A New Approach to Round-Optimal Secure Multiparty Computation

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What is the round complexity of MPC?

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Computational security.

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In the CRS model: 2 rounds [Garg-Gentry-Halevi-Raykova14, Mukherjee-Wichs16, Dodis-Halevi-Rothblum-Wichs16]

Brief history

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Polynomial round protocol:

[Goldreich-Micali-Wigderson87]

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Constant round protocols:

[Beaver-Micali-Rogaway90, Katz-Ostrovsky-Smith03, Pass04, Pass-Wee10, Wee10, Goyal11]

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4 round impossible w.r.t black-box simulation for 2PC in the unidirectional message model.

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5 round MPC protocol based on iO + other assumptions.

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Does there exist a 5 round MPC protocol from standard assumptions?

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Exact round complexity

Does there exist a 5 round MPC protocol from standard assumptions?

Does there exist a 4 round MPC protocol?

[Garg-Mukherjee-Pandey-Polychroniadou16]:

3 round impossible w.r.t black-box simulation in the simultaneous message model.

5 round MPC protocol based on iO + other assumptions.

Our results

Result 1:

Assuming DDH, there exists a 5 round MPC protocol.

Result 2:

Assuming OWP + sub-exponentially secure DDH, there exists a 4 round MPC protocol.

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Concurrent work [Brakerski-Halevi-Polychroniadou17]:

4 round MPC protocol assuming adaptive commitments + sub-exponential LWE.

[Garg-Mukherjee-Pandey-Polychroniadou 16] template

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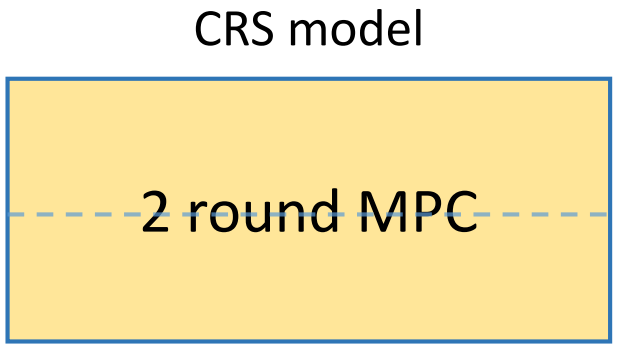

- from iO [GGHR14]
- from LWE [MW16]

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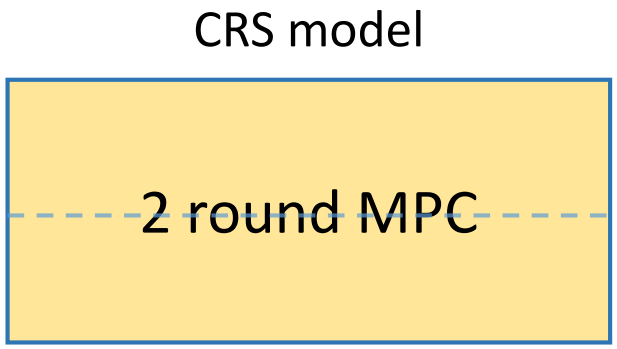

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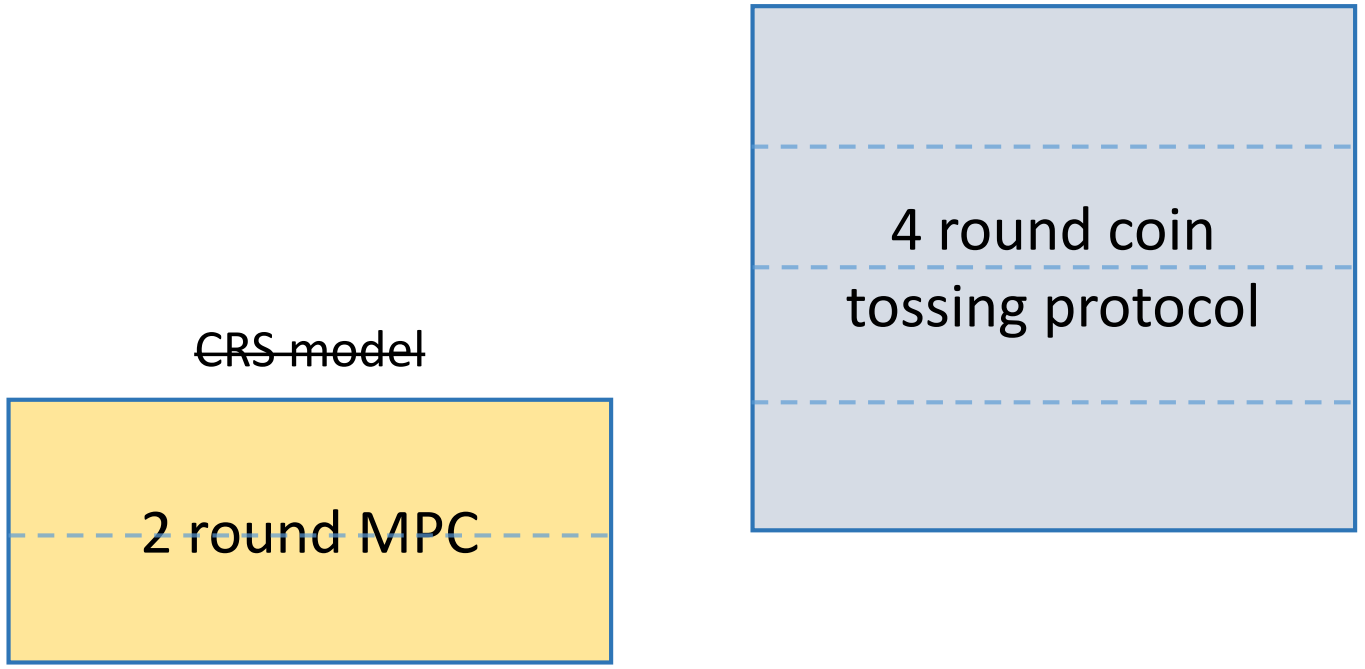

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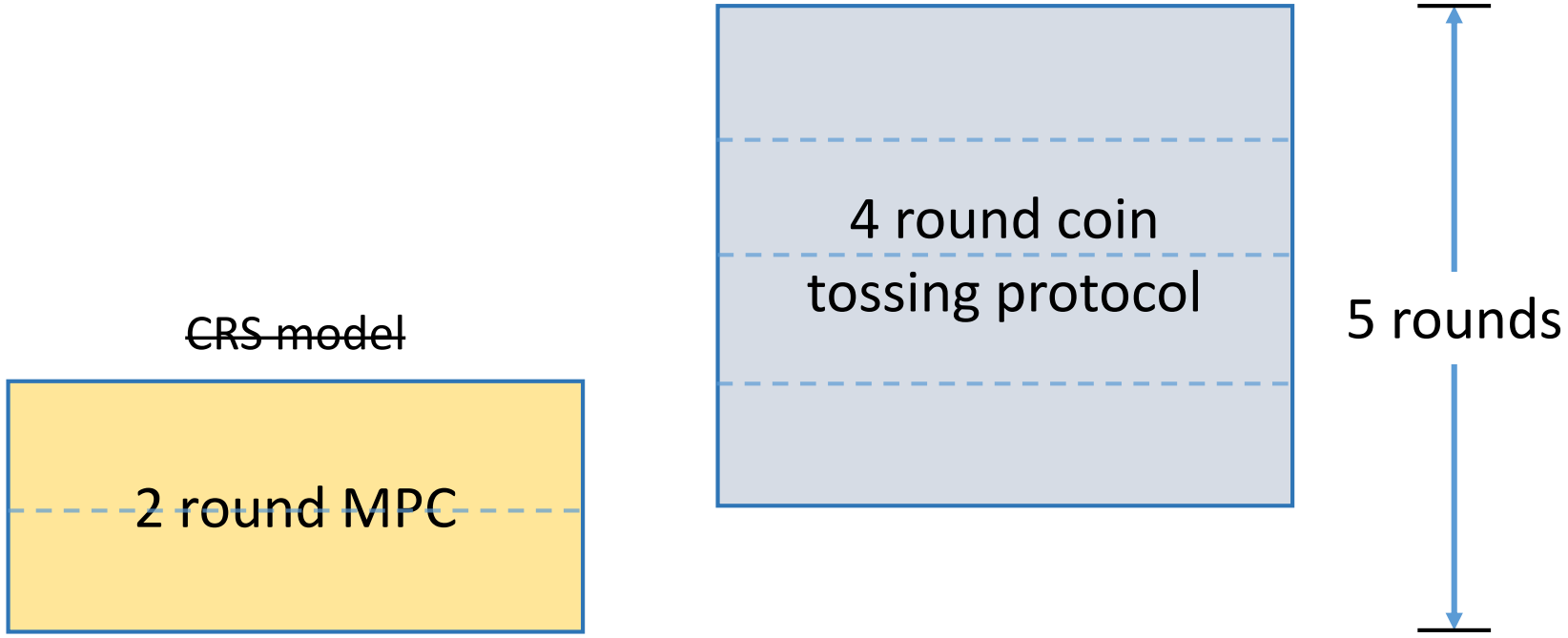

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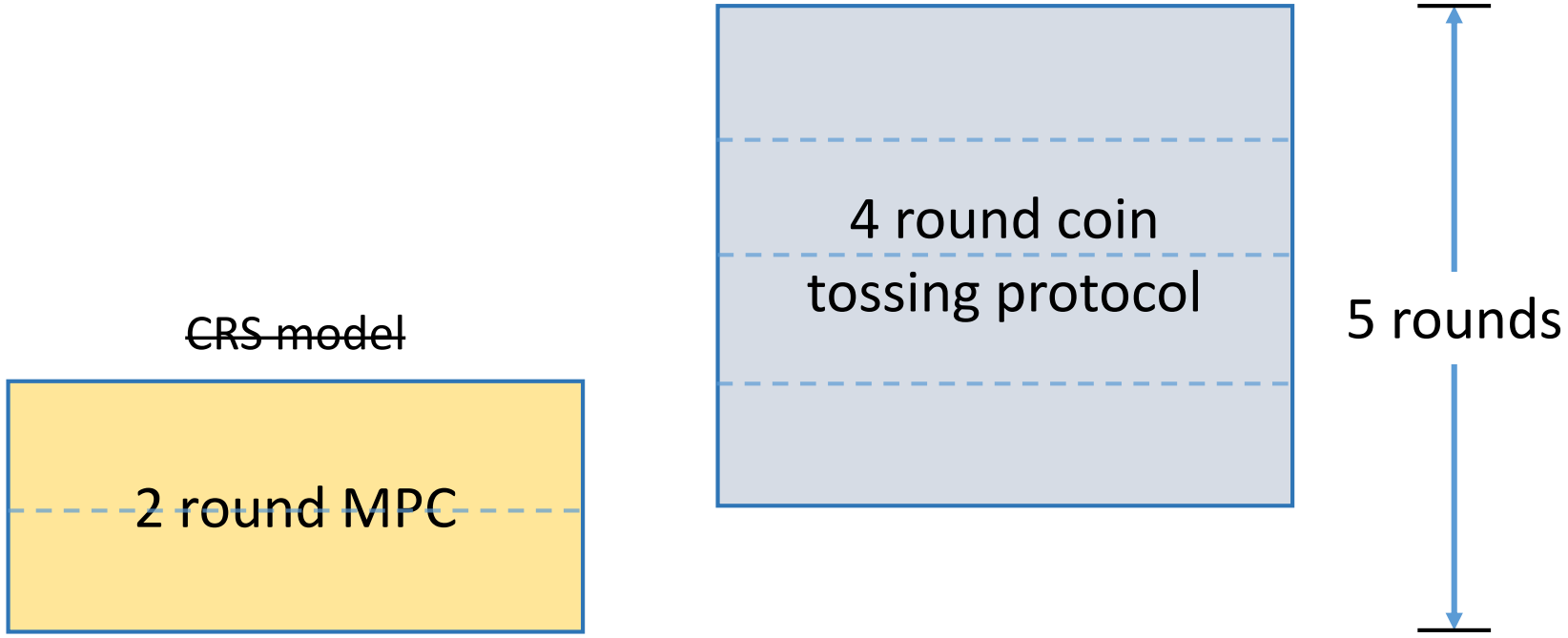

Limitations of this approach:

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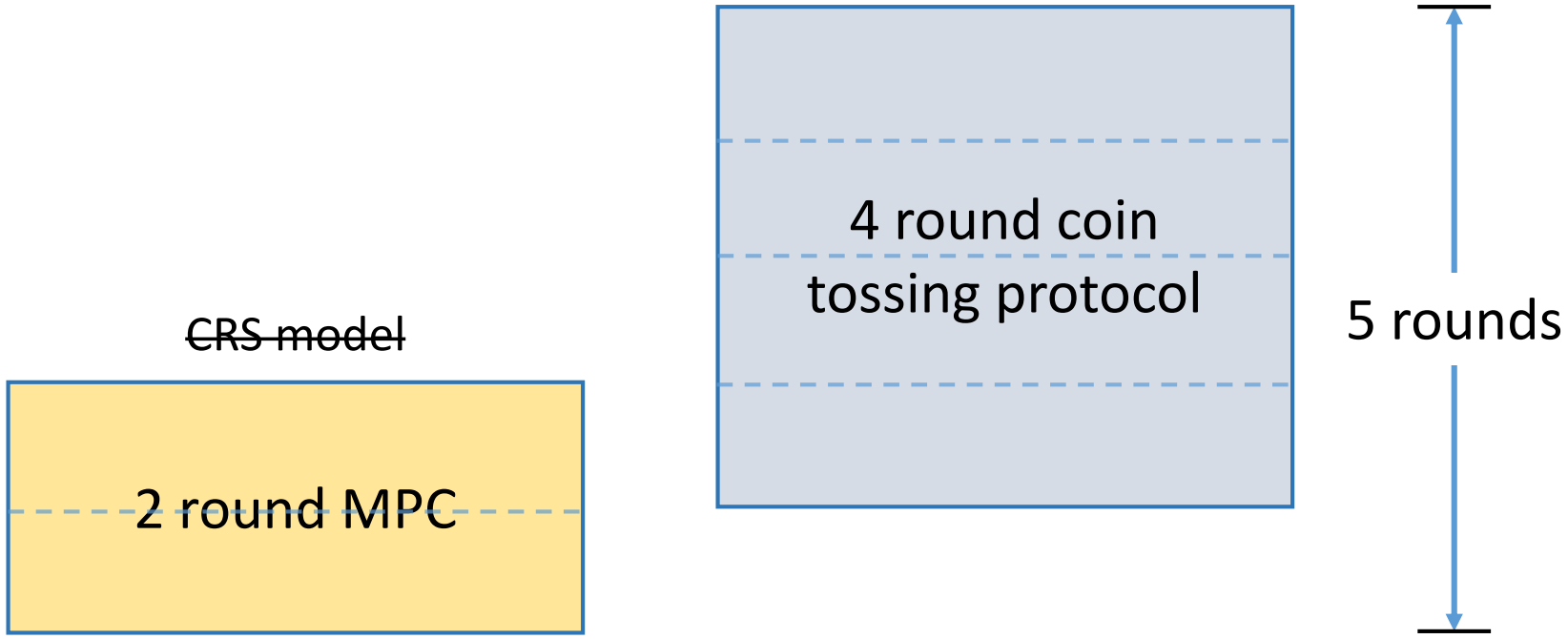

Limitations of this approach:

Unclear how to parallelize both rounds.

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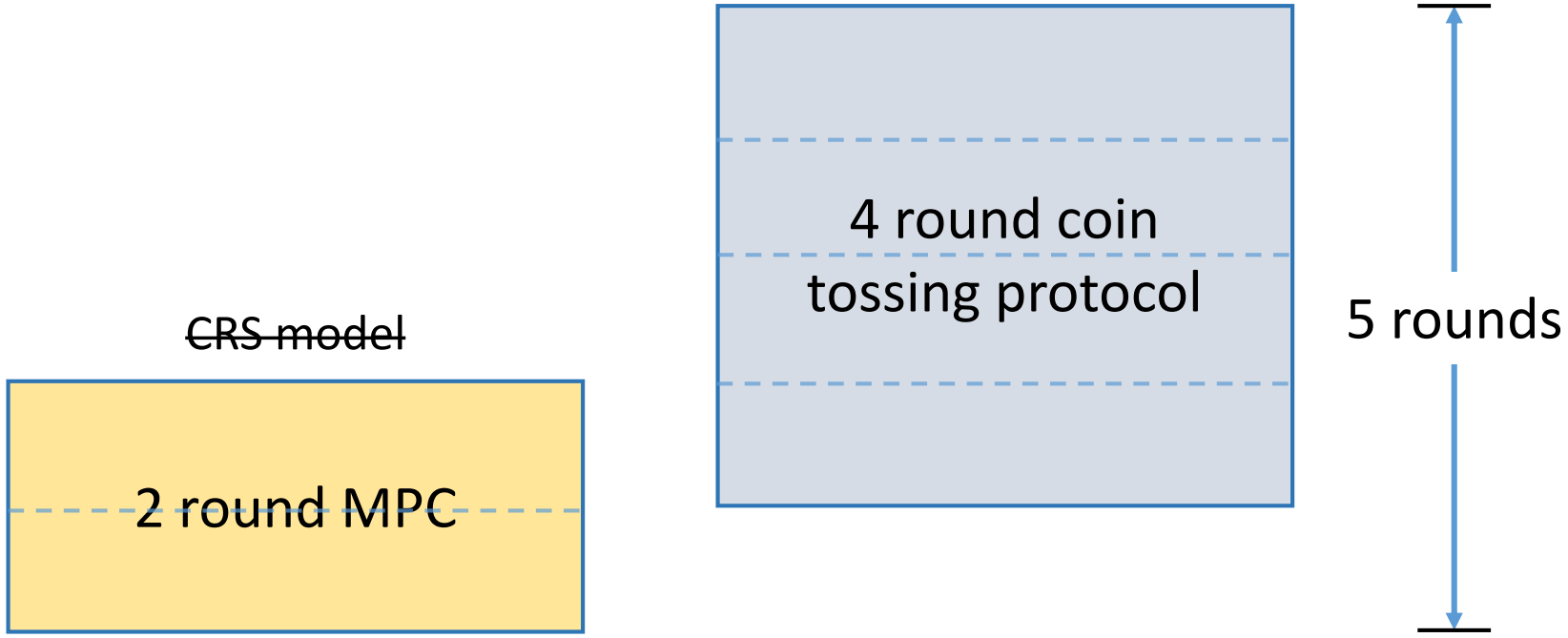

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Limits to the 2 round MPC assumptions.

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GMW compiler.

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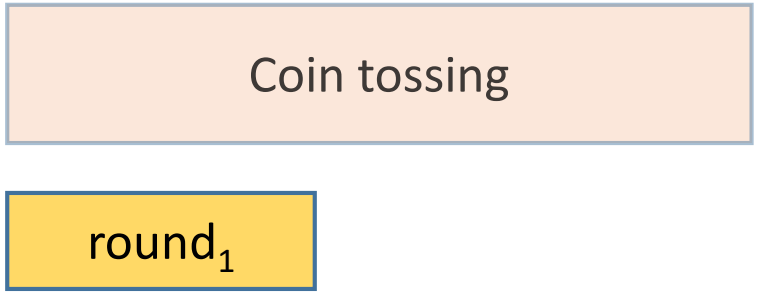

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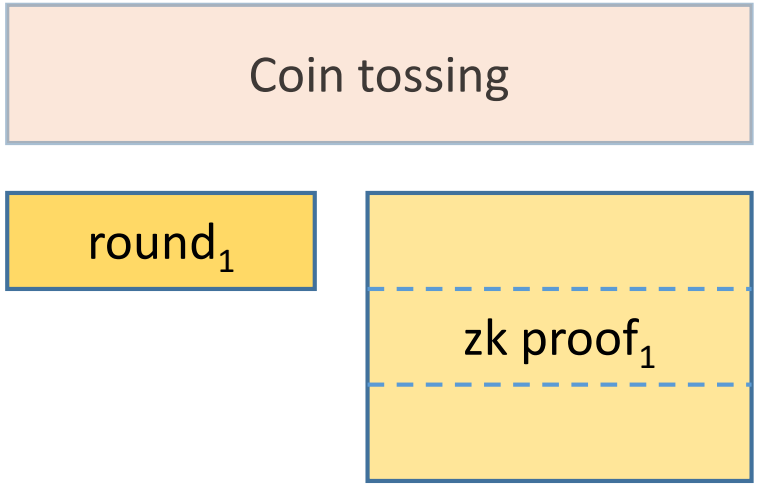

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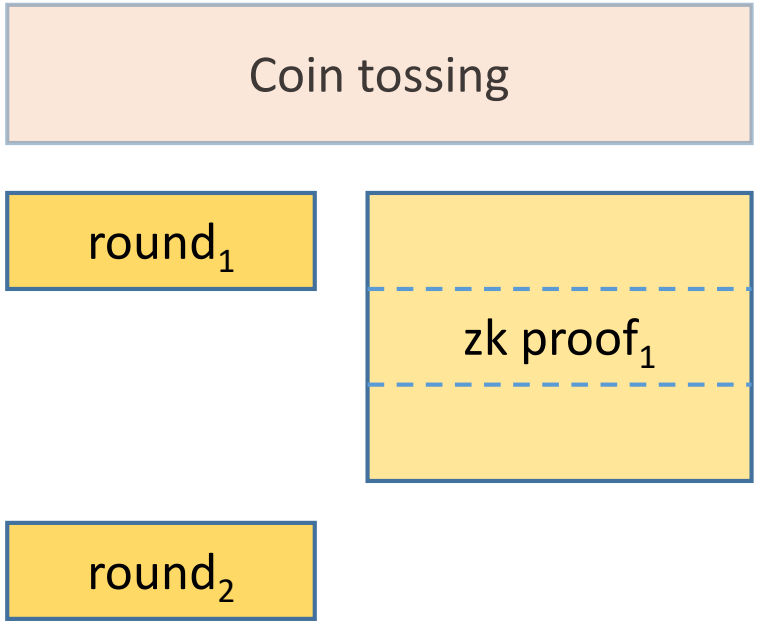

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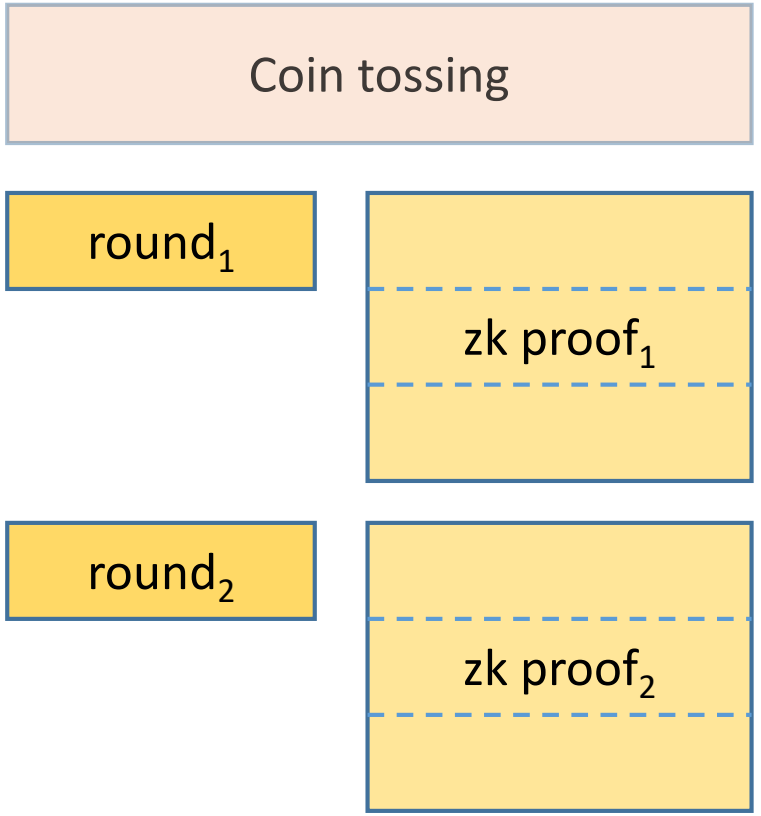

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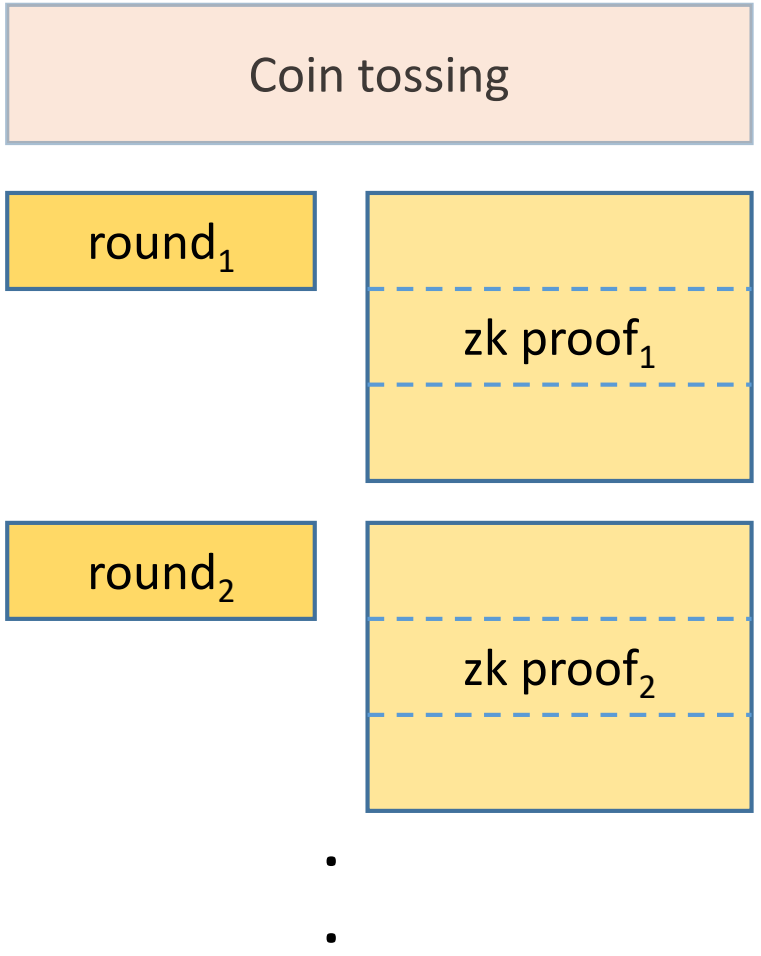

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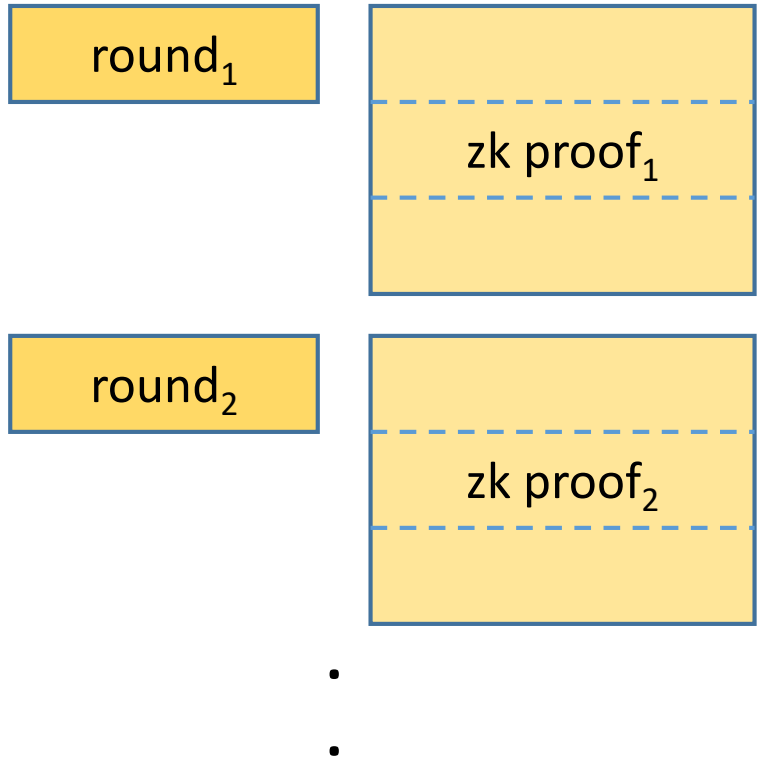

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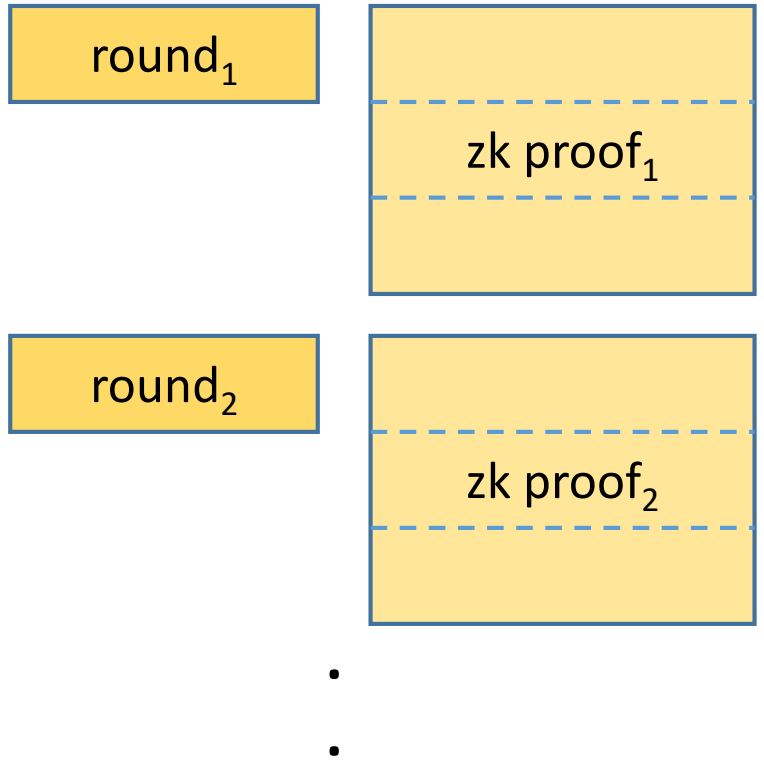
GMW compiler.

Semi-honest to malicious security.

Proof of honest behavior with each round.

Main challenge is to reduce the number of proofs.



Our strategy

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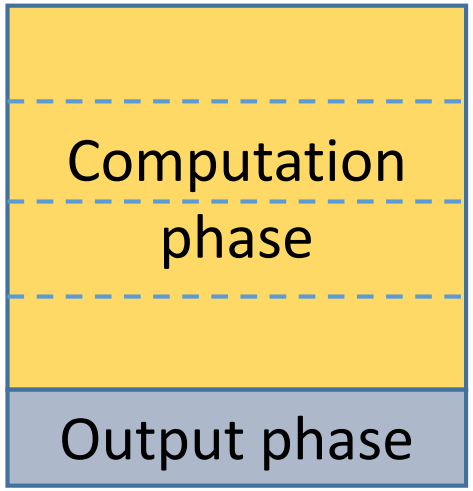

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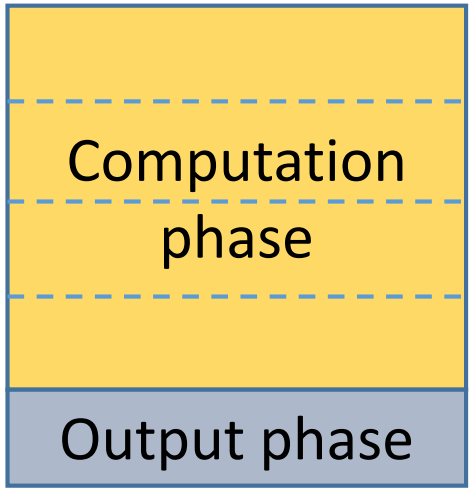

Semi-honest protocol whose structure is satisfied by most MPC protocols.

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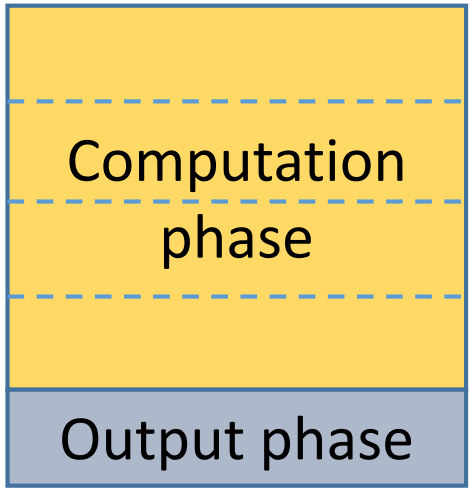

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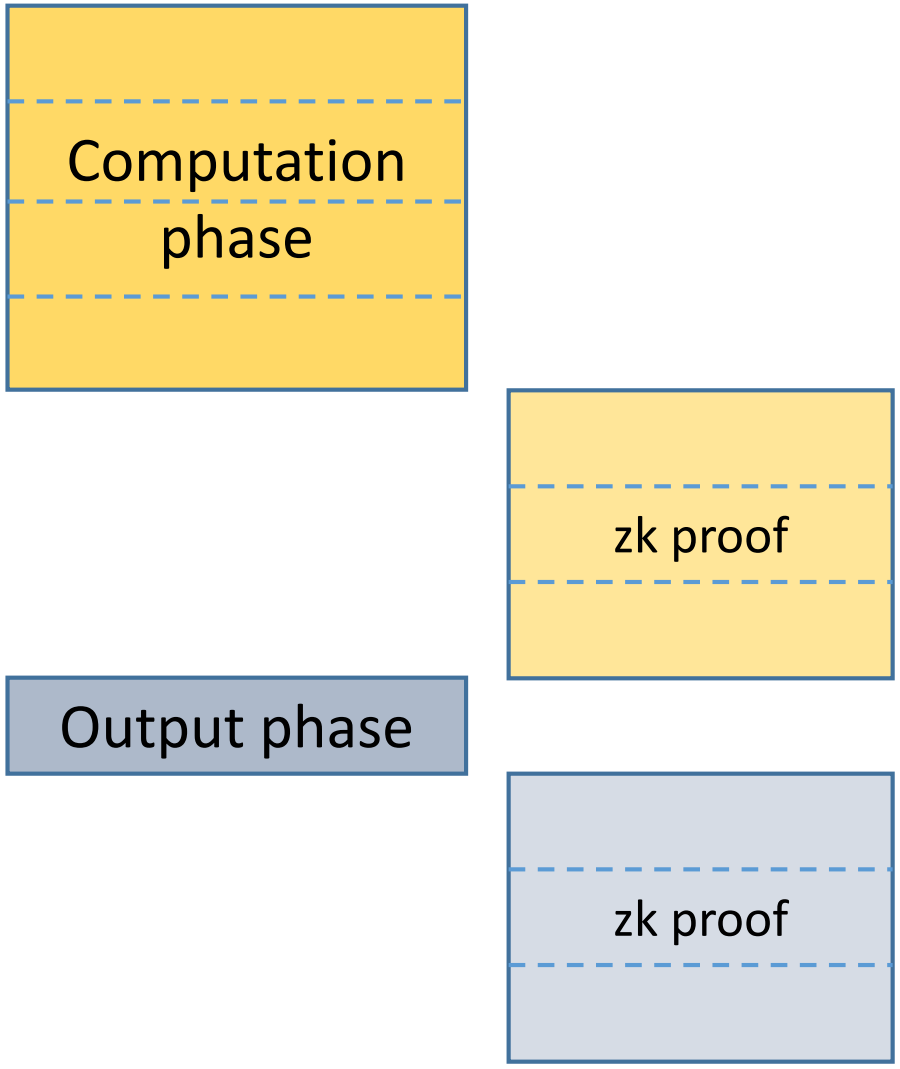

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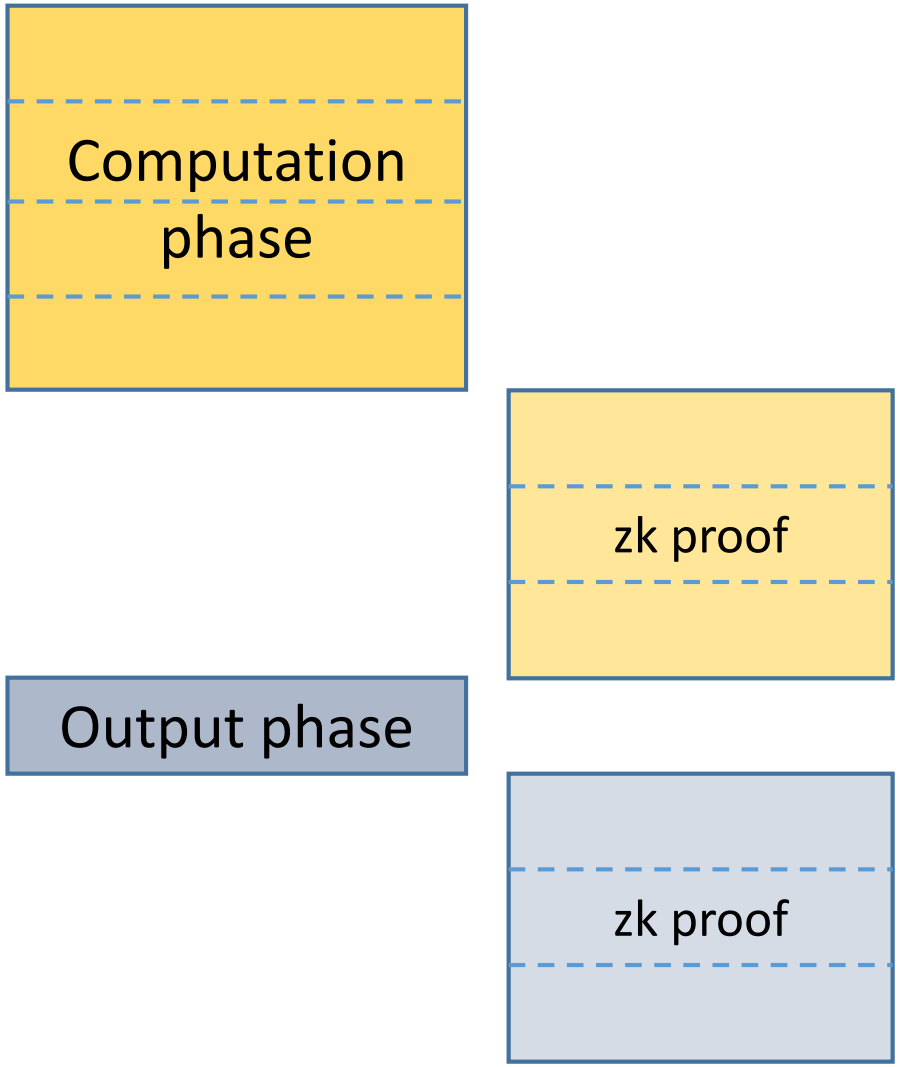

Semi-honest protocol whose structure is satisfied by most MPC protocols.

Prove honest behavior once for the computation phase?

Might be too late.

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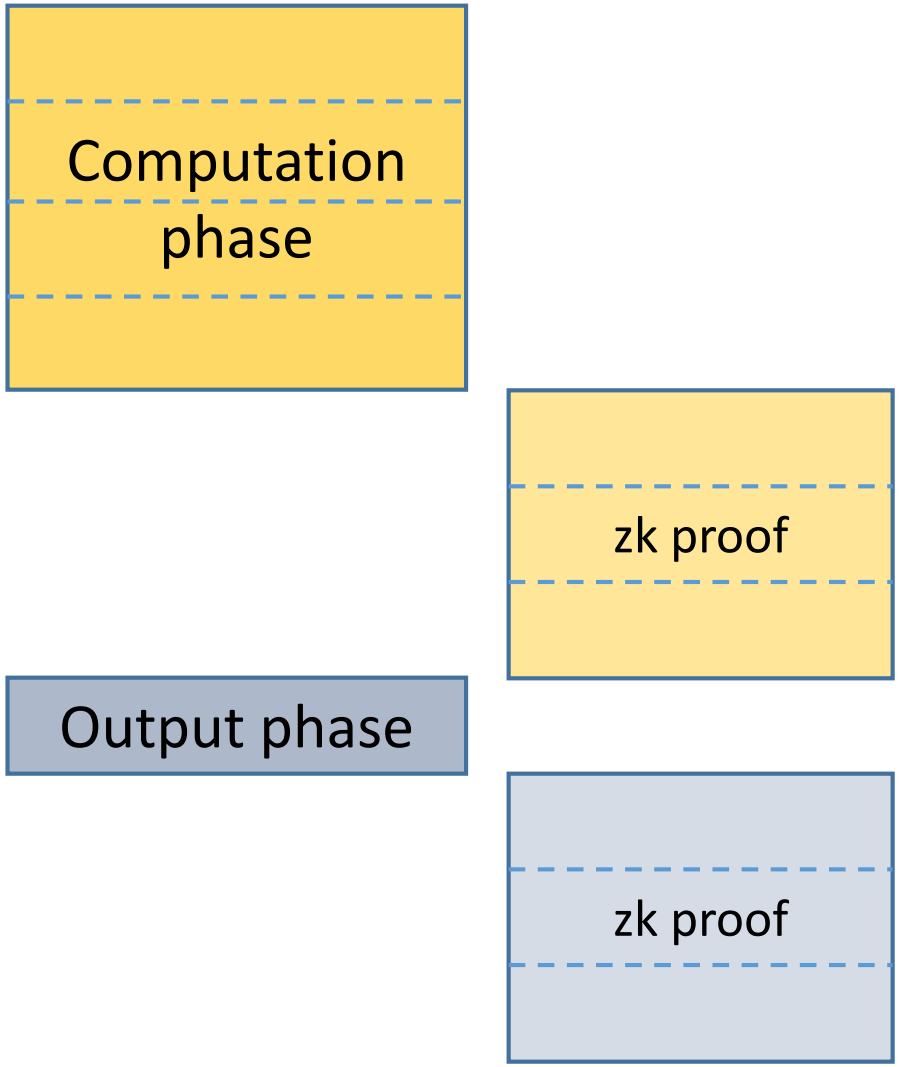

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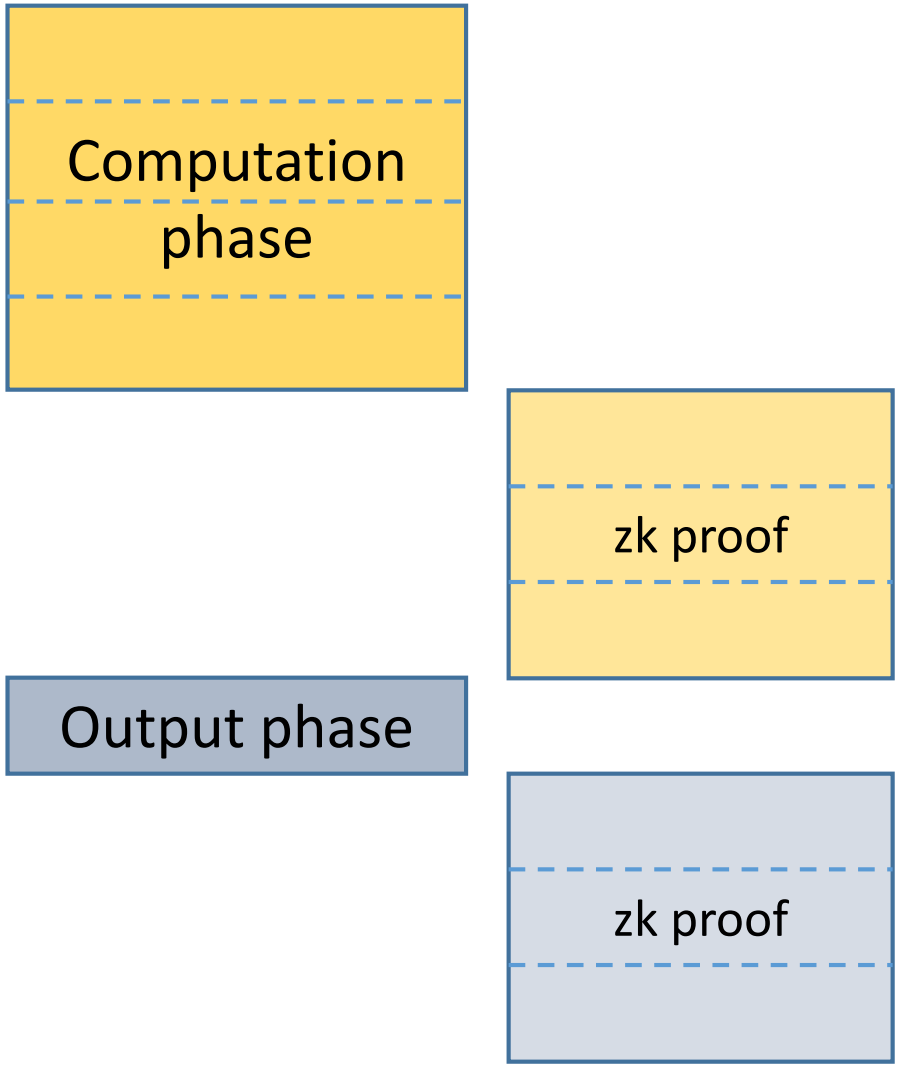
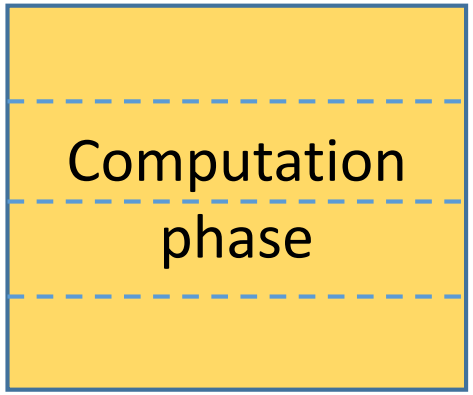
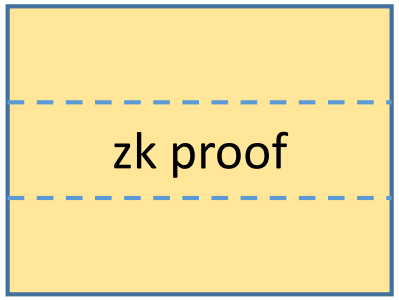
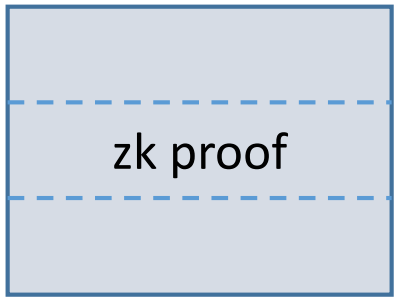


Require additional property

Our strategy







Require additional property: Robustness

Computation phase:
maintains privacy against malicious adversaries till end of phase, however the correctness of computation is not guaranteed.

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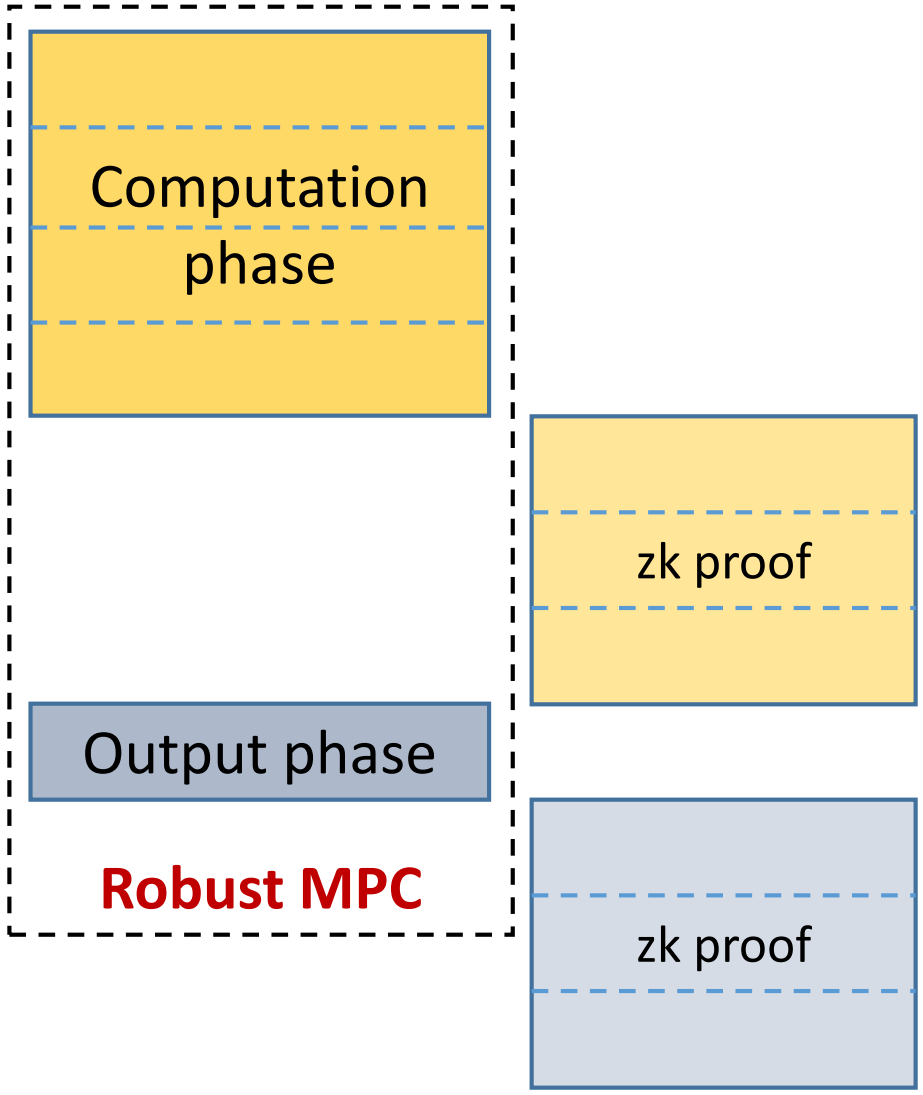

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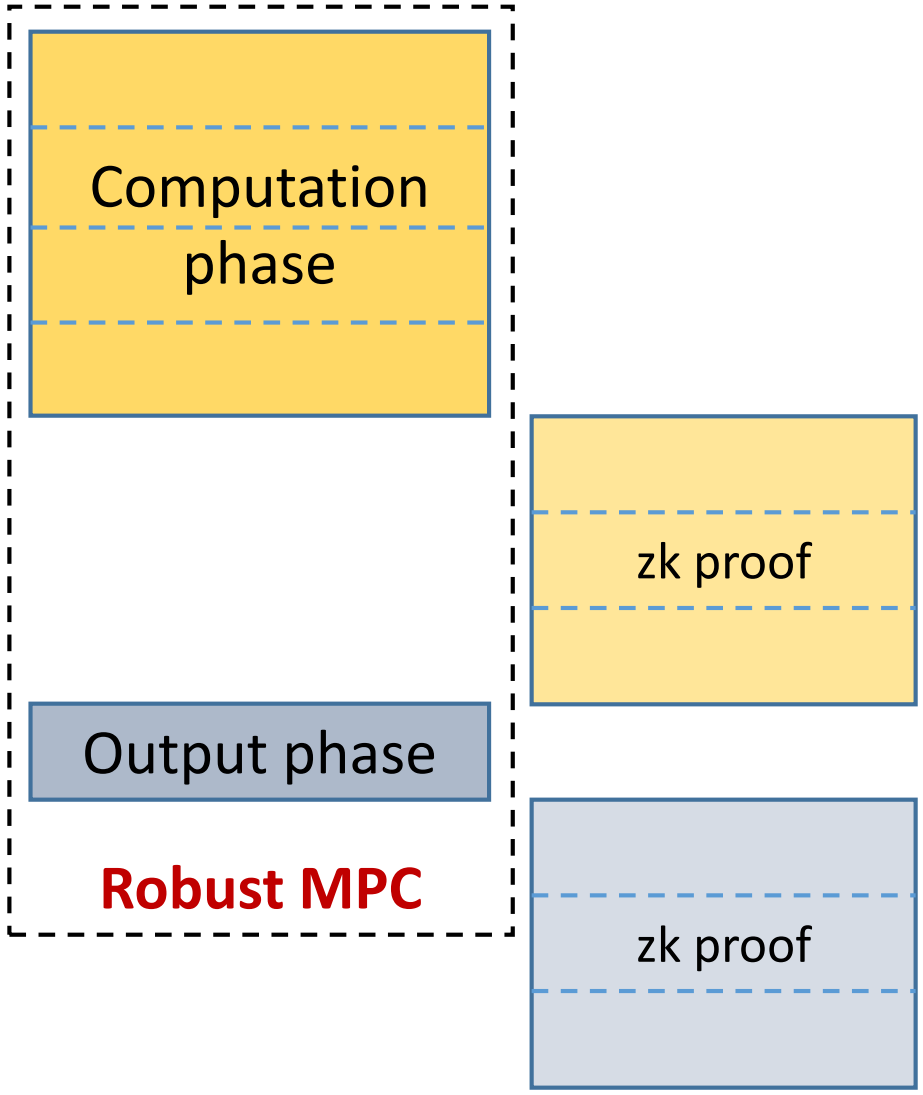

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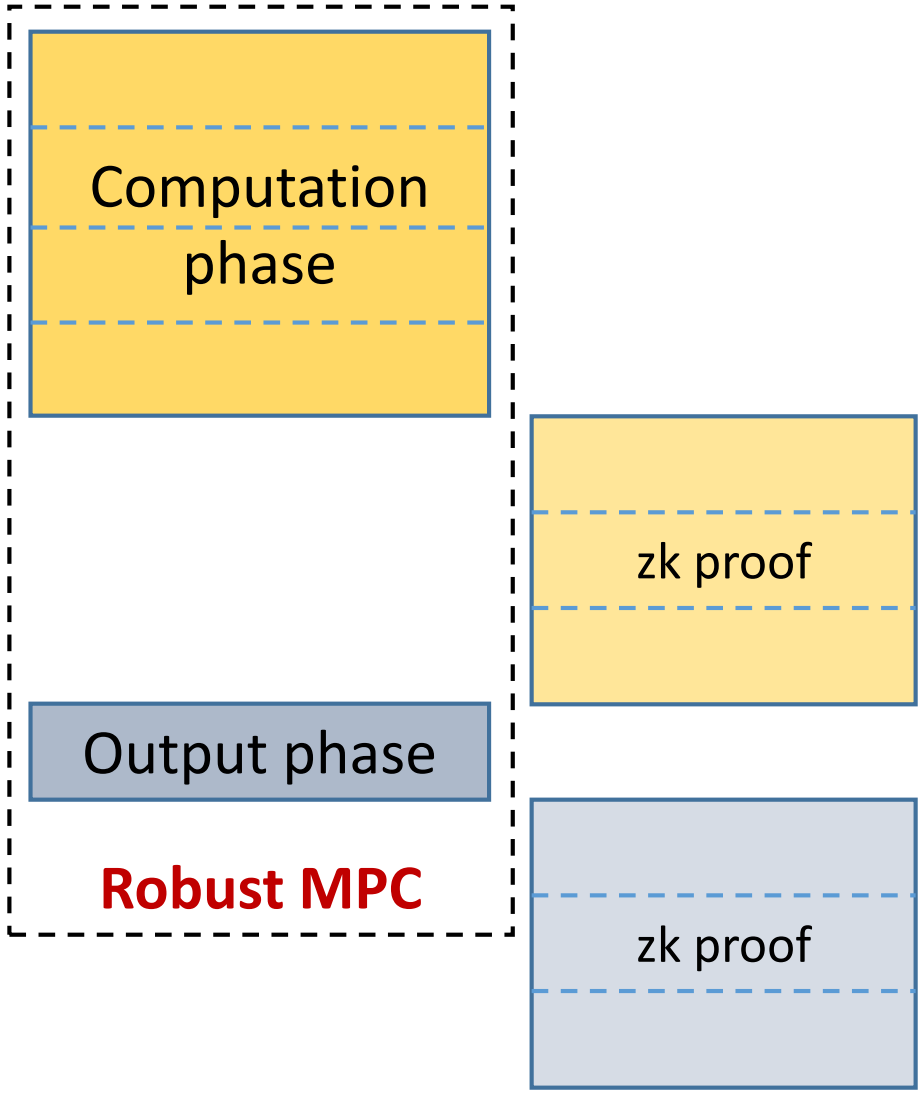

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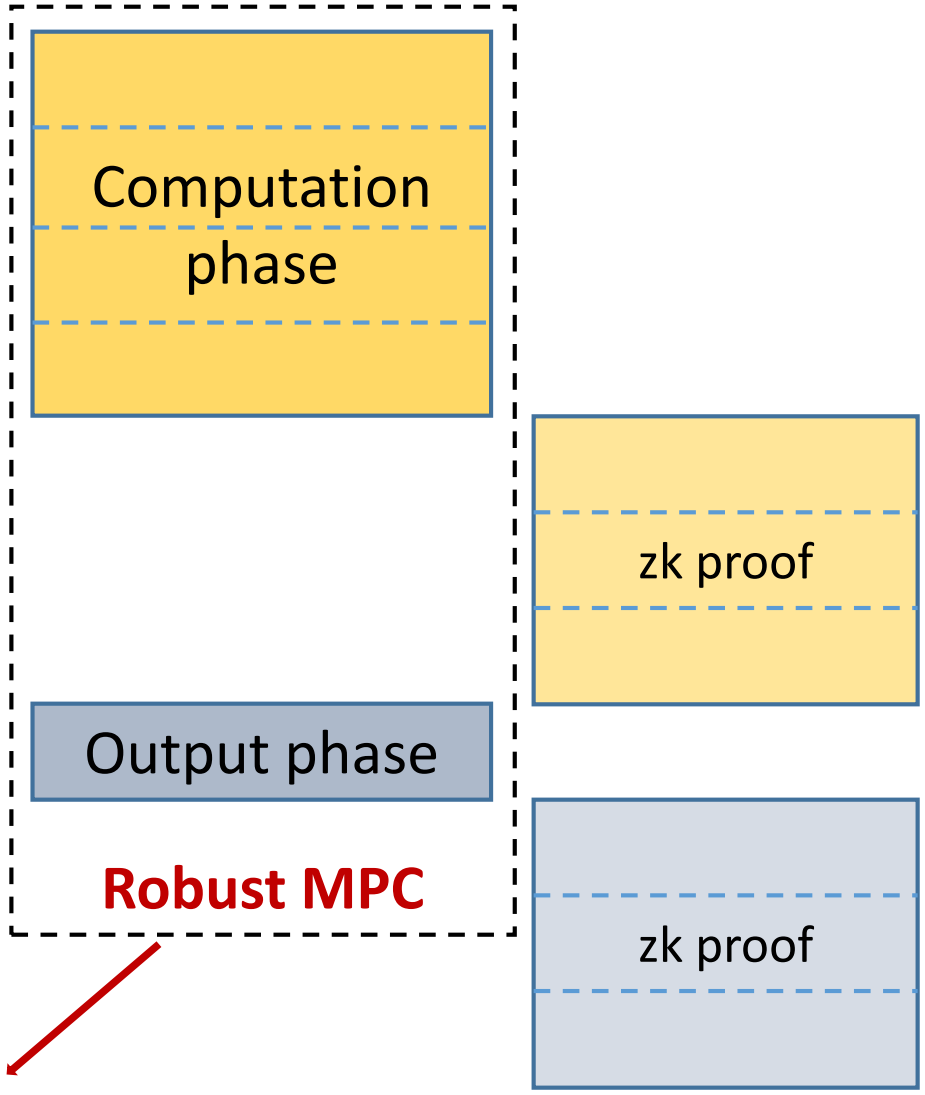
Our strategy: Delayed verification



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Already secure against bad randomness.

Rest of the talk

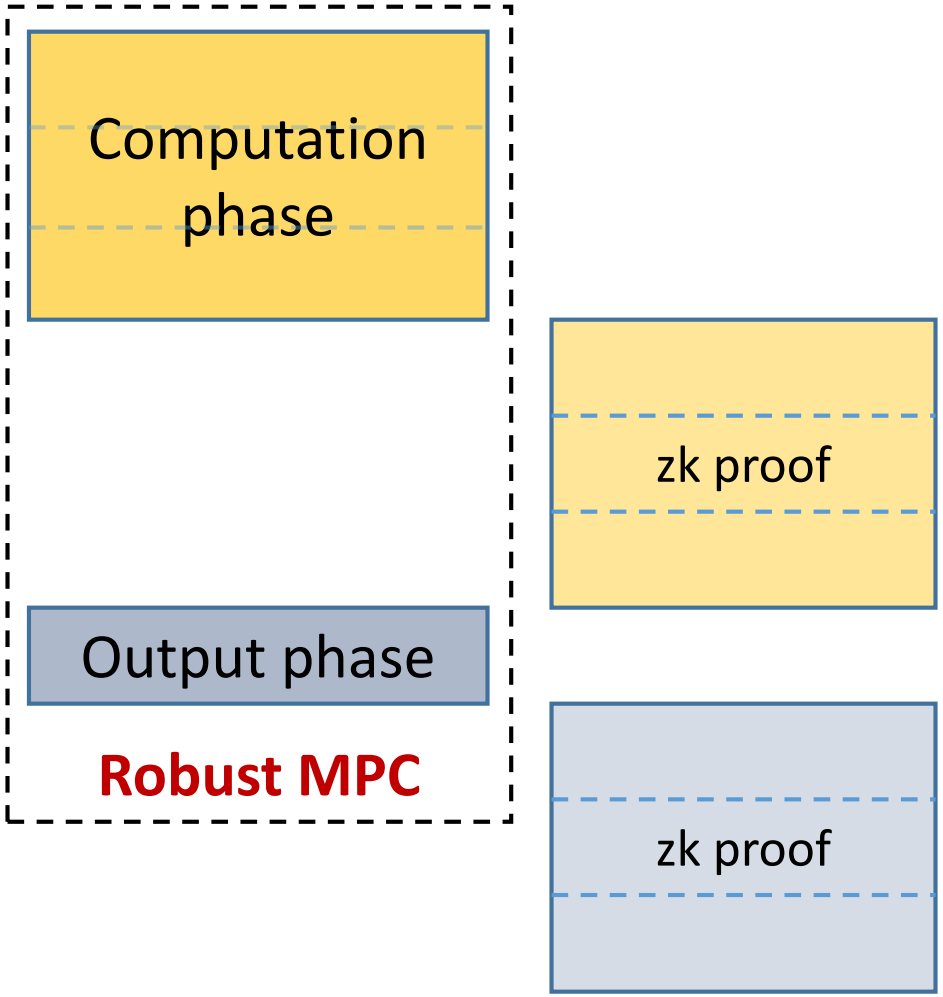
Compiler from

- 4 round robust MPC to 5 round protocol
- 4 round robust MPC to 4 round protocol

Construction of 4 round robust MPC

5 Round Protocol

Blueprint of 5 round protocol



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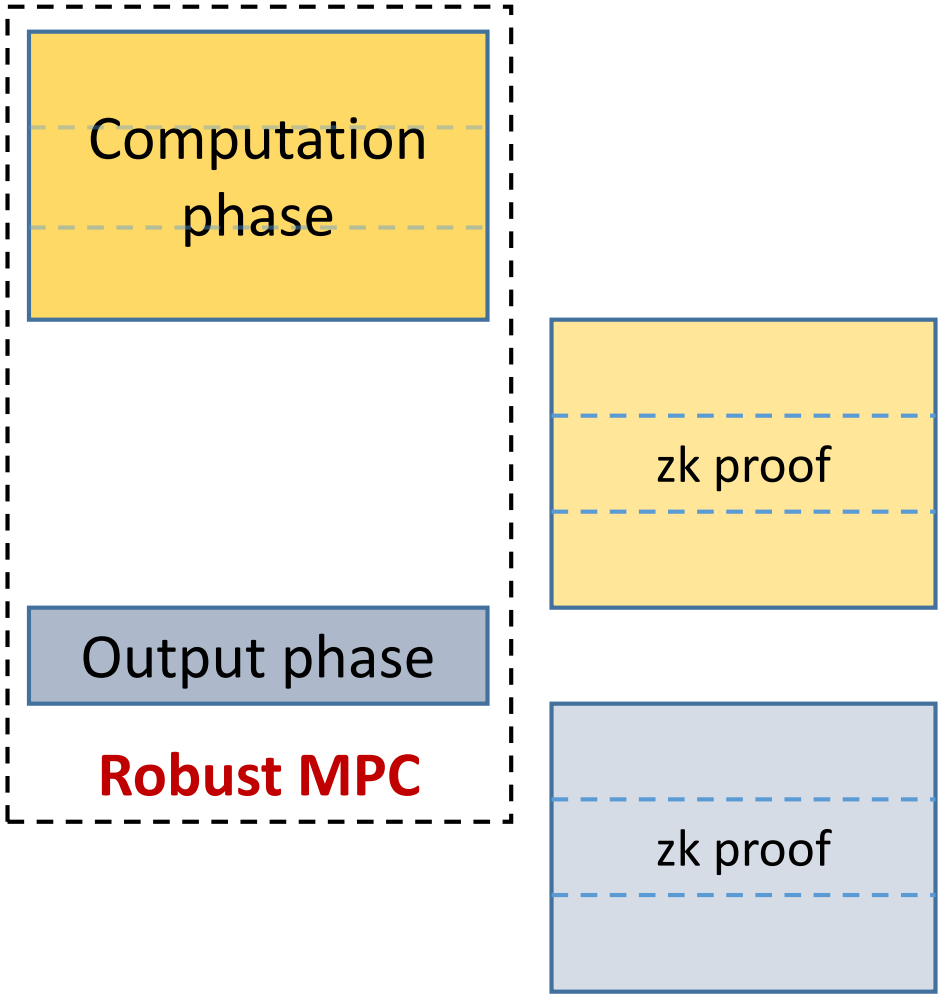

Parallelize proofs.

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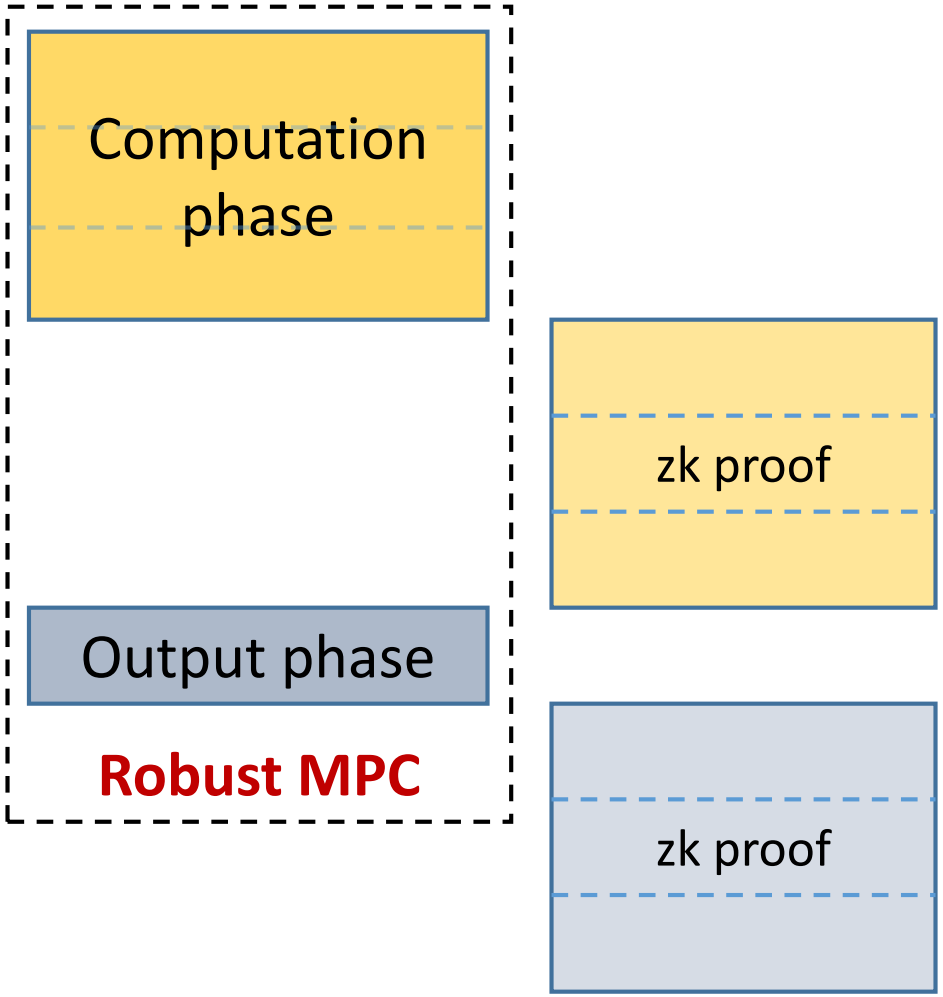

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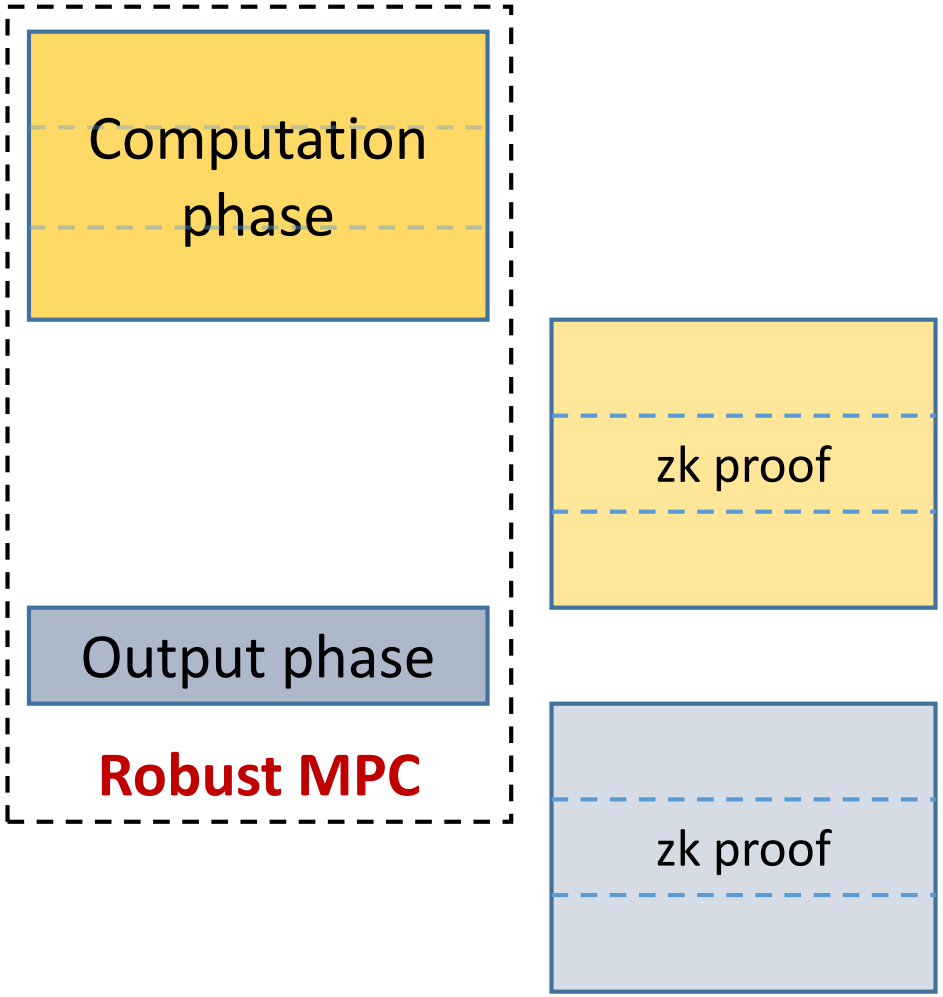

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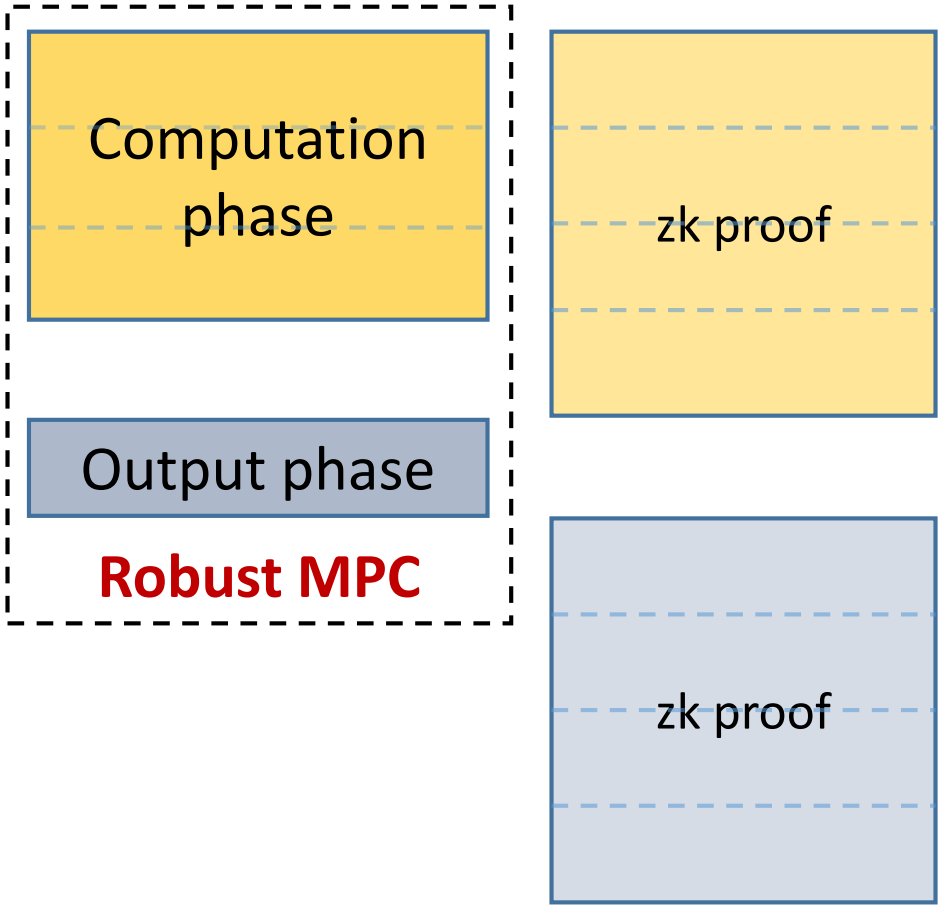

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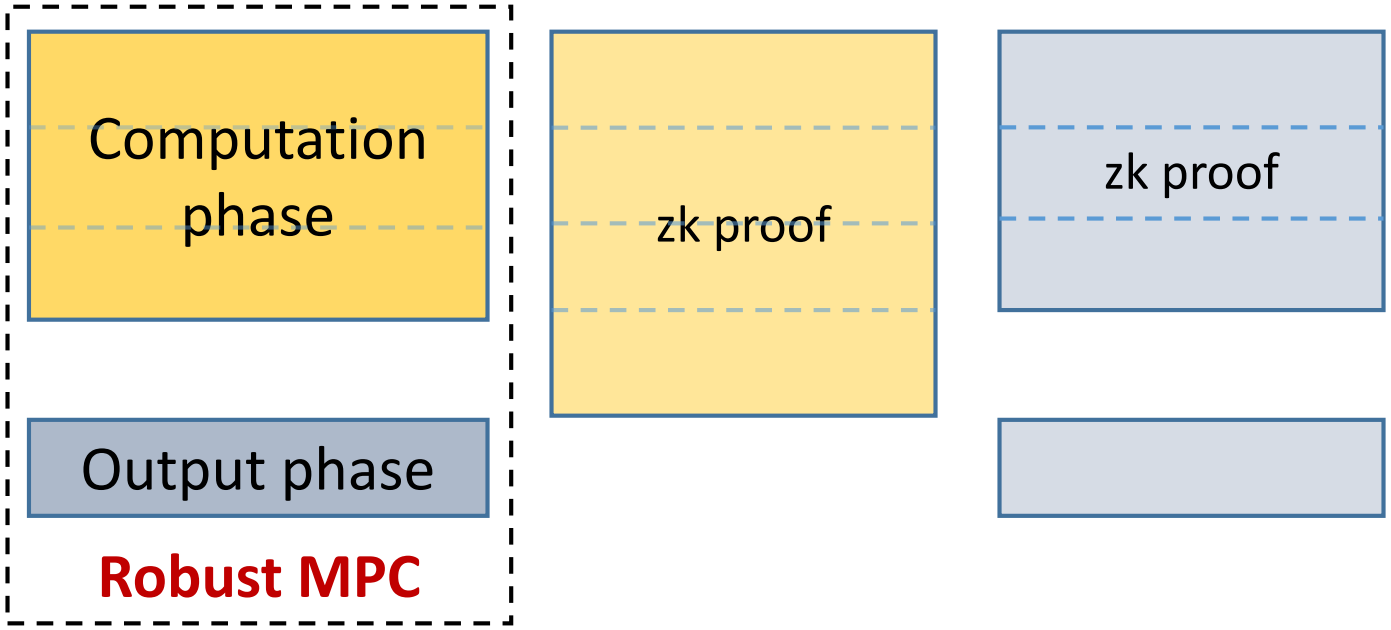

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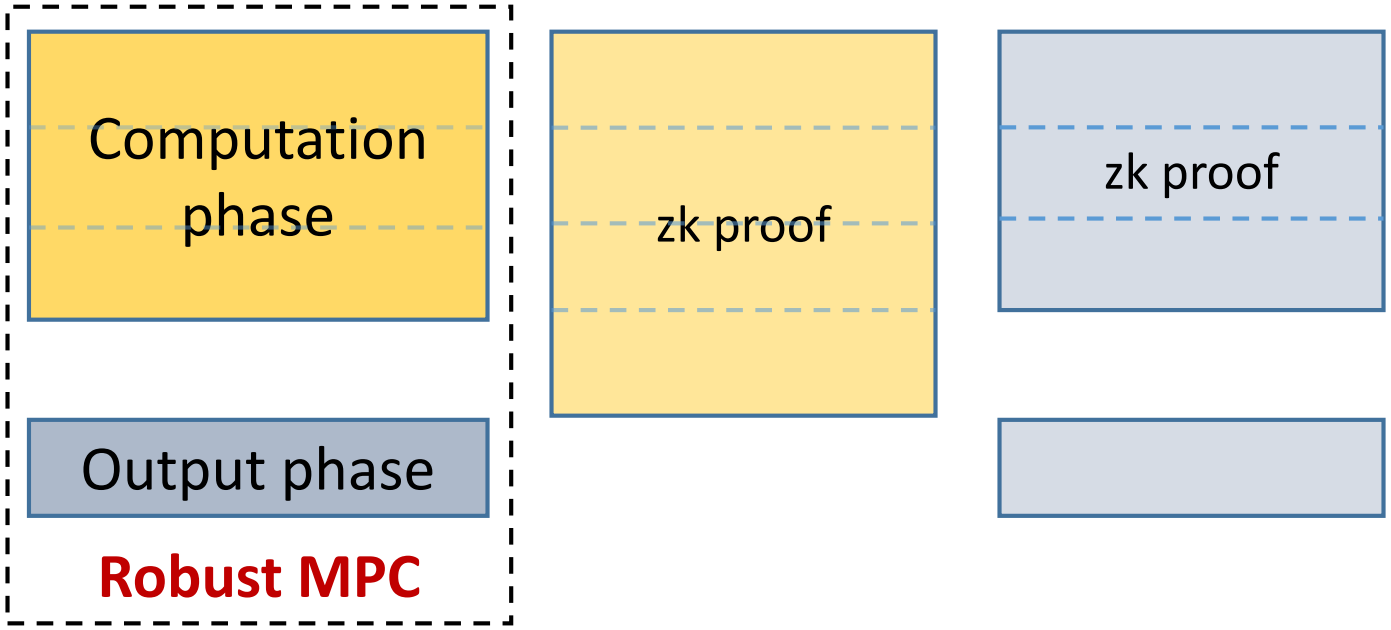

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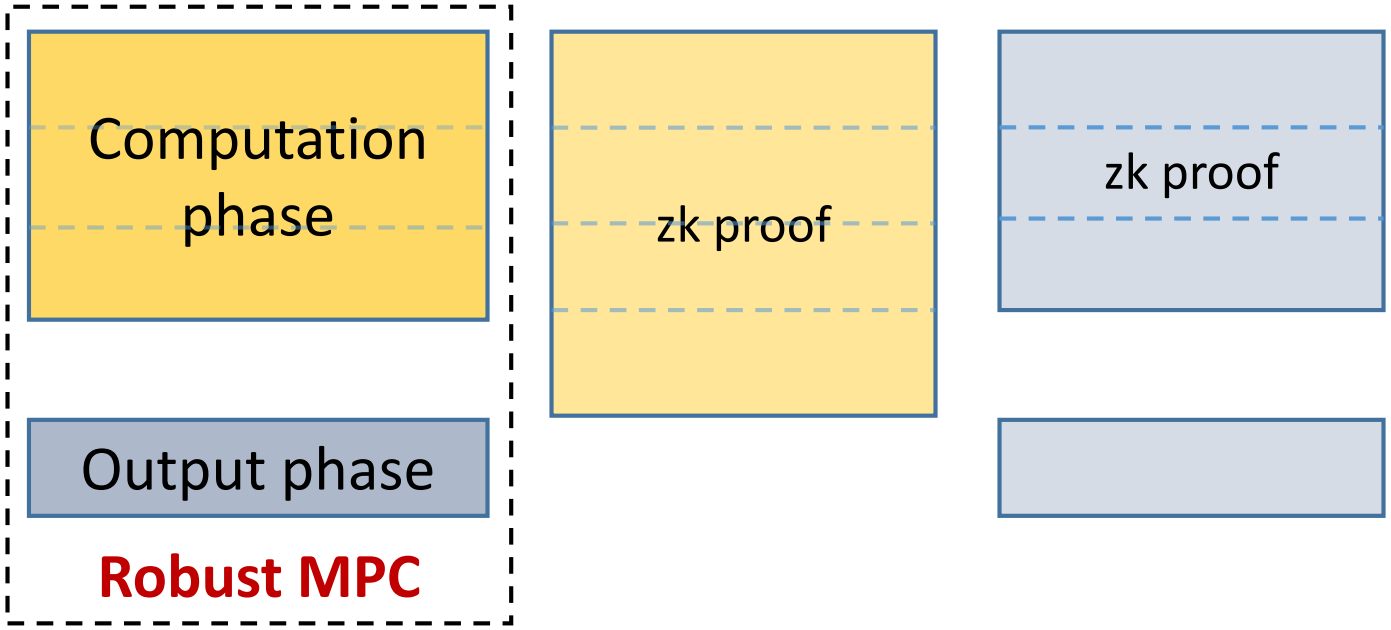

Non-malleability is a big challenge.

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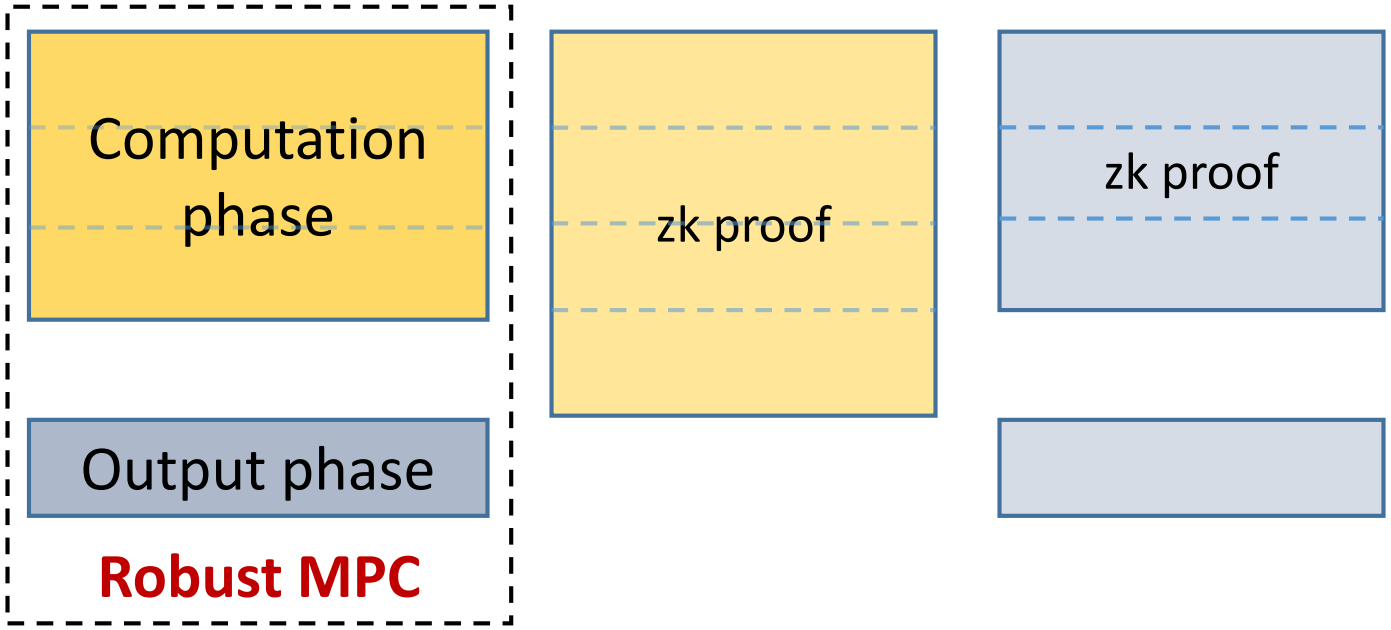

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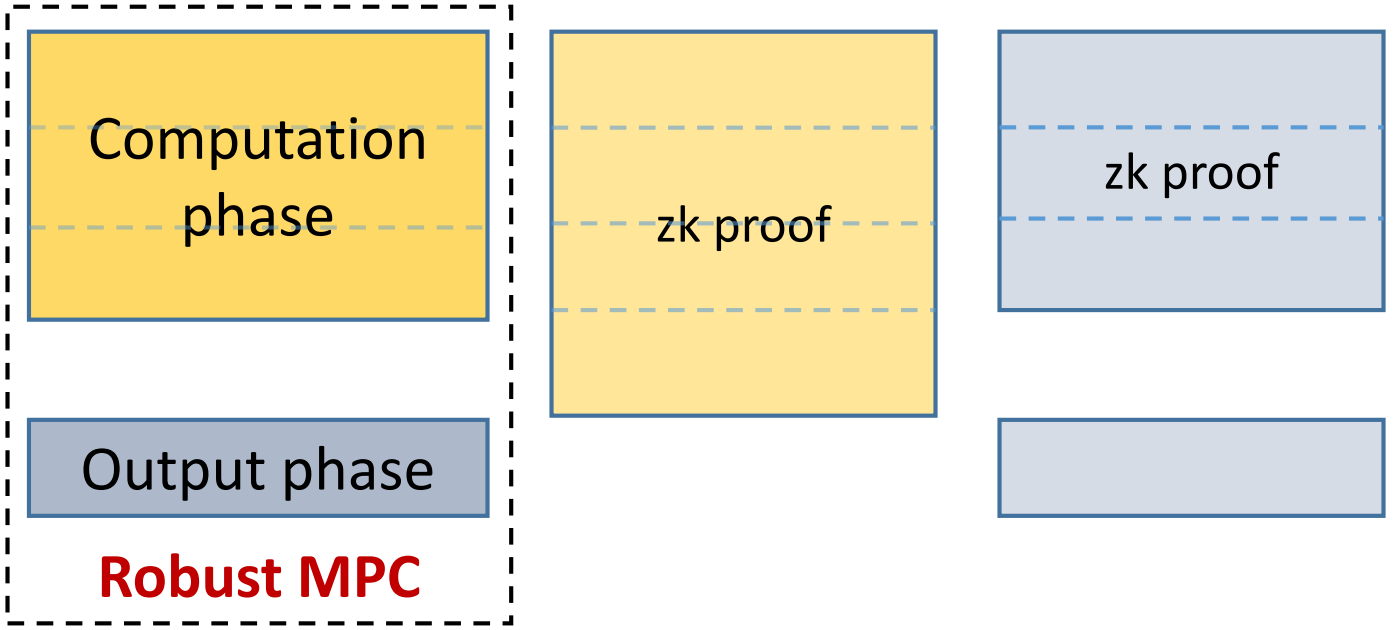

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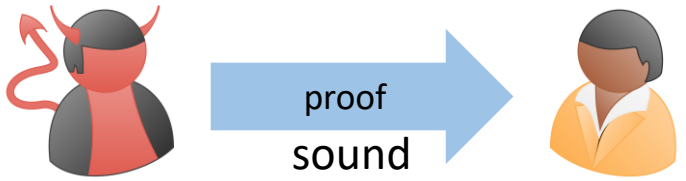

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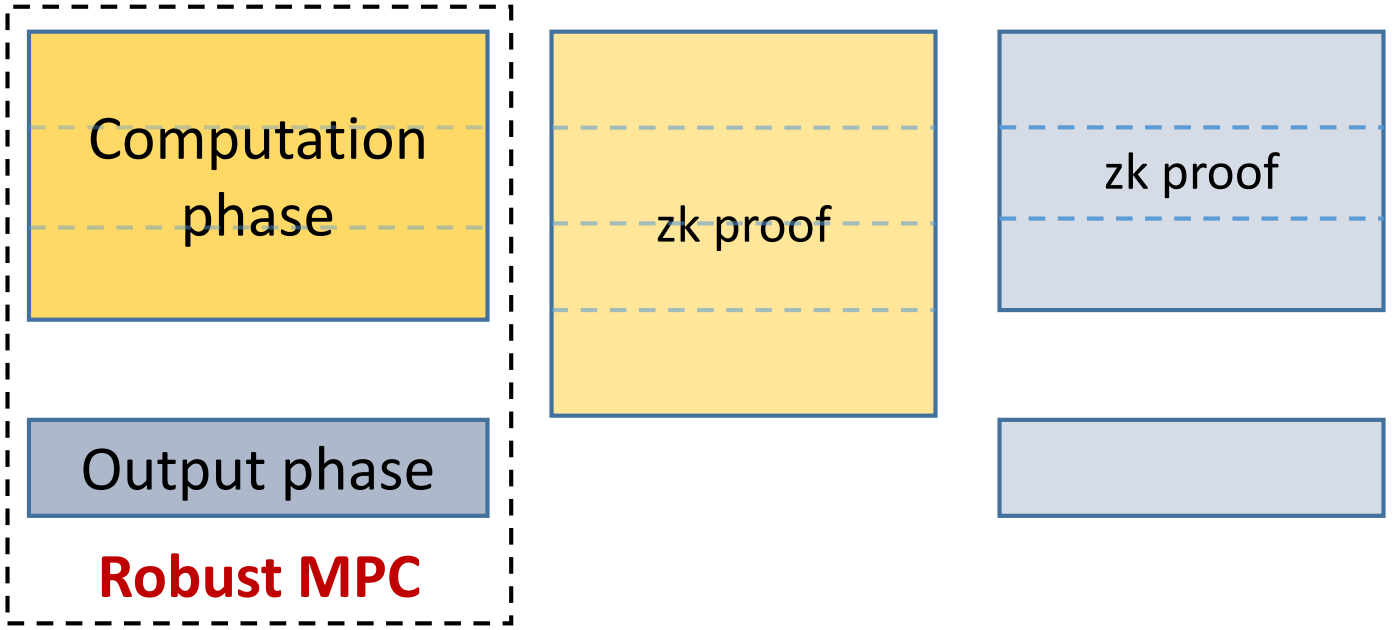

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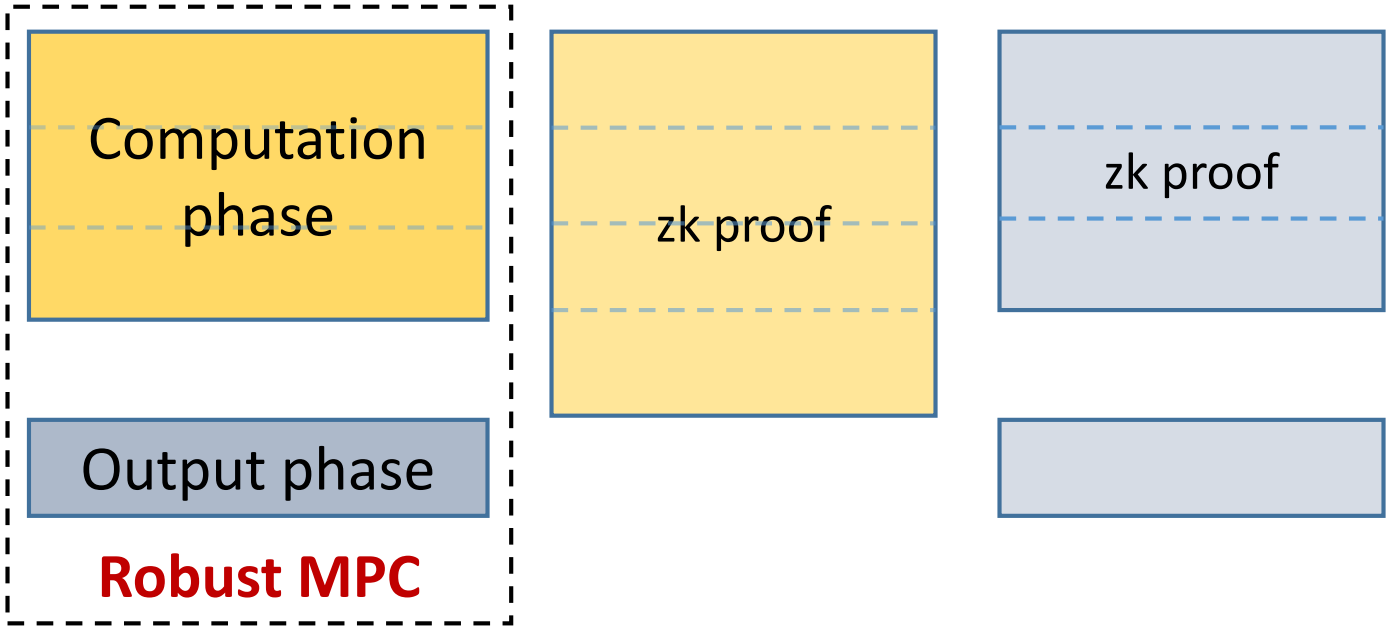

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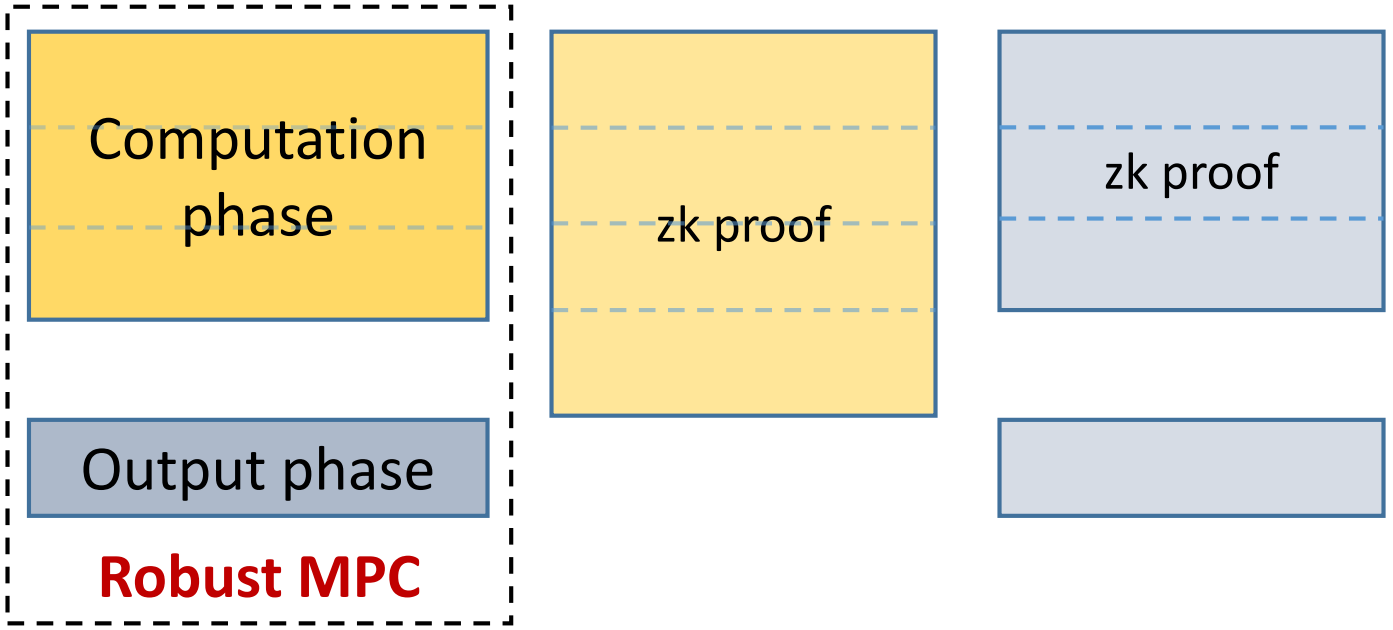

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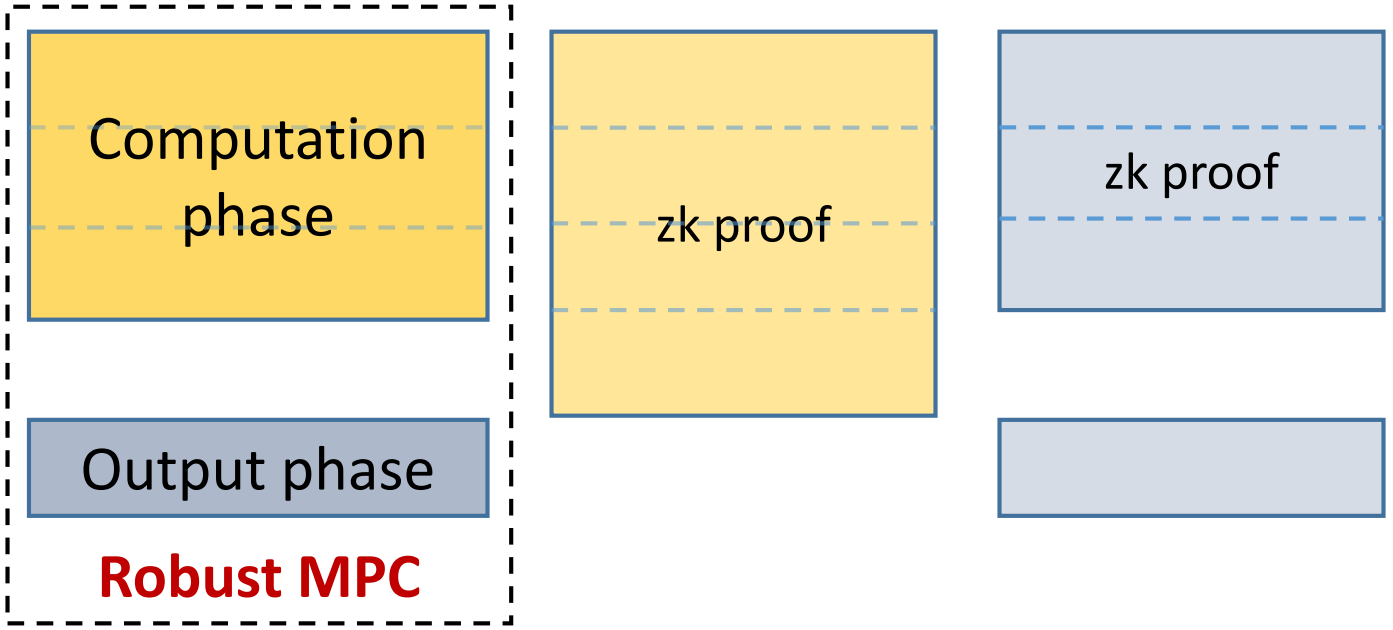

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simulation-soundness [DDN91,Sah99]

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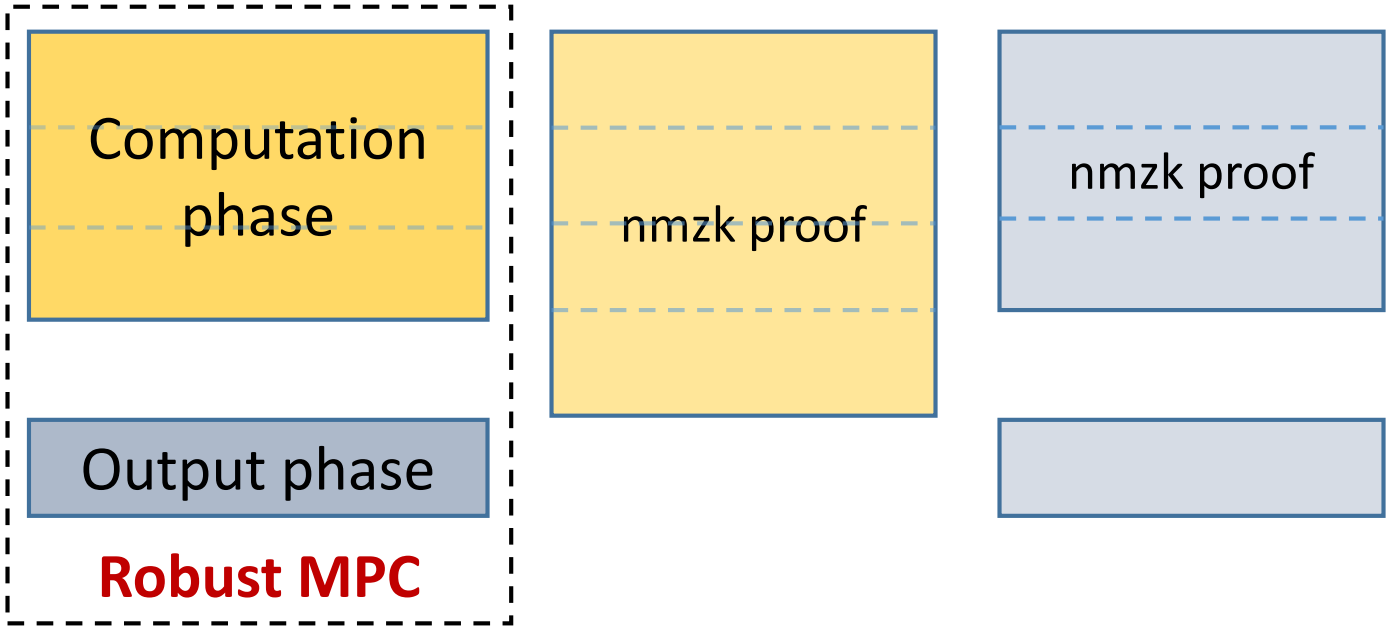

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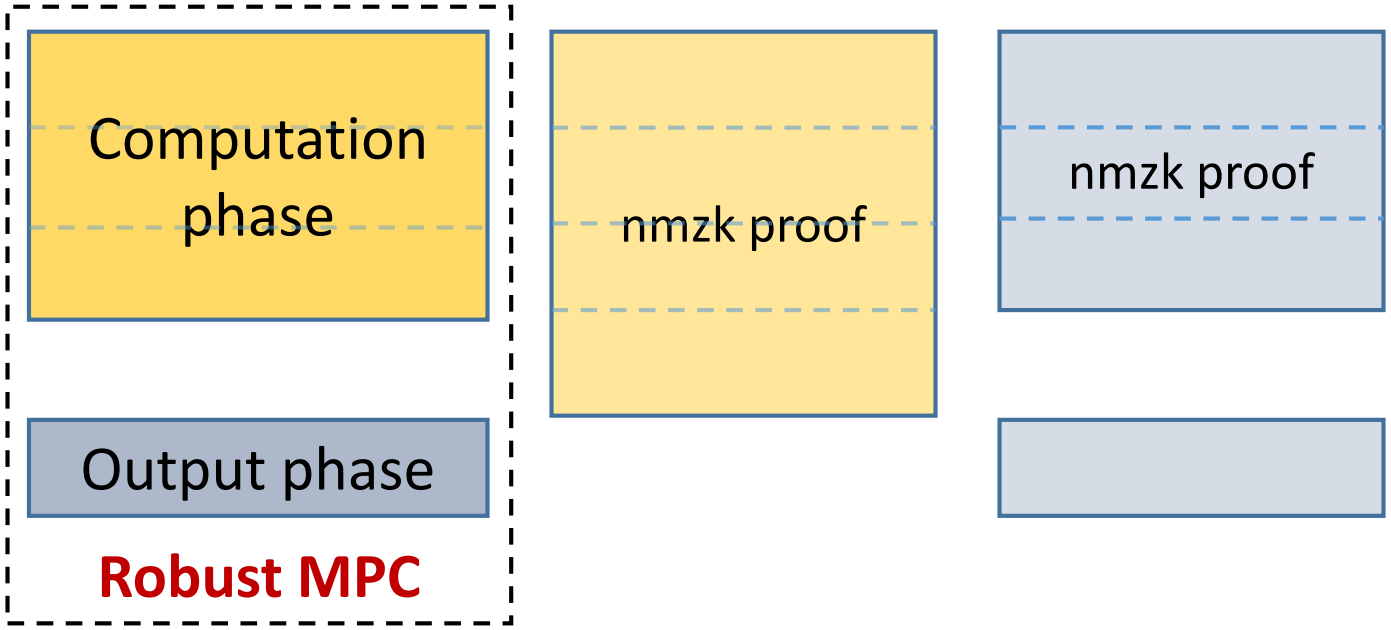

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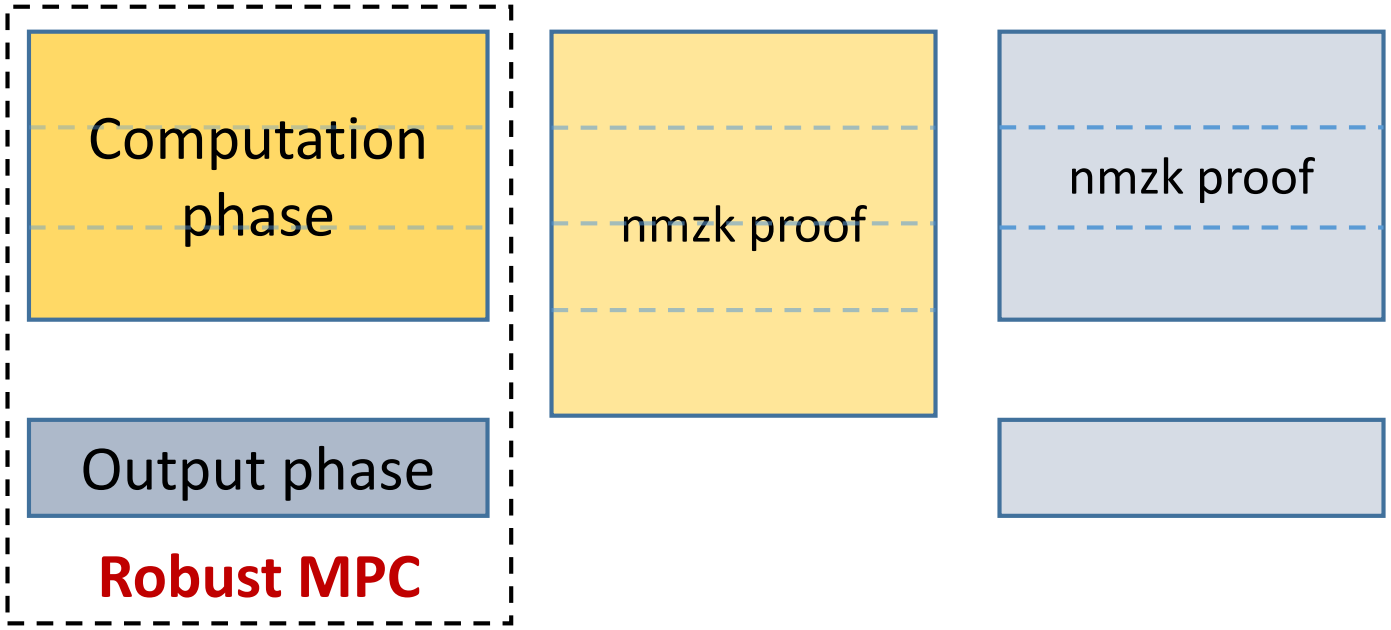
4 round input delayed NMZK can be constructed from CRHF [Ciampi-Ostrovsky-Siniscalchi-Visconti17].

4 Round Protocol

Main challenge



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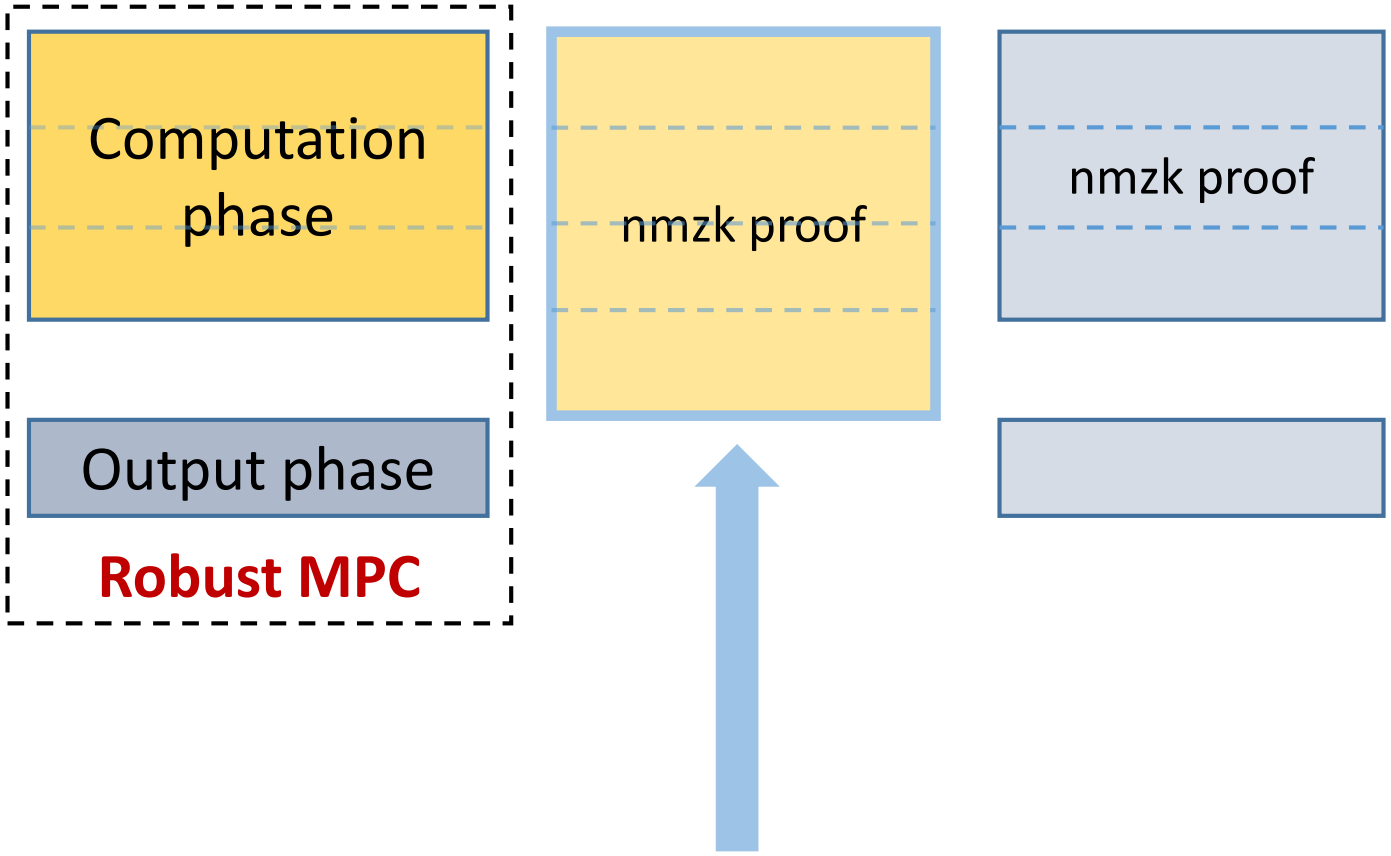

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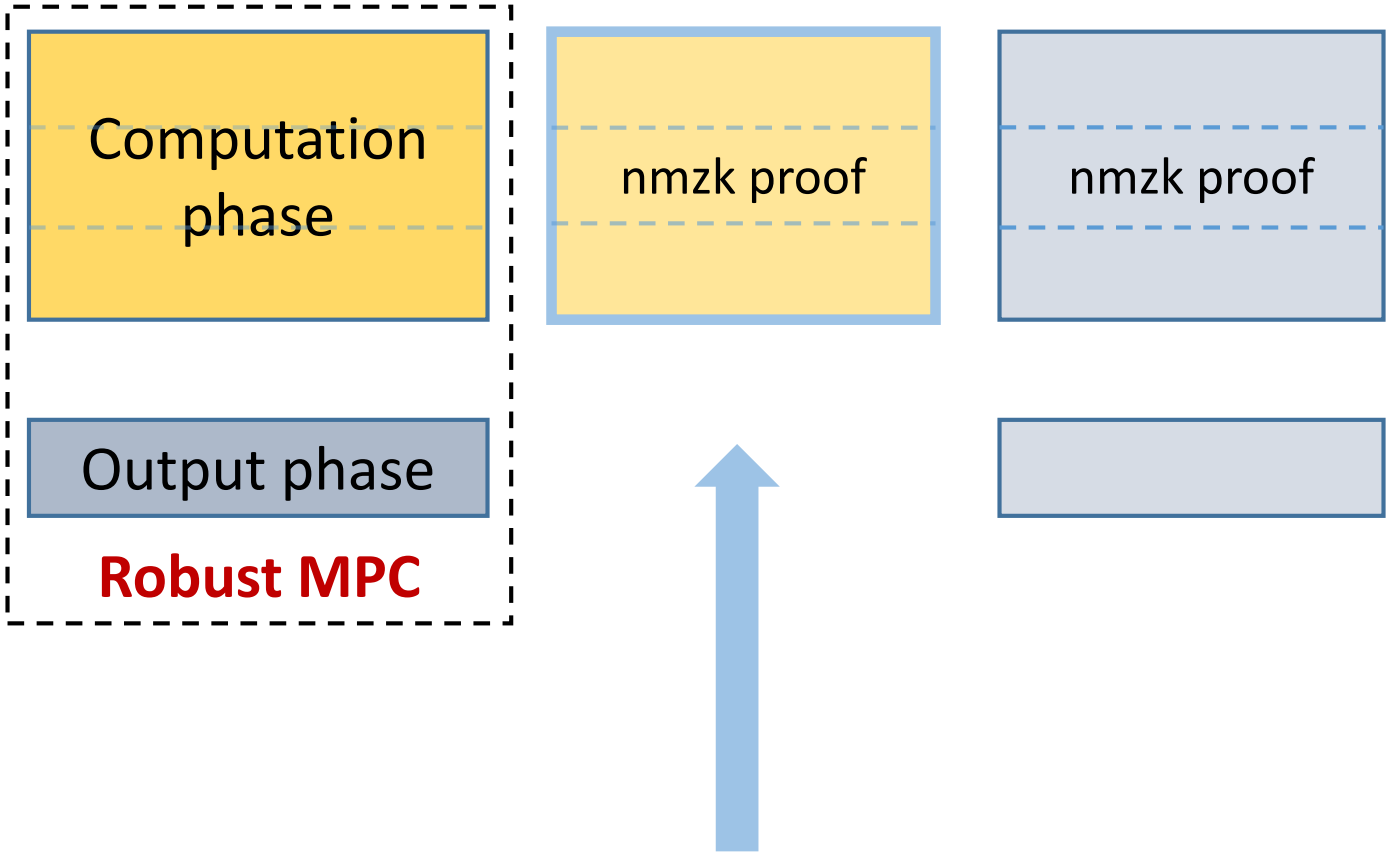

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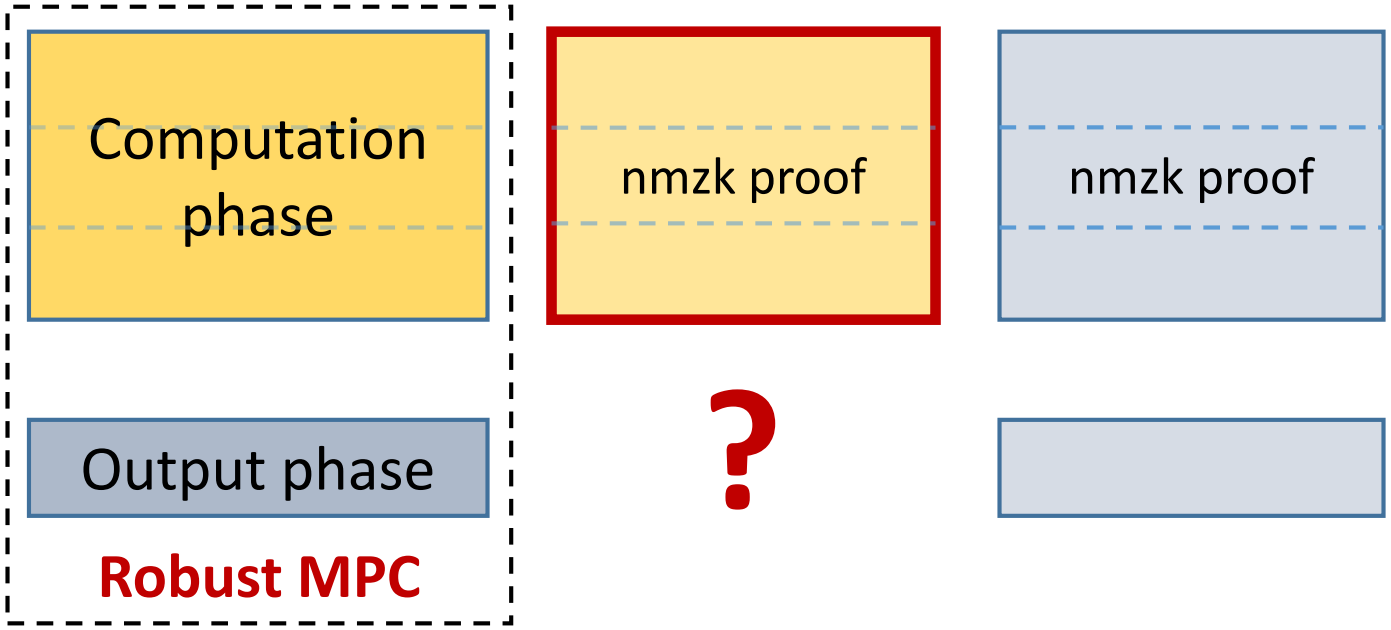

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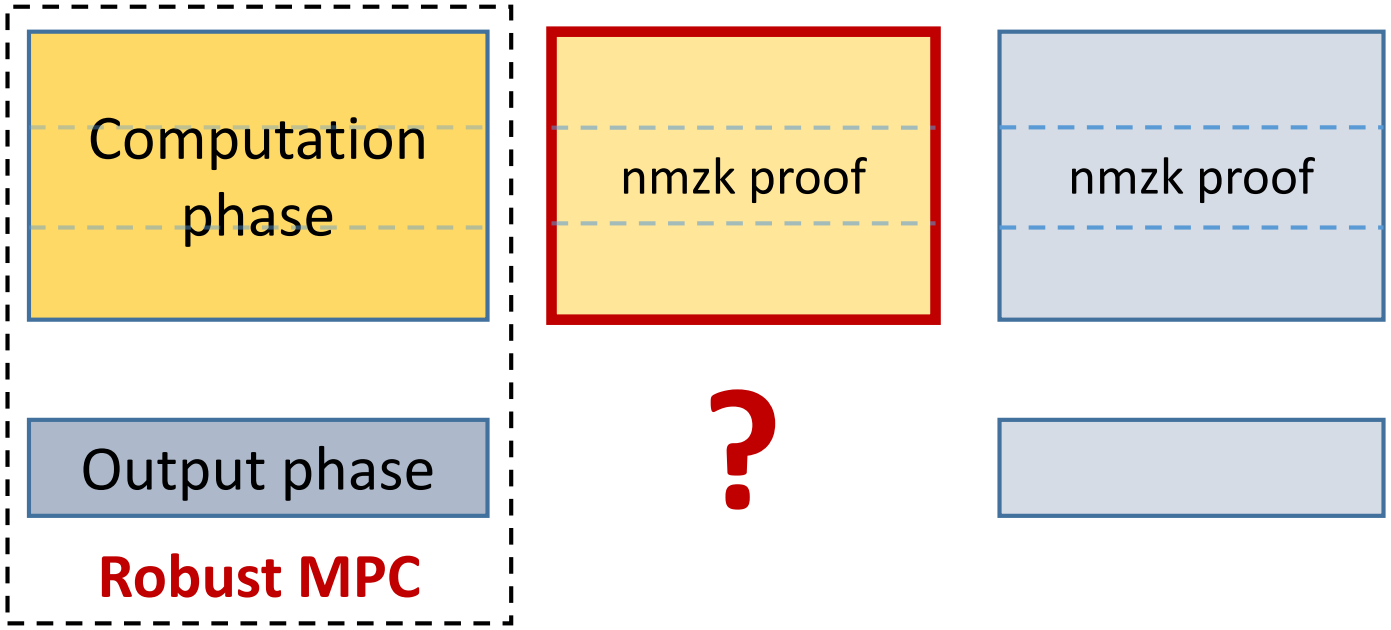

Not clear how to go beyond 5 rounds.

Key idea

Robust MPC:

Simulator needs to cheat only in the output phase.

In the computation phase, simulator uses a *random input*.

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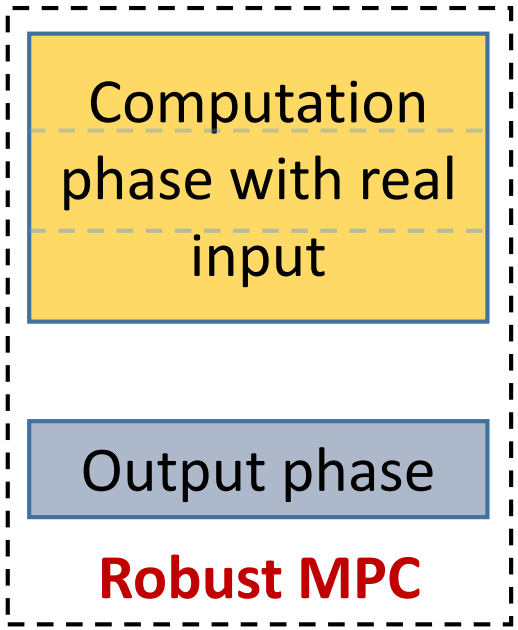

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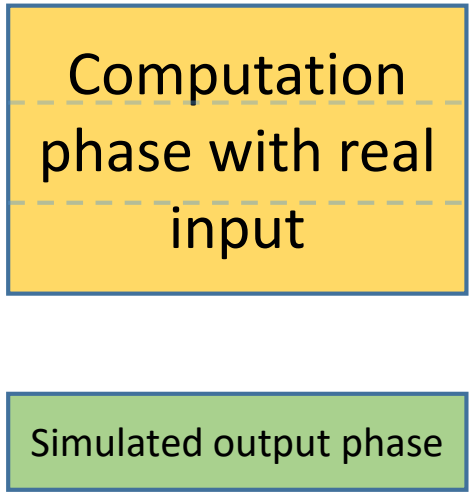

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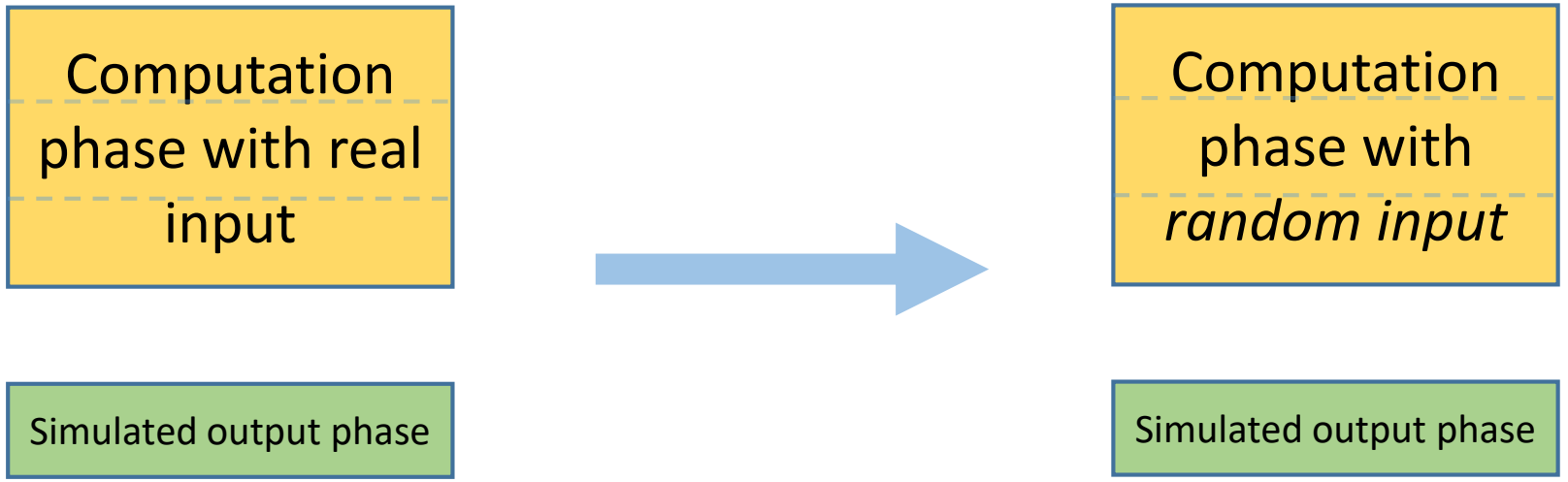

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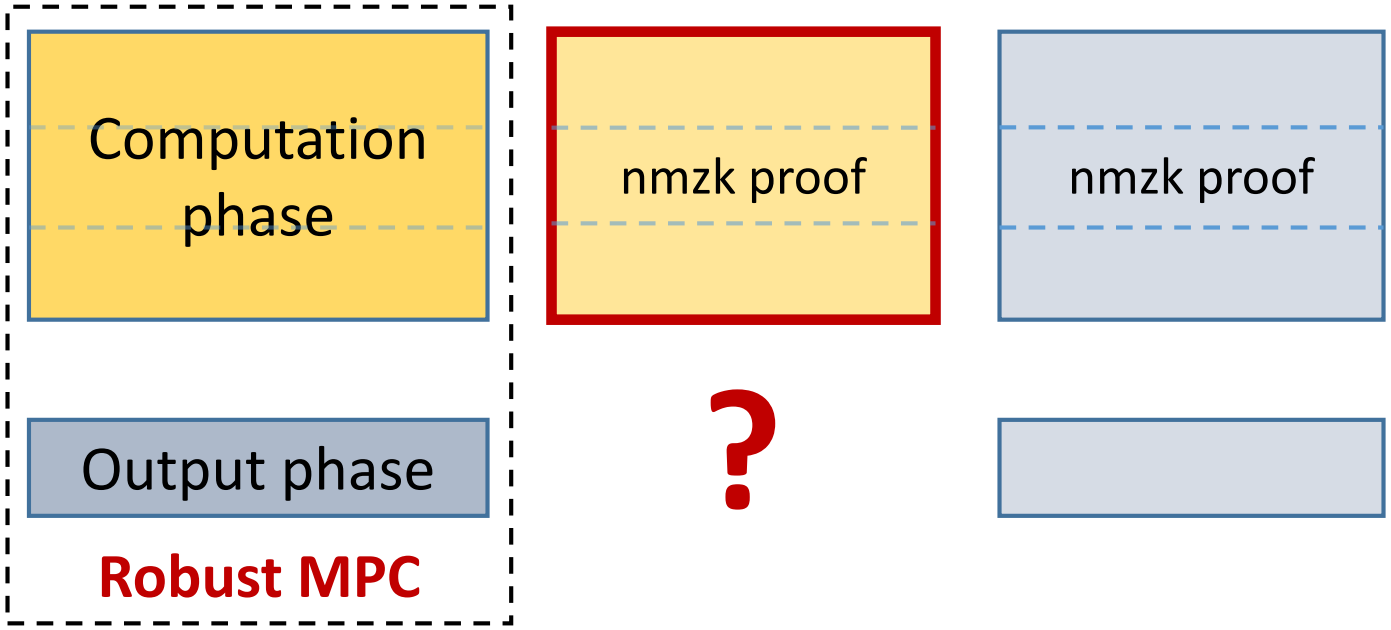
Computation phase
Output phase
Robust MPC
nmzk proof
?
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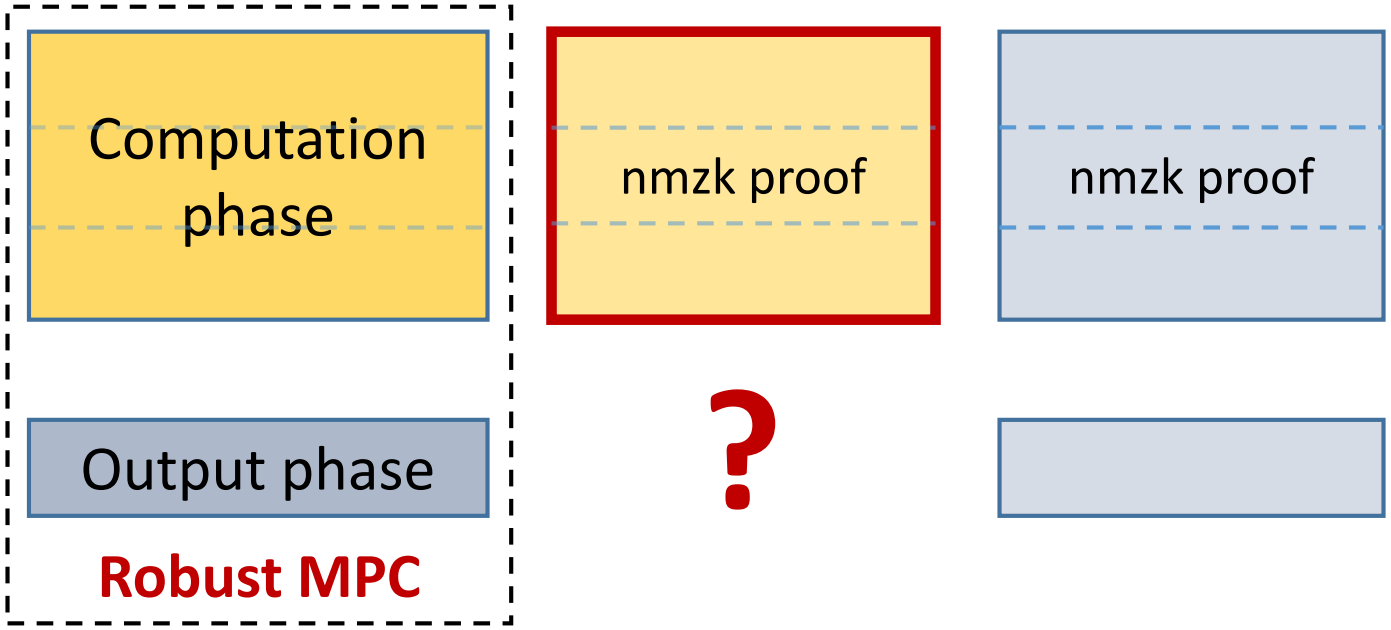
Key idea



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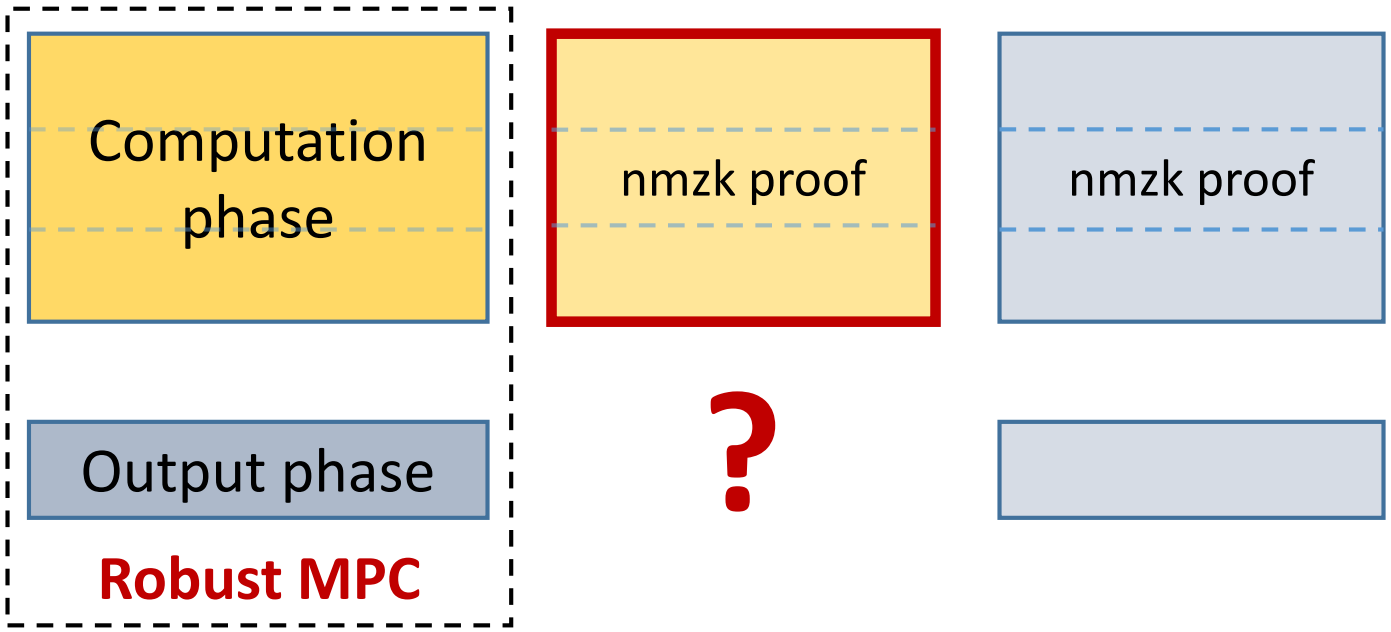

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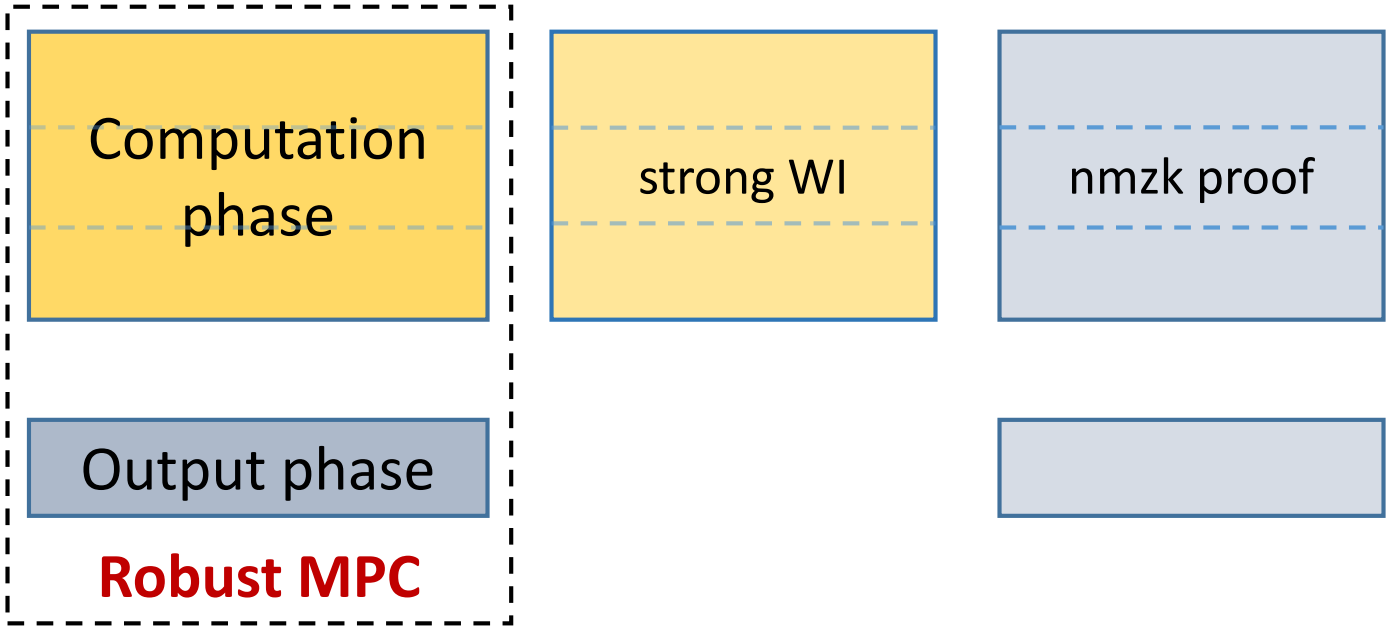

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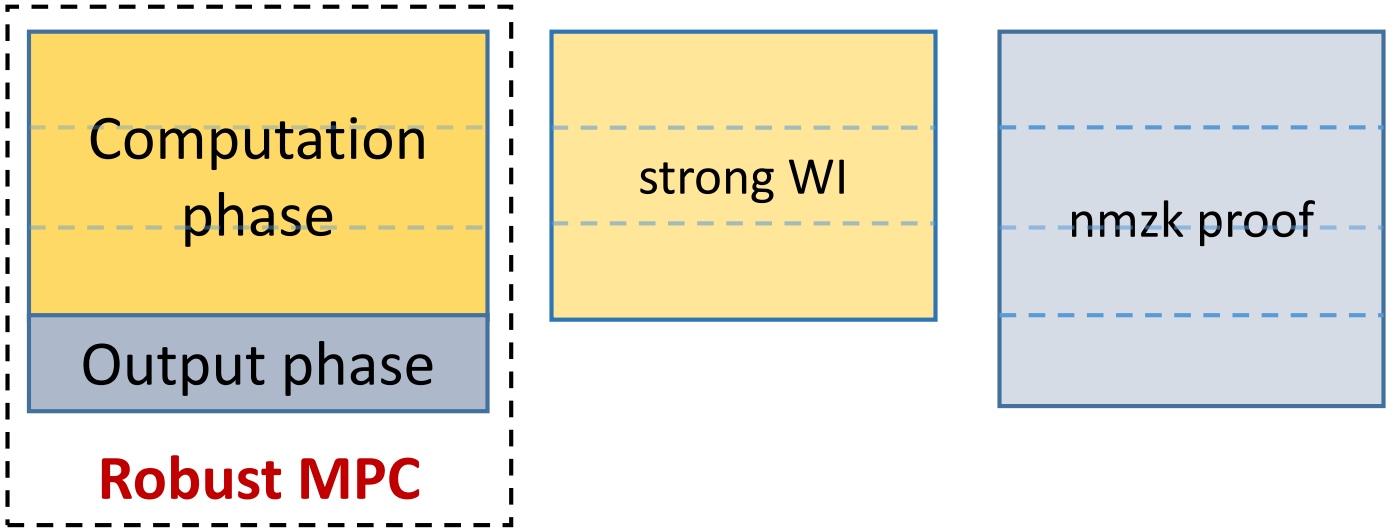

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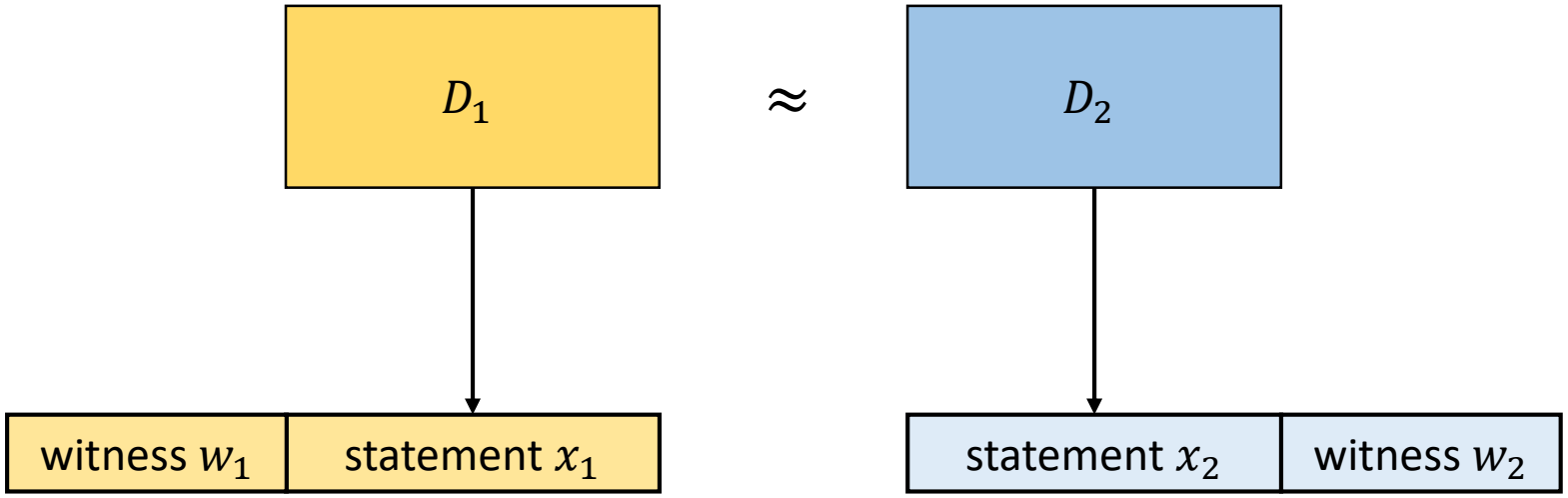

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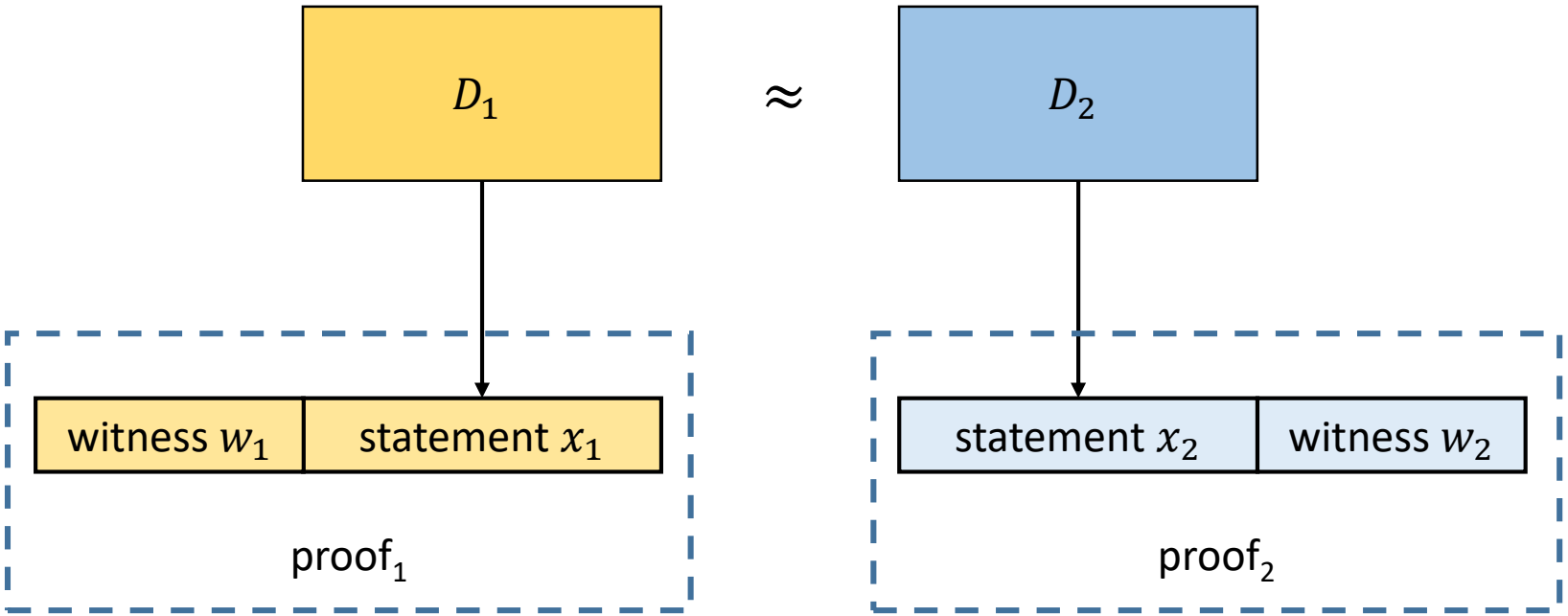

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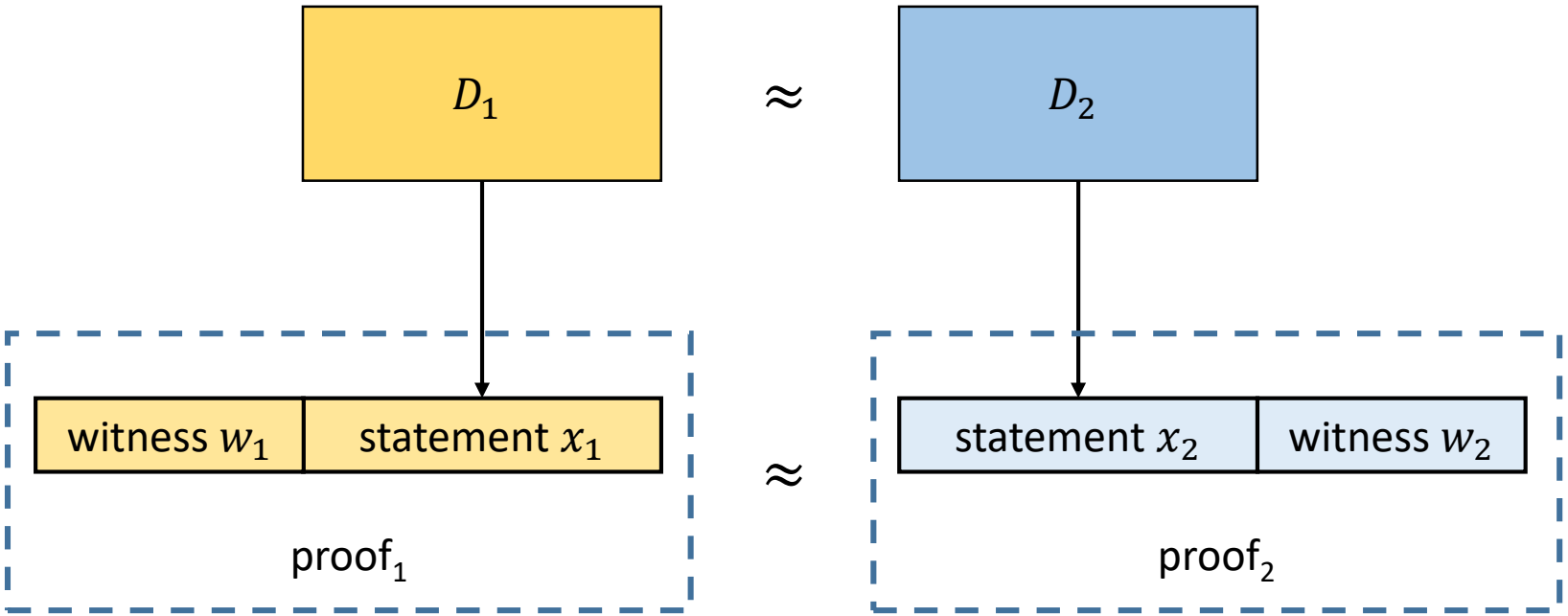

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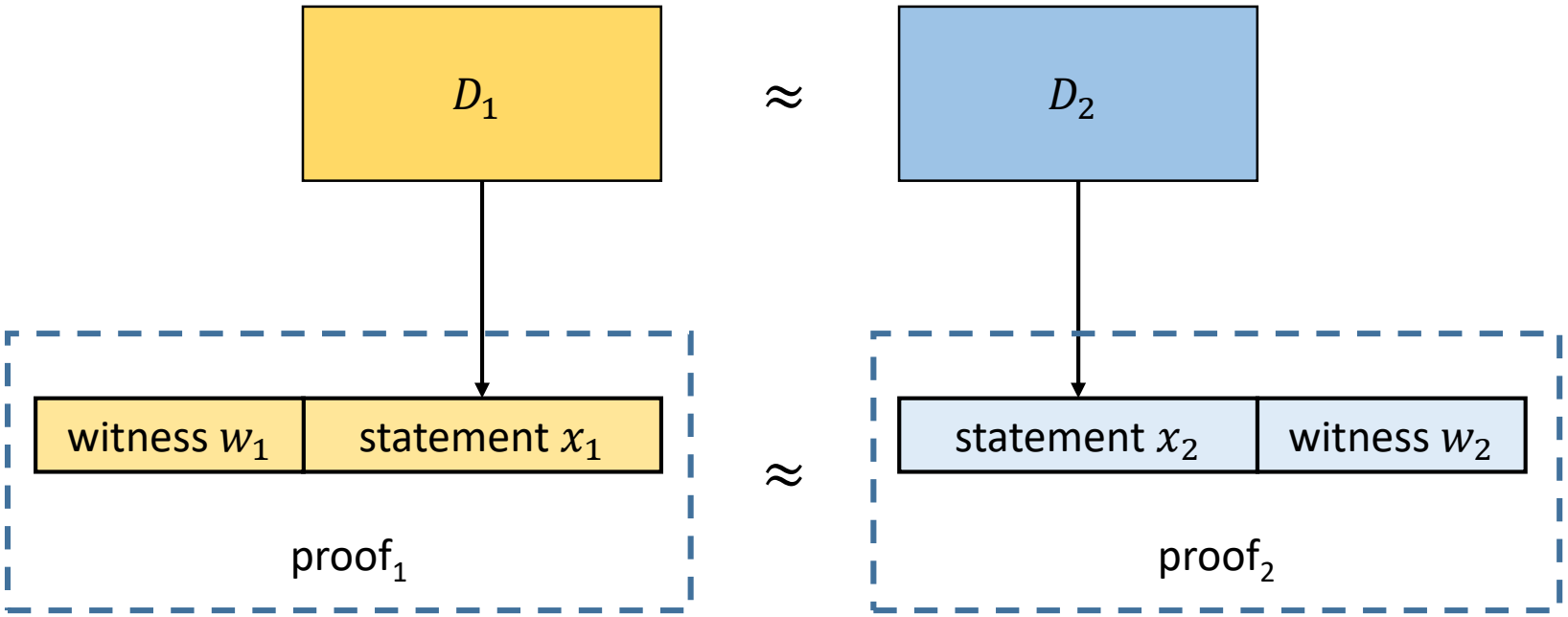

We change both witness and statement during simulation.

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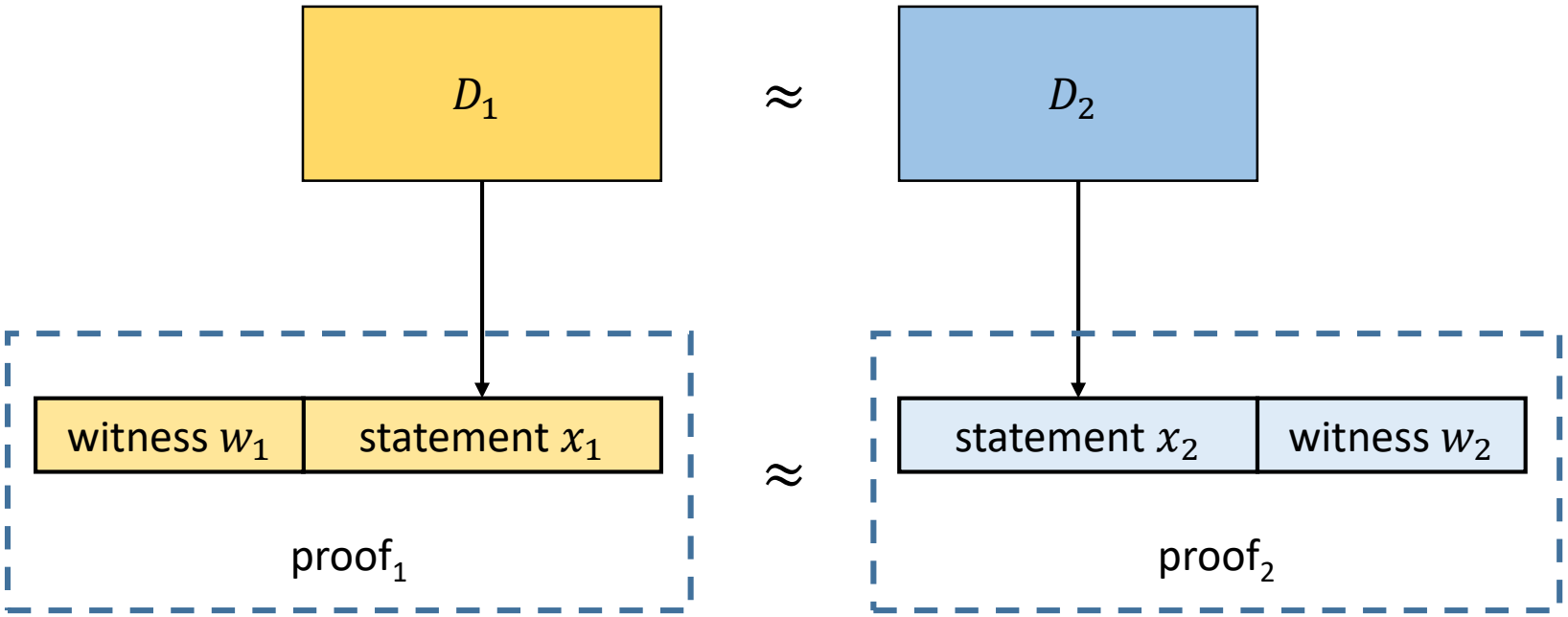

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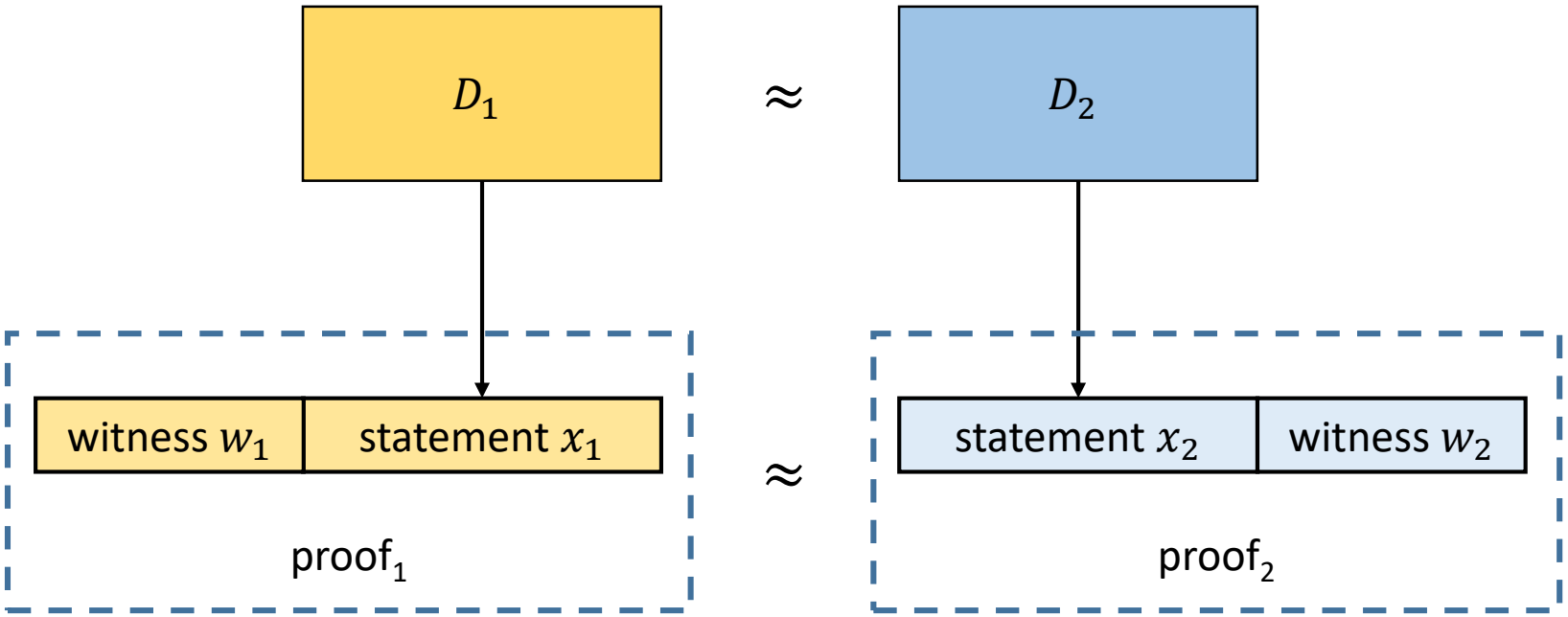

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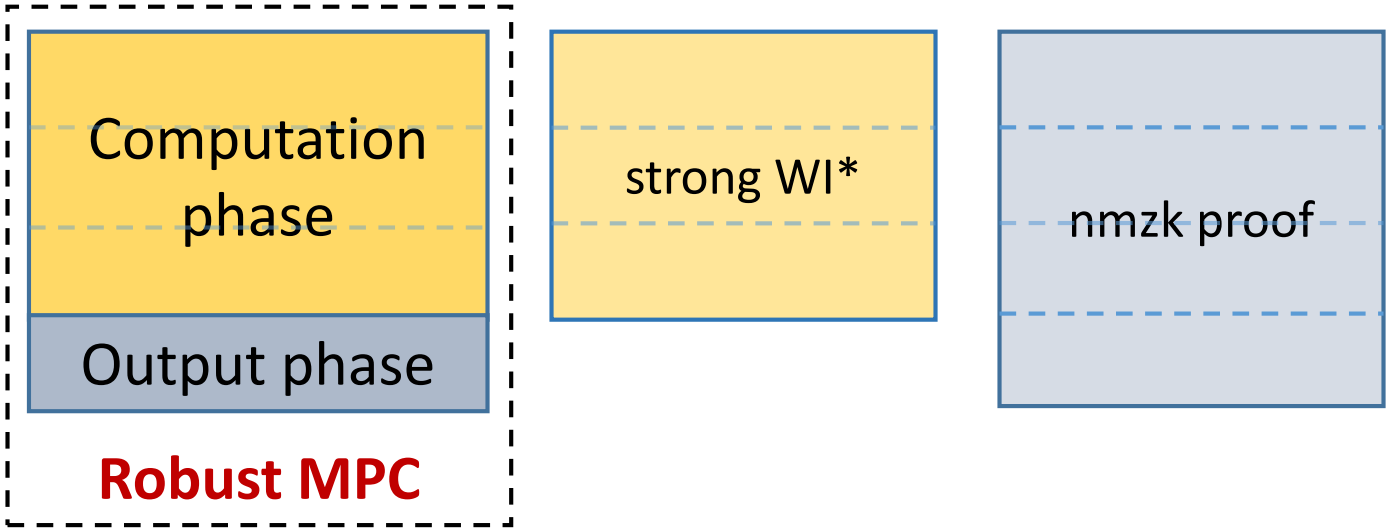
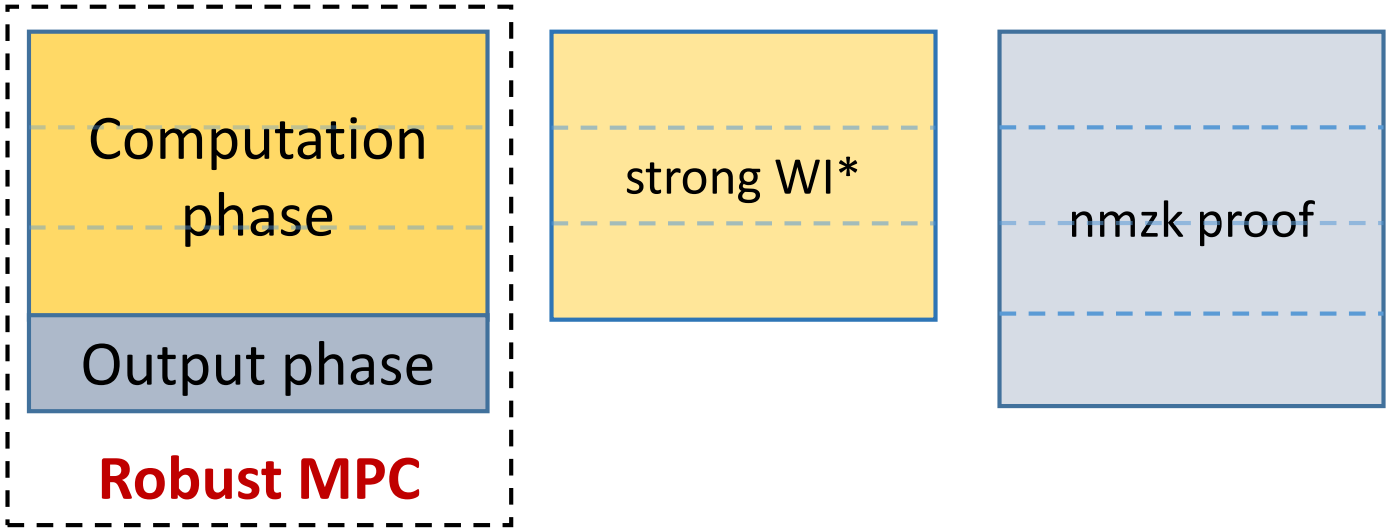
[JKKR17] constructed 3 round strong WI from DDH in a limited setting. Not applicable to our setting.

Blueprint of 4 round protocol



We construct 3 round strong WI*

Blueprint of 4 round protocol



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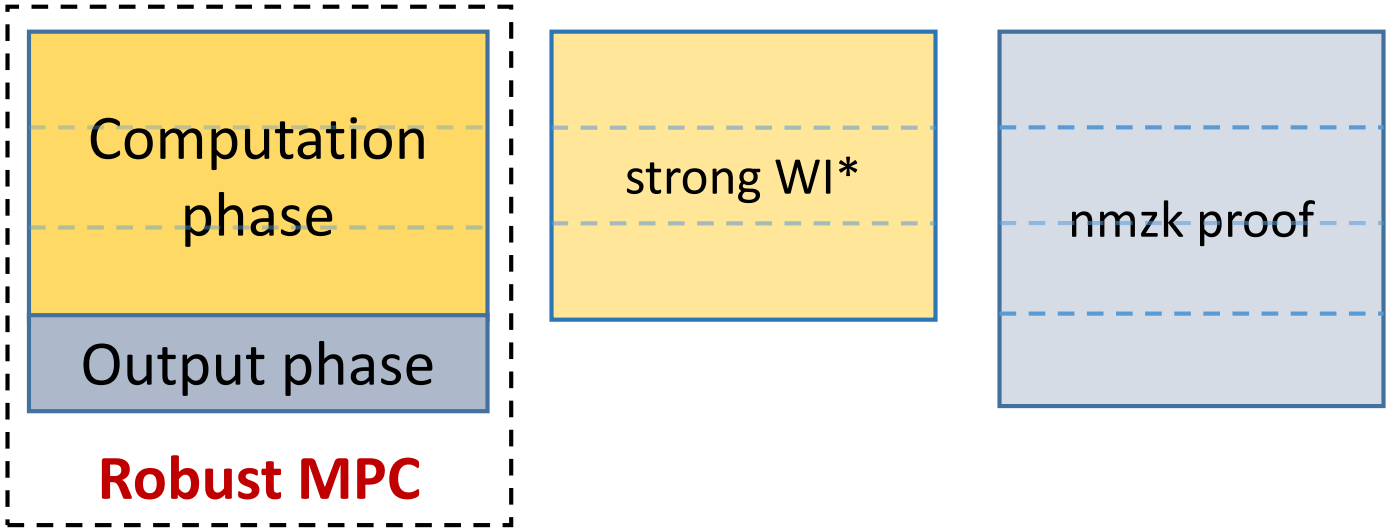

Final **simulator polynomial time**. Sub-exponential hardness used only in the hybrids.

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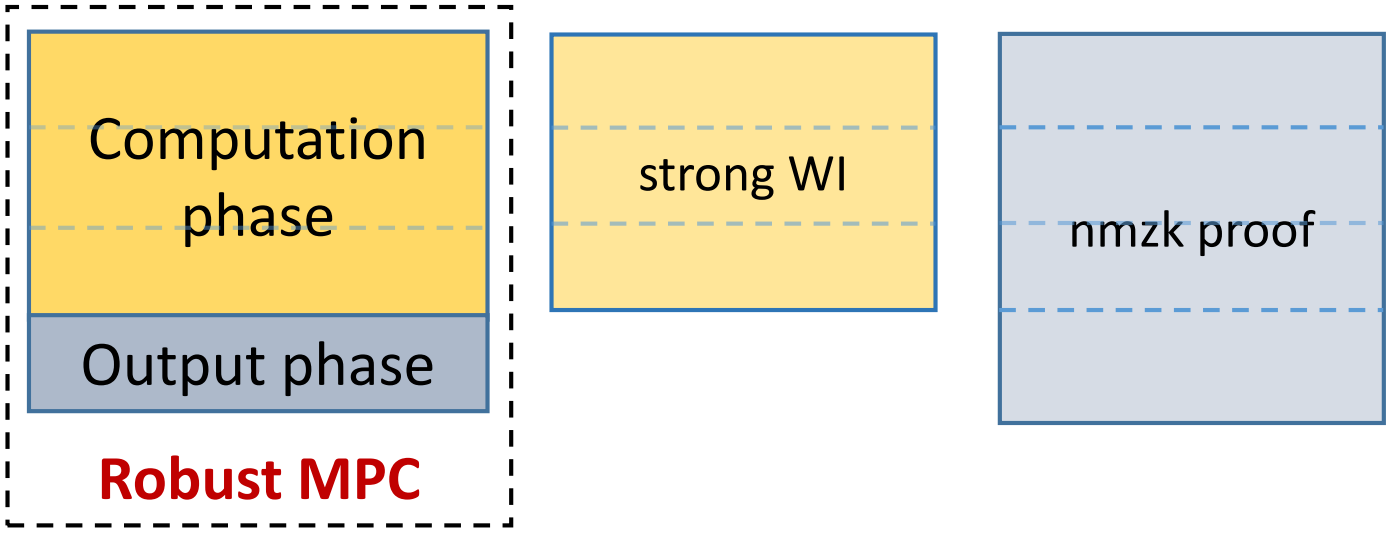
Remarks on security proofs

Several challenges, and specific constructions modified accordingly.



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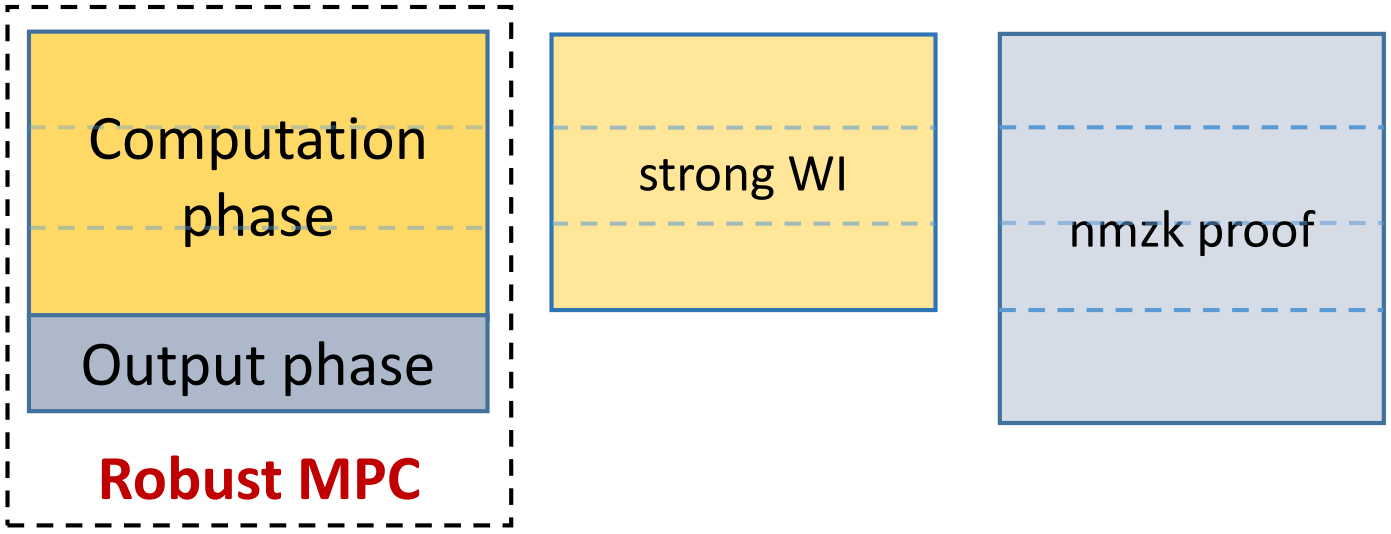

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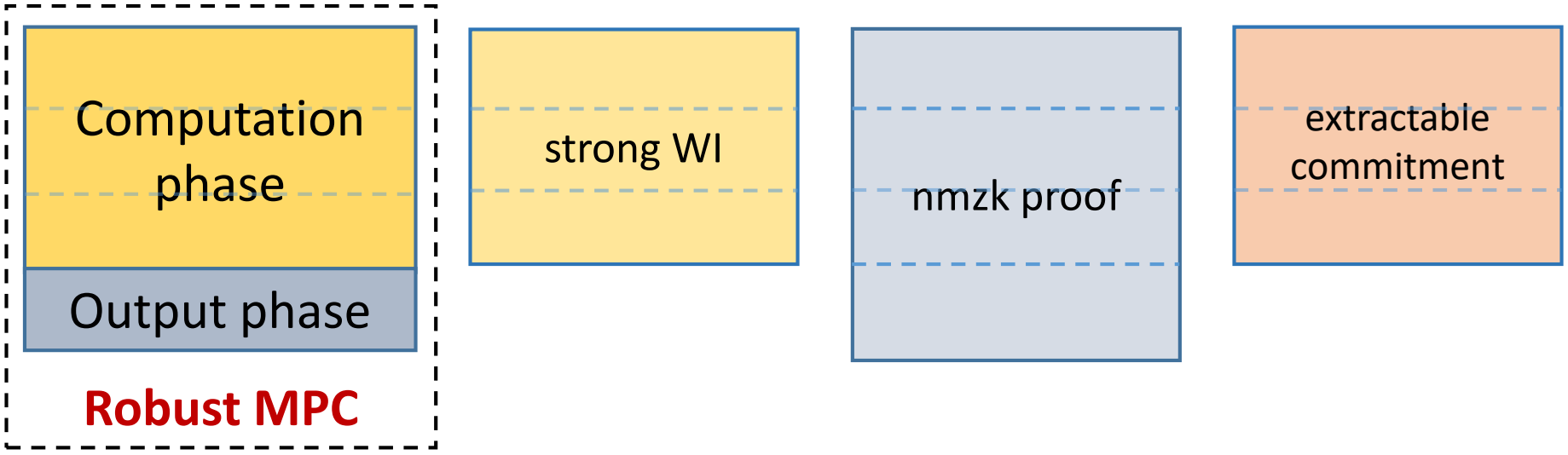

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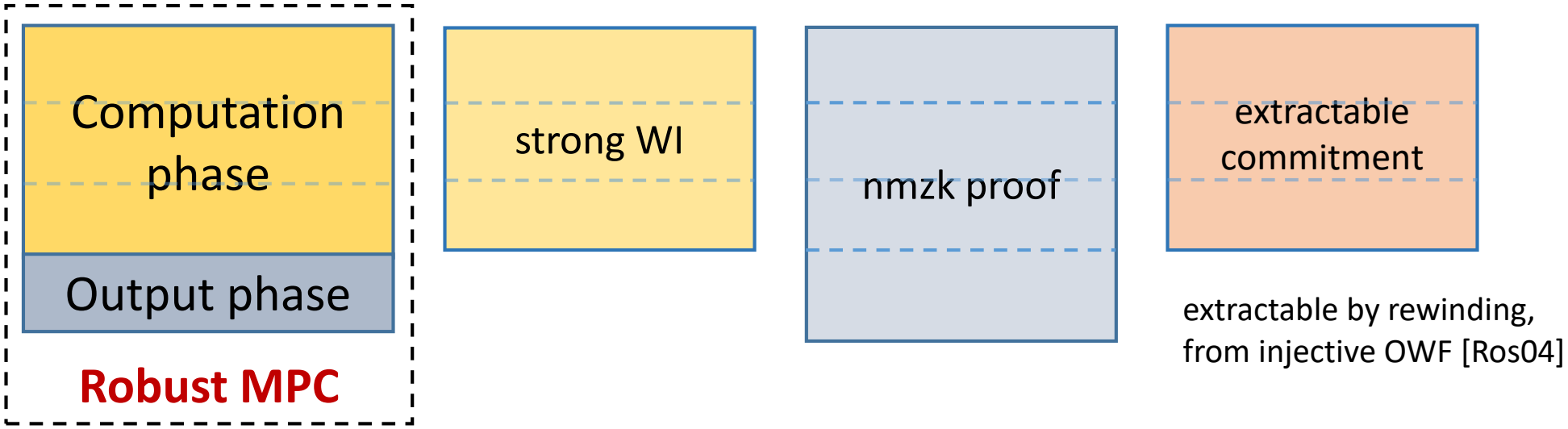

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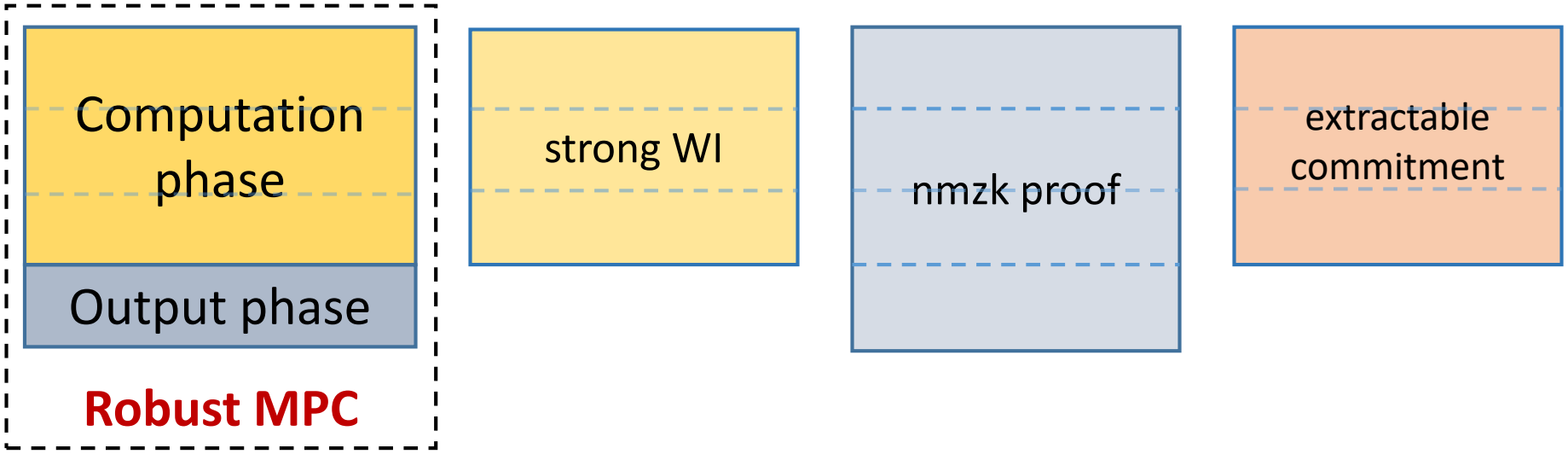

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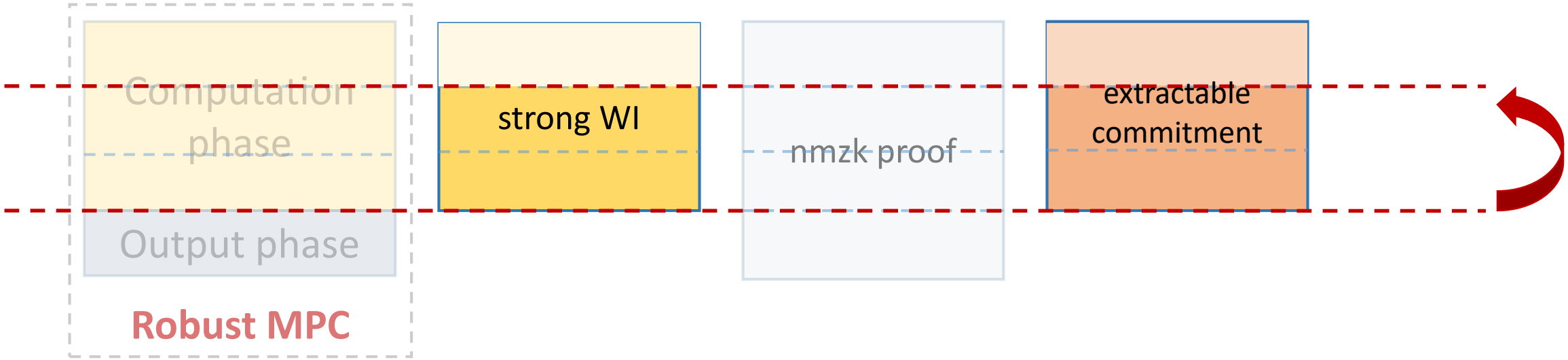

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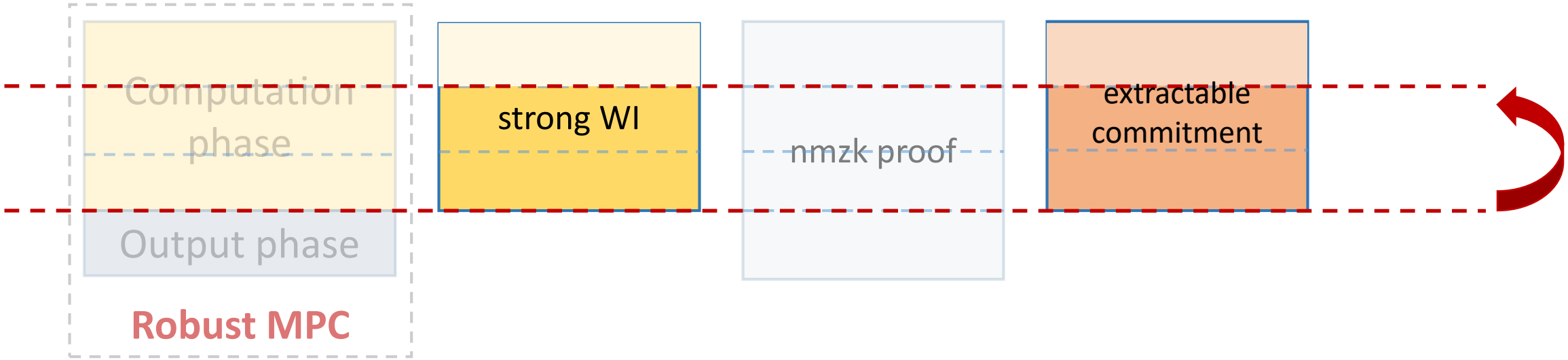

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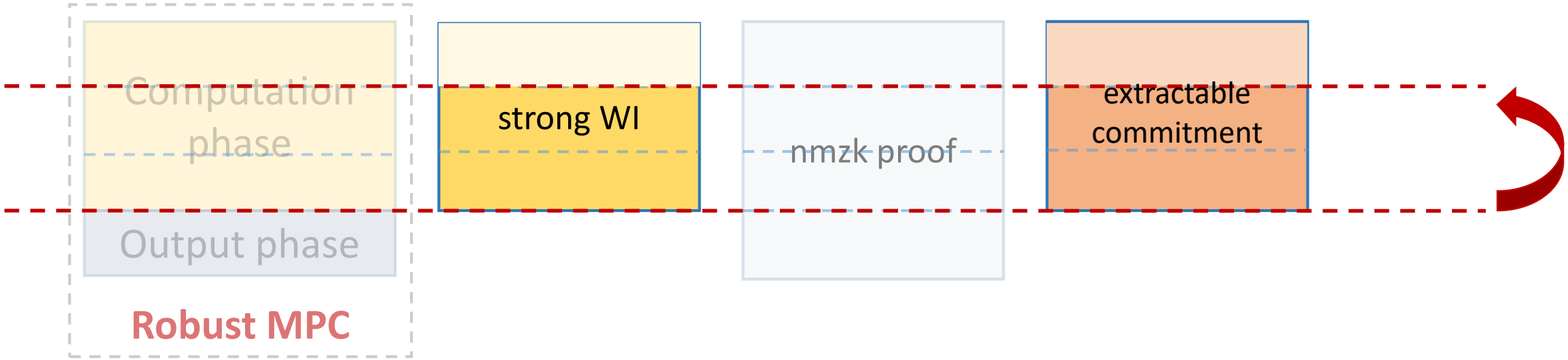

Primitives need to be secure in the presence of rewinding.

Overcome this issue by using rewinding secure primitives, or use complexity leveraging to bypass it.

4 Round Robust MPC

Key points

[GMW87]

Round complexity proportional to the depth.

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Use randomized encodings to reduce depth of computation.

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Main contribution is to bring it down to 4 rounds.

Thank you. Questions?

Arka Rai Choudhuri

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ia.cr/2017/402