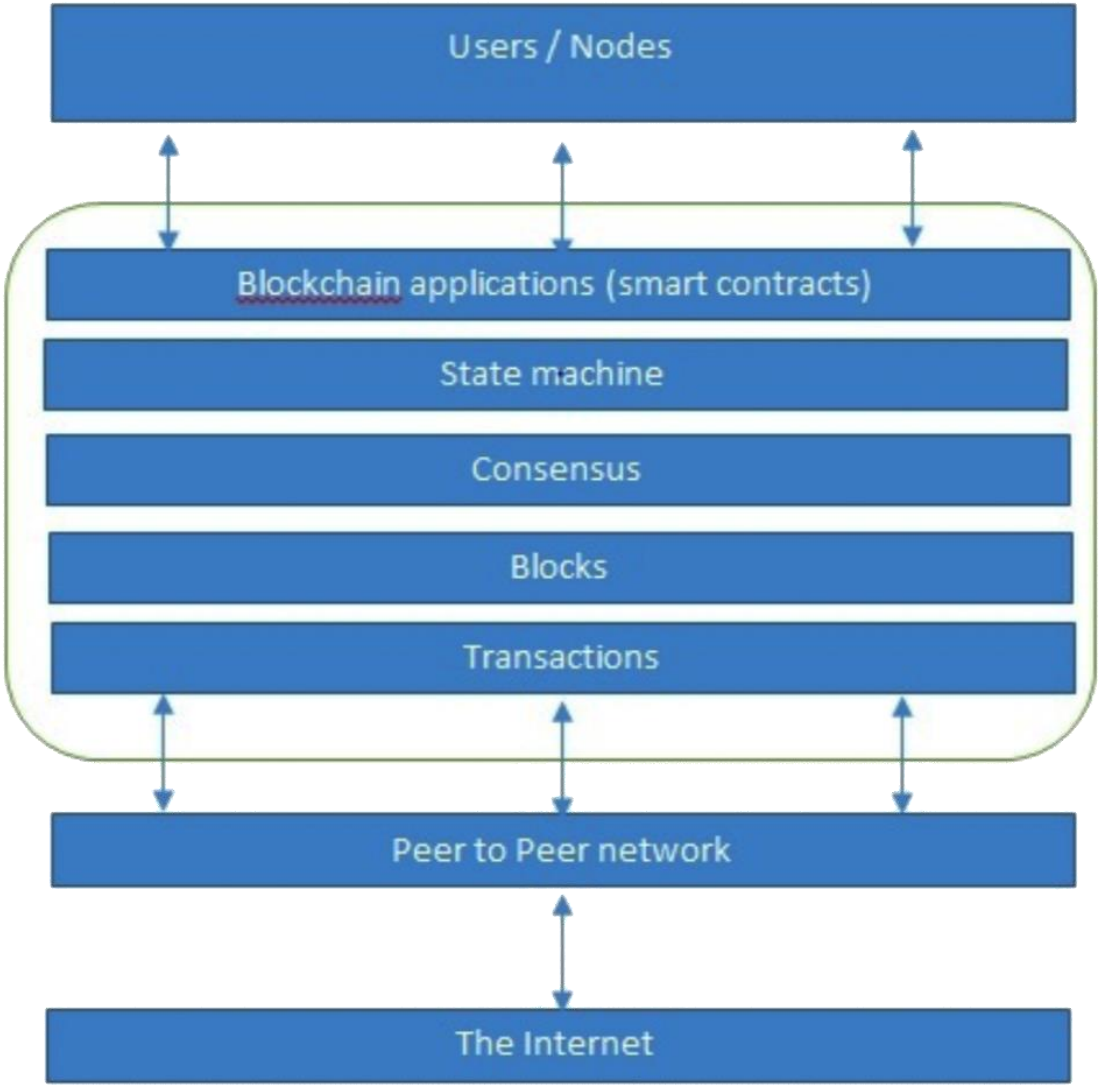
Blockchain

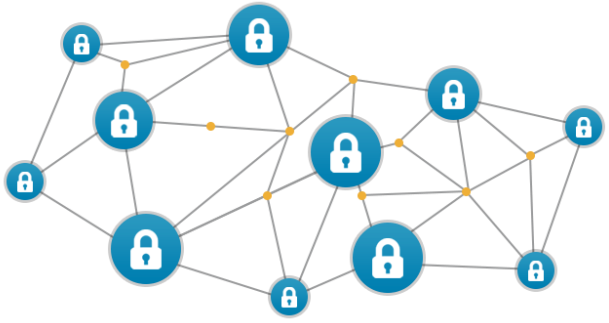
BLUEPRINT FOR A NEW ECONOMY

Ethereum Architecture

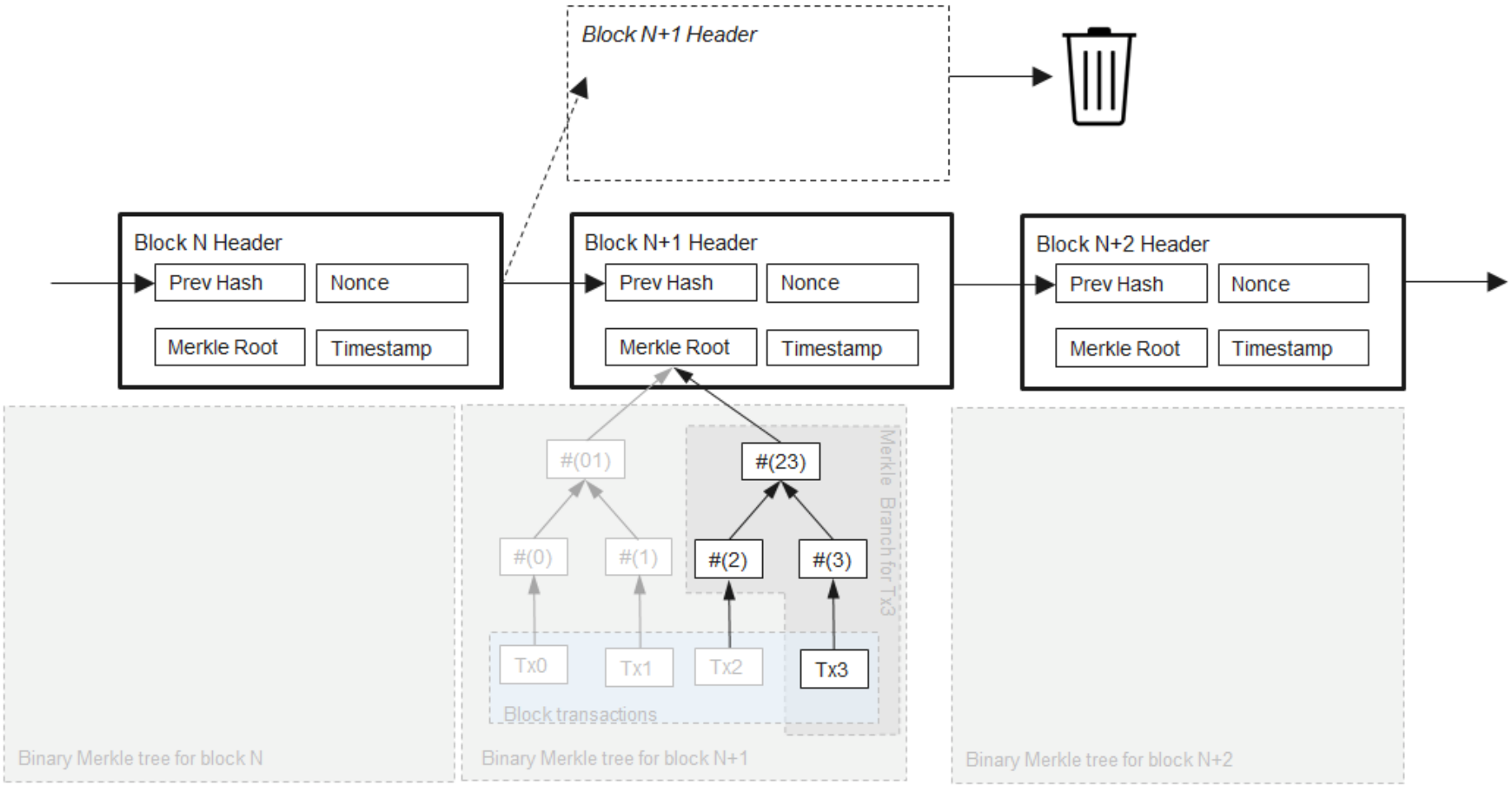
Foundation of Blockchain Architecture



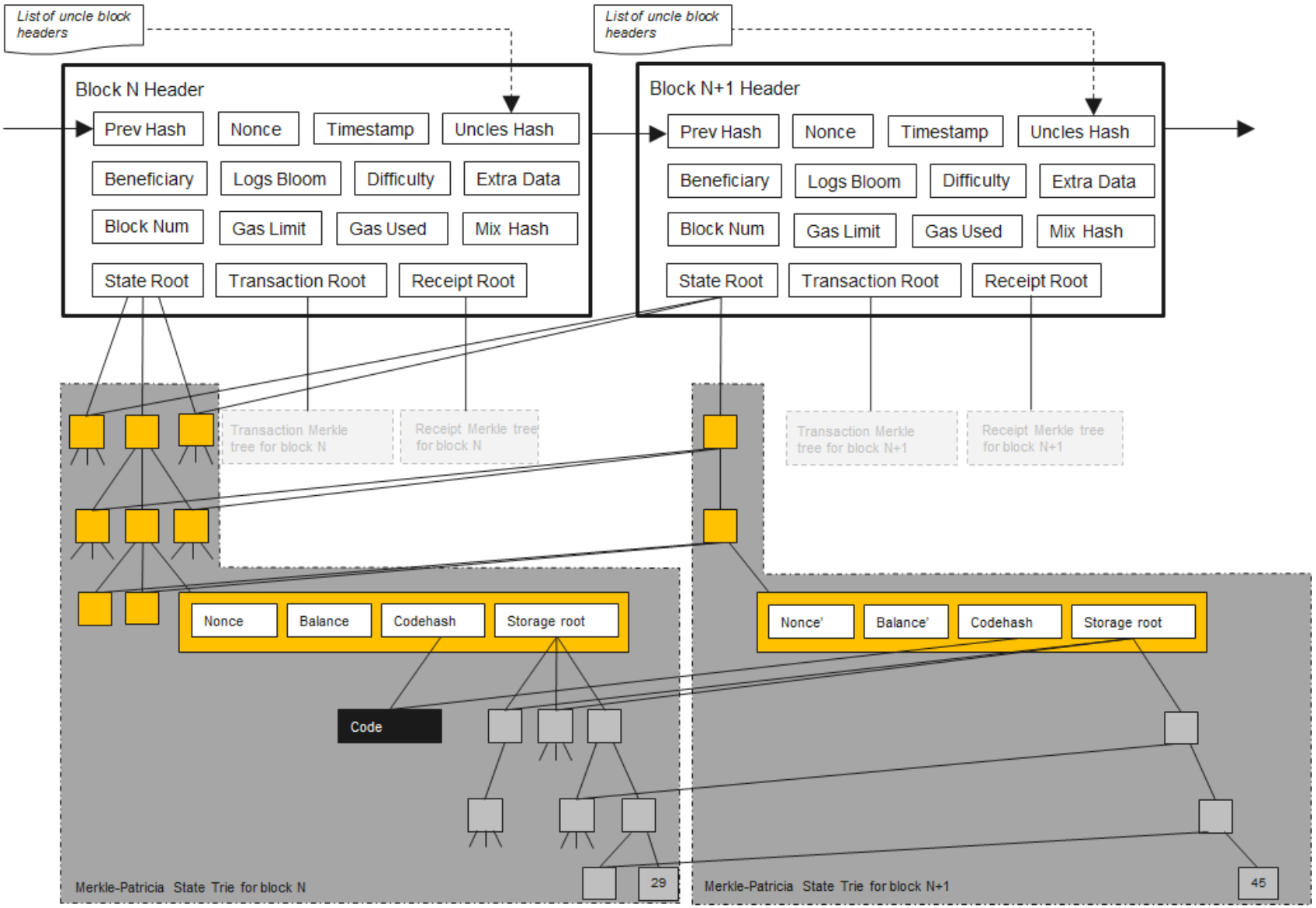
Blockchain at its core is a peer-to-peer distributed ledger that is cryptographically secure, append-only, immutable (extremely hard to change), and updateable only via consensus or agreement among peers.



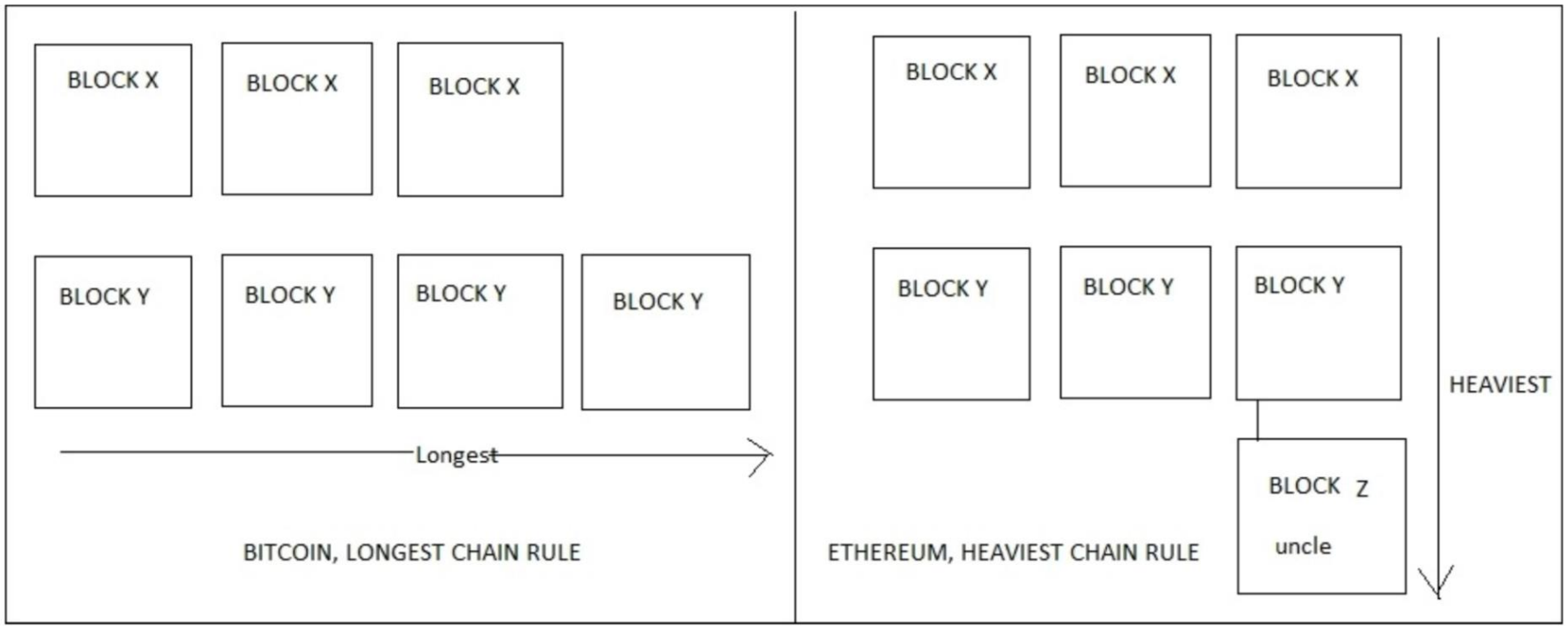
Bitcoin block structure



Ethereum Block Structure

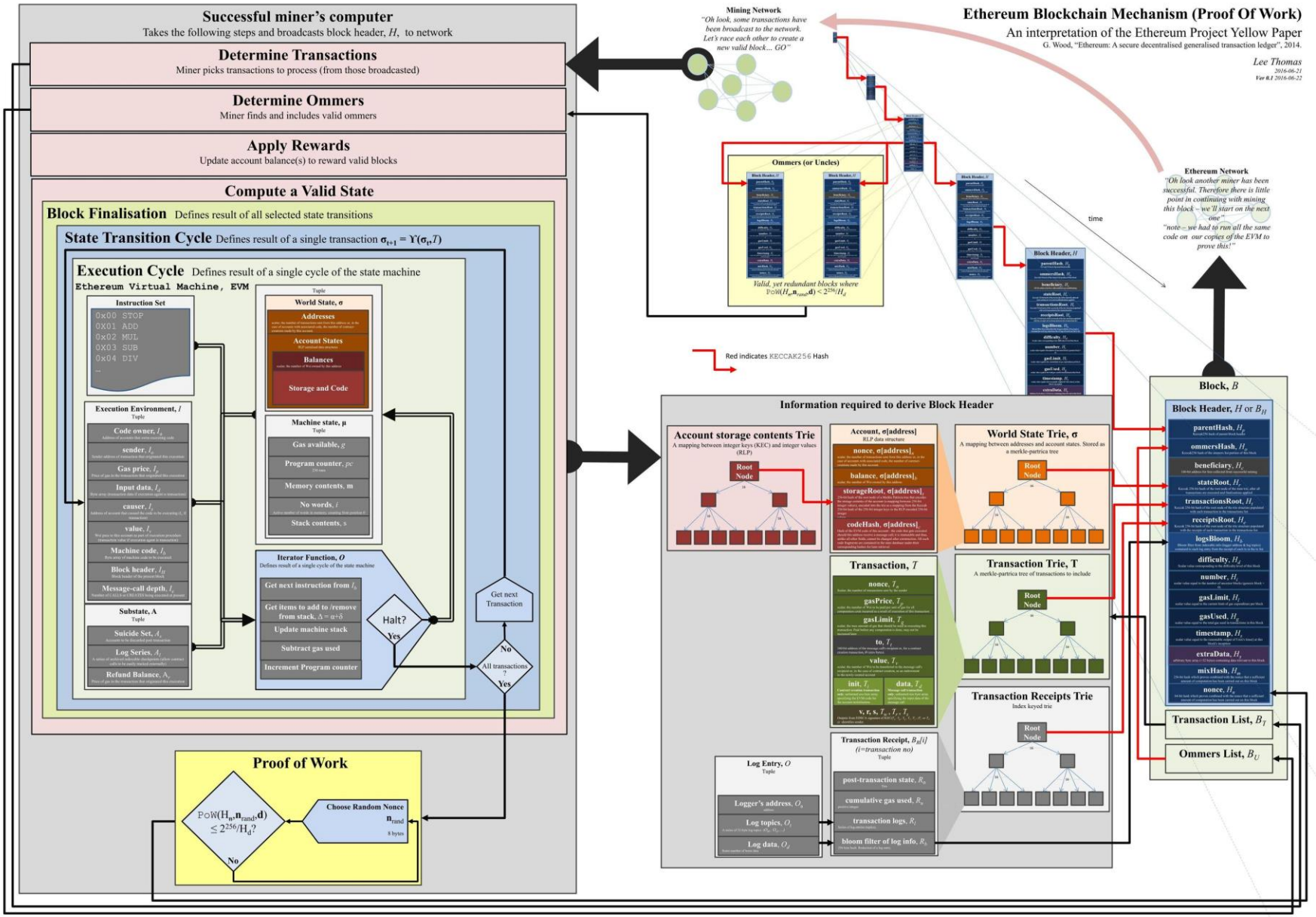


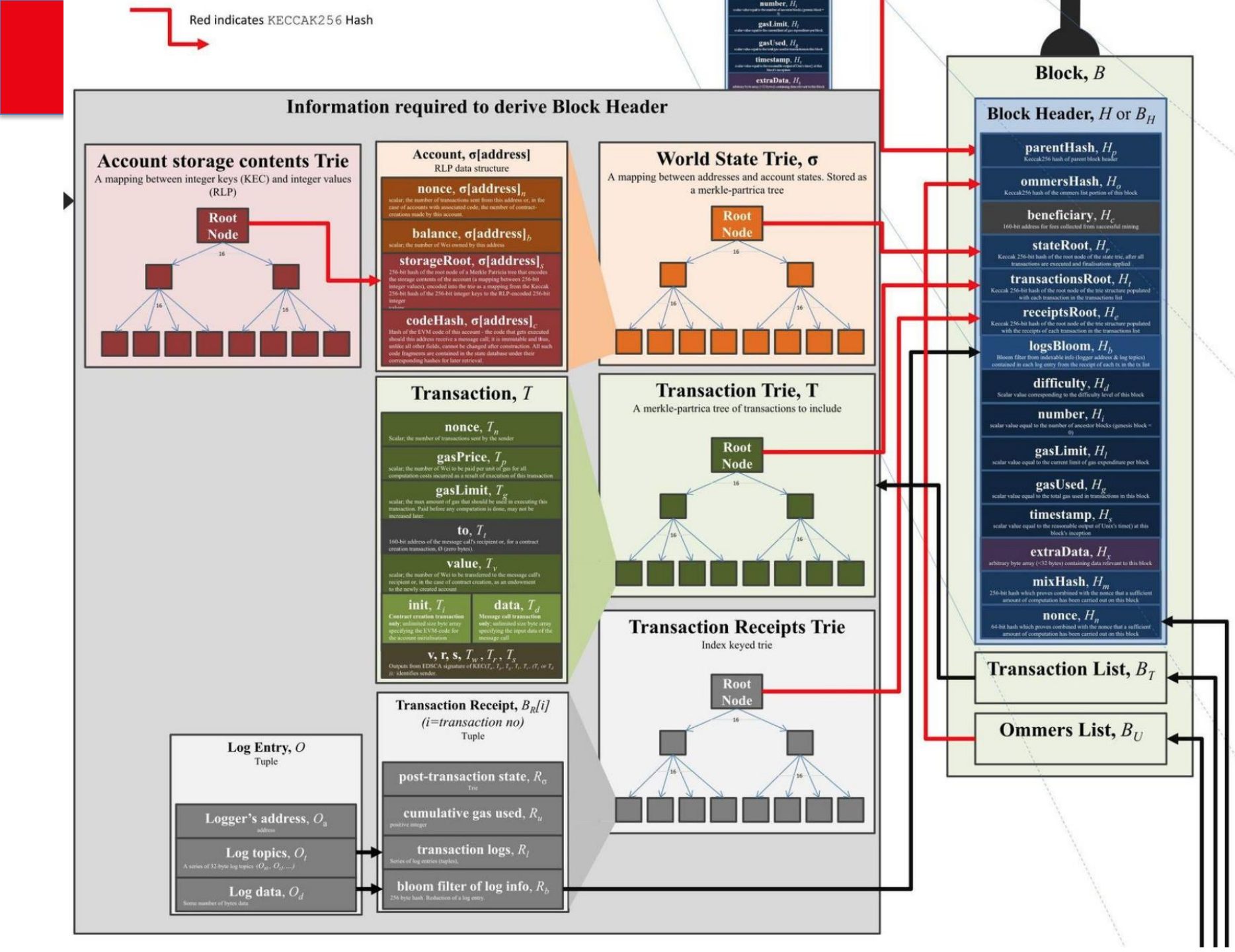
Concensus mechanism in Ethereum



- **Greedy Heaviest Observed Subtree (GHOST)** was first introduced as a mechanism to alleviate the issues arising out of fast block generation times that led to stale or orphan blocks. In GHOST, The stale blocks are added in calculations to figure out the longest and heaviest chain of blocks. Stale blocks are called Uncles in Ethereum.

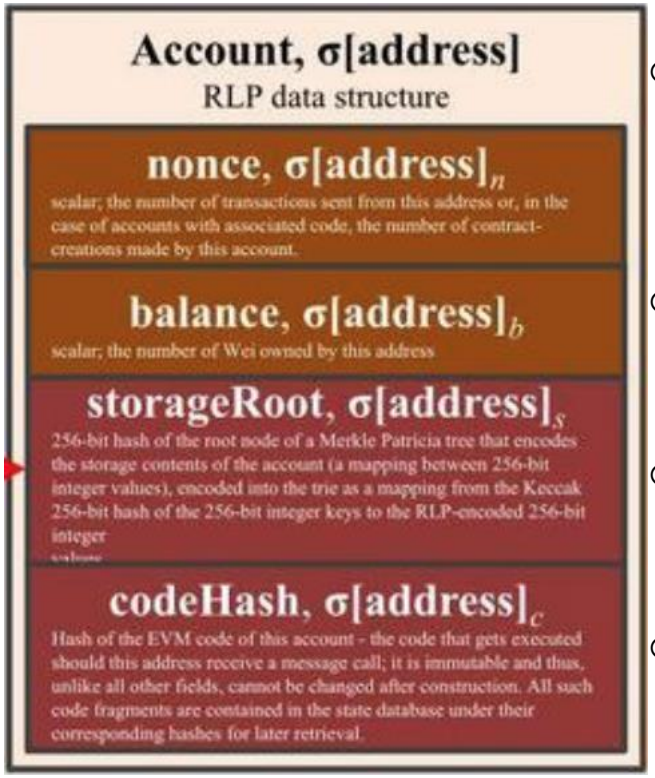
Ethereum Blockchain Archtecture




Red indicates KECCAK256 Hash
Information required to derive Block Header
Account storage contents Trie
A mapping between integer keys (KEC) and integer values (RLP)
Root Node
16
Account, σ[address]
RLP data structure
nonce, σ[address]n
balance, σ[address]b
storageRoot, σ[address]s
codeHash, σ[address]c
World State Trie, σ
A mapping between addresses and account states. Stored as a merkle-partrica tree
Transaction, T
nonce, Tn
gasPrice, Tp
gasLimit, Tg
to, Tt
value, Tv
init, Ti
Contract creation transaction only; unlimited size byte array specifying the EVM-code for the account initialisation
data, Td
Message call transaction only; unlimited size byte array specifying the input data of the message call
v, r, s, Tw, Tr, Ts
Transaction Trie, T
A merkle-partrica tree of transactions to include
Transaction Receipts Trie
Index keyed trie
Transaction Receipt, BR[i]
(i=transaction no)
Tuple
post-transaction state, Rσ
cumulative gas used, Ru
transaction logs, Rl
bloom filter of log info, Rb
Log Entry, O
Tuple
Logger's address, Oa
Log topics, Ot
Log data, Od
Block, B
Block Header, H or BH
parentHash, Hp
ommersHash, Ho
beneficiary, Hc
stateRoot, Hr
transactionsRoot, Ht
receiptsRoot, He
logsBloom, Hb
difficulty, Hd
number, Hi
gasLimit, Hl
gasUsed, Hg
timestamp, Hs
extraData, Hx
mixHash, Hm
nonce, Hn
Transaction List, BT
Ommers List, BU

Account State

The account state consists of four fields: nonce, balance, storageroot and codehash

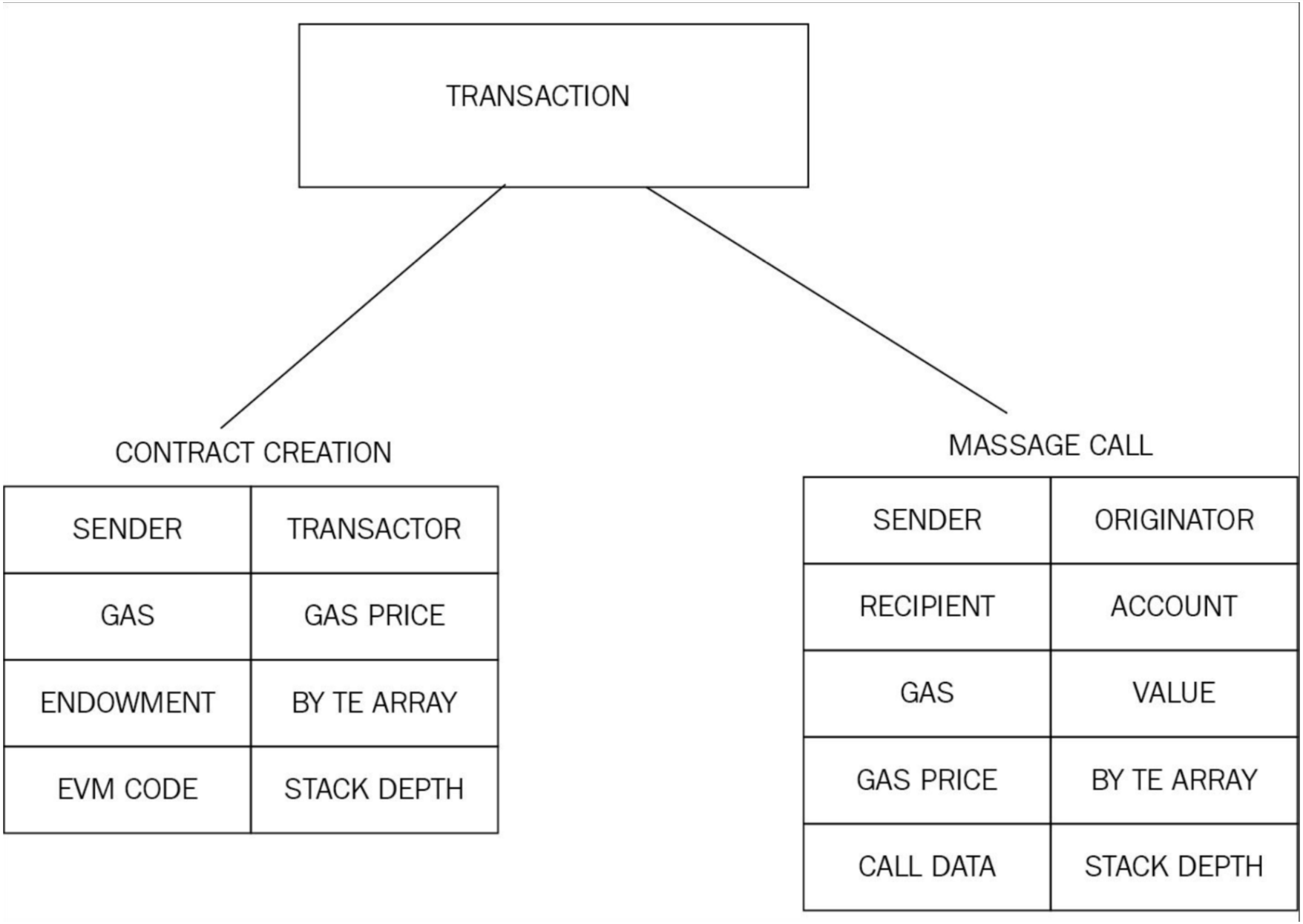


- **Nonce,** This is a value that is incremented every time a transaction is sent from the address. In case of contract accounts, it represents the number of contracts created by the account.
- **Balance ,** This value represents the number of Weis which is the smallest unit of the currency (Ether) in Ethereum held by the address.
- **Storageroot ,**This field represents the root node of a Merkle Patricia tree that encodes the storage contents of the account.
- **Code Hash,** This is an immutable field that contains the hash of the smart contract code that is associated with the account.

Transaction

- **Nonce** is a number that is incremented by one every time a transaction is sent by the sender.
- **gasPrice** represents the amount of Wei required in order to execute the transaction. gasLimit
- **gasLimit** contains the value that represents the maximum amount of gas that can be consumed in order to execute the transaction. It is sufficient to say that this is the amount of fee in Ether that a user is willing to pay for computation.
- **To** is a value that represents the address of the recipient of the transaction. Value
- **value** represents the total number of Wei to be transferred to the recipient; in the case of a contract account, this represents the balance that the contract will hold.
- **Init** is used only in transactions that are intended to create contracts. This represents a byte array of unlimited length that specifies the EVM code to be used in the account initialization process.
- **Data** , If the transaction is a message call, then the data field is used instead of init, which represents the input data of the message call. It is also unlimited in size and is organized as a byte array.
- **Sender Signature,** These values represent the digital signature (R, S) and some information that can be used to recover the public key (V).

Type of Transaction



Contract Creation Transaction

CONTRACT CREATION

SENDER	TRANSACTOR
GAS	GAS PRICE
ENDOWMENT	BY TE ARRAY
EVM CODE	STACK DEPTH

- Sender
- Original transactor
- Available gas
- Gas price
- Endowment, which is the amount of ether allocated initially
- A byte array of arbitrary length
- Initialization EVM code
- Current depth of the message call/contract-creation stack (current depth means the number of items that are already there in the stack)

- The account is initialized when the EVM code (Initialization EVM code) is executed. In the case of any exception during code execution, such as not having enough gas, the state does not change.

Message Call Transaction

- A message call requires several parameters for execution, which are listed as follows:
  - Sender
  - The transaction originator
  - Recipient
  - The account whose code is to be executed
  - Available gas
  - Value
  - Gas price
  - Arbitrary length byte array
  - Input data of the call
  - Current depth of the message call/contract creation stack

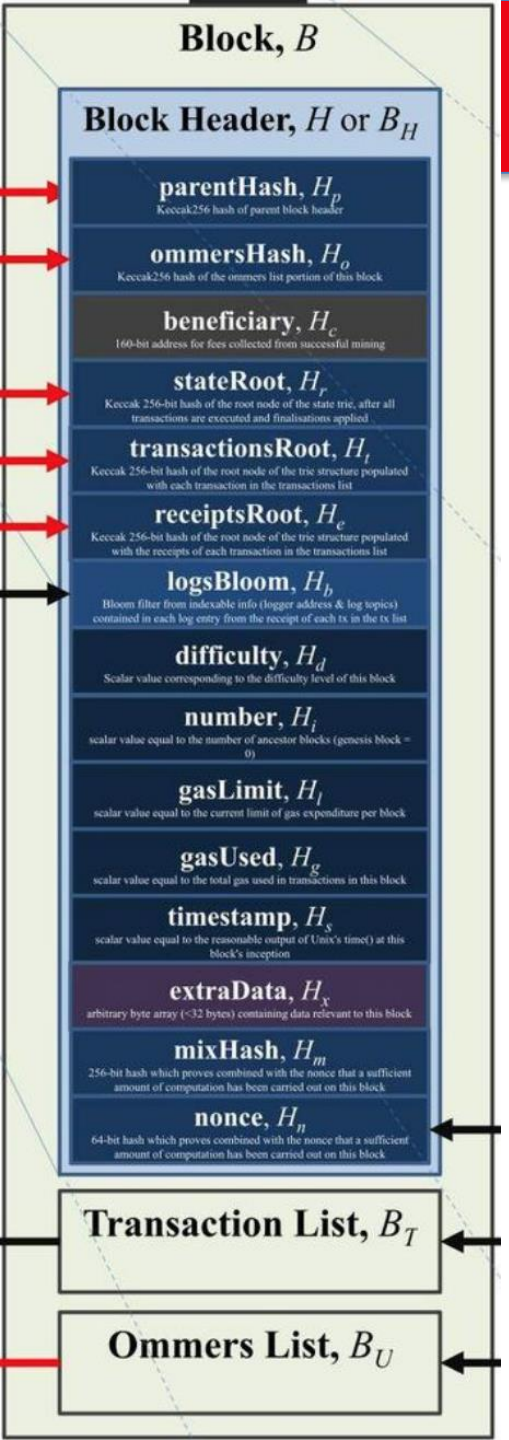
MASSAGE CALL	
SENDER	ORIGINATOR
RECIPIENT	ACCOUNT
GAS	VALUE
GAS PRICE	BY TE ARRAY
CALL DATA	STACK DEPTH

- Message calls result in state transition. Message calls also produce output data, which is not used if transactions are executed. In cases where message calls are triggered by VM code, the output produced by the transaction execution is used.

Type of Account

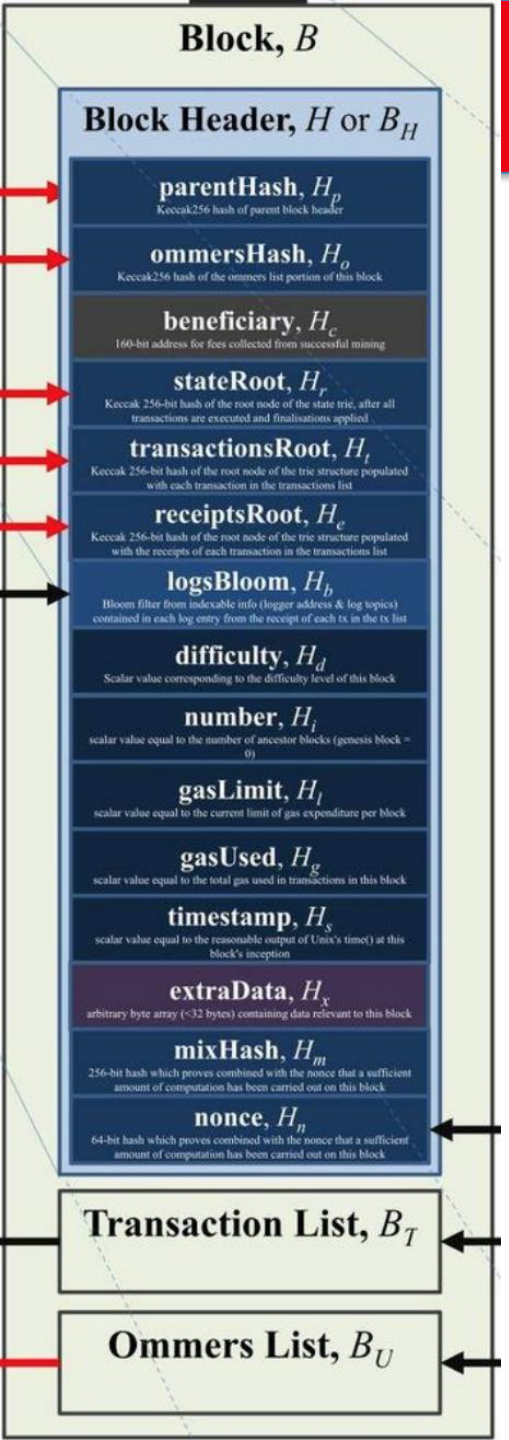
- **Externally owned accounts (EOAs)** are similar to accounts that are controlled by a private key in bitcoin. An EOA has ether balance, is able to send transactions, and has no associated code
- **Contract Account (CA)** has ether balance, associated code, and the ability to get triggered and execute code in response to a transaction or a message.

Block Structure



- **Parent hash**,is the Keccak 256-bit hash of the parent (previous) block's header.
- **Ommers hash,** is the Keccak 256-bit hash of the list of Ommers (Uncles) blocks included in the block.
- **Beneficiary** contains the 160-bit address of the recipient that will receive the mining reward once the block is successfully mined.
- **State root** contains the Keccak 256-bit hash of the root node of the state trie. It is calculated after all transactions have been processed and finalized.
- **Transaction root** is the Keccak 256-bit hash of the root node of the transaction trie. Transaction trie represents the list of transactions included in the block.
- **Receipts root** is the keccak 256 bit hash of the root node of the transaction receipt trie. This trie is composed of receipts of all transactions included in the block. Transaction receipts are generated after each transaction is processed and contain useful post-transaction information. Logs bloom
- **logs bloom** is a bloom filter that is composed of the logger address and log topics from the log entry of each transaction receipt of the included transaction list in the block.

Block Structure



- **Difficulty**, The difficulty level of the current block.
- **Number**, The total number of all previous blocks; the genesis block is block zero.
- **Gas limit** , The field contains the value that represents the limit set on the gas consumption per block.
- **Gas used** , The field contains the total gas consumed by the transactions included in the block
- **Timestamp** is the epoch Unix time of the time of block initialization.
- **Extra data** field can be used to store arbitrary data related to the block.
- **Mixhash** field contains a 256-bit hash that once combined with the nonce is used to prove that adequate computational effort has been spent in order to create this block.
- **Nonce** is a 64-bit hash (a number) that is used to prove, in combination with the mixhash field, that adequate computational effort has been spent in order to create this block.

Ether

Unit	Wei Value	Weis
Wei	1 Wei	1
Babbage	1e3 Wei	1,000
Lovelace	1e6 Wei	1,000,000
Shannon	1e9 Wei	1,000,000,000
Szabo	1e12 Wei	1,000,000,000,000
Finney	1e15 Wei	1,000,000,000,000,000
Ether	1e18 Wei	1,000,000,000,000,000,000

Gas Cost

Operation Name	Gas Cost
step	1
stop	0
suicide	0
sha3	30
sload	20
txdata	5
transaction	500
contract creation	53000

- **Gas** is required to be paid for every operation performed on the ethereum blockchain. This is a mechanism that ensures that infinite loops cannot cause the whole blockchain to stall.
- A **transaction fee** is charged as some amount of Ether and is taken from the account balance of the transaction originator.
- A fee is paid for transactions to be included by miners for mining. If this fee is too low, the transaction may never be picked up; the more the fee, the higher are the chances that the transactions will be picked up by the miners for inclusion in the block.
- if the transaction that has an appropriate fee paid is included in the block by miners but has too many complex operations to perform, it can result in an **out-of-gas exception** if the gas cost is not enough. In this case, the transaction will fail but will still be made part of the block and the transaction originator will not get any refund.
- Transaction cost can be estimated using the following formula:
- Total cost = gas Used * **gasPrice**