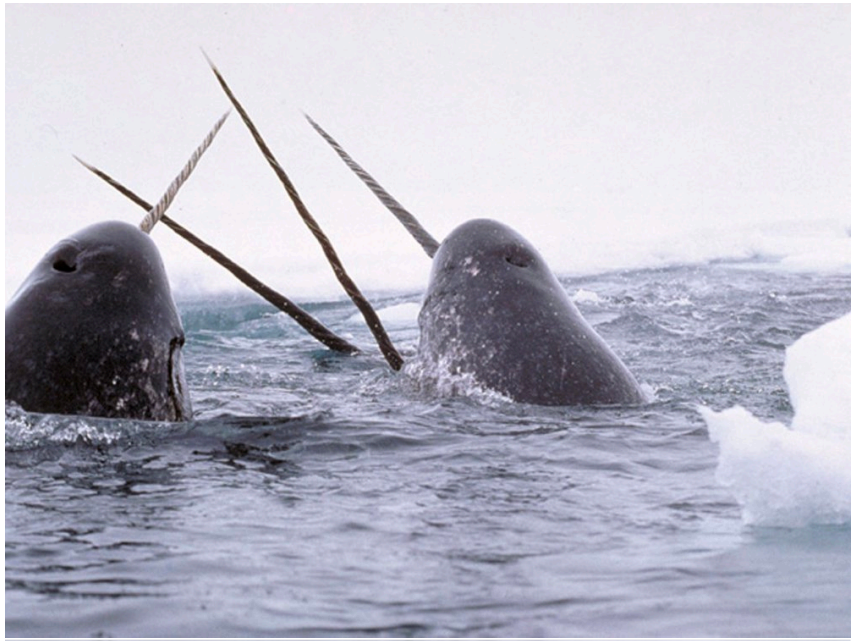
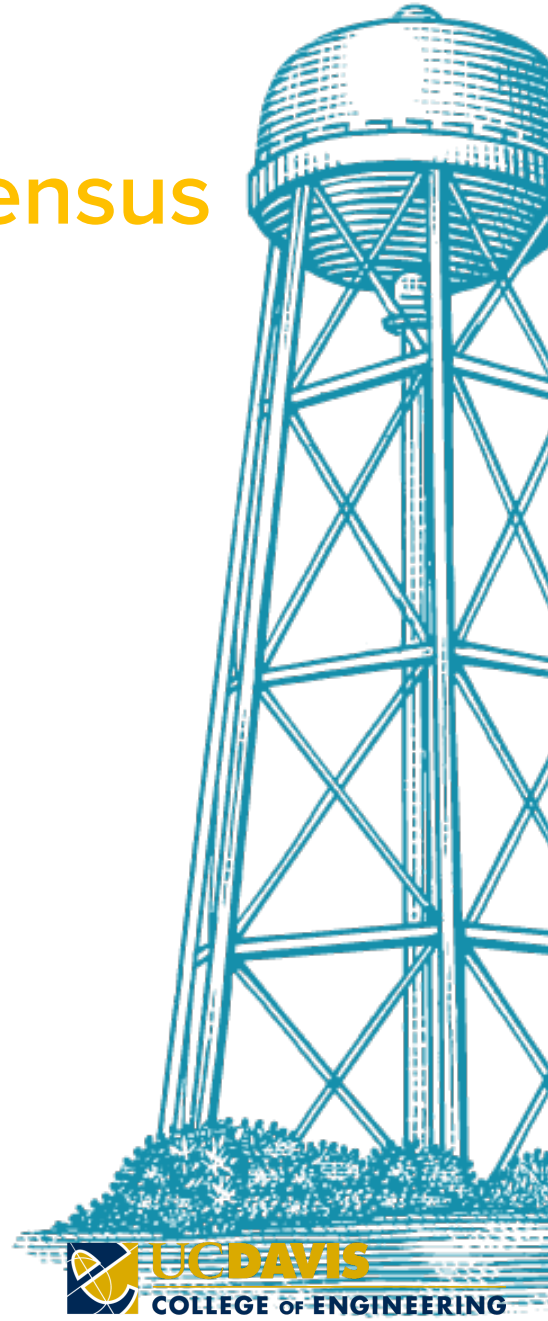
Narwhal and Tusk:
A DAG-based Mempool and Efficient BFT Consensus



Presented by:
Aditya Kumar Bej, Madhumitha Santhanakrishnan, Shreya Gundu and Shristi Suman

The slides are closely adapted from Alberto Sonnino's slides



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To build (really) high performance blockchains

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To build (really) high performance blockchains

But how?

INTRODUCING NARWHAL AND TUSK

Narwhal

A Directed Acyclic Graph (DAG) based Mempool protocol

Tusk

Zero-message overhead asynchronous consensus protocol

NARWHAL AND TUSK

Narwhal

A Directed Acyclic Graph (DAG) based Mempool protocol

Questions

What is DAG?

Tusk

Zero-message overhead asynchronous consensus protocol

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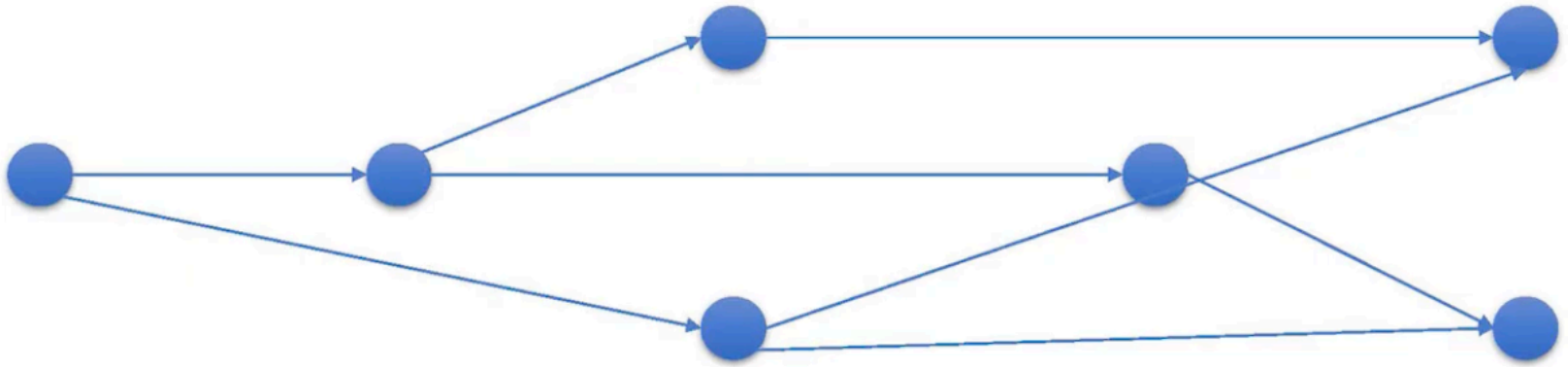
DAG - Directed Acyclic Graph



Graph - Node connected to other nodes
Directed - Connection between nodes have direction (A -> B != B -> A)
Acyclic - Non-circular. No closed loop in the connections.

Mempool 101

Fundamental Understanding

Transactions =
Complexity

What happens when you swipe and wait?

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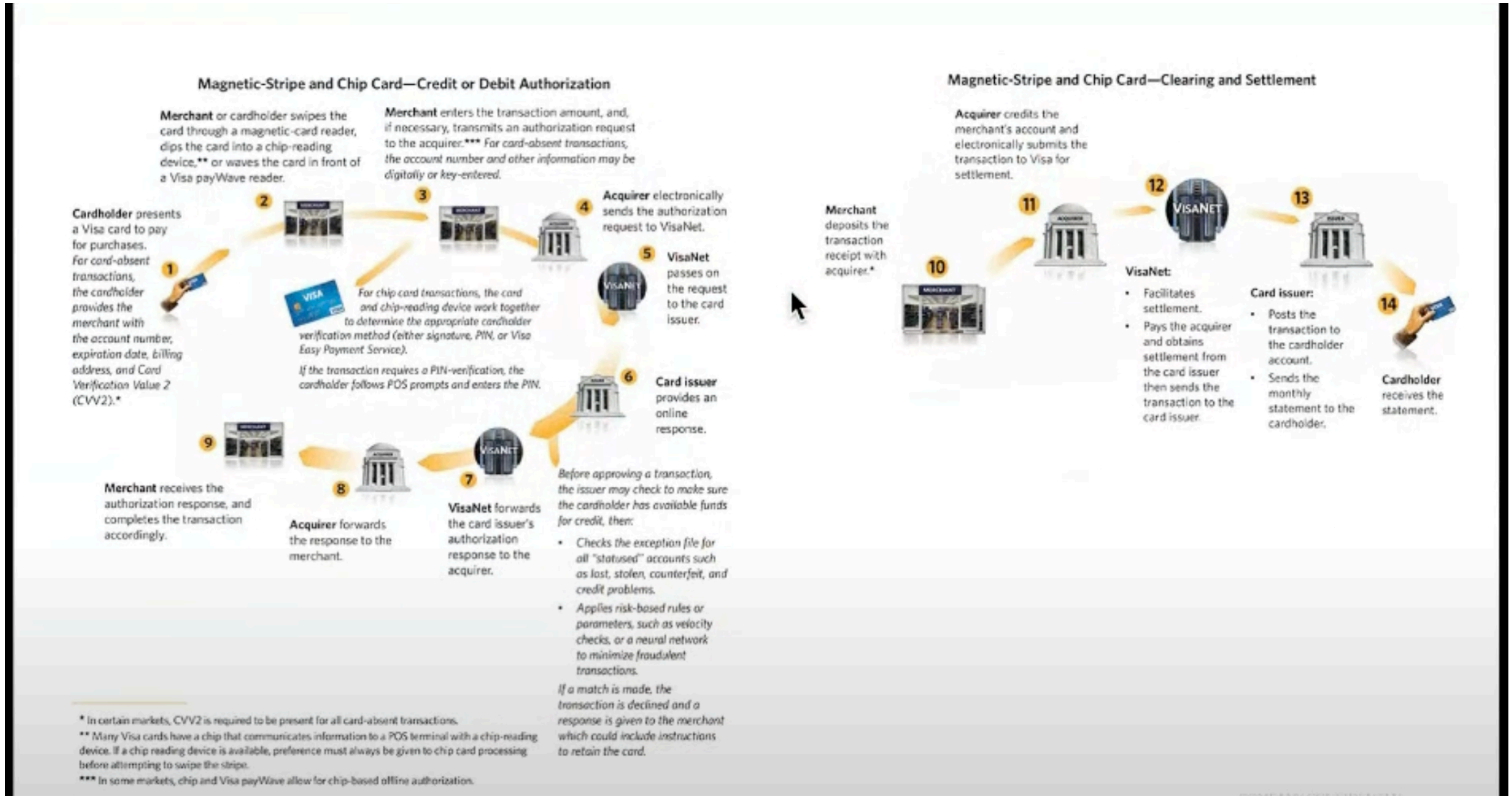
This happens



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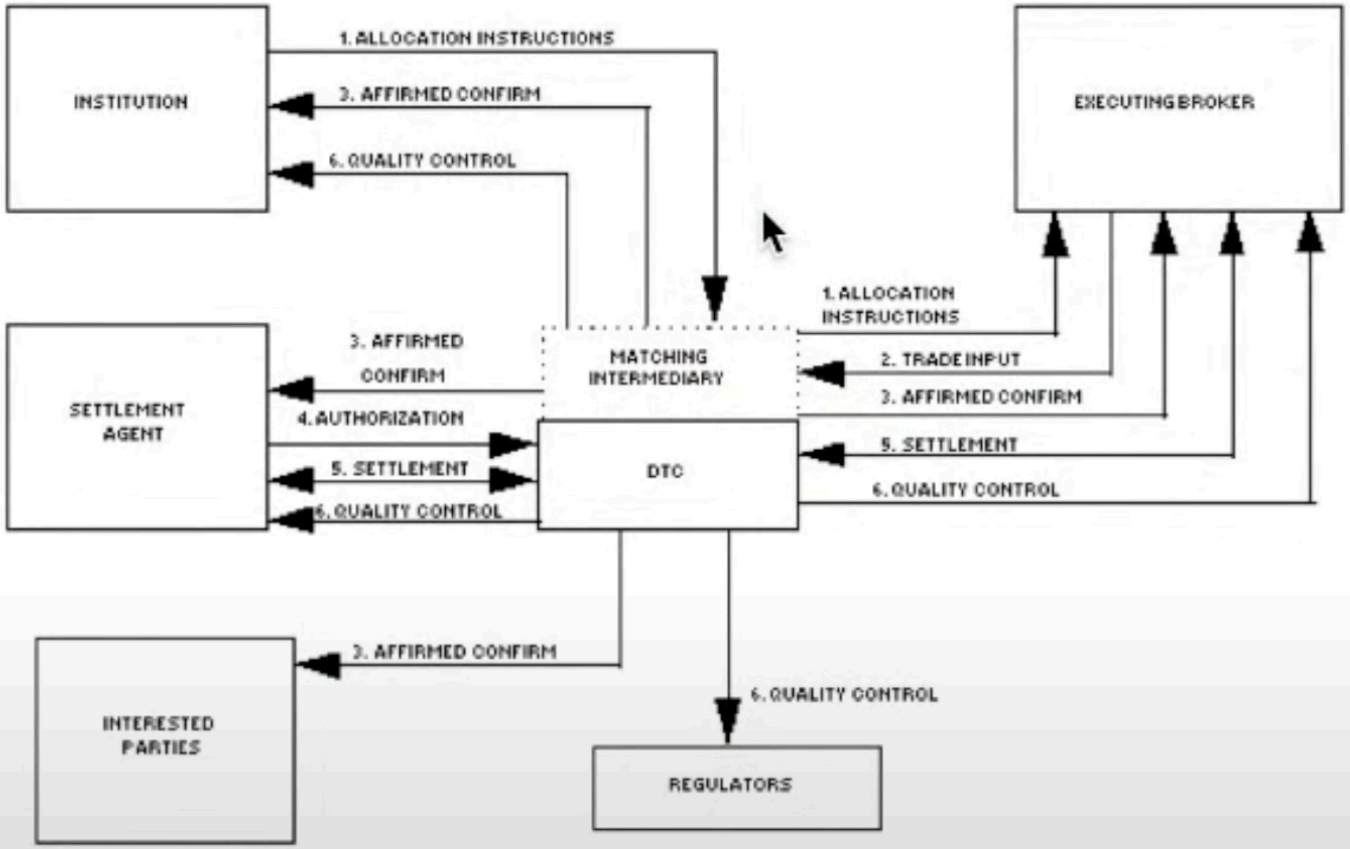
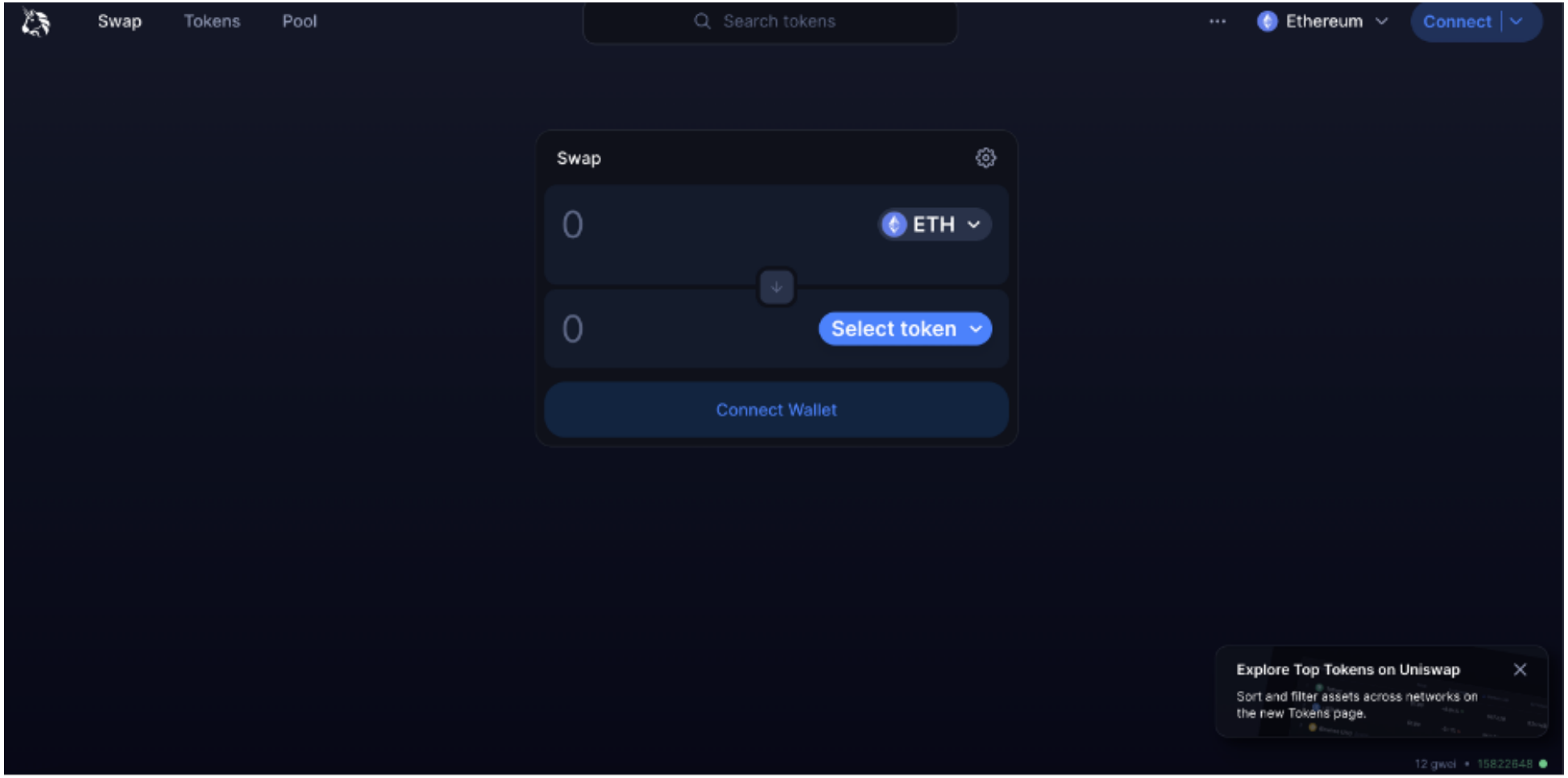
Same is true for a stock market application



Onto a Crypto Trading application



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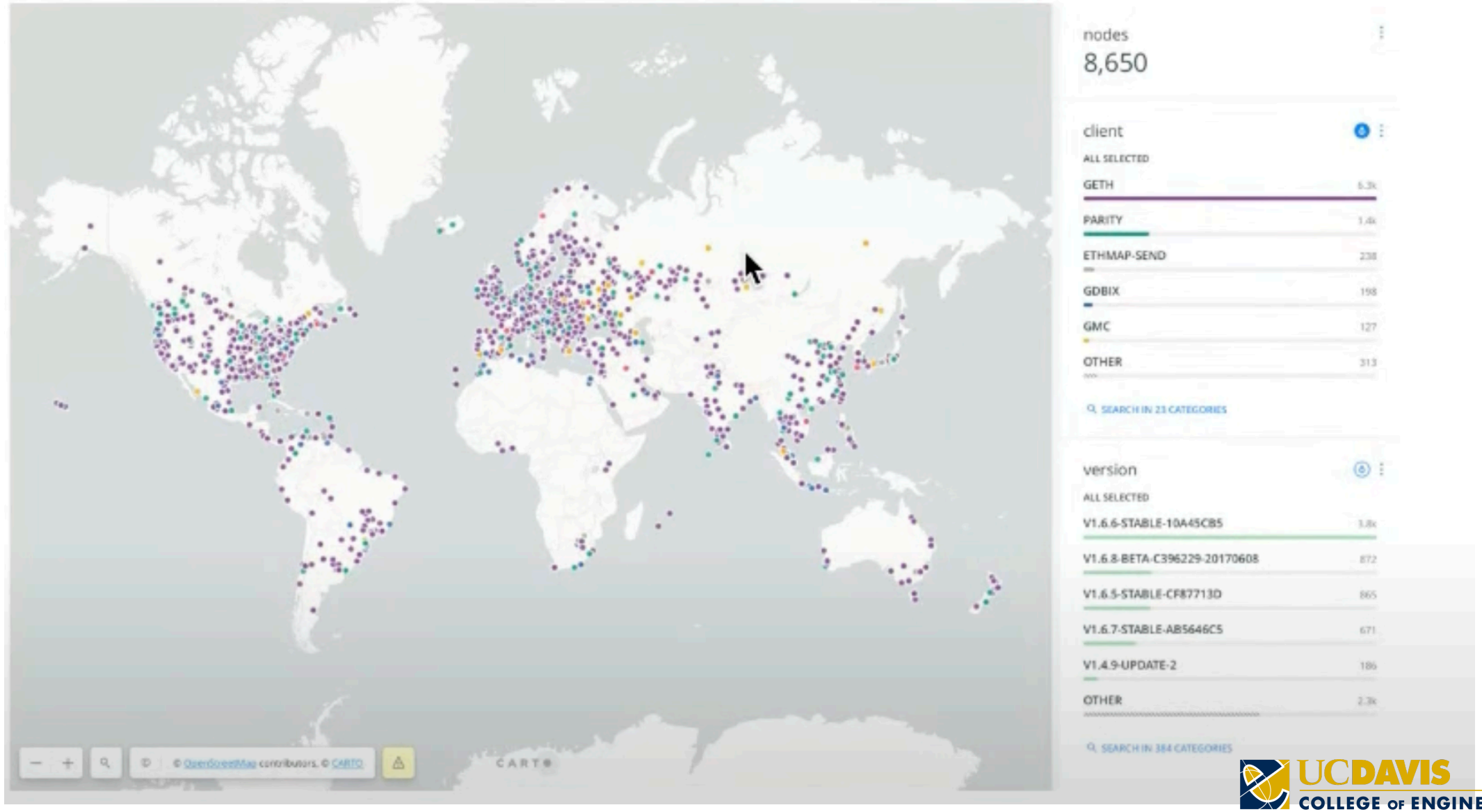
Ethereum Network



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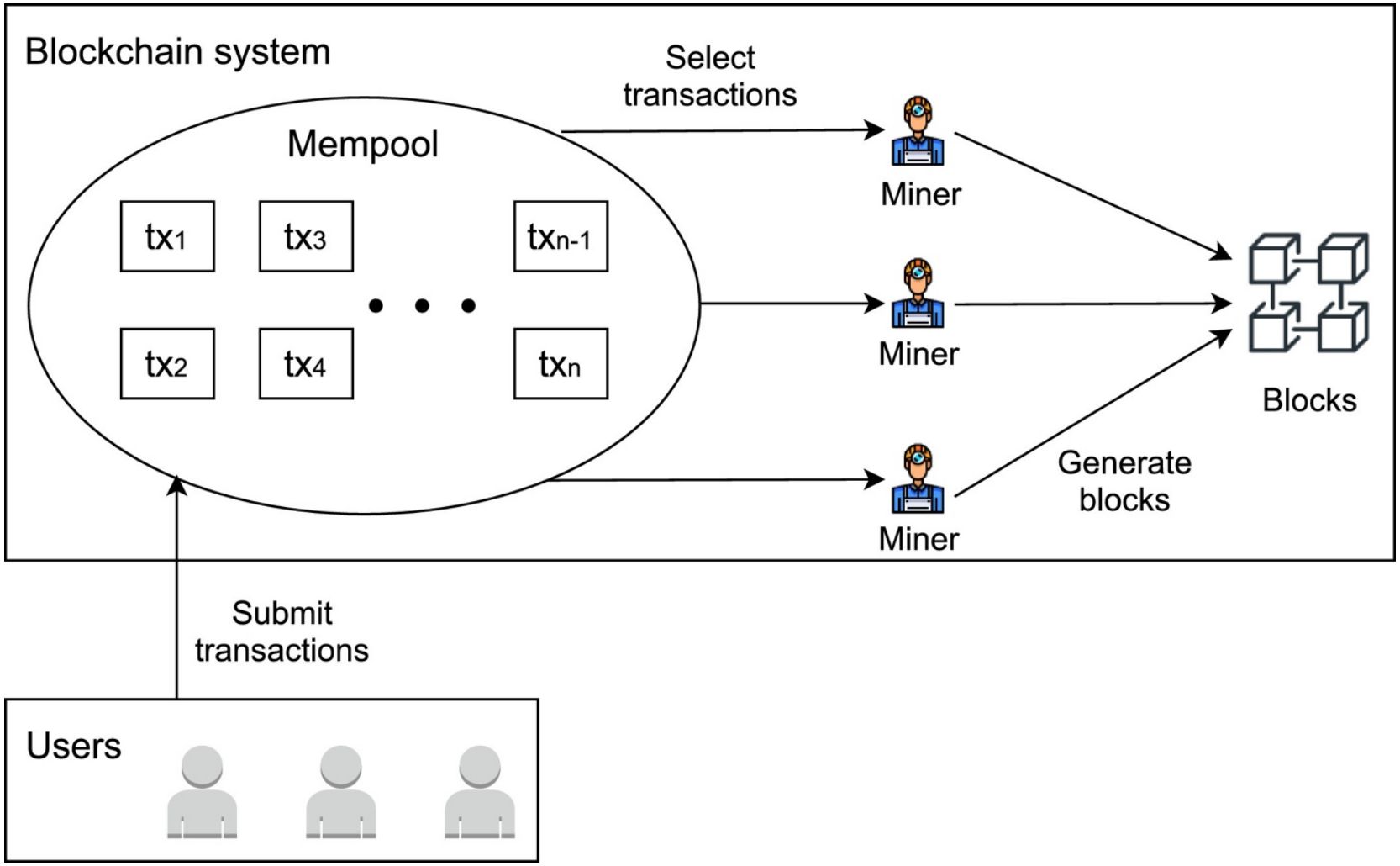
Mempool



1
Mempool = PRE-CONSENSUS

2

There is **no single** mempool

3

Each mempool has its **own unique set of transactions**

4

Each mempool has its **own unique characteristics** based on client type, configuration, peers

5

The mempool is mutable due to Replacement Transactions, including Speed ups & Cancels

6

The mempool is an **inconsistent** ‘**fabric**’ that grows lumpy during congestion/pressure

7

Your transaction competes in the mempool for block space

Traditional Transactions

Like a ballroom dance

- Very orderly
- Plays by the rules

Blockchain Transactions: Expectations

Like a flash mob

- More spontaneous
- Organic

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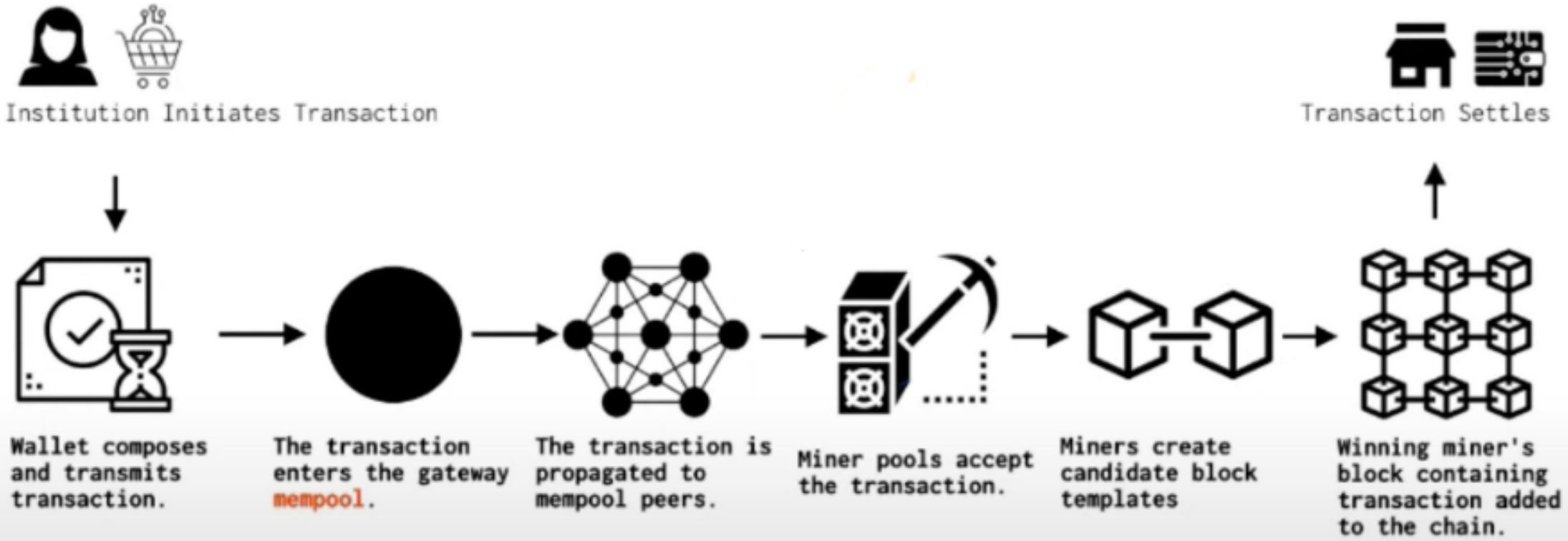
Blockchain Transactions: Reality

Like a mosh pit

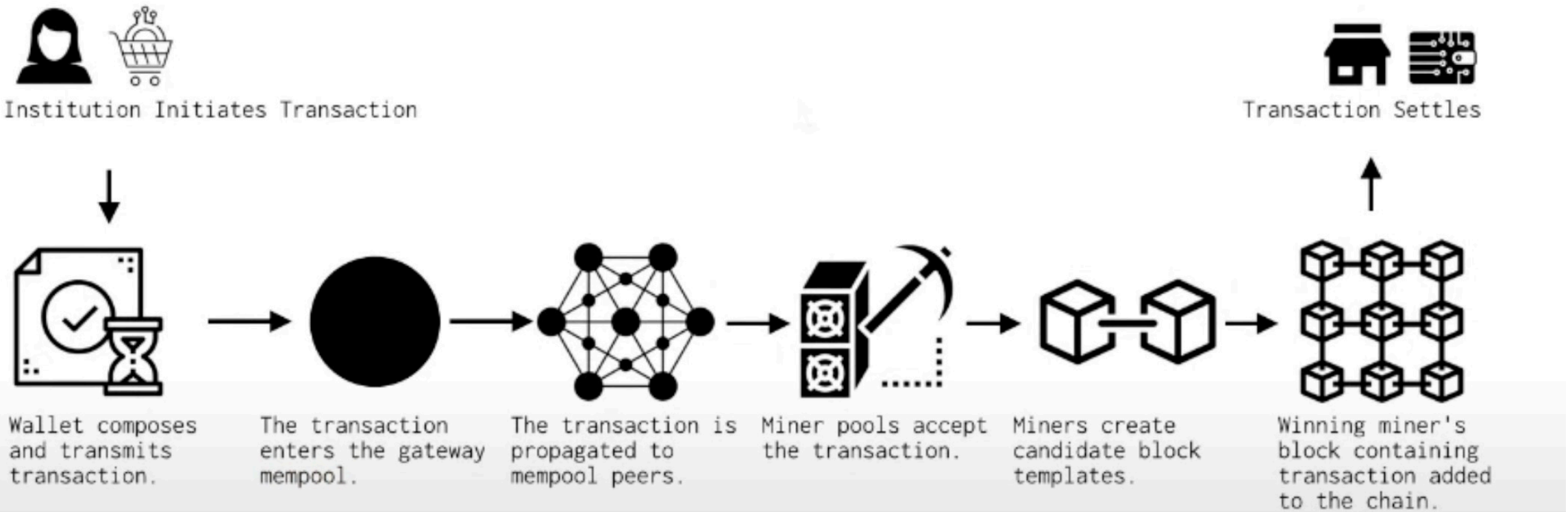
- Txs competing for confirmation
- Un-orchestrated fashion

Behind the scenes of Blockchain Transaction Operations and our **Area of Focus**

Blockchain Transaction Operations:
Behind The Scenes



Blockchain Transaction Operations:
Risks



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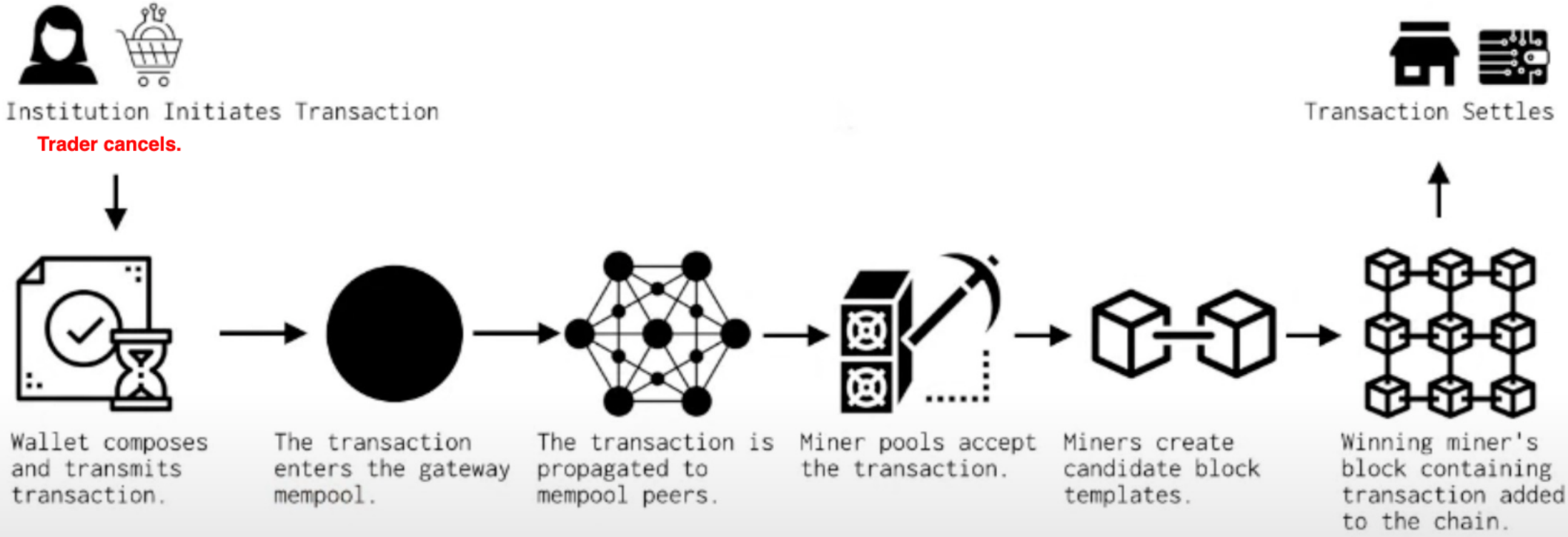

Blockchain Transaction Operations:
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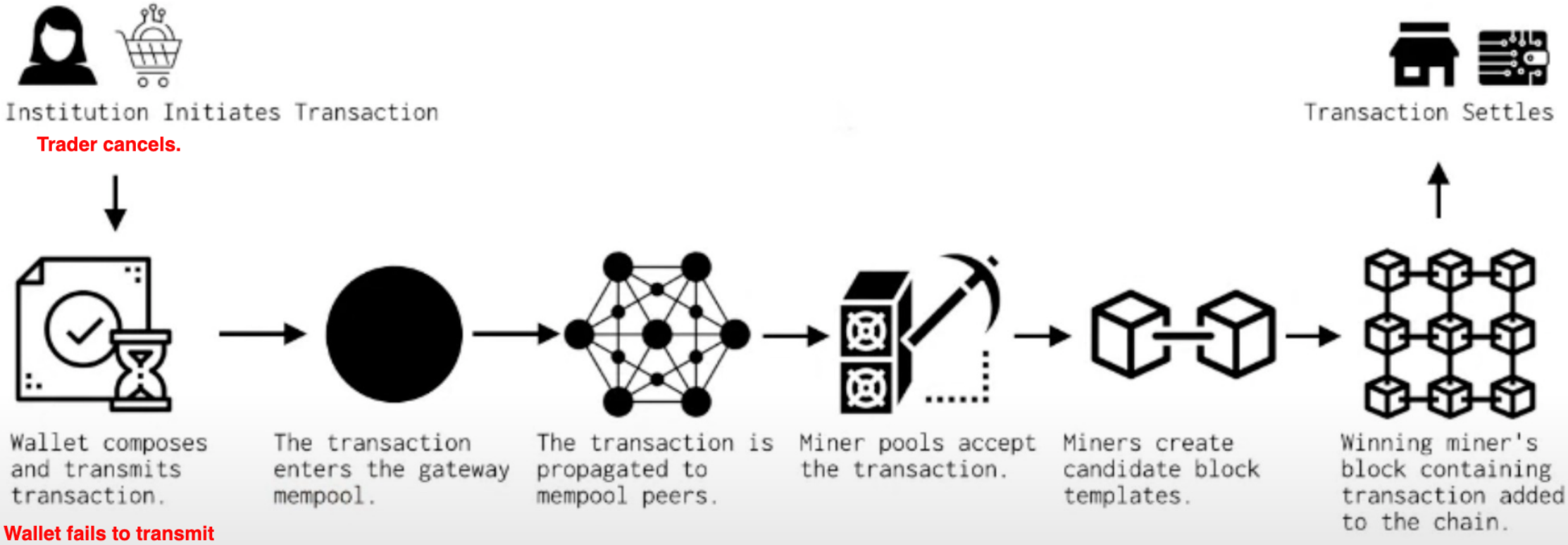

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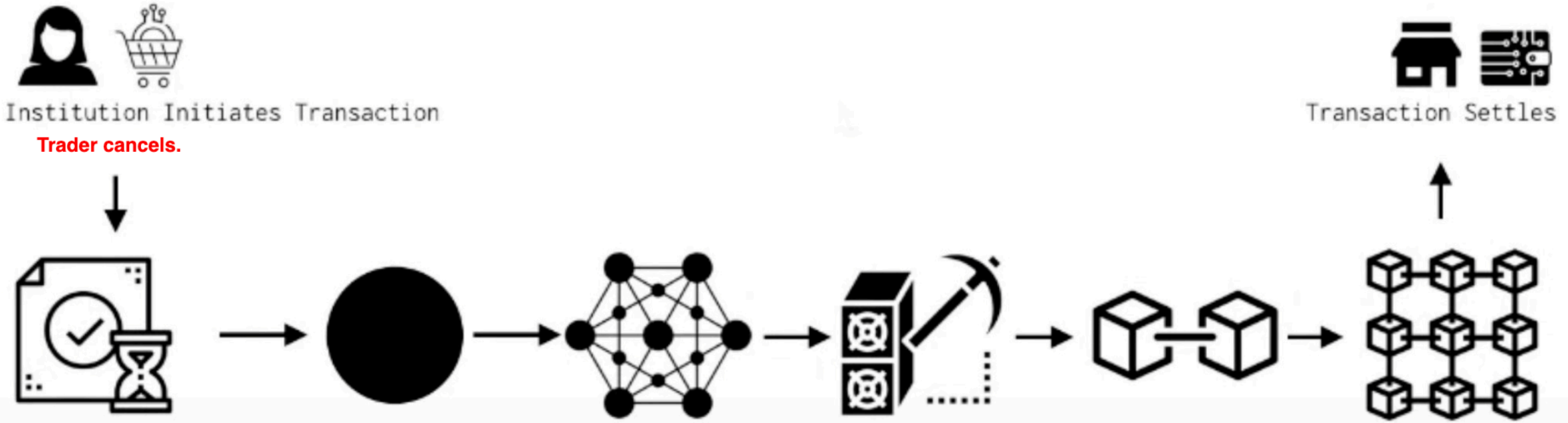

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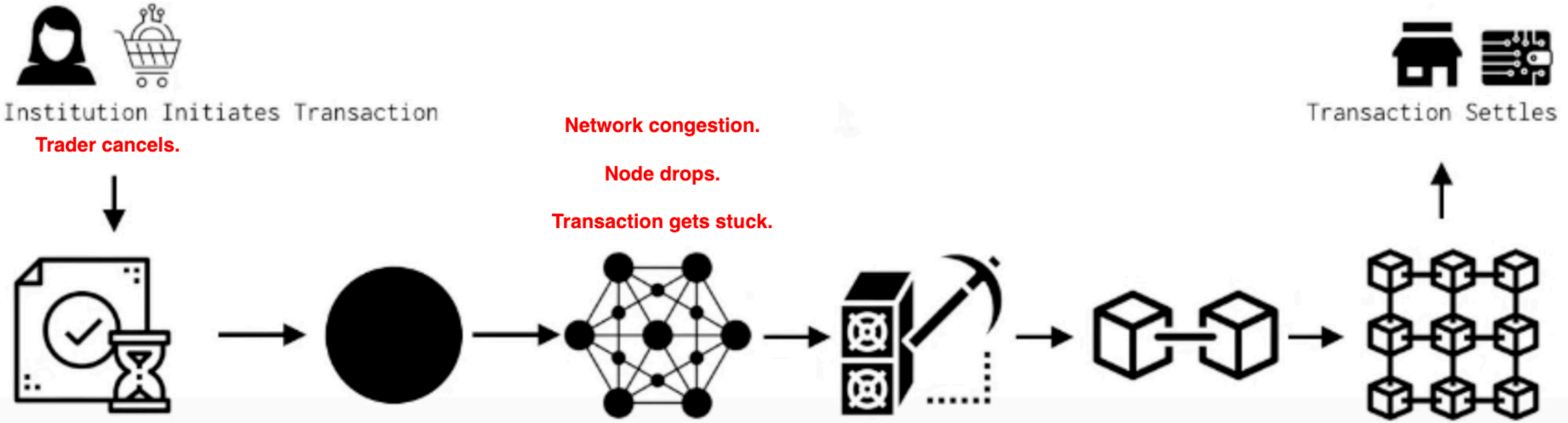

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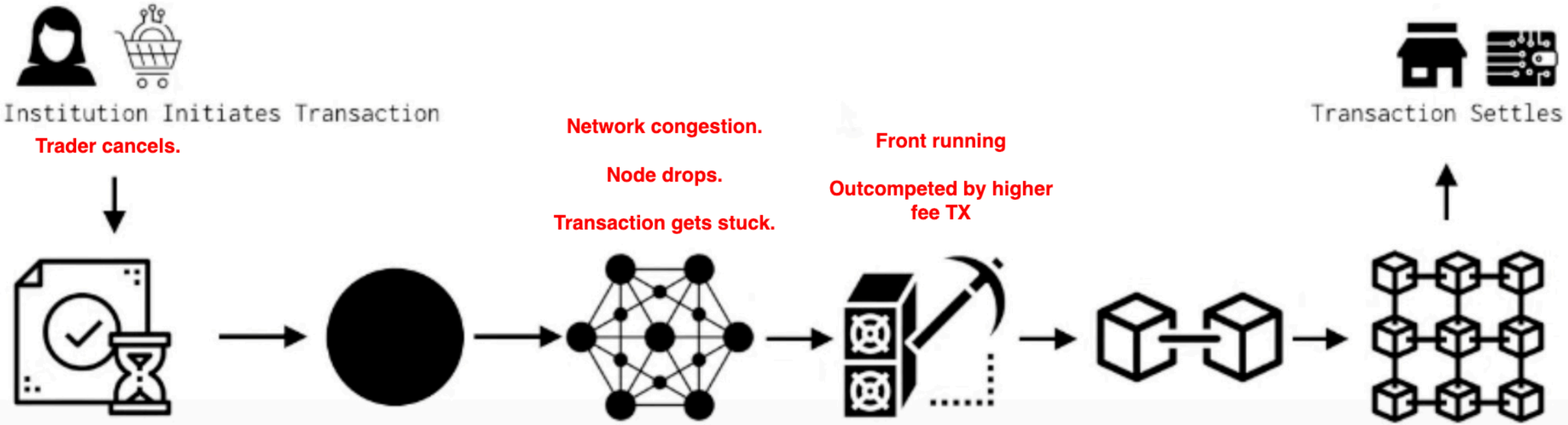

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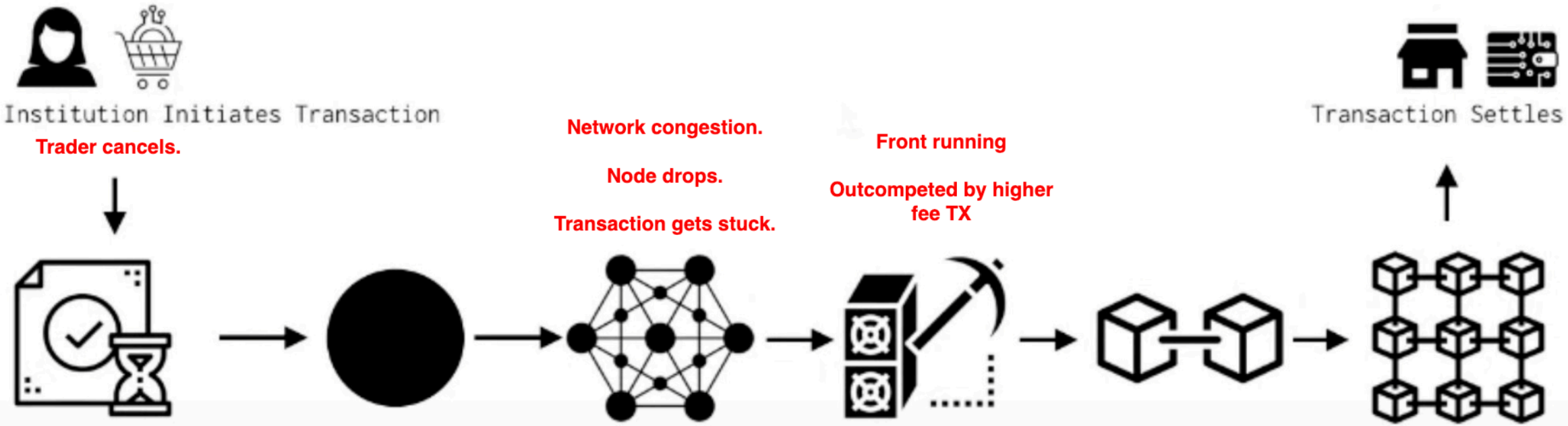

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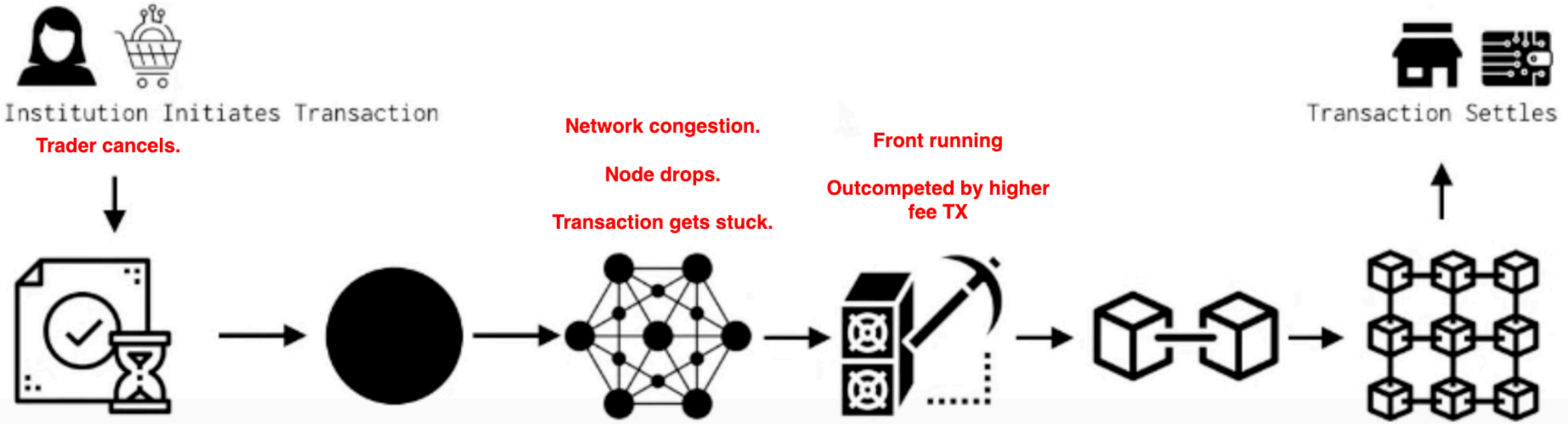

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Blockchain Transaction Operations:

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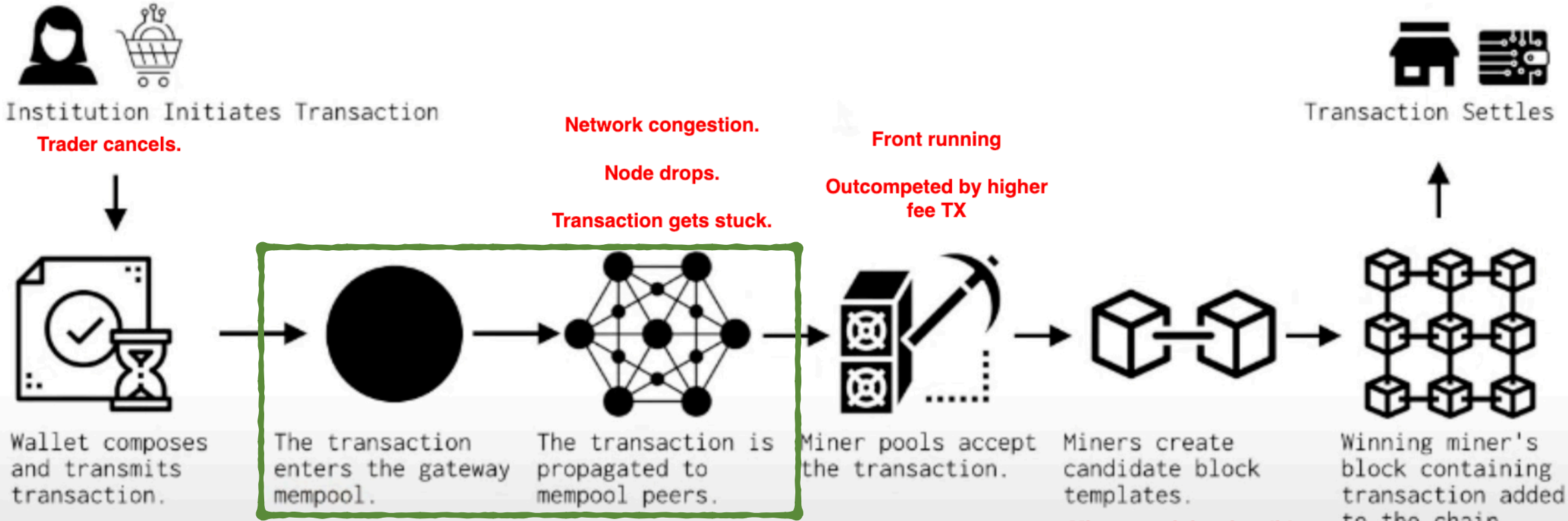

NARWHAL AND TUSK

Narwhal

A Directed Acyclic Graph (DAG) based Mempool protocol

Tusk

Zero-message overhead asynchronous consensus protocol

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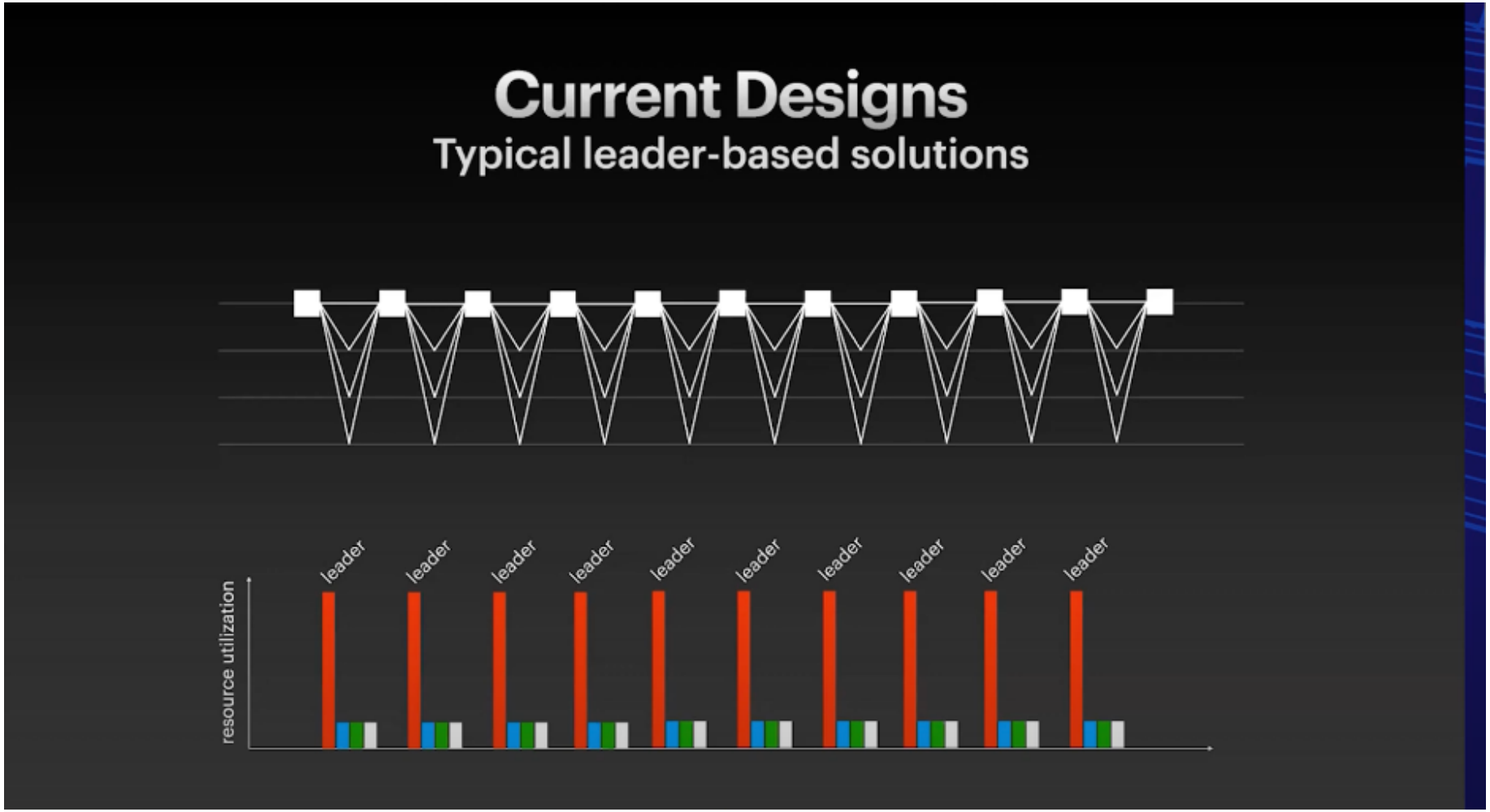
Consensus engine **does not send any message** at all. Hence the term.

NON-EGALITARIAN RESOURCE UTILIZATIONS

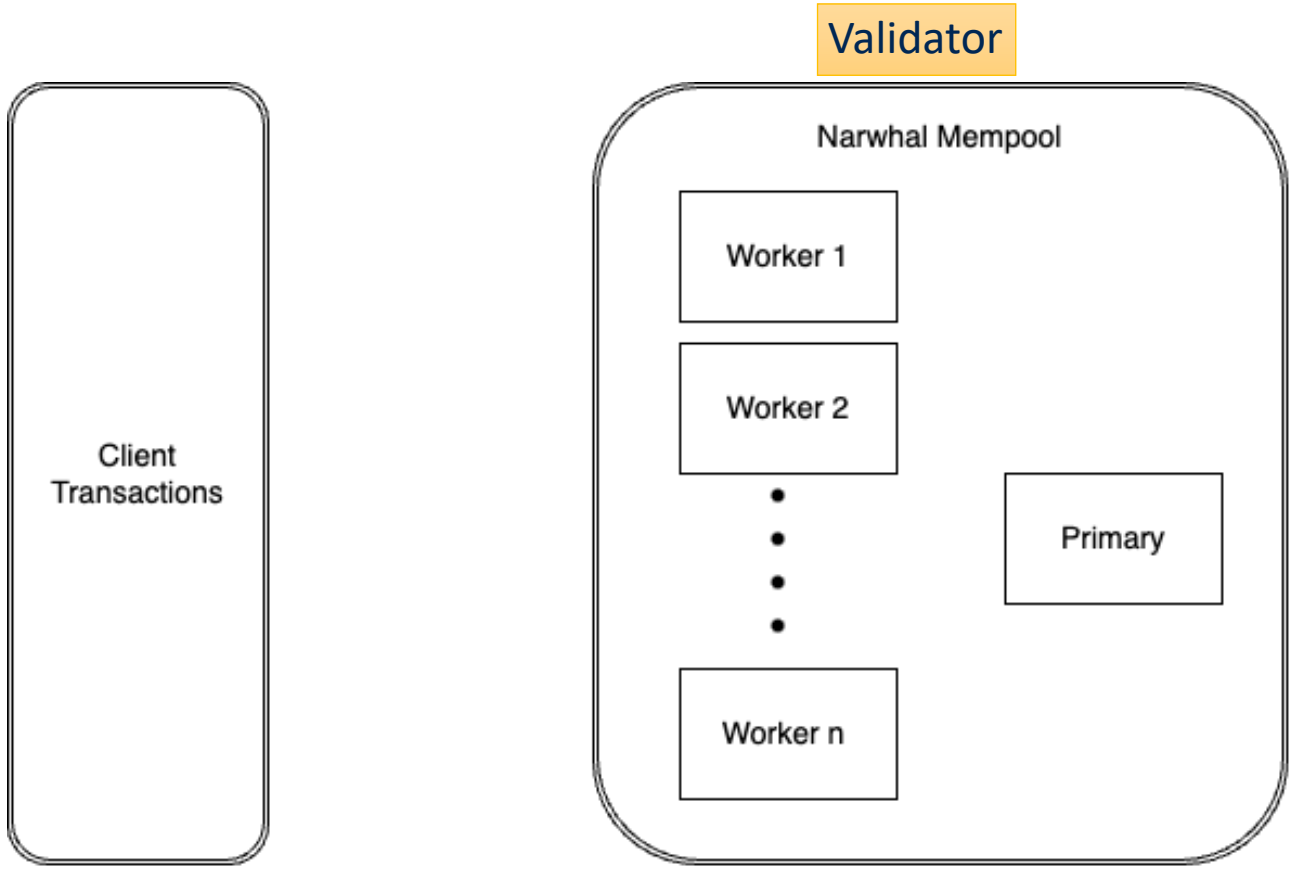


MEMPOOL IS THE KEY

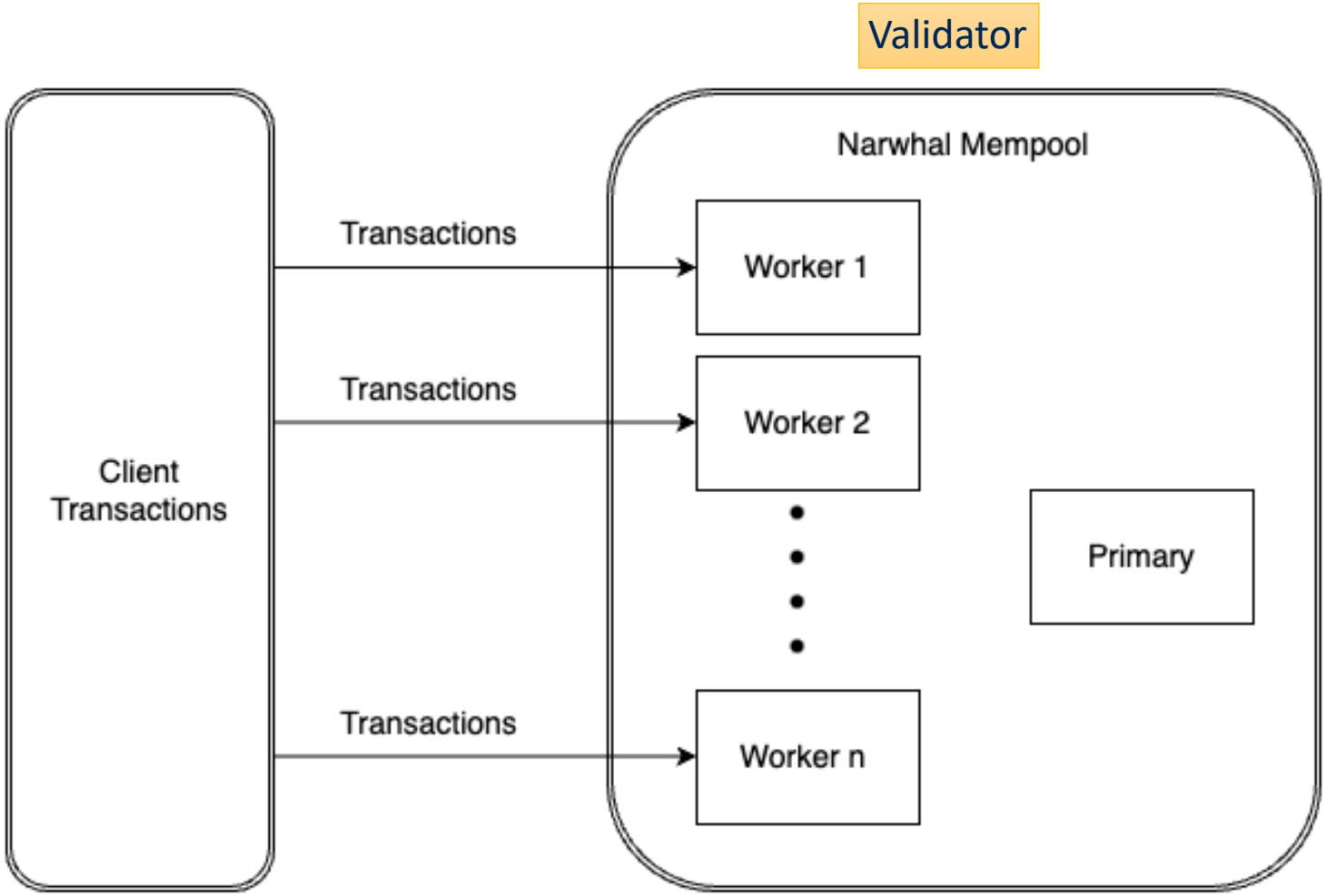
NARWHAL

Narwhal

The workers and the primary in Mempool



Client sends transactions



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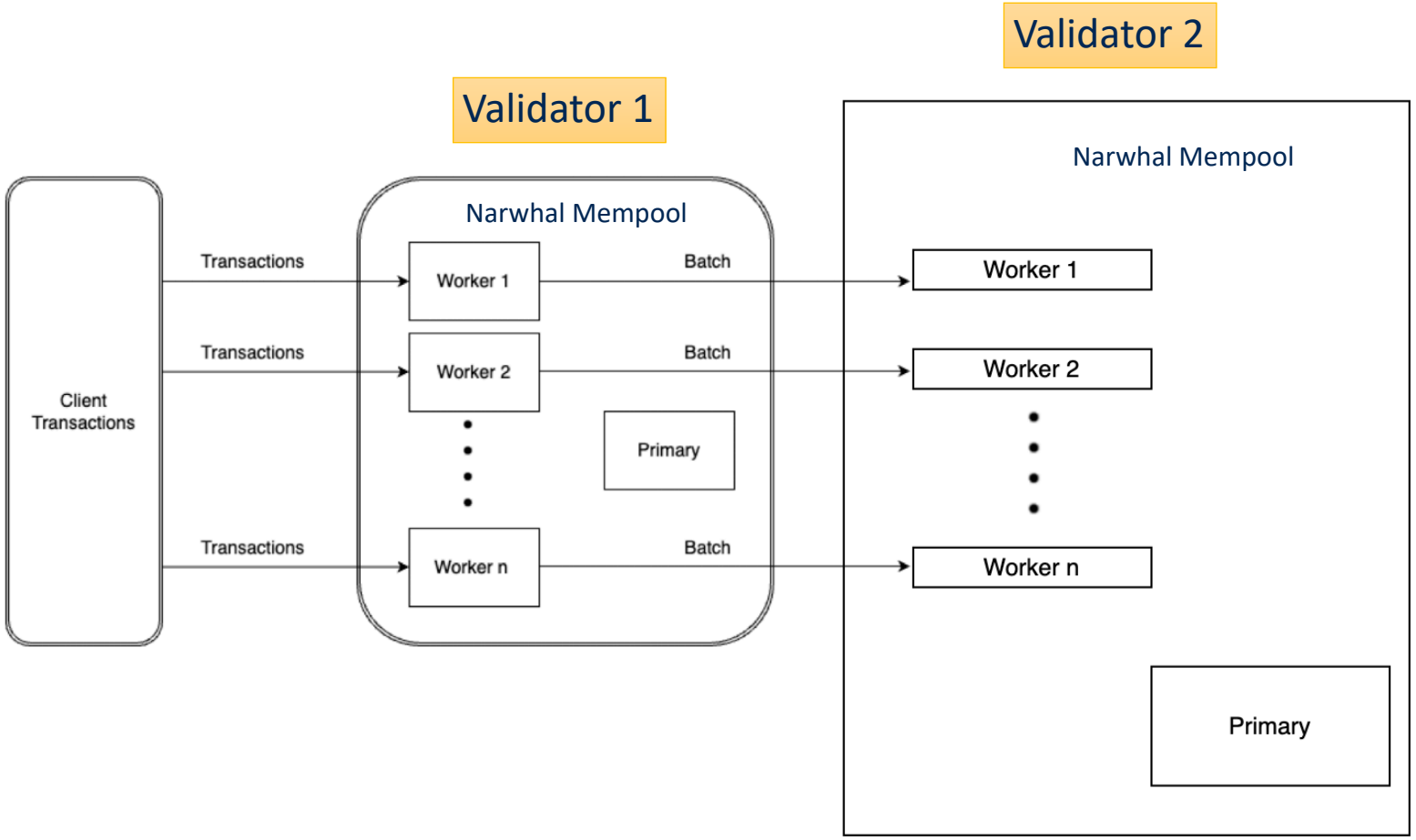
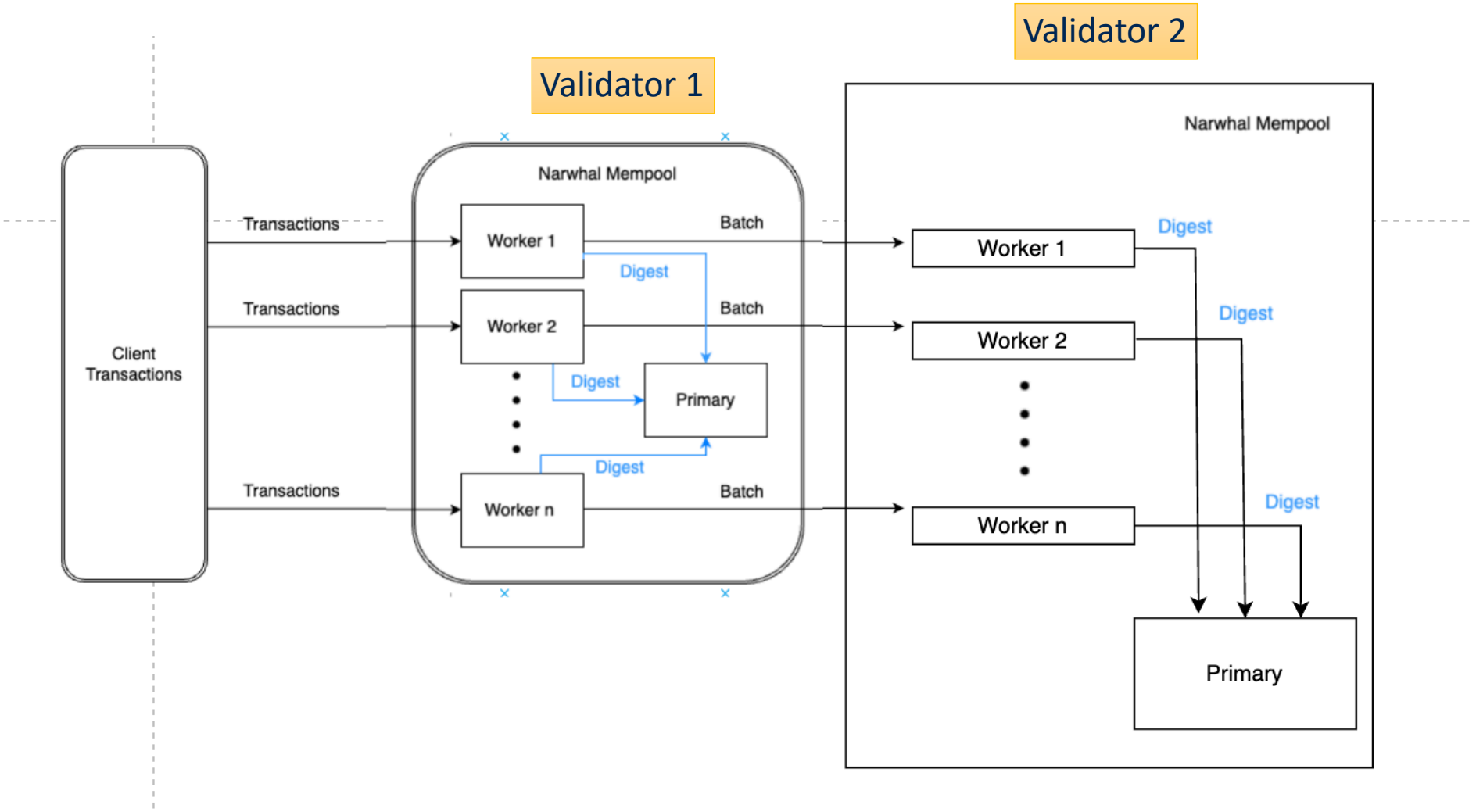
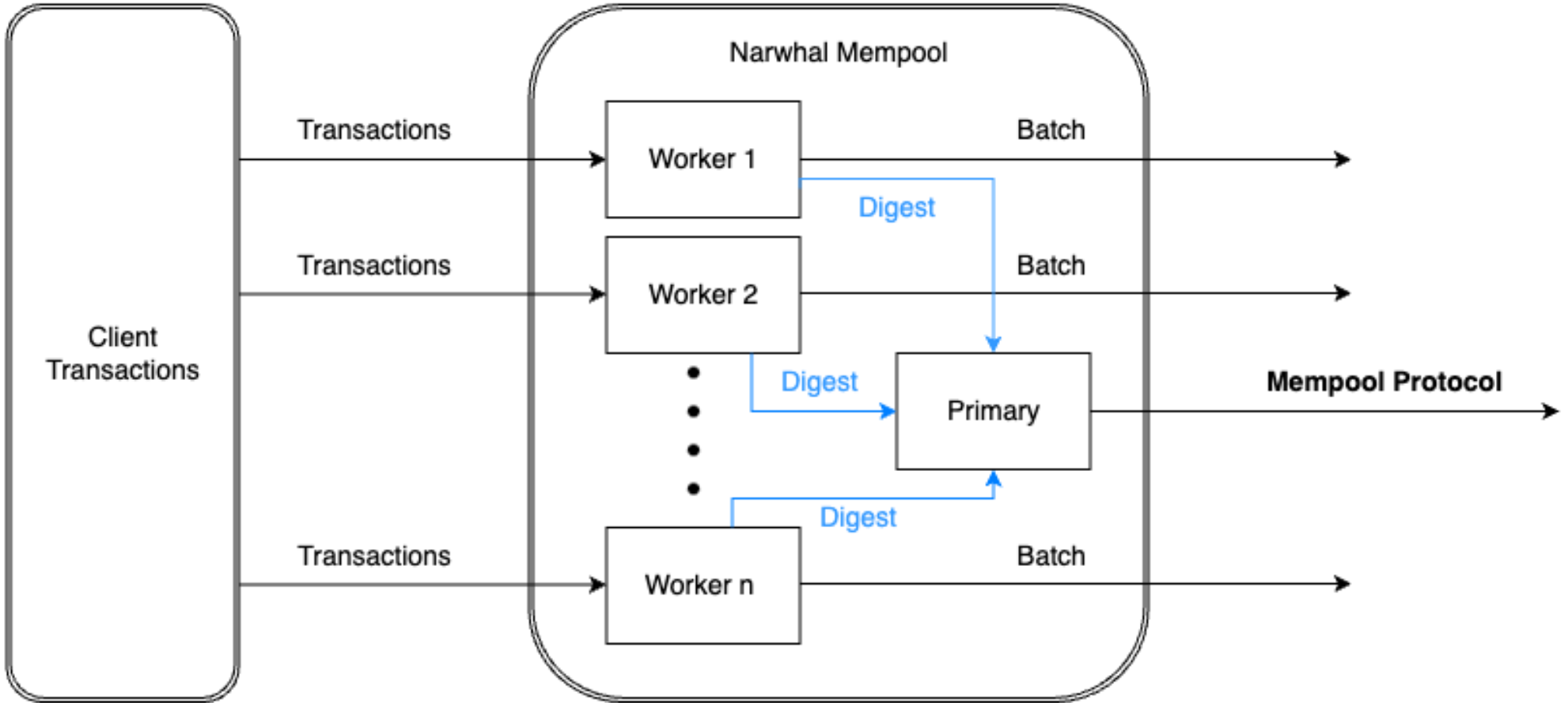
Batching Transactions



Digest sent to primary



Mempool Protocol Initialization



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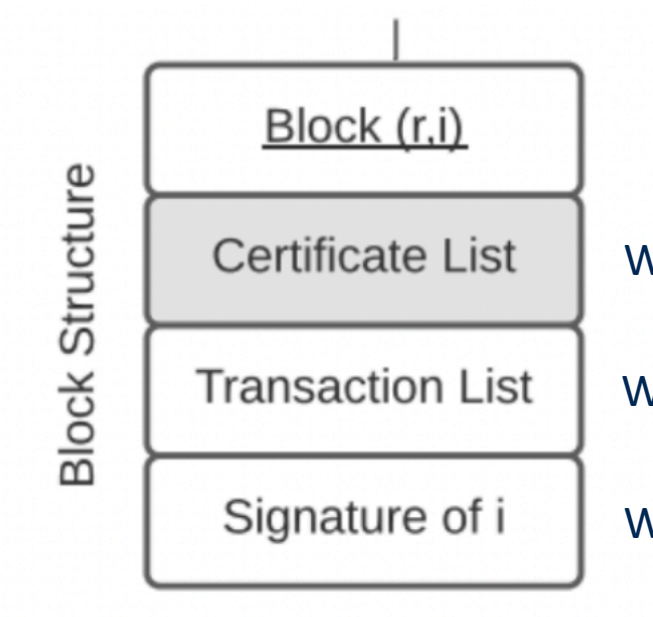
Every Primary creates a Block

Every Primary creates a Block

What does it contain?

Block Structure



Where is this coming from?

We know where this is from. The Client

Where is this coming from?

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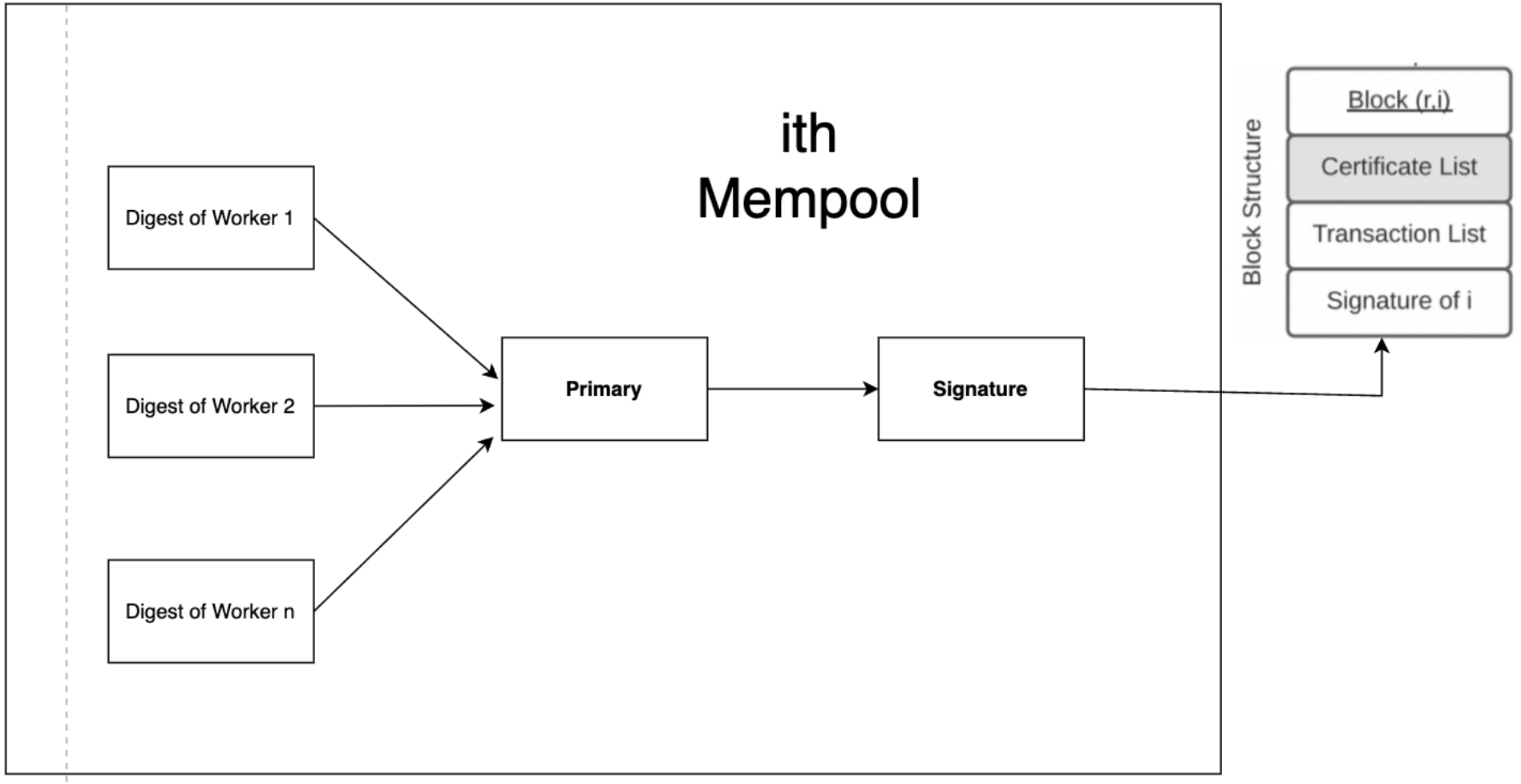
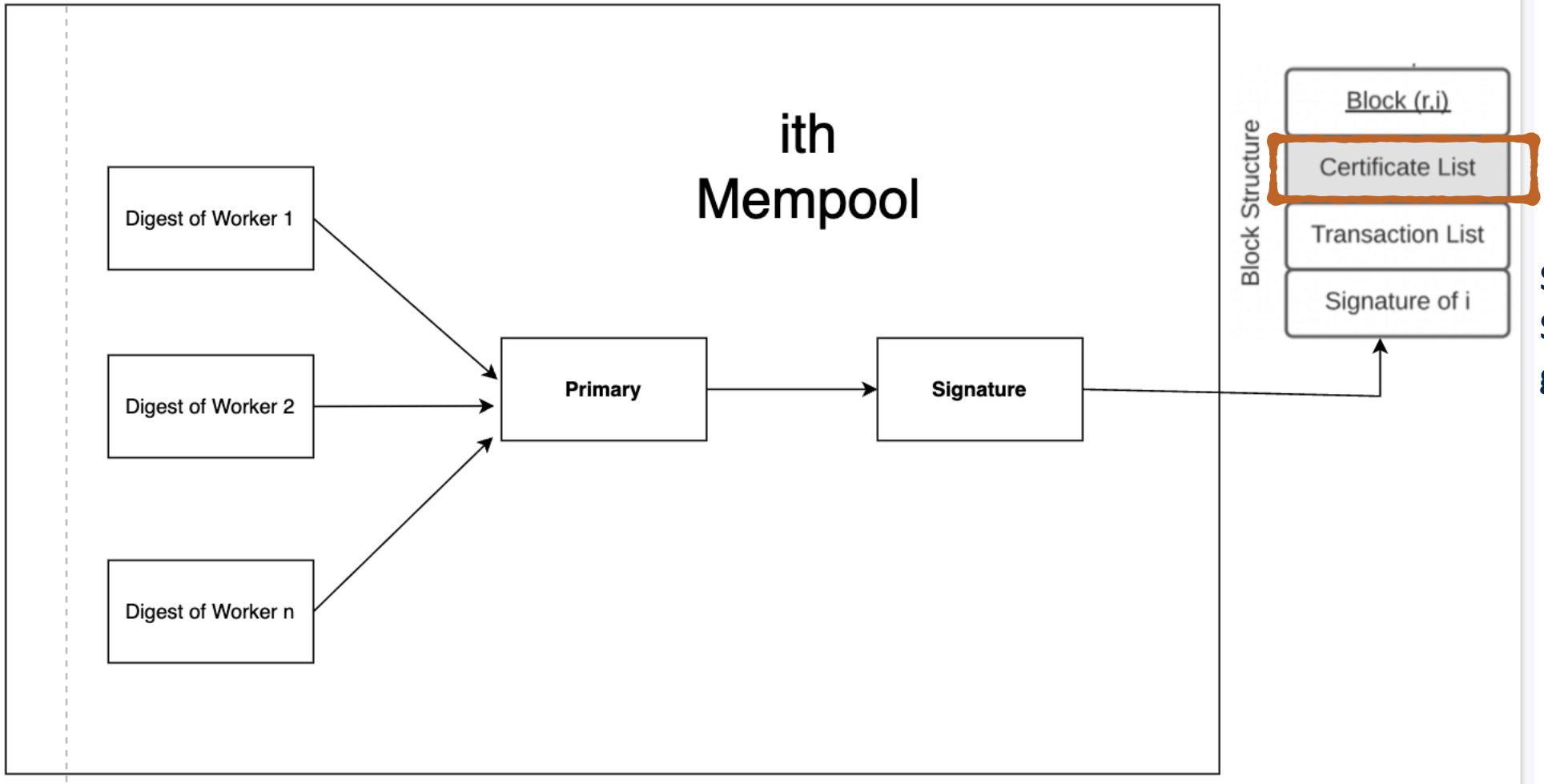
Signature of the Block



So this is how Signature is generated

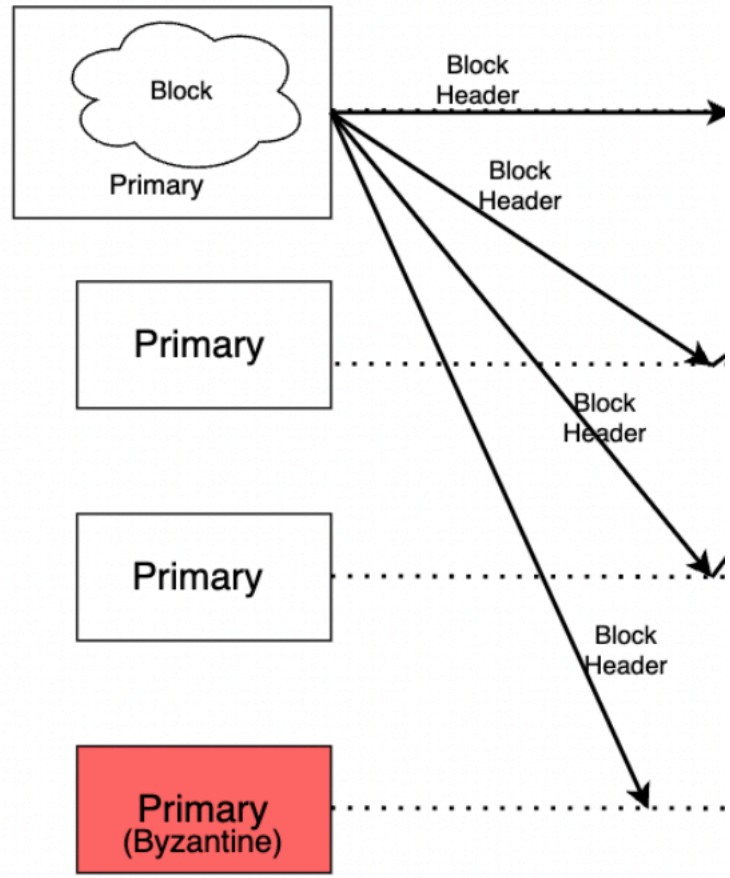
Signature of the Block

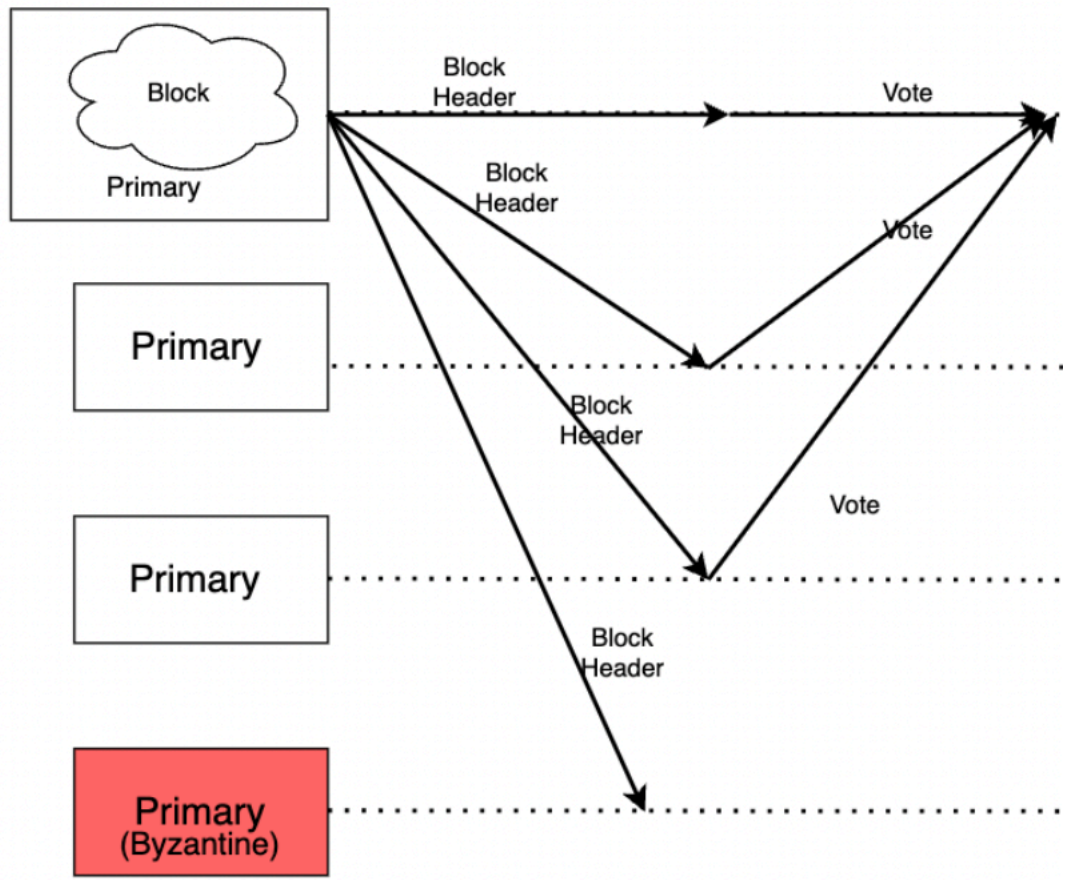


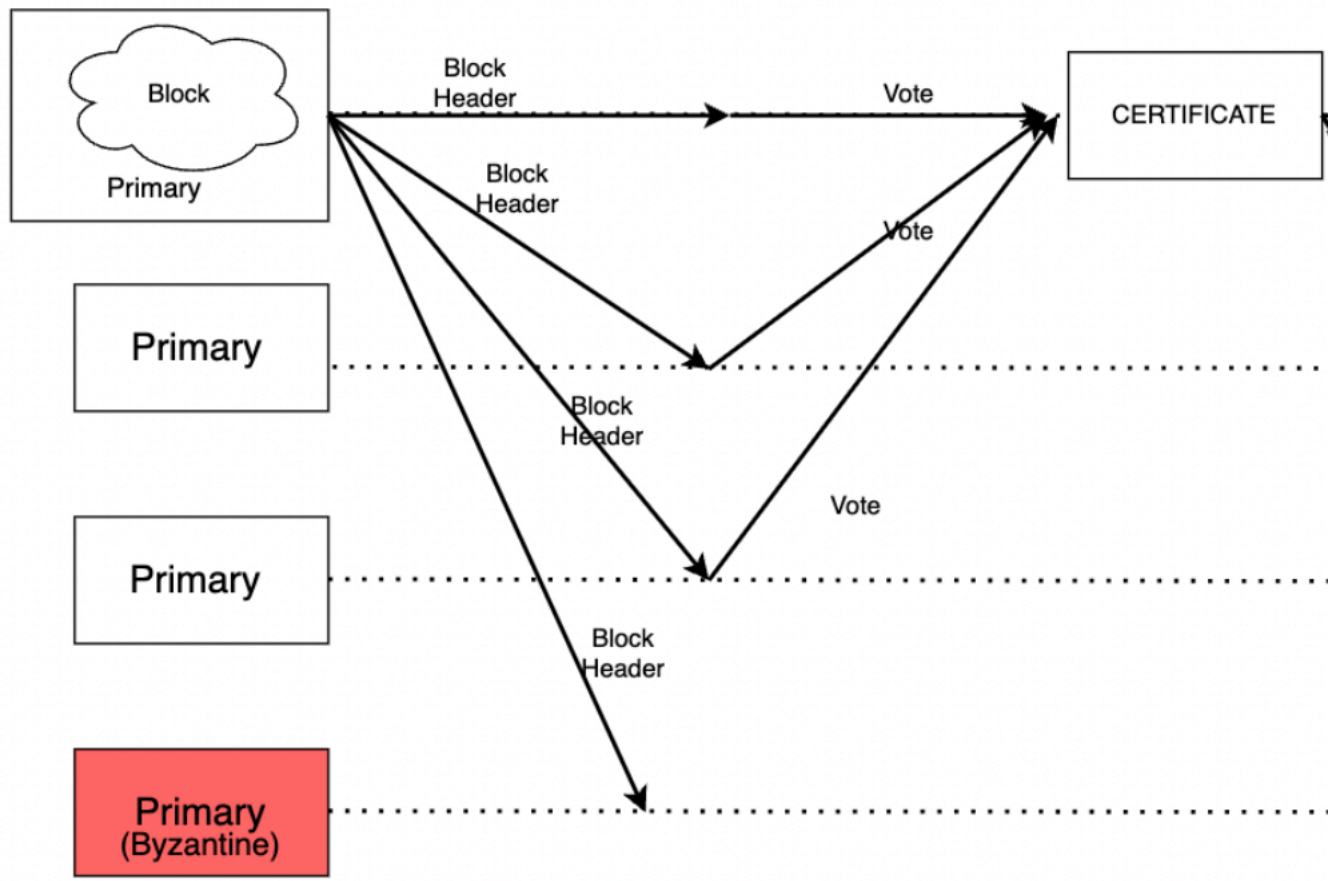
What about this?

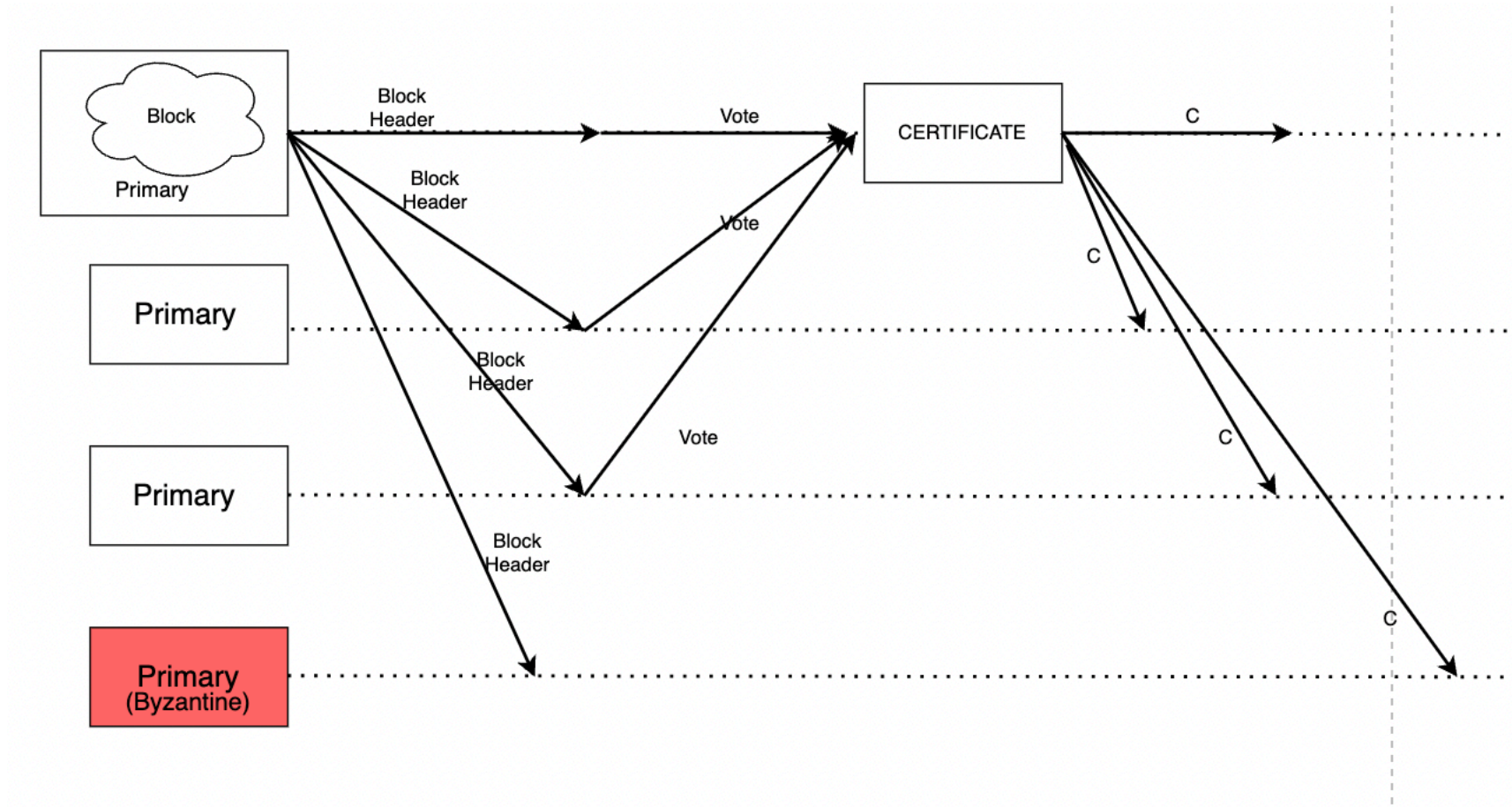
So this is how Signature is generated

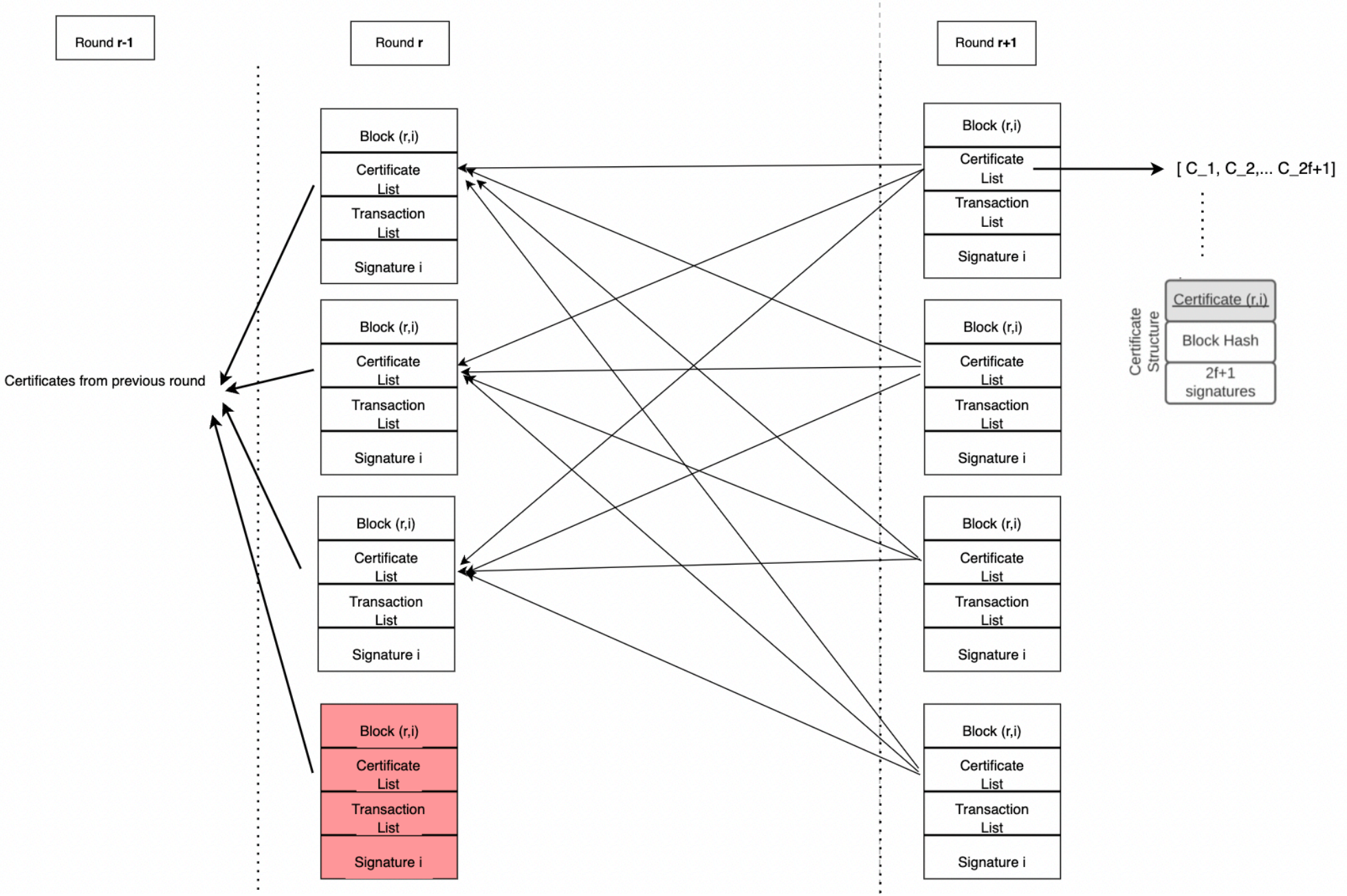
Where are these certificates coming from?


Block
Primary
Block Header
Block Header
Primary
Block Header
Primary
Block Header
Primary
(Byzantine)

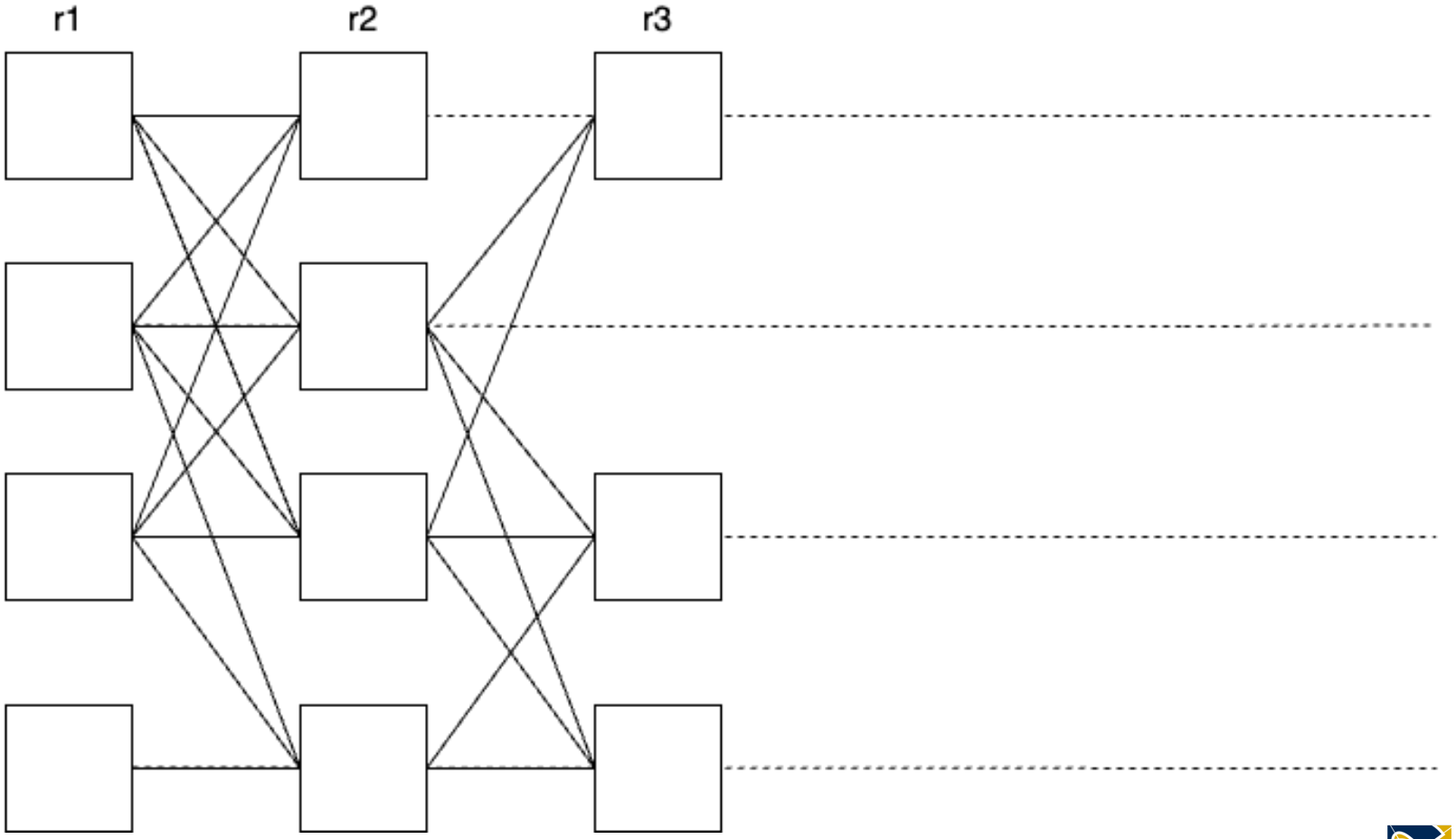

Block
Primary
Block Header
Vote
Block Header
Vote
Primary
Block Header
Vote
Primary
Block Header
Primary
(Byzantine)


Block
Primary
Block Header
Vote
CERTIFICATE
Block Header
Vote
Primary
Block Header
Vote
Primary
Block Header
Primary
(Byzantine)


Block
Primary
Block Header
Vote
CERTIFICATE
C
Block Header
Vote
C
Primary
Block Header
Vote
C
Primary
Block Header
C
Primary
(Byzantine)


Round r-1
Round r
Round r+1
Certificates from previous round
Block (r,i)
Certificate List
Transaction List
Signature i
[C_1, C_2,... C_2f+1]
Certificate Structure
Certificate (r,i)
Block Hash
2f+1 signatures

This is the DAG created in Narwhal



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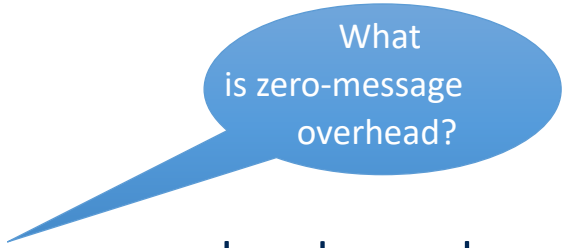

- A zero-message overhead asynchronous consensus protocol
- DAG —> Starting point
- Three consecutive rounds
  - First round - Each validator proposes its block and **causal** history (**PROPOSE**)
  - Second round - Each validator votes on the proposal by including them in their block (**VOTE**)
  - Third round - Validators produce randomness to elect a random leader's block.

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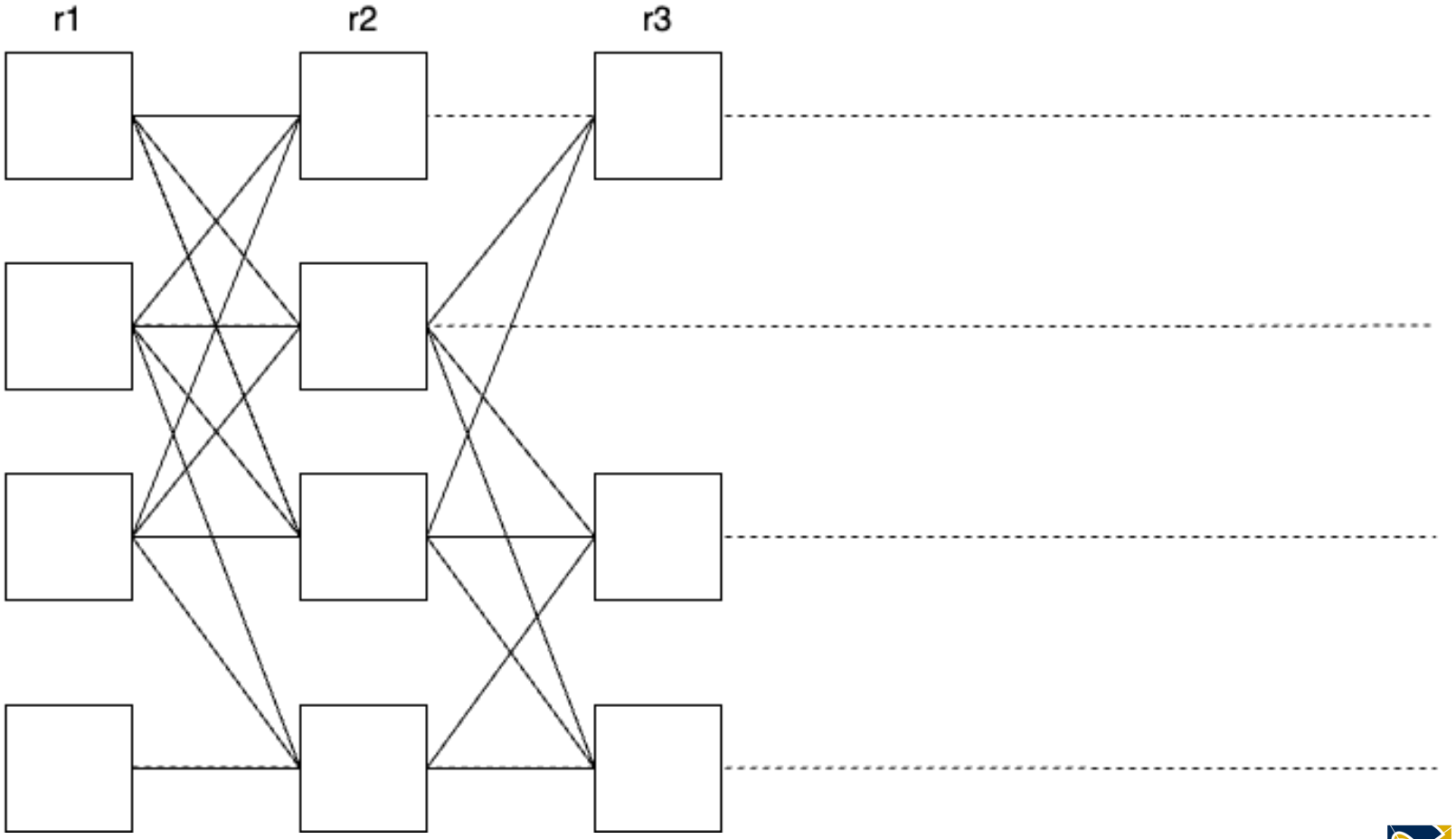
Just interpret the DAG created in Narwhal



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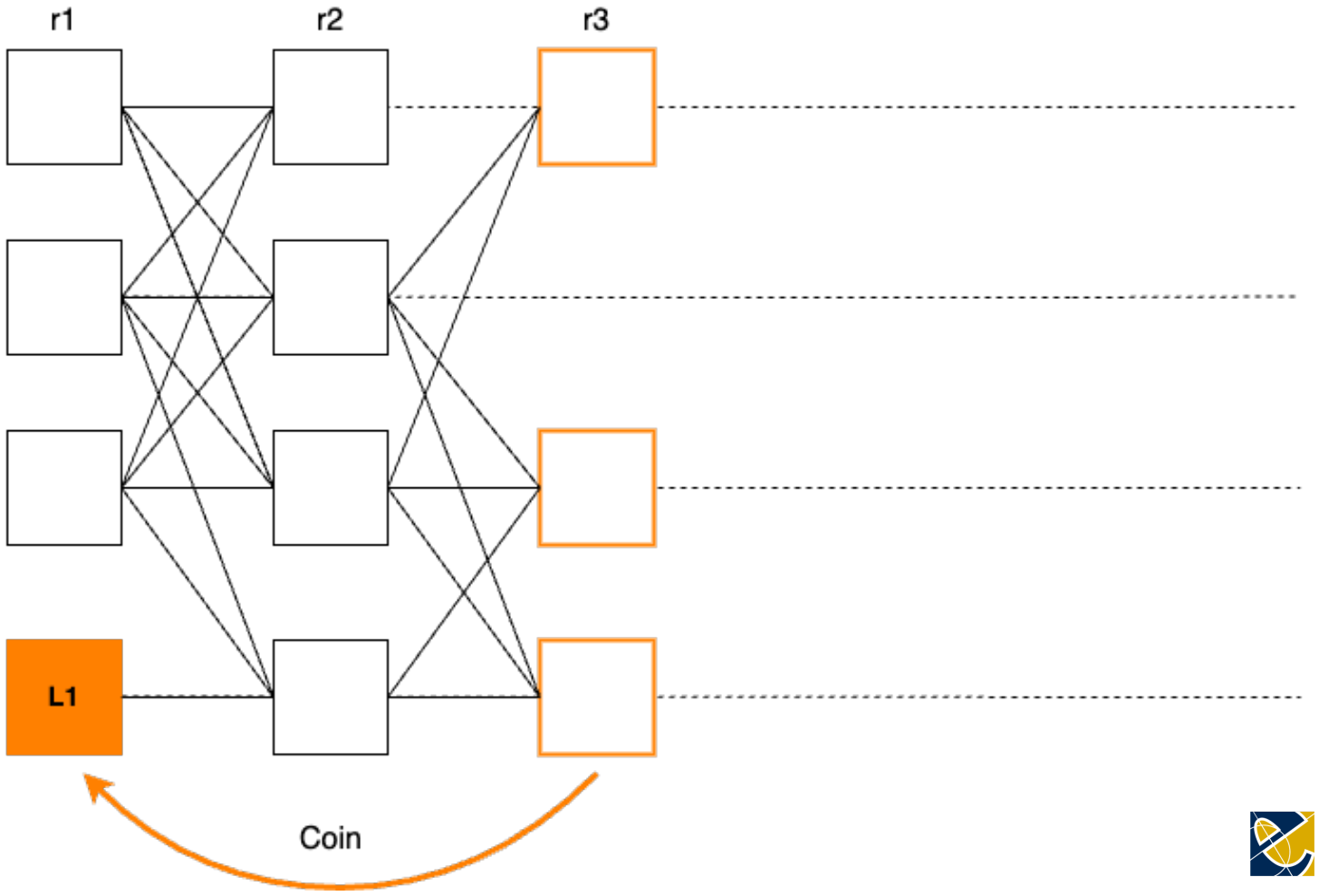
The random coin elects the leader of r-2



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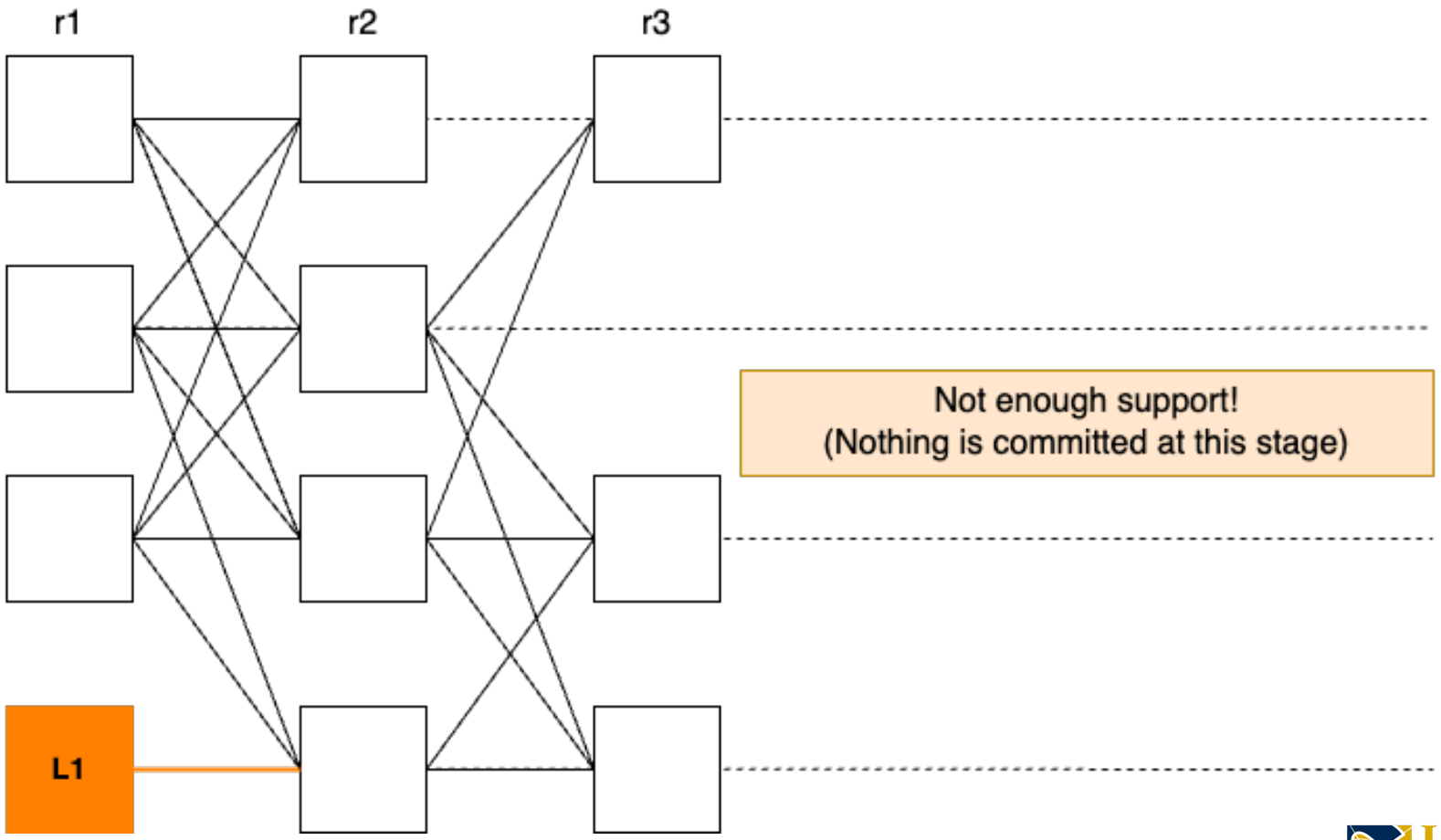
The chosen leader needs **f+1** links from round **r-1 to get committed**



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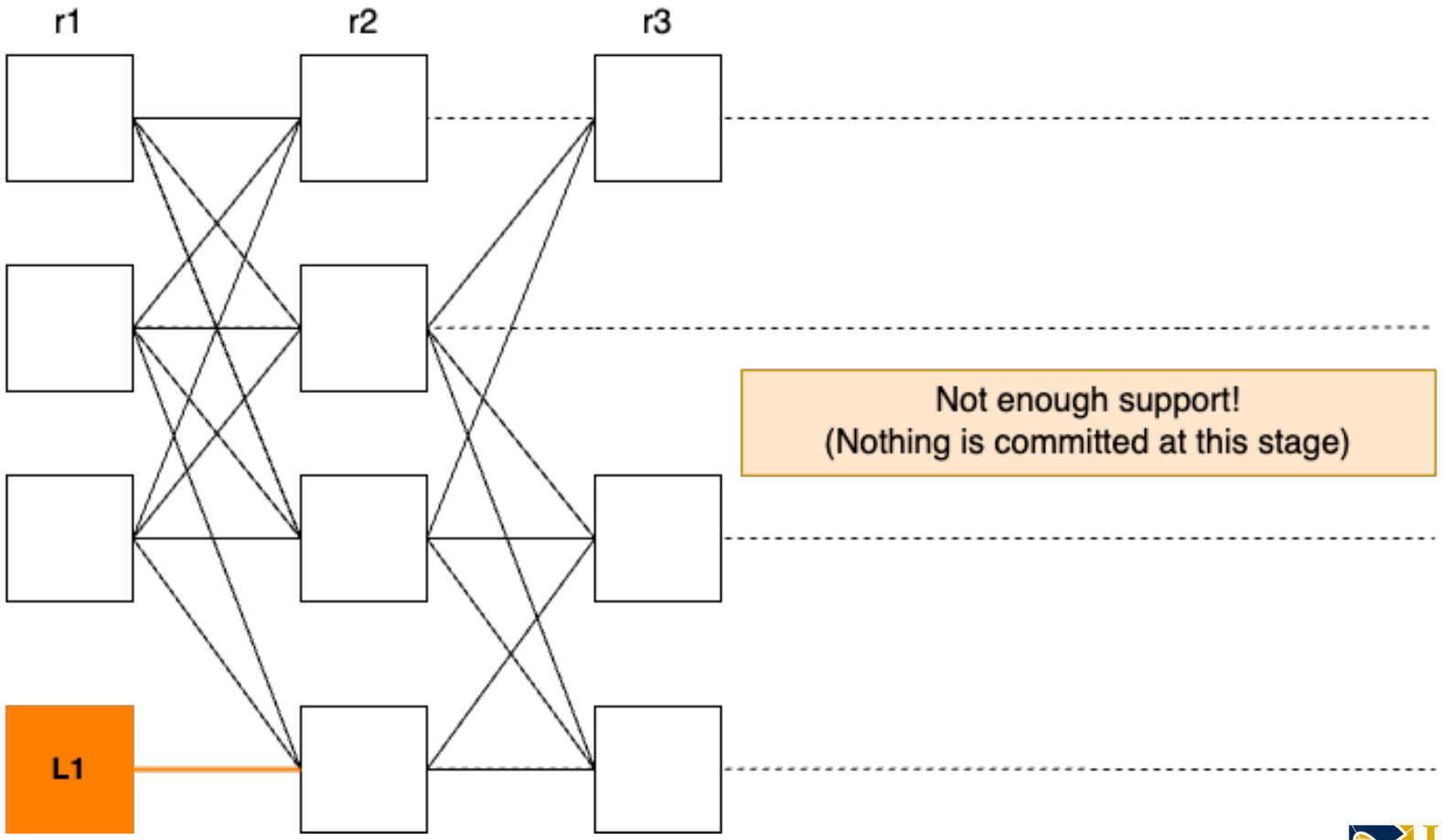
Let us discuss the intuition behind f+1 later.

The chosen leader needs **f+1** links from round **r-1 to get committed**



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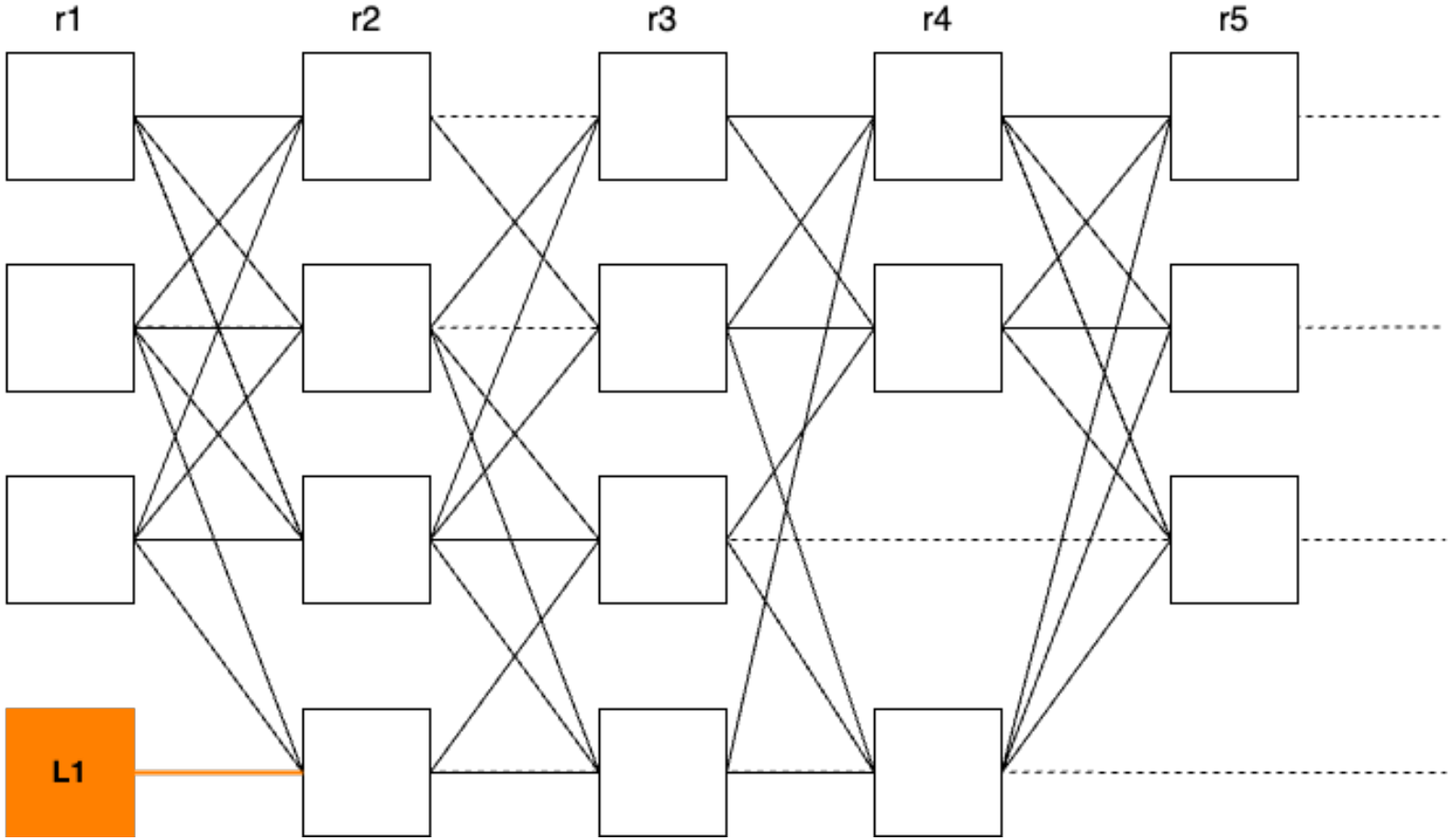
Tusk

Nothing is committed so we keep building the DAG



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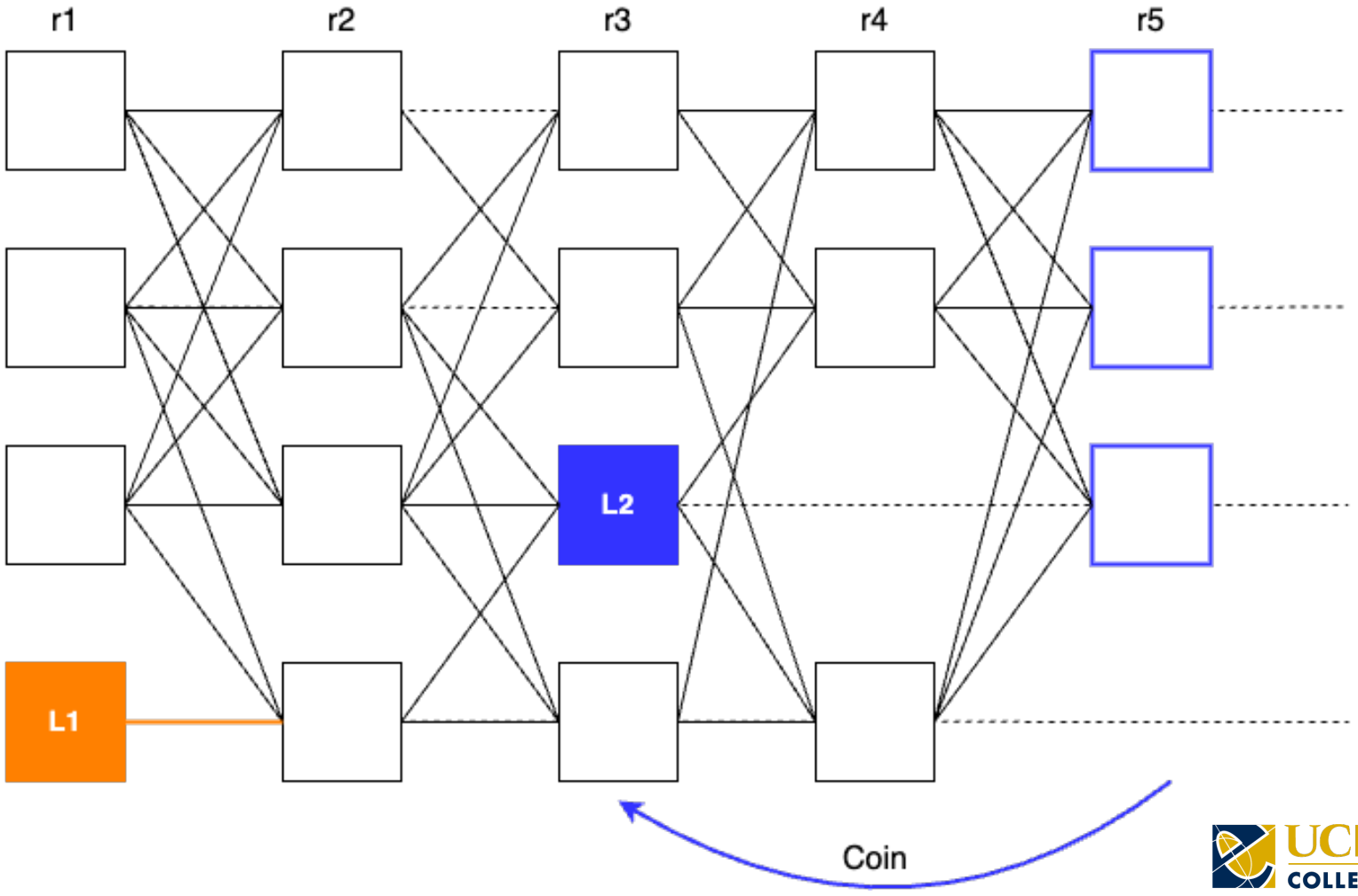
Tusk

Elect the leader of r3



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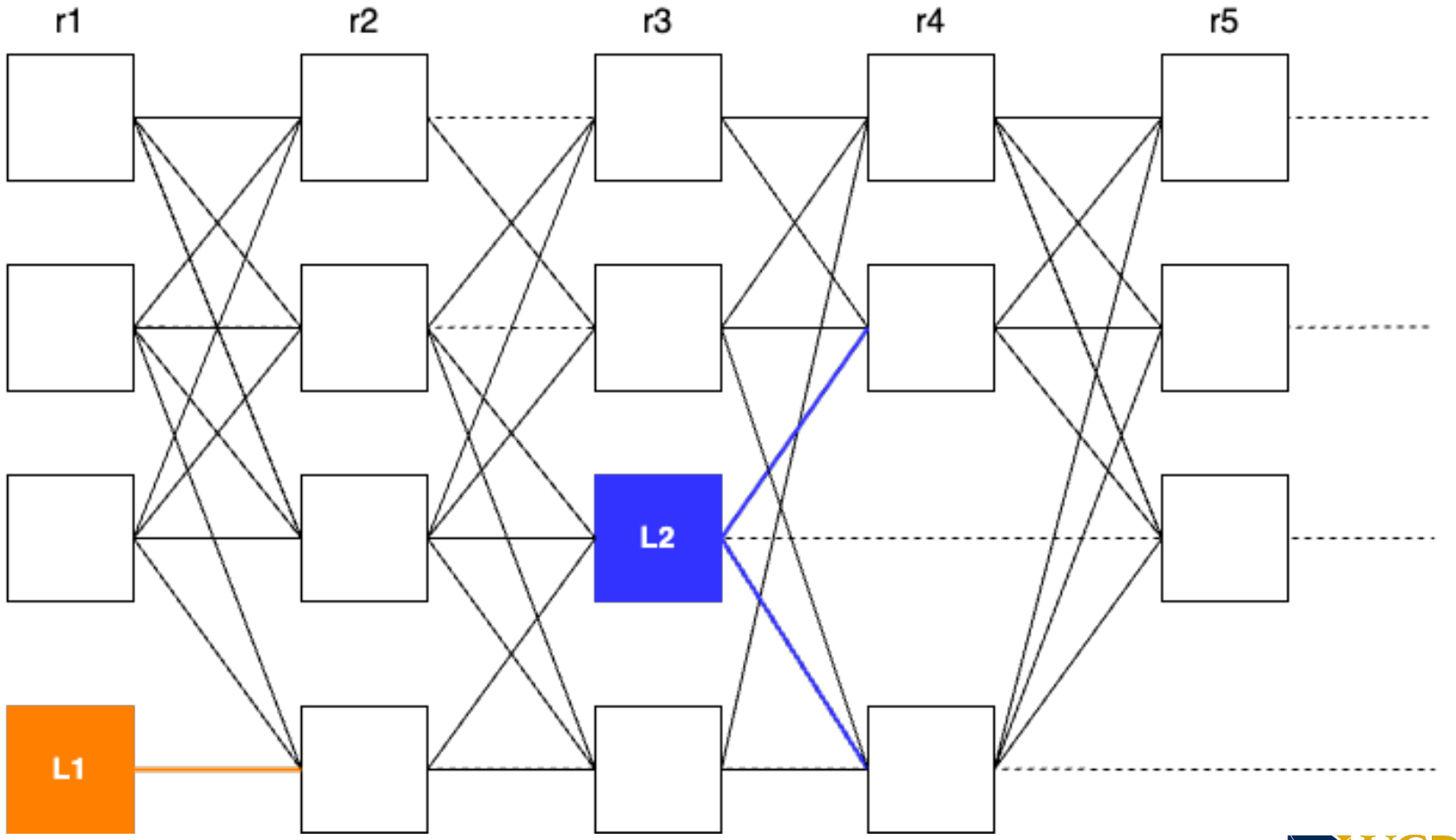
Tusk

Leader L2 has enough support



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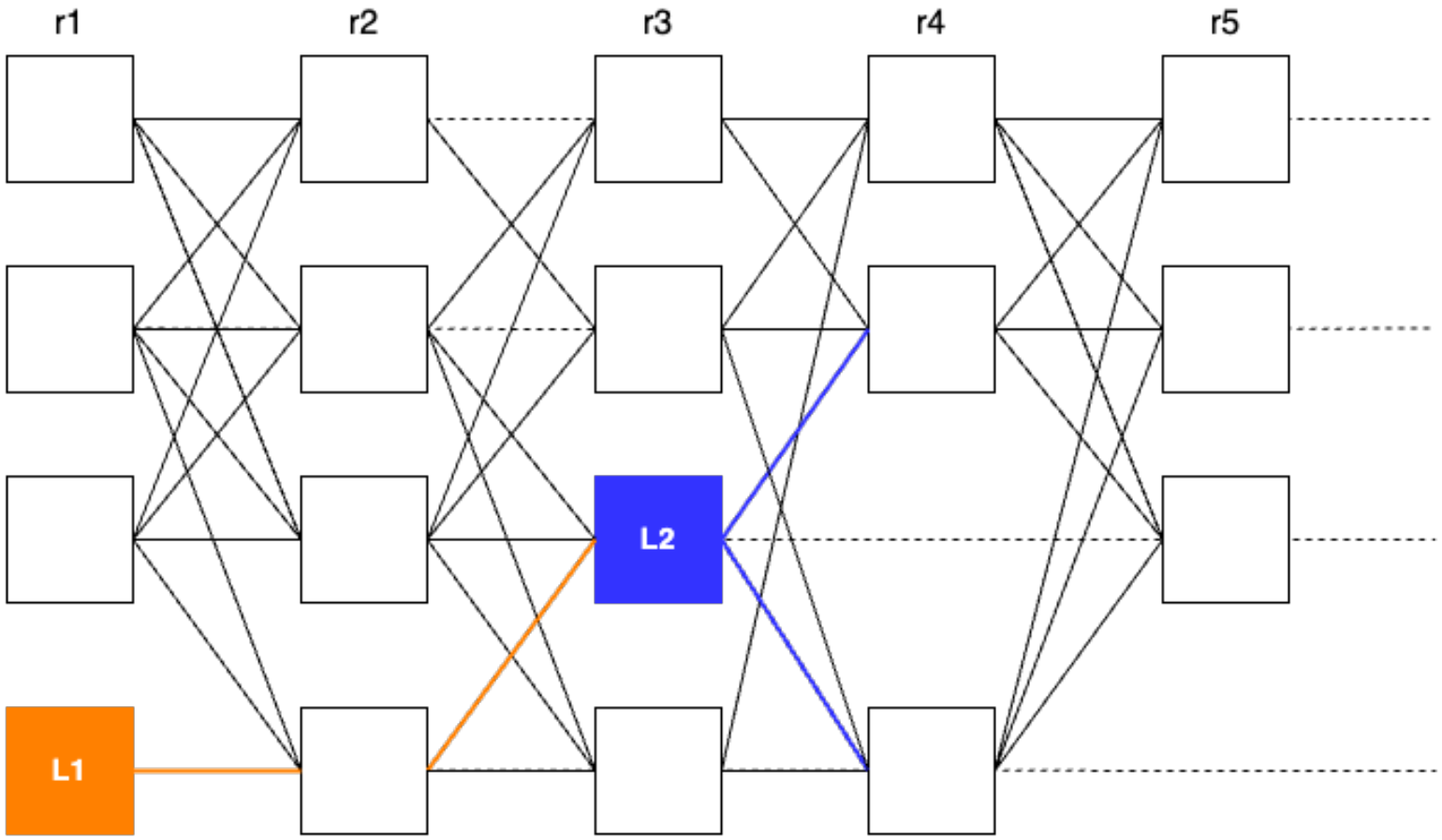
Tusk

Leader L2 has links to Leader L1



First commit L1

Then commit L2

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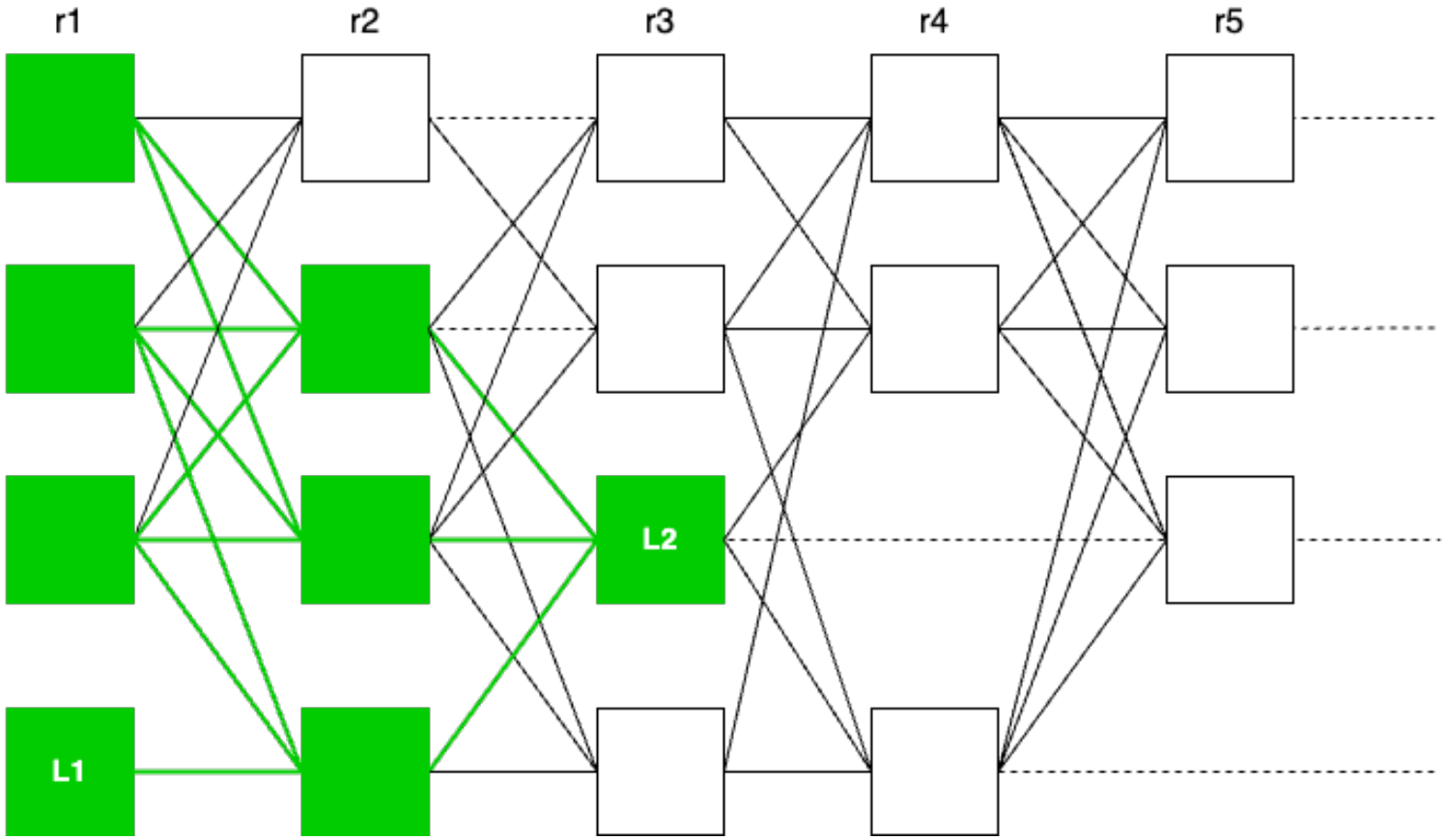
Tusk

Commit all the sub-DAG of the leader



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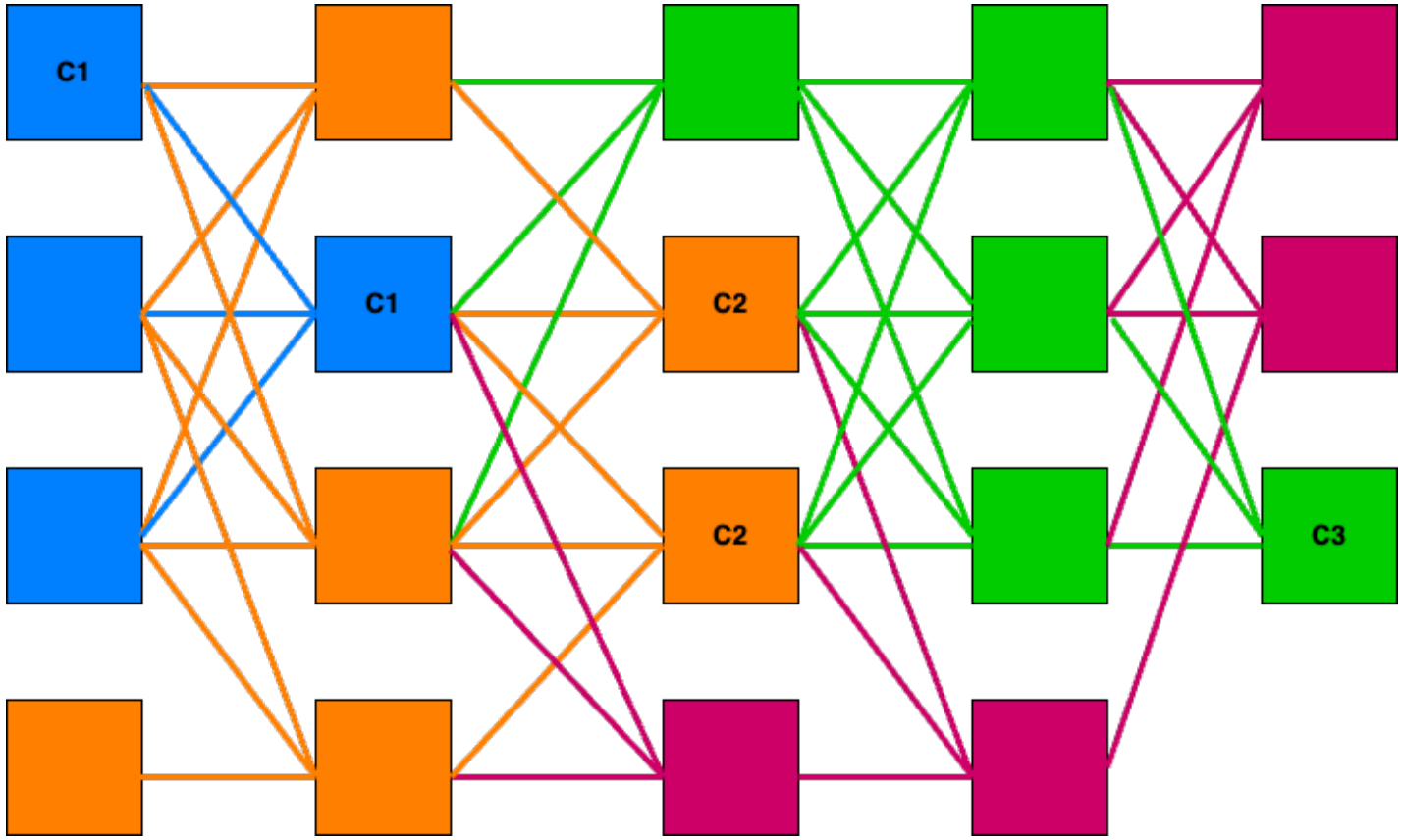
What is the intuition behind **f+1?**

What is the intuition behind **f+1?**

For safety

How to ensure **liveness**?

HotStuff on Narwhal



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Implementation and Metrics

- Written in Rust
- Networking: Tokio (TCP)
- Storage: RocksDB
- Cryptography: ed25519-dalek

https://github.com/facebookresearch/narwhal

Evaluation - Experimental setup on AWS

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Evaluation - Throughput latency graph

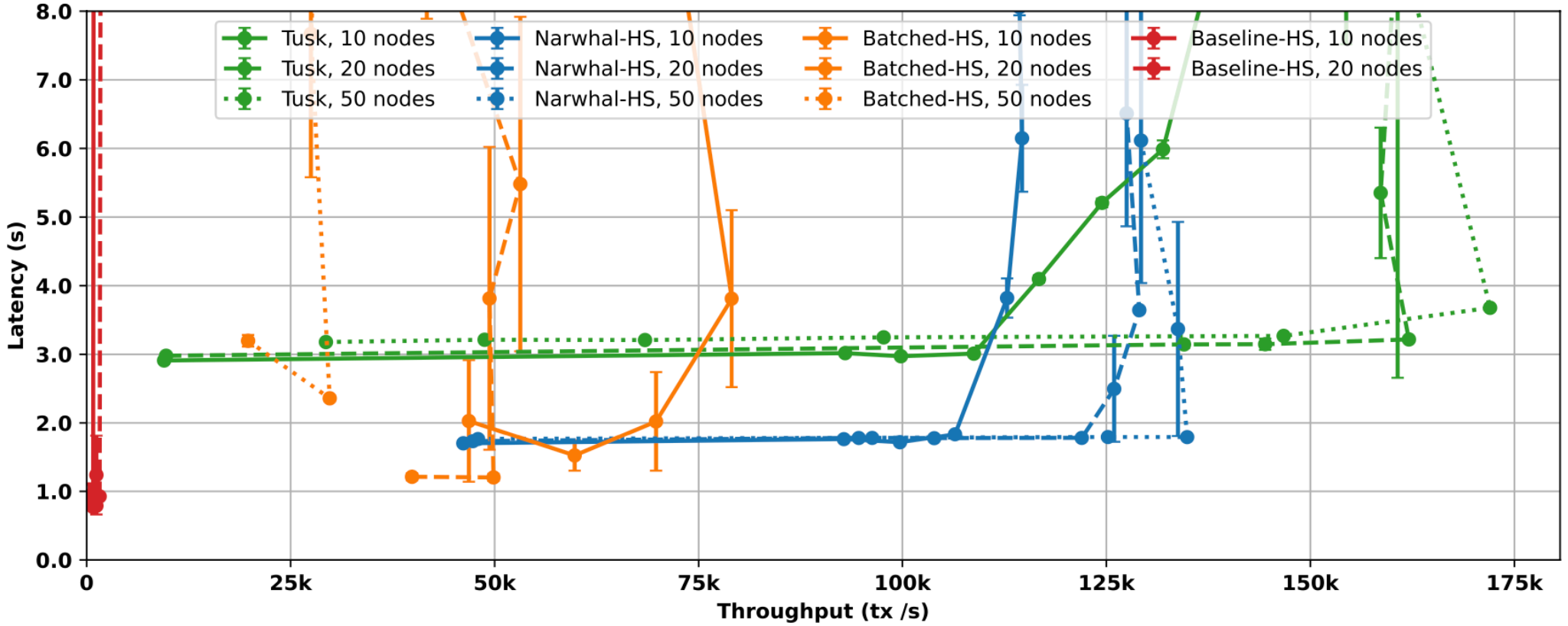

Figure 6. Comparative throughput-latency performance for the novel Narwhal-HotStuff, Tusk, batched-HotStuff and the baseline HotStuff. WAN measurements with 10, 20, and 50 validators, using 1 worker collocated with the primary. No validator faults, 500KB max. block size and 512B transaction size.

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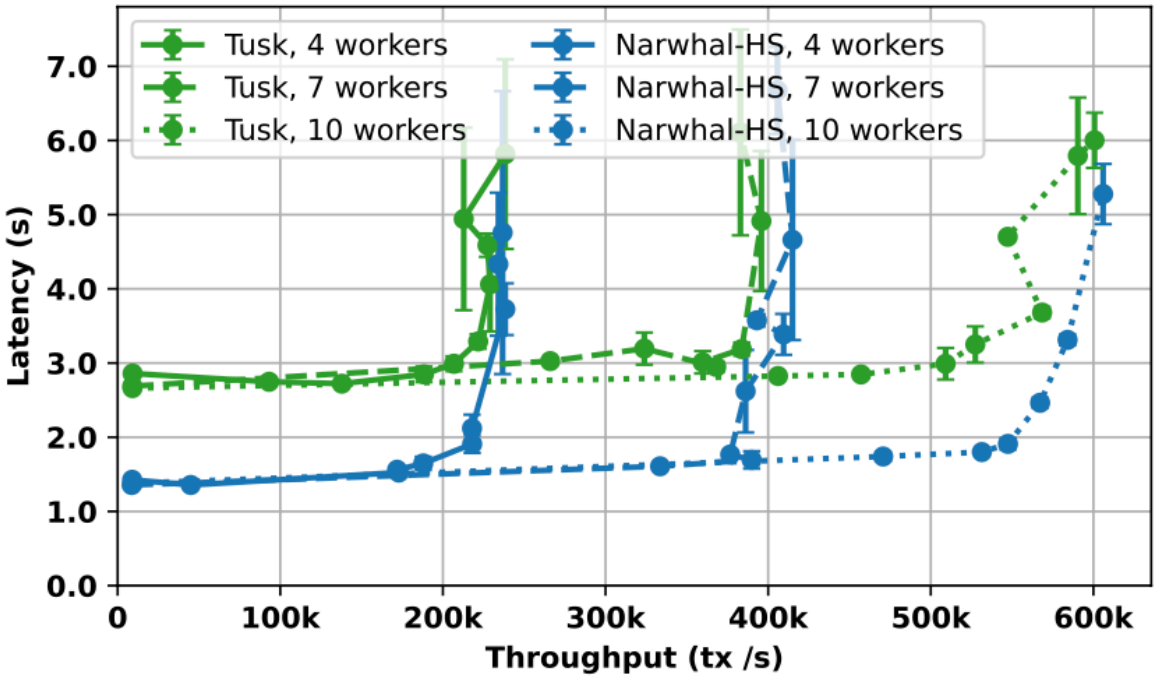
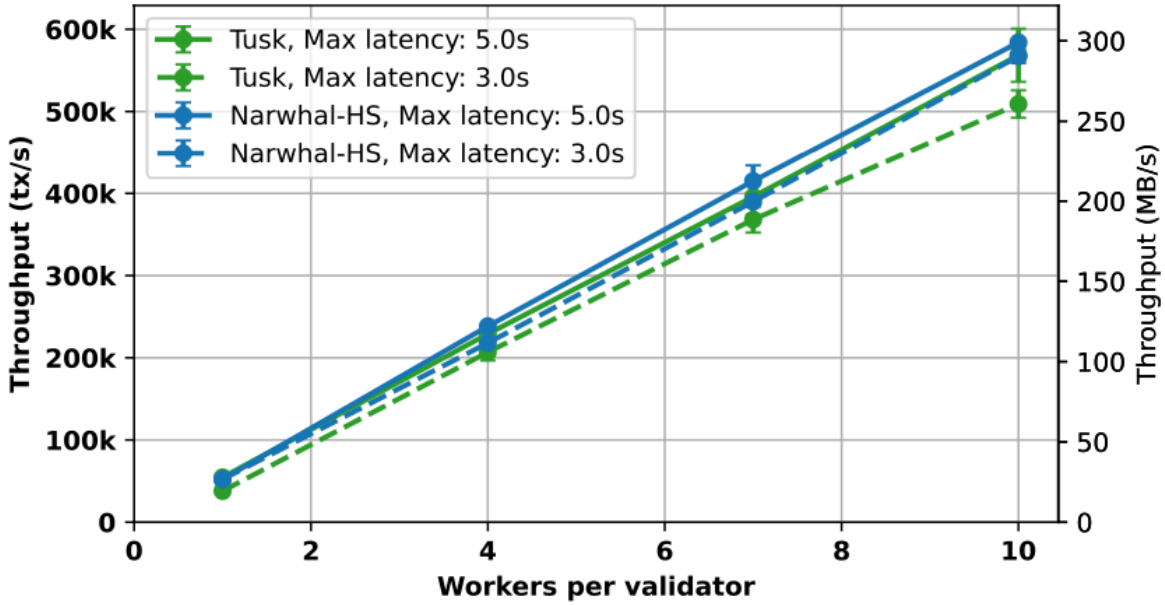
Evaluation - Scalability





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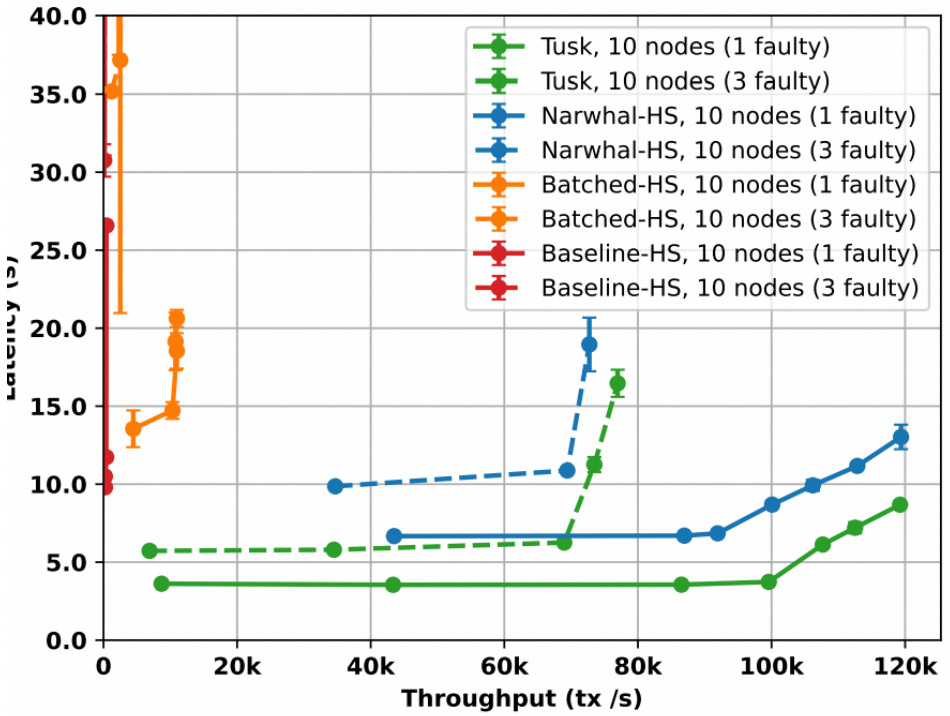
Conclusion

NARWHAL AND TUSK

- Separate consensus and data dissemination for high performance.
- Scalable design, egalitarian resource utilizations.

Performance under faults



Comparative throughput-latency under faults. WAN measurements with 10 validators using 1 worker co-located with the primary. 1 and 3 faults, 500KB max block size, and 512B transaction size.

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References

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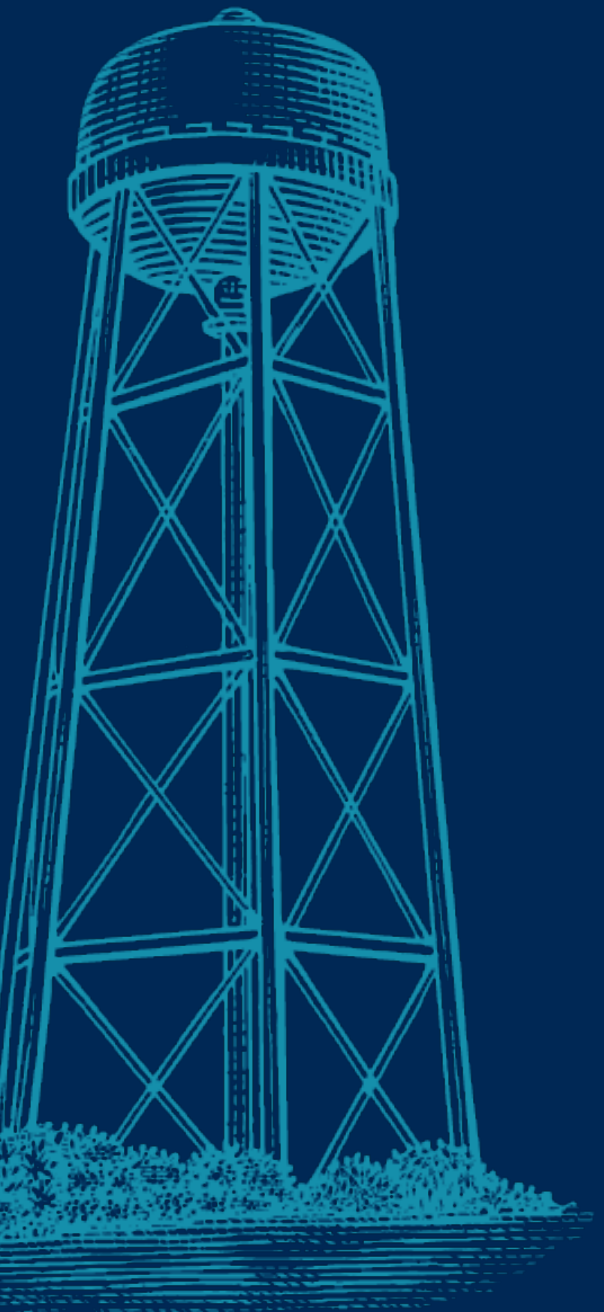

THANK YOU!

ANY QUESTIONS? ASK AWAY!

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