The Economic Limits of Permissionless Consensus

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SBC 2024

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WHY NOT LAUNCH A 51% ATTACK?

Recall: Adversary controlling 51% of the hashrate of a PoW chain (e.g. Bitcoin) or 34% of the stake of a BFT-style PoS chain can cause consistency failures (e.g. to double-spend).

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This is something Nakamoto considered in the original whitepaper...

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Question: Are these issues fundamental to permissionless consensus, or specific to Bitcoin's design decisions (e.g. PoW)?

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CASE STUDY: ETHEREUM

The intention is to make 51% attacks extremely expensive, so that even a majority of validators working together cannot roll back finalized blocks without undertaking an extremely large economic loss — a loss so large that

Minimal Slashing Conditions

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PROOF-OF-STAKE (POS)

Last edit: @nhsz, January 25, 2024

See contributors

Proof-of-stake (PoS) underlies Ethereum's consensus mechanism. Ethereum switched on its proof-of-stake mechanism in 2022 because it is more secure, less energy-intensive, and better for implementing new scaling solutions compared to the previous proof-of-work architecture.

PROS AND CONS

Pros

Proof-of-stake offers greater crypto-economic security than proof-of-work

- economic penalties for misbehavior make 51% style attacks more costly for an attacker compared to proof-of-work

source: official Ethereum documentation at https://ethereum.org/en/developers/docs/consensus-mechanisms/pos/

CAN SLASHING FULFIL ITS PROMISE?

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- How does the answer depend on our assumptions?
  - About message delays, active participation by honest players, etc.

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- How does the answer depend on our assumptions?

Key definition: An EAAC protocol [i.e. what we want]

(1) Honest players never lose resources (e.g. don't get slashed)
(2) Double Spend $\Rightarrow$ attacker guaranteed to lose resources

IMPOSSIBILITY RESULTS

Note: if protocol is secure (no consistency violations) with f-bounded attacker (f =fraction of stake), trivially EAAC.

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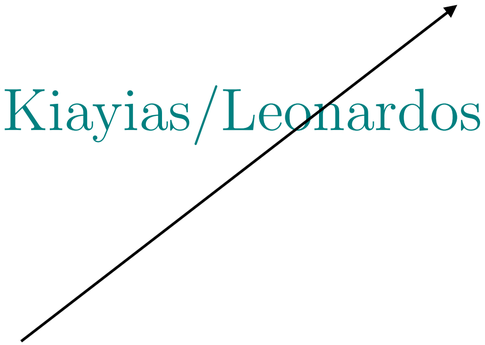

adversary controls 50% of stake/hashrate

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Communication is reliable: there exists a known bound on message delay

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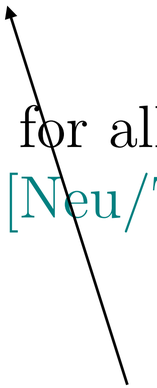

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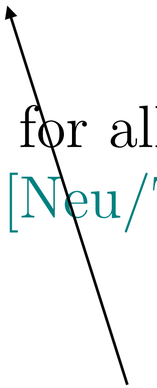

Note: BFT-style protocols are generally NOT live in this setting.

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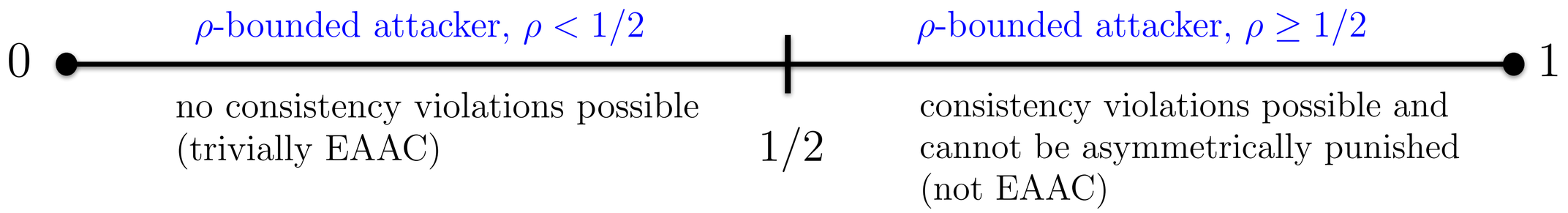

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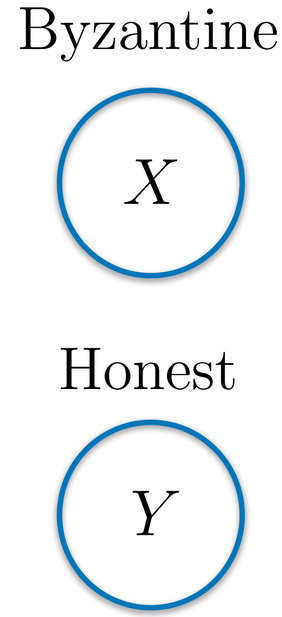
- can't implement slashing in a typical longest-chain-style protocol

Proof idea: let player sets X, Y have equal resources:

- X Byzantine, proceeds as if Y does not exist. Liveness in DA setting $\Rightarrow$ X, Y must confirm (conflicting) transactions



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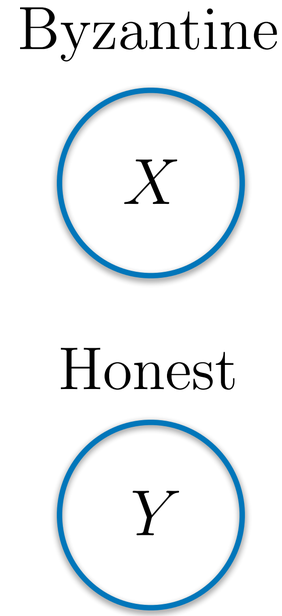

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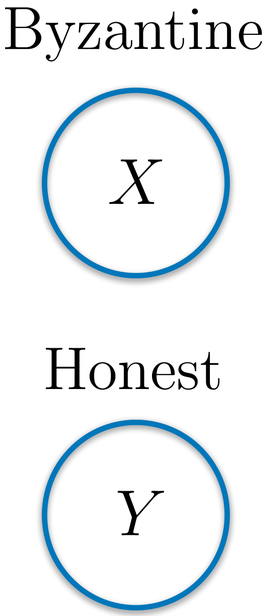

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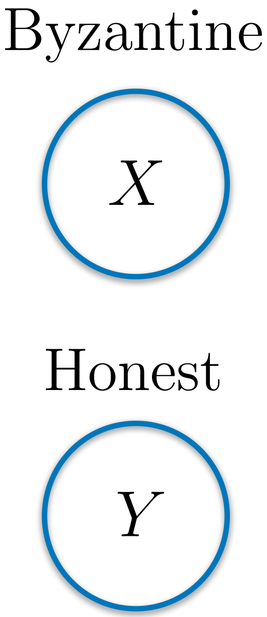
- No asymmetric punishment is possible!



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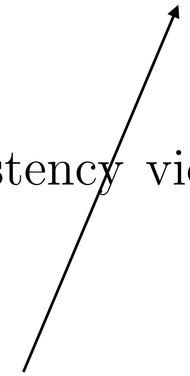

communication network may sometimes be unreliable

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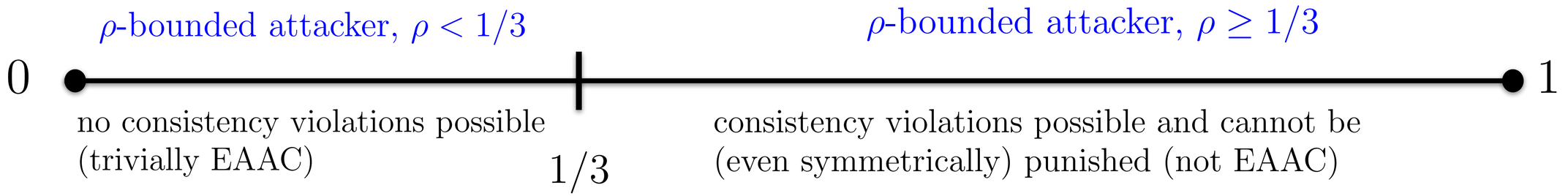

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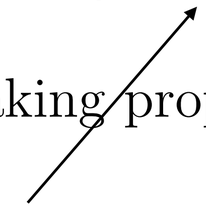

2/3 is best possible [Tas et al. 2023]

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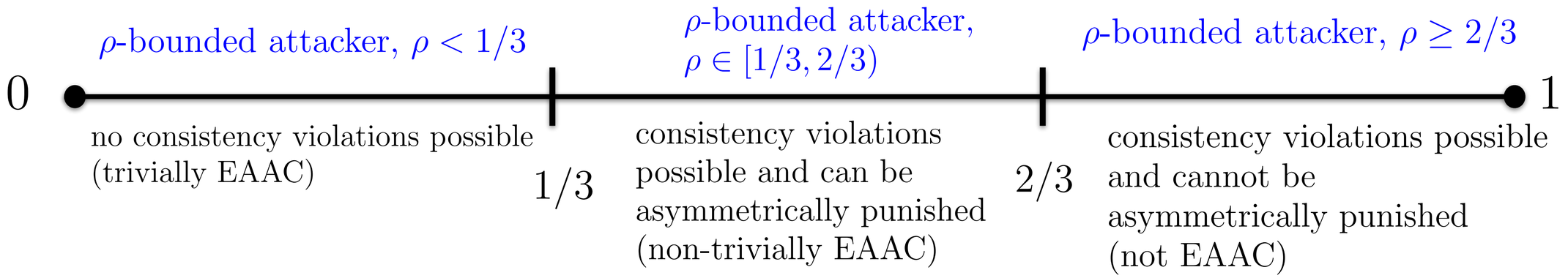

The PoST protocol

Starting point: Tendermint (2 stages of voting per view)

- Execution divided into "epochs", each tasked with finalizing N blocks.
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Challenge 2: if $f > 5/9$, post slashing, adversary still not 1/3-bounded

- Seems they will be able to kill liveness, preventing consensus on slashing conditions

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- solution: reboot epoch with consistency violation as many times as needed (slashing each time) until adversary $< 1/3$-bounded
  - increase QC threshold with each reboot, eventually get back to 2/3rds.

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  - Rules out typical longest-chain protocols (e.g. Ethereum 1.0).
- Cannot carry out slashing without bounds on worst-case message delays.
  - Accords with use of long cooldown periods in Ethereum 2.0.
- Can augment PBFT/Tendermint-style protocols to carry out slashing, provably recover from any $< 2/3$-bounded attacker.
  - To go from 5/9 to 2/3 (efficiently), trade-off consistency for liveness in recovery mode.

Thanks for listening!