A High-Performance Solution for Data Security and Traceability in Civil Production and Value Networks through Blockchain

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Presenter

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- Works as a blockchain developer in the project “safe-UR-chain” at the Blockchain Competence Center Mittweida
- Is studying in the Blockchain & Distributed Ledger Technologies (DLT) program toward a M. Sc. at the University of Applied Sciences Mittweida
- Research interests: consensus algorithms, distributed computing, blockchain

Introduction

- Cybercrime is becoming more frequent [1]
- Value chains are increasingly interconnected and production data is stored digitally
- Cyberattacks on value chains pose a threat to the civil infrastructure
- The project “safe-UR-chain” [2] explores a blockchain-based solution to combat data manipulation

Introduction

Motivation

- Confidentiality, integrity, and availability are basic protection objectives for digital communication
- Current solutions allow for confidentiality (e.g., by encryption) and availability (e.g., through cloud solutions), but not usually for integrity (i.e., ensuring that stored data is correct)
- Blockchain networks can provide this missing property by storing data in a distributed linked list
- If the stored data also is signed, it can be irrefutably linked to a source

Introduction

Motivation

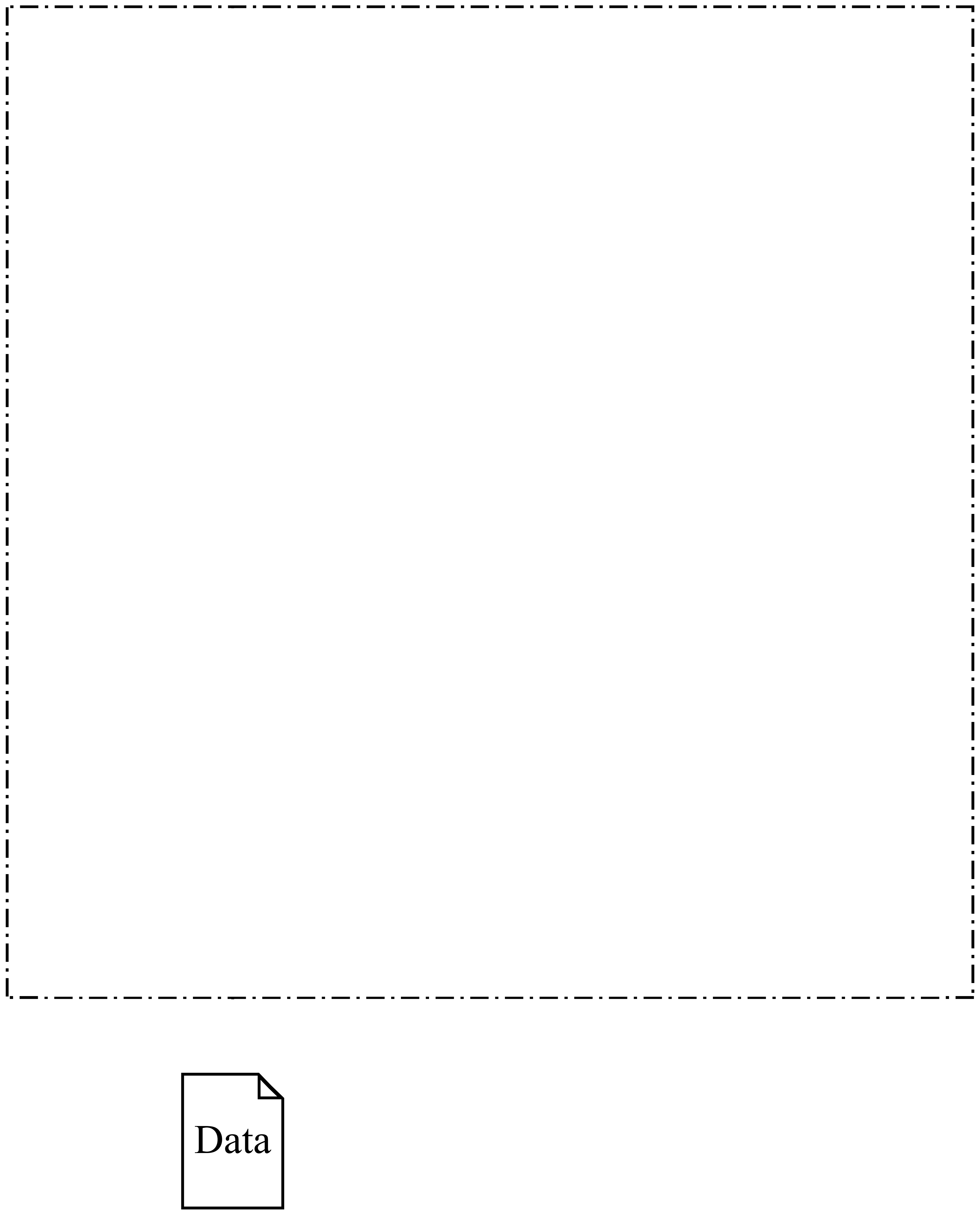
- Public blockchain networks provide a high level of security, but low bandwidth
- Private blockchain networks can provide higher bandwidth, but due to the lower number of participants, a relatively lower level of security
- “safe-UR-chain” aims to provide a traceable and tamper-proof data storage for companies in a value chain by entangling private blockchain networks

Architectural Overview

- To add records into the system, data is
  1. Collected
  2. Distributed
  3. Included into the blockchain
  4. “Countersiged” by the other networks
- This process is distributed over multiple layers within the system

Architectural Overview
Nodes

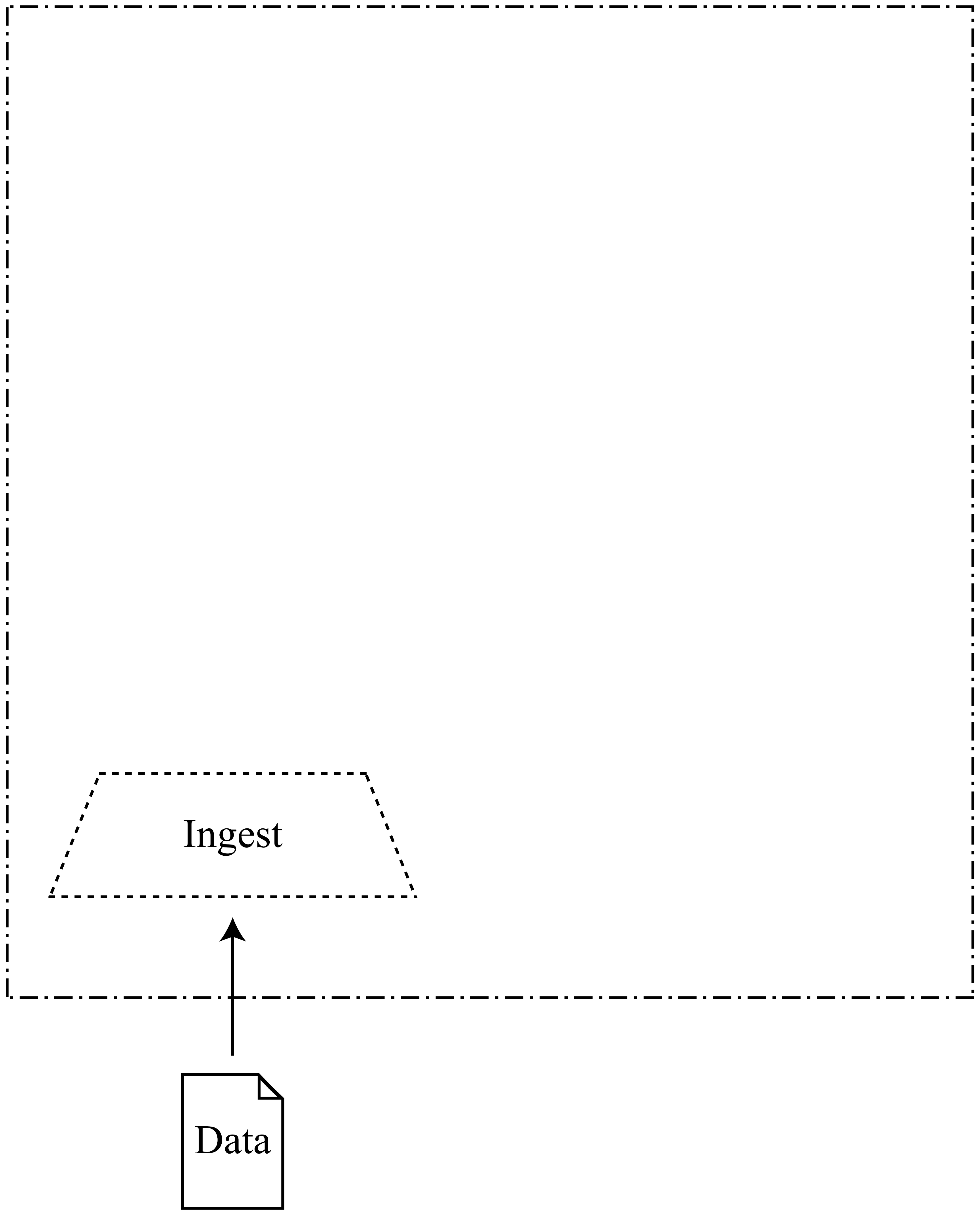
- Nodes form the backbone of local blockchain networks
- They consist of multiple modules



Architectual Overview

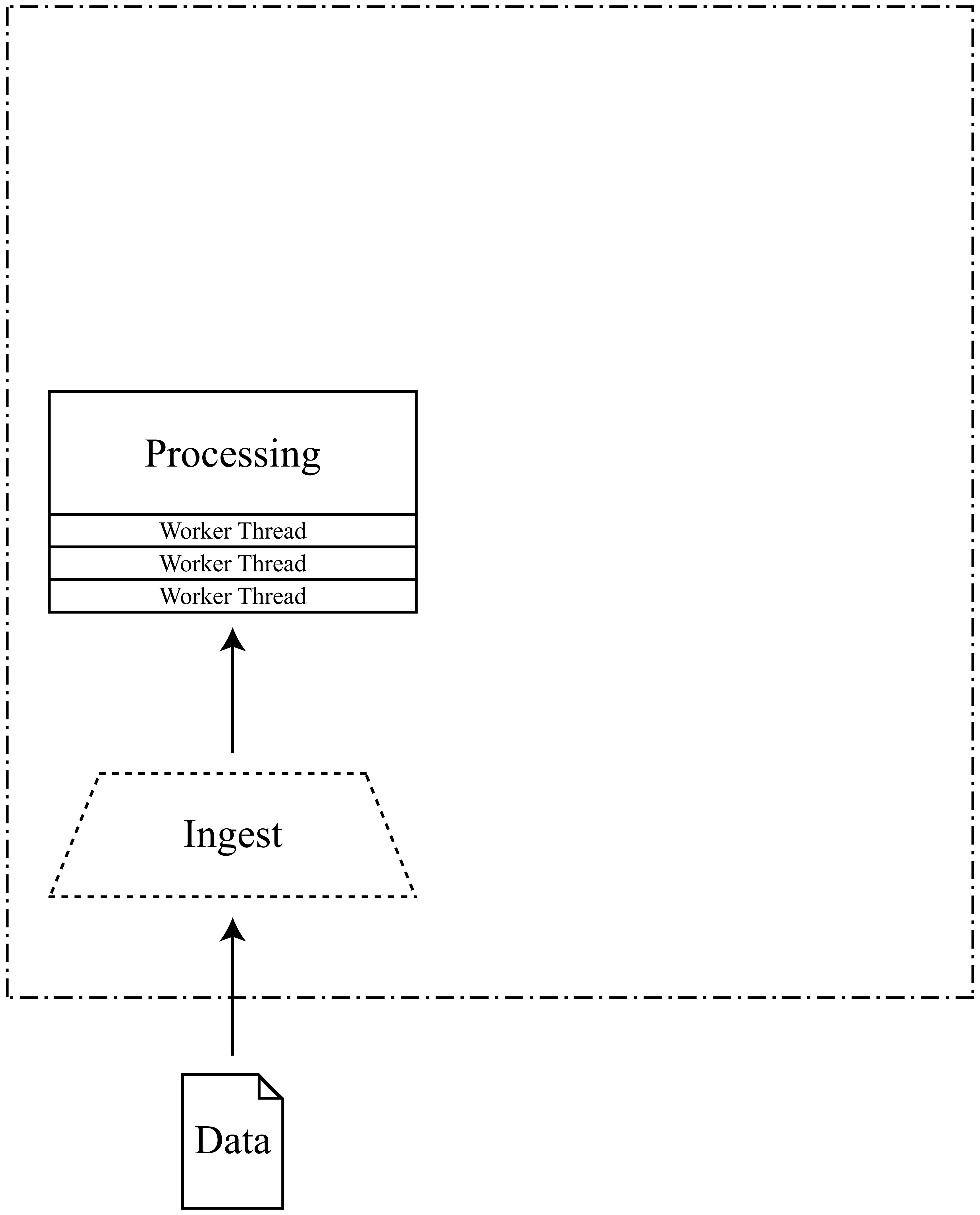
Nodes

- **Ingest** module
  - Provides a generic interface for feeding data into the system
  - Can consume data from files, the network, serial communication, etc.
  - Ingested data is signed and broadcast as "transactions"



Architectural Overview
Nodes

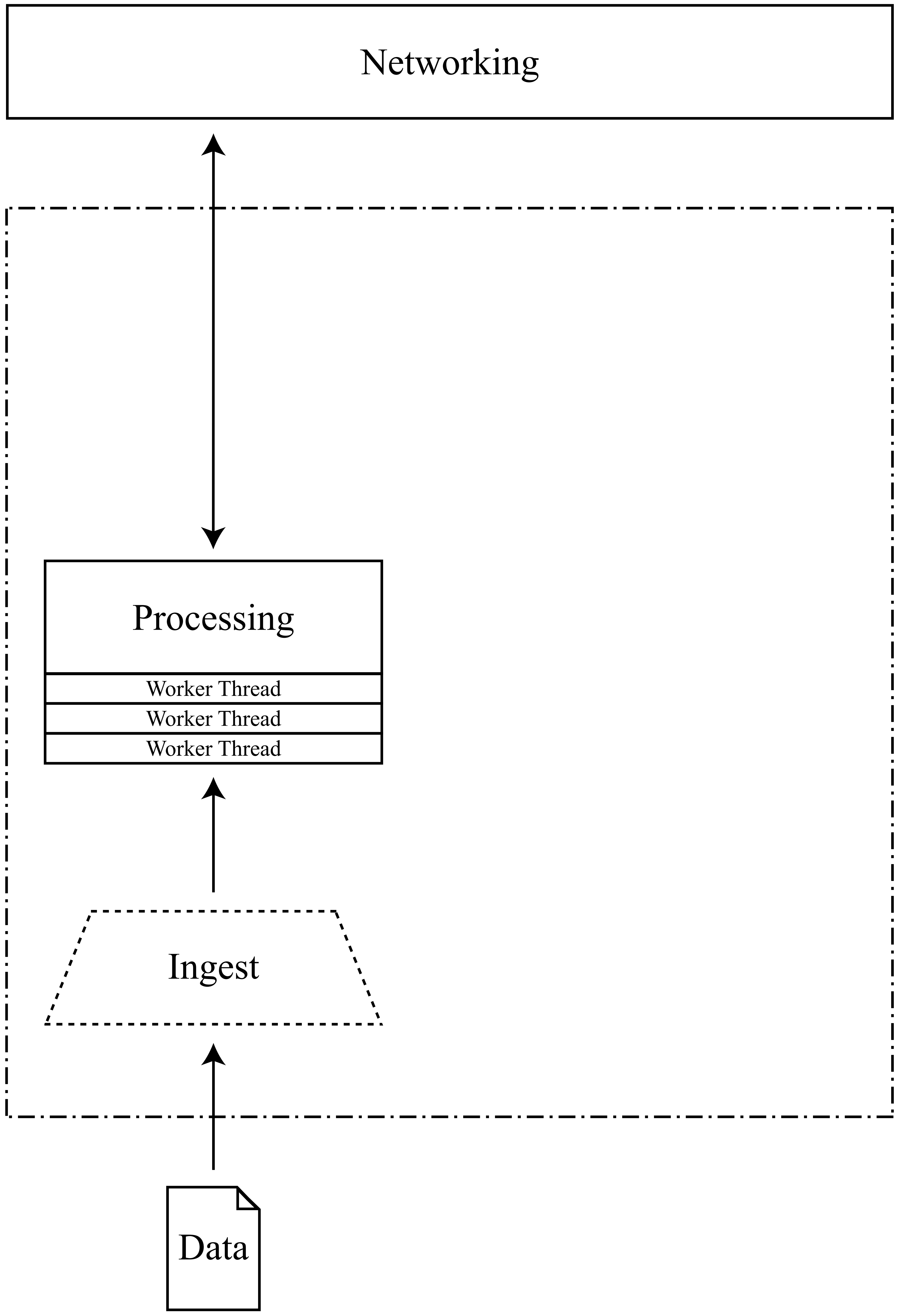
- **Processing** module
  - Processes internal tasks via a configurable amount of worker-threads
  - Passes data between the other modules
  - Queues outgoing network messages
  - Processes incoming network messages



Architectural Overview

Nodes

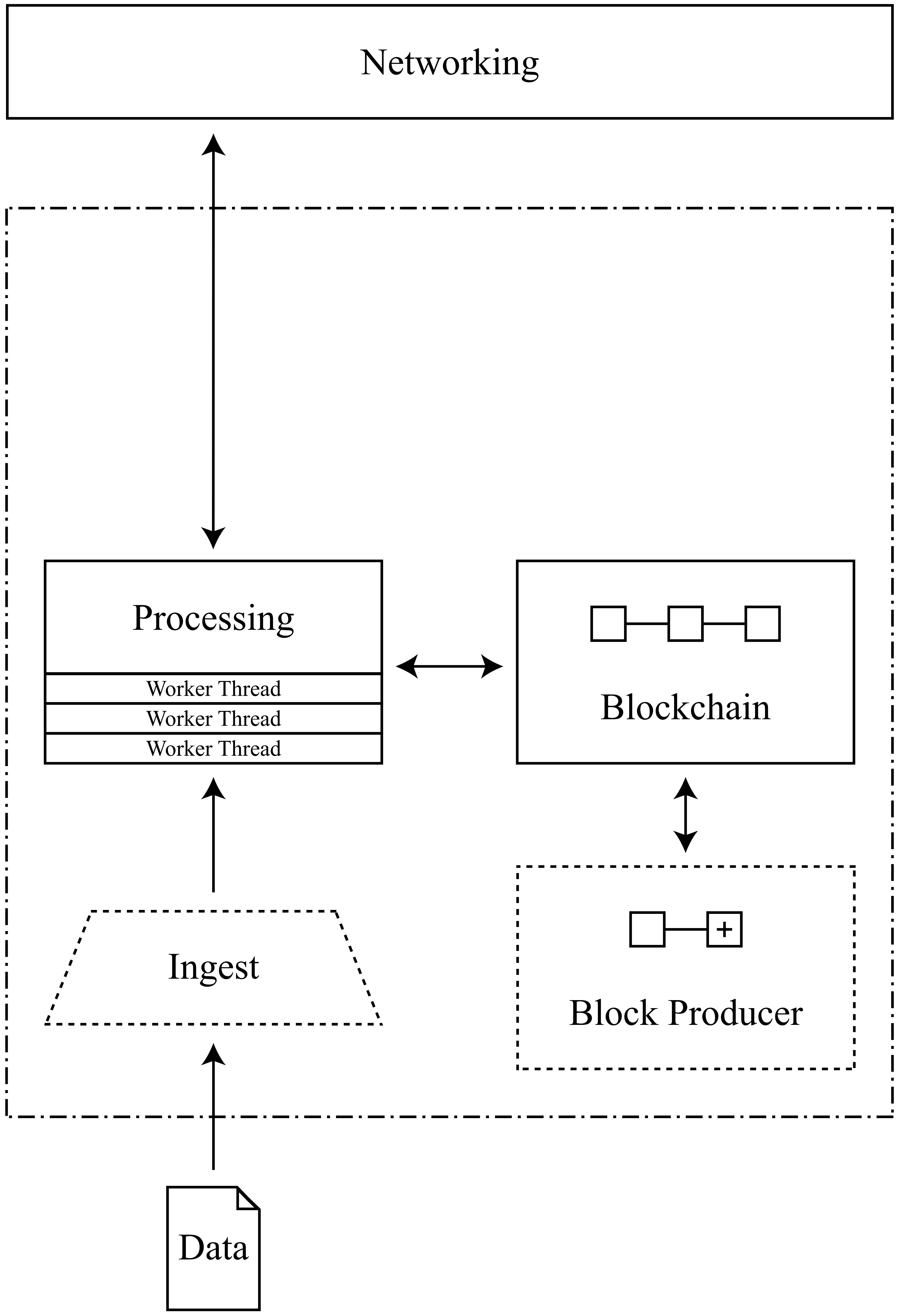
- **Networking** module
  - Maintains a list of other nodes on the network
  - Sends and receives network messages



Architectual Overview

Nodes

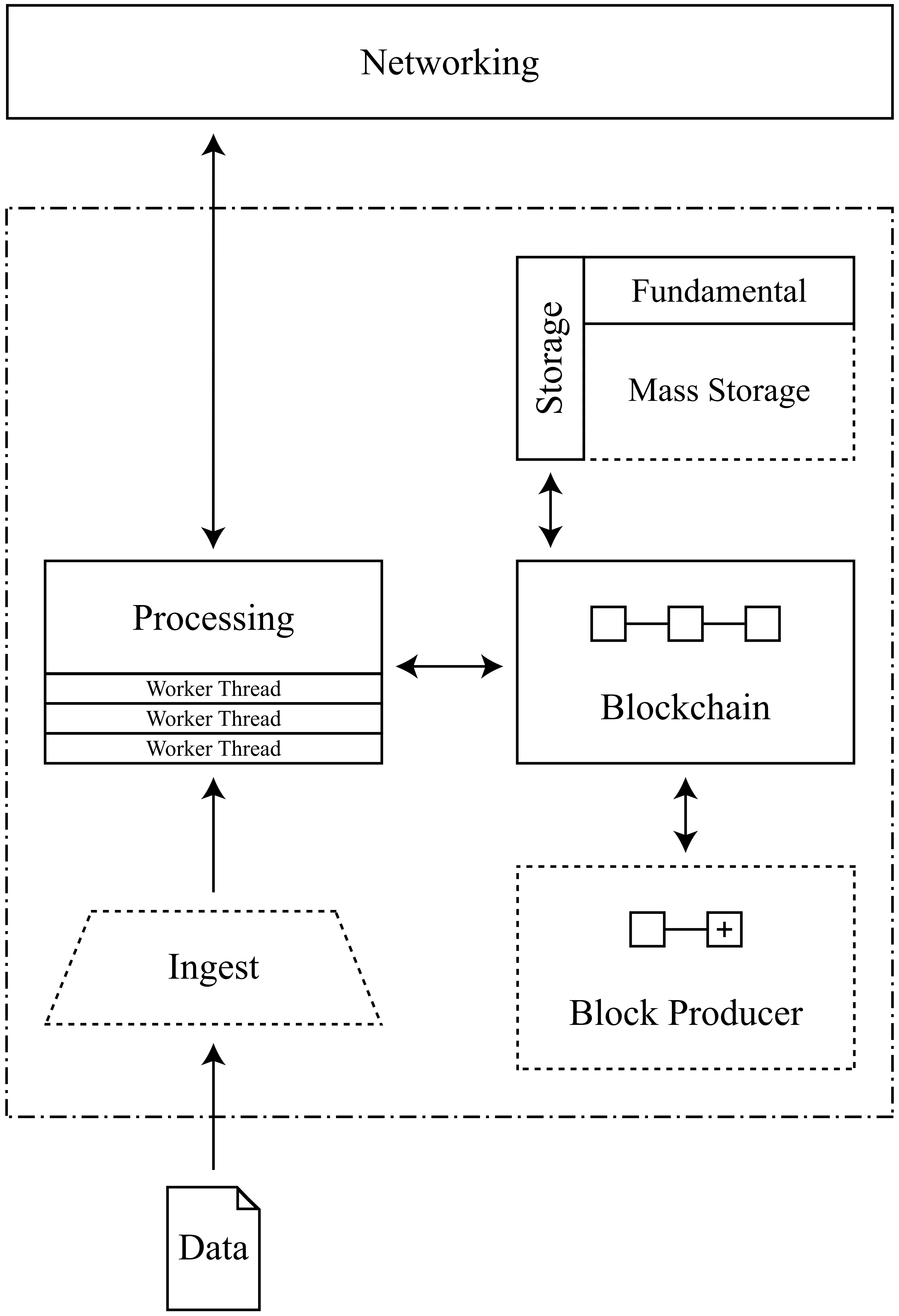
- **Blockchain & Block Producer** modules
  - Transactions are bundled into blocks
  - Blocks are created according to the rules of a consensus mechanism
  - New Blocks are appended to the blockchain



Architectural Overview

Nodes

- **Storage** module
  - Blocks can be stored with all associated data or partial data
  - This is done to save disk space
  - The stored data is determined by a configurable filter



Architectural Overview

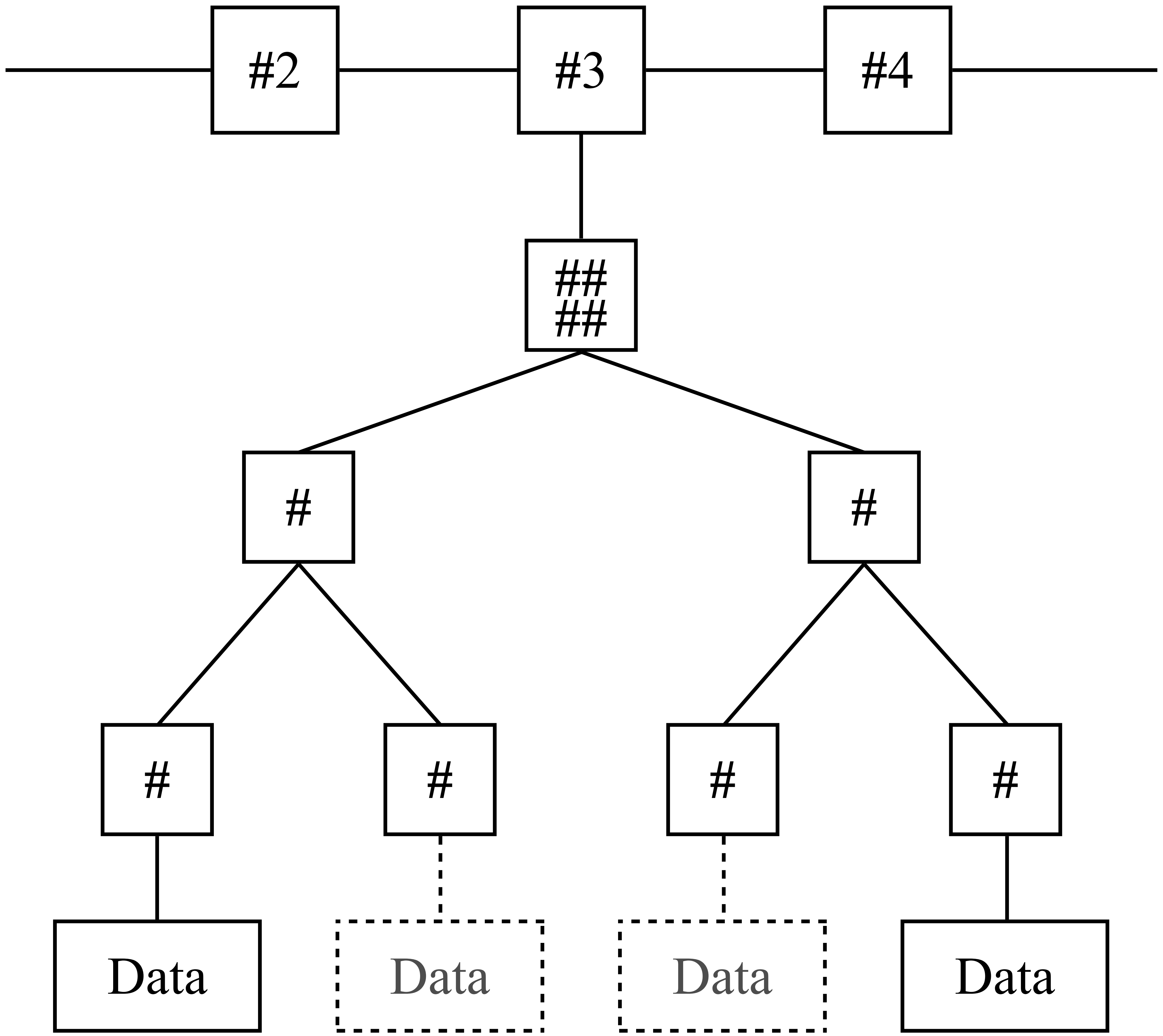
Nodes

- By selectively disabling some modules, different node types can be created
- These types differ in their hardware requirements
- The **Block Producer** module can be disabled to reduce CPU requirements
- The **Storage** module can be configured to store only essential data and therefore reduce disk space requirements
- By configuring nodes in this way, companies can tailor their local blockchain networks to their needs/resources

Architectural Overview

Blockchain

- Data is stored in a block via a Merkle Tree [8]
- The root-hash of this tree is stored within the block header
- Hash values are used as proxies for data
- Data can be left out without changing the root-hash
- Blocks with partial partial retain their hash

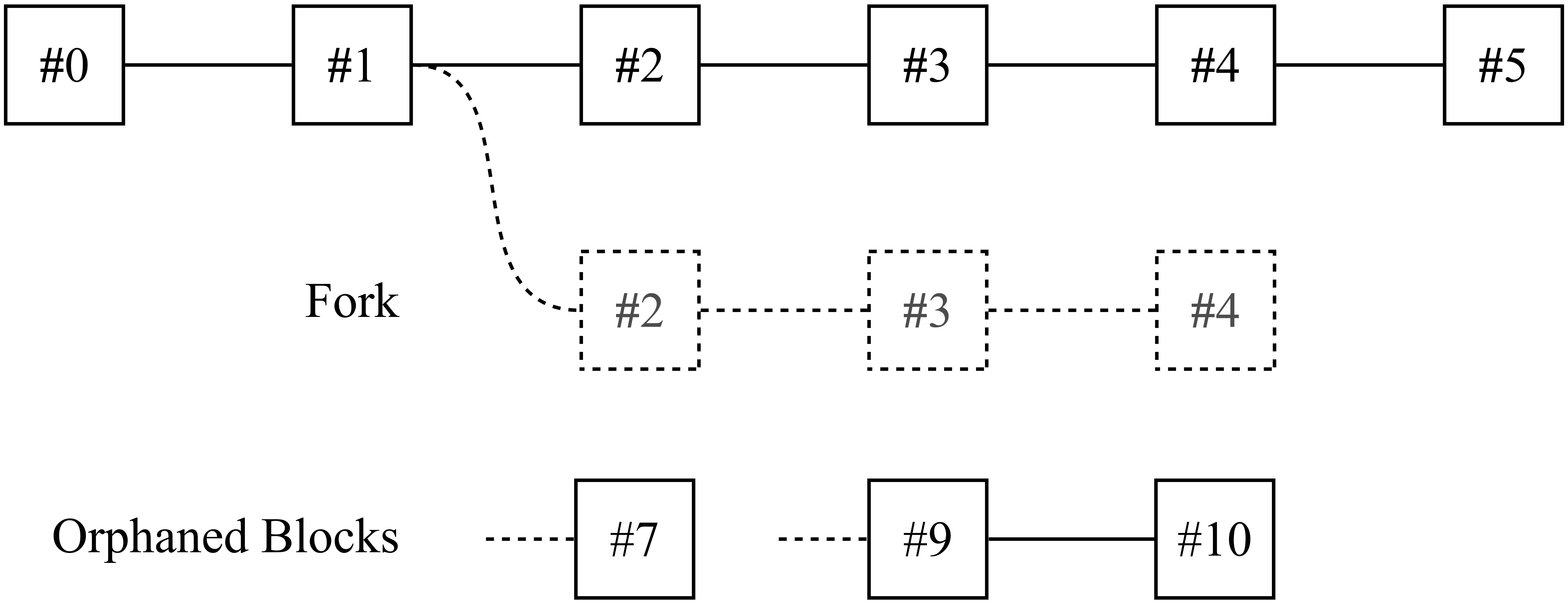


Architectural Overview
Blockchain

- Blocks are stored in a tree like data structure
- This structure uses the rules of the consensus protocol to determine the canonical chain
- If blocks arrive before their predecessor (orphaned blocks), they are stored until they can be appended

Architectural Overview

Blockchain



Architectural Overview
Local Network

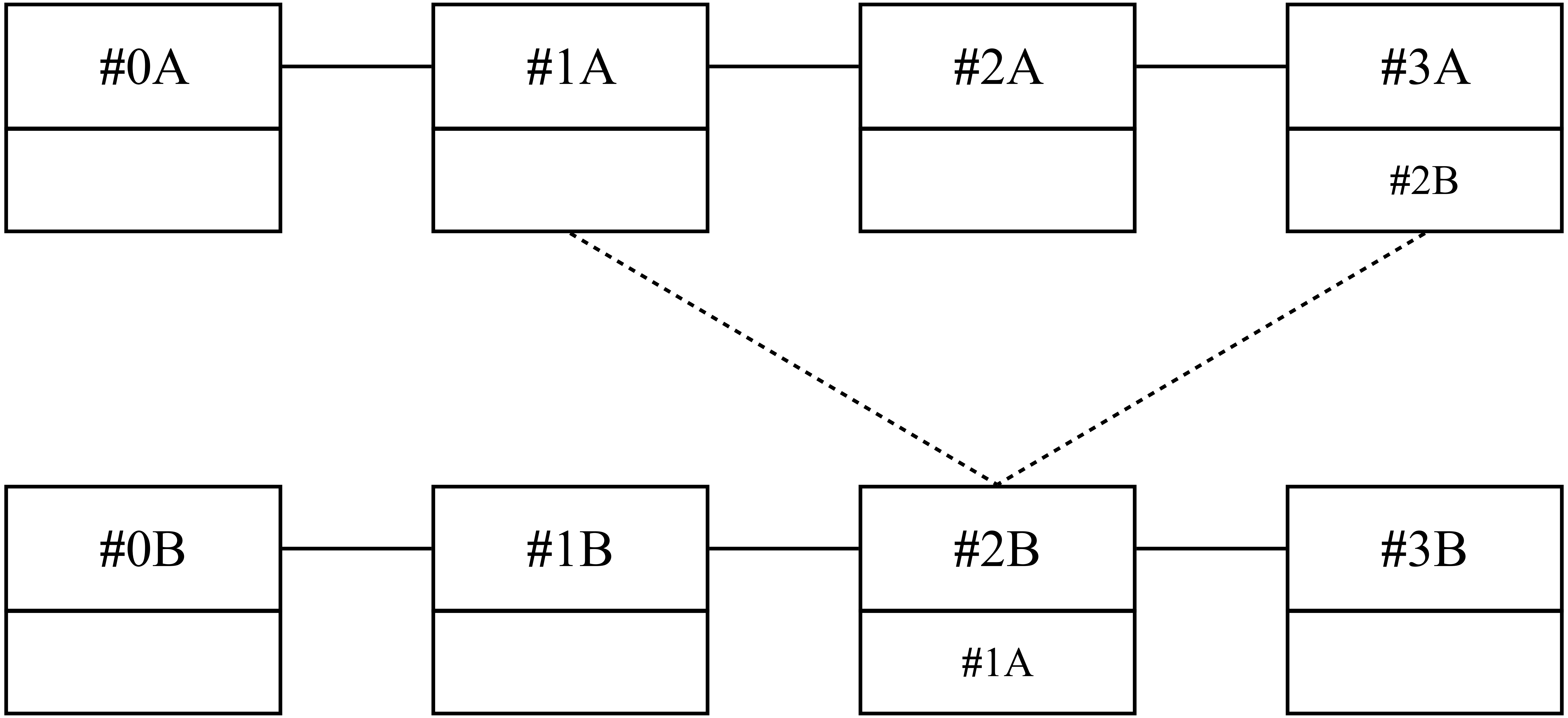
- Blockchain Nodes communicate via a peer-to-peer network
- This network automatically bootstraps by using known nodes that have a high availability within the network
- The network has self-repairing capabilities
- A flooding protocol [7] ensures message delivery without the need for complicated routing

Architectural Overview
Global Network

- Local networks exchange block-hashes via an HTTPs message broker
- The hashes are included in the blockchains of the other networks
- This eliminates the possibility of retroactive changes to a participant's blockchain
- Messages sent via the broker are network-to-network encrypted

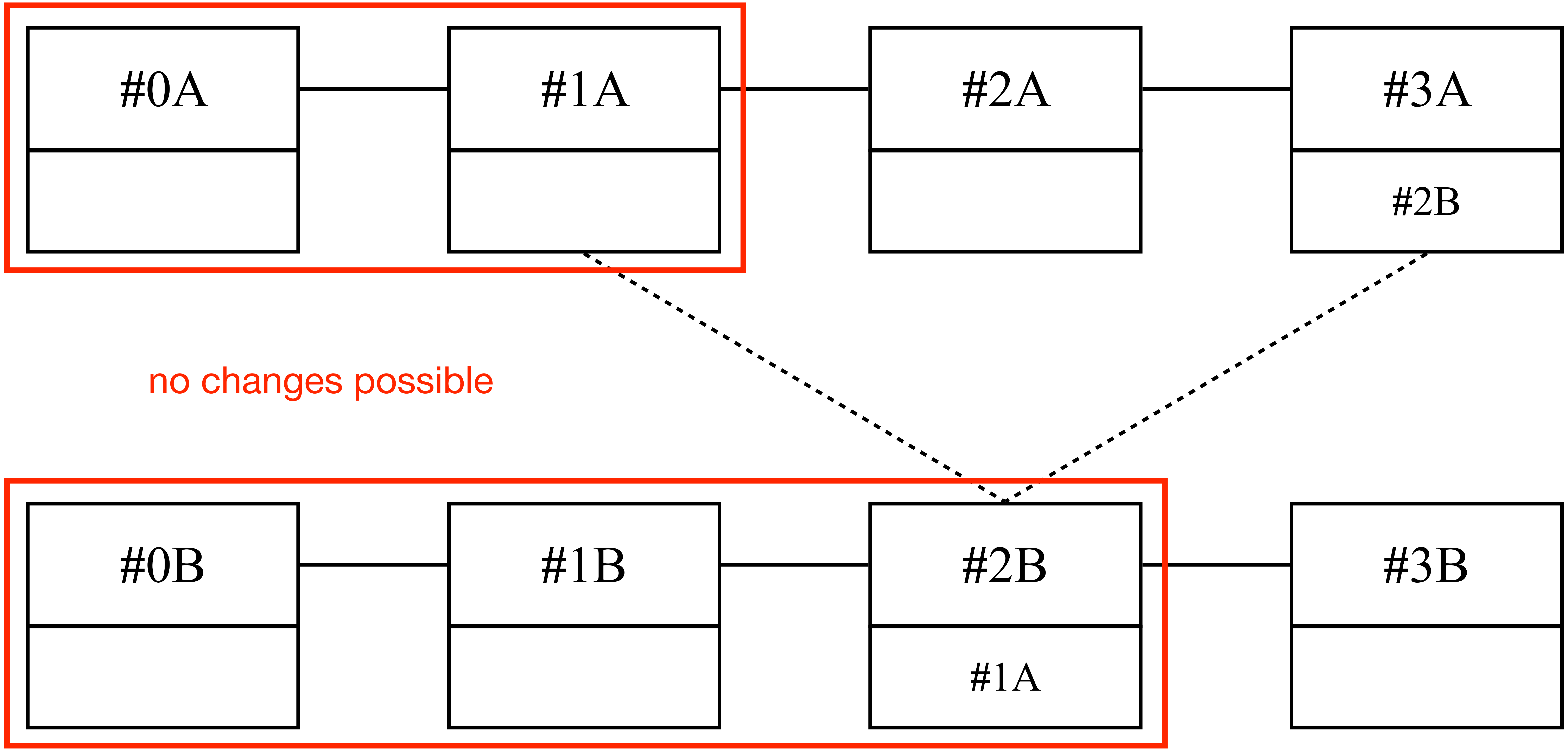
Architectural Overview

Global Network



Architectural Overview

Global Network



Example Scenario

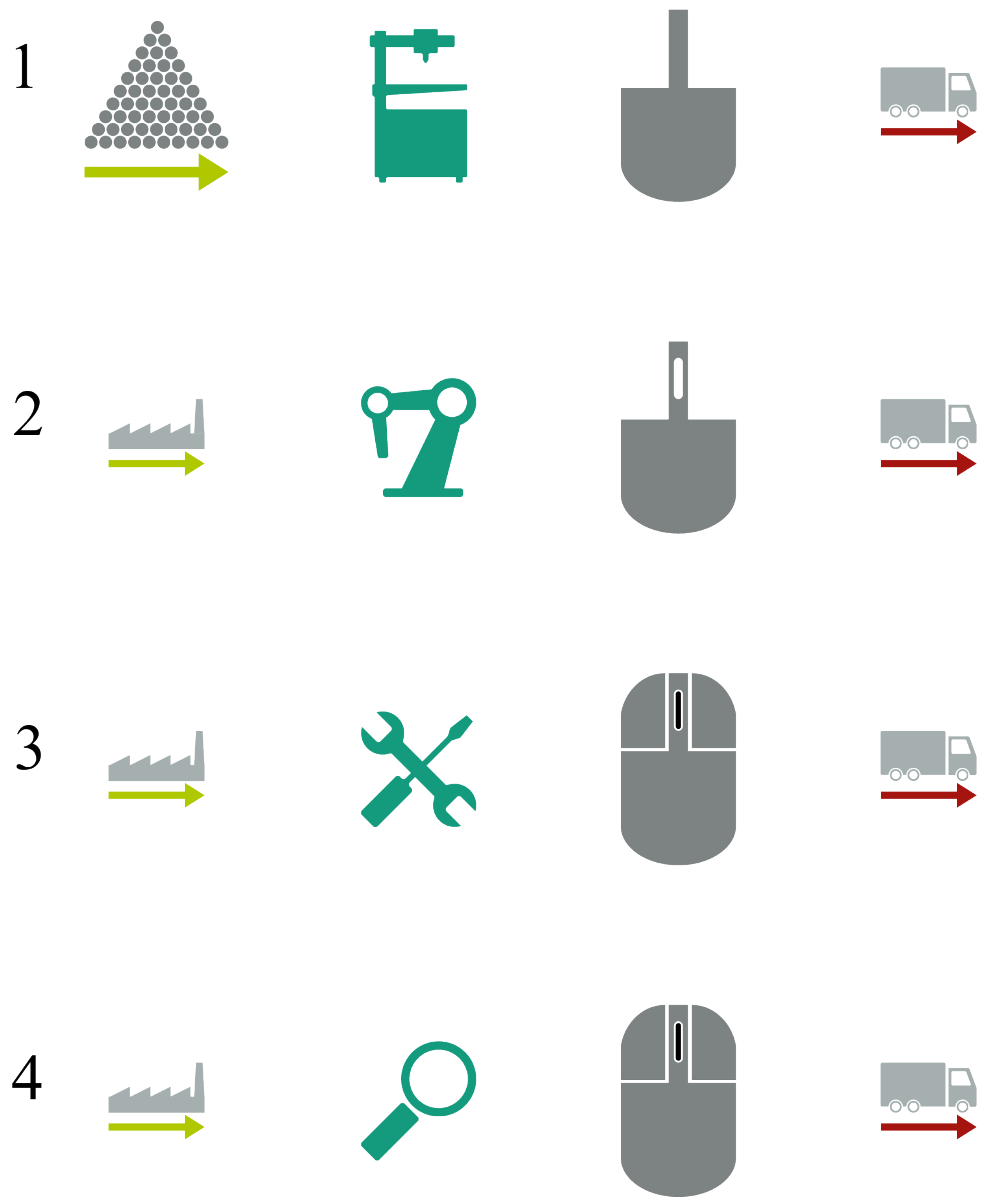
- A four-step example scenario was set up to simulate real-world data flows

  1. Raw material is turned into a semi-finished product

  2. The product is further processed

  3. The product is assembled using supplier components

  4. The product goes through quality control



Example Scenario

- All steps are associated with an identifier-code that is applied to the product
- The real-world version of the scenario was modeled using 3D-printed parts with an Automated Guided Vehicle (AGV) for transport between steps
- The blockchain network for the scenario used a main node with 32 GB of RAM and multiple nodes for data ingestion with 8 GB of RAM
- All nodes were equipped with SSD storage and used Ubuntu 20.4 LTS as their operating system
- Data was collected via OPC UA [9]

Evaluation
Proceeding

- Main questions:
  - Do packets get lost, especially during high transaction loads?
  - What is the effect of varying the payload of a transaction?
  - How big is the latency between transaction and block creation?

Evaluation

Proceeding

- The experiment was conducted with a block time of 15 seconds and ran for 44 blocks (11 minutes)
- Several test runs with different transaction sizes were carried out
- The data generated by the machines was also stored locally to facilitate the detection of possible packet losses
- The blockchain was reset between test runs

Evaluation

Results

- Up to 100 transactions per second could be processed
- No packet loss could be observed
- The payload size did not affect the throughput
- The transaction latency was at least 15 seconds (one block)
- When few transactions with large payloads were generated, they were included within one block
- When many transactions with small payloads were generated, they were included within two blocks

Conclusion

- Blockchain technology has significant potential in industries relying on sensitive data processing (e.g., aerospace, medical, and automotive)
- With this technology, faulty or manipulated product data can be detected
- The described system provides a flexible, high-throughput blockchain solution for tamper-proof and transparent data storage
- The system combines the high performance of a private blockchain with the high trustworthiness of a public one

Future Work

- A procedure to authenticate domain-specific data across locations and to distribute it in a tamper-proof manner
- A system extension for the exchange of data in horizontal value chains
- A detailed investigation of possible attack vectors on the system

Acknowledgement

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