BLOCKCHAINS

ARCHITECTURE, DESIGN AND USE CASES

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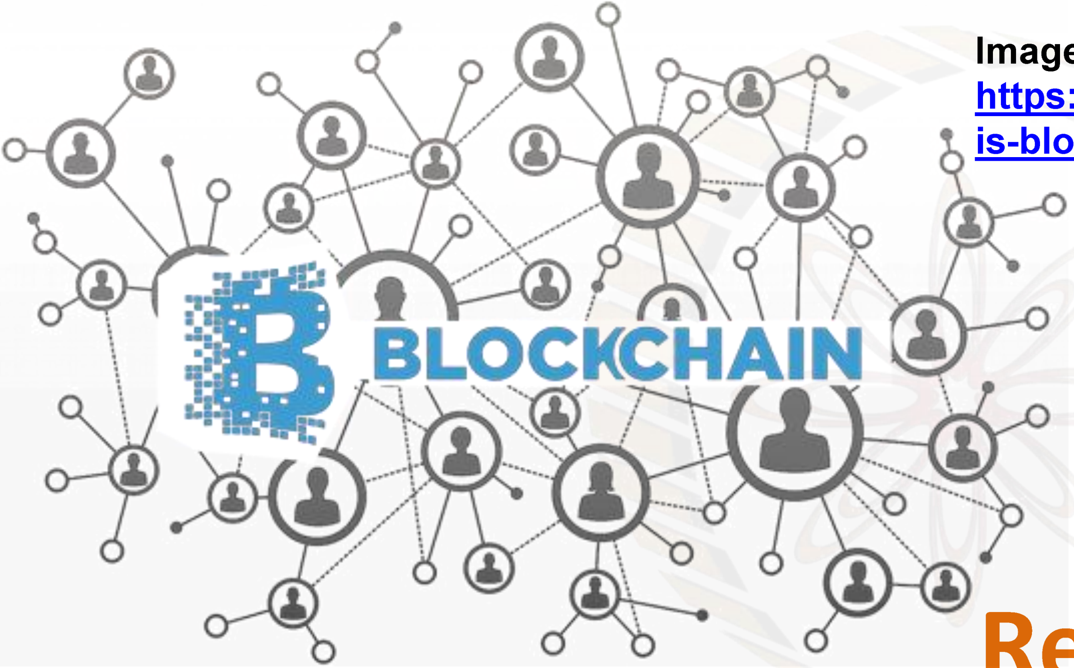


Image Source: https://steemit.com/blockchain/@tariq3njr/what-is-blockchain-technology

Research Aspects - I
Consensus Scalability

Blockchain Consensus Protocols

- Permissionless Blockchain
  - Proof of Work (PoW)
  - Proof of State (PoS)
  - Proof of Burn (PoB)
  - Proof of Elapsed Time (PoET)

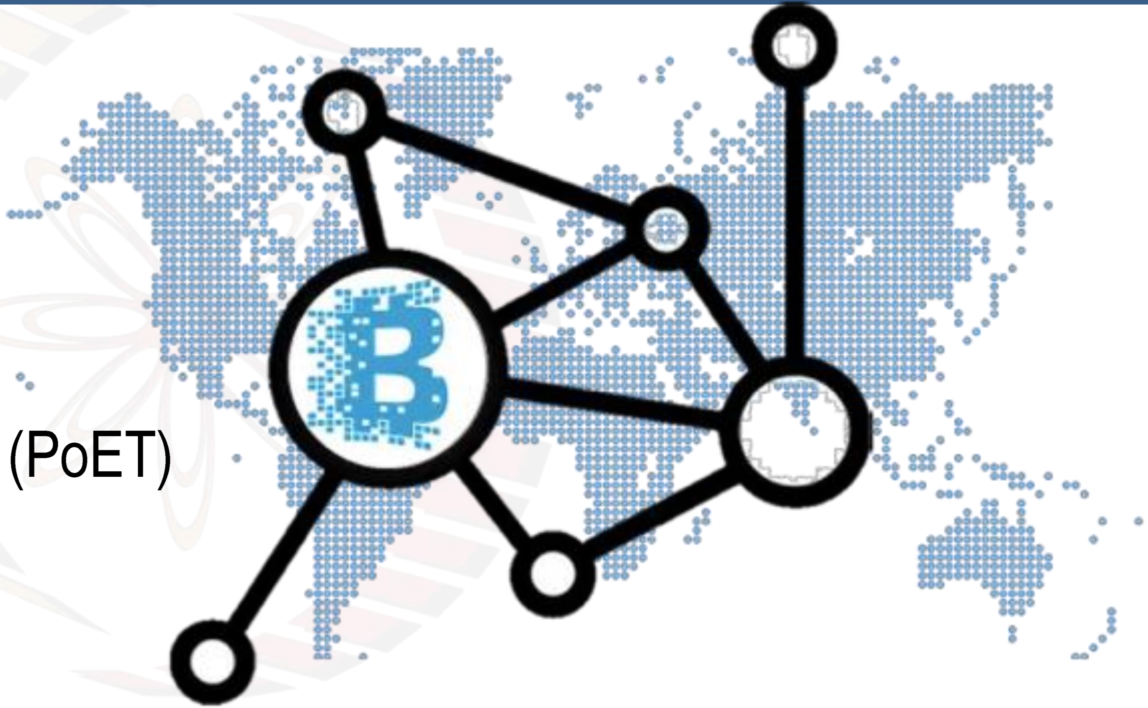


Image Source: https://www.ictworks.org/eight-practical-blockchain-use-cases/

Blockchain Consensus Protocols

- Permissioned Blockchain
  - BFT
  - PBFT
  - RBFT

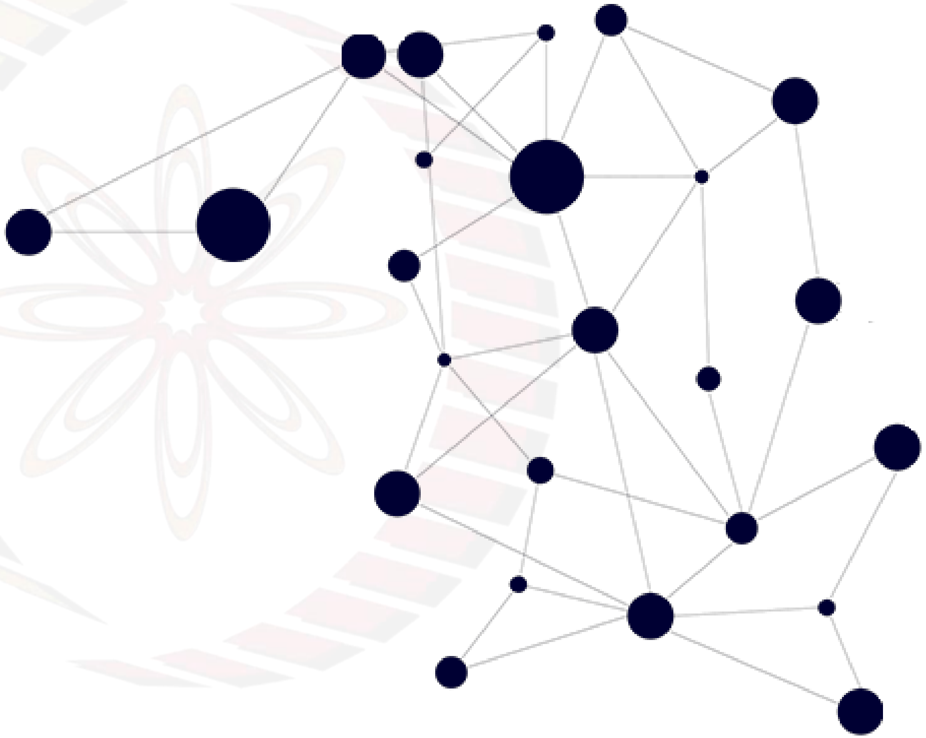


Image Source: https://www.challenge.org/demo/blockchain-challenge-2/

PoW vs PBFT

- PoW
  - Open environment, works over a large number of nodes
  - Scalable in terms of number of nodes
  - Transaction throughput is low

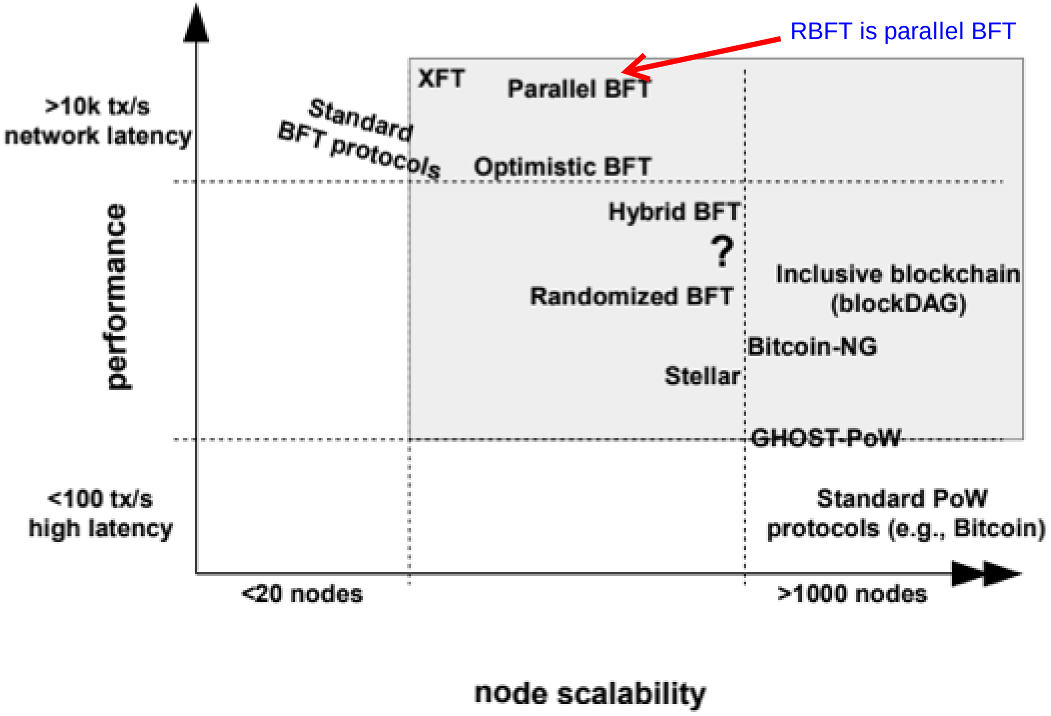
- PBFT
  - Closed, not scalable in terms od number of nodes
  - High transaction throughput

PoW Scalability

- Two magic numbers in PoW
  - **Block frequency** - 10 minutes
  - **Block size** - 1 MB

- Transaction throughput - 7 transactions per second (with 200-250 bytes transactions)

Performance vs Scalability for PoW and BFT



Vukolić, Marko. "The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication." ***International Workshop on Open Problems in Network Security*****. Springer, Cham, 2015.**

PoW vs PBFT - Consensus Finality

- *If a correct node p appends block b to its copy of blockchain before appending block b', then no correct node q appends block b' before b to its copy of the blockchain* (Vukolic, 2015)

- PoW is a randomized protocol - does not ensure consensus finality
  - Remember the forks in Bitcoin blockchain

- BFT protocols ensure total ordering of transactions - ensures consensus finality

PoW Consensus vs BFT Consensus

	PoW consensus	BFT consensus
Node identity management	**open, entirely decentralized**	permissioned, nodes need to know IDs of all other nodes
Consensus finality	no	**yes**
Scalability (no. of nodes)	**excellent (thousands of nodes)**	limited, not well explored (tested only up to $n \leq 20$ nodes)
Scalability (no. of clients)	**excellent (thousands of clients)**	**excellent (thousands of clients)**
Performance (throughput)	limited (due to possible of chain forks)	**excellent (tens of thousands tx/sec)**
Performance (latency)	high latency (due to multi-block confirmations)	**excellent (matches network latency)**
Power consumption	very poor (PoW wastes energy)	**good**
Tolerated power of an adversary	$\leq 25\%$ computing power	$\leq 33\%$ voting power
Network synchrony assumptions	physical clock timestamps (e.g., for block validity)	**none for consensus safety** (synchrony needed for liveness)
Correctness proofs	no	**yes**

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Bitcoin-NG

Eyal, I., Gencer, A. E., Sirer, E. G., & Van Renesse, R. (2016, March). **Bitcoin-NG: A Scalable Blockchain Protocol**. In *NSDI 2016*

Bitcoin-NG

Issues with Nakamoto Consensus (PoW)

- **Transaction scalability**
  - Block frequency of 10 minutes and block size of 1 MB during mining reduces the transactions supported per second

- **Issues with Forks**
  - Prevents consensus finality
  - Makes the system unfair - a miner with poor connectivity has always in a disadvantageous position

Bitcoin-NG: A Scalable PoW Protocol

- Bitcoin - think of the winning miner as the **leader** - the leader serializes the transactions and include a new block in the blockchain

- Decouple Bitcoin's blockchain operations into two planes
  - **Leader election**: Use PoW to randomly select a leader (an infrequent operation)
  - **Transaction Serialization**: The leader serializes the transaction until a new leader is elected

Bitcoin vs Bitcoin-NG

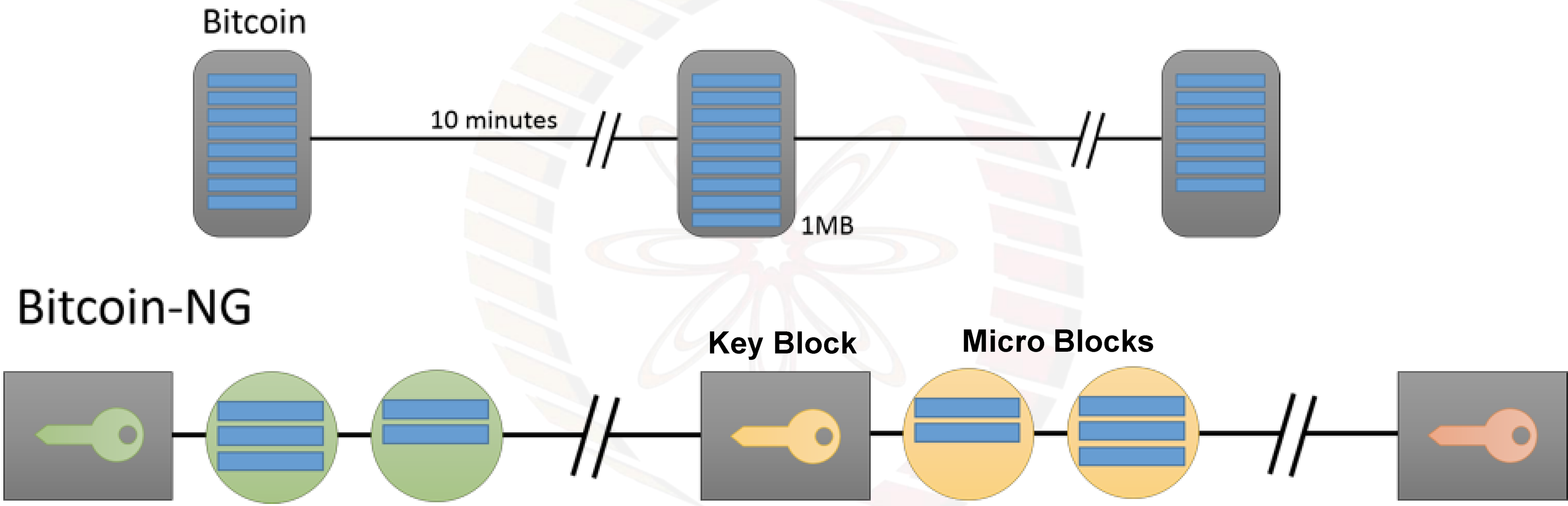


Image Source: http://hackingdistributed.com/2015/10/14/bitcoin-ng/

Bitcoin-NG: Key Blocks

- Key blocks are used to choose a leader (similar to Bitcoin)

- A key block contains
  - The reference to the previous block
  - The current Unix time
  - A coinbase transaction to pay of the reward
  - A target hash value
  - A nonce field

Bitcoin-NG: Key Blocks

- For a key block to be valid, the cryptographic hash of its header must be smaller than the target value.

- The key block also contains a public key (so the name, key block)
  - Used in subsequent microblocks

Bitcoin-NG: Key Blocks

- Key blocks are generated based on regular Bitcoin mining procedure
  – Find out the nonce such that the block hash is less than the target value

- Key blocks are generated infrequently - the intervals between two key blocks is exponentially distributed

Bitcoin-NG: Microblocks

- Once a node generates a key block, it becomes the **leader**
- As a leader, the node is allowed to generate microblocks
  - Microblocks are generates at a set rate smaller than a predefined maximum
  - The rate is much higher than the key block generation rate

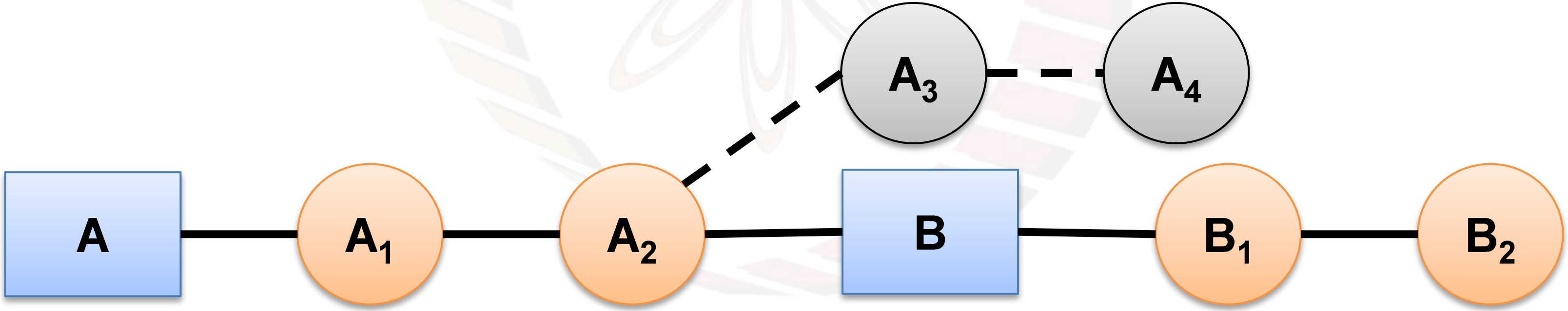
Bitcoin-NG: Microblocks

- A microblock contains
  - Ledger entries
  - Header
    - Reference to the previous block
    - The current Unix time
    - A cryptographic hash of the ledger entries (Markle root)
    - A cryptographic signature of the header

- The signature uses private key corresponding to the key block public key

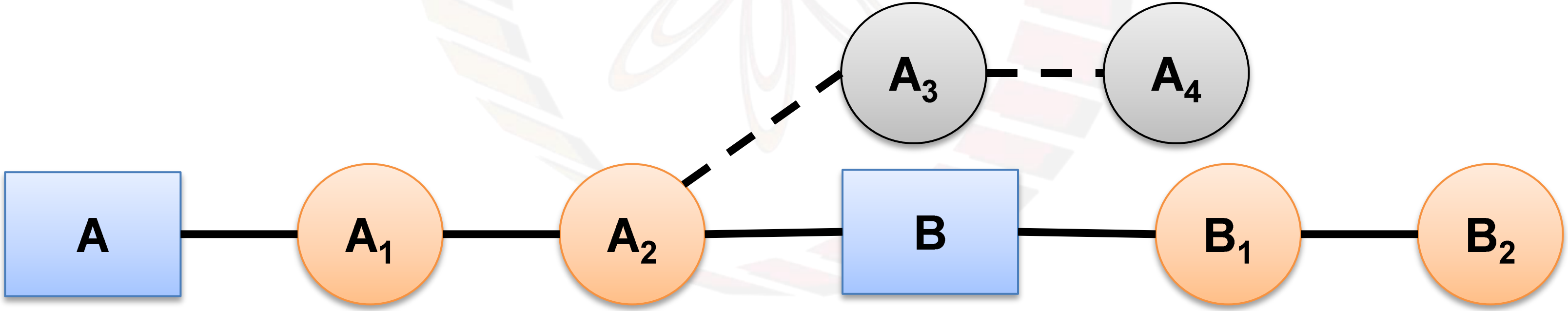
Bitcoin-NG: Confirmation Time

- When a miner generates a key block, he may not have heard of all microblocks generated by the previous leader
  - Common if microblock generation is frequent
  - May result in microblock fork

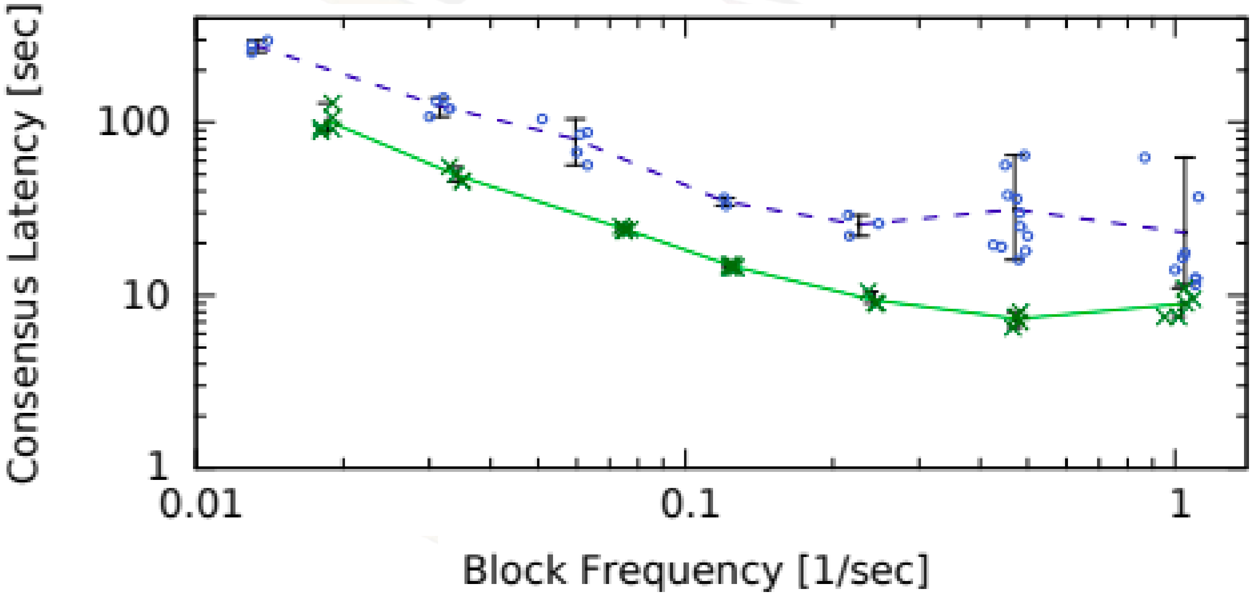


Bitcoin-NG: Confirmation Time

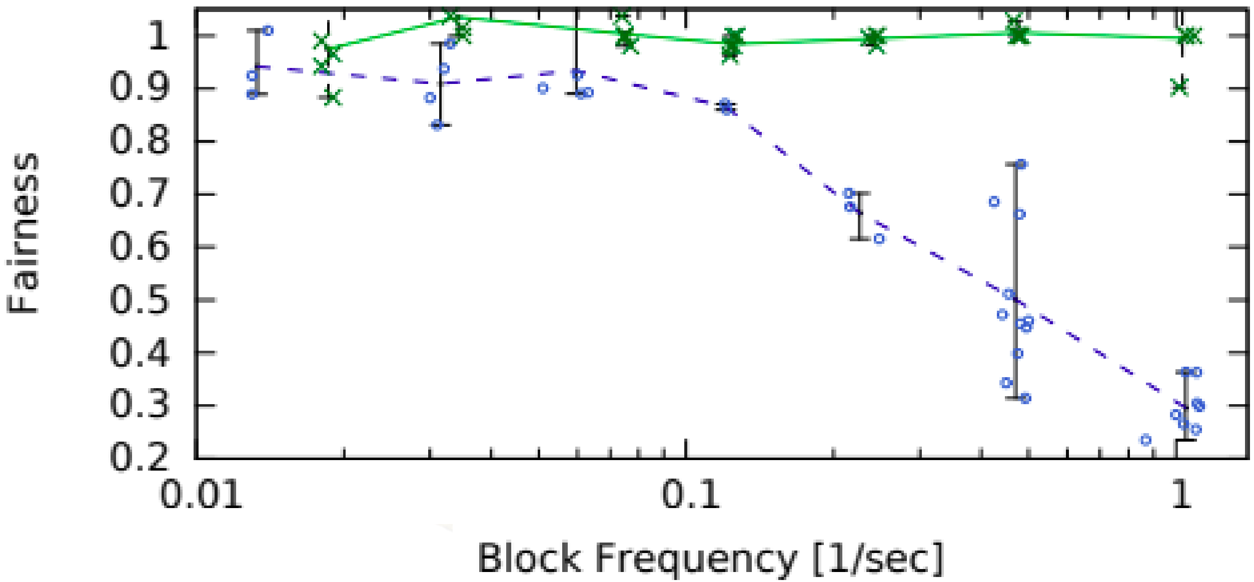
- A node may hear a forked microblock (A_3) but not the new key block (B)
  - This can be prevented by ensuring the reception of the key block
  - When a node sees a microblock, it waits for propagation time of the network, to make sure it is not pruned by a new key block



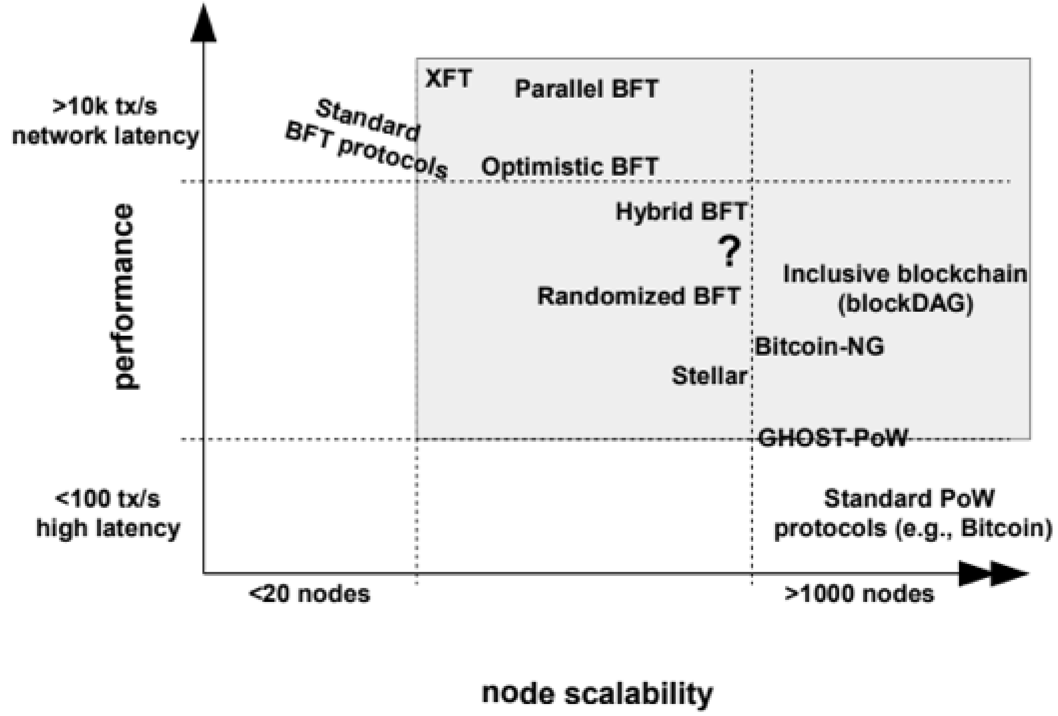
Bitcoin vs Bitcoin-NG



Bitcoin vs Bitcoin-NG



Performance vs Scalability for PoW and BFT



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thank you!