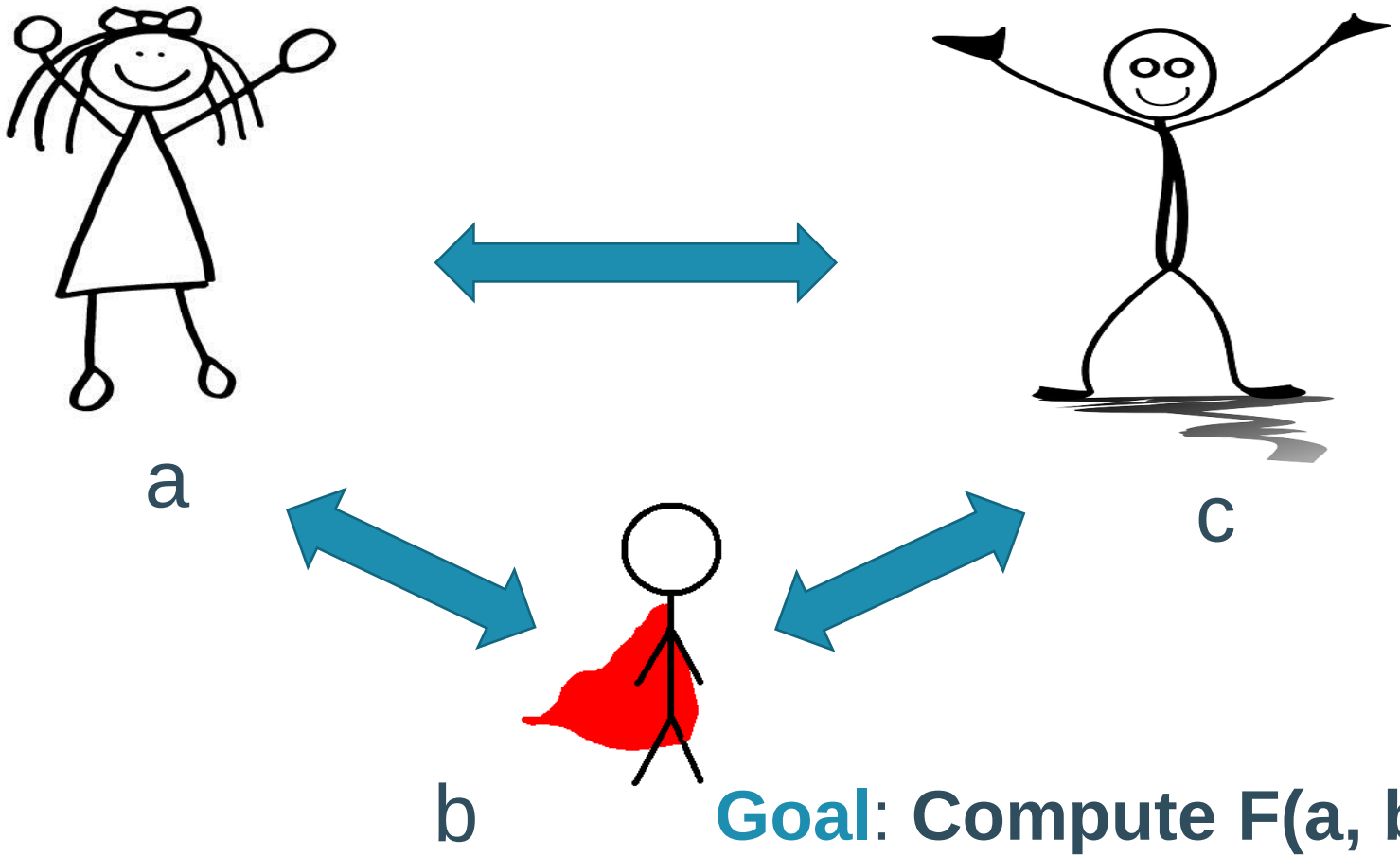
FSE 2018

Modes of operations for computing on encrypted data

Dragos Rotaru, N.P. Smart, and Martijn Stam

KU Leuven, University of Bristol

Multiparty computation hijacks FSE'18



Goal: **Compute F(a, b, c)**

What is the problem?

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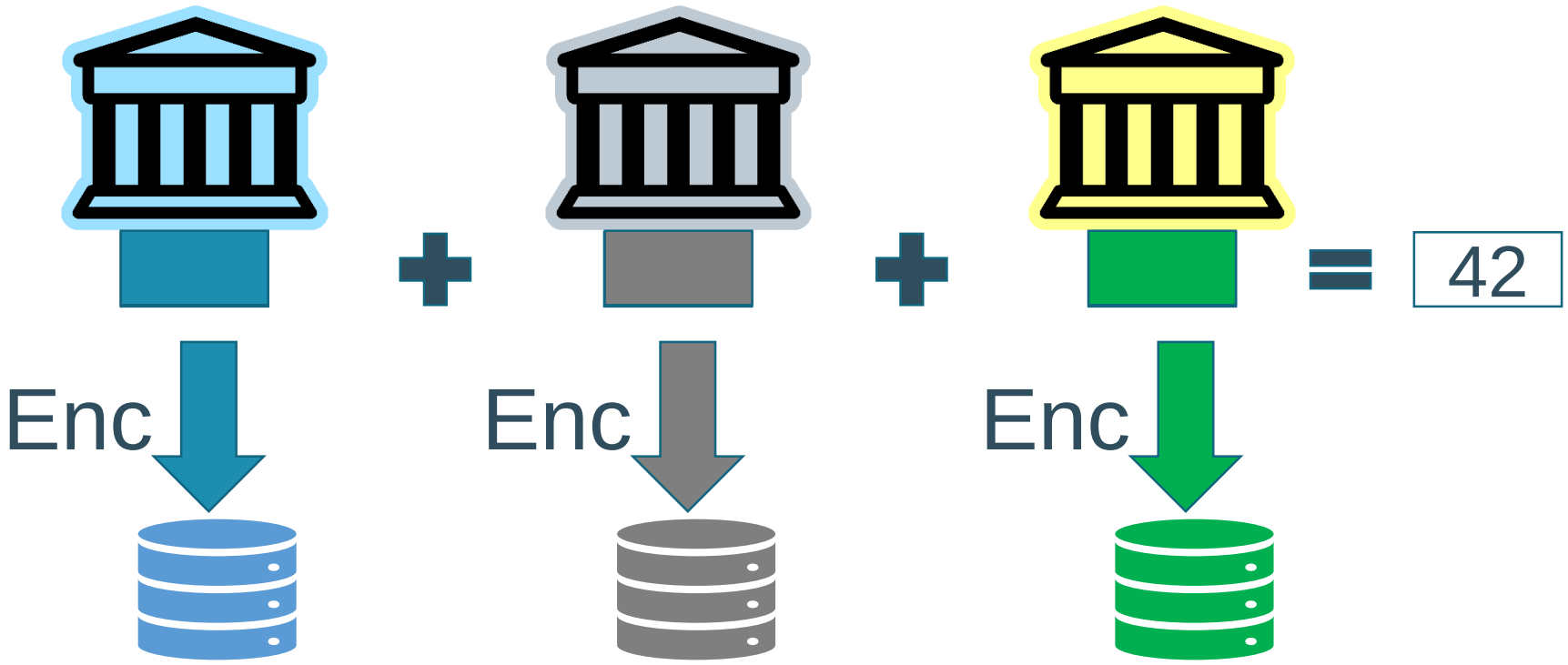

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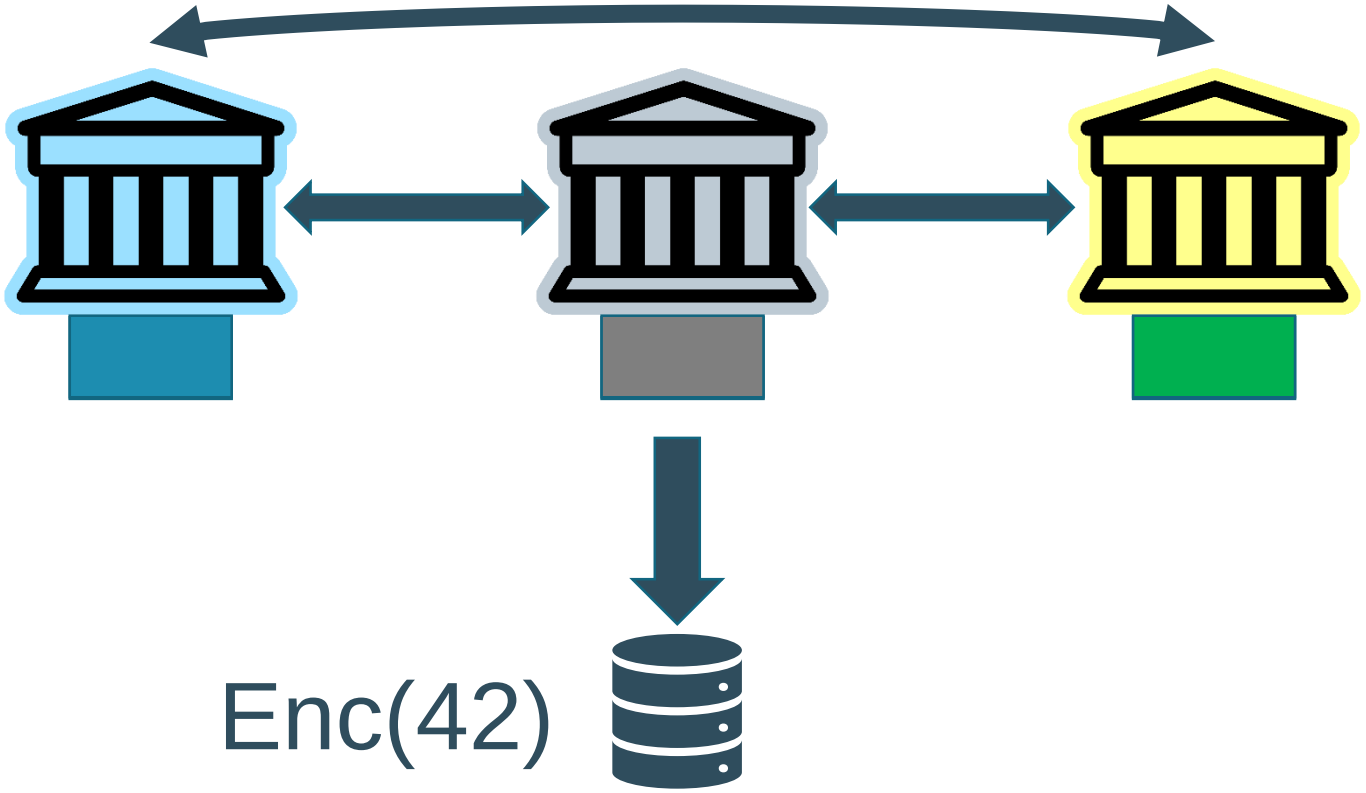

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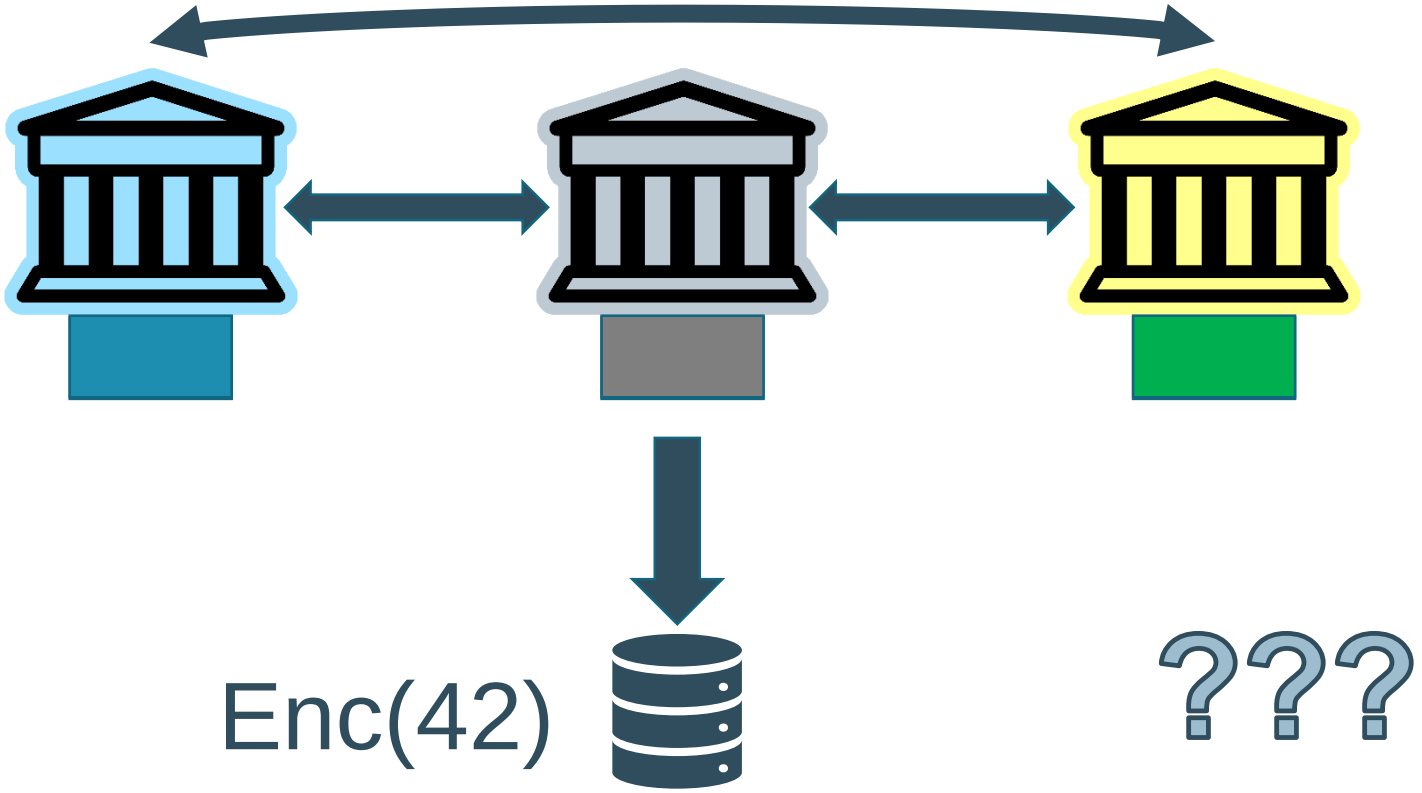

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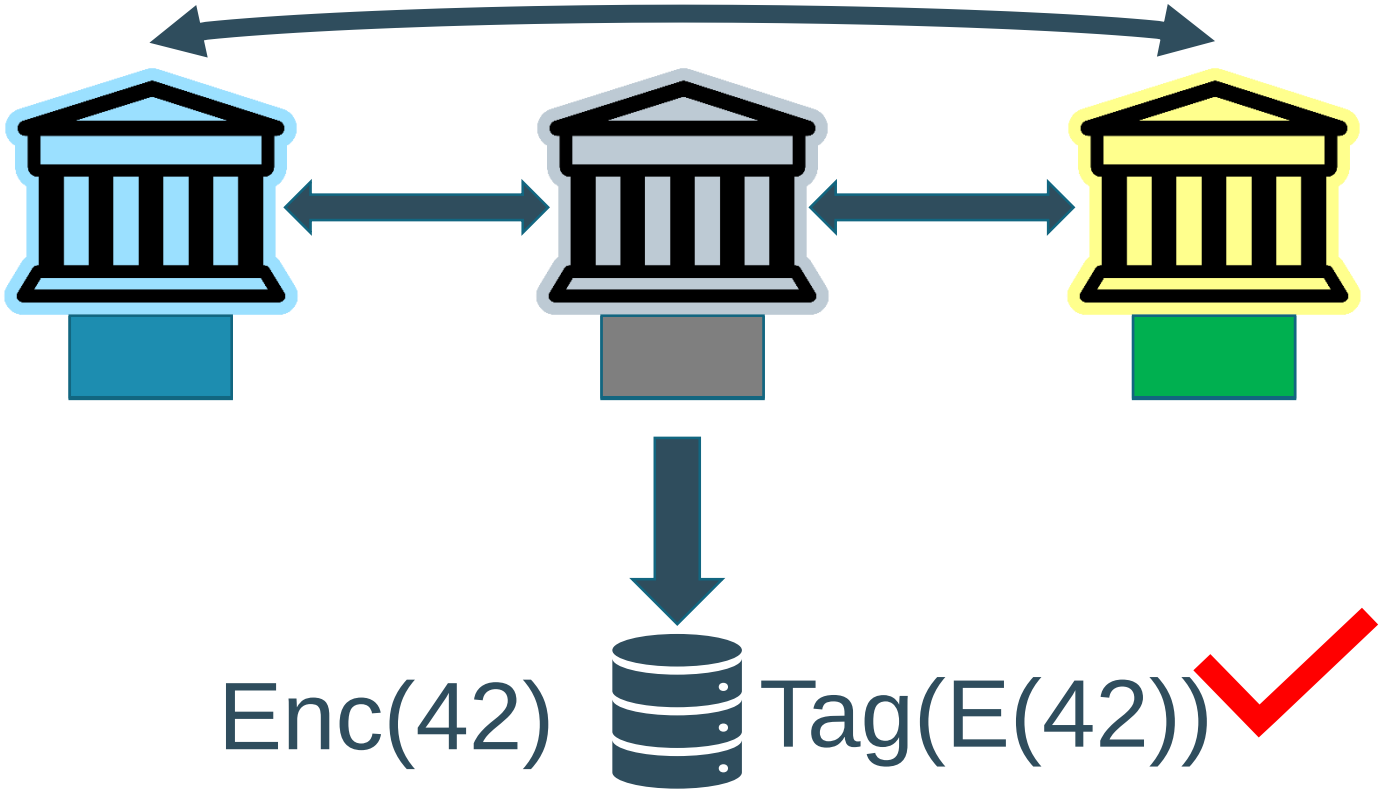

What is the problem?

For free: detect malicious encryption keys.

Prior work – PRFs in MPC (CCS'16)

Enc(42)  Tag(Enc(42))

- MiMC
- Legendre PRF

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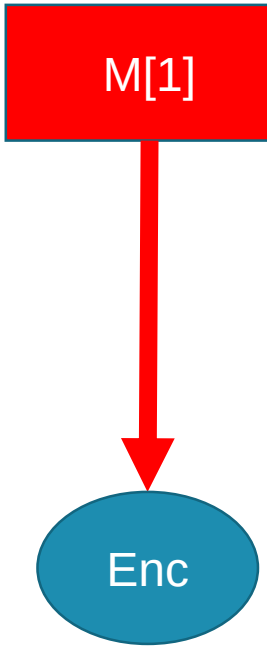

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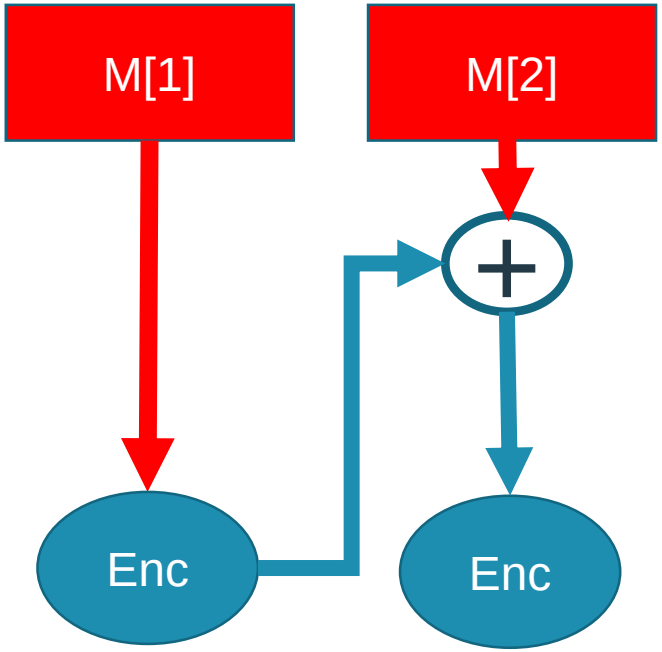

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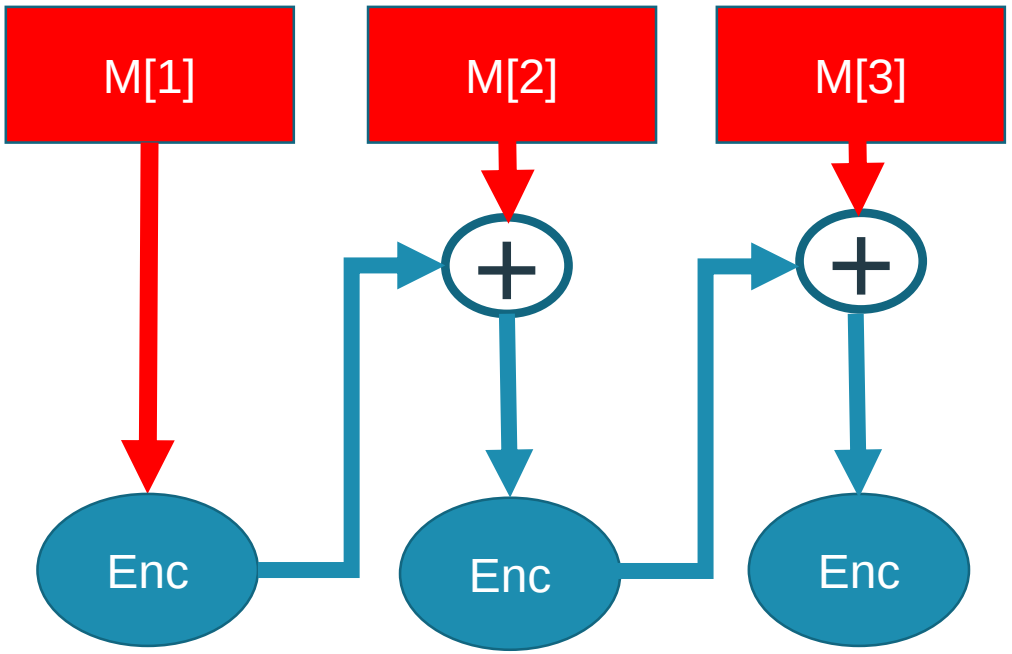

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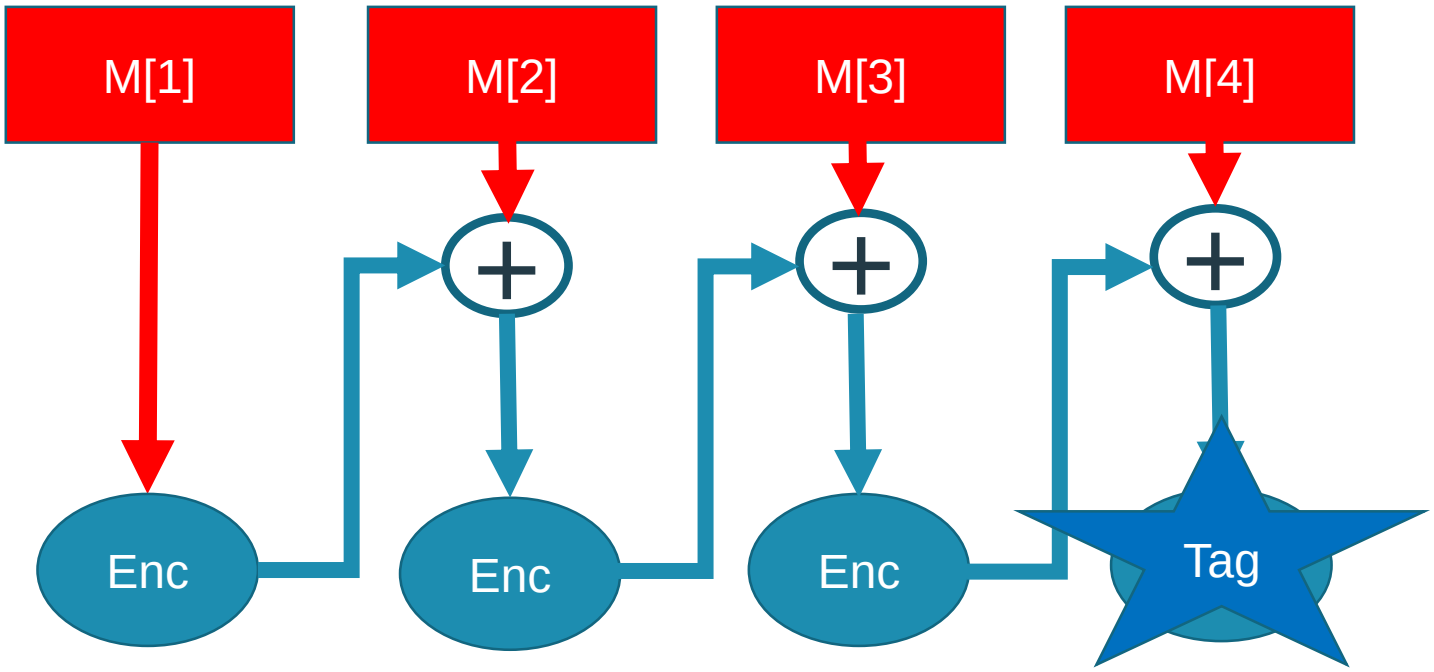

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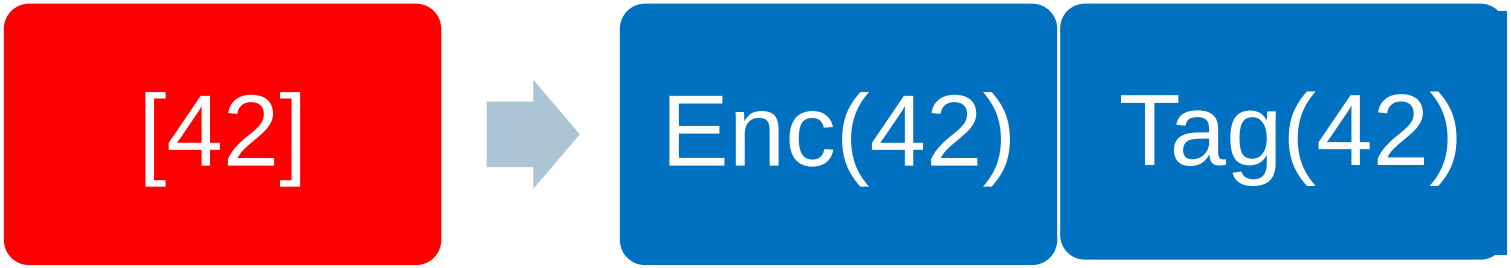
What we have done



- Analyze AE in Multiparty Computation (MPC).
- Useful MPC happens in Fp => Need AE and PRFs modp.
- Look for parallel AE: CTR+PMAC, OTR.

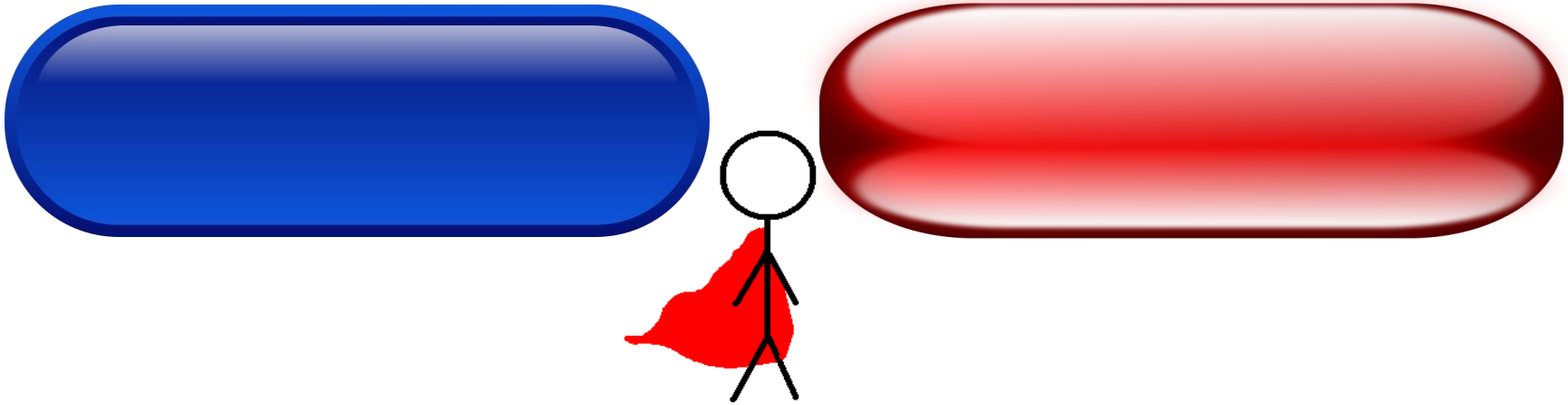
The story

The story

‘You take the blue pill—the story ends, you wake up in your bed and believe whatever you want to believe.

You take the *red* pill—you stay in Wonderland, and I show you how deep the rabbit hole goes.’

The story



‘You take the blue pill—the story ends, you wake up in your bed and believe whatever you want to believe.

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Down the rabbit hole - MPC with Secret Sharing

$$x = x_1 + \cdots + x_n$$

Each P_i has $[x] \leftarrow x_i$

$[x] \leftarrow x_1$

$[x] \leftarrow x_2$

$[x] \leftarrow x_3$

MPC Preprocessing Phase

Generate triples
[c] = [a][b]

MPC Preprocessing Phase

Generate triples

[c] = [a][b]

MPC Preprocessing Phase

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MPC Preprocessing Phase

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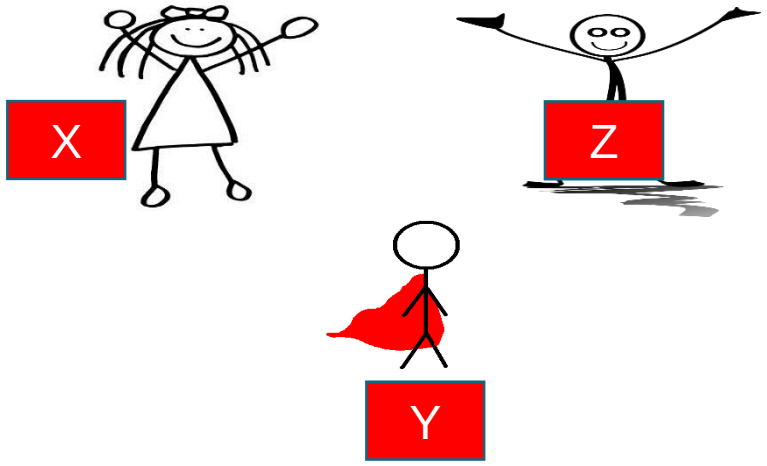
MPC Online Phase

Use Triples.

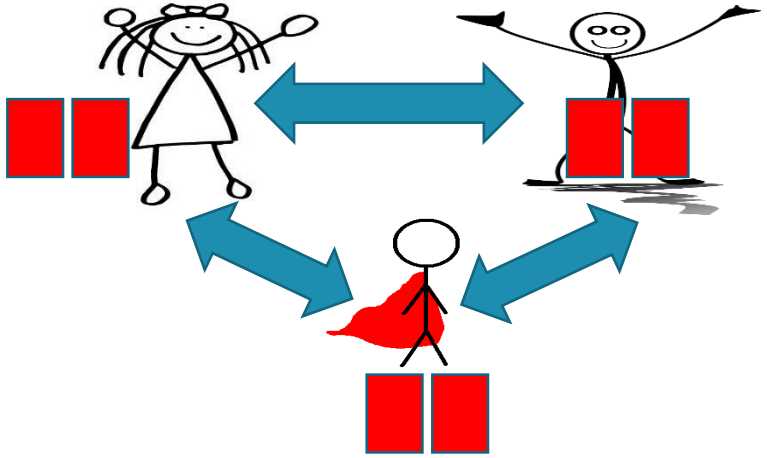
MPC Online Phase

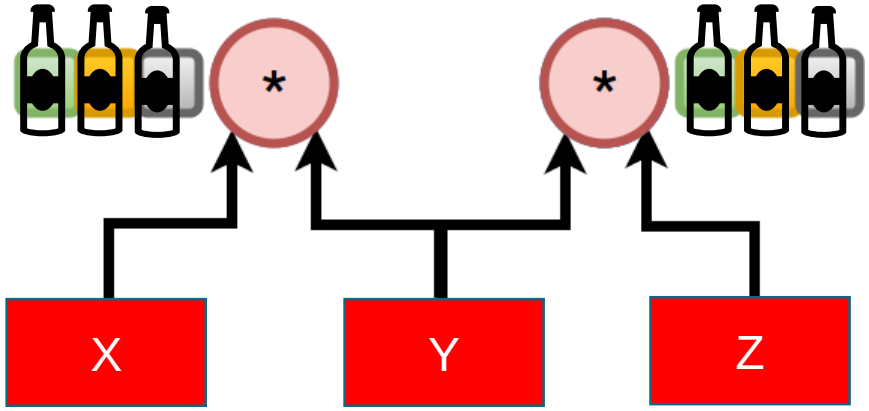
MPC Circuit Evaluation



X Y Z

MPC Circuit Evaluation





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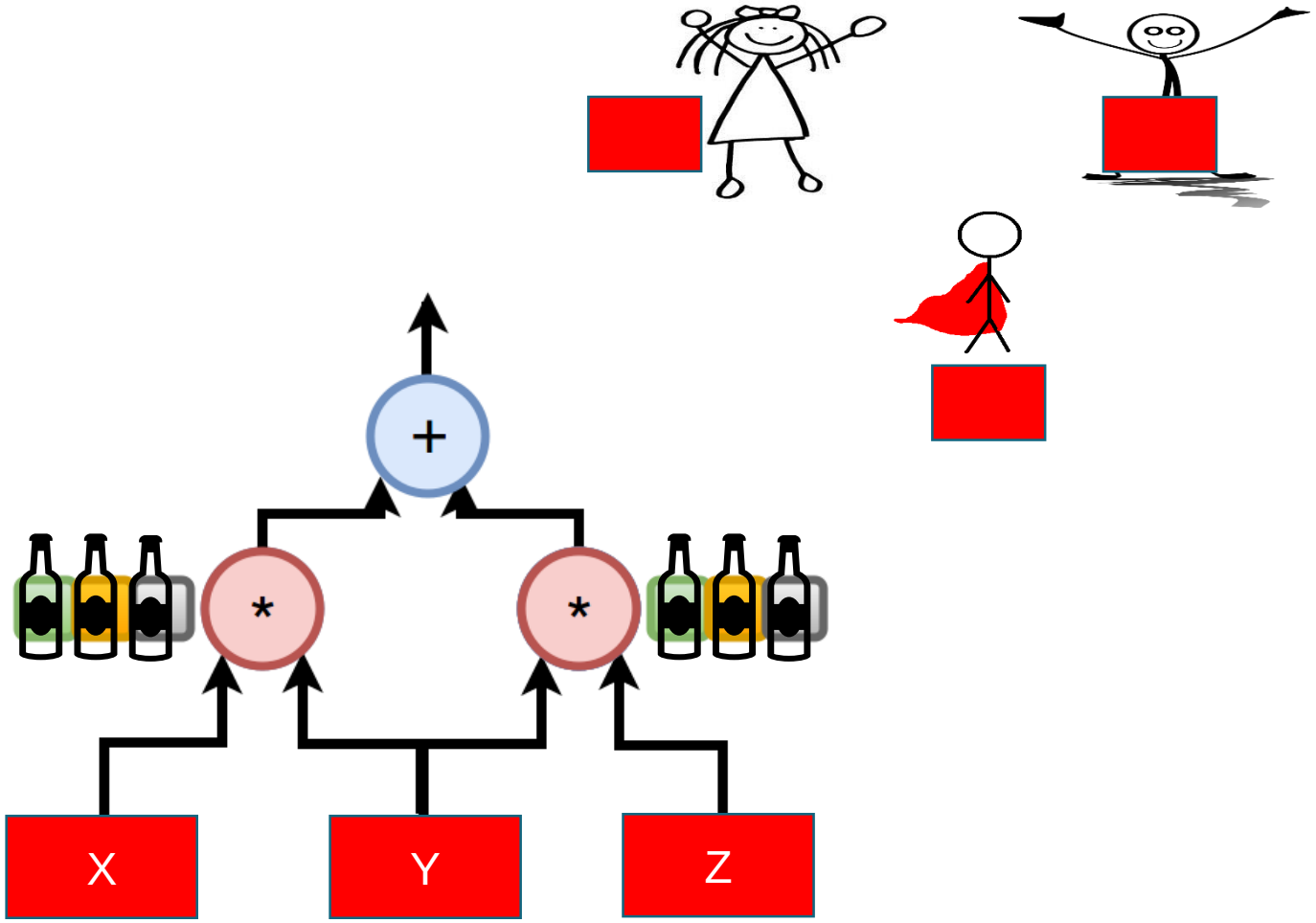

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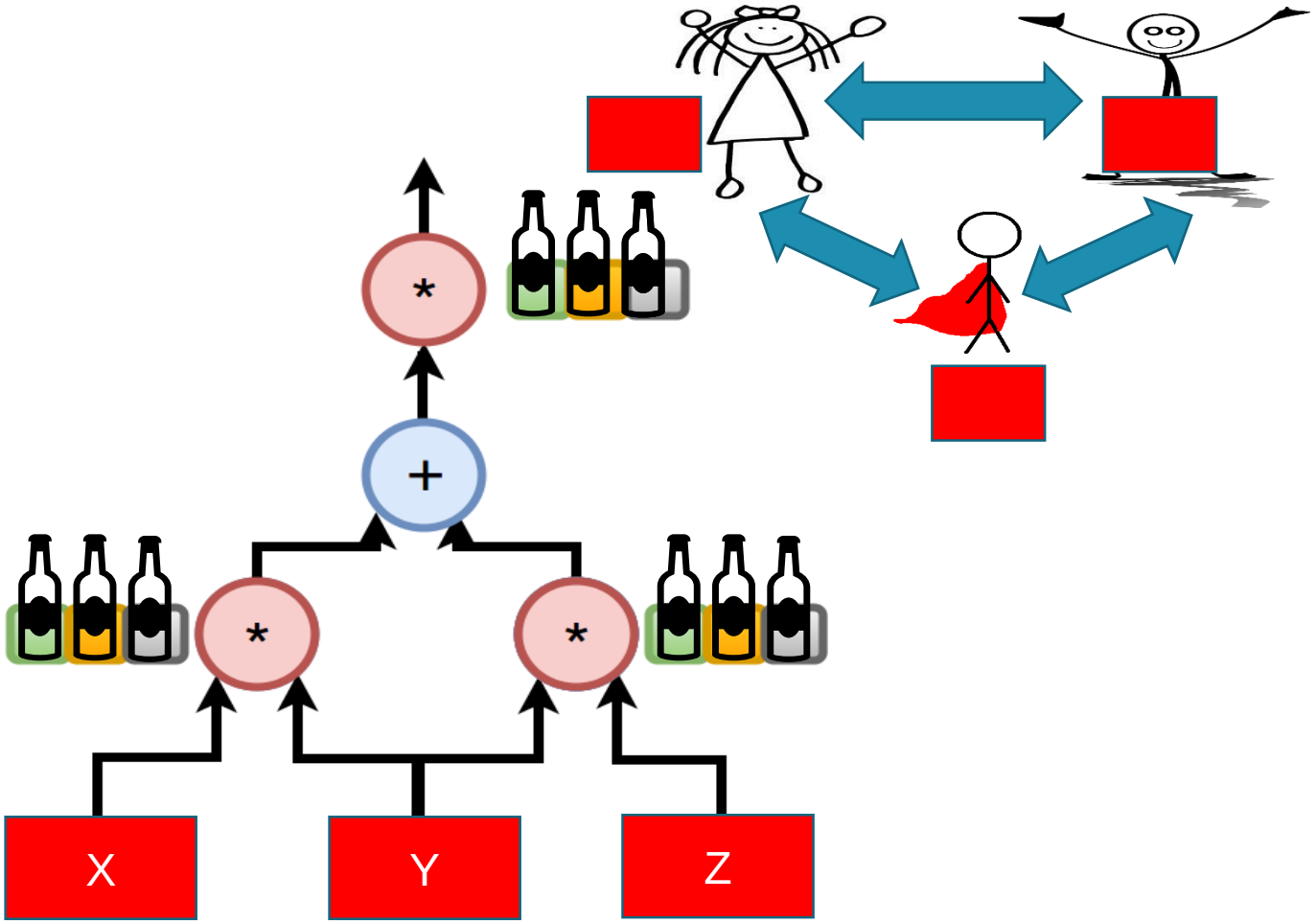
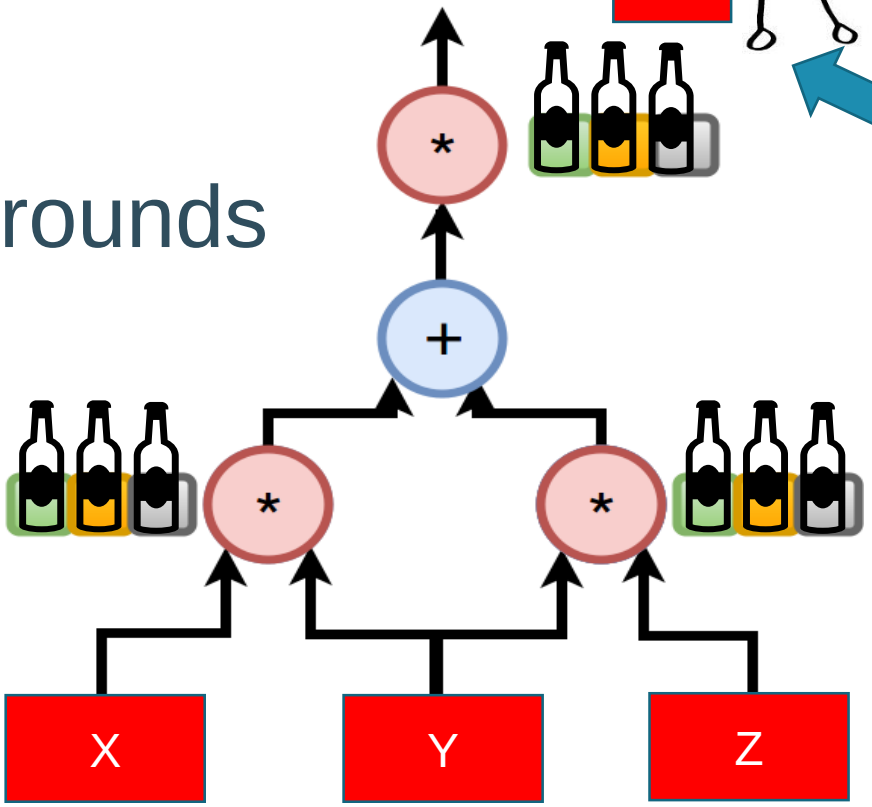
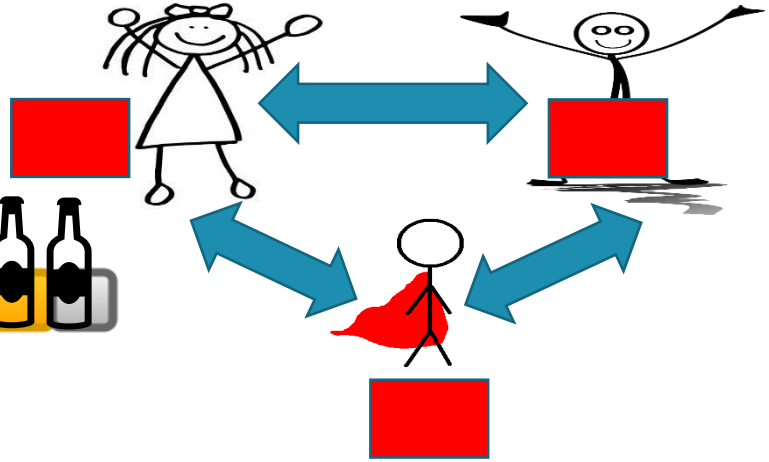


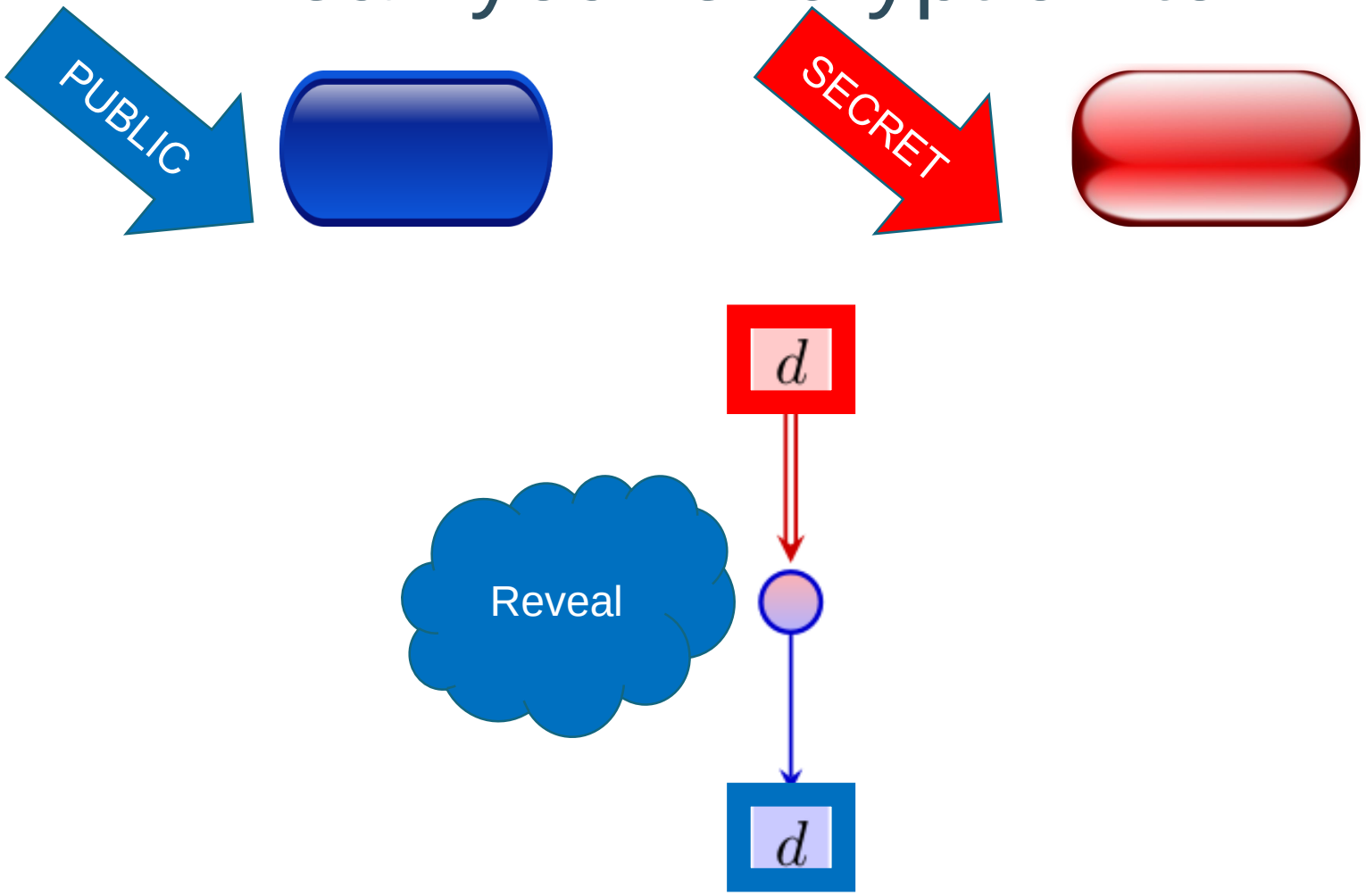
MPC Circuit Evaluation

3 triples.
2 comm. rounds





Tweak your encryption to MPC



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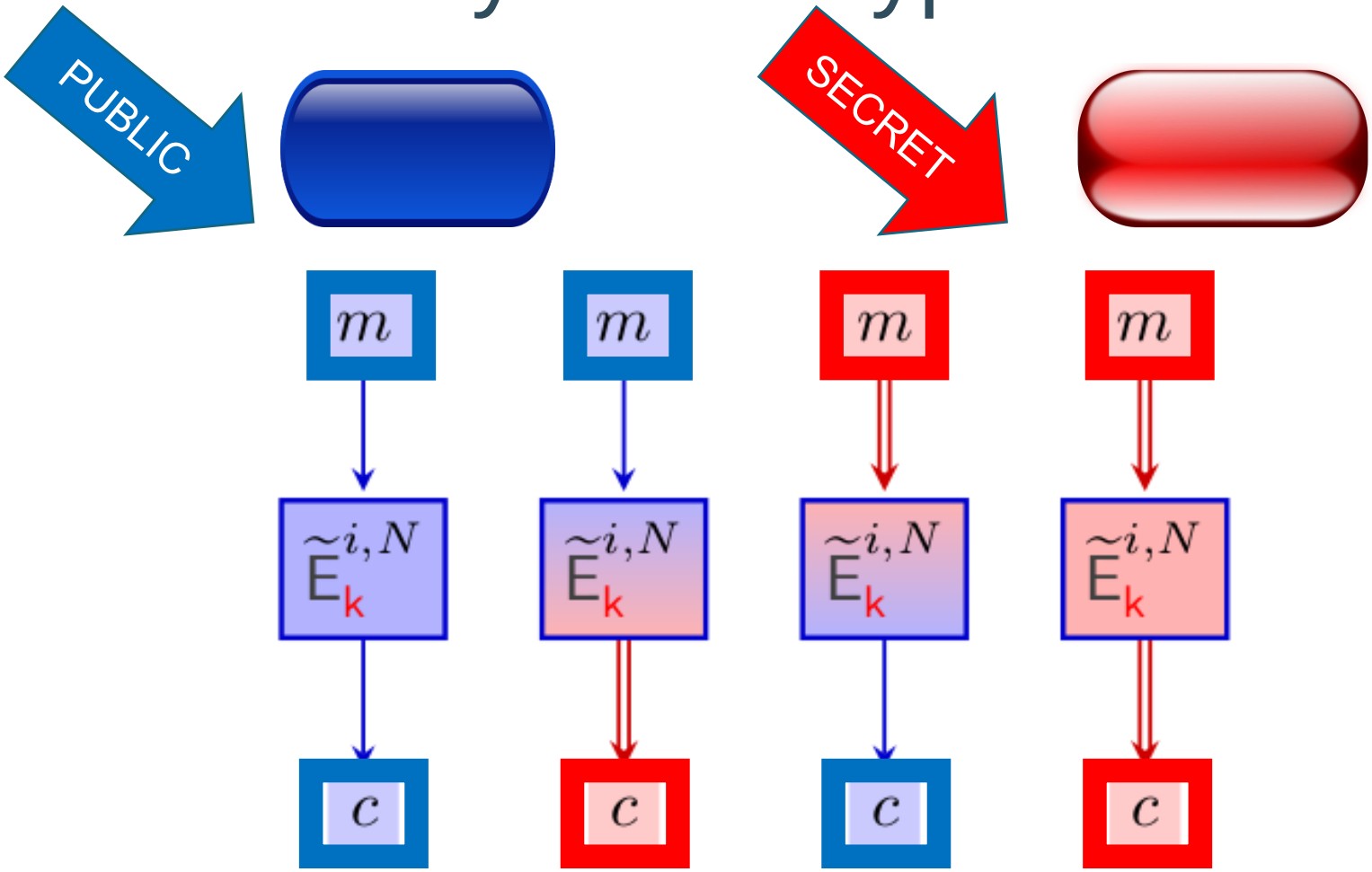

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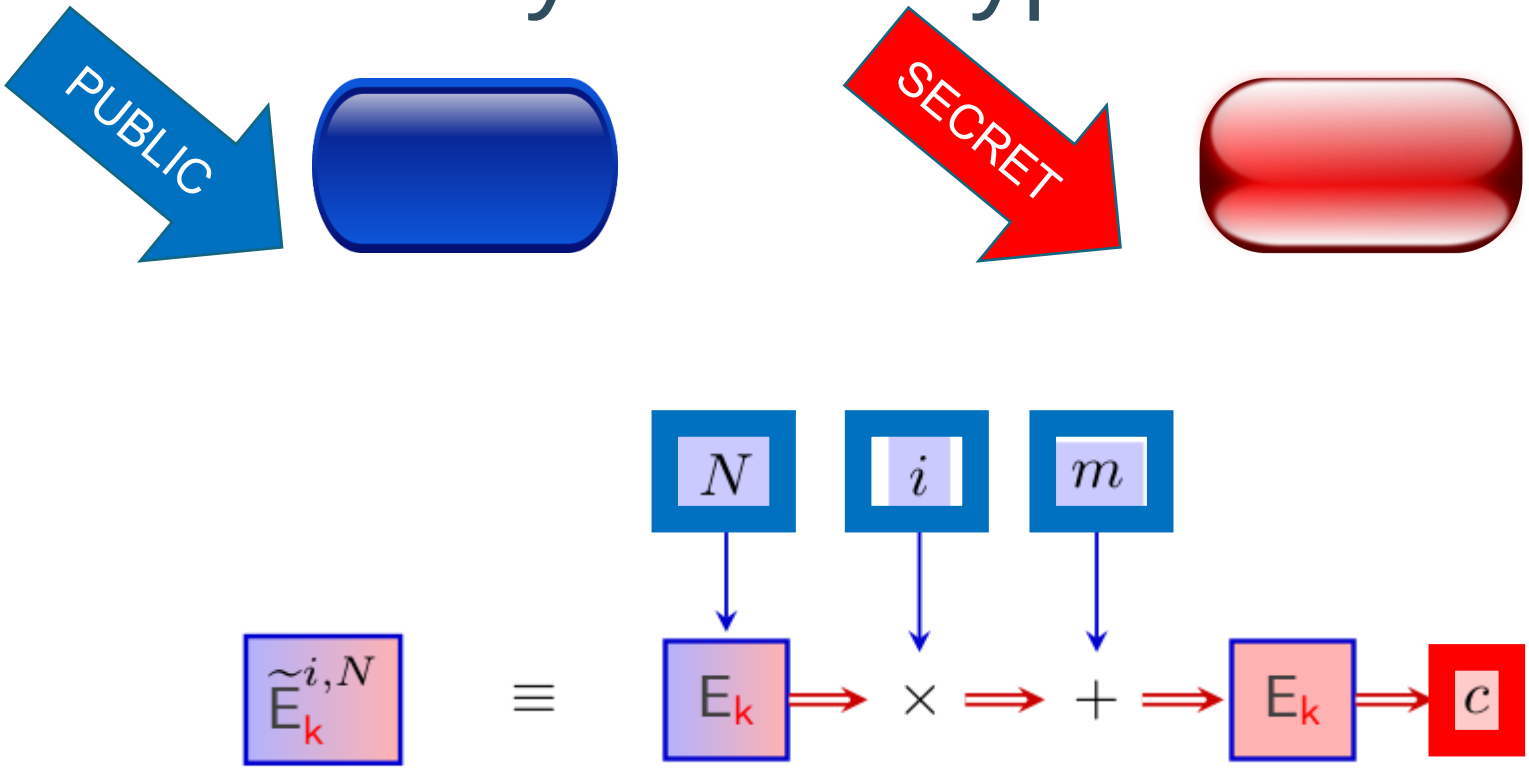
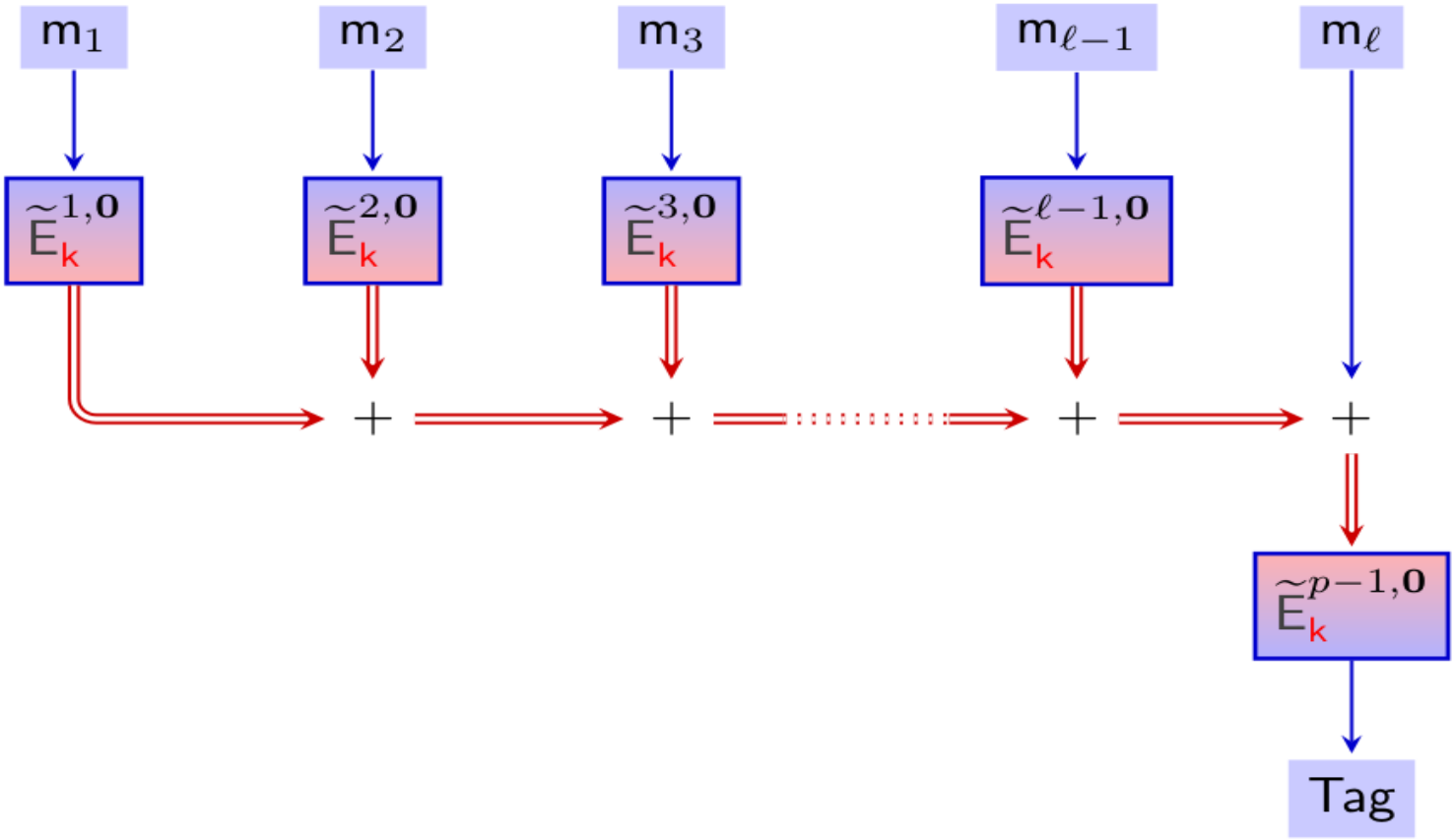


How-to compute PMAC



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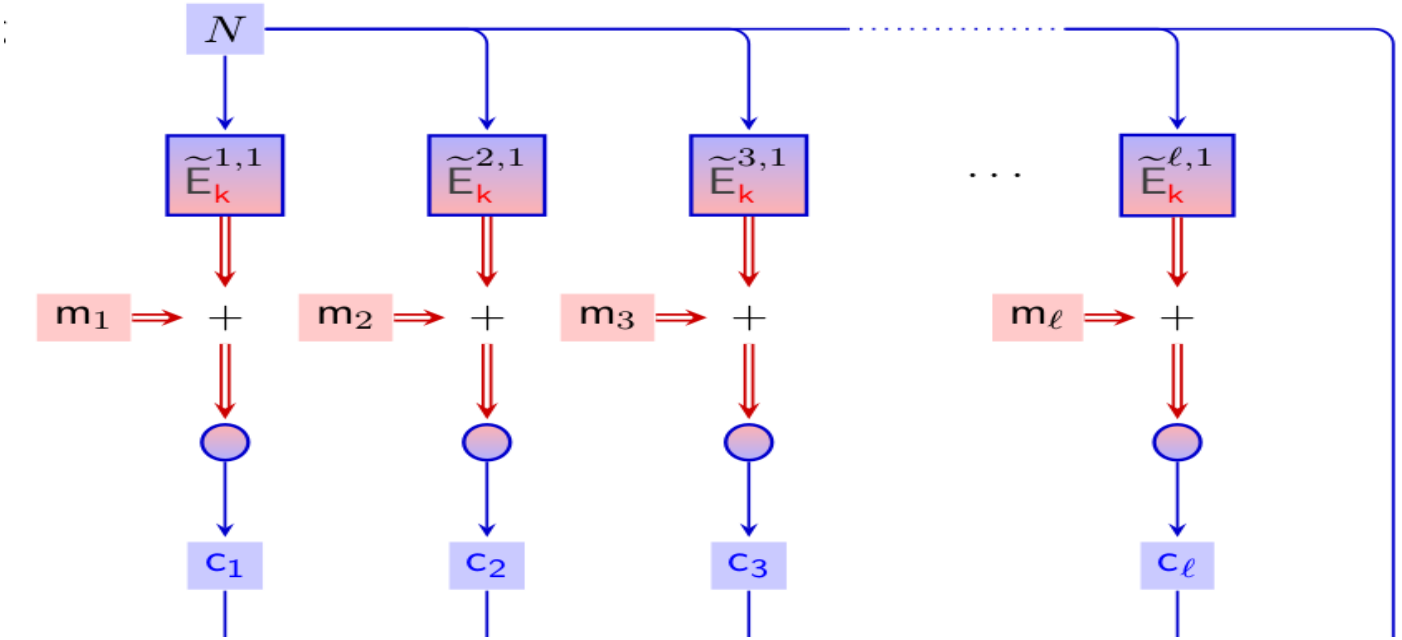
Let's do AE with CTR+pPMAC



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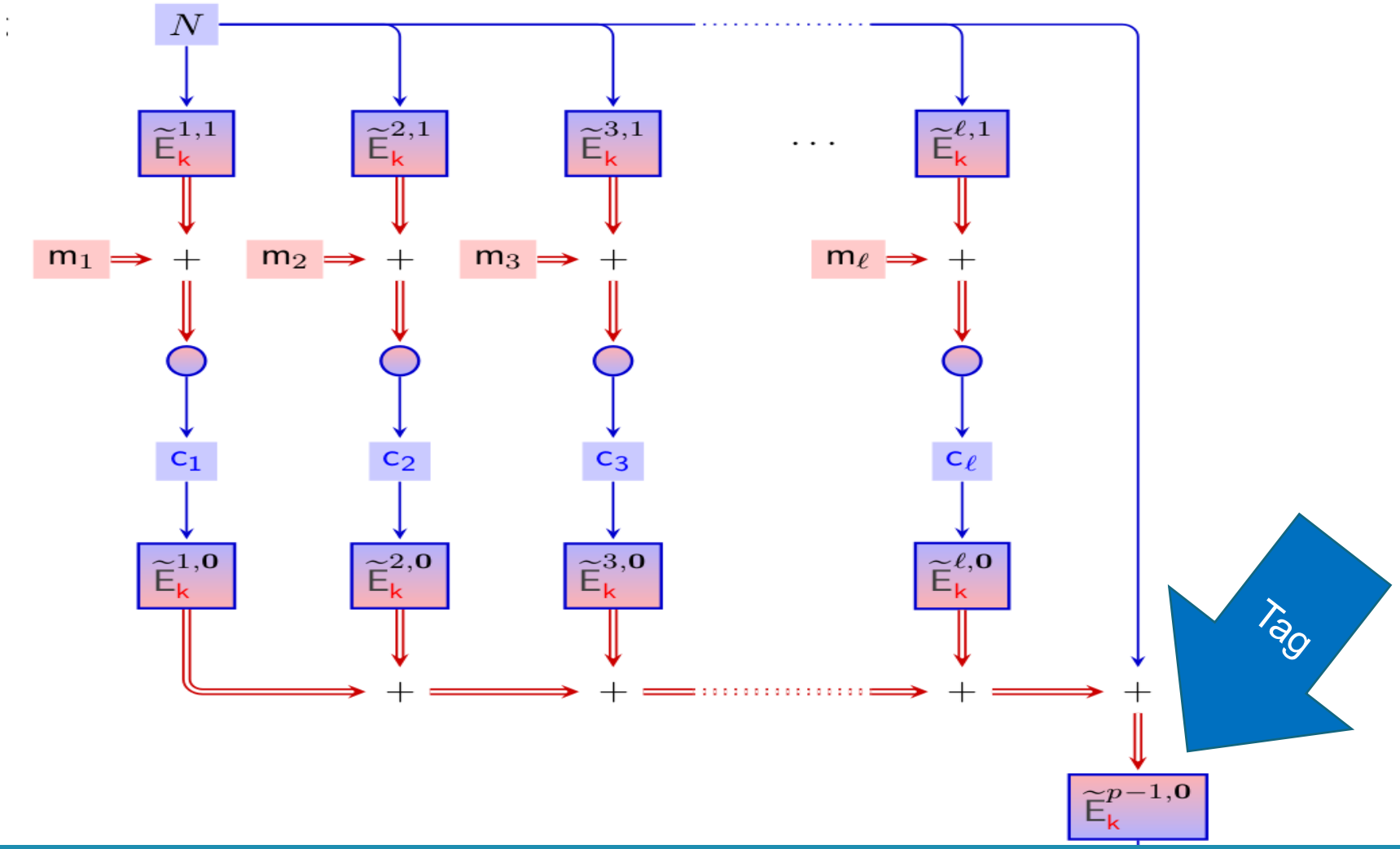

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When ideal meets real

When ideal meets real – surprise!

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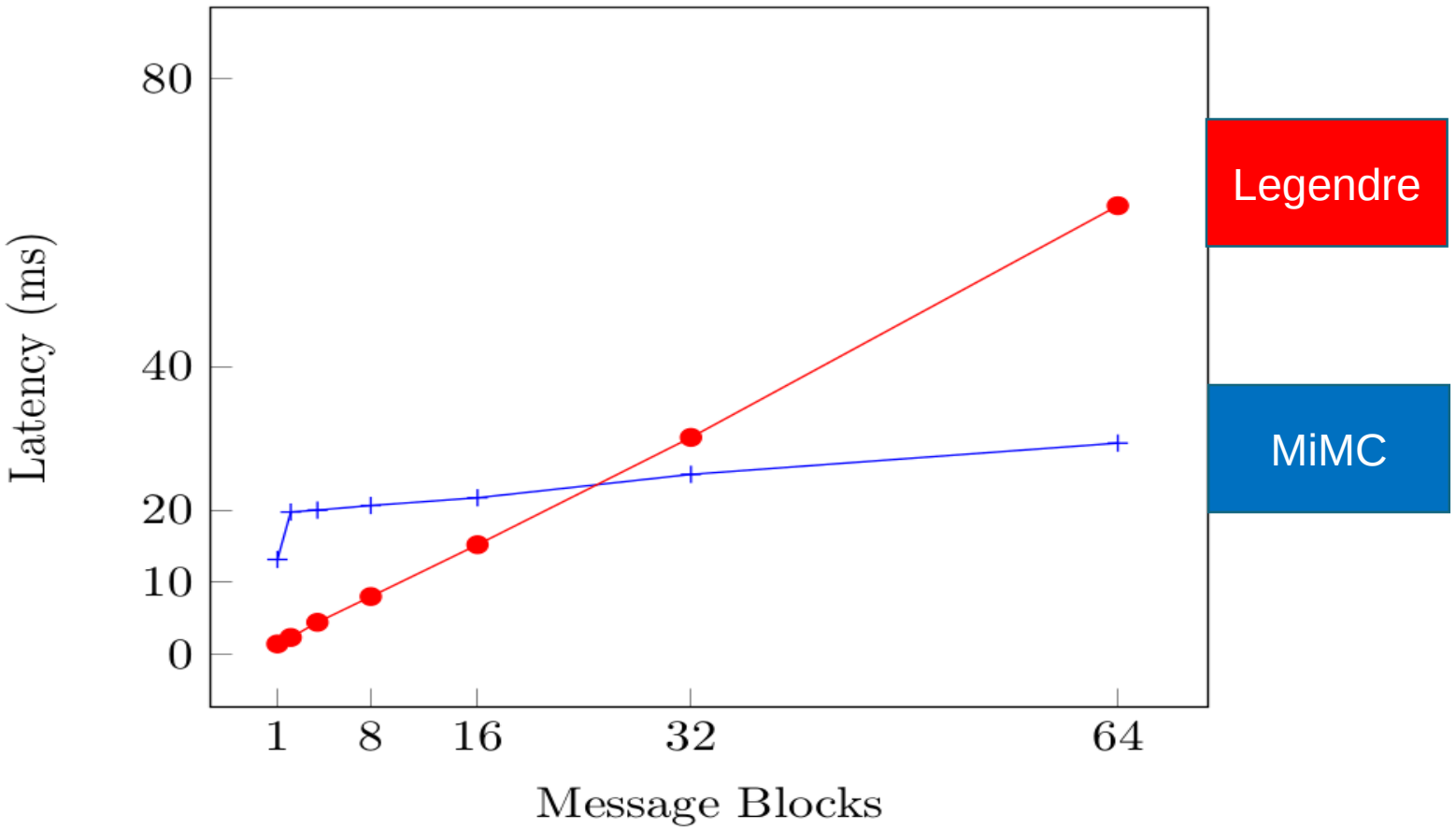

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Other competitive modes

PRF	Mode	Online cost	
		Rounds (Enc/Dec)	Openings
Leg	CTR+pPMAC	7/6	$768 \cdot \ell + \ell$
MiMC	CTR+pPMAC	221/147	$146 \cdot \ell + \ell + 1$
Leg	CTR+HtMAC	5/4	$384 \cdot (\ell + 1) + \ell$
MiMC	CTR+HtMAC	148/75	$73 \cdot (\ell + 1) + \ell + 1$
Leg	OTR	6/9	$384 \cdot (\ell + 128) + \ell$
MiMC	OTR	220/295	$73 \cdot (\ell + 2) + \ell + 1$

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Some open problems

- Preprocessing scales linearly in terms of number of message blocks - roughly n PRFs for n messages.
- Number of rounds of a cipher vs. multiplicative depth in MPC.

Thank you!

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- Questions?