Ethereum in numbers

Where physics meets TPS

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Detour: The Boring Company

Tunnels are expensive, but must they be?

- Why have an excessive 8.5m diameter?
- Why drill and reinforce in phases?
- Why not near thermal limits?

Vegas Loop tunnel

"Physics is the law, everything else is a recommendation" ~Elon Musk

Back to us: EtHiRUeM DoEs nOT sCaLe

Ethereum is too expensive for me!

- Expensive, or **too** expensive? Capacity supply vs. demand?

Ethereum can barely do 15-25 TPS!

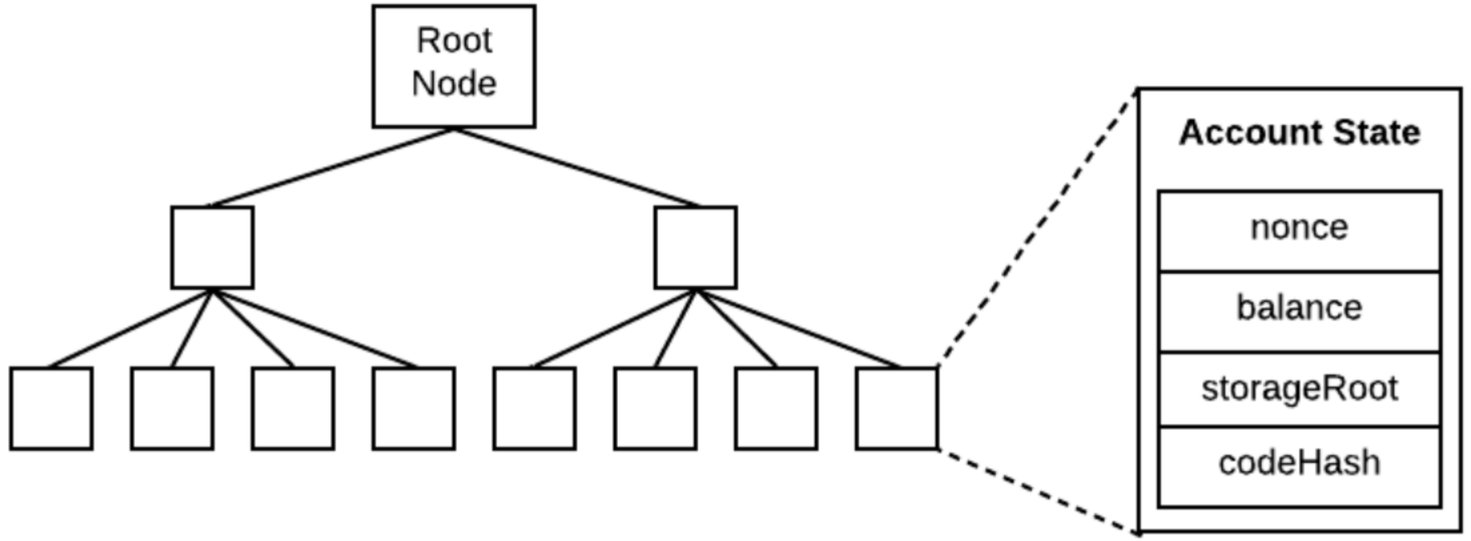
- ETH send; ERC transfer; DEX swap; NFT auction? How to measure?

Ethereum runs 1.1M gas per second!

- Avalanche C-chain 1.8M, Binance 7M (was 25M too)?! But they're Geth?!

Problem: Throughput is proportional to gas, but gas isn't proportional to load.

Bane of Ethereum: Merkle Patricia trie



👋 *Merkle tree containing account data leaves, linked together via 16-child internal nodes.* 👋

Catch: The more accounts there are, the deeper the state trie becomes.

Bane of Ethereum: State trie depth

Logarithmic depth surely doesn't matter?

- Ethereum has 174M accounts ⇒ 6.85 internal depth + 1 leaf layer
- Plain transfers update 2 accounts ⇒ 15 new nodes in the account trie
- LevelDB stores data in 7 disk layers ⇒ amplifies at worse into 105 writes
- Old path read for root hash calculation ⇒ bumps to potentially 210 IO ops
- Mined blocks need to propagate ⇒ 210 ops miner side, 210 ops full node side

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HDD                    capped at         80 IOPS  ⇒  0.19 TPS  (x2/3 = 0.12 TPS with disk pruning)
SSD (SATA 6)           capped at     90.000 IOPS  ⇒   214 TPS  (x2/3 =  142 TPS with disk pruning)
SSD (NVMe over PCIe 3) capped at    360.000 IOPS  ⇒   857 TPS  (x2/3 =  571 TPS with disk pruning)
SSD (NVMe over PCIe 4) capped at 1.000.000 IOPS  ⇒  2381 TPS  (x2/3 = 1587 TPS with disk pruning)
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**Purely disk latency bounds, no in-memory optimizations (archive), no caching (small RAM)*

Bane of Ethereum: State trie size

To raise the TPS, we must lower the disk IOPS:

- Keep things in memory and avoid hitting the disk
- OS uses free memory as disk cache ⇒ db shuffling in RAM
- Geth does in-memory pruning ⇒ ephemeral state never hits the db

Unfortunately, system memory is limited

- State outgrows the RAM ⇒ db writes revert to physical disk writes
- State becomes bigger ⇒ pruning needs more RAM or it flushes more

Bane of Ethereum: State trie growth

How fast is Ethereum's state growing (5th June, '22 - Sunday)?

- Approximately 0.64 account/s[1], 7.8 storage-slot/s
- Approximately 31.7B/s for accounts, 593B/s for storage ~= 54MB/day, 19.7GB/y

Catch: above growth is the pure useful state data

- Account trie weighs ~155.2B/acc, storage tries weigh ~142.3B/slot[2]
- Trie grows 99.3B/s for accounts, 1110B/s for storage ~= 104.5MB/day, 38.2GB/y[3]

[1]+25% according to Etherscan; *[2]computer said so, maybe lied*; *[3]disregarded log component*

What does this all mean?

Ethereum (along with all forks) is on a – potential – death trajectory 😱

- Constant TPS ⇒ state growth ⇒ higher RAM ⇒ more IOPS ⇒ lower TPS ⇒ brick wall
- Mainnet **can** do a lot more TPS ⇒ brings the brick wall closer

But does the brick wall *need to* exist?

- EIP-4444: Bound Historical Data in Execution Clients
- EIP-4844: Shard Blob Transactions
- State rent or exponential costs

Thank you

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