Scalability Challenges & Proof of Stake

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Scalability

Scalability Problem

PayPal
VISA

Transactions per Second:	~7	~30	~200	~3000

Undesirable user experience, long processing delay, and skyrocketing transaction fees!

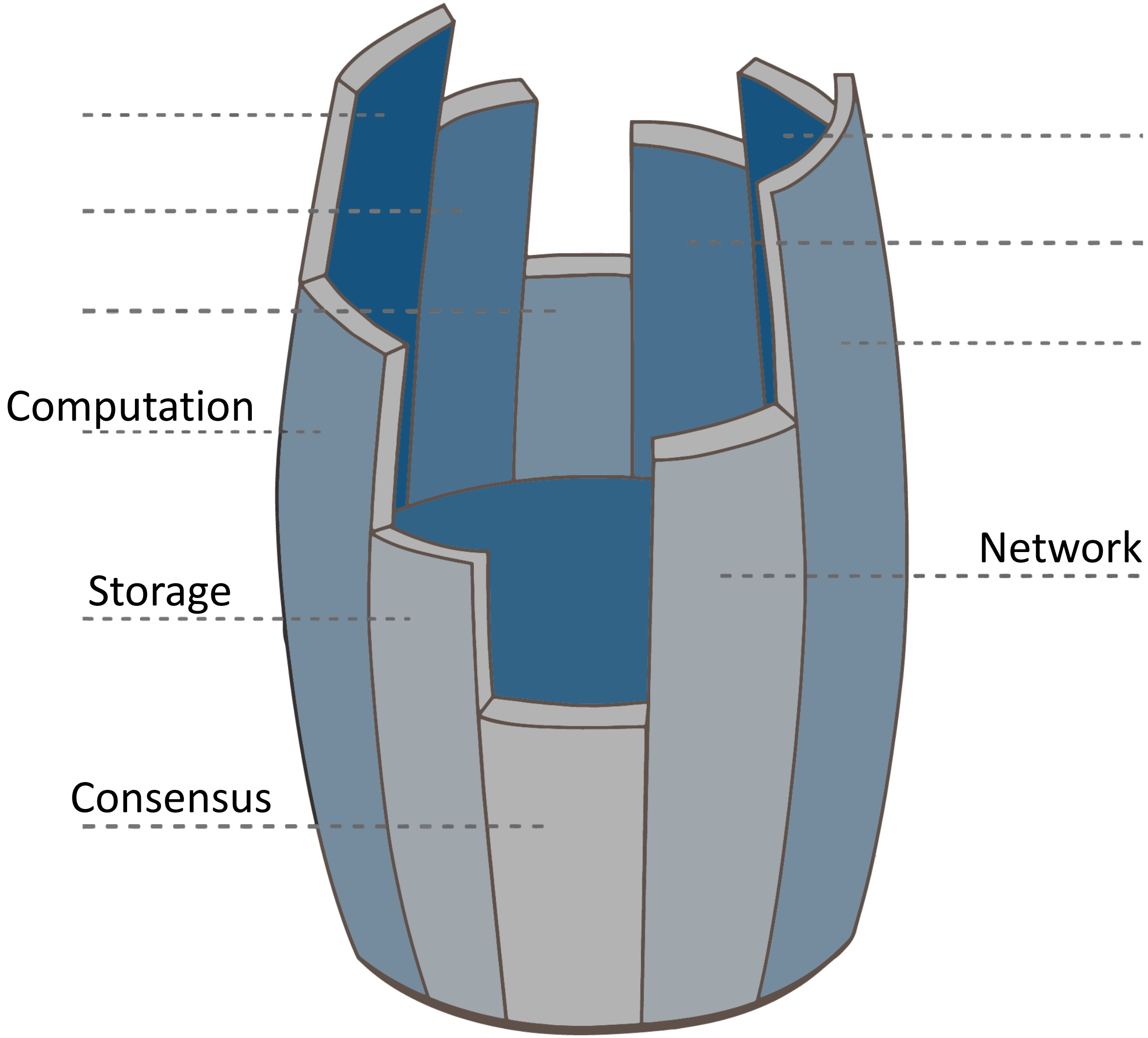
Why standard blockchain systems have very low throughput?

Standard Nakamoto Consensus

- **Proof-of-work**: participants perform computation tasks to generate blocks
- **Longest-chain**: all participants agree on the longest chain as the valid transaction history
- **Slow/small** block generation
  - Bitcoin: **1MB block per 10 minutes**
  - Ethereum: **~100k block per 15 seconds**
  - Each transaction takes 250-300B at least
  - Very limited throughput

Blockchain Scalability Barrel

- High throughput requires:
  - More storage for blockchain data
  - More network communication
  - More computation to process txs
- Consensus algorithm is the most limiting factor right now
- But to build a scalable blockchain, we need to address all of them



Possible Solutions

- **Large** blocks / **fast** block generation

- **Consensus** with a **small** number of selected nodes
  - Elect a potentially rotating committee to generate blocks
  - Often use BFT algorithms to improve throughput
- Different chain structures to process **concurrent blocks**
  - Organize blocks in Direct Acyclic Graph (DAG)

- Partition of the state – **sharding**

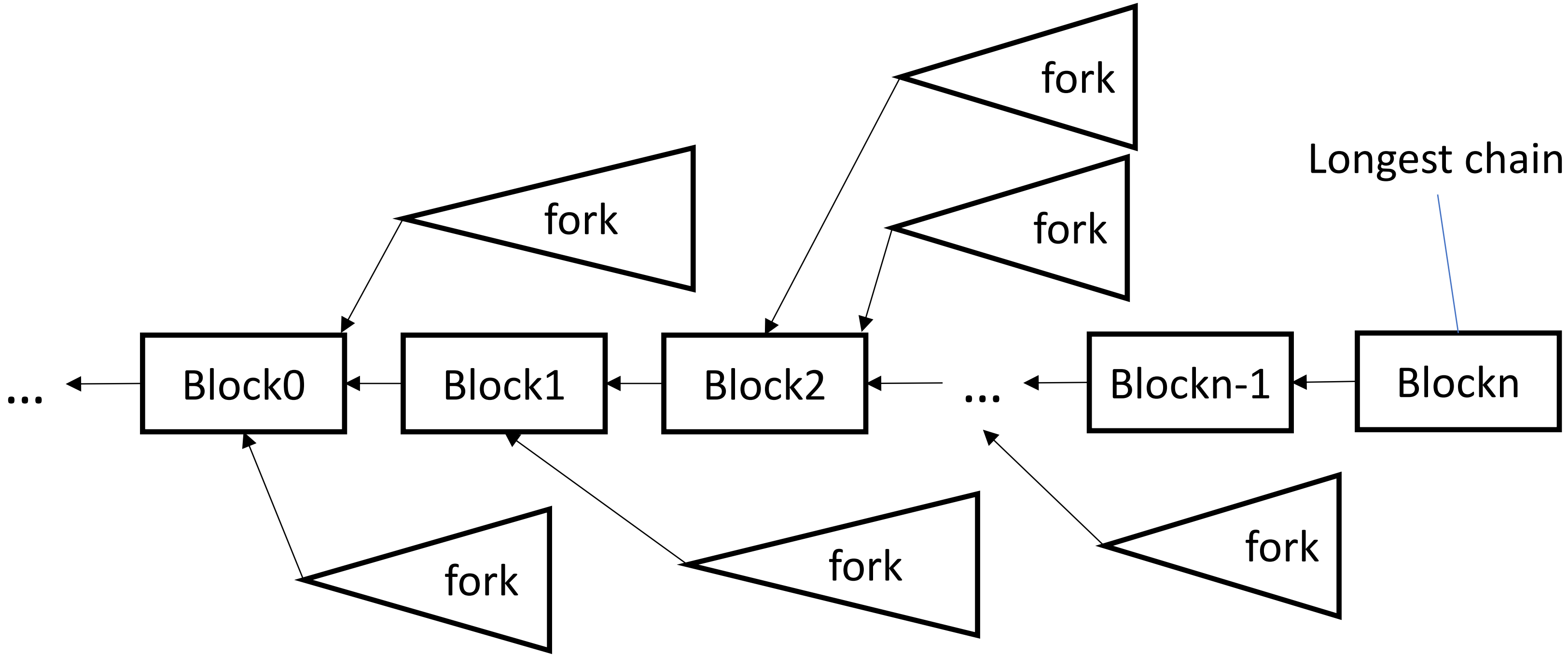
Eternal Fights on Bitcoin Block Size

- Bitcoin starts to get congested around year 2013-2014
- Some minor optimizations like SegWit implemented, but not enough
- Miners and developers fighting on whether to increase the block size
  - Arguments for: Solve congestion
  - Arguments against: Make the chain too large and harm decentralization

- Hard fork of Bitcoin Cash, which uses 8MB block
- Proposals on even removing block limit

What if we run Nakamoto Consensus with **large/fast** blocks generation?

Forks in Nakamoto Consensus



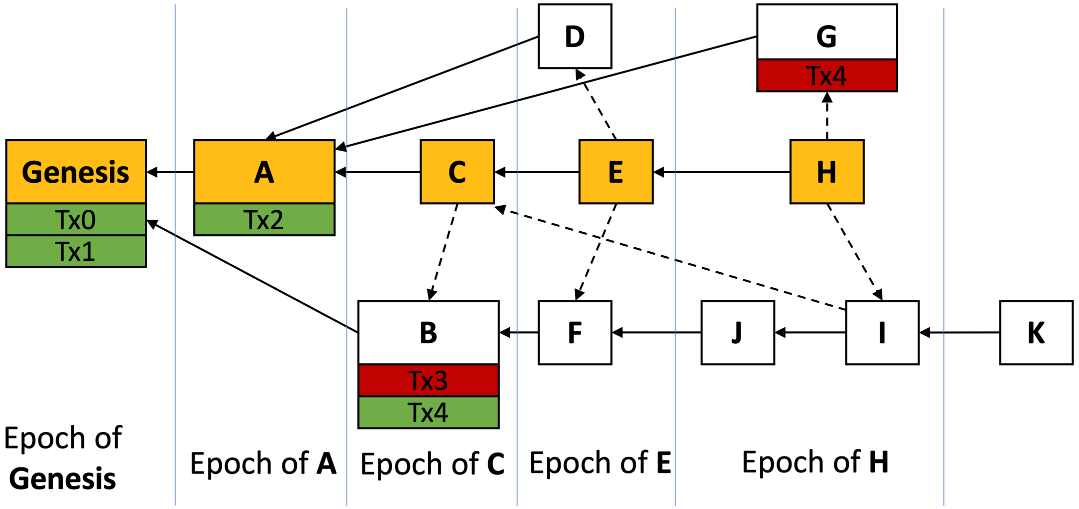
- Forks waste network/processing resources
- Downgrade safety
    - Attacker needs less resource to beat the longest chain

Run Consensus in a Small Group

- Manually elected nodes
  - For example, 21 full nodes in EOS
  - Permissioned network like Ripple/Stellar
  - Sacrifice decentralization completely for efficiency

- Have a rotating committee
  - Recent PoW miners form the committee [ByzCoin, HybridConsensus]
  - Use a verifiable random function to elect a committee [Algorand]
  - Run BFT among committee members to determine each block

Process Concurrent Blocks with DAG



- Allow multiple predecessors for the block to form a direct acyclic graph (DAG)
  - GHOST / Conflux
  - Specter and Phantom
- **Challenge**: How to obtain a total order of blocks

Sharding

- Each node in the network verifies every transaction in the blockchain
- **Idea:** Partition the state and each node verifies part of transactions
    - Each partition is called a shard
- Many security problems and challenges
    - How to partition the blockchain state?
    - How to handle inter-shard transactions?
    - Each shard becomes more vulnerable. Attacker can focus on one shard
- Trading security for efficiency
    - OmniLedger
    - ETH Casper

Proof of Stake

Proof of Work Alternatives

- Energy inefficient
- Tons of power wasted on securing the Bitcoin network
  - Computing useless hash results

- Could we find better solutions to defend against **Sybil attacks**?
  - Proof of Work: Voting power = Computation power
  - **Proof of Stake: Voting power = Your stake in the system**

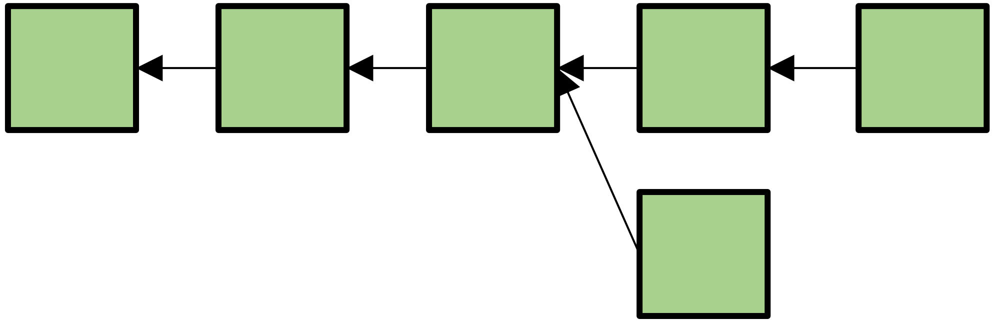
- **Proof of Stake** does not waste energy and is safe against Sybil attacks

Proof of Stake Challenges

- Economic Problem: **Rich gets richer**
  - Rich can generate more blocks and claim mining more rewards in PoS

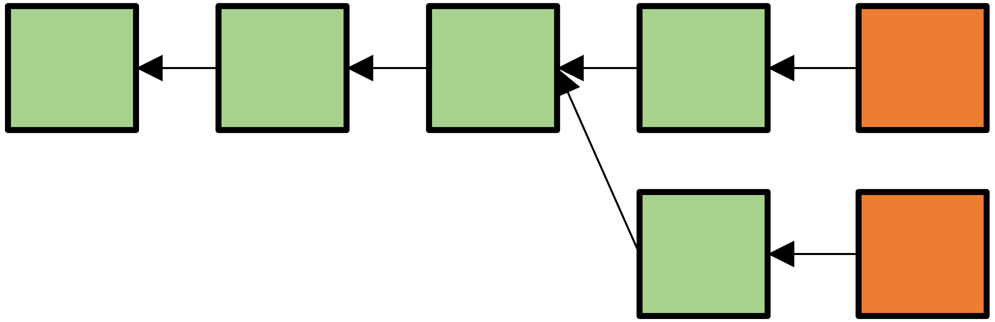
- Security Problem 1: **Nothing at stake**
  - When facing forks in the chain, nothing stops a node to work on multiple branches
- Security Problem 2: **Long range attack**
  - Malicious majority in history can create alternative chains
  - No good solution so far

Nothing At Stake



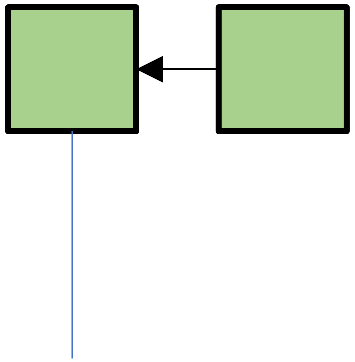
- Forks appear during the process of Nakamoto Consensus
- In PoW, a miner appends his new block to one fork to break tie
- He can only generate one block at a time
  - because each block costs computation power

Nothing At Stake



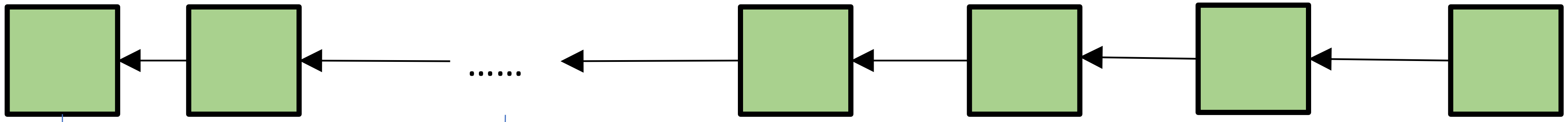
- In PoS, generating a block is cheap as long as you own stake
- Incentivized to generate multiple blocks, one for each branch
- No matter which branch wins, the miner will be able to get reward
- **Consequence:** Forks may never get resolved!
- **Solution**: Design penalties to such behavior

Long Range Attack



Suppose Alice, Bob, and Charles together own a majority of stakes of the system

Long Range Attack



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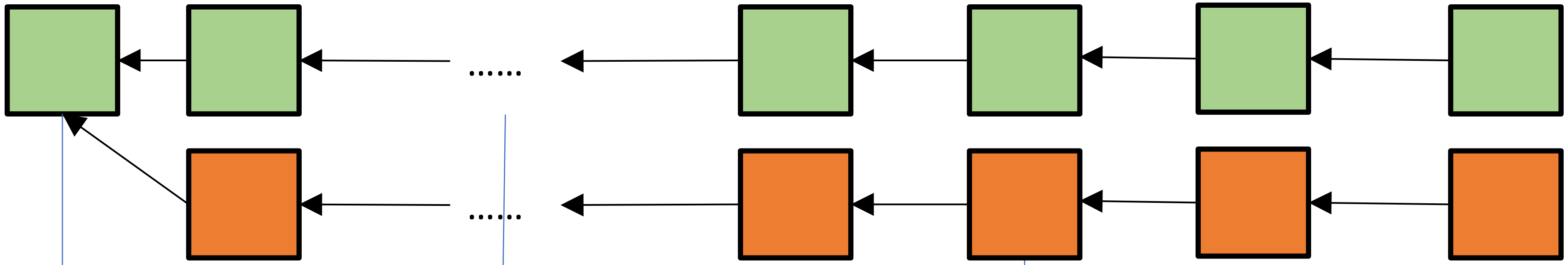

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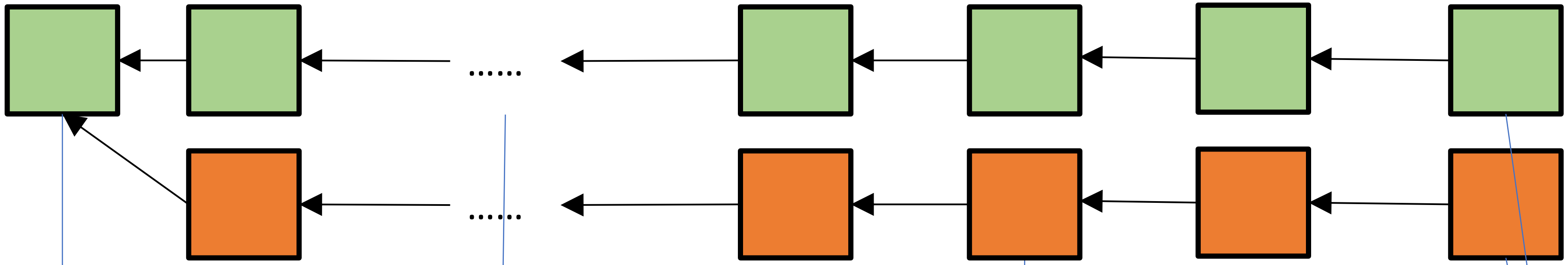

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Now you are an new user joining the system. How could you know which chain is valid?

Discussion

- Many believe that Bitcoin has low throughput because of Proof-of-Work.

- A chain with Proof of Stake will always process more transactions than a chain with Proof of Work.

- Is this true or not?