Scalability

50.037 Blockchain Technology
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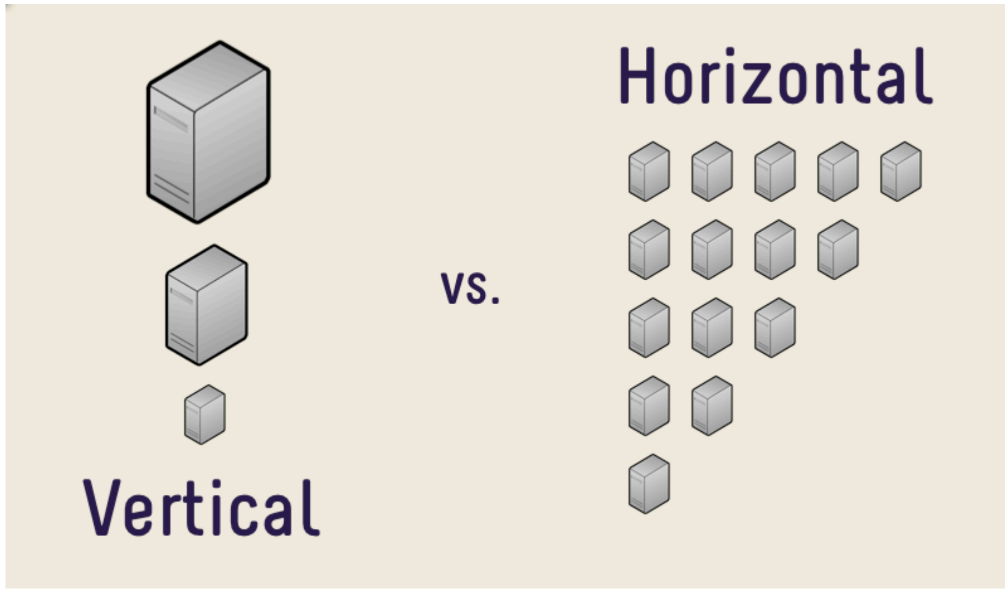
Scalability

- “*Scalability is the capability of a system, network, or process to handle a growing amount of work, or its potential to be enlarged to accommodate that growth.*”
- Horizontal and vertical scaling



https://pudgylogic.blogspot.com/

Blockchain Stack

- Network: propagate transactions
  - Latency, bandwidth, # of nodes, …
- **Consensus**: order Txs
  - # of nodes, # of Txs (throughput)
- RSM: Txs validation, contract execution, …
  - State size, execution complexity, …
- Apps: use the current state to implement some logic

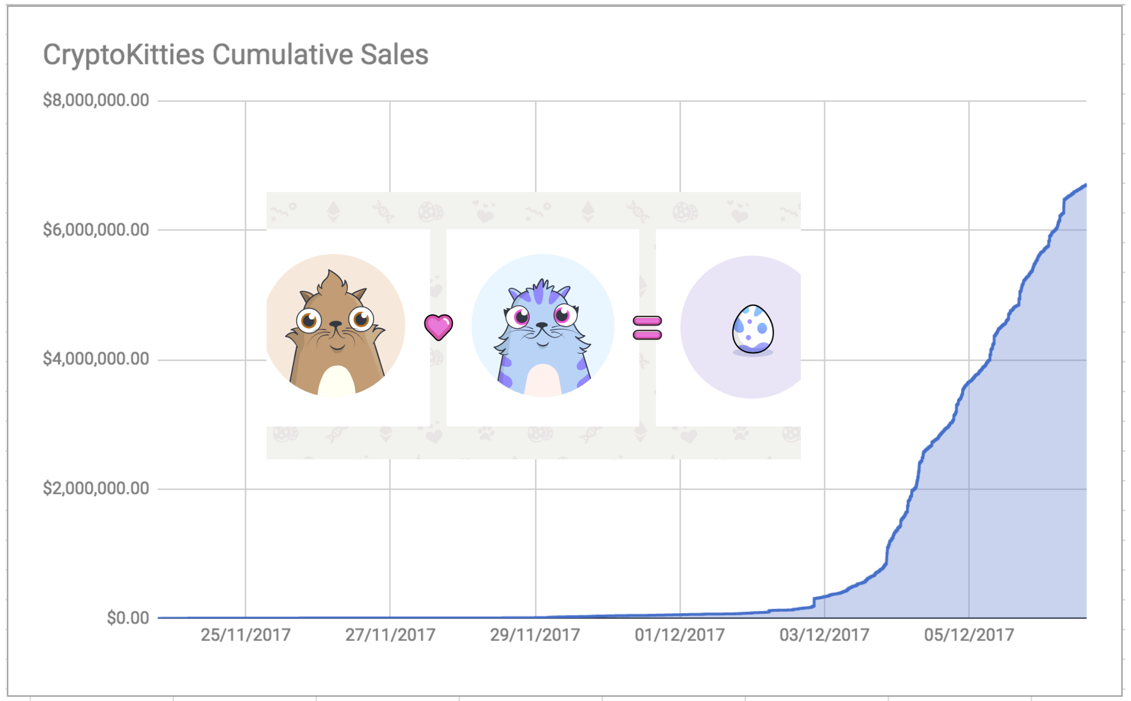
Current State

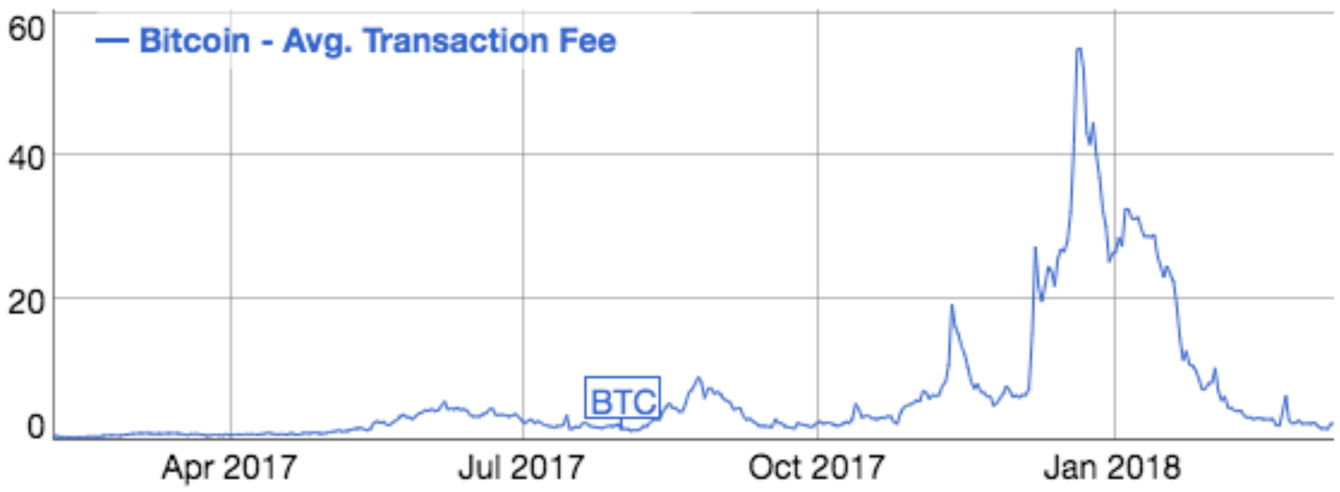
- Throughput
  - Bitcoin: 7 tx/s
  - Ethereum: 10 tx/s
  - Visa: 50k tx/s

- Strategy
  - Faster tx processing
  - Faster consensus
  - Parallel execution

Why needed?

- Adoption
    - Real-world apps require high throughput and low latency
- Inverse scale effect
    - Fees





Blockchain Performance

- Bandwidth:
  - How many Txs can be processed?
- Latency
  - What is the consensus delay?
- Mining power utilization
  - The ratio between the mining power of the current chain and the mining power of the entire blockchain (describes stale block rate too), describes *security*
- Fairness
  - A miner should benefit from rewards proportionally to its mining power

Naive Improvements

- Blocks not every 10 minutes, but e.g., every 10 seconds
  - More forks => less mining power utilization => weaker security
- Larger blocks (very controversial topic BTW)
  - It takes longer to propagate
    - More forks => ….
  - Bitcoin -> Bitcoin Cash -> Bitcoin ABC vs Bitcoin SV

Security vs Performance

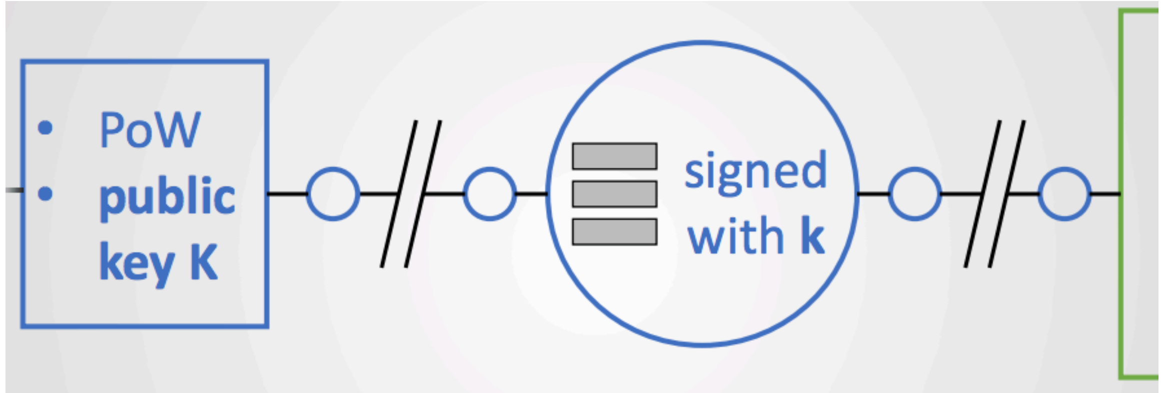
- Seems like Nakomoto consensus has some inherent tradeoffs
    - Security vs performance tradeoff
- Does it have to be like that?
    - We cannot significantly increase block or make them very frequent
- Design space
    - Why we need PoW?
    - Does it have to be combined with transactions propagation?

Bitcoin-NG

- https://www.usenix.org/node/194907 (paper, slides, talk)
- Insights
  - In Bitcoin, leader election and transaction serialization is combined
  - Why do not try to decouple it?
    - Elect leader via PoW and let her commit transactions
    - (Different order than in Bitcoin)

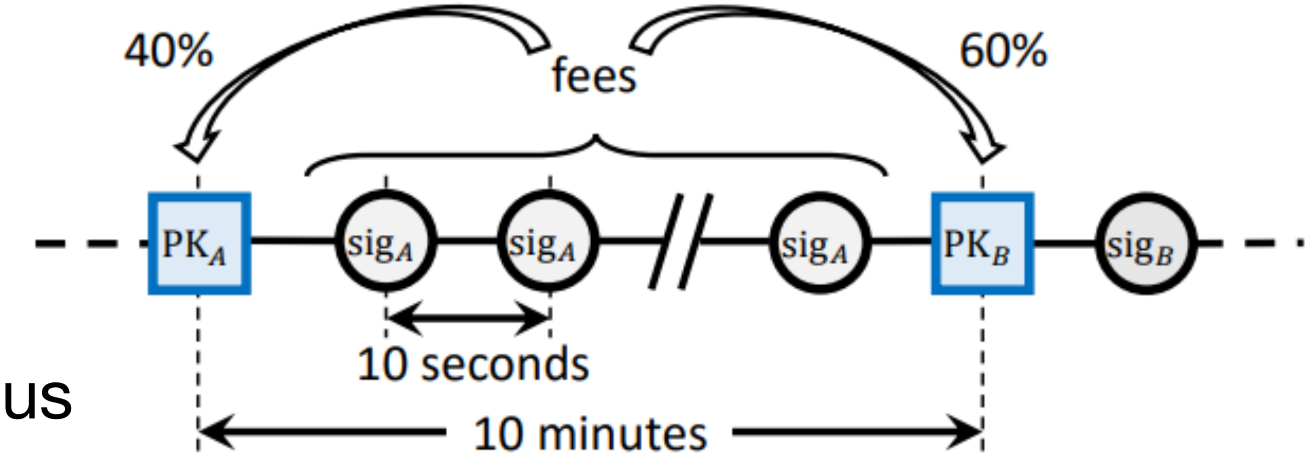
Bitcoin-NG

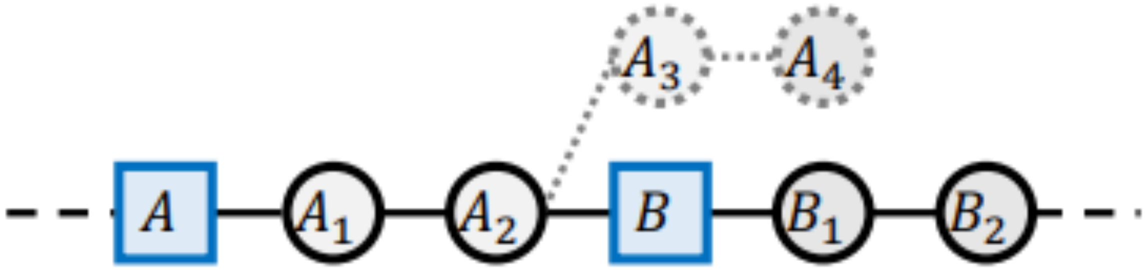
- Key blocks
  - Used for PoW-based leader election, i.e., H(header) < T
  - Point to the previous block (key or microblock)
  - The strongest-chain rule
- Microblocks
  - Generated by leader, at a defined rate
  - Contain header (with PrevHash) and a set of transactions



Bitcoin-NG

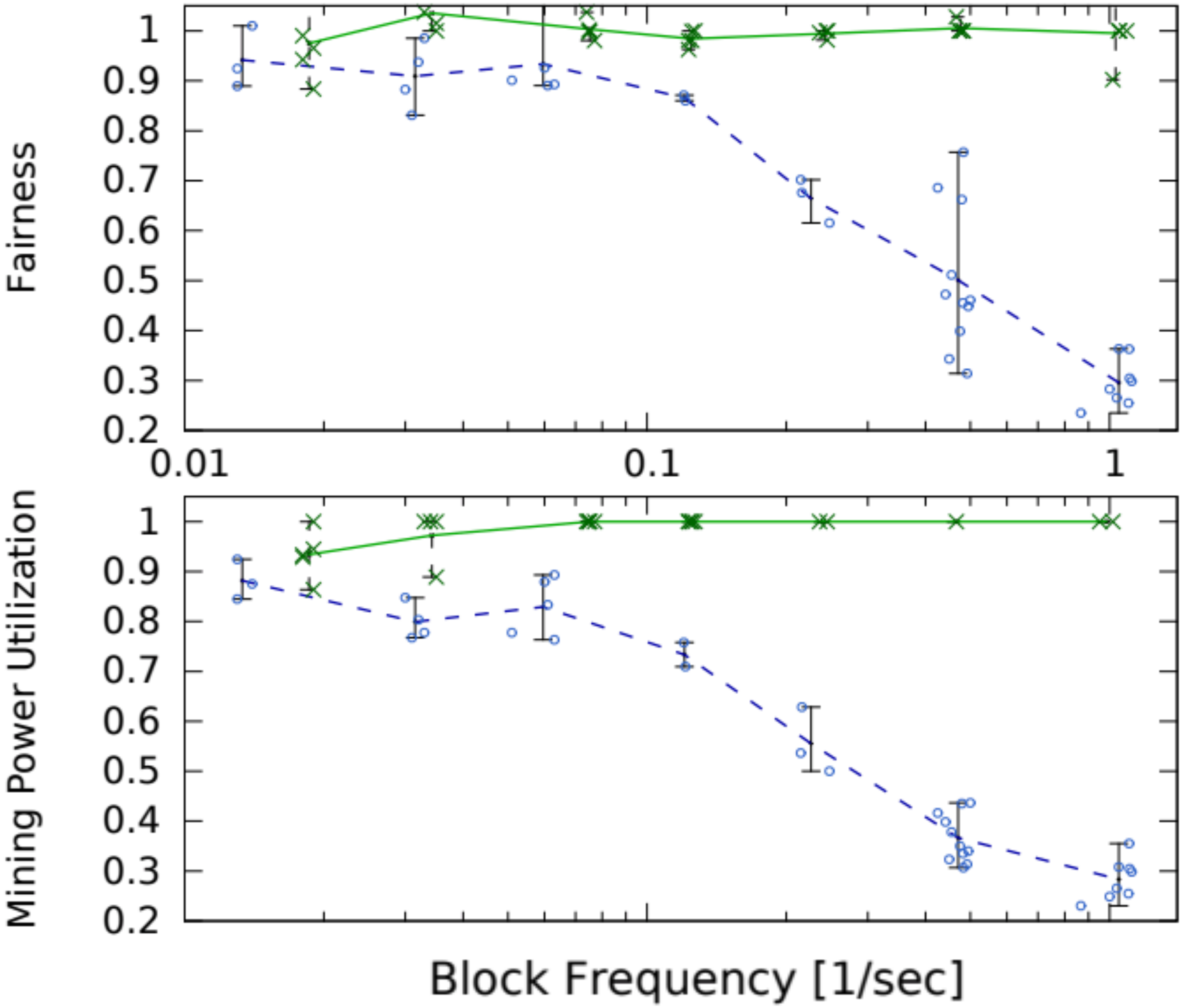
- Incentives
  - Leaders get rewards and tx fees
  - The next leader gets 60% of the previous tx fees (why?)
- Confirmations
  - Short forks will be frequent
- Microblock forks may be malicious
  - Entry with a proof of fraud can invalidate the revenue of malicious leaders





Bitcoin-NG

- Much better scalability and performance than Bitcoin
- Many systems build on this or similar ideas
- Everyone validates Txs
  - Throughput limited by a single machine
  - Can we do better?

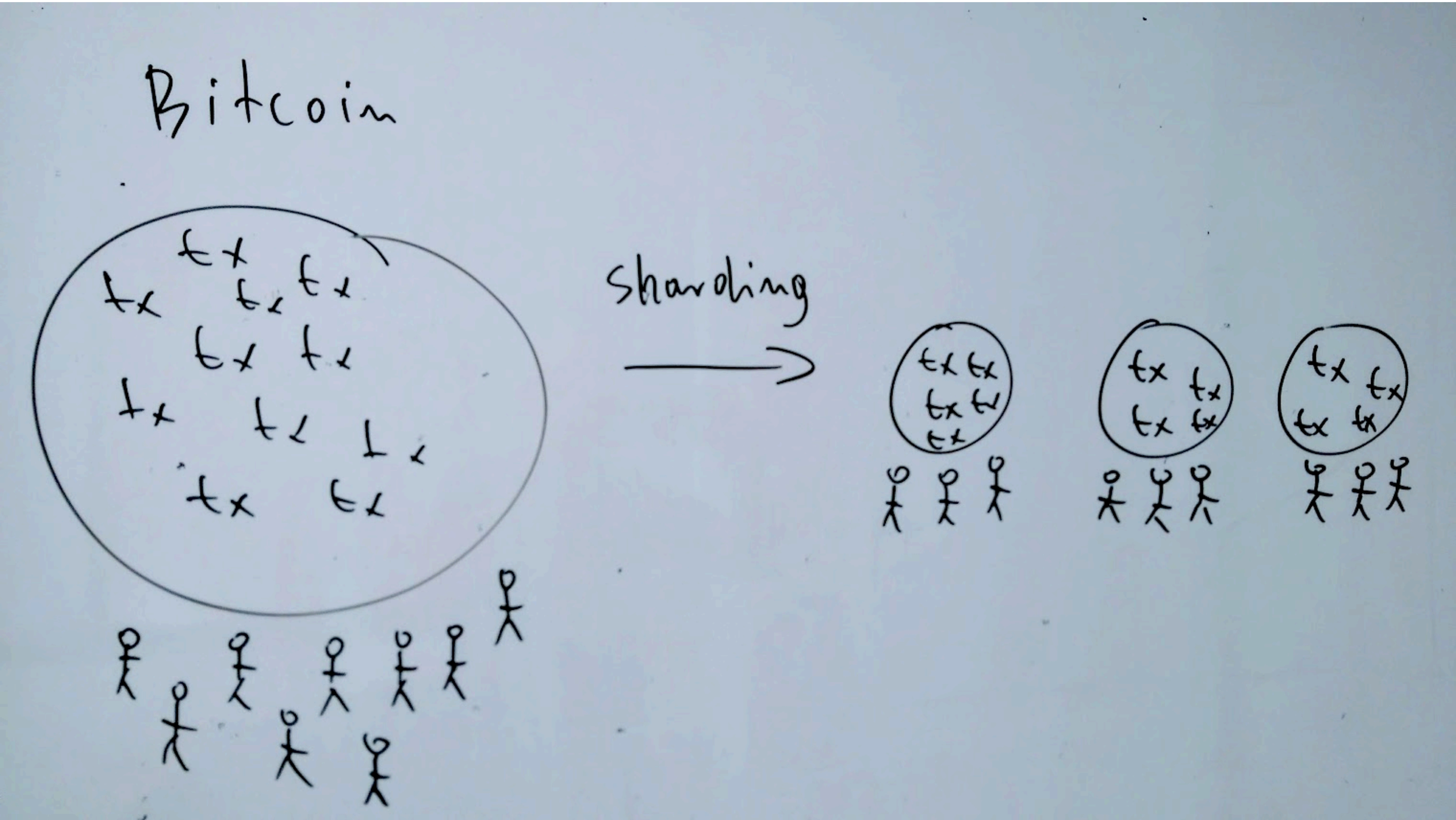


Sharding

Sharding

- The concept from database processing
- Divide transactions into groups and let different nodes process them
- Horizontal scaling
  - Throughput increases linearly as the network grows
- Ideas: establish identities via PoW, divide work, run BFT

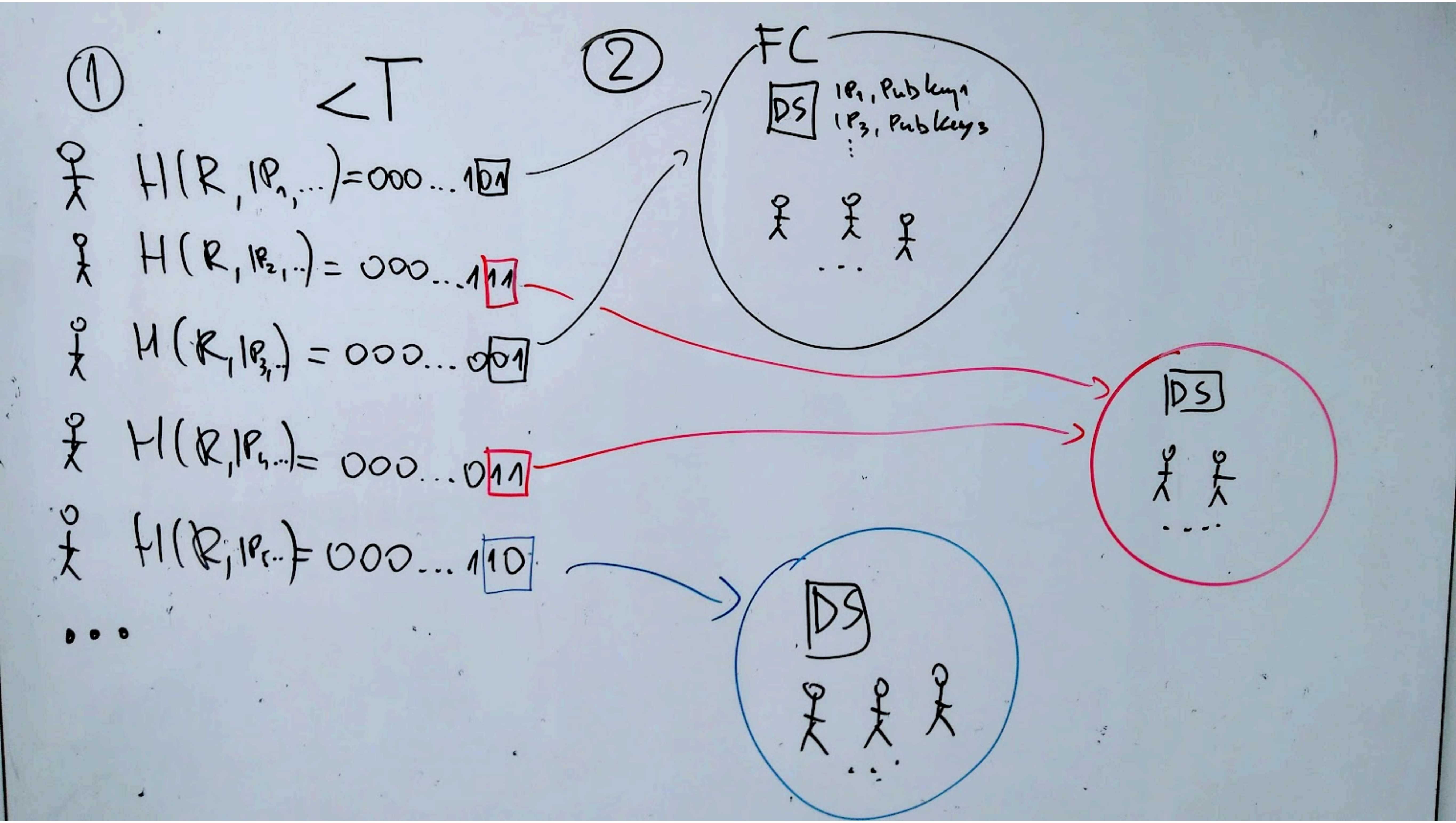
Sharding

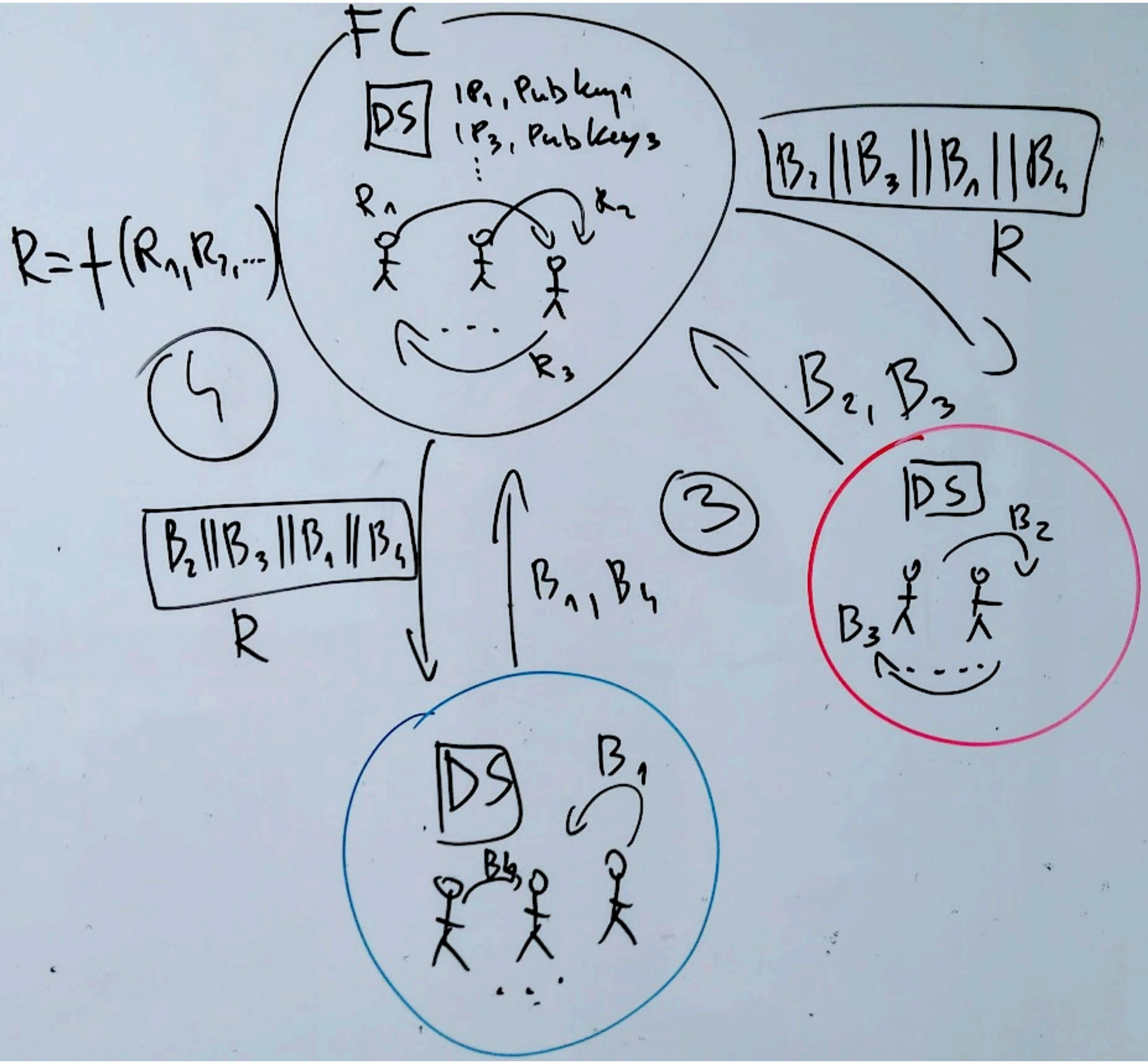


Sharding: Elastico

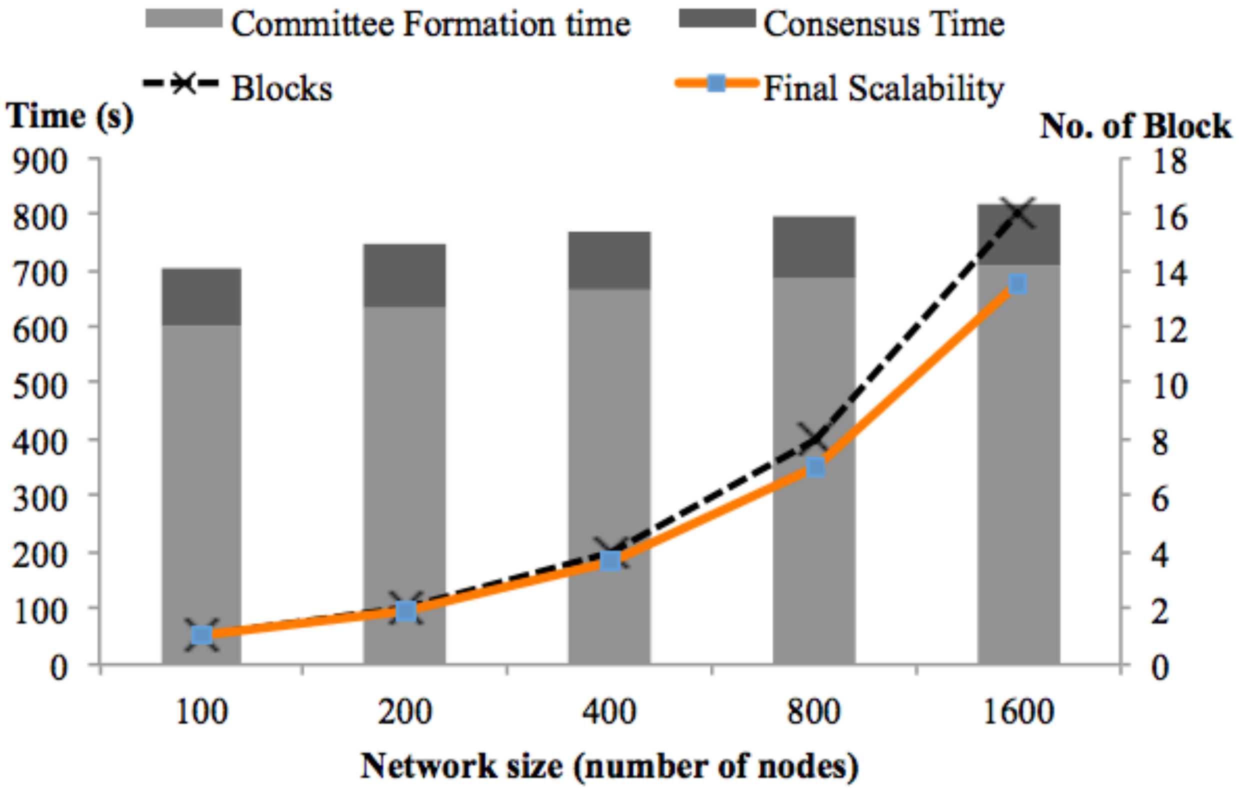
https://dl.acm.org/citation.cfm?id=2978389

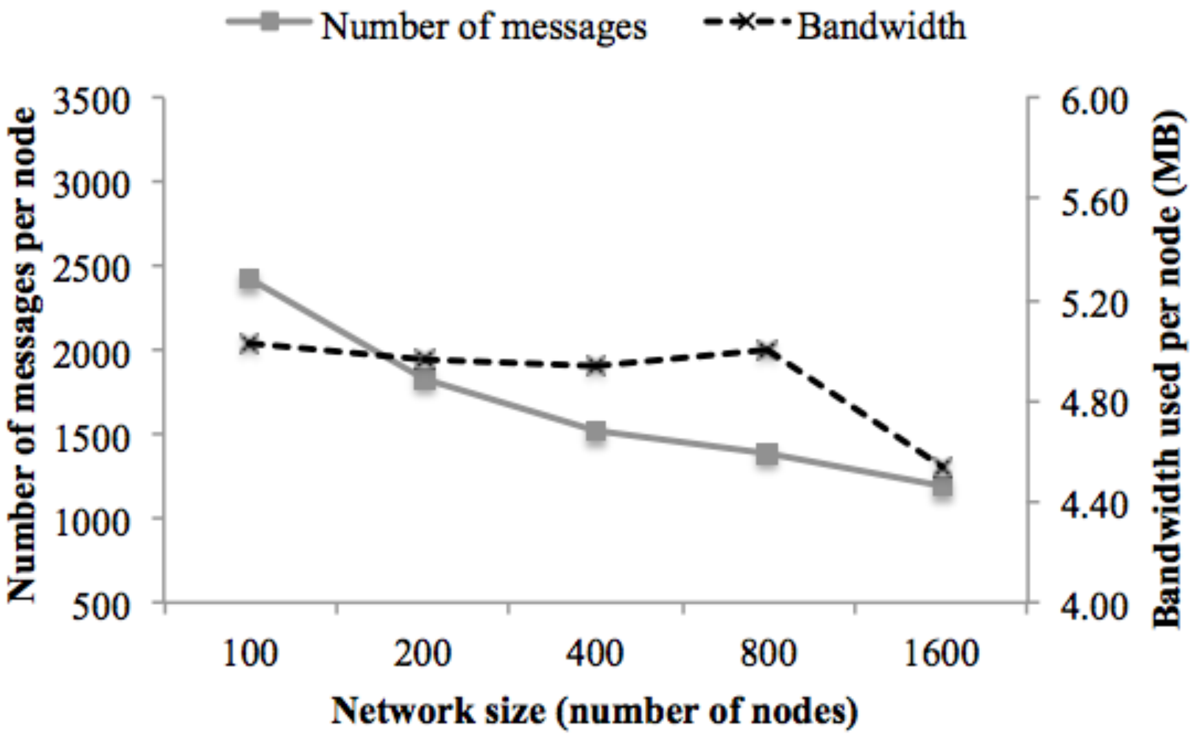
1. Use PoW to establish identities
   - ID = H(R, IP, PubKey, Nonce) < T
   - R is security-critical, see below
2. Assign committees (use randomness of IDs)
   - Each committee has C members and a directory server (w/ members)
3. Propose a block within a committee
   - Run BFT agreement, valid blocks have 2C/3 + 1 signatures
4. Final committee to union all data blocks
   - Run BFT to produce a final block, that is then broadcast to everyone
   - R generated using R_x of final committee members


1
<T
2
FC
DS
IP1, PubKey1
IP3, PubKey3
H(R, IP1, ...)=000...101
H(R, IP2, ...) = 000...111
H(R, IP3, ...) = 000...001
H(R, IP4 ...)= 000...011
H(R, IP5 ...)= 000...110
...
DS
DS


FC
DS
IP1, PubKey1
IP3, PubKey3
⋮
R1
R2
R3
R=f(R1,R2,...)
4
B2||B3||B1||B4
R
B2, B3
3
DS
B2
B3
B2||B3||B1||B4
R
B1, B4
DS
B1
B4

Sharding: Elastico





- Multiple improvements (ongoing research)
    - ZILLIQA, OmniLedger, Chainspace, Saber, …

Reading

- https://fc16.ifca.ai/bitcoin/papers/CDE+16.pdf
- https://eprint.iacr.org/2016/555.pdf
- + inline references