

Ethereum Blocks

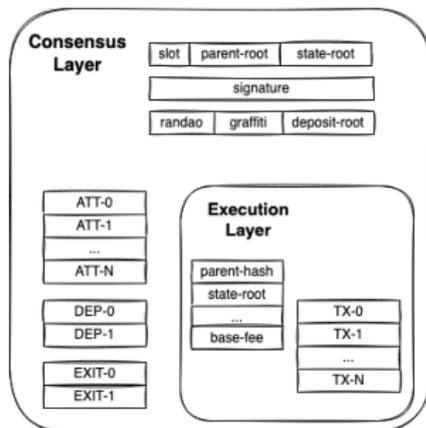
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Ethereum Blocks

- Ethereum launched as a PoW chain in July 2015
- In Sept 2022, it transitioned to proof-of-stake (the Merge)
- Ethereum node components
 - **Execution client:** Executes transactions and updates world state
 - **Beacon chain client:** Implements the PoS algorithm to achieve consensus on the execution client blocks
- Ethereum blocks



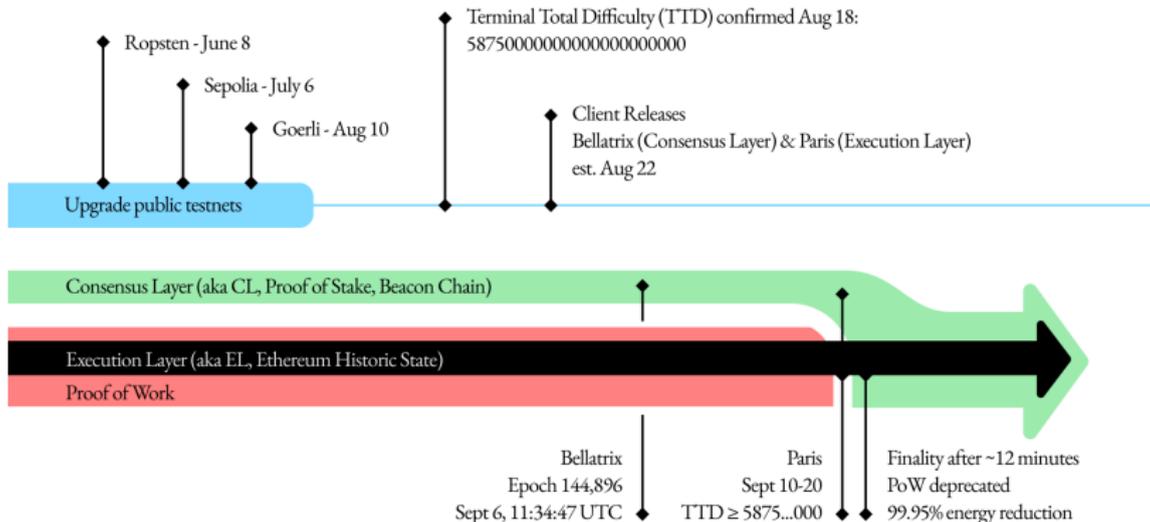
Source: Ethereum Blog

The Merge

Approaching the Merge

Offchain Onchain

Aug 22 2022 - @trent_vanepps
pixels between events may not scale to reality



Source: Ethereum Blog

Ethereum 1.0 Block Header

Block = (Header, Transactions, Uncle Headers)

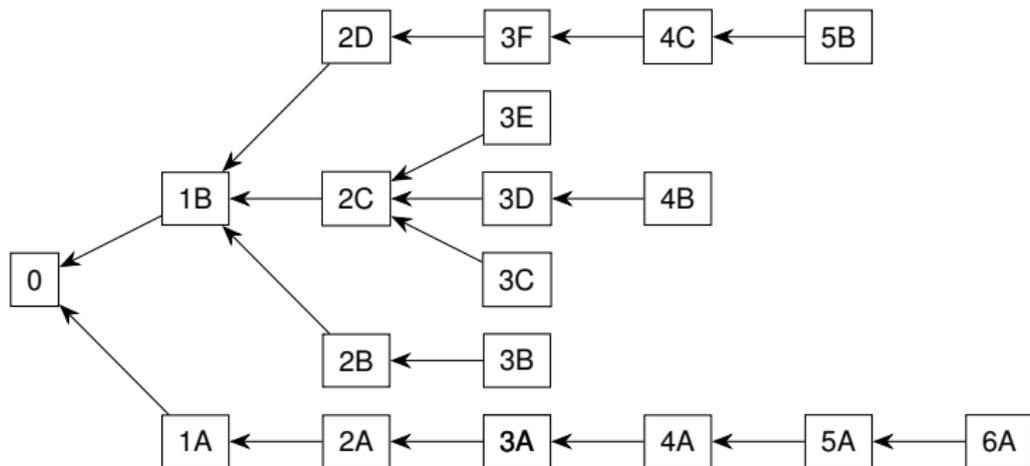
Block Header

parentHash	32	bytes
ommersHash	32	bytes
beneficiary	20	bytes
stateRoot	32	bytes
transactionsRoot	32	bytes
receiptsRoot	32	bytes
logsBloom	256	bytes
difficulty	≥ 1	byte
number	≥ 1	byte
gasLimit	≥ 1	byte
gasUsed	≥ 1	byte
timestamp	≤ 32	bytes
extraData	≤ 32	bytes
mixHash	32	bytes
nonce	8	bytes

Uncle Blocks in Ethereum 1.0

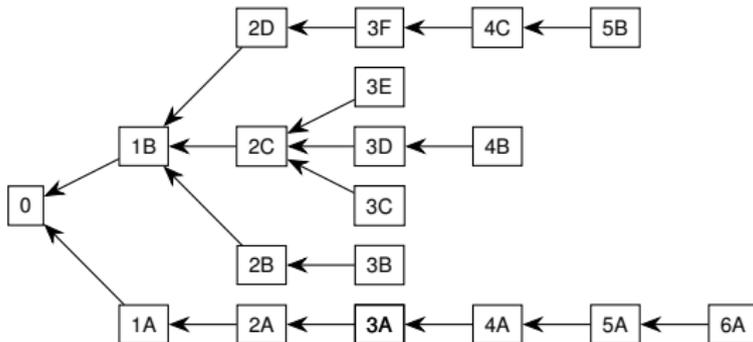
- Block = (Header, Transactions, Uncle Header List)
- `ommersHash` in block header is hash of uncle header list
- Ommer = Gender-neutral term that means “sibling of parent”
- **Problem:** Low inter-block time leads to high stale rate
 - Stale blocks do not contribute to network security
- **Solution:** Reward stale block miners and also miners who include stale block headers
- Rewarded stale blocks are called uncles or ommers
 - Transactions in uncle blocks are invalid
 - Only a fraction of block reward goes to uncle creator; no transaction fees
- How to resolve forks in the presence of uncle blocks?
 - Greedy Heaviest Observed Subtree (GHOST) protocol proposed by Sompolinsky and Zohar in December 2013
 - Ethereum 1.0 used a simpler version of GHOST
- Ethereum 2.0 also uses a version of GHOST called LMD GHOST

GHOST Protocol



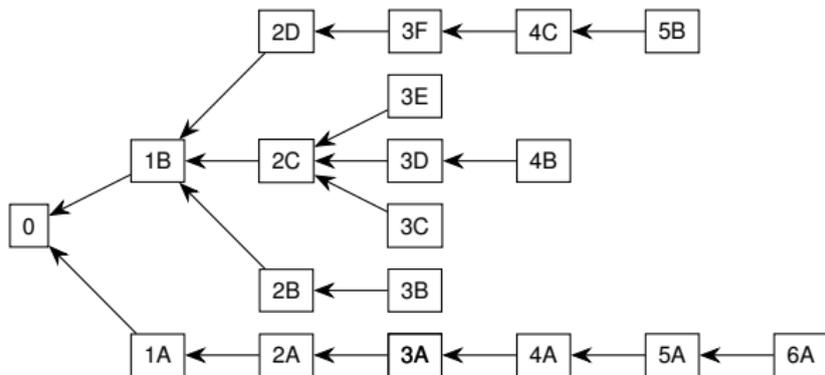
- A policy for choosing the main chain in case of forks
- Given a block tree T , the protocol specifies $\text{GHOST}(T)$ as the block representing the main chain
- Mining nodes calculated $\text{GHOST}(T)$ locally and mine on top of it
- Heaviest subtree rooted at fork is chosen

GHOST Protocol



```
function CHILDRENT(B)
    return Set of blocks with B as immediate parent
end function
function SUBTREET(B)
    return Subtree rooted at B
end function
function GHOST(T)
    B ← Genesis Block
    while True do
        if CHILDRENT(B) = ∅ then return B and exit
        else B ← argmaxC ∈ CHILDRENT(B) |SUBTREET(C)|
        end if
    end while
end function
```

GHOST Protocol Example



- Suppose an attacker secretly constructs the chain 1A, 2A, ..., 6A
- All other blocks are mined by honest miners
- Honest miners' efforts are spread over multiple forks
- Longest chain rule gives 0, 1B, 2D, 3F, 4C, 5B as main chain
 - Shorter than attacker's chain
- GHOST rule gives 0, 1B, 2C, 3D, 4B as main chain

Eth2 Execution Client Block Header

Block = (Header, Transactions, Uncle Headers)

Block Header

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logsBloom	256	bytes
difficulty	1	byte
number	≥ 1	byte
gasLimit	≥ 1	byte
gasUsed	≥ 1	byte
timestamp	≤ 32	bytes
extraData	≤ 32	bytes
prevRandao	32	bytes
nonce	8	bytes
baseFeePerGas	≥ 1	byte

Block Header Fields Deprecated in Eth2

Block Header

parentHash	32	bytes
ommersHash	32	bytes
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difficulty	1	byte
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prevRandao	32	bytes
nonce	8	bytes
baseFeePerGas	≥ 1	byte

- `ommersHash` = Hash of an empty list
- `difficulty` = Set to zero
- `nonce` = Set to 8 zero bytes
- `mixHash` is replaced with `prevRandao`
 - RANDAO is a pseudorandom value generated by validators in the PoS consensus algorithm

Fields in the Execution Client Header

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- `parentHash` = Keccak-256 hash of parent block header
- `beneficiary` = Destination address of block reward and transaction fees
- `stateRoot` = Root hash of world state trie after all transactions are applied
- `transactionsRoot` = Root hash of trie populated with all transactions in the block
- `number` = Number of ancestor blocks
- `timestamp` = Unix time at block creation
- `extraData` = Arbitrary data; validators identify themselves in this field

receiptsRoot

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- receiptsRoot is the root hash of transaction receipts trie
- A transaction receipt contains logs emitted by smart contracts
- Smart contracts can write to logs using events

```
event Transfer(address indexed from, address indexed to,  
uint256 value);
```

logsBloom

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- Bloom filter = Probabilistic data structure for set membership queries
- Each transaction receipt contains Bloom filter of addresses and “topics”
- `logsBloom` is the OR of all transaction receipt Bloom filters
- KECCAK-256 of the logger’s address and indexed topics are used to set 3 bits out of 2048
- Light clients can efficiently retrieve only transactions of interest

Fee-related Fields

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baseFeePerGas	≥ 1	byte

- `gasUsed` is the total gas used by all transactions in the block
- `gasLimit` is the maximum gas which can be used (currently 60 million)
- `baseFeePerGas` is the minimum required transaction fees per unit of gas
 - Burned by the protocol
 - Updated every block depending of how far `gasUsed` is from a target limit of 30 million

Base Fee Calculation

- Proposed in EIP 1559; included in London hard fork (Aug 2021)

$$\text{gasTarget} = \frac{\text{gasLimit}}{2}$$

$$\delta = \frac{\text{gasUsed} - \text{gasTarget}}{4 \times \text{gasLimit}} \times \text{baseFeePerGas}$$

$$\text{baseFeePerGas}_{\text{new}} = \text{baseFeePerGas} + \delta$$

- Previously gas prices were a first-price auction
- Users had to guess the gas price which would result in block inclusion of their transactions
- Base fees gives an indication of blockspace demand
- Users can pay a tip to miners via priority fee

References

- **Yellow paper** <https://ethereum.github.io/yellowpaper/paper.pdf>
- **GHOST paper** <https://eprint.iacr.org/2013/881>
- **Ethereum blog post** <https://blog.ethereum.org/2021/11/29/how-the-merge-impacts-app-layer>
- **Solidity events and logs**
- **Upgrading Ethereum book** <https://eth2book.info/>
- **An Economic Analysis of EIP-1559**
<https://timroughgarden.org/papers/eip1559.pdf>