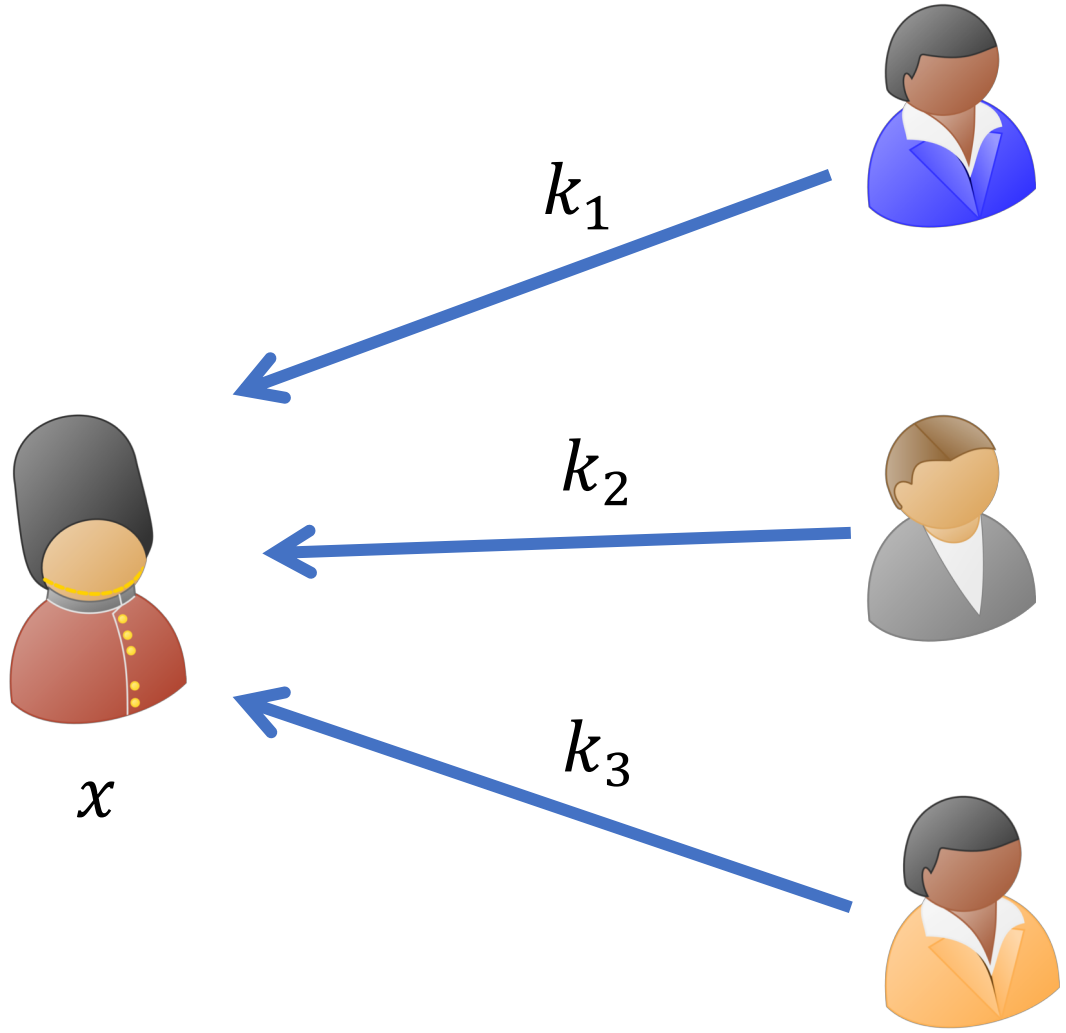
Output Correctness

Honest Parties either output $f(x_1, x_2, x_3)$ or $\perp$

First Step


Constant Round IT-MPC
(Security with Abort)
Broadcast + P2P
2 Round IT-MPC
(Privacy with Knowledge of Outputs)
Broadcast + P2P
Multi-Key MAC
2 Round IT-MPC
(Security with Abort)
Broadcast + P2P

Our Tool: Multi-Key MAC



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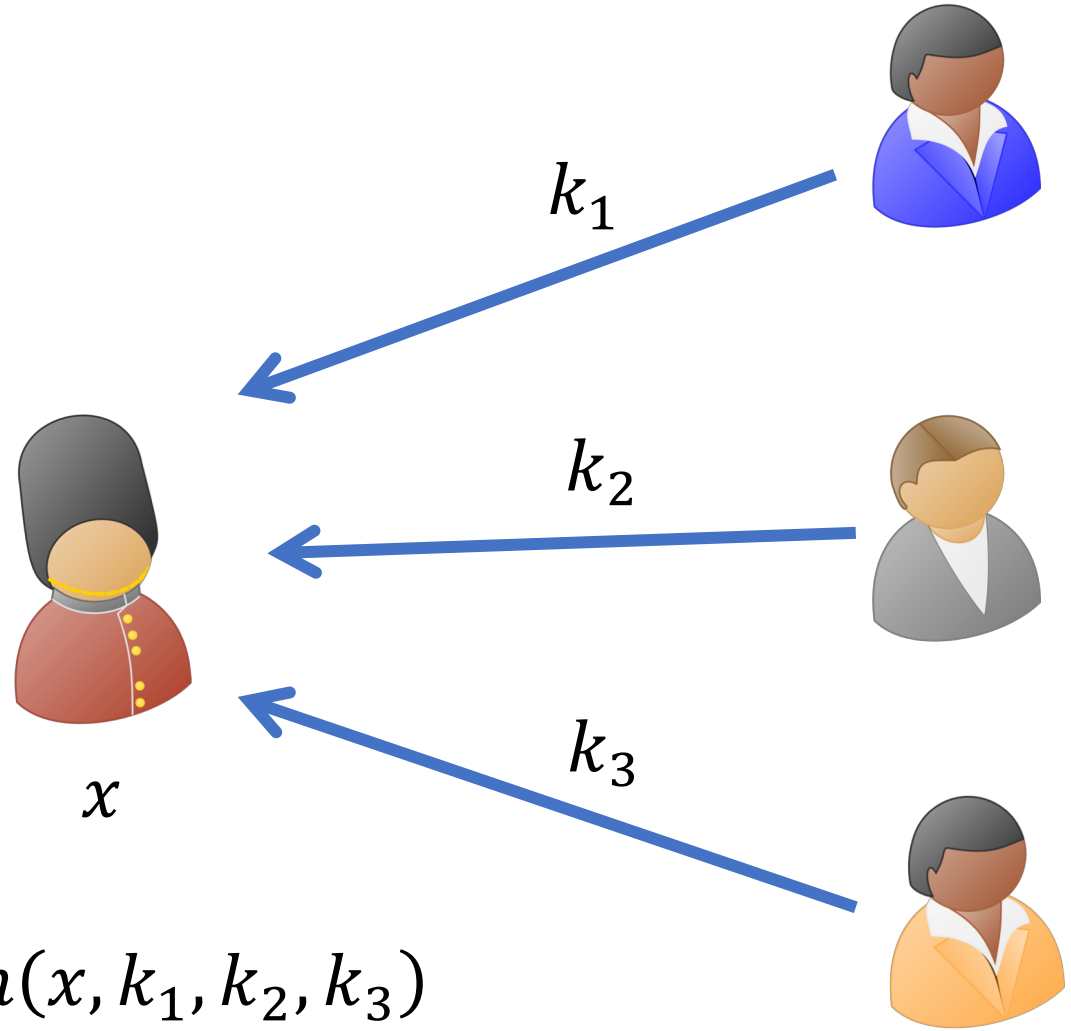
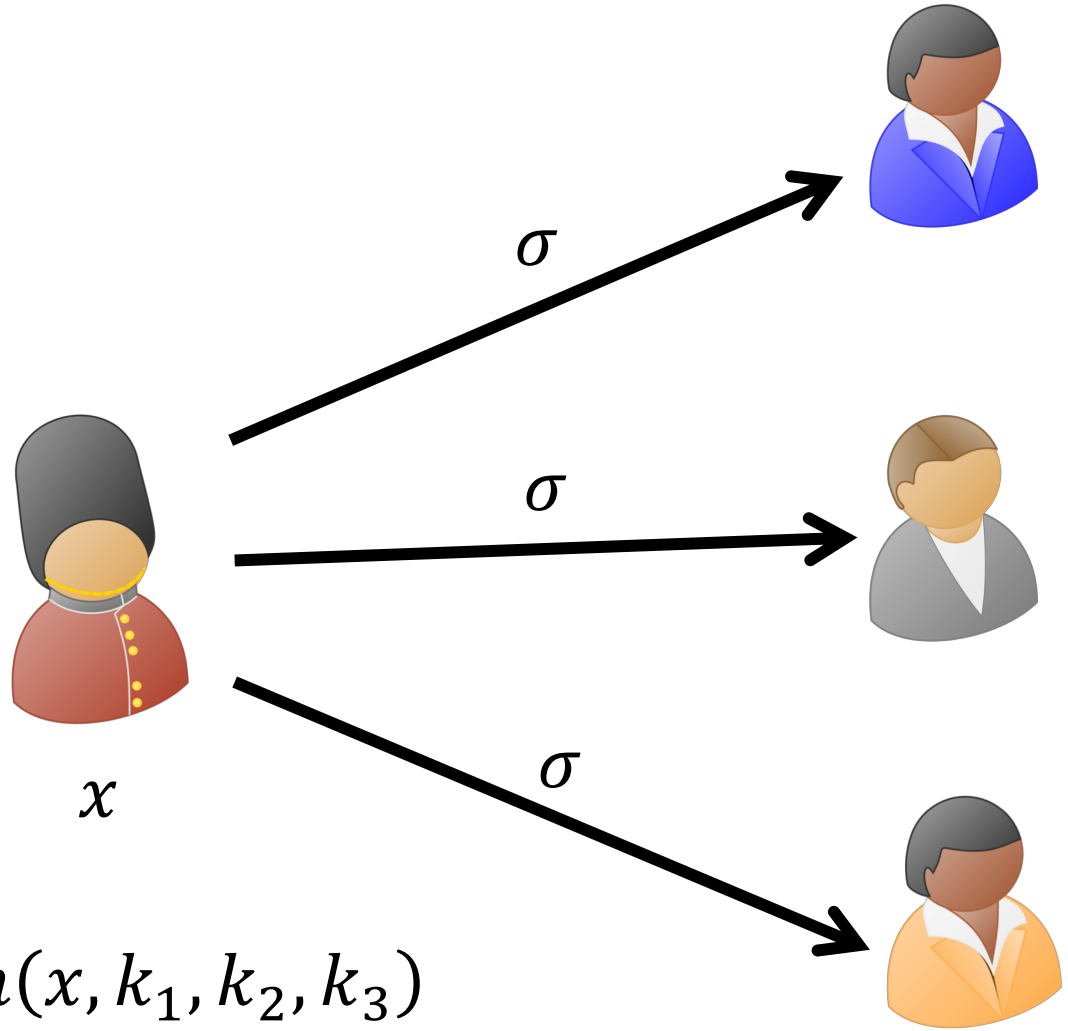


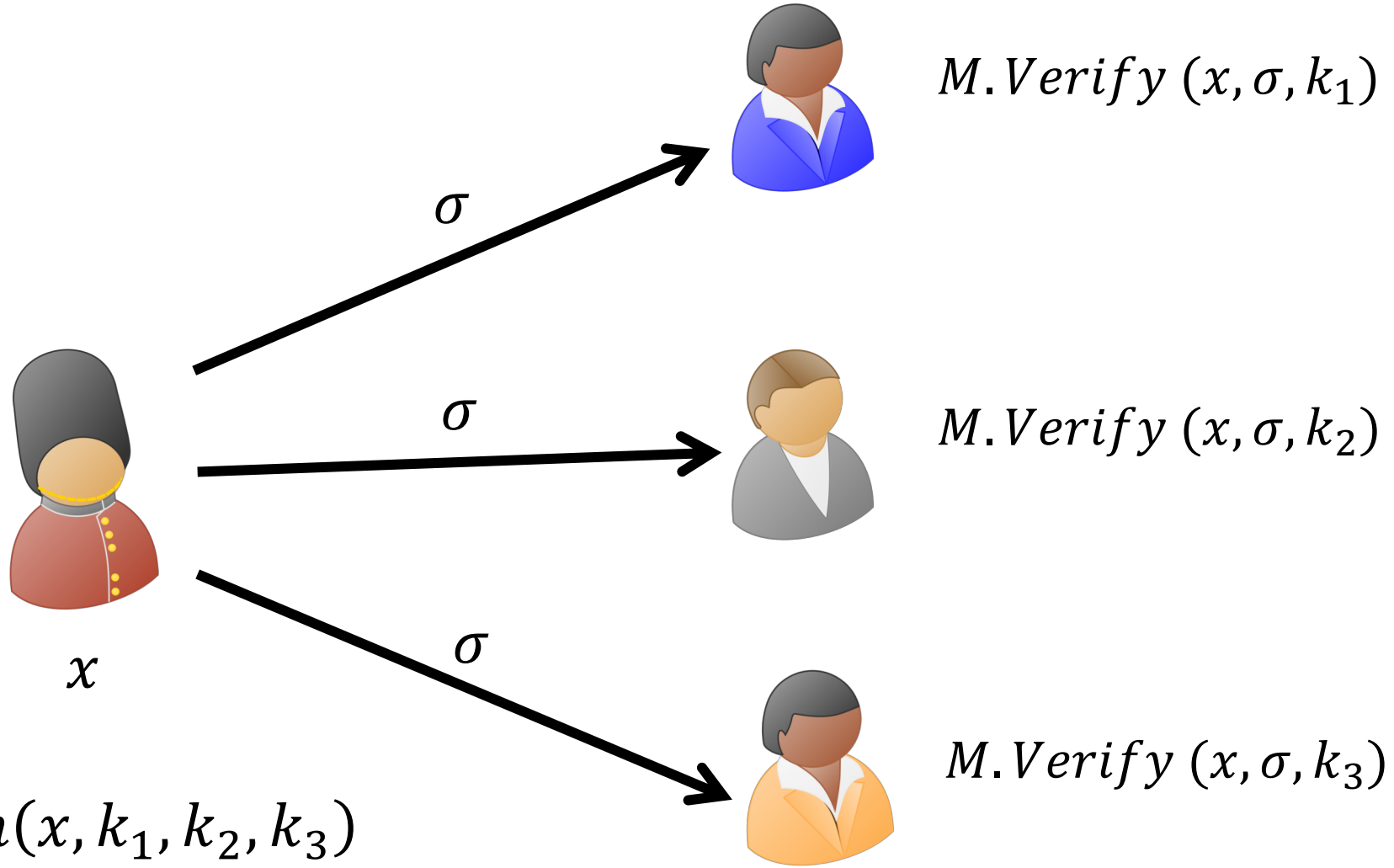
$$\sigma = Sign(x, k_1, k_2, k_3)$$

Our Tool: Multi-Key MAC



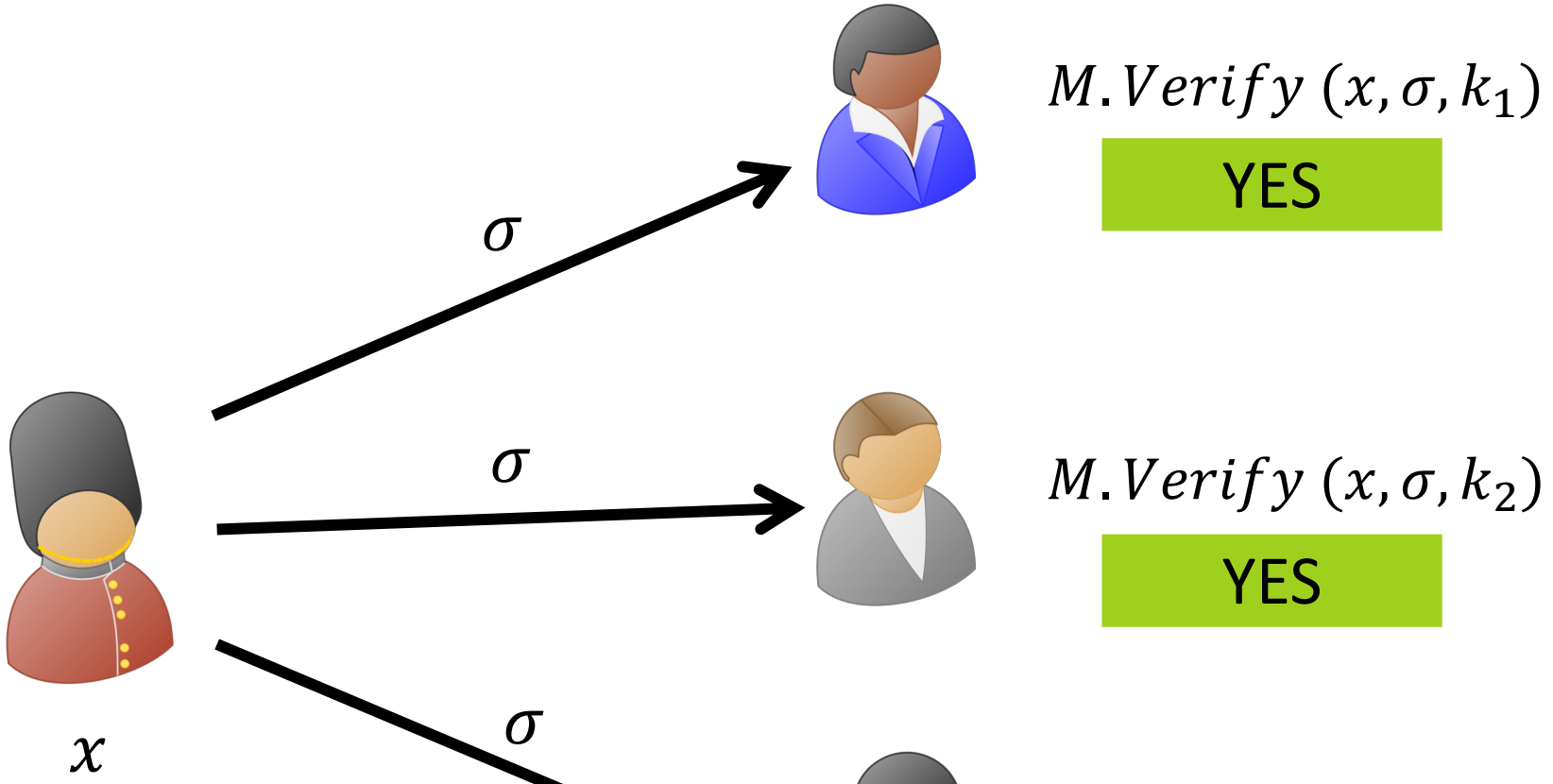
$\sigma = Sign(x, k_1, k_2, k_3)$

Our Tool: Multi-Key MAC



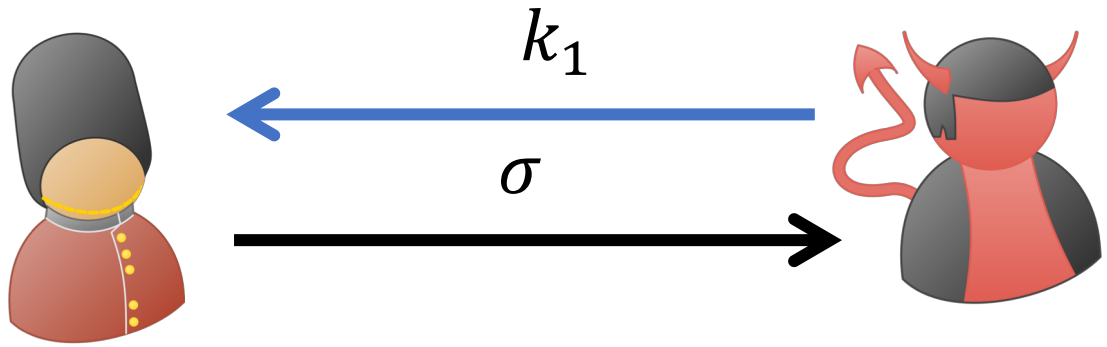
$\sigma = Sign(x, k_1, k_2, k_3)$

Our Tool: Multi-Key MAC (Correctness)



$$\sigma = Sign(x, k_1, k_2, k_3)$$

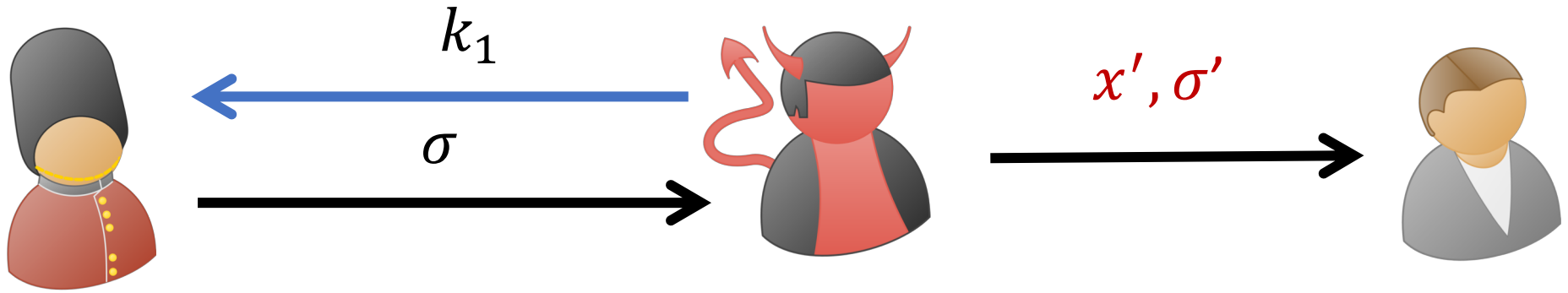
Our Tool: Multi-Key MAC (Security)



x, k_2, k_3

$\sigma = Sign(x, k_1, k_2, k_3)$

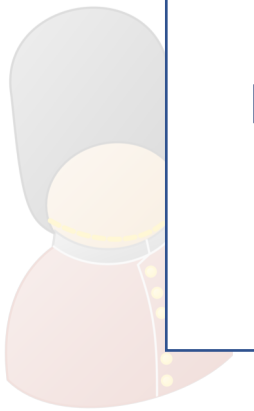
Our Tool: Multi-Key MAC (Security)



$\sigma = Sign(x, k_1, k_2, k_3)$

Our Tool: Multi-Key MAC (Security)

An adversary cannot output any valid message-signature pair other than the one it received



x, k_2, k_3

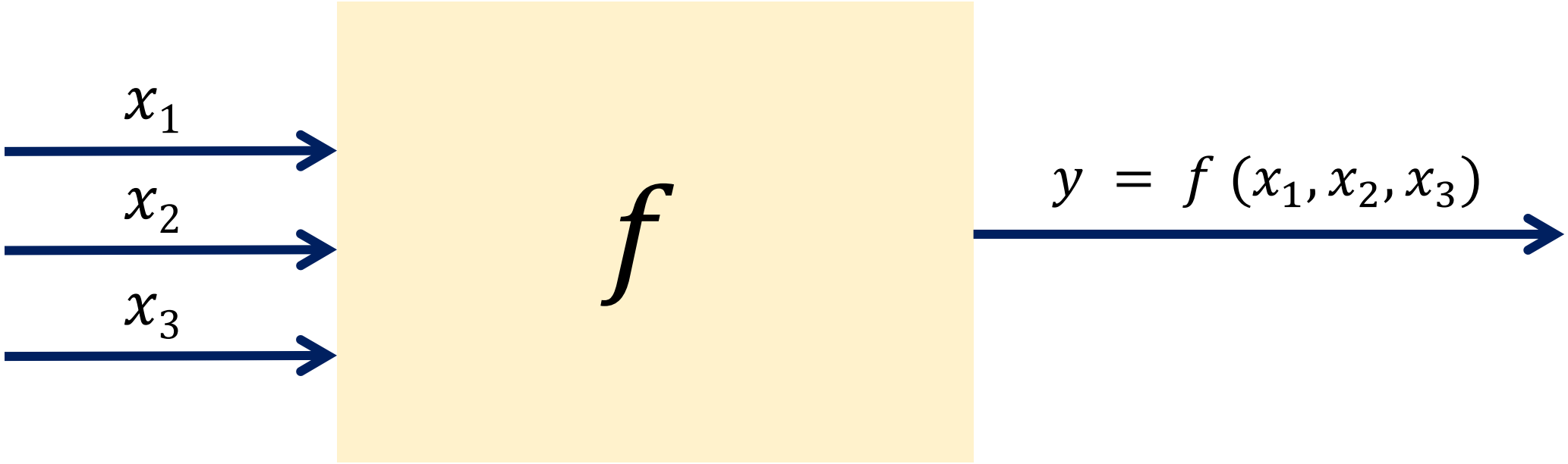
$\sigma = Sign(x, k_1, k_2, k_3)$

k_2

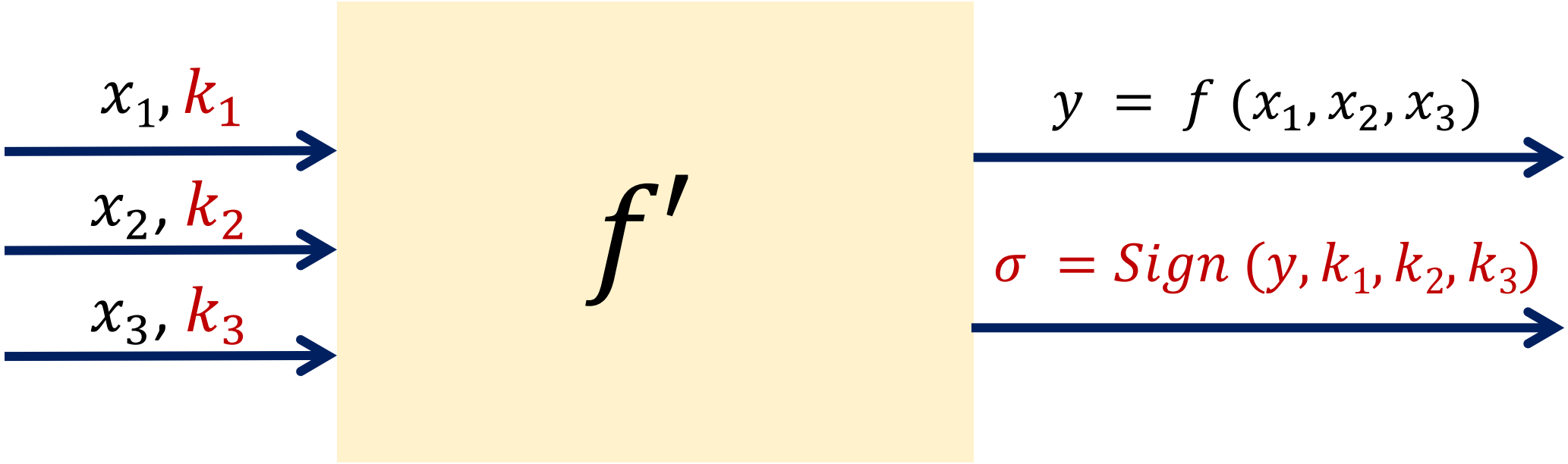
$M.Verify\ (x', \sigma', k_2)$

NO

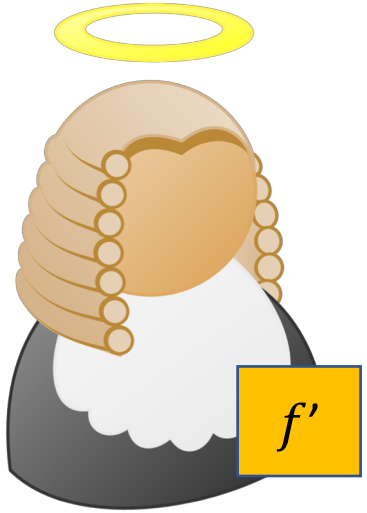
Using Multi-Key MAC



Using Multi-Key MAC

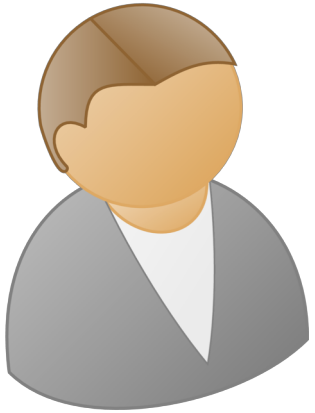


Using Multi-Key MAC



x_2, k_2

y, σ

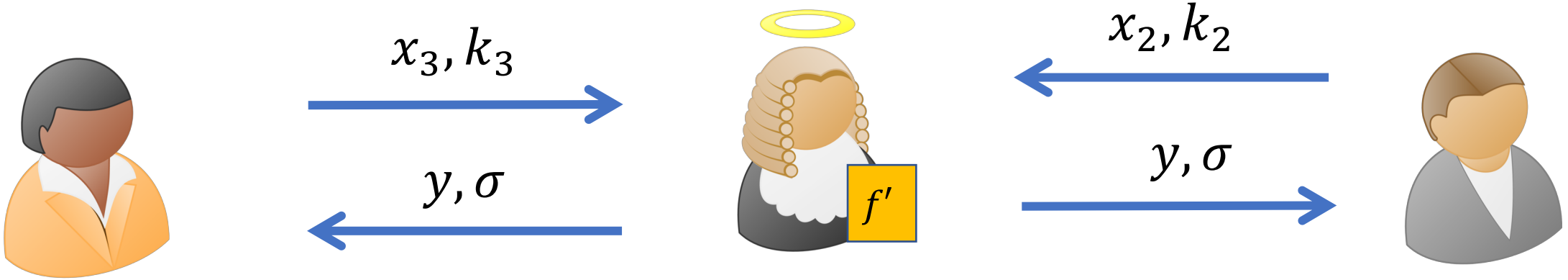


$M.Verify(y, \sigma, k_2)$

Trusted Party

Party 2

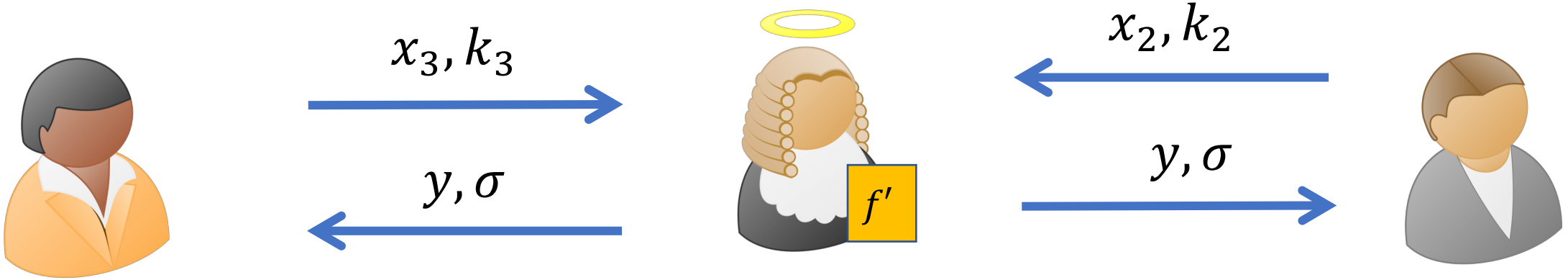
Security with abort: Using Multi-Key MAC



Honest Party 3 Trusted Party Honest Party 2

IF $y, \sigma = f'((x_1 k_1), (x_2, k_2), (x_3, k_3))$

Security with abort: Using Multi-Key MAC



Honest Party 3

Trusted Party

Honest Party 2

$M.Verify(y, \sigma, k_3)$

YES

IF $y, \sigma = f'((x_1 k_1), (x_2, k_2), (x_3, k_3))$

$M.Verify(y, \sigma, k_2)$

YES

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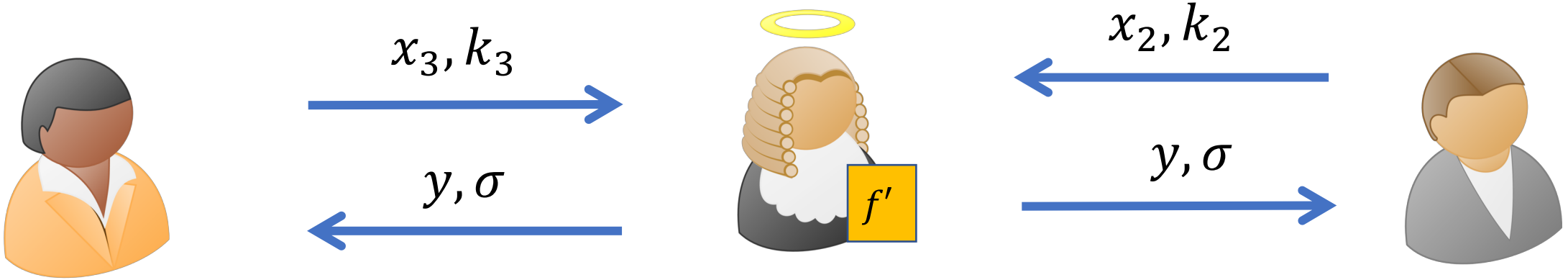
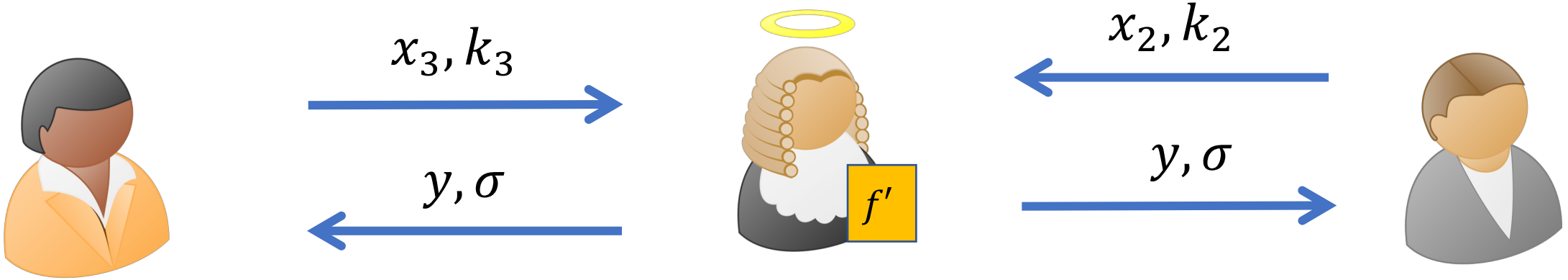


Honest Party 3 Trusted Party Honest Party 2

IF $y, \sigma \neq f'((x_1 k_1), (x_2, k_2), (x_3, k_3))$

Security with abort: Using Multi-Key MAC



Honest Party 3

Trusted Party

Honest Party 2

$M.Verify(y, \sigma, k_3)$

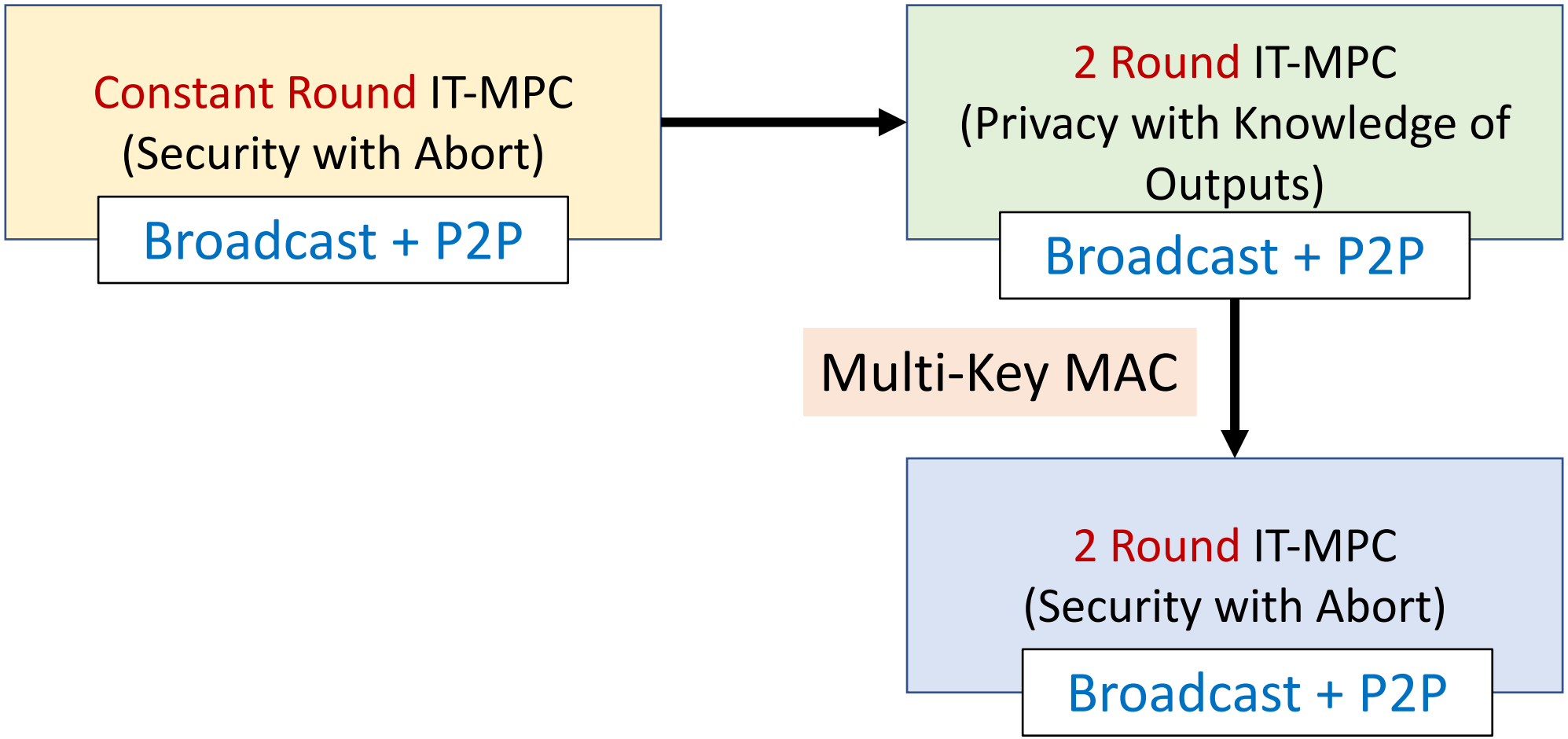
NO

IF $y, \sigma \neq f'((x_1 k_1), (x_2, k_2), (x_3, k_3))$

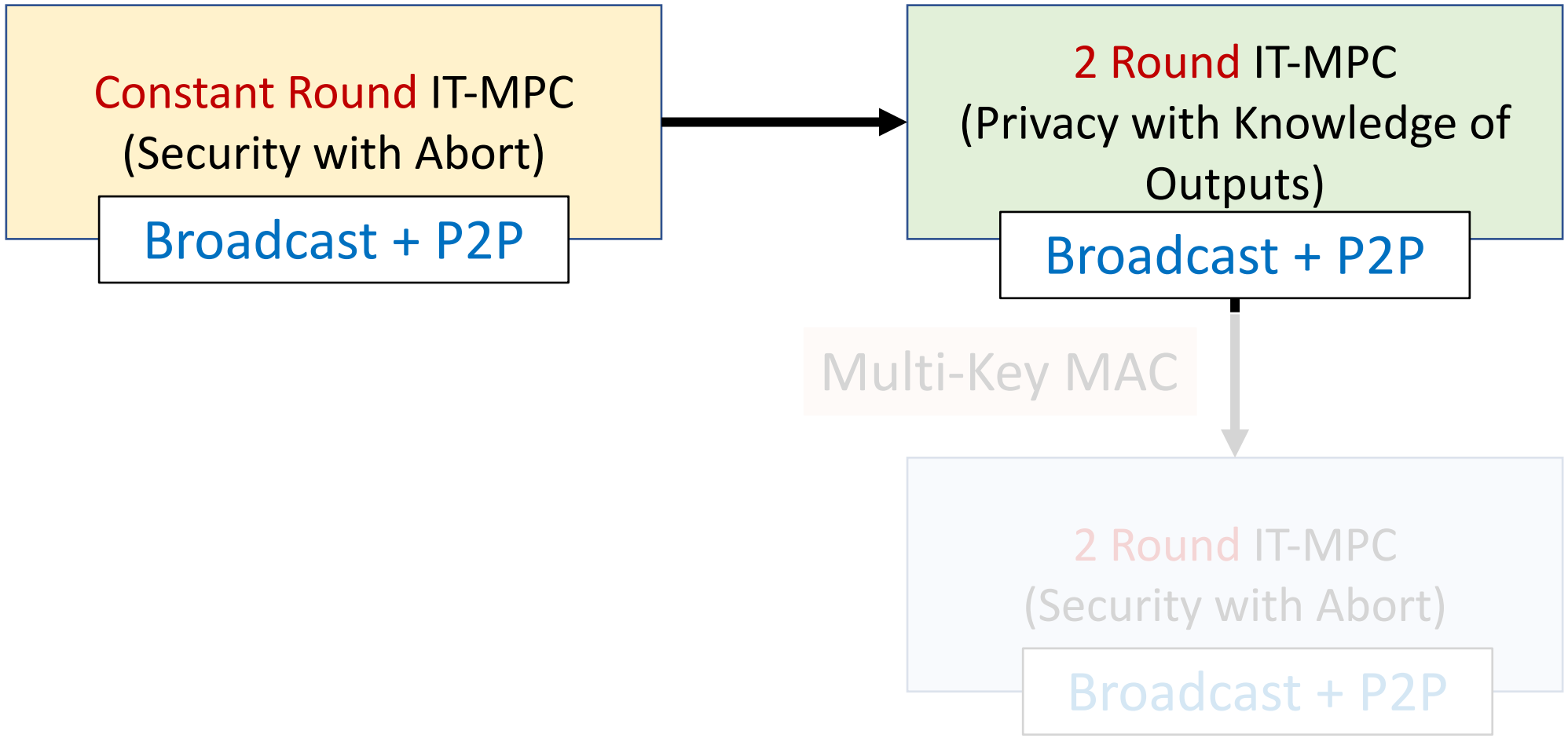
$M.Verify(y, \sigma, k_2)$

NO

Recall: Our Strategy



Second Step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(Security with Abort)
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2 Round IT-MPC
(Privacy with Knowledge of Outputs)
Broadcast + P2P
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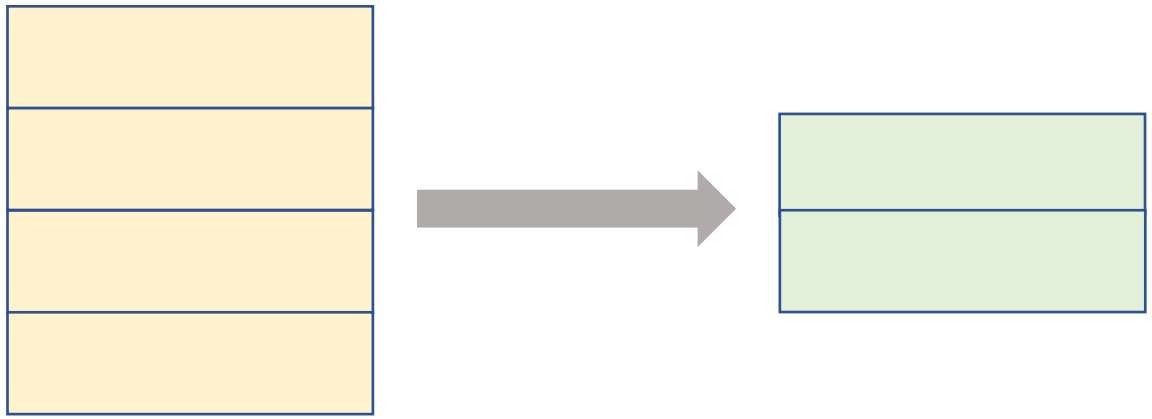
Broadcast + P2P

Technique: Round Compression



Interactive secure MPC

2 round secure MPC

[GGHR'13]
Indistinguishability Obfuscation

[GLS'15]
Witness Encryption + Garbled circuits

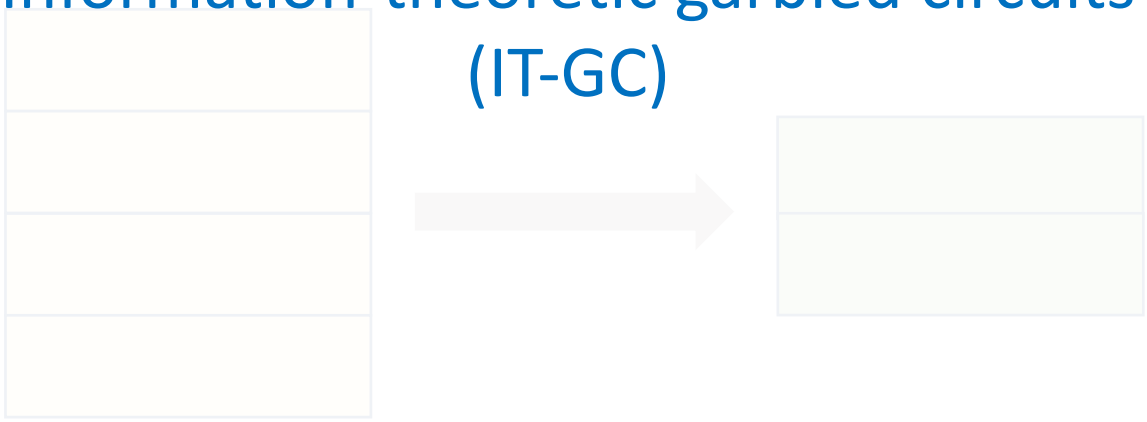
[GS'17]
Bilinear Maps + Garbled circuits

[GS'18, BL'18]
OT + Garbled Circuits

[ACGJ'18]
Garbled circuits

Initial Idea

Replace garbled circuits with
Information-theoretic garbled circuits
(IT-GC)



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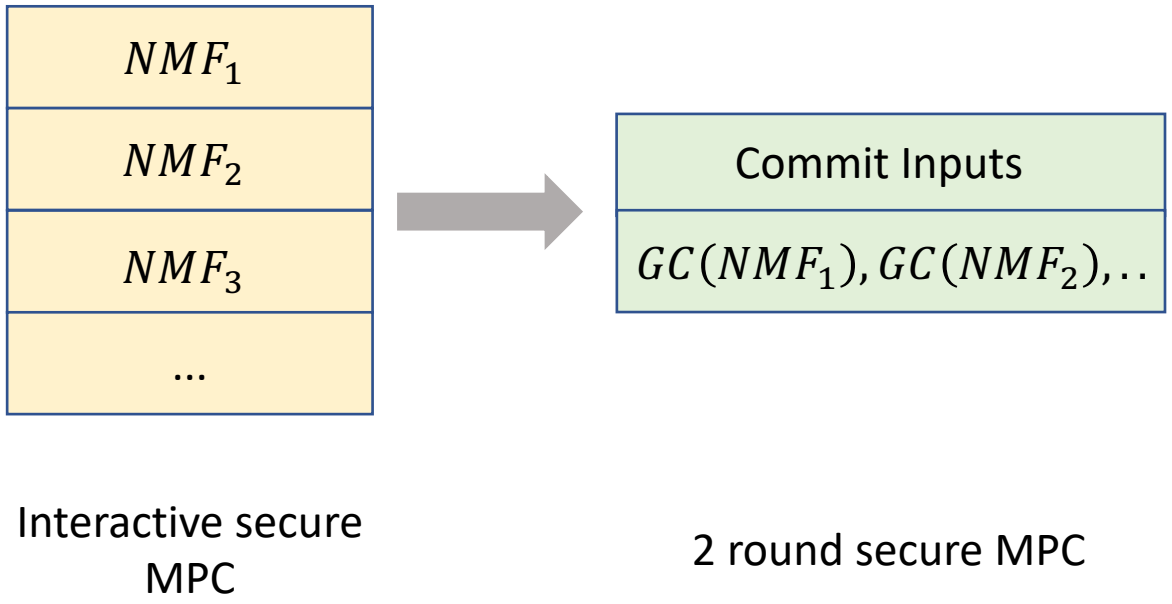
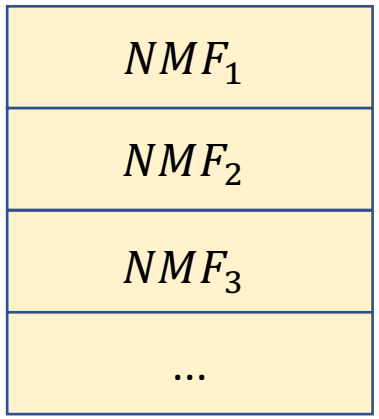
Garbled circuits

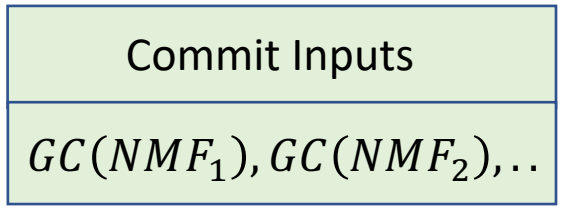
Round Compression Template



Round Compression Template

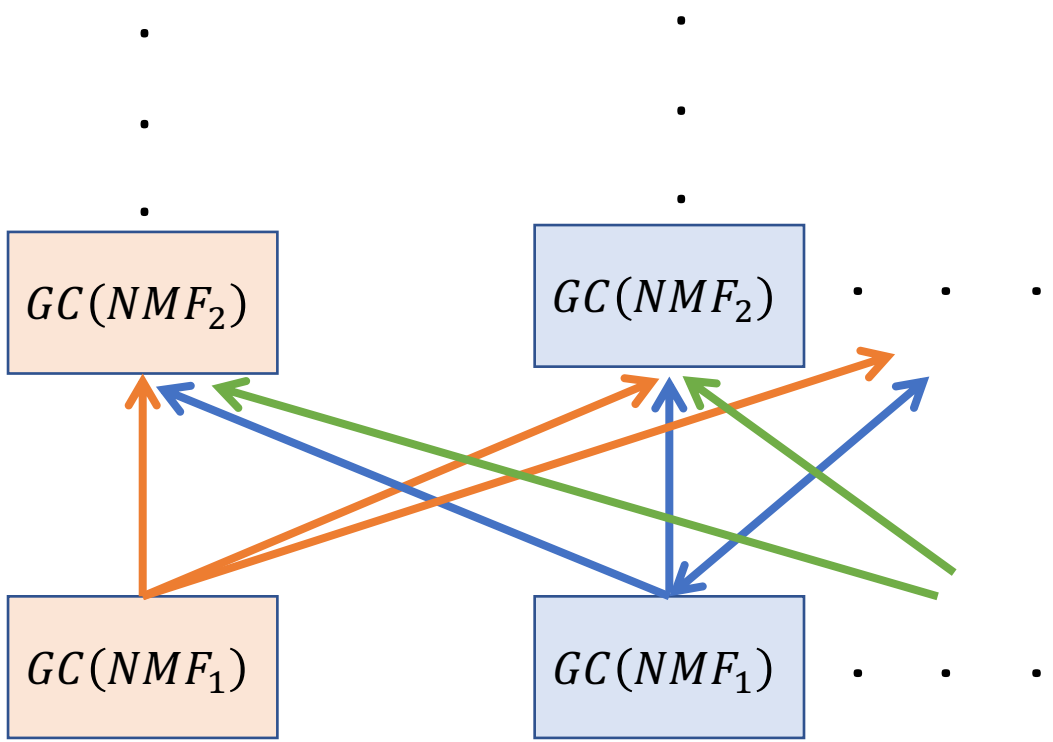


Interactive secure MPC



2 round secure MPC

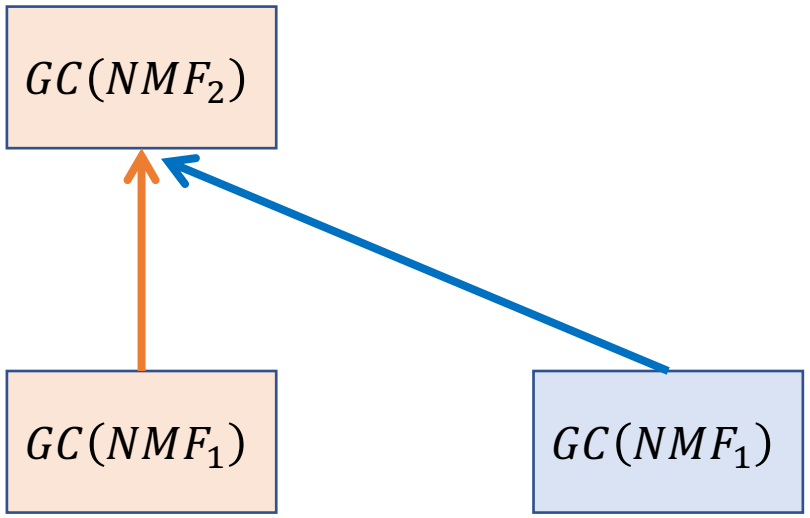
After Round 2



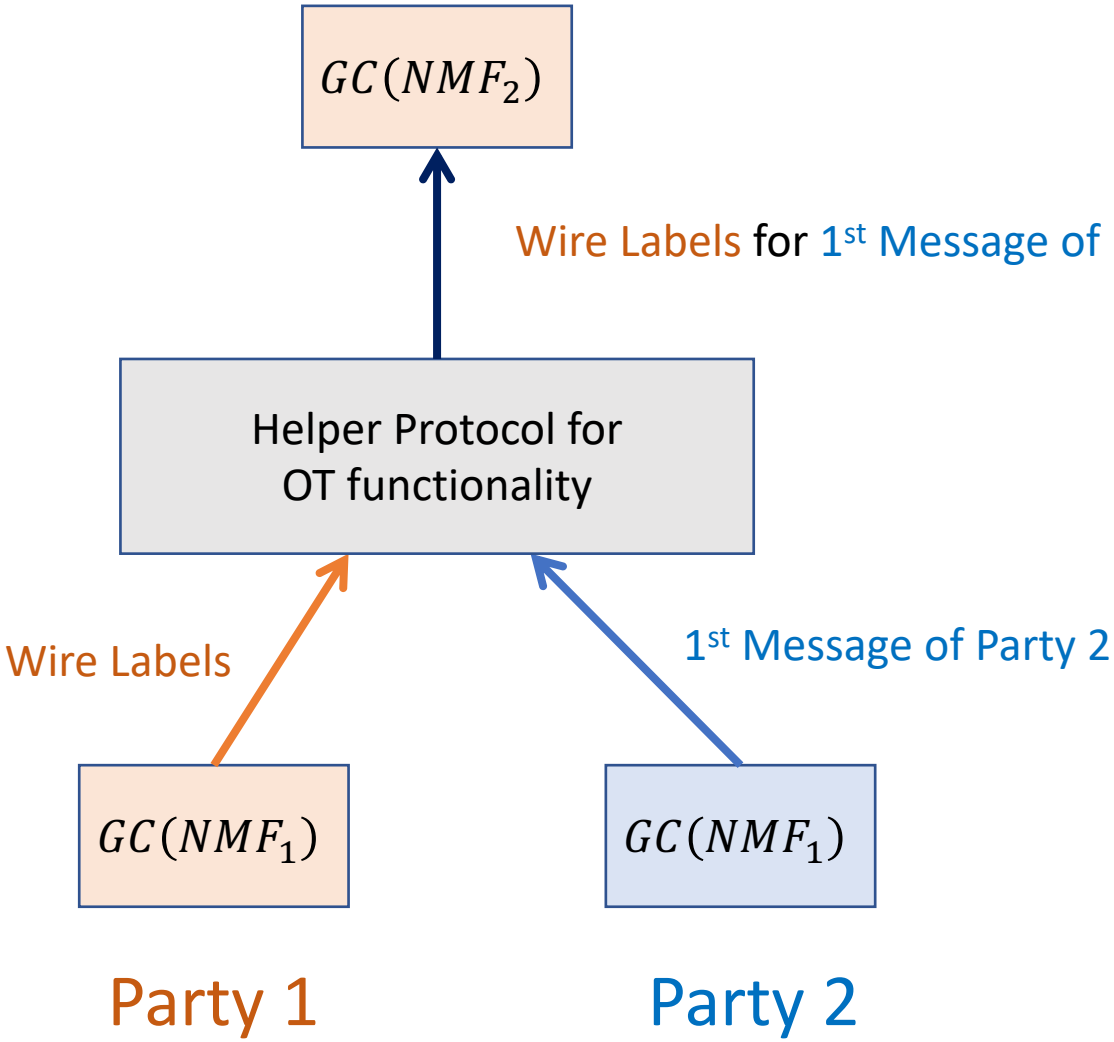
Party 1

Party 2

Round Compression Template: After Round 2



Round Compression Template: After Round 2



Initial Idea: Doesn't Work

Replace garbled circuits with
Information-theoretic garbled circuits
(IT-GC)

Problem

Size of the input wire labels in IT-GC grows exponentially in the depth of the circuit being garbled.

[GGHR'13]
Indistinguishability Obfuscation

[GLS'15]
Witness Encryption + Garbled circuits

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$$Size(NMF) \approx |C|$$

[ACGJ'18]
Garbled circuits

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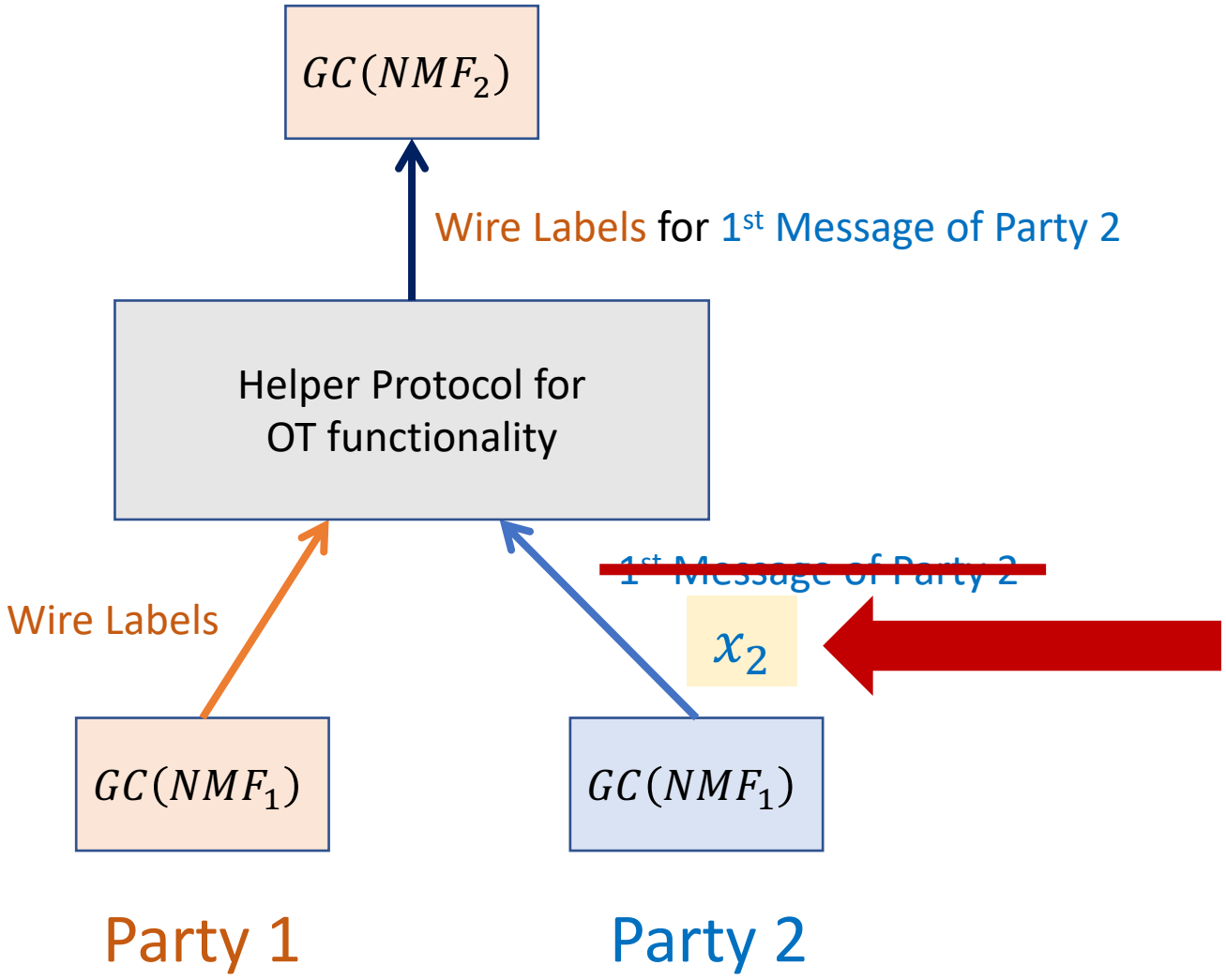
Interactive secure MPC

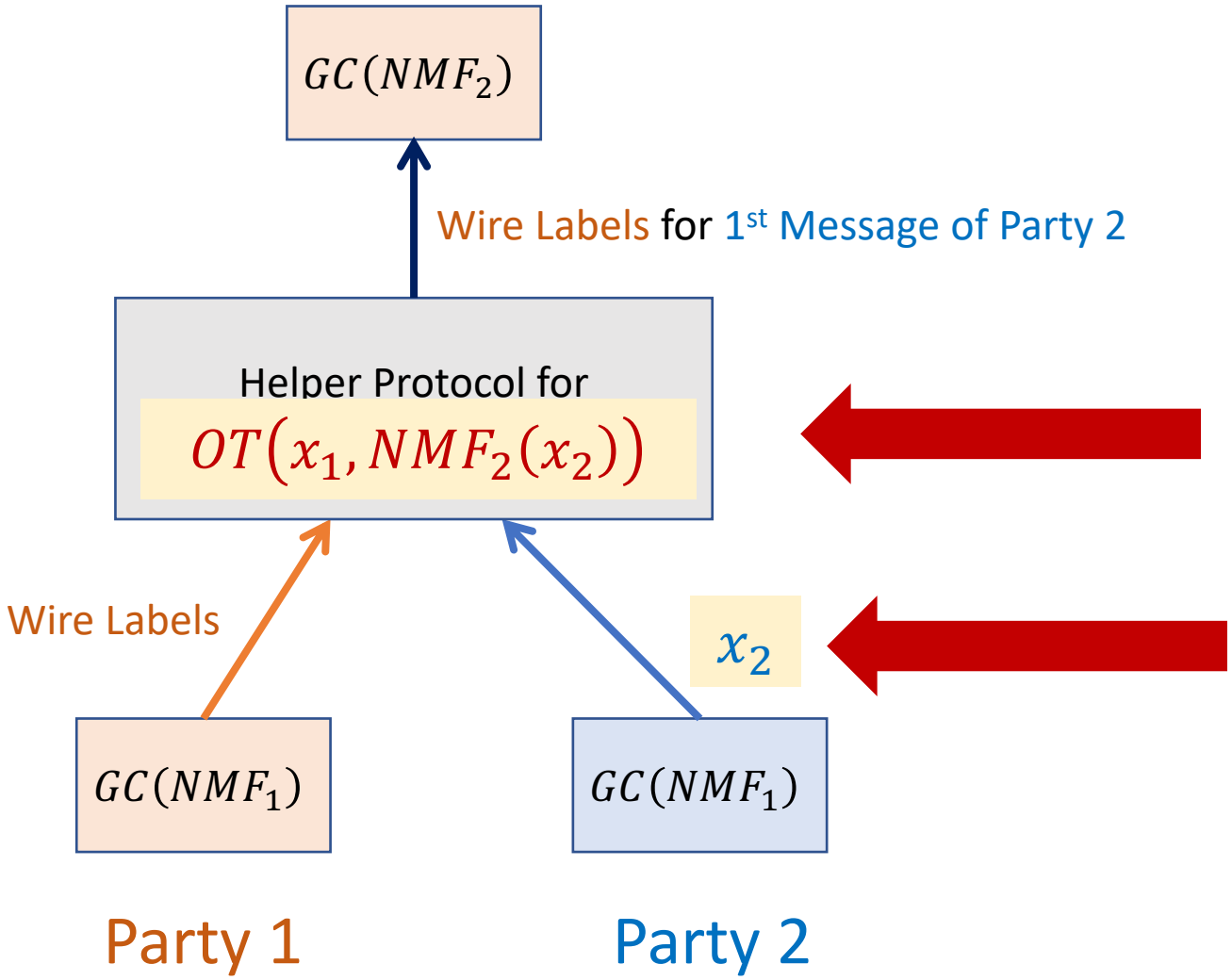
2 round secure MPC

Our Approach



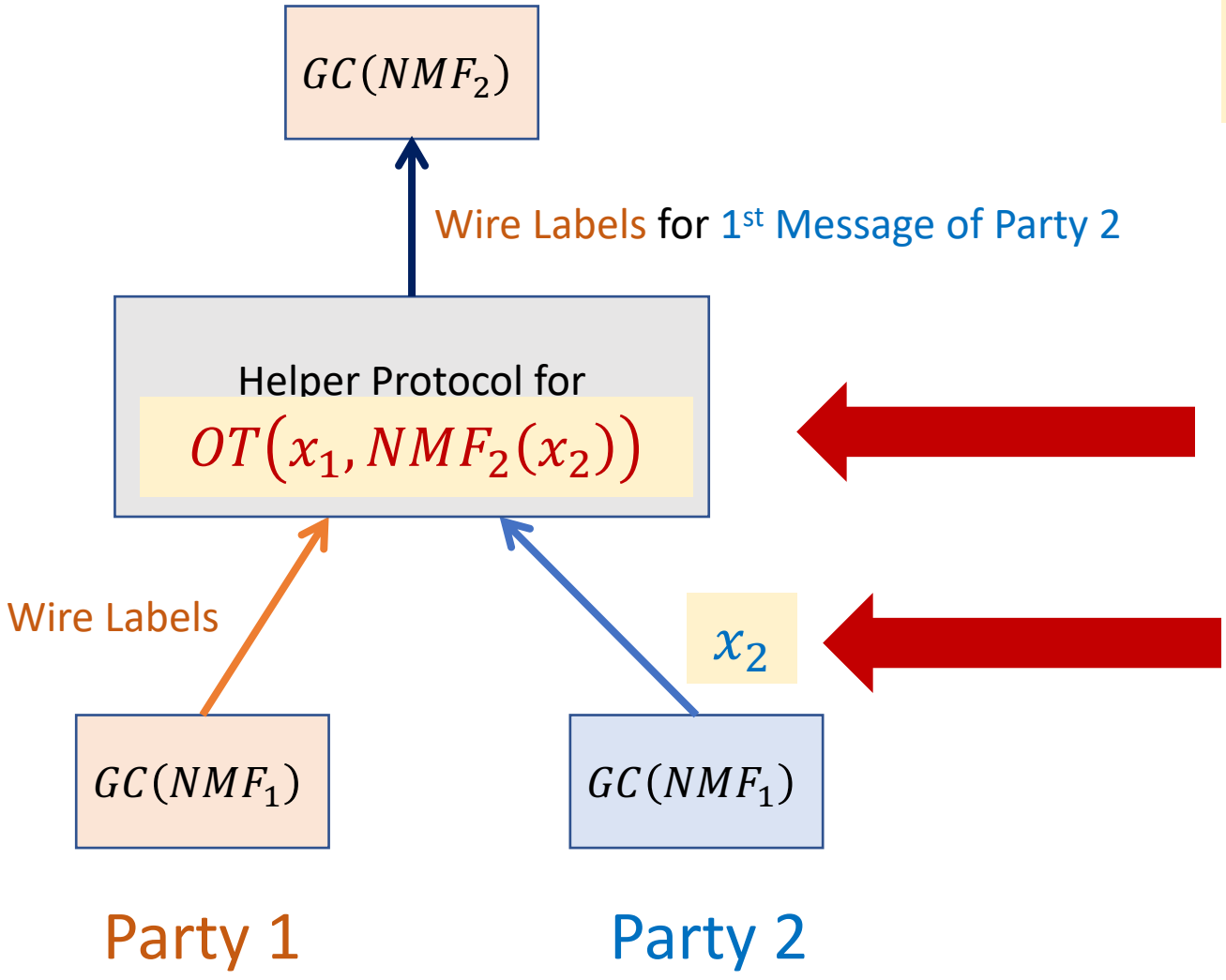
Similar to the approach used in [BL'18]

Our Approach



Our Approach

Design a 2 round helper protocol for $OT\left(x_1, NMF_2(x_2)\right)$



Challenges in Designing such a protocol

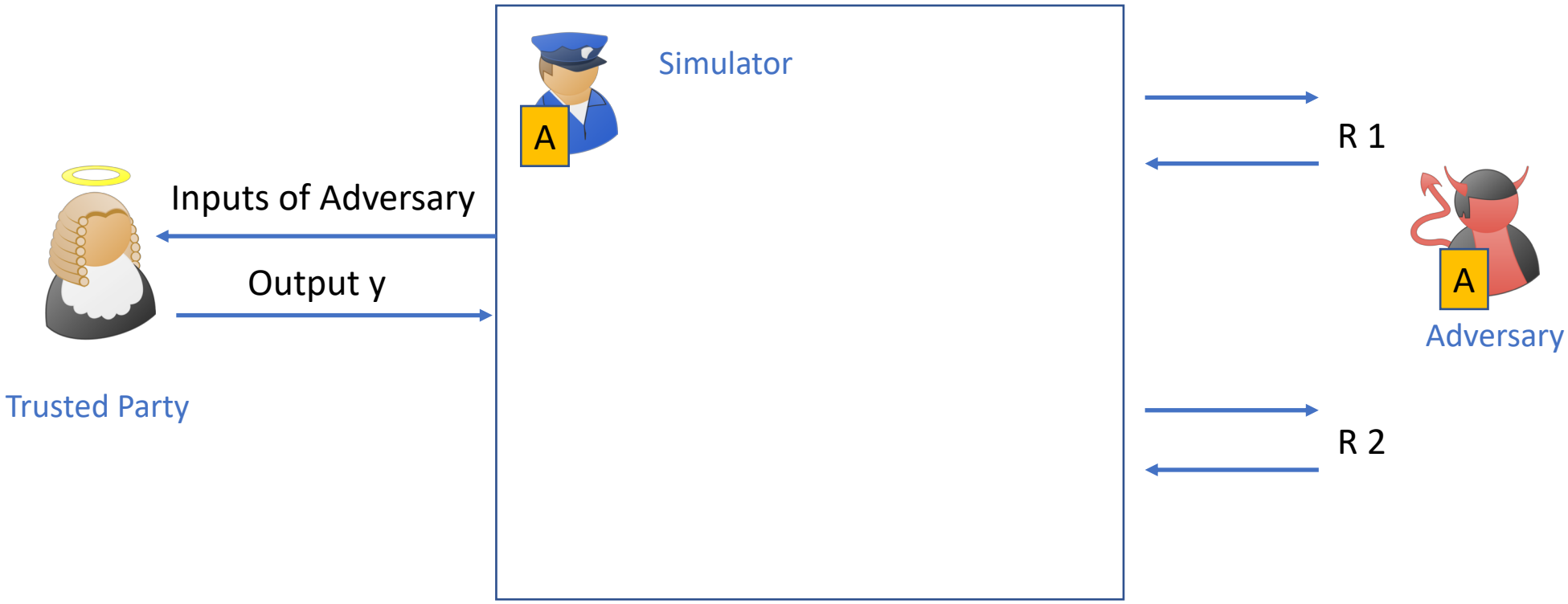
2 Round MPC Template using a 2 Round Helper Protocol

R 1 — 1st round of Helper Protocol (implicitly commits to inputs)

R 2 — 2nd round of Helper Protocol & $GC(NMF_1), GC(NMF_2), ..$

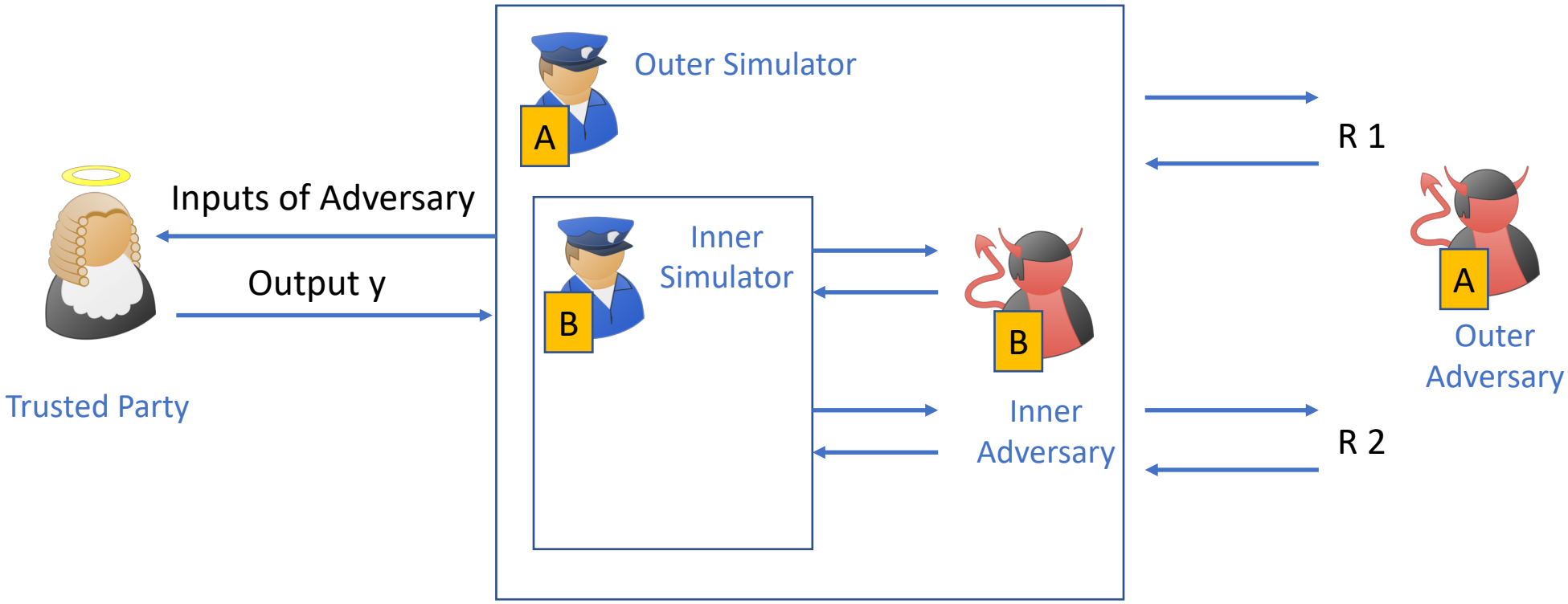
Challenges in Designing such a protocol

Malicious Security



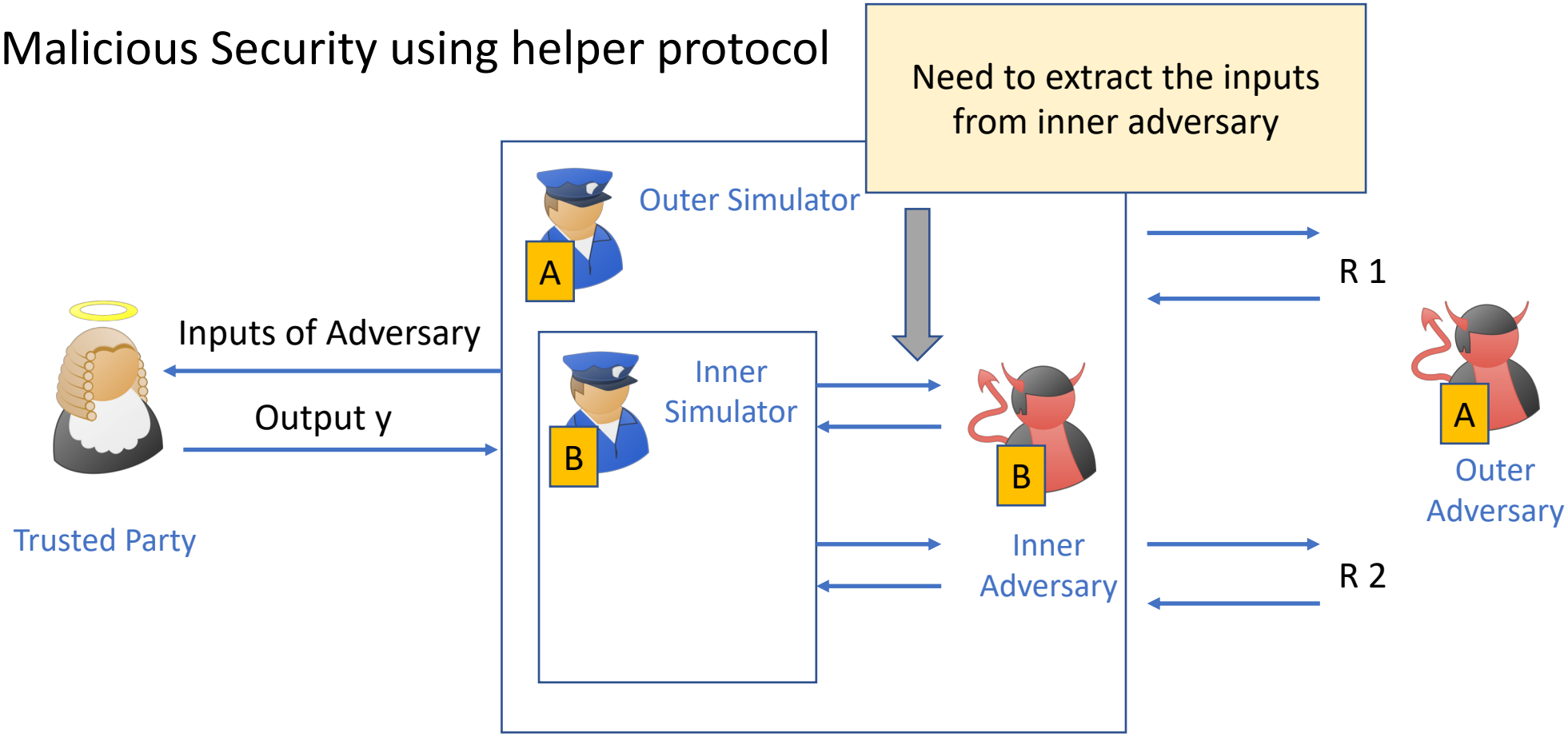
Challenges in Designing such a protocol

Malicious Security using helper protocol

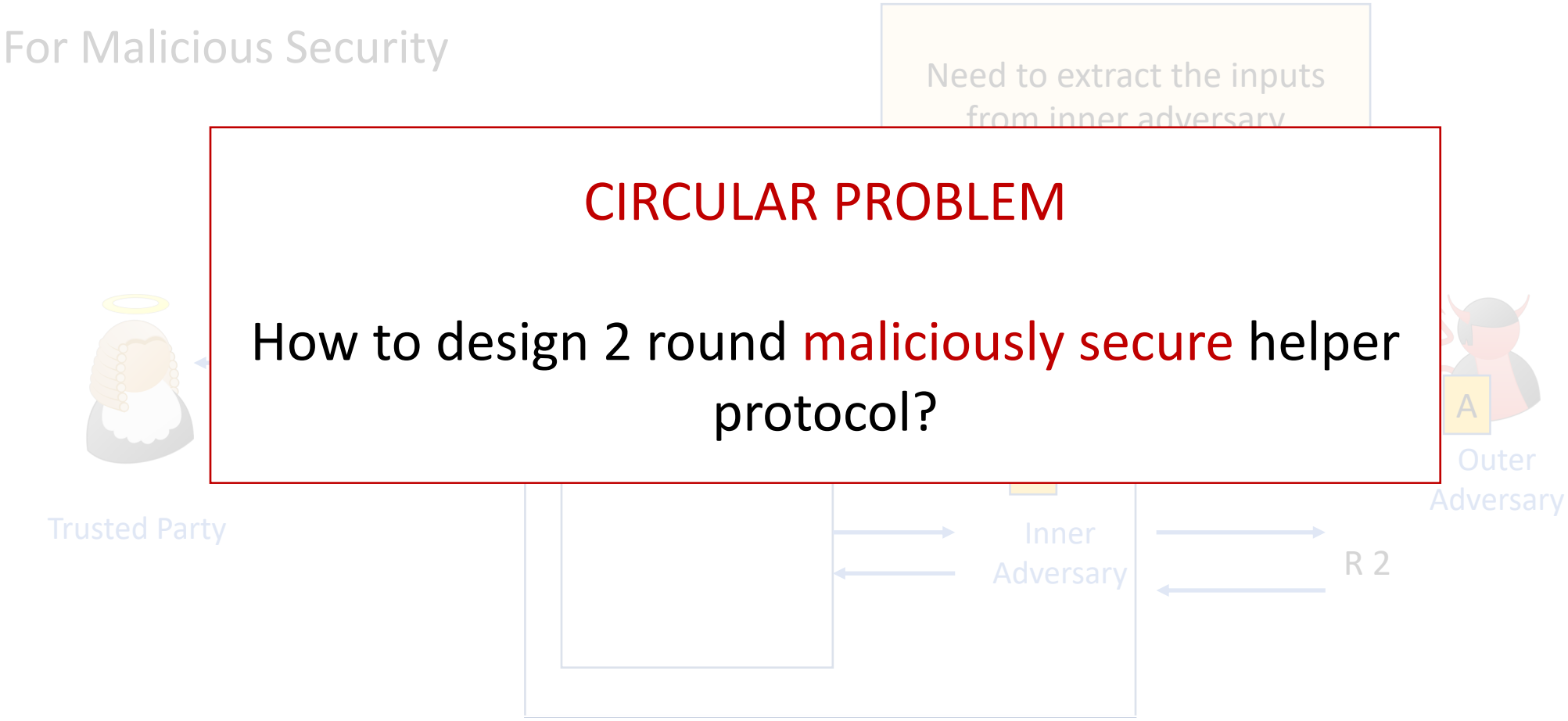


Challenges in Designing such a protocol

Malicious Security using helper protocol



Challenges in Designing such a protocol



Thank You

https://eprint.iacr.org/2018/1078

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