Your Reputation's Safe with Me: Framing-Free Distributed Zero-Knowledge Proofs

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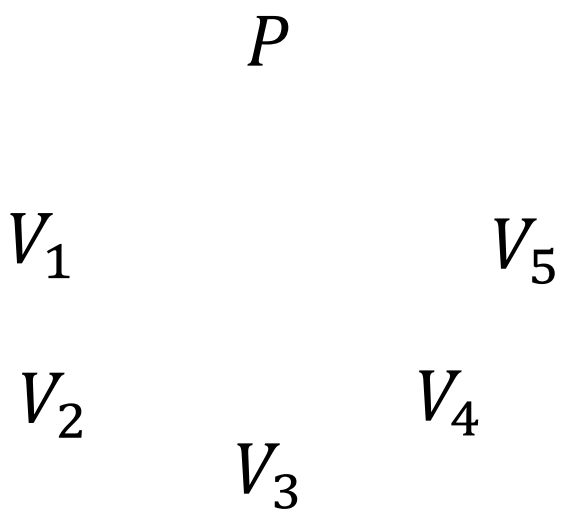
Mor Weiss — Bar-Ilan University

Framing-Free Distributed ZK Proofs



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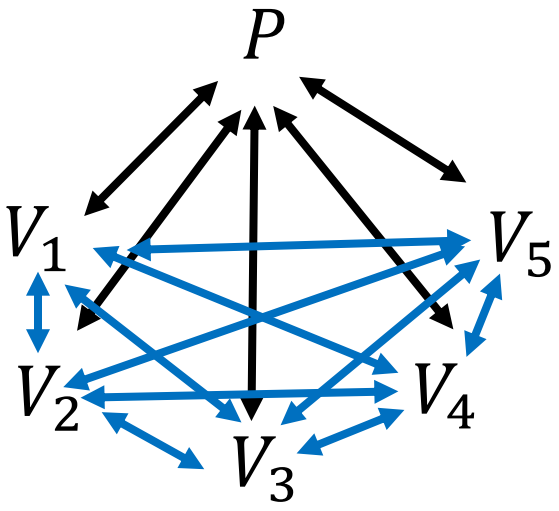

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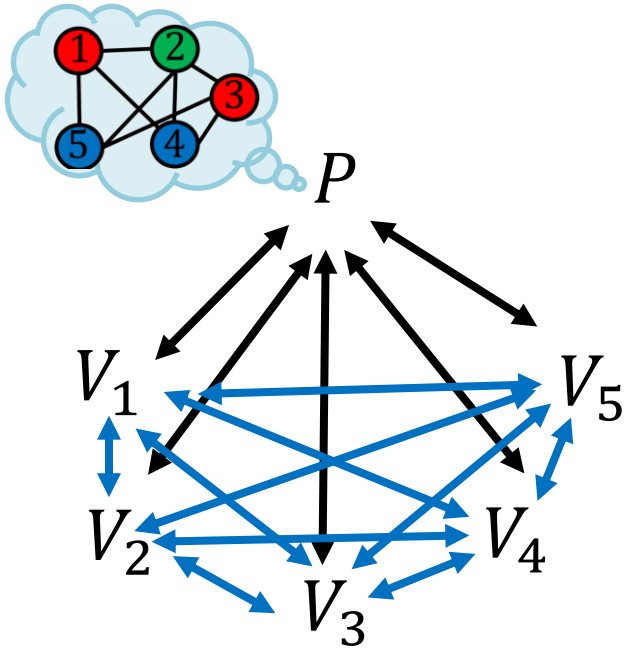

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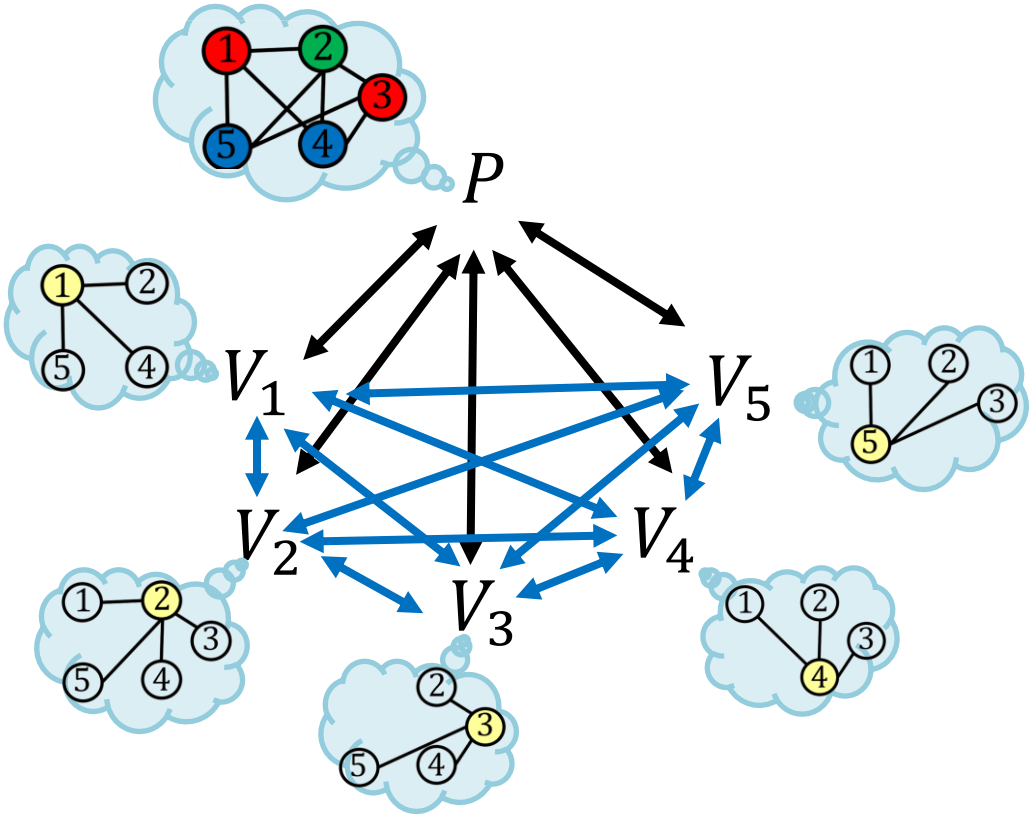

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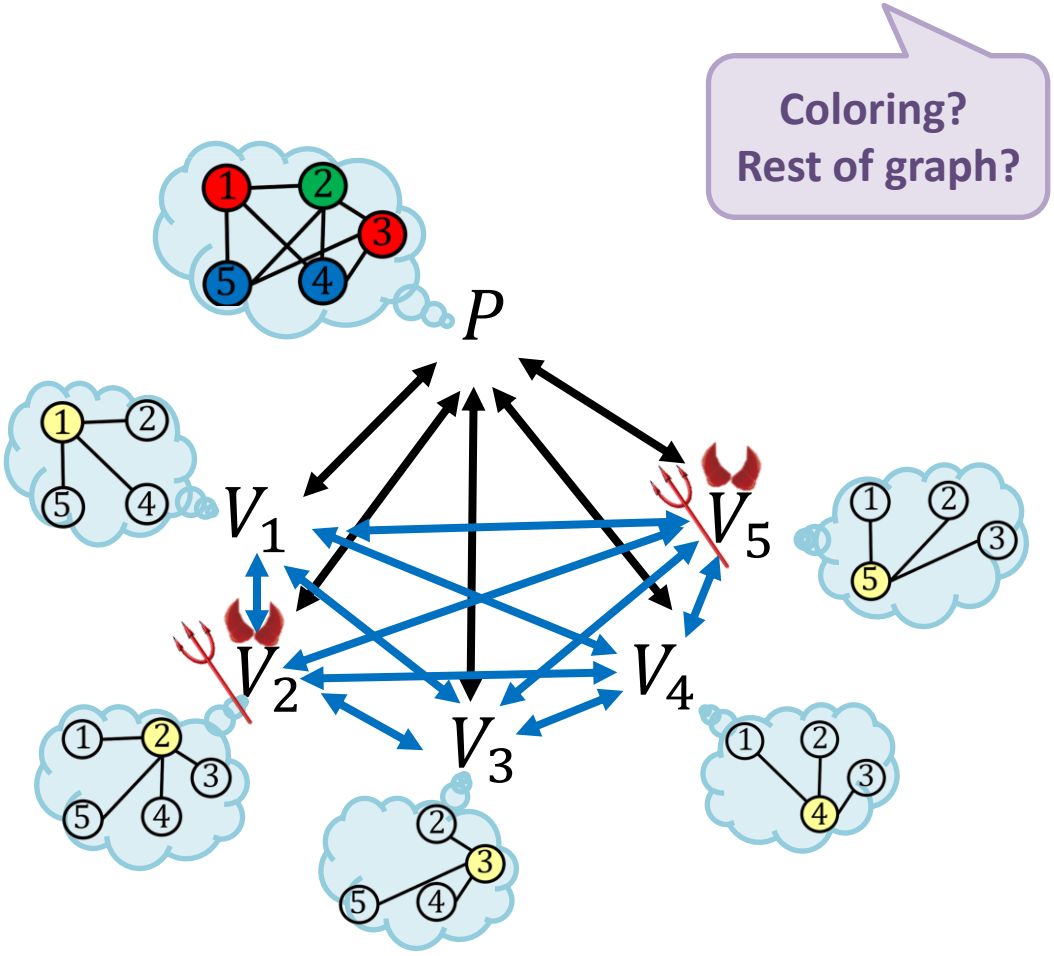

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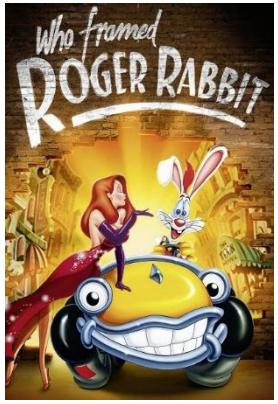

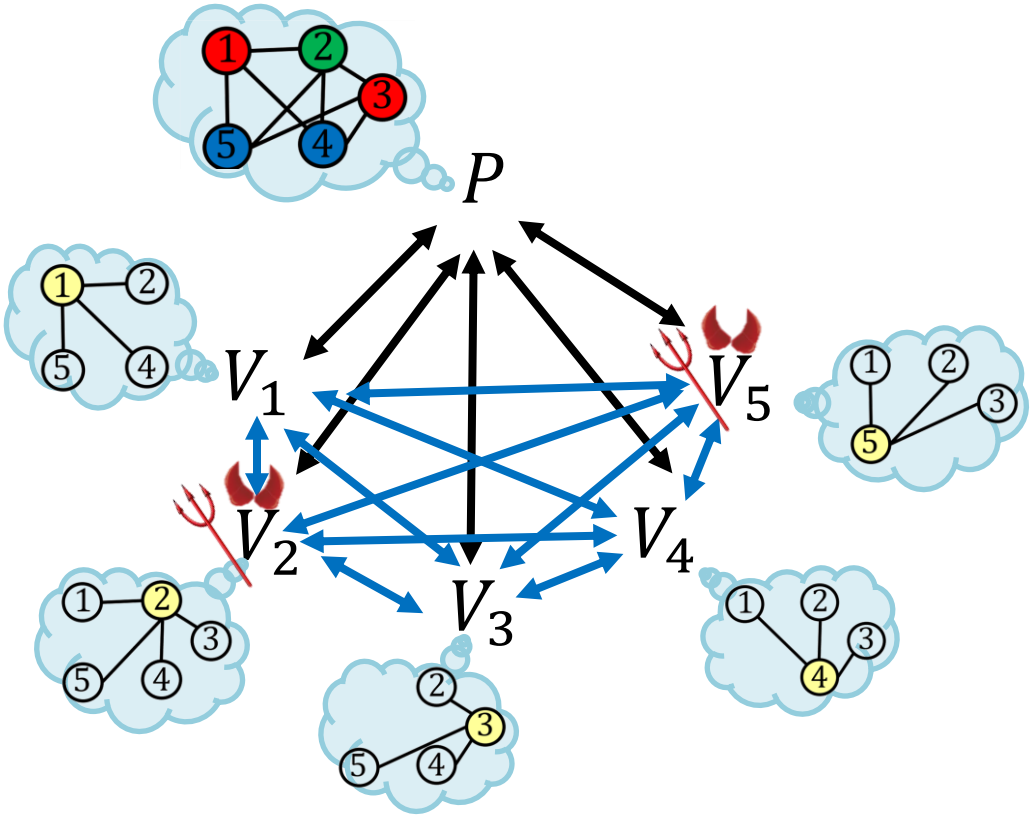

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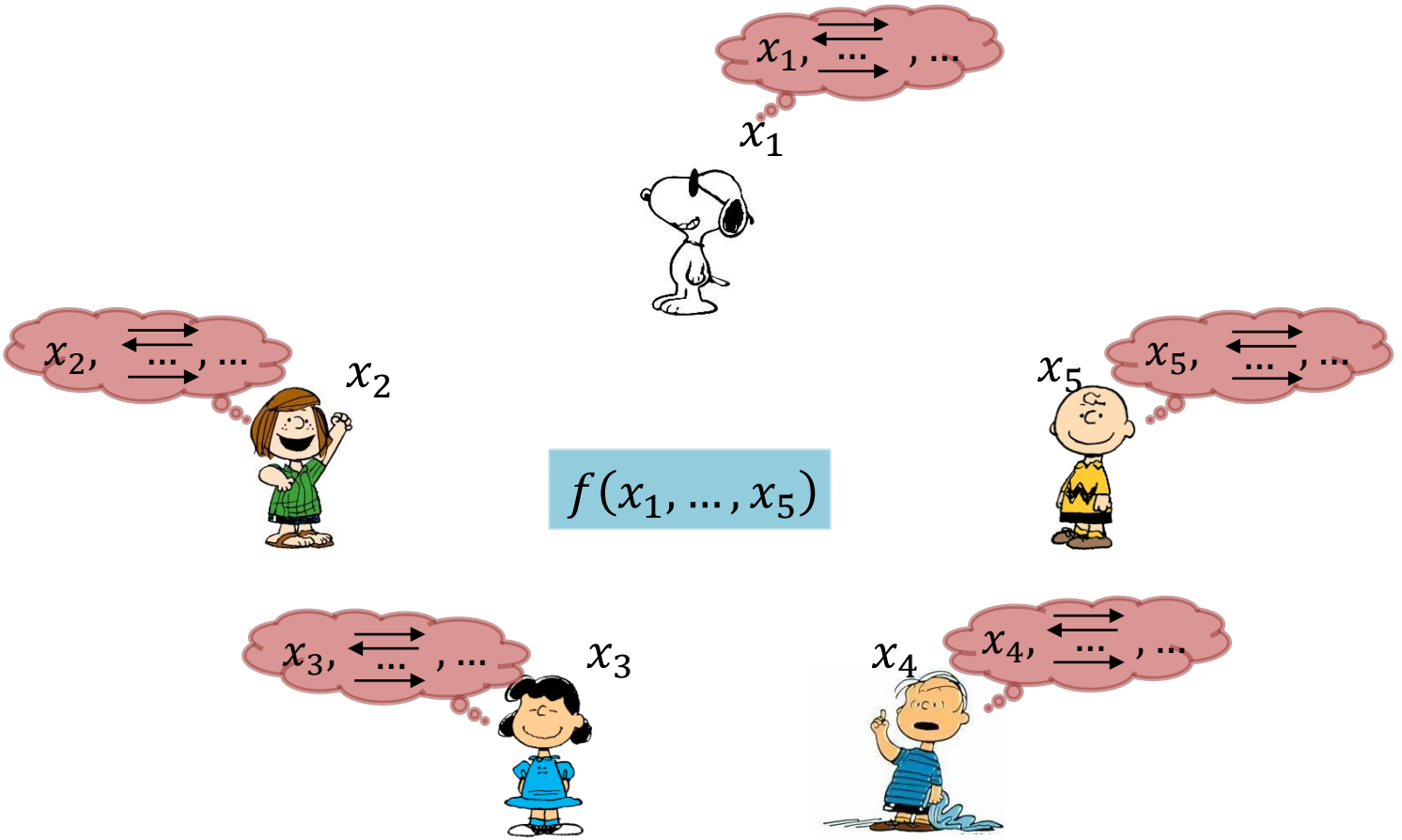

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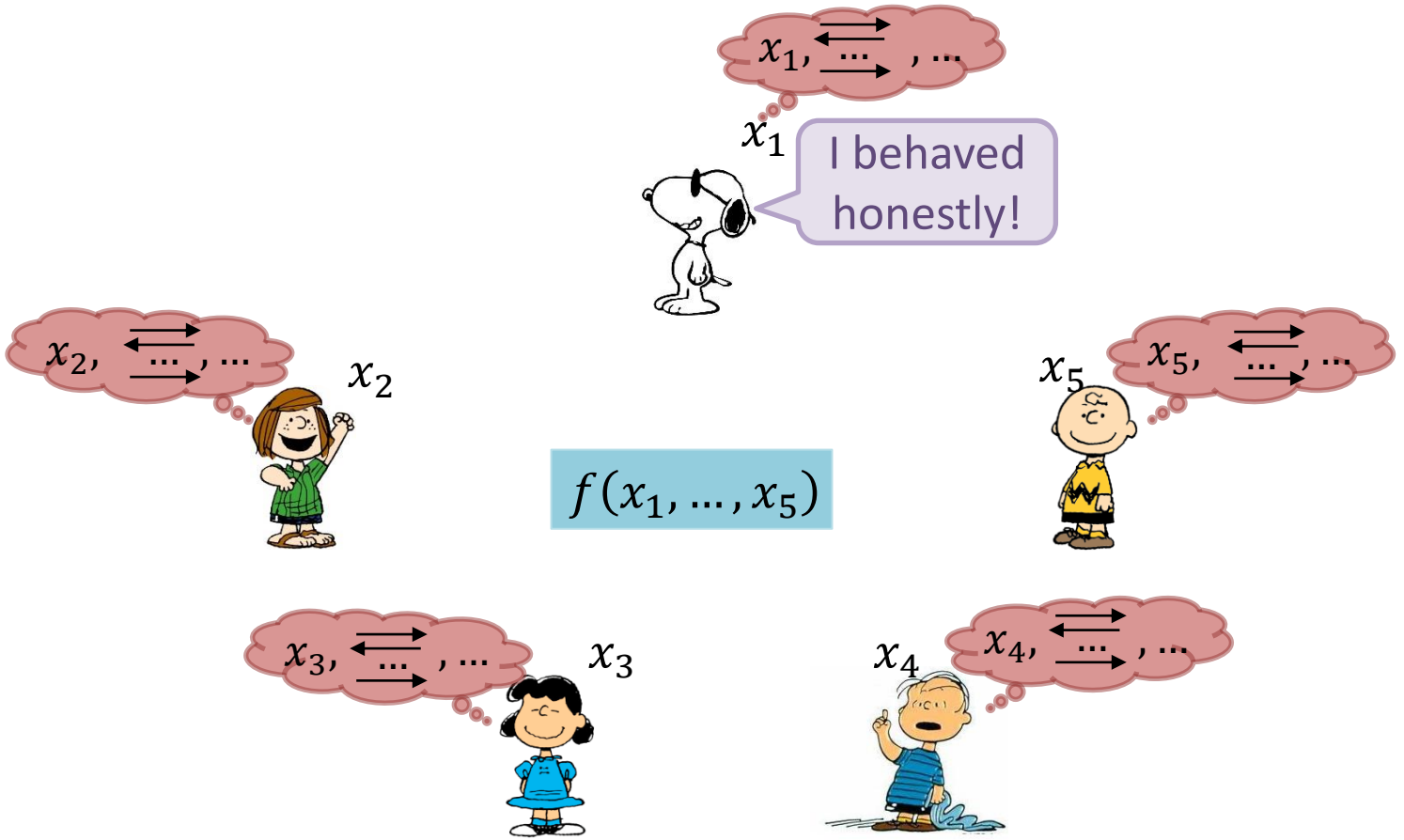

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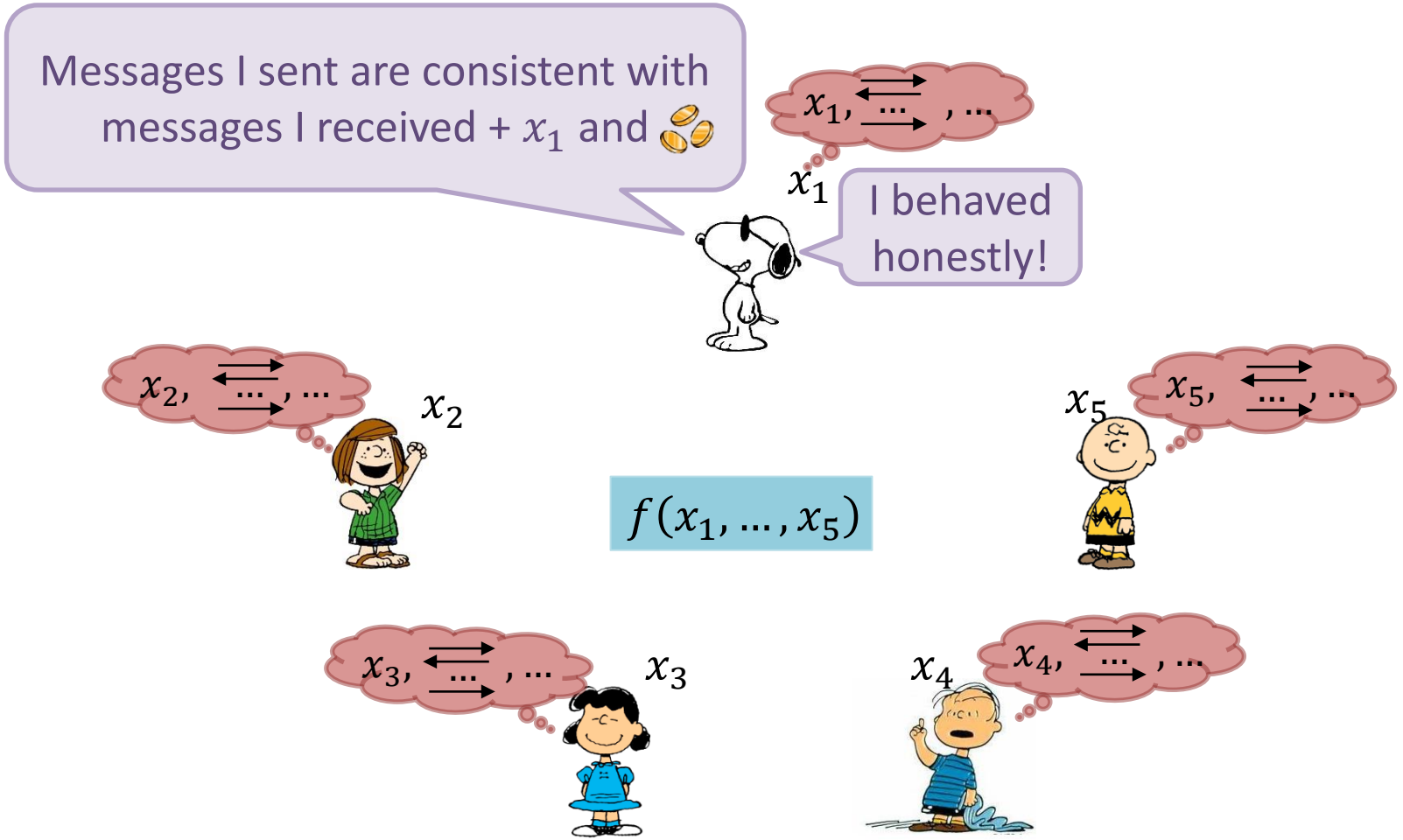

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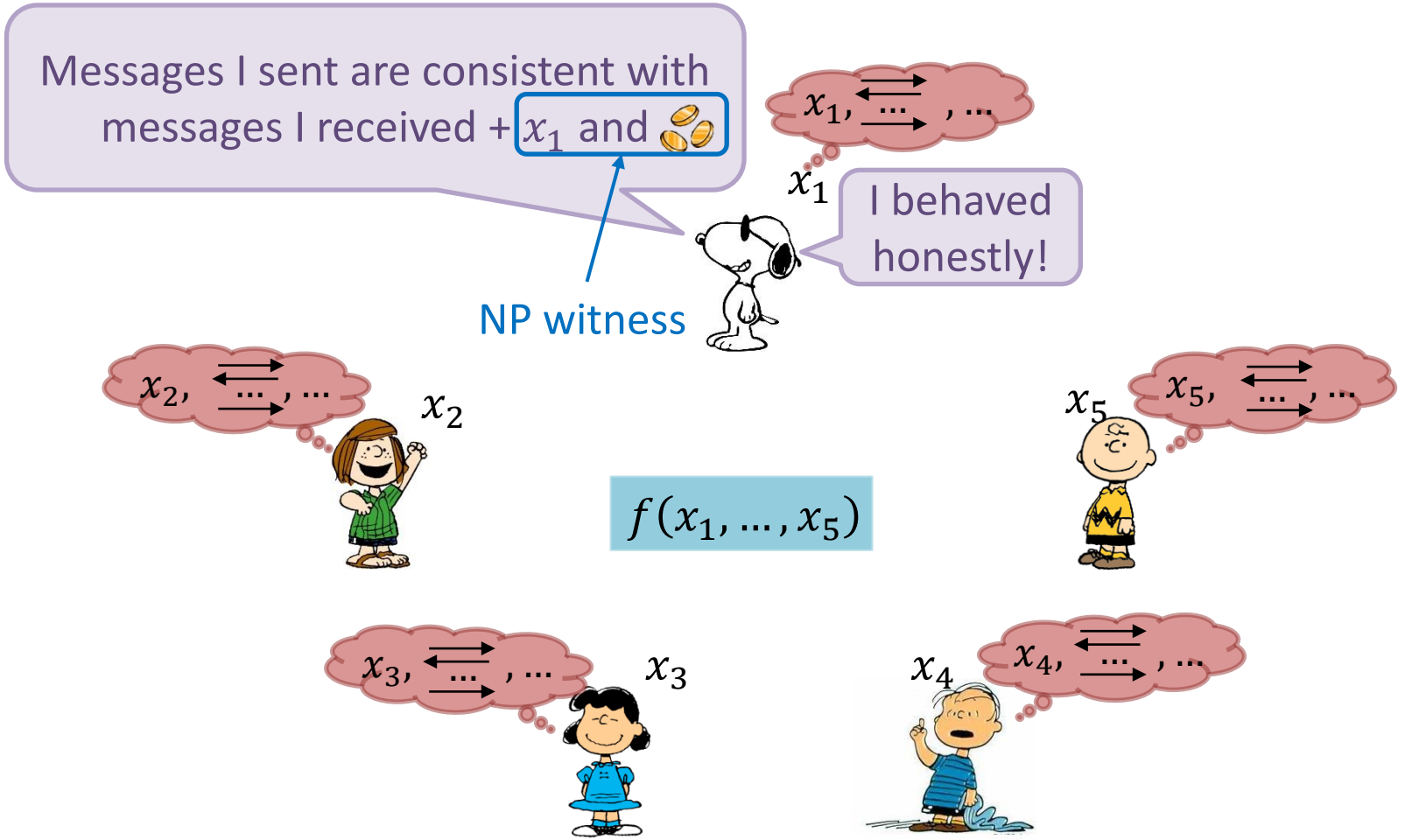

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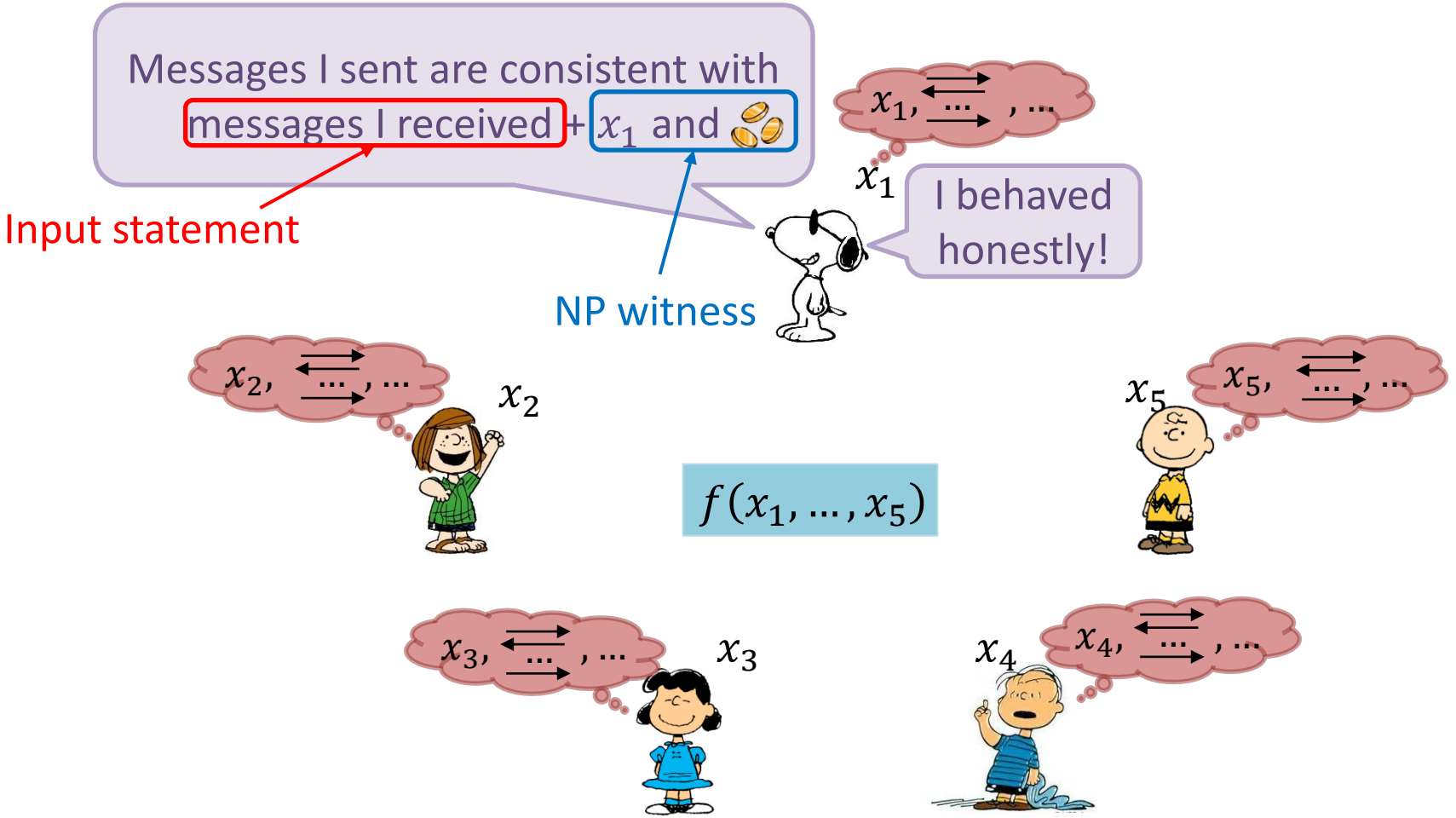

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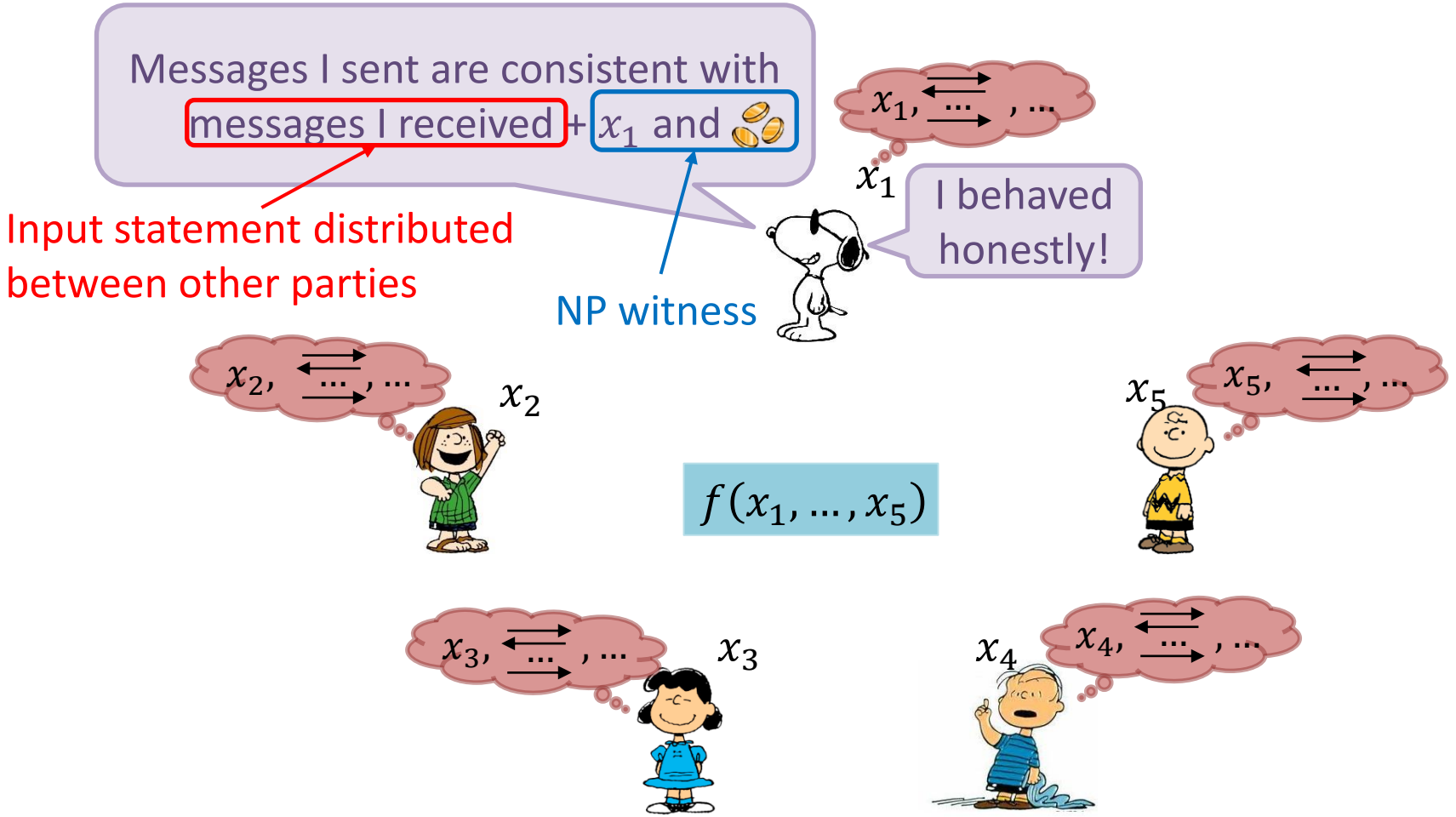

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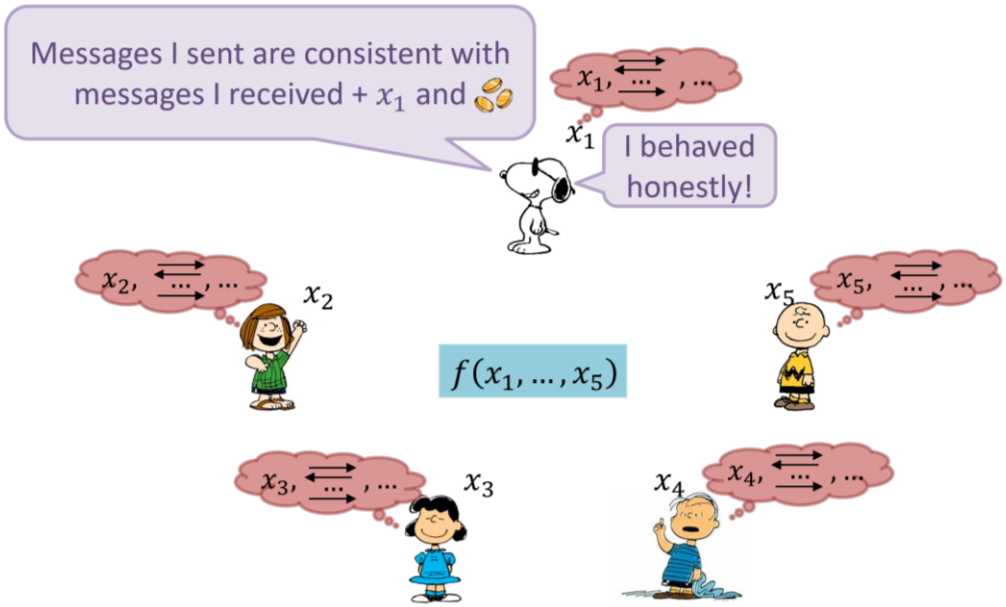

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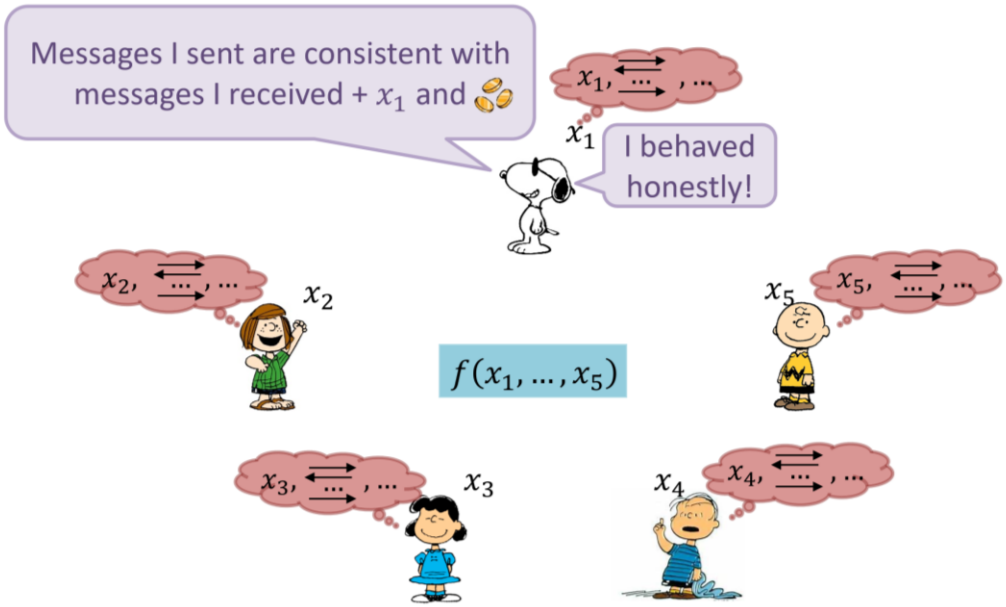

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- **Our goal:** verification-efficient framing free dZKs

Distributed ZK Proofs: Previous Works

- **Many different models**
  - Verifiers colluding with prover, computational powers of corrupted parties, who knows input statement, … [ABD91,CF02,GIKR02,GO07,CBM15,CB17, BBCGI19,AKP20a,BBGIN20,BGIN21,BJOSS22,WY22, AKP22]

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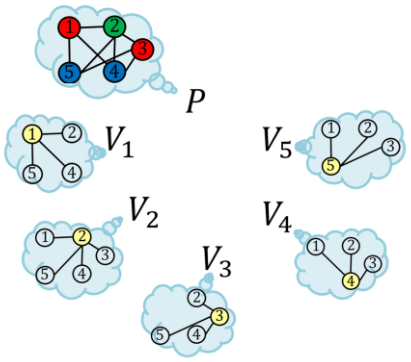

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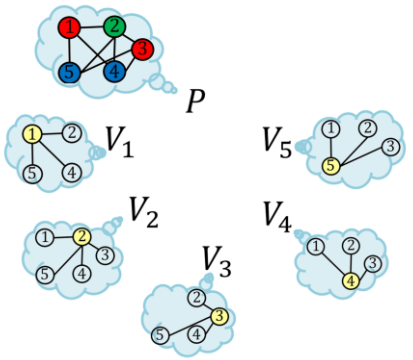

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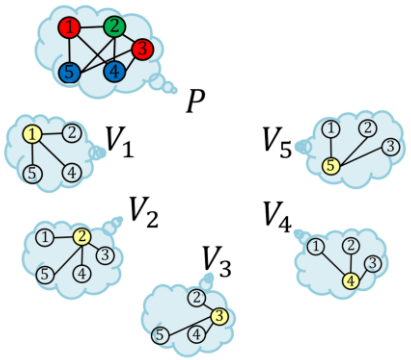

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- **Generic MPC protocols [BGW88,CCD88] give dZK**
  - Even with $O(1)$ rounds [IK02,ABT19,ACGJ18,ACGJ19] and tight thresholds and round complexities [AKP20a,AKP20b]
  - **Not verification-efficient!**

Our Contribution

- **First verification-efficient "framing-free" dZK for NP**
  - k verifiers, $t < \frac{k-2}{6}$ corruptions
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  - Based on "MPC in the head"
    - Using new analysis for "MPC in the head" in distributed setting (fundamentally different from the analysis in [AKP22])
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- **Instantiations** (assuming ideal coin tossing, $\Omega(k)$ corruptions):

# Rounds	Total proof length	Verification CC
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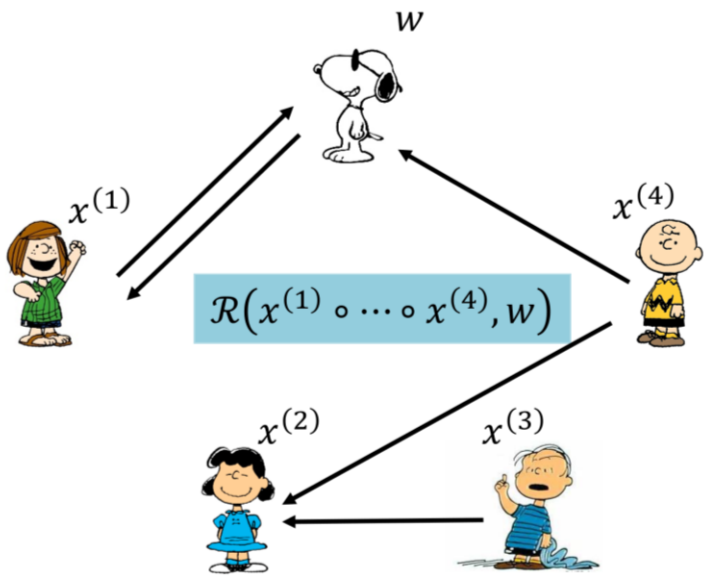
- **Applications:** aggregate statistics, VSS, (reusable) certifiable VSS, proving honest behavior

Highlights of Our dZK Construction

Proofs from “MPC in the Head”



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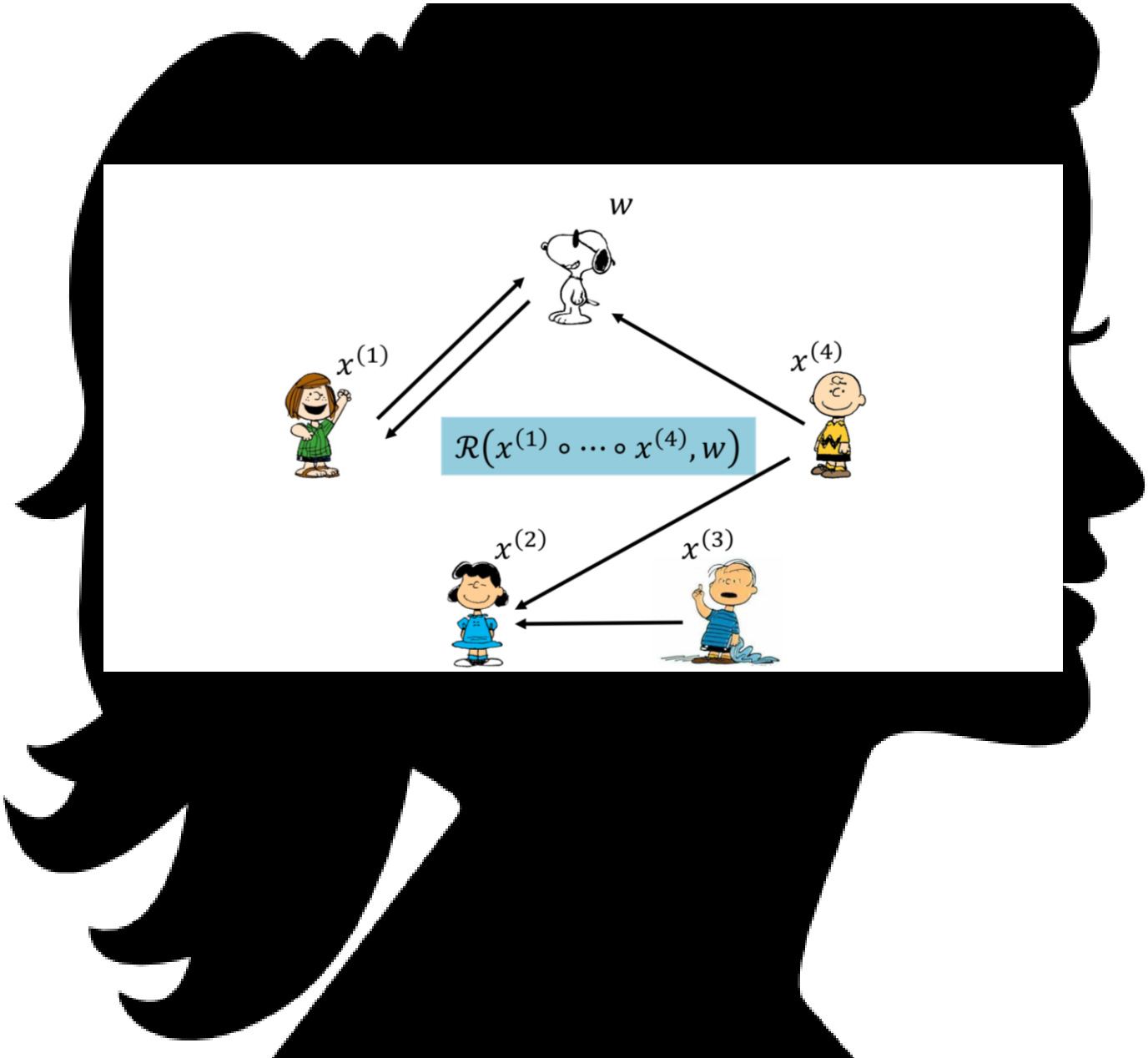

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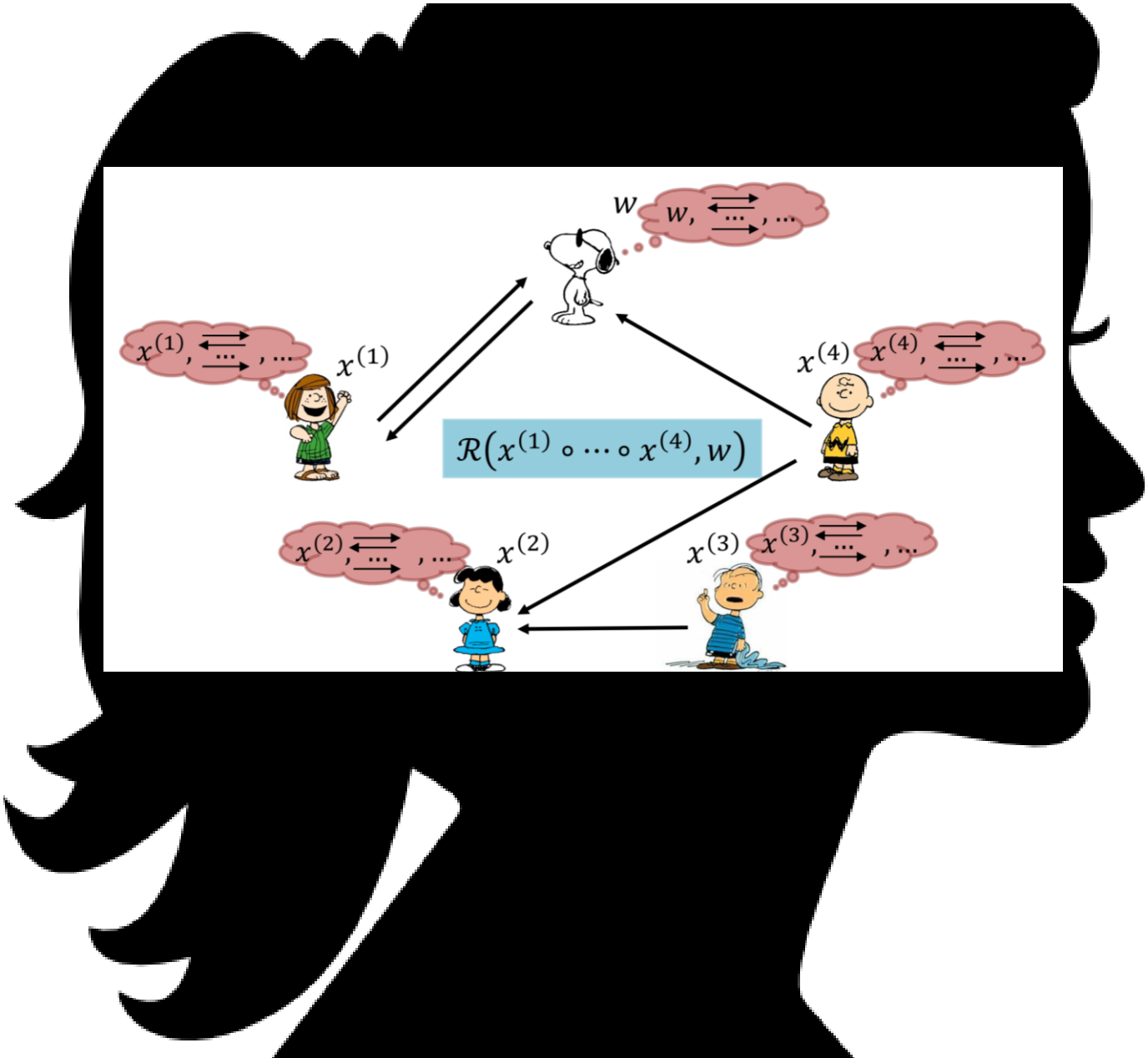

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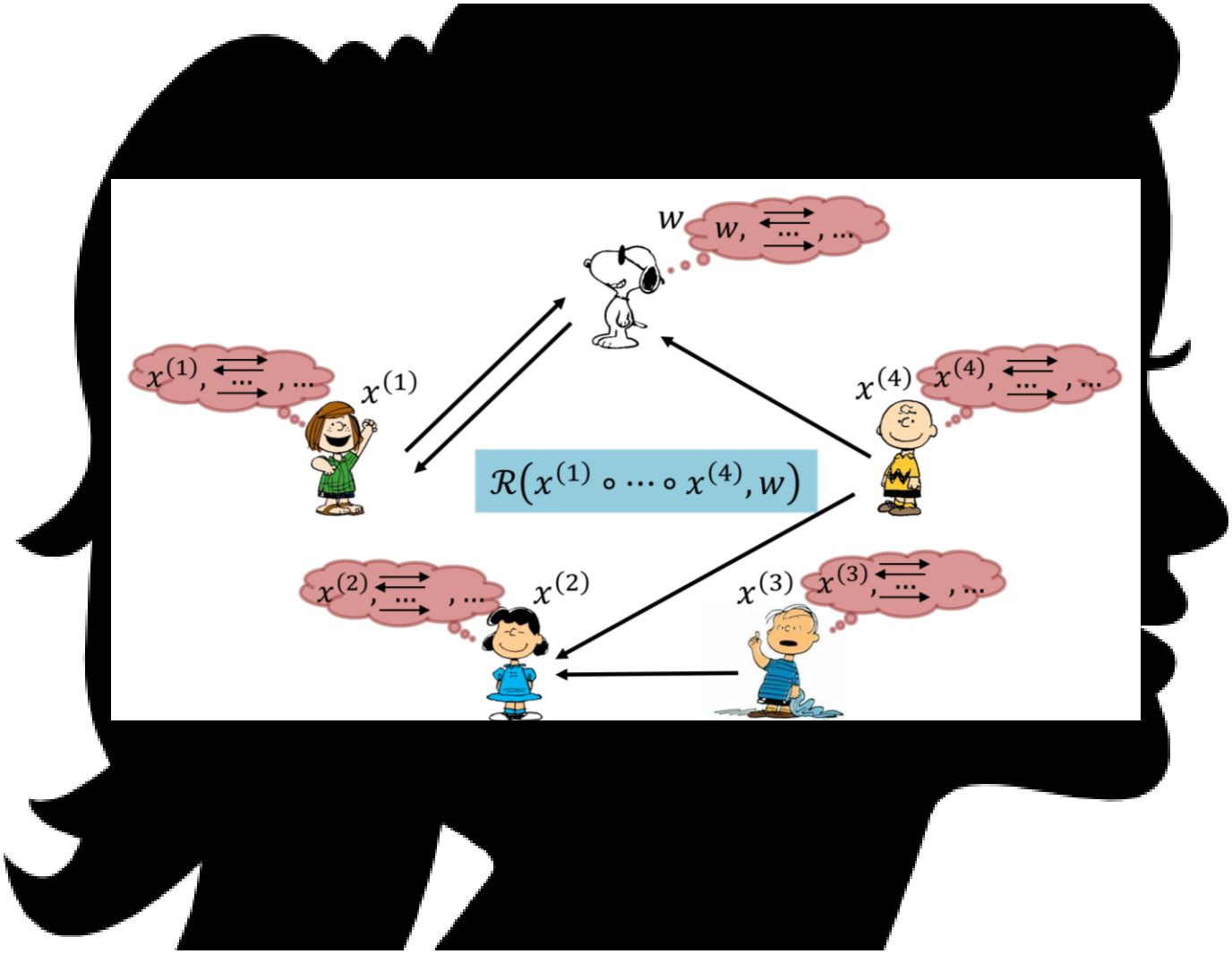

Pairwise consistency ⇒ global consistency ⇒ soundness [IKOS07]

dZK from “MPC in the Head” (Warmup)

Prover Zone

$V_1^{x^{(1)}}$ $V_2^{x^{(2)}}$ $V_3^{x^{(3)}}$ $V_4^{x^{(4)}}$

Verification Zone

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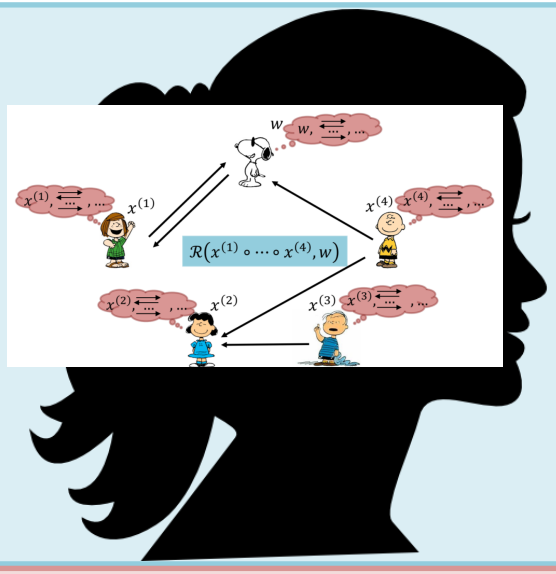

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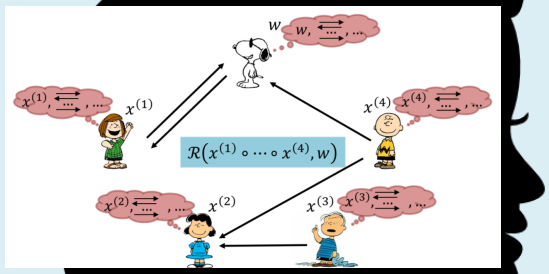

$x^{(1)}$

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V_1 $x^{(1)}$ V_2 $x^{(2)}$ V_3 $x^{(3)}$ V_4 $x^{(4)}$

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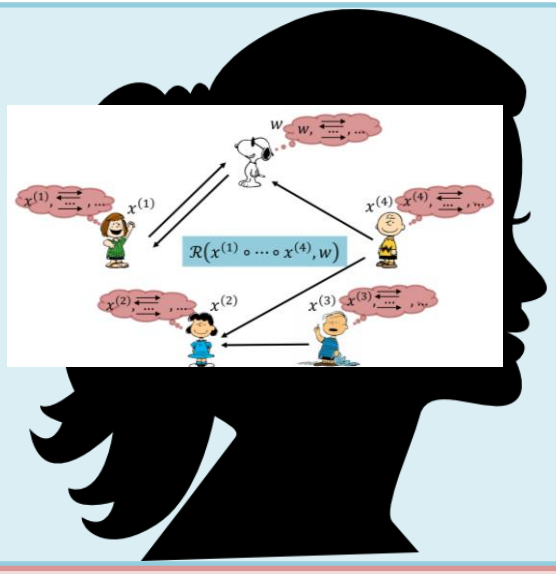
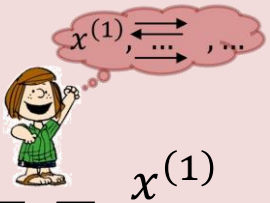
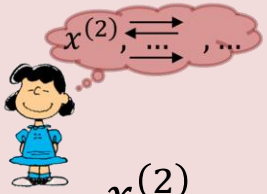
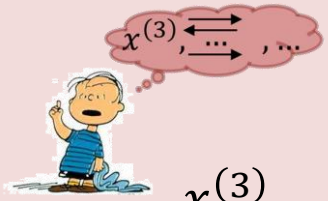




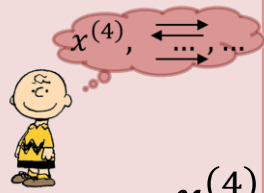
V_1 $x^{(1)}$



V_2 $x^{(2)}$



V_3 $x^{(3)}$



V_4 $x^{(4)}$

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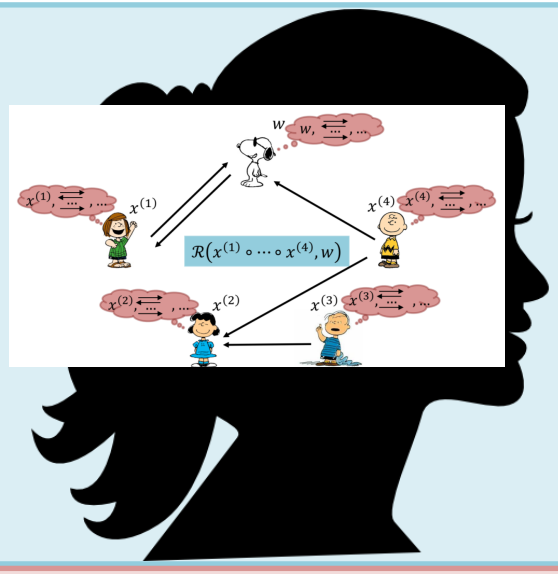

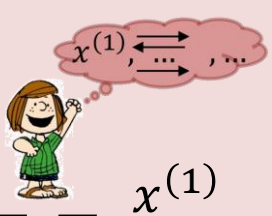

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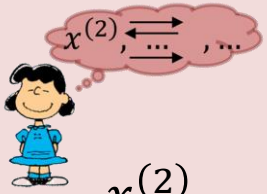

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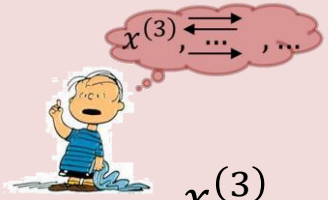

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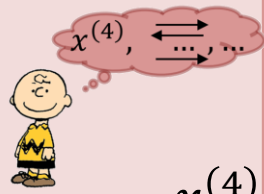


V_4 $x^{(4)}$

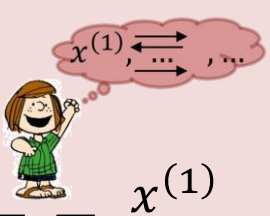
Each V_i checks:

- Local consistency: input $x^{(i)}$ and output 1
- Pairwise consistency with every V_j

Accept if no verifier b\casts complaint

Verification Zone

Getting Verification Efficiency



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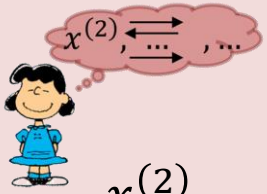

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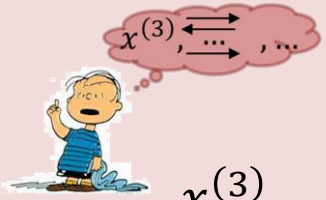
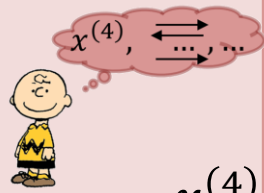


V_3 $x^{(3)}$



V_4 $x^{(4)}$

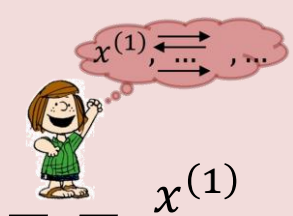
Each V_i checks:

- Local consistency: input $x^{(i)}$ and output 1
- Pairwise consistency with every V_j

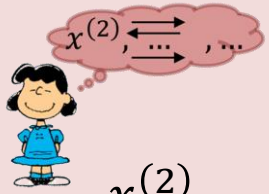
Accept if no verifier b\casts complaint

Getting Verification Efficiency

- **To get verification efficiency:** compress communication with information-theoretic MACs
  - Verifiers exchange only tags
  - All MACs generated using one random coin (from the oracle)



V_1 $x^{(1)}$



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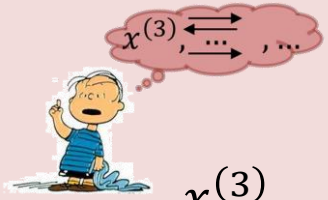

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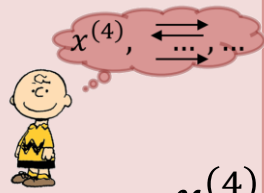

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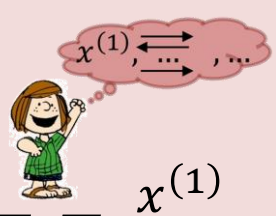
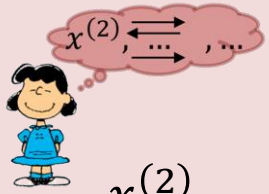


V_1 $x^{(1)}$

$t_{1,2} =^{?} t_{2,1}$



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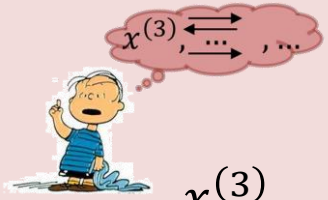

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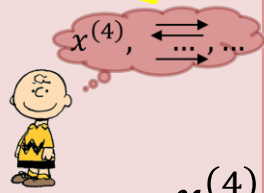

V_4 $x^{(4)}$

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Getting Verification Efficiency

- **To get verification efficiency:** compress communication with information-theoretic MACs
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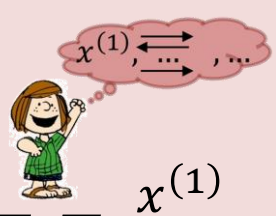
- Matches dZK of [BBCGI19]



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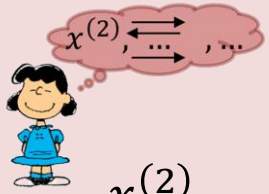

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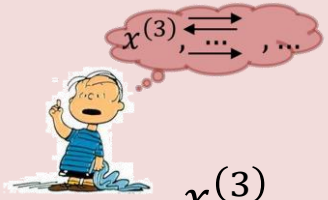

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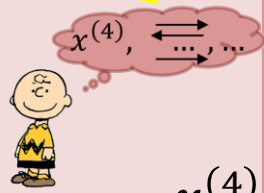

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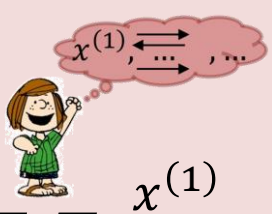
Getting Framing Free



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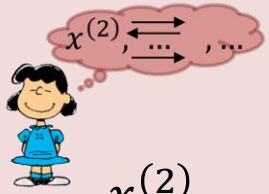

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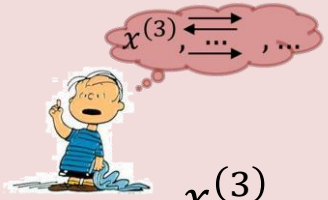

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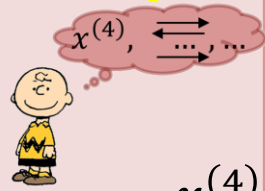

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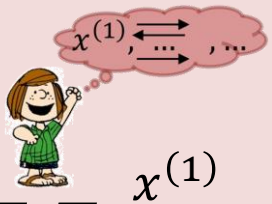

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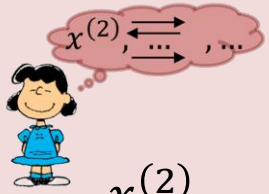

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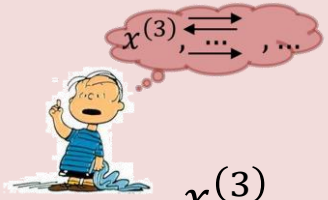

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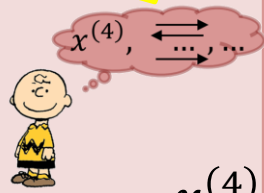

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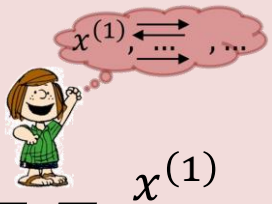

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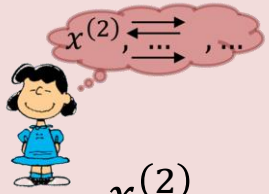

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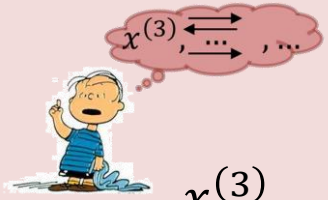

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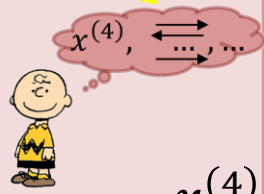

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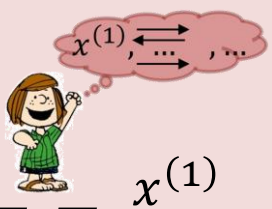

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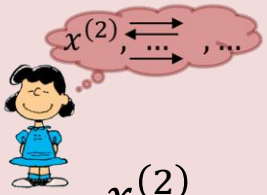

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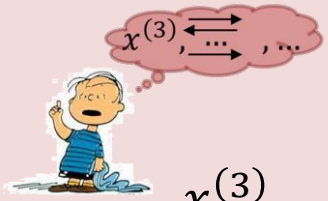

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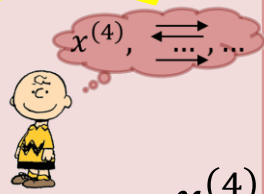

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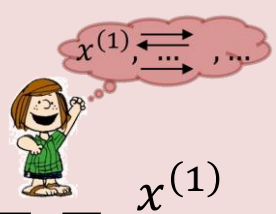

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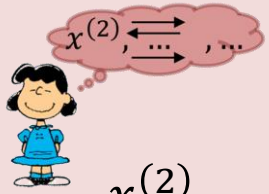

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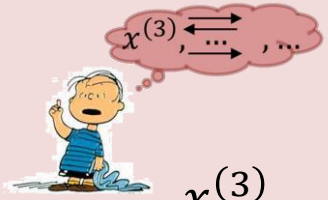

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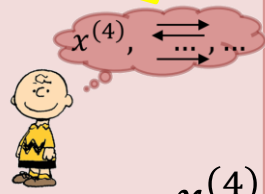

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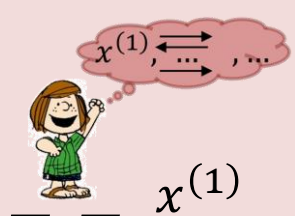

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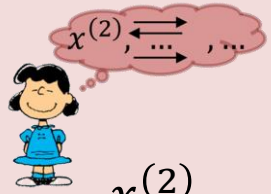

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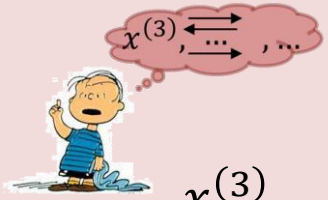

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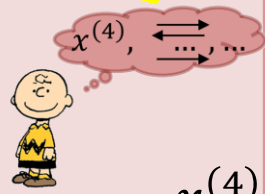

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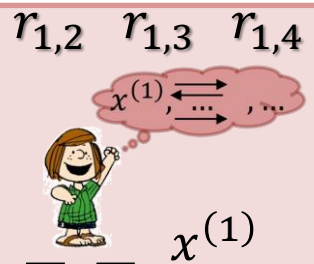

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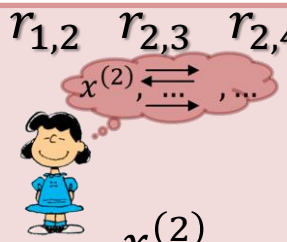
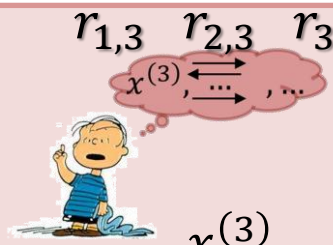


V_2 $x^{(2)}$



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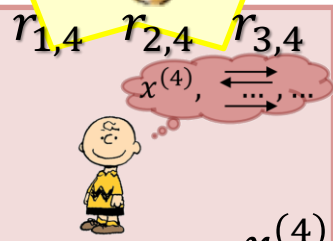

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$t_{1,2} + r_{1,2}, t_{1,3} + r_{1,3}, t_{1,4} + r_{1,4}$
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Our dZK Proof (Summary)

$V_1^{x^{(1)}}$ $V_2^{x^{(2)}}$ $V_3^{x^{(3)}}$ $V_4^{x^{(4)}}$

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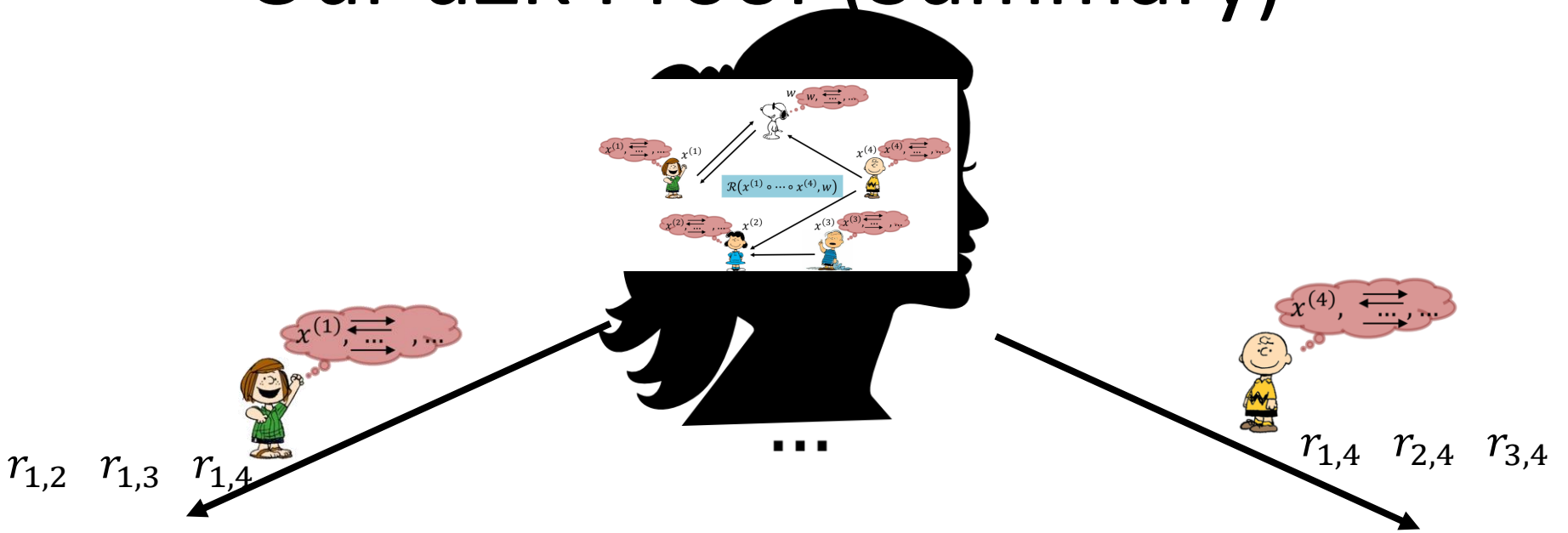

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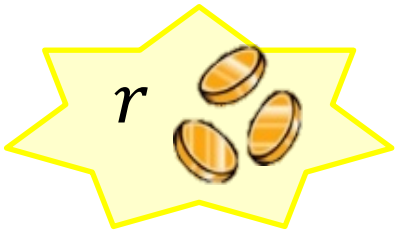
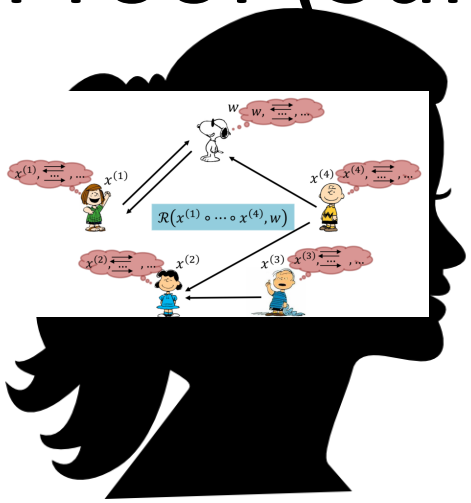
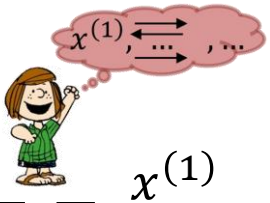




$r_{1,2}$ $r_{1,3}$ $r_{1,4}$



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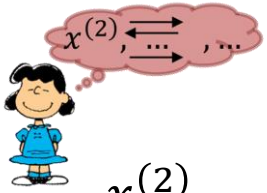
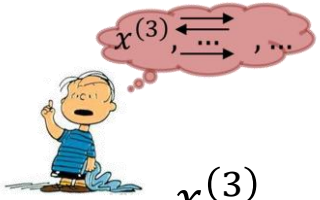
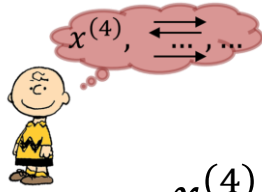


V_2 $x^{(2)}$



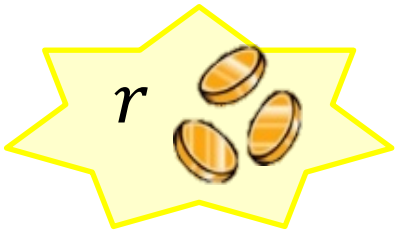
V_3 $x^{(3)}$

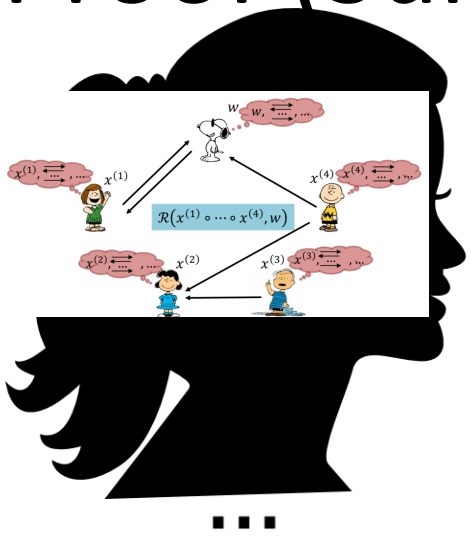
$r_{1,4}$ $r_{2,4}$ $r_{3,4}$



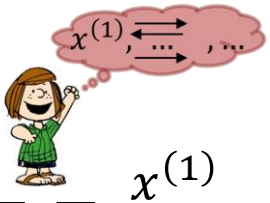
V_4 $x^{(4)}$

Our dZK Proof (Summary)





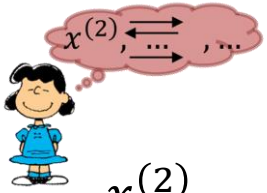
$r_{1,2}$ $r_{1,3}$ $r_{1,4}$



$x^{(1)}$

V_1

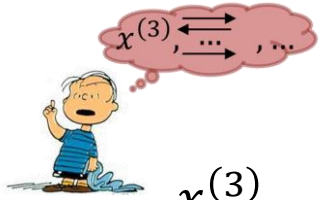
$t_{1,2} + r_{1,2}$
$t_{1,3} + r_{1,3}$
$t_{1,4} + r_{1,4}$
$view_1$ consistent?



$x^{(2)}$

V_2

$t_{2,1} + r_{1,2}$
$t_{2,3} + r_{2,3}$
$t_{2,4} + r_{2,4}$
$view_2$ consistent?

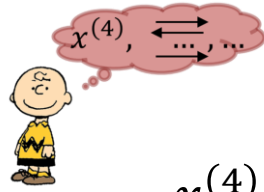


$x^{(3)}$

V_3

$t_{3,1} + r_{1,3}$
$t_{3,2} + r_{2,3}$
$t_{3,4} + r_{3,4}$
$view_3$ consistent?

$r_{1,4}$ $r_{2,4}$ $r_{3,4}$



$x^{(4)}$

V_4

$t_{4,1} + r_{1,4}$
$t_{4,2} + r_{2,4}$
$t_{4,3} + r_{3,4}$
$view_4$ consistent?

MPC in the Head: Distributed vs. 2-Party

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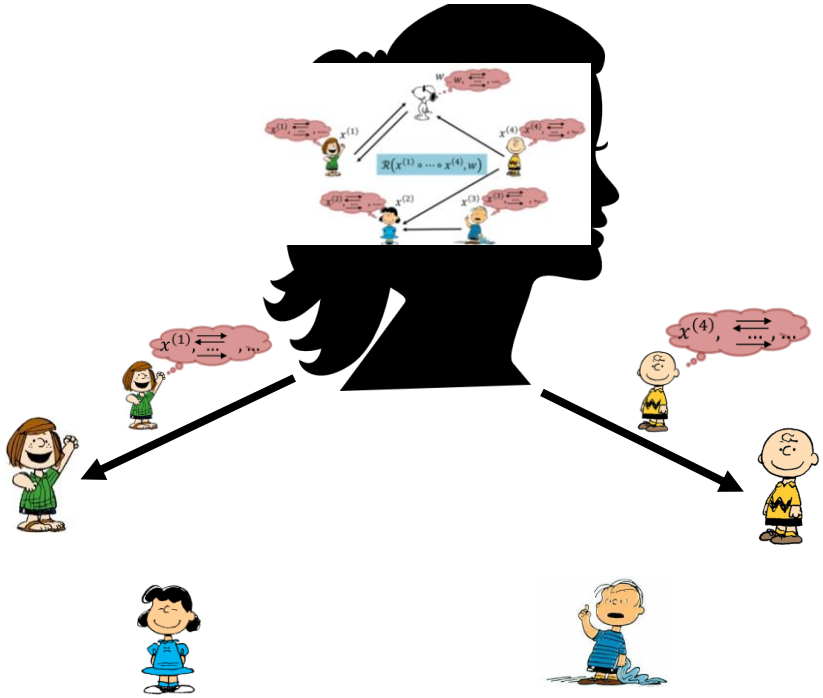
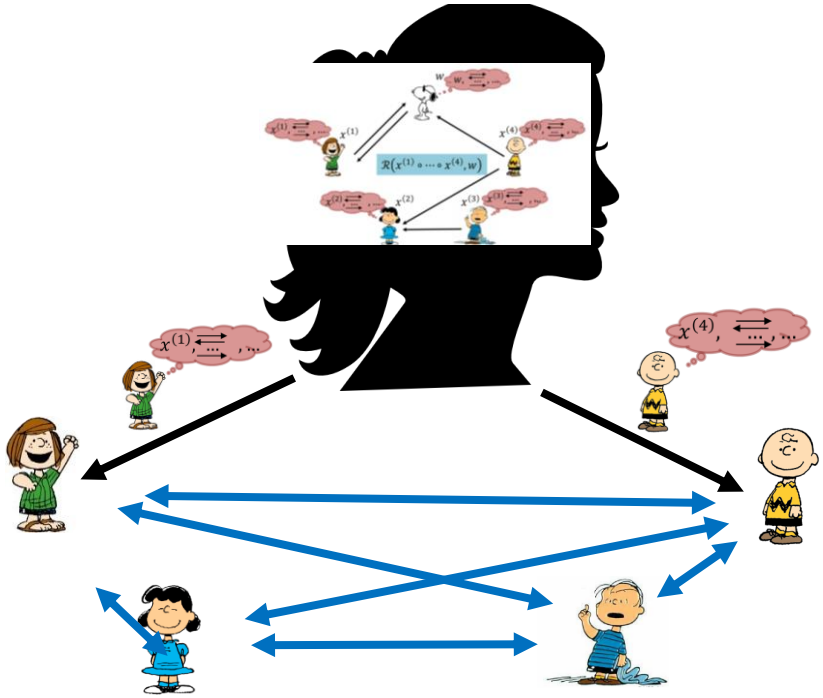
Distributed



MPC parties correspond to verifiers

MPC in the Head: Distributed vs. 2-Party

Distributed



MPC parties correspond to verifiers

Entire execution trace checked

MPC in the Head: Distributed vs. 2-Party

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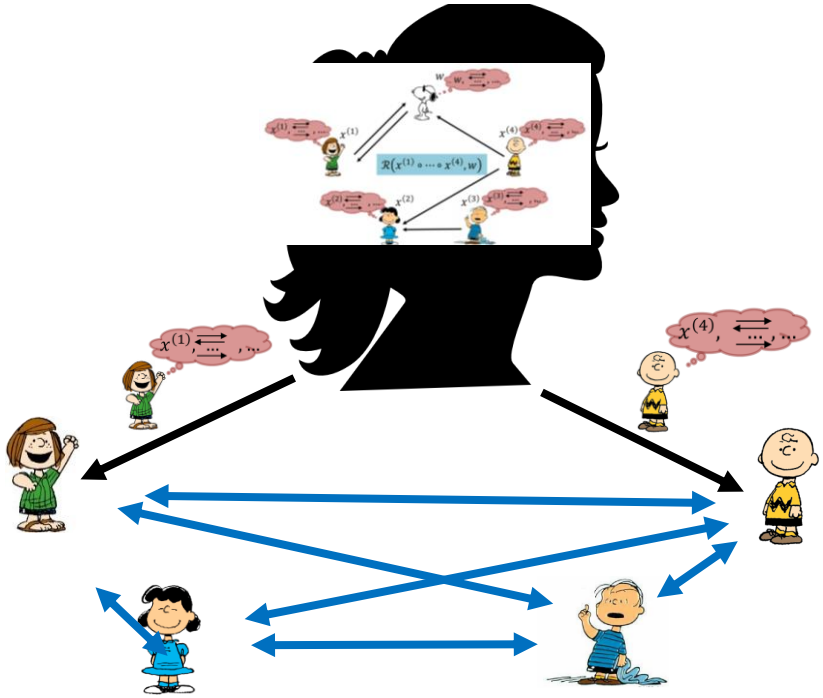

MPC parties correspond to verifiers
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$negl(s)$ error, independent of # MPC parties

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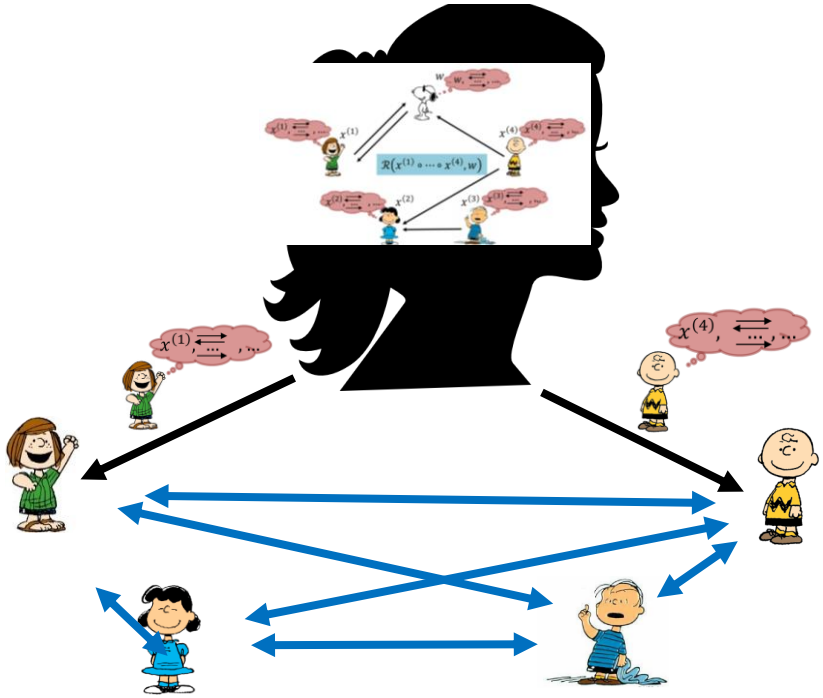
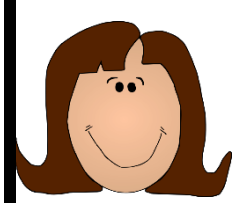


2-Party [IKOS07]



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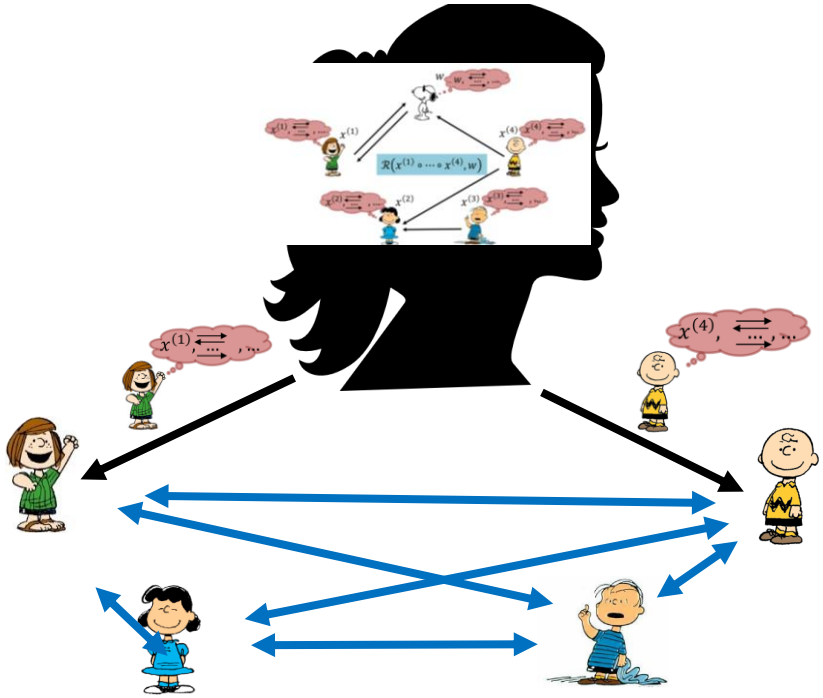

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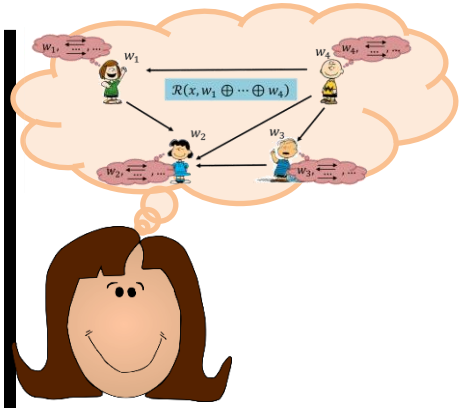

MPC parties correspond to verifiers	MPC parties are virtual
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$negl(s)$ error, independent of # MPC parties	

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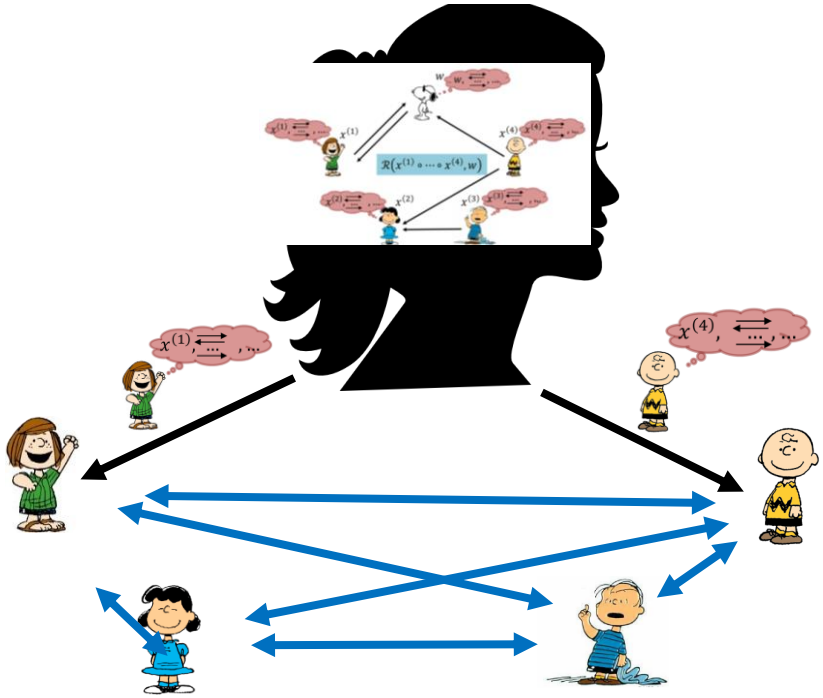
Distributed



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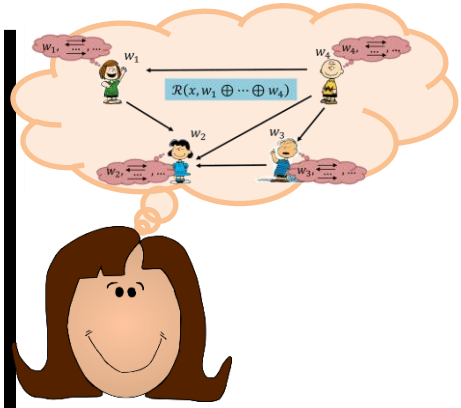
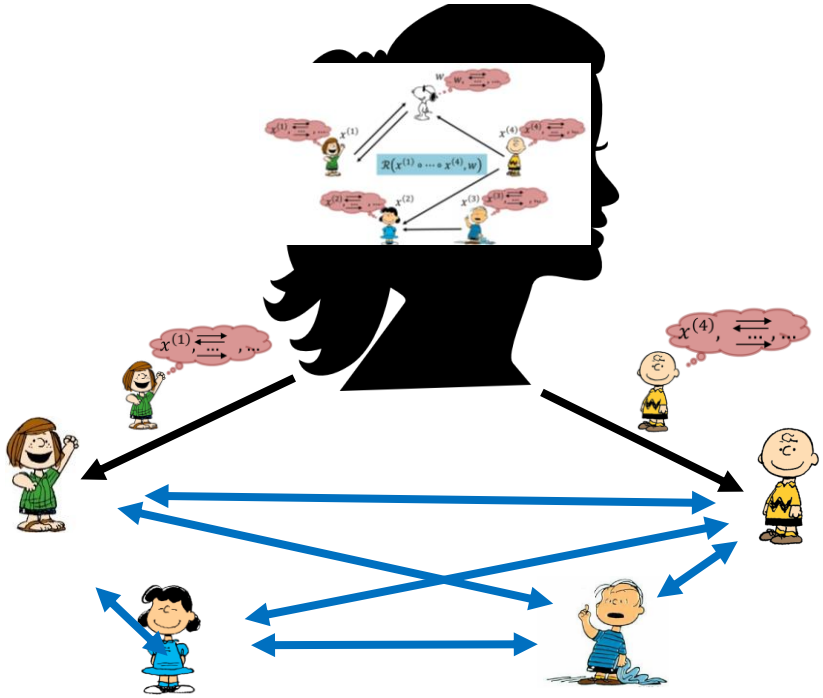


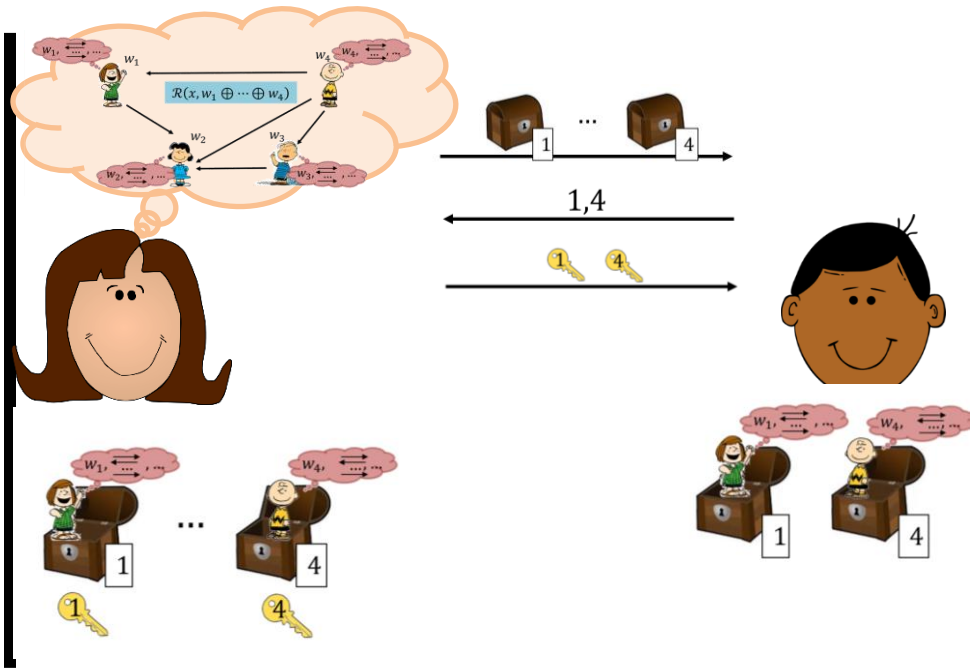
MPC parties correspond to verifiers	MPC parties are virtual
Entire execution trace checked	
$negl(s)$ error, independent of # MPC parties	$negl(s)$ error with s MPC parties

MPC in the Head: Distributed vs. 2-Party

Distributed



2-Party [IKOS07]



MPC parties correspond to verifiers	MPC parties are virtual
Entire execution trace checked	Partial execution trace checked
$negl(s)$ error, independent of # MPC parties	$negl(s)$ error with s MPC parties

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Thank you!