Max Attestation Matters: Making Honest Parties Lose Their Incentives in Ethereum PoS

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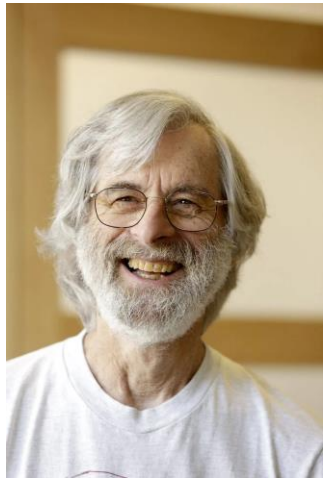
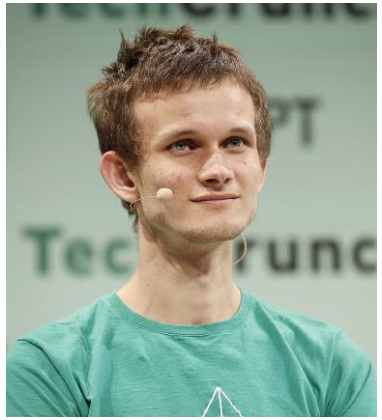
The History of Distributed System



Leslie Lamport
Byzantine Generals Problem

Babara Liskov
First practical BFT

Satoshi Nakamoto
Bitcoin



Vitalik Buterin
Ethereum

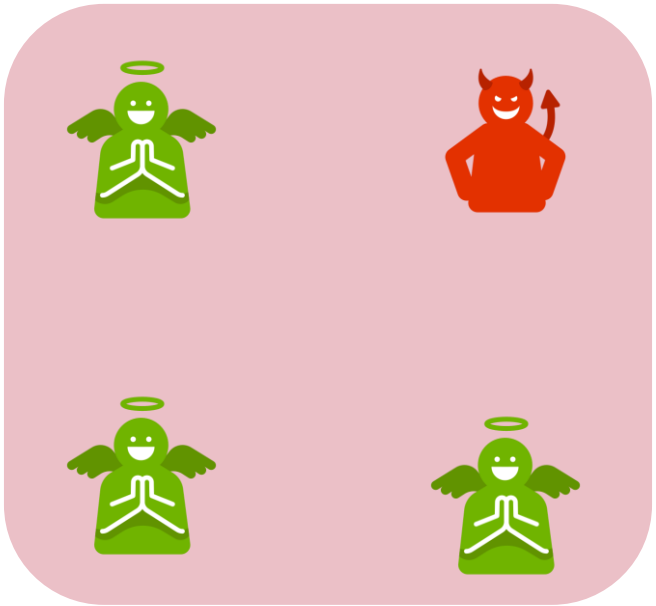
1982 1999 2008 2013

Figure source: Wikipedia

Understanding Blockchain Security

System model

- The system is maintained by a group of nodes;
- Allowing for the existence of some malicious nodes;
- The majority of nodes are honest.

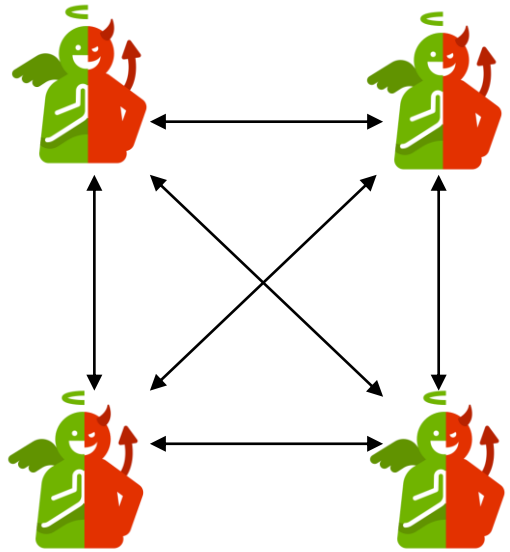


Security goals

- **Safety**: ensures that all honest nodes have a consistent view of the system's state at all times.
- **Liveness**: ensures that the system can continue to process and confirm new transactions

Using Economic Incentive to Bridge the Gap

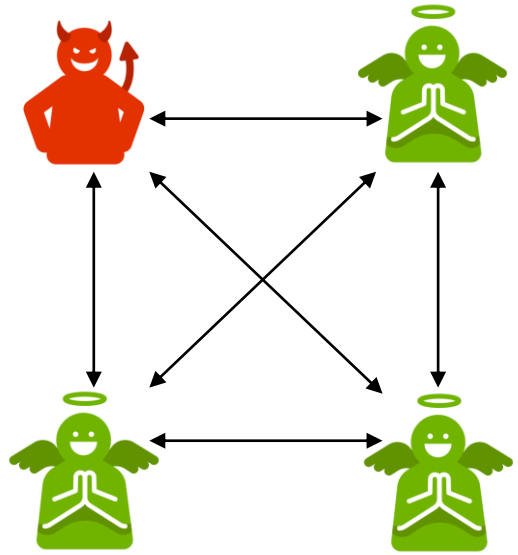
Real-world



Any node is rational and may choose to do evil for its interest

Economic Incentive

Real-world



Using incentives to keep the majority honest

Ethereum

- Ethereum is the second biggest blockchain.
- In September 2022, Ethereum transitions from Proof-of-Work to a Proof-of-Stake consensus mechanism, Gasper.

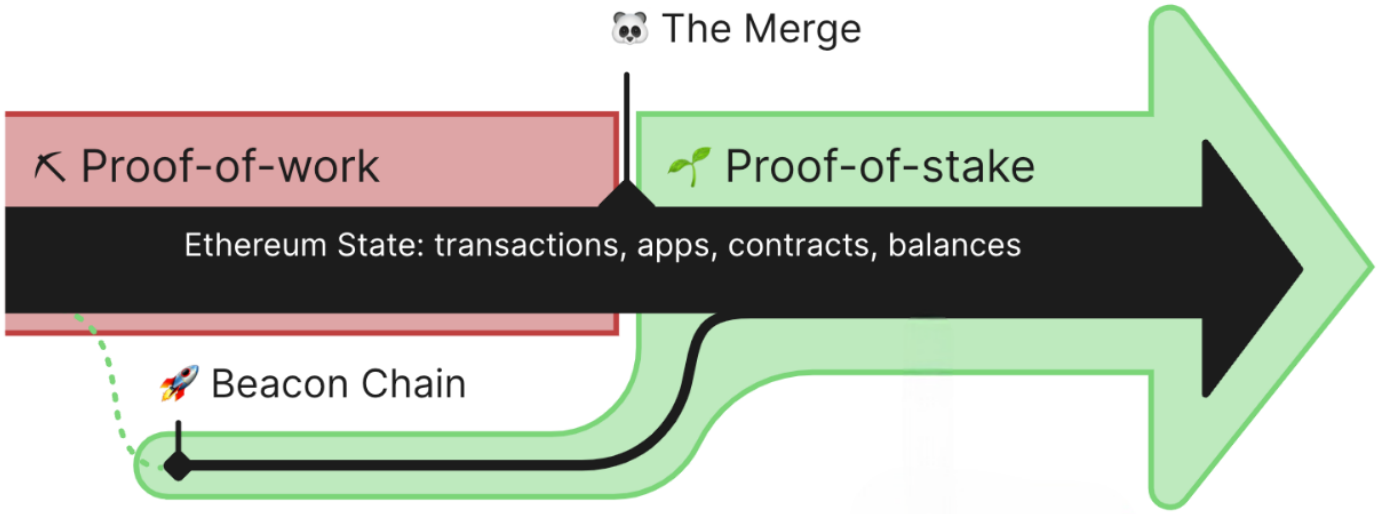
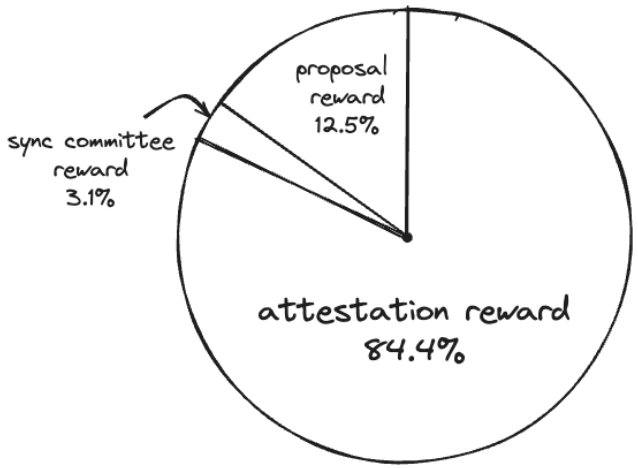
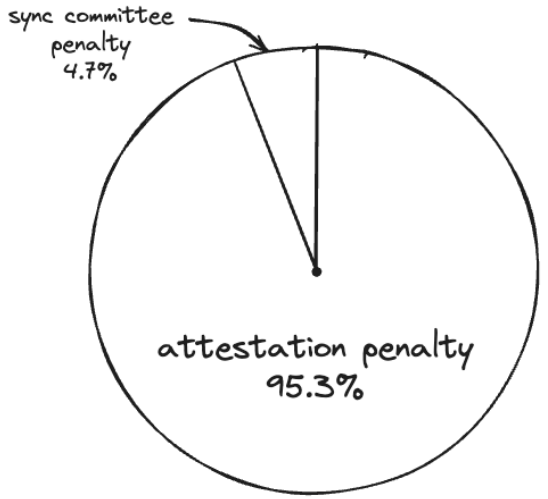


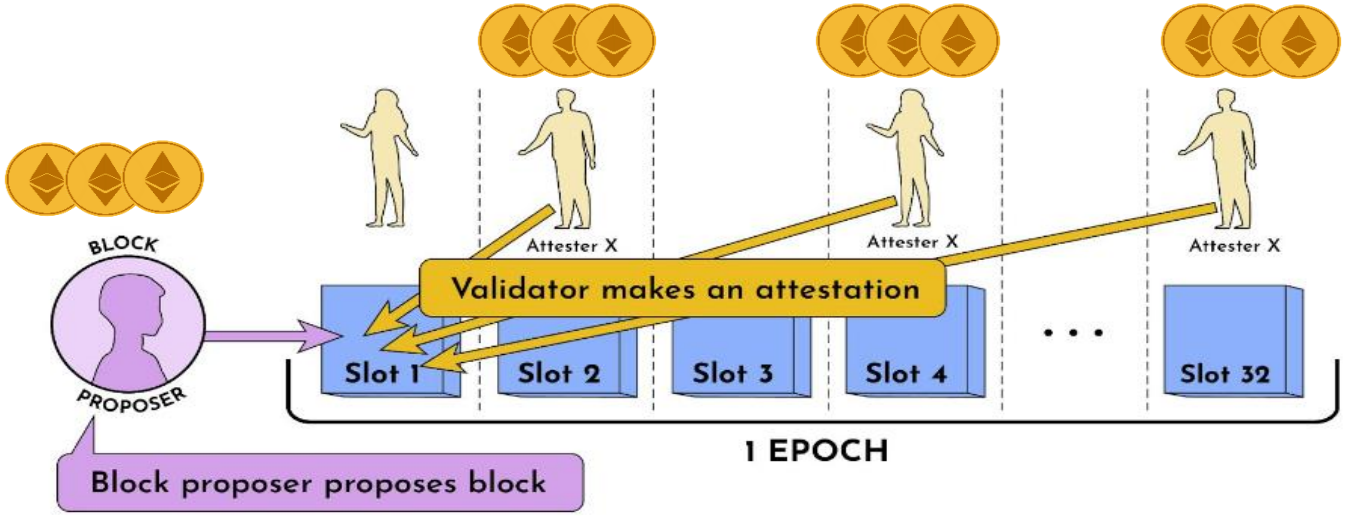
Figure source: https://ethereum.org/en/roadmap/merge/

Incentive Mechanism in Ethereum

- Attestation Incentives
  - Rewards
  - Penalties
- Block Rewards
- Sync Committee Incentives

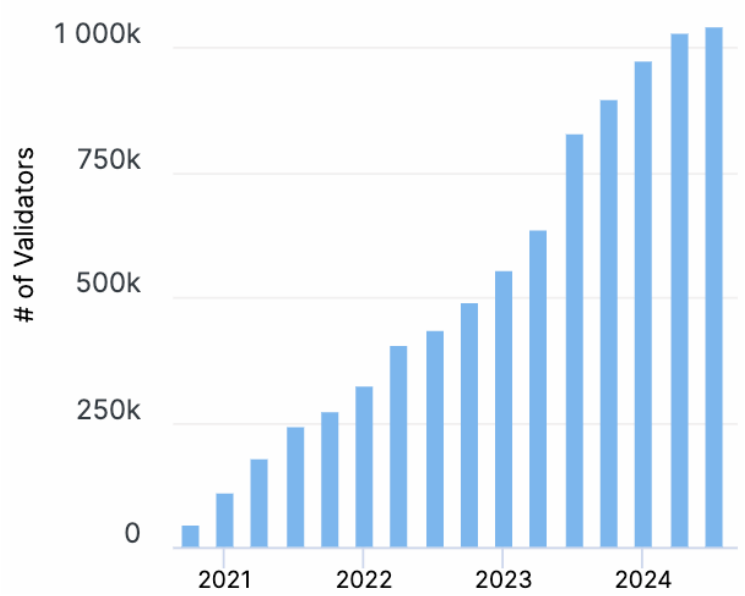






Incentive Mechanism is Successful

- Up to now, more than one million validators are in the system.
- Ethereum uses an incentive mechanism to keep validators active.
- The participation rate is very high, exceeding 99%.



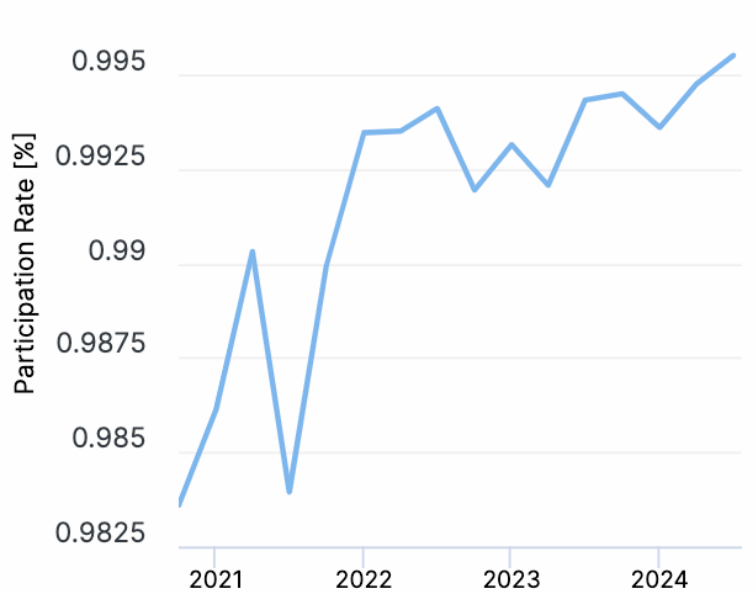


Figure source: beaconcha.in

Research Problems

Can we make honest players suffer from penalties (at least without receiving rewards) even if they strictly follow the protocol?

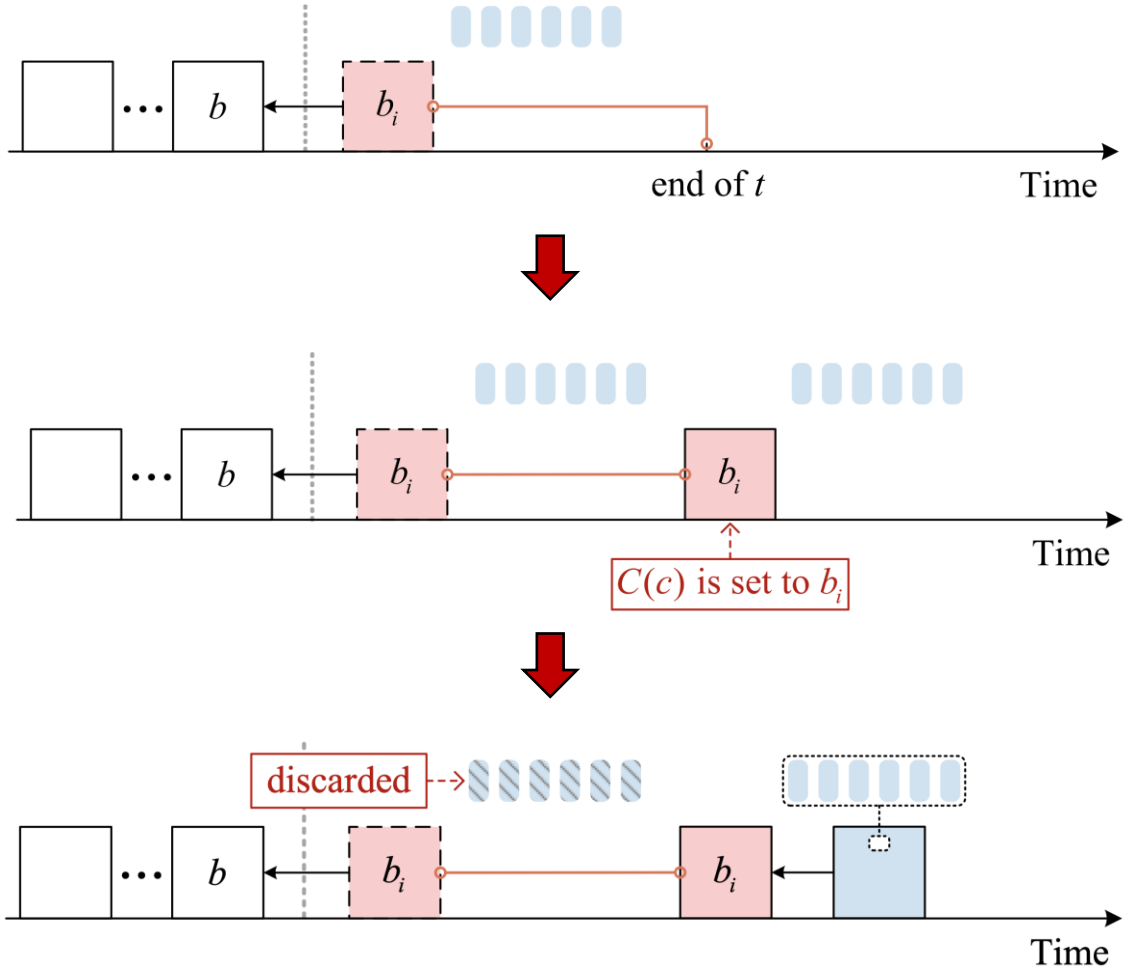
- Attacks on the attestation incentive mechanism causing honest validators to lose their incentives.

Attacks Overview

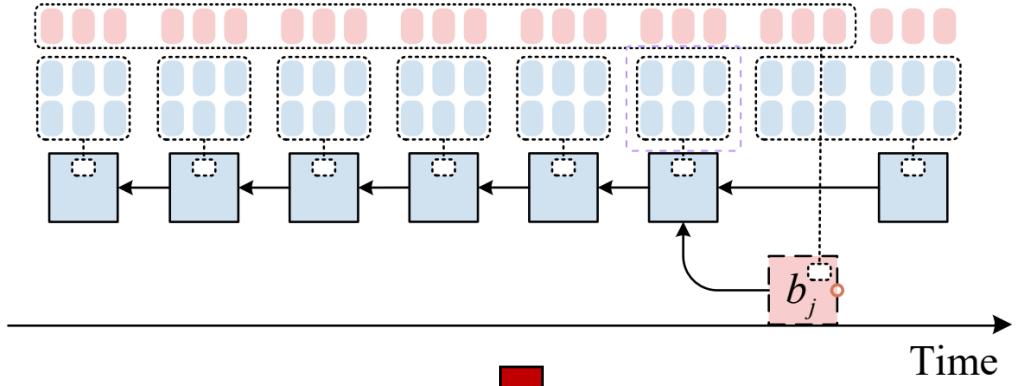
- We have identified two kinds of attacks:
  - Warm-up attack
  - Staircase attack
- In the warm-up attack, a single Byzantine validator can cause the honest validators to lose their attestation incentives.
- In the staircase attack, the adversary can cause the honest validators to lose all their attestation incentives, even lose their stake.

Warm-up Attack

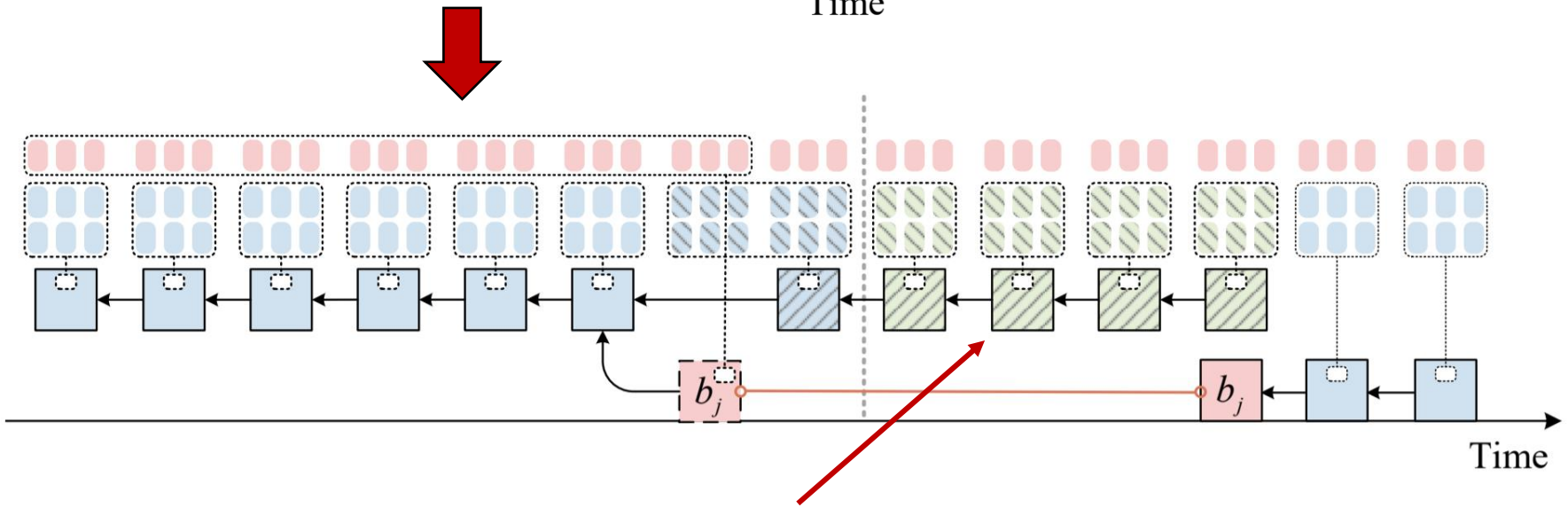
- Only one Byzantine validator is required to conduct the attack.
- To conduct the attack, the Byzantine validator must be the proposer at the first slot of an epoch.
- The adversarial strategy is withholding its blocks for 4 seconds.
- Approximately 1/32 honest validators will receive penalties after the attack.



Staircase Attack: One-time Attack



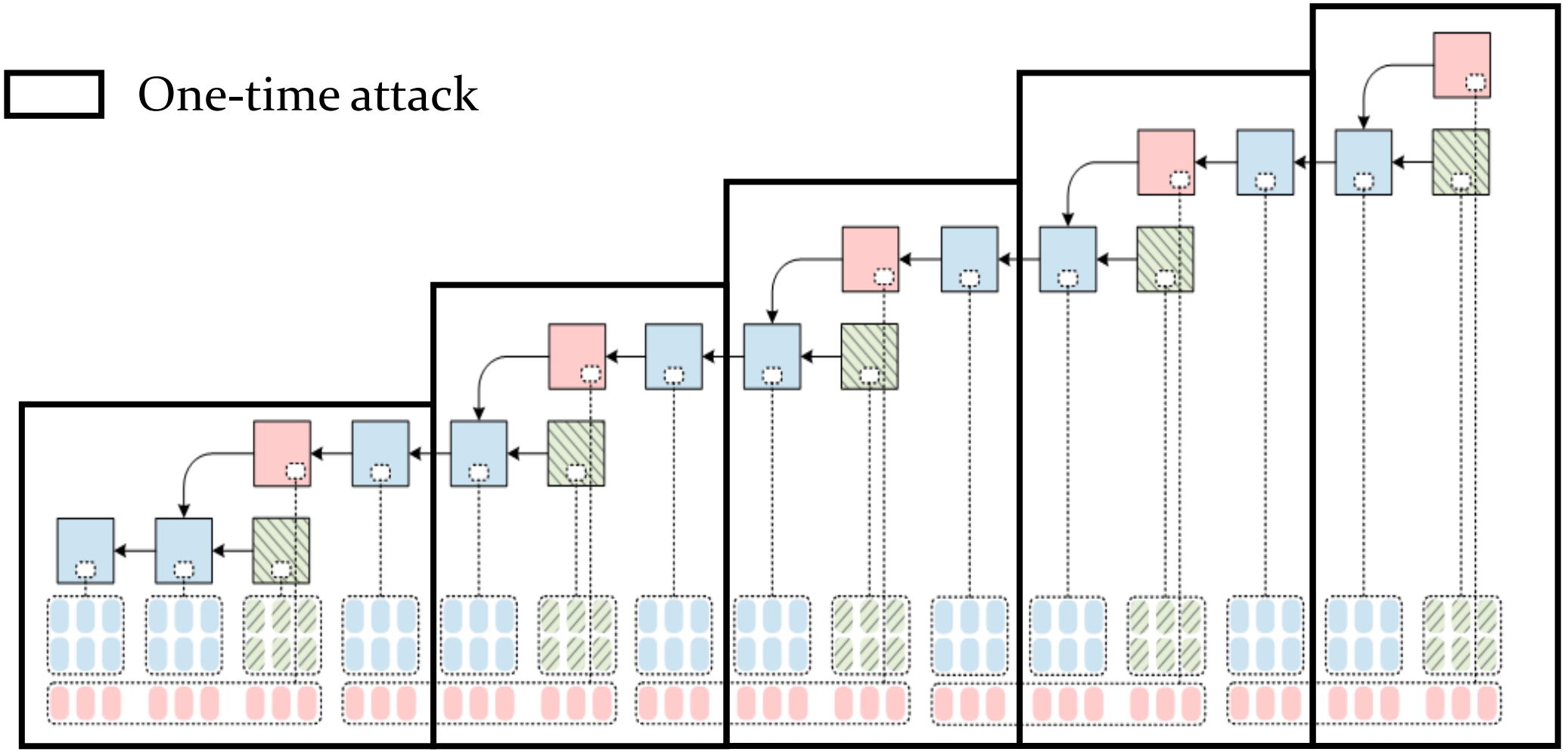
Step 1: The adversary creates and withholds a fork. The attestations from the adversary are included in the fork to affect the canonical chain.



Step 2: After waiting for half of the honest validators to vote in the next epoch, the adversary releases the withheld block b_j.

The chain from honest validators is forked out and the attestations in the chain are discarded.

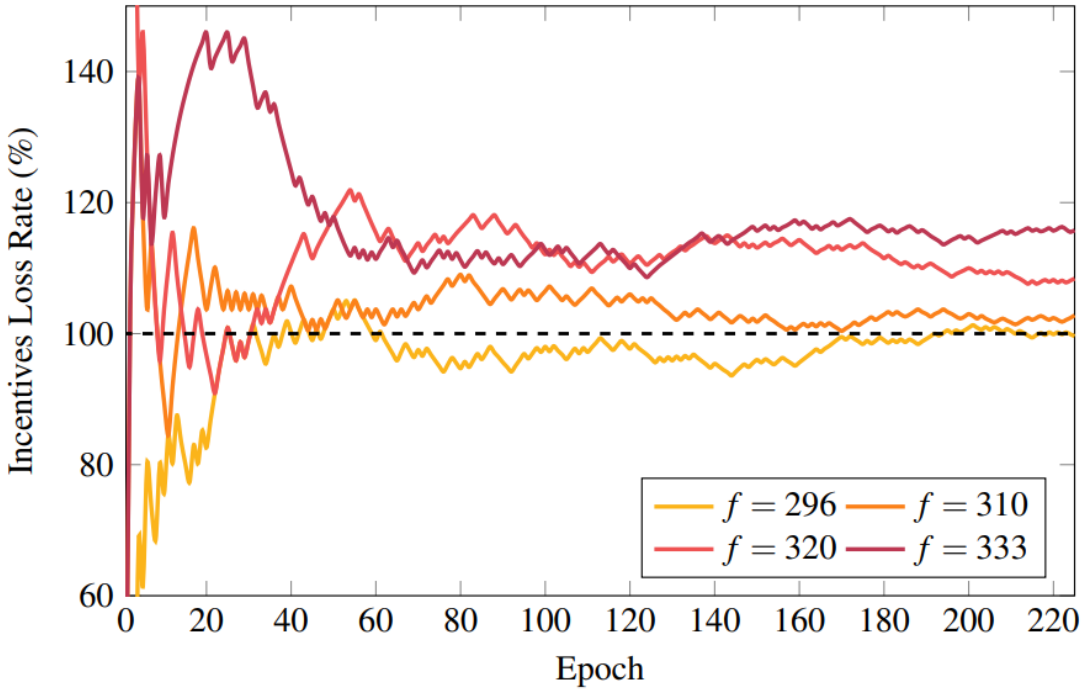
Staircase Attack: Repeat



Our Results

Theorem 1. *According to the configuration in Ethereum where* $W_r \leq 27W_p/20$ *(see Appendix A for more details), the expected incentive of any honest validators becomes lower than* 0 *when* $f \geq 8N/27 \approx 29.6\%N$.

- If there are 29.6% Byzantine validators, eventually all honest validators suffer from no attestation incentives;
- If the adversary controls a 33.3% stake, all honest validators are expected to suffer from a 20% stake loss compared to their fair share;



Attack Feasibility and Mitigation

- The feasibility of our attack is related to two parameters: the number of validators and the number of attestations each block can carry, i.e., the MAX_ATTESTATIONS parameter.

- Mitigation implemented by Ethereum significantly reduced the probability of continuing the attack in each epoch. The mitigation is already effective after the Deneb upgrade in March 2024.

Max Attestation Matters: Making Honest Parties Lose Their Incentives in Ethereum PoS

- Incentive mechanisms play an important role in the safety and liveness of the blockchain system.
- Two attacks against incentive mechanism in Ethereum PoS: warm-up attack and staircase attack.

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