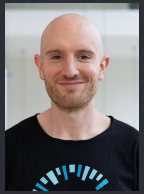
Transparent Batchable Time-lock Puzzles and Applications to Byzantine Consensus

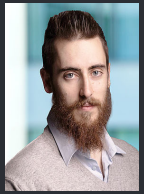
Shravan Srinivasan

UMD



Julian Loss

CISPA

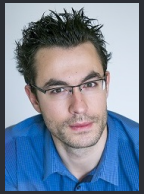


Giulio Malavolta

MPI-SP

Kartik Nayak

Duke



Charalampos Papamanthou

Yale

Sri AravindaKrishnan Thyagarajan

NTT Research

PKC ’23

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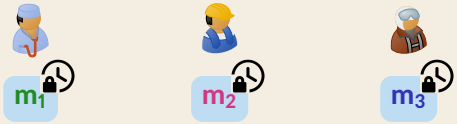
- Security against parallel adversaries
- Applications in auctions, blockchains, timed-commitments, and more

Batchable Time-Lock Puzzles [MT19, TBM+20]

Traditional TLPs [RSW96]:



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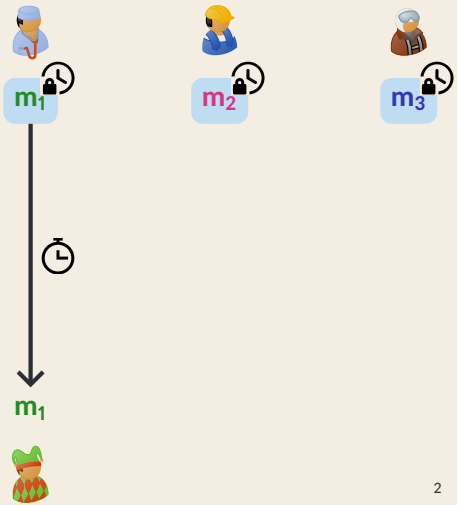

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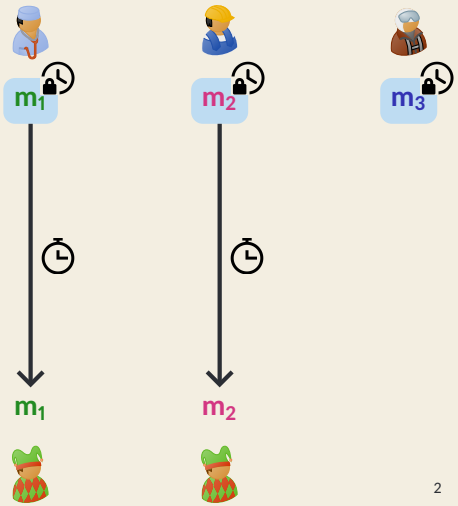

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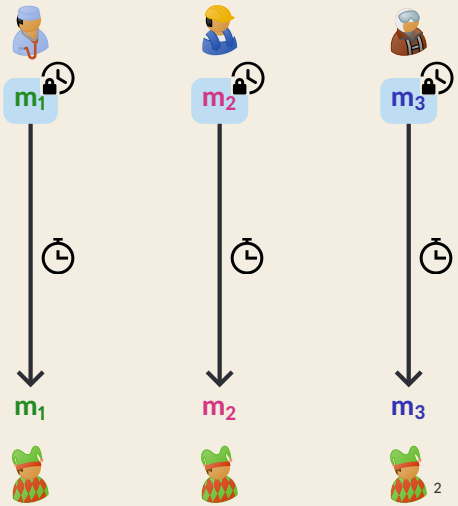

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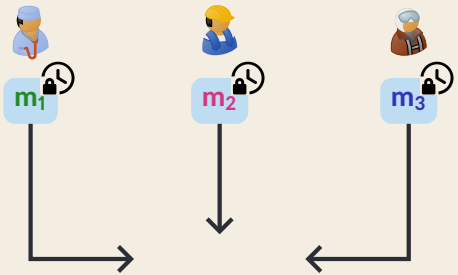

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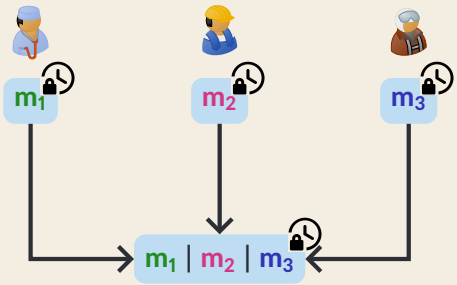

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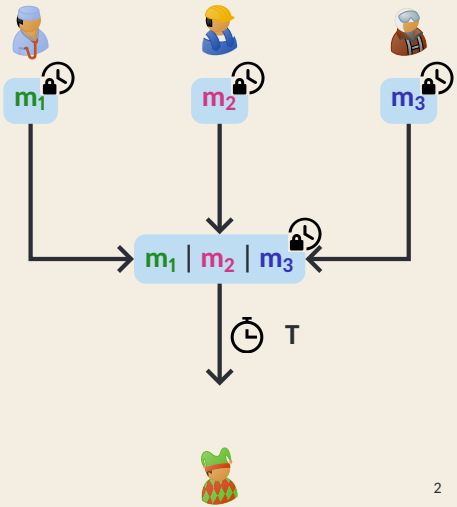

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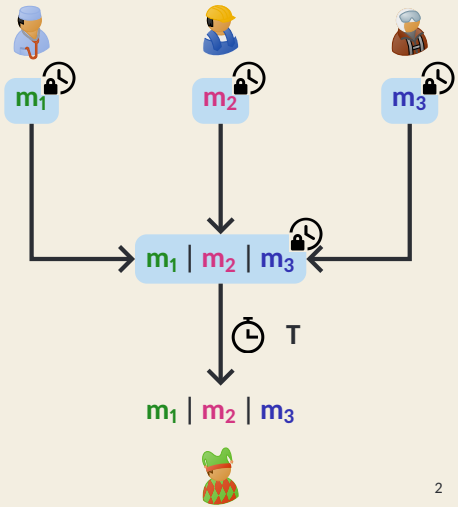

Problem Statement

Scheme	Batchable	Transparent setup	No apriori bound	Compact puzzles
RSA-based [TBM+20, MT19]	✓	×	×	×
Class-groups based [TCLM21]	✓	✓	×	×

Problem Statement

Unbounded batching

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Why do we care?

Useful in the decentralized setting [TBM+20, WXDS20, tez22]:

- Impractical to rely on trusted setup
- Unknown number of nodes
- Large puzzles increases communication overhead

Contributions

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This work	✓	✓	✓	✓

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Applications in consensus:

- First permissionless protocol in the *mobile sluggish* model
- First expected $O(1)$-round Byzantine broadcast under strongly adaptive and corrupt majority setting

Outline

1. Preliminaries

2. TLP construction
   - 2.1 Puzzle generation
   - 2.2 Batch Solving

3. Application: Permissionless Consensus
   - 3.1 Network model
   - 3.2 Protocol

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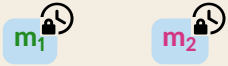

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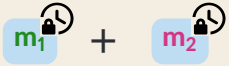

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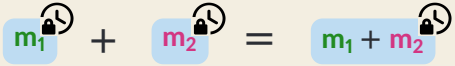

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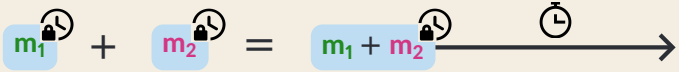

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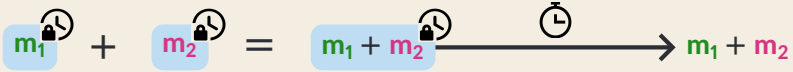

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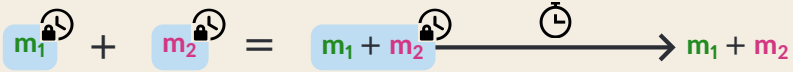

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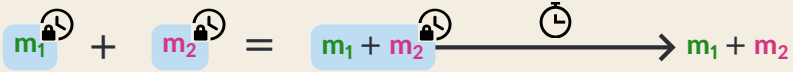

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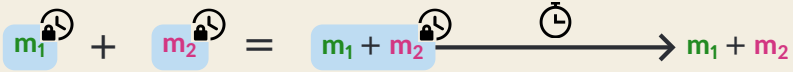

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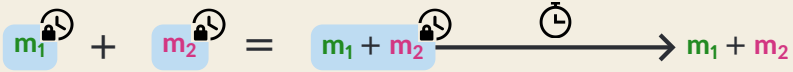

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for all keys k_1, k_2 and all message m.

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$$\begin{bmatrix} F(k_i, 1) \\ \vdots \\ F(k_i, i) \\ \vdots \\ F(k_i, n) \end{bmatrix} + m_i$$

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Masked cipher txt.

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HTLP k_1 + k_2 + k_3

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Outline

Application: Permissionless Consensus

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- Exact number of nodes unknown
- No authentication mechanism
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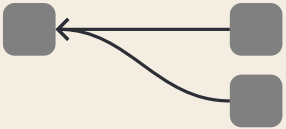

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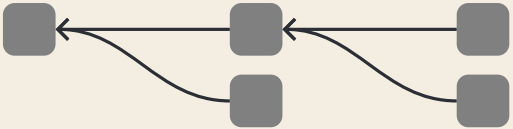

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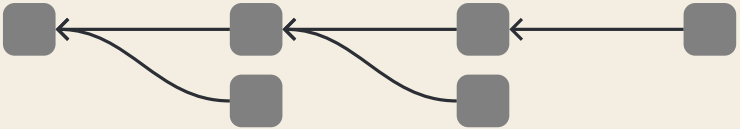

Secure in the synchronous model [GKL15, PSS17, LG19]

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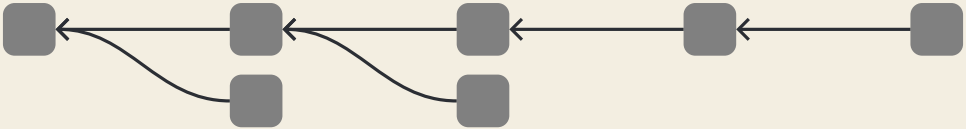

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Is it possible to achieve consensus in the permissionless setting in the presence of mobile sluggish faults?

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- Set hiding time, $\mathbf{T} = \Delta$
- Non-block winners send *decoys*
- Decoys give “cover” for the block winner
- Adversary has to corrupt or deliver messages randomly

Decoys

- *Decoys*: Dummy TLP messages
- Need to prevent Sybil attack

payload

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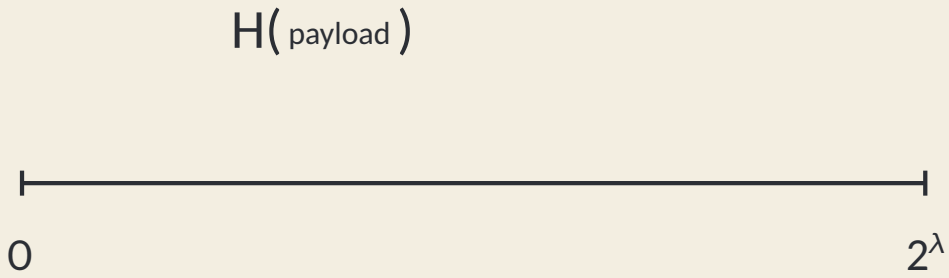

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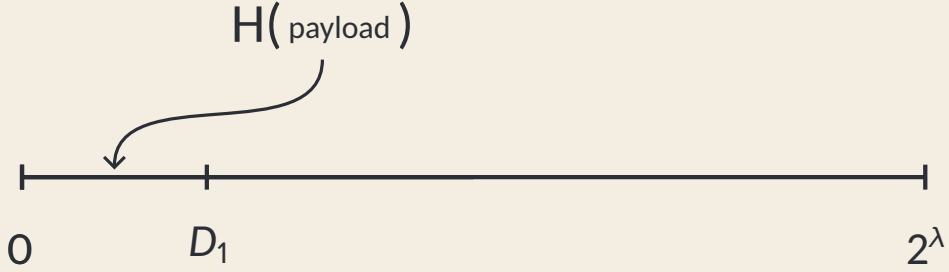

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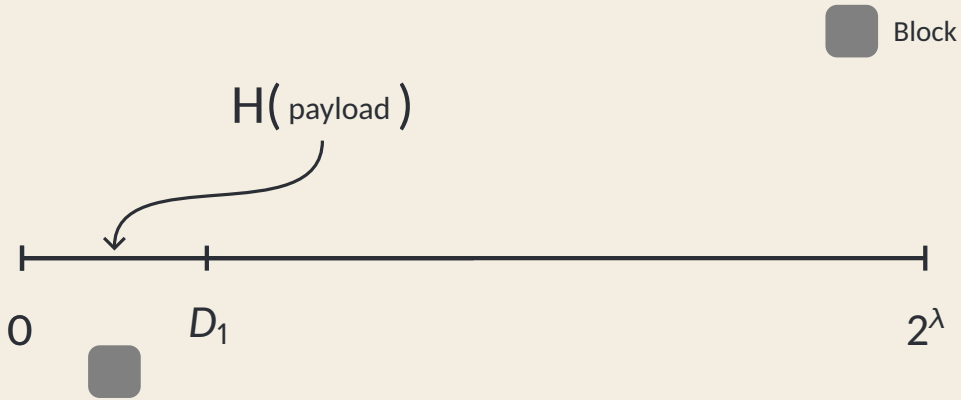

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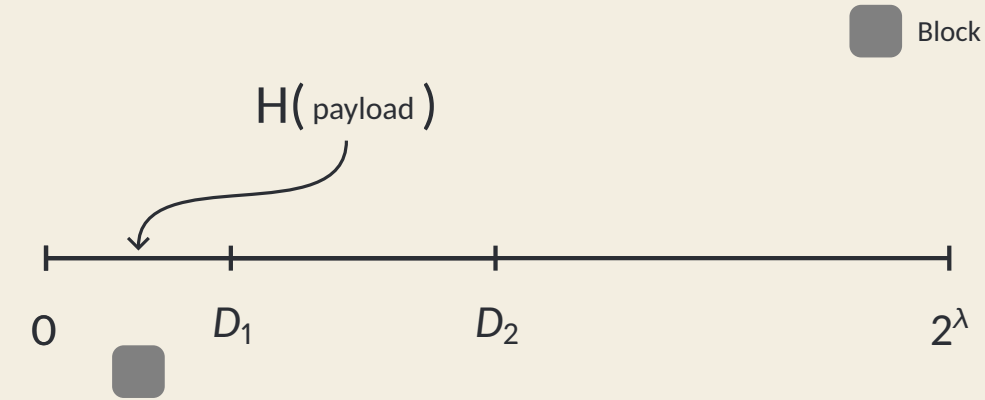

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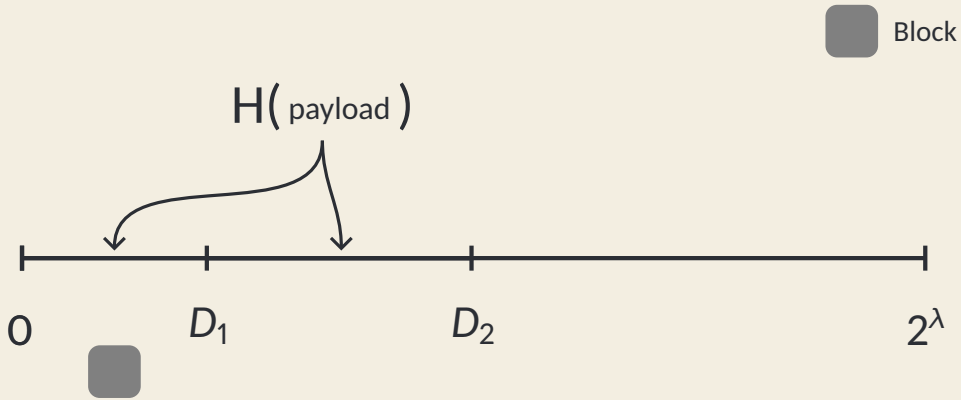

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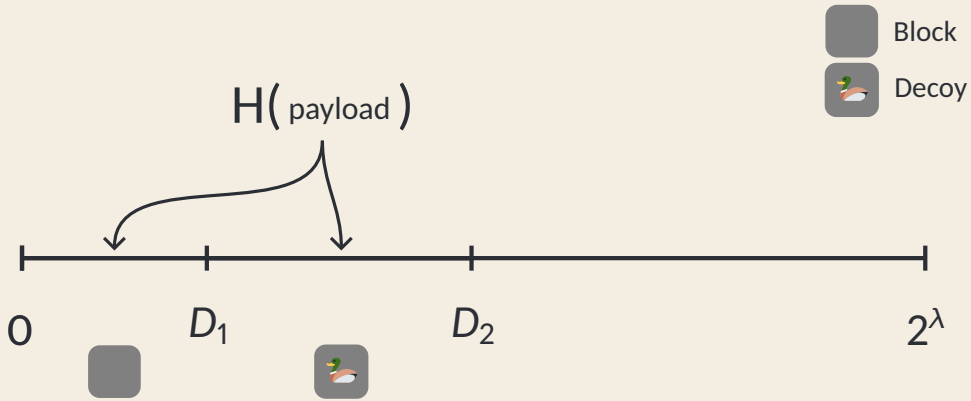

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   - Multicast the puzzle
   - Receive puzzles
   - Batch open puzzles
   - Extend the chain and go to step 1

Block Decoy

Protocol

Miner 1

Miner 3

Miner 2

Miner 4

Block Decoy

Protocol

Miner 1

Mine Phase

Miner 3

Miner 2

Miner 4

Block Decoy

Protocol

Miner 1

Mine Phase

Miner 3

Miner 2

Miner 4

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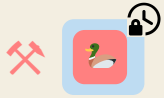

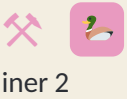

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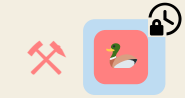

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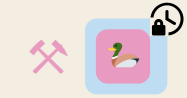

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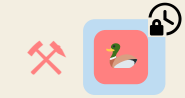

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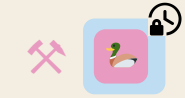

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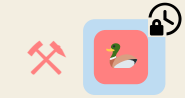

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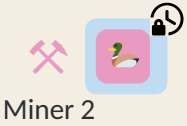

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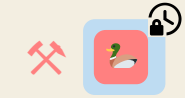

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Solve Phase

Miner 3

Miner 2

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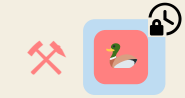

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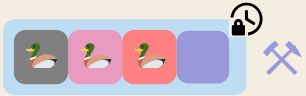

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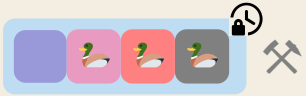

Miner 4

Block Decoy

Protocol

Miner 1

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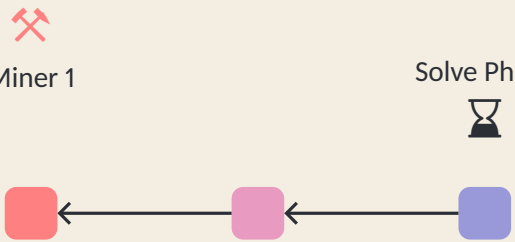

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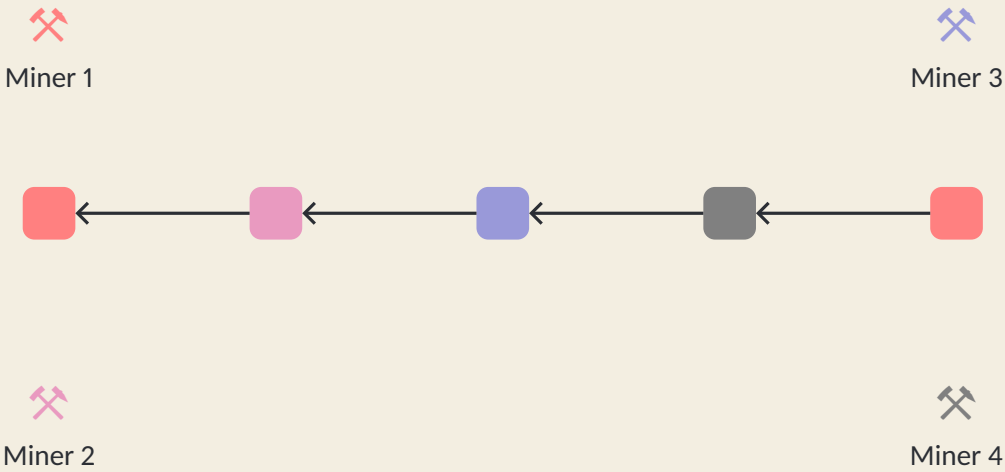

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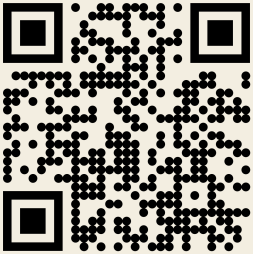

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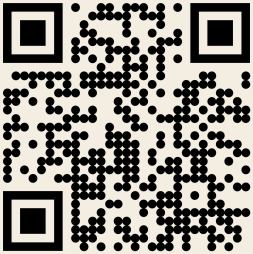

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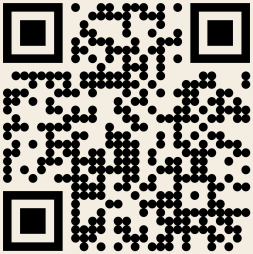

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Broadcast under strongly adaptive and majority corruptions

- Byzantine broadcast is a classical problem in consensus
- Building block for other flavours of consensus
- *Strongly* adaptive adversary:
  - Can corrupt the victim on-the-fly
  - Can perform *after-the-fact* removal in the ongoing round
- *Weakly* adaptive adversary:
  - Can corrupt the victim on-the-fly
  - Cannot perform *after-the-fact* removal

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