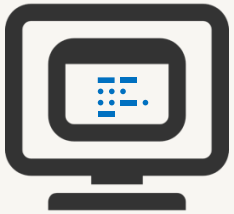
CSE446: Blockchain & Cryptocurrencies

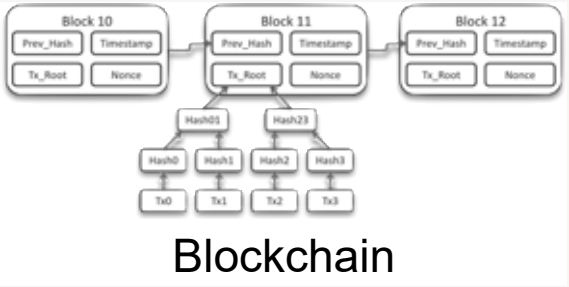
Lecture – 13: Ethereum - 2

Ethereum components

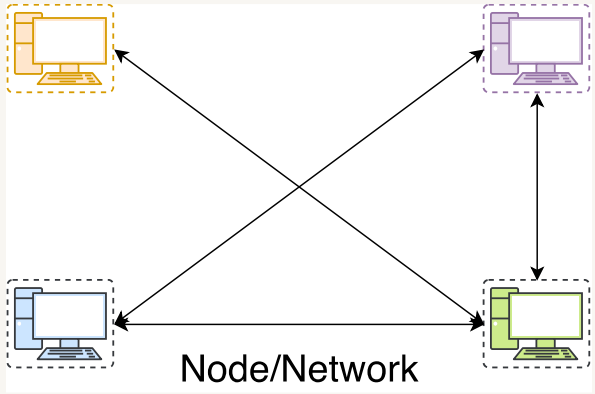
Users & code representation

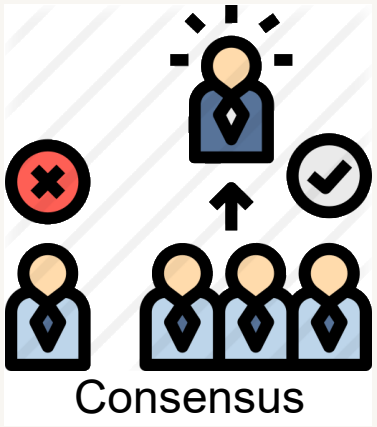


EVM



Blockchain





Consensus

Ethereum accounts

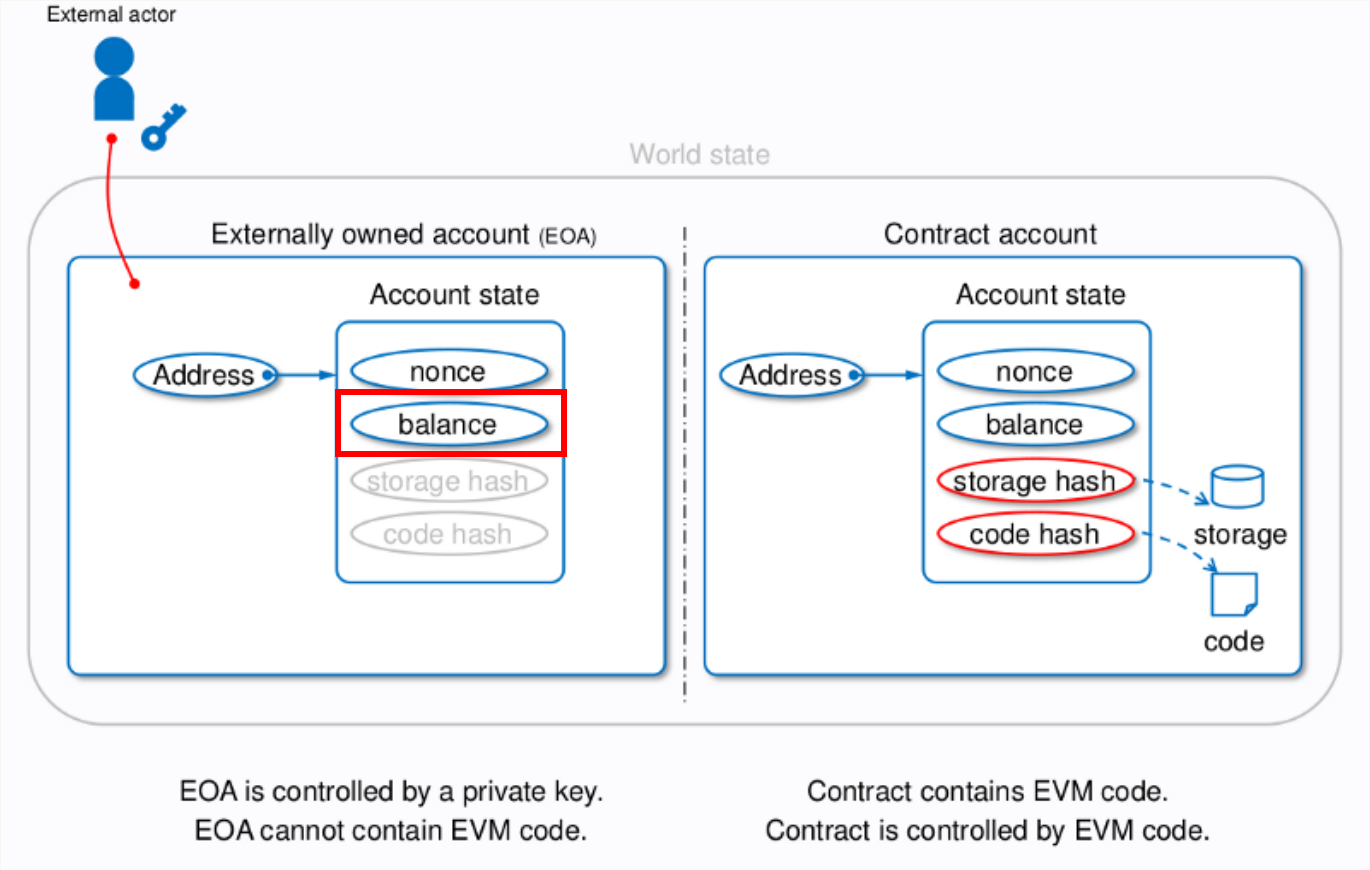
- Compared to Bitcoin, Ethereum uses an account-based ledger
  - Remember Bitcoin uses a transaction-based ledger
- Each distinct address represents a separate, unique account
- Accounts that are controlled by private keys and owned externally are EOA accounts
- EOA accounts do not have any code stored on the blockchain
  - This type can be seen as the default wallet of a user
- It can sign transactions, issue smart-contract functions calls and send Ether from one account to another
- The origin of any transaction is always an account controlled by a private key

Ethereum accounts

- Smart-contract accounts are controlled by their code
- Smart-contracts are treated as account entities with their own, unique address
- Such contract accounts don’t have any private key associated with it
- They can receive and send Ether just like an EOA
- Contracts can send messages to other accounts, both externally controlled accounts and smart contract accounts
- They can be invoked only by a transaction (similar to calling a function of a programming language program)
  - Either by an EOA or by another contract
- They have a persistent internal storage to write and read data from

Ethereum accounts

- Every EOA has its balance stored in the blockchain
- This is unlike Bitcoin where no separate balance database is maintained

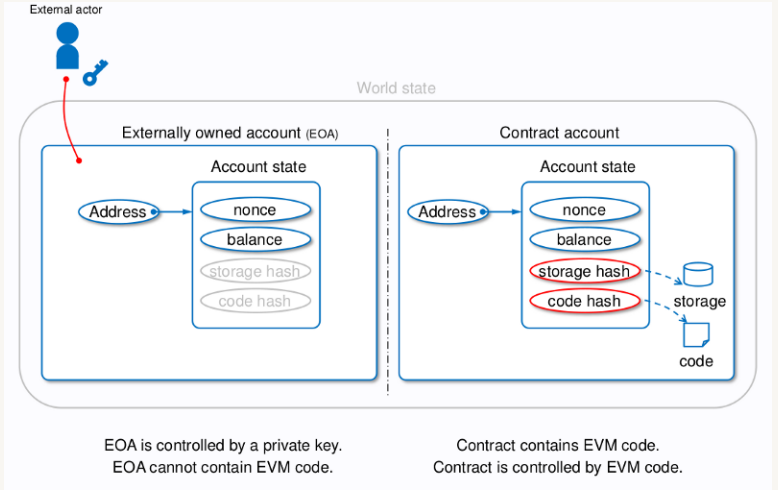


Here, world state represents the blockchain

https://cdn-images-1.medium.com/max/800/1*YC5PFXSJIZPw6zQWOuE7WQ.png

Ethereum accounts

- nonce: # of transactions sent / # of contracts created
- balance: # Wei owned (1 ether = 10^{18} Wei)
- storageRoot: Hash of the root node of a *Merkle Patricia* tree (MPT) of storage contents of the account
  - MPT will be discussed later
  - The tree is empty by default
- codeHash: Hash of the EVM (Ethereum Virtual Machine) code of this account



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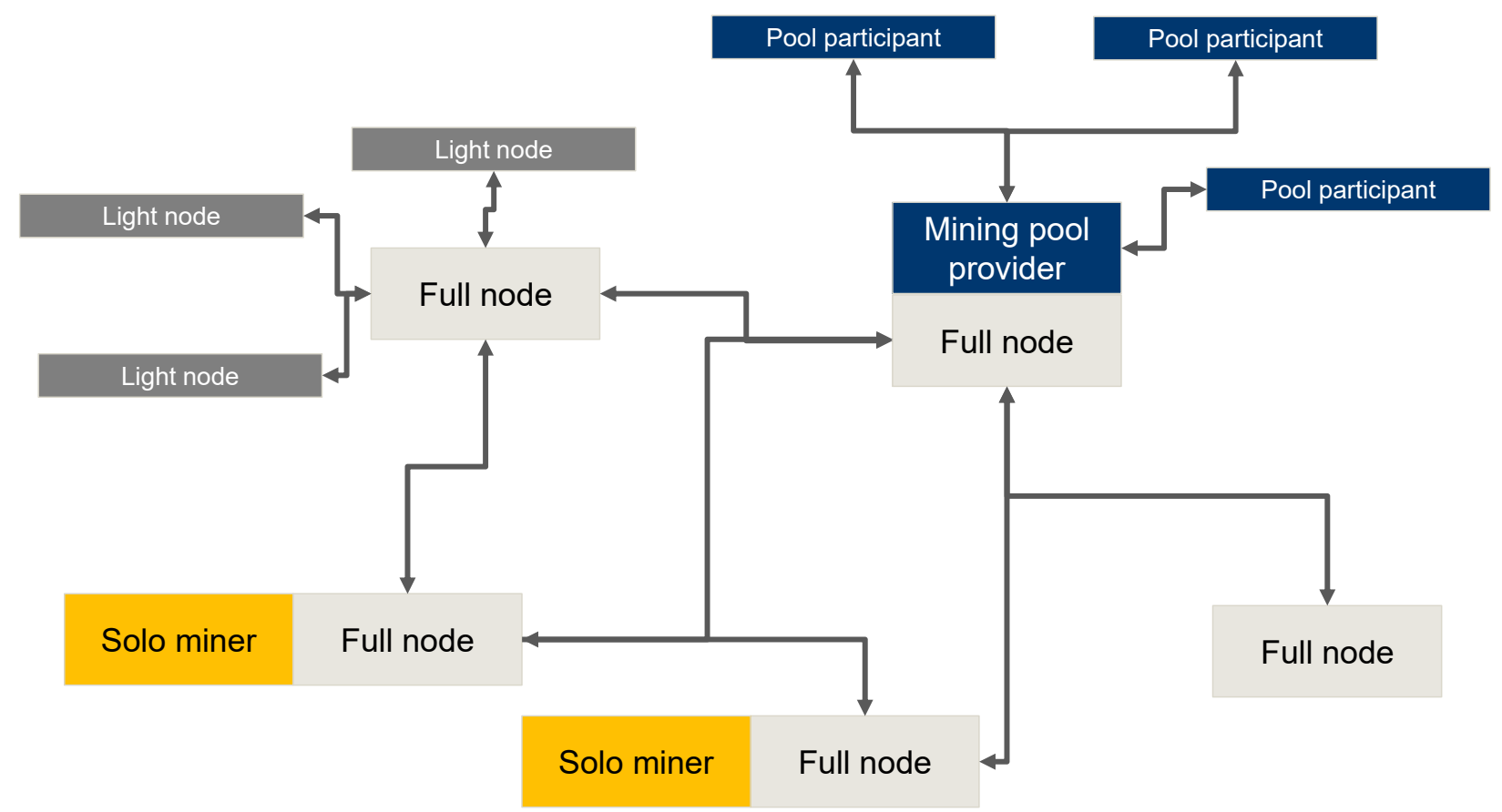
Ether denomination

Babbage, Lovelace and others represent influential CS/blockchain people

Unit	Wei Value	Wei
wei	1 wei	1
Kwei (babbage)	1e3 wei	1,000
Mwei (lovelace)	1e6 wei	1,000,000
Gwei (shannon)	1e9 wei	1,000,000,000
microether (szabo)	1e12 wei	1,000,000,000,000
milliether (finney)	1e15 wei	1,000,000,000,000,000
ether	1e18 wei	1,000,000,000,000,000,000

http://ethdocs.org/en/latest/ether.html

Ethereum network



Ethereum network node types

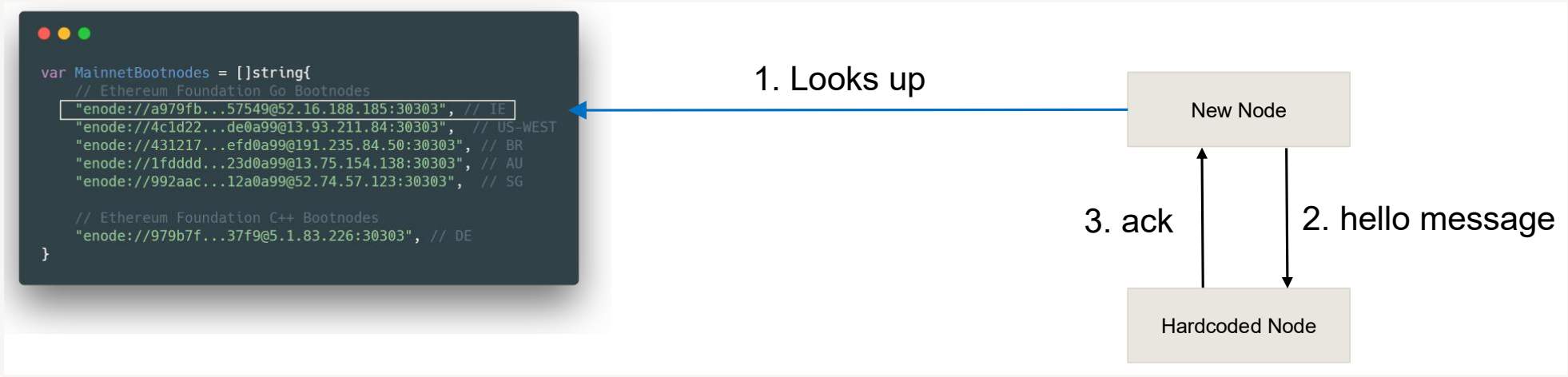
- Full nodes are the foundation of the Ethereum network
- Each full node holds a copy of the entire blockchain and syncs it with other nodes
- Transactions must be sent to a full node which distributes it among the network participants
- A light node is a client that is connected to a full node for the sake of not having to sync and download the entire blockchain
- For most private people, light nodes are the most comfortable way of interacting with the Ethereum blockchain
- One of the most common light nodes is https://myetherwallet.com (always triple check the domain)

Ethereum implementation

- To connect to the Ethereum network, you will need to download an Ethereum implementation
- Not all Ethereum nodes are using the same code base
- Since the specification for an Ethereum node is open source, basically anyone could create a different implementation
- The two major Ethereum implementations are: Geth and OpenEthereum

Node discovery

- Both Geth and OpenEthereum have a maintained list of default peers hardcoded into their source code
- Otherwise, it would be possible that no nodes are found, and the sync will always fail
- The Geth client comes with 6 hardcoded peers
- Once a node is selected, a hello message is sent to make an initial connection with the node



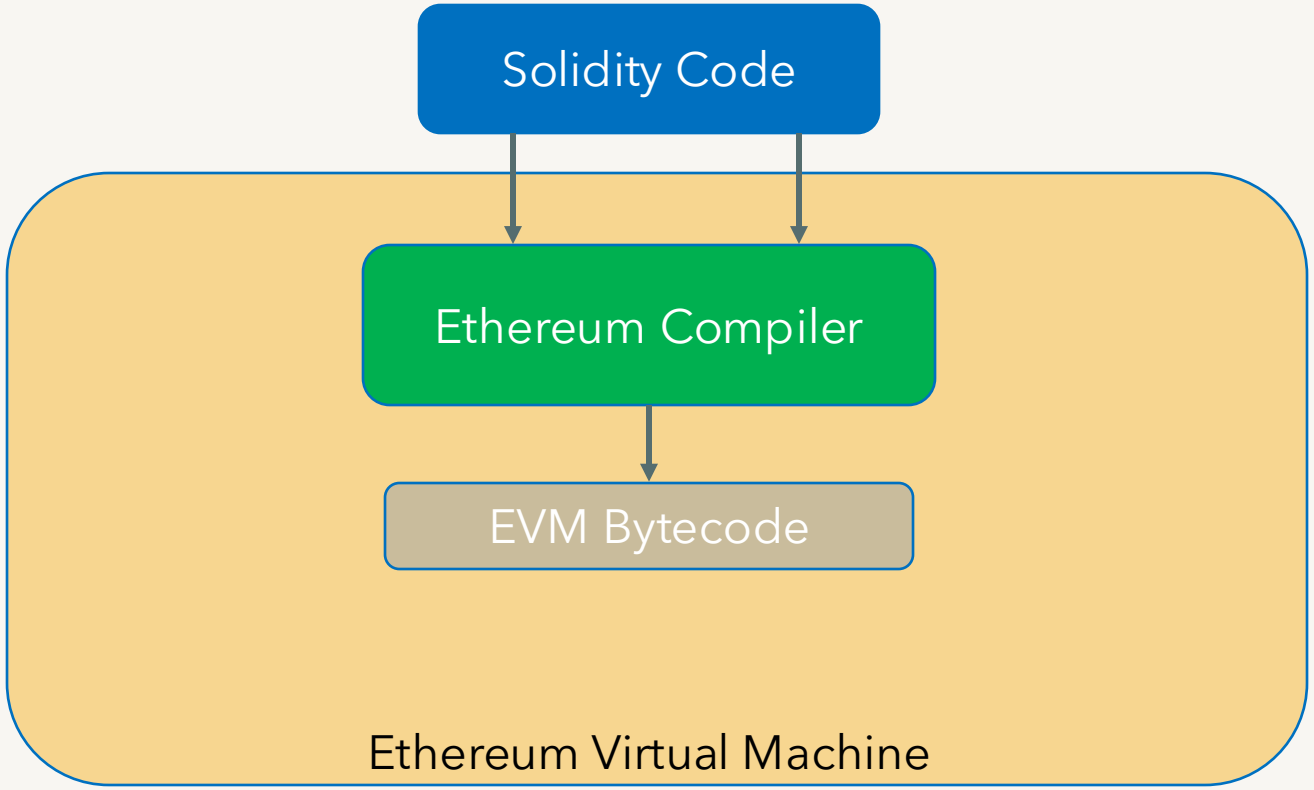
Ethereum Virtual Machine (EVM)

- The Ethereum Virtual Machine (EVM) is a simple but powerful, Turing complete 256bit Virtual Machine that allows anyone to execute arbitrary EVM Byte Code
- Turing completeness means you can write programs (contracts) that can (for the most part) solve any reasonable computational problem or write sophisticated logic
- It allows anyone to execute arbitrary code in a trust-less environment in which the outcome of an execution can be guaranteed and is fully deterministic

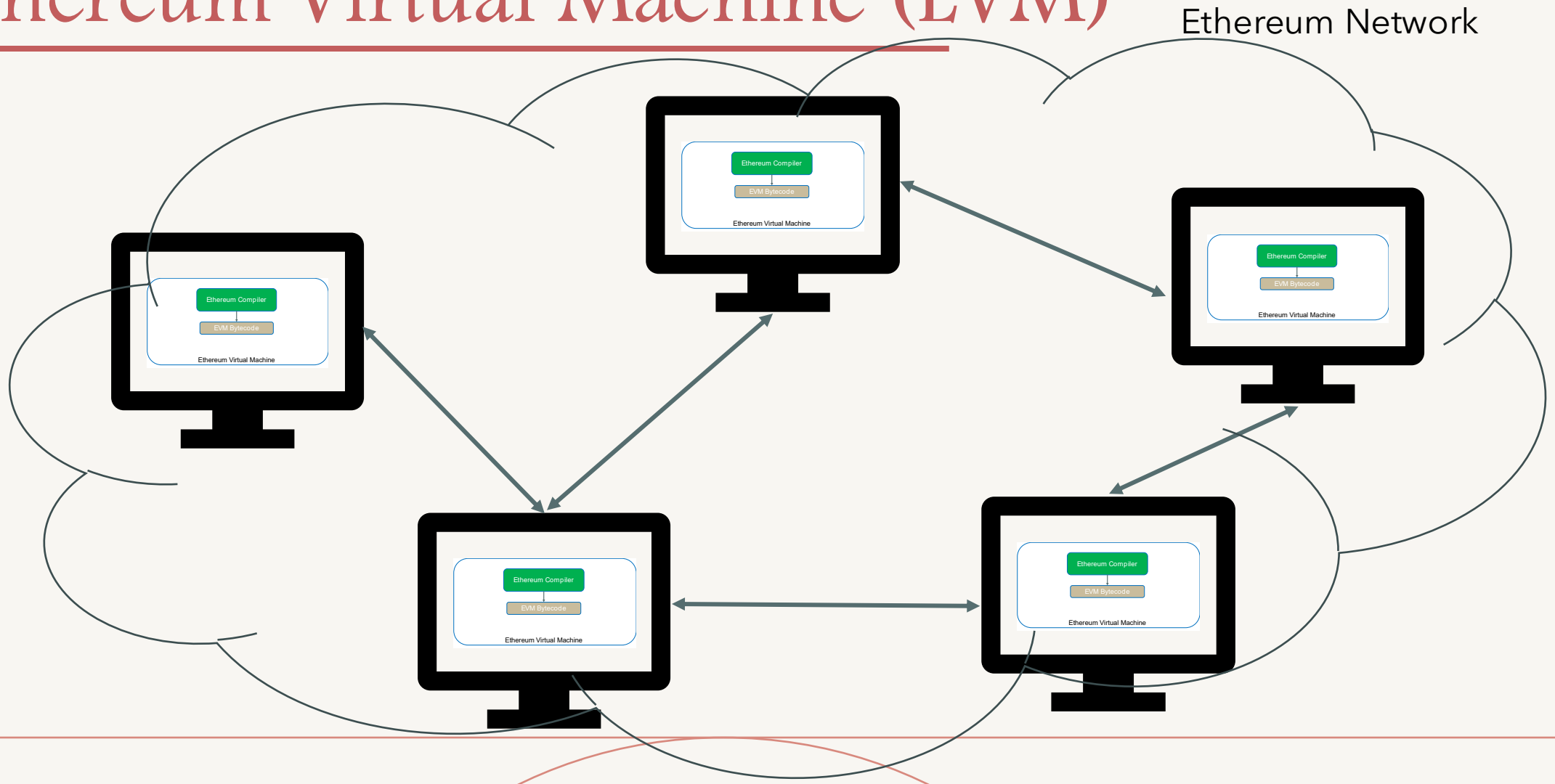
Ethereum Virtual Machine (EVM)

- Smart contract code is usually written in a high level programming language such as Solidity
- This code gets compiled to something called the EVM bytecode which gets deployed to the Ethereum blockchain
- This is very similar to a programming language like Java where the code gets converted to JVM Byte code
- The Ethereum runtime environment only understands and can execute the bytecode

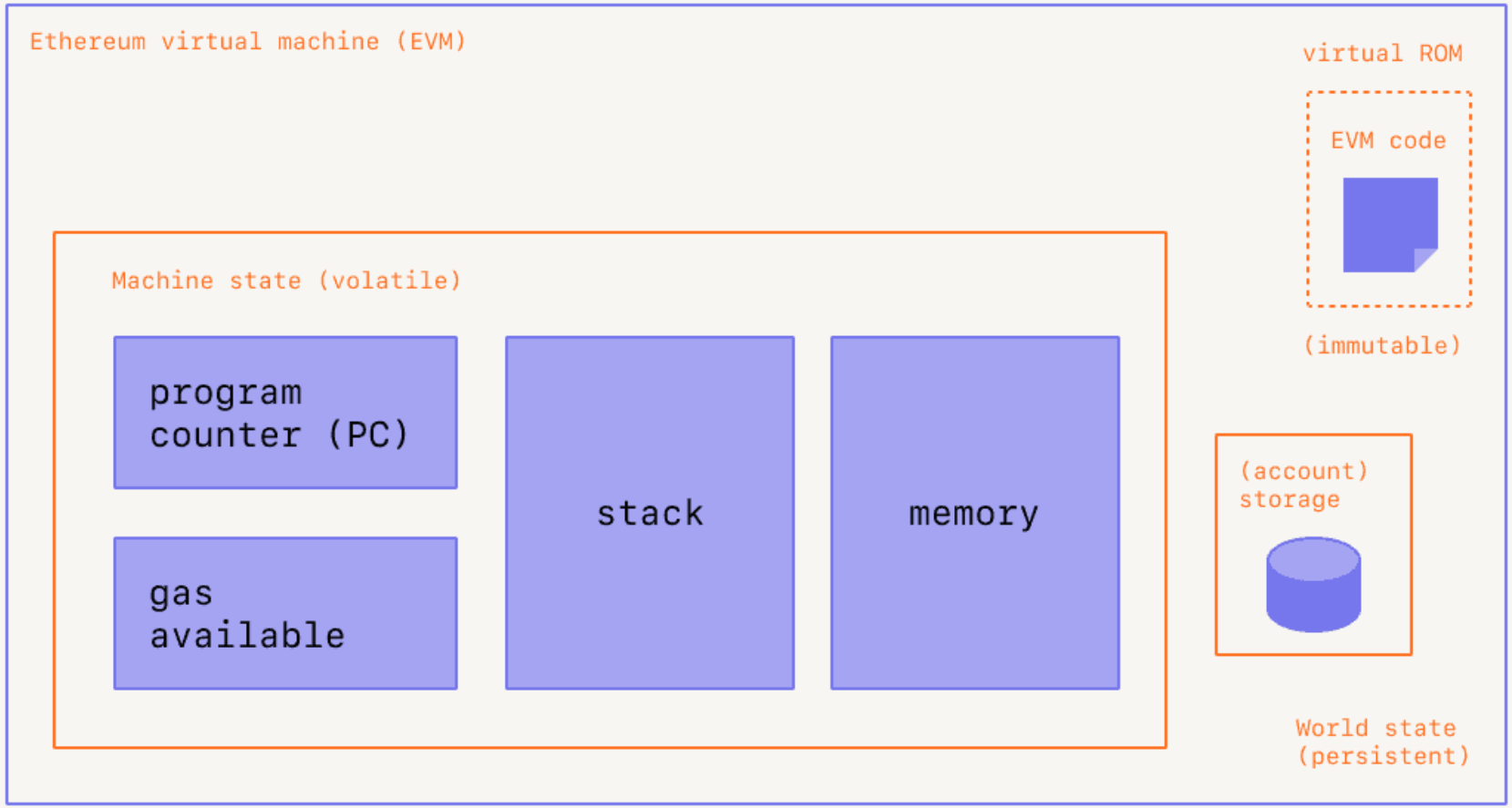
Ethereum Virtual Machine (EVM)



Ethereum Virtual Machine (EVM)

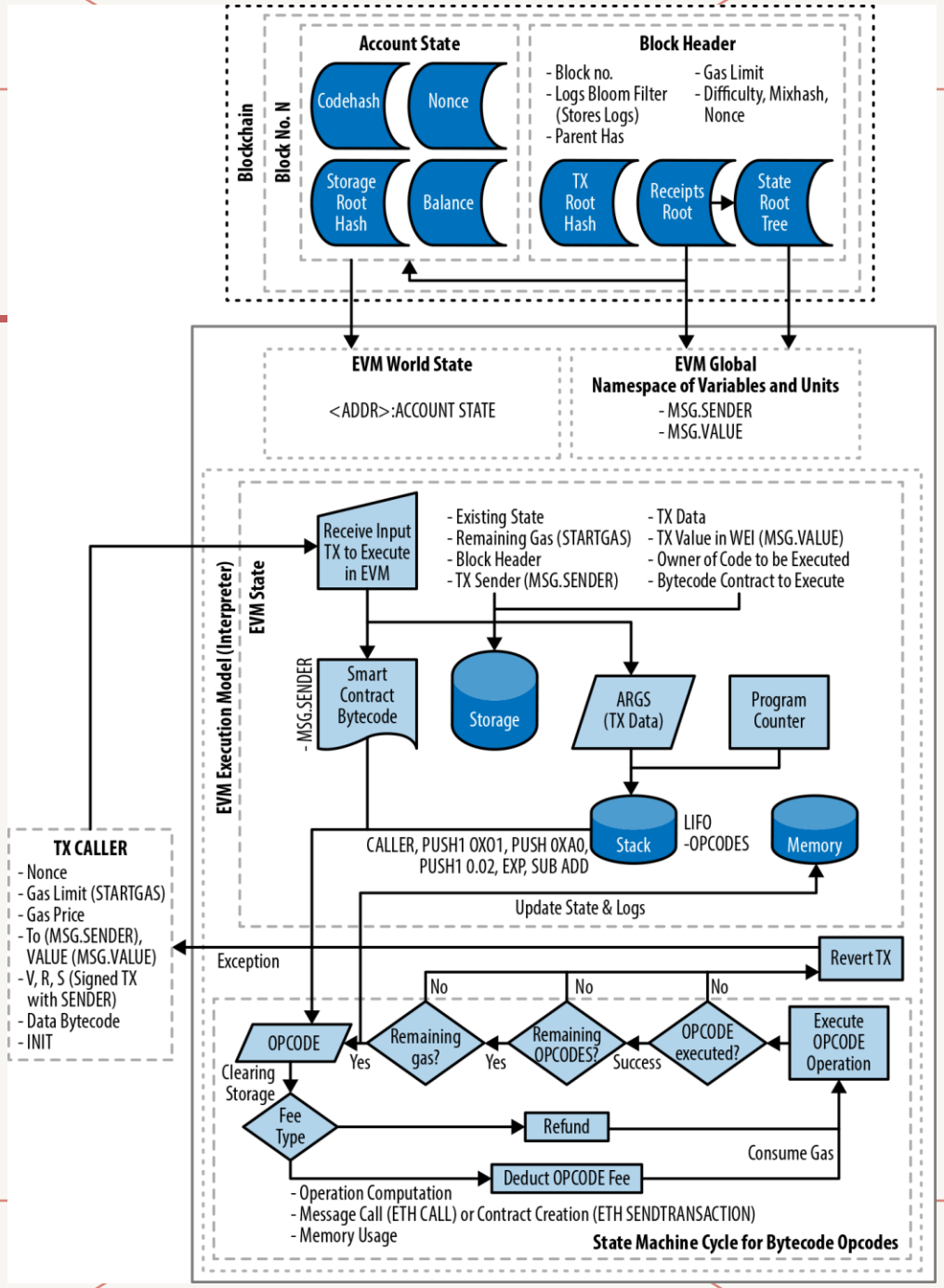


Ethereum Virtual Machine (EVM)



https://ethereum.org/static/e8aca8381c7b3b40c44bf8882d4ab930/302a4/evm.png

EVM



https://cypherpunks-core.github.io/ethereumbook/13evm.html

EVM Bytecode

- EVM bytecode is the instruction sets for the EVM
- The EVM instruction set offers most of the operations you might expect, including
  - Arithmetic and bitwise logic operations
  - Stack, memory, and storage access
  - Control flow operations
  - Logging, calling, and other operators
  - Access to account information (e.g., address and balance) and block information (e.g., block number and current gas price) (Blockchain state information)

https://cypherpunks-core.github.io/ethereumbook/13evm.html

Ethereum blockchain

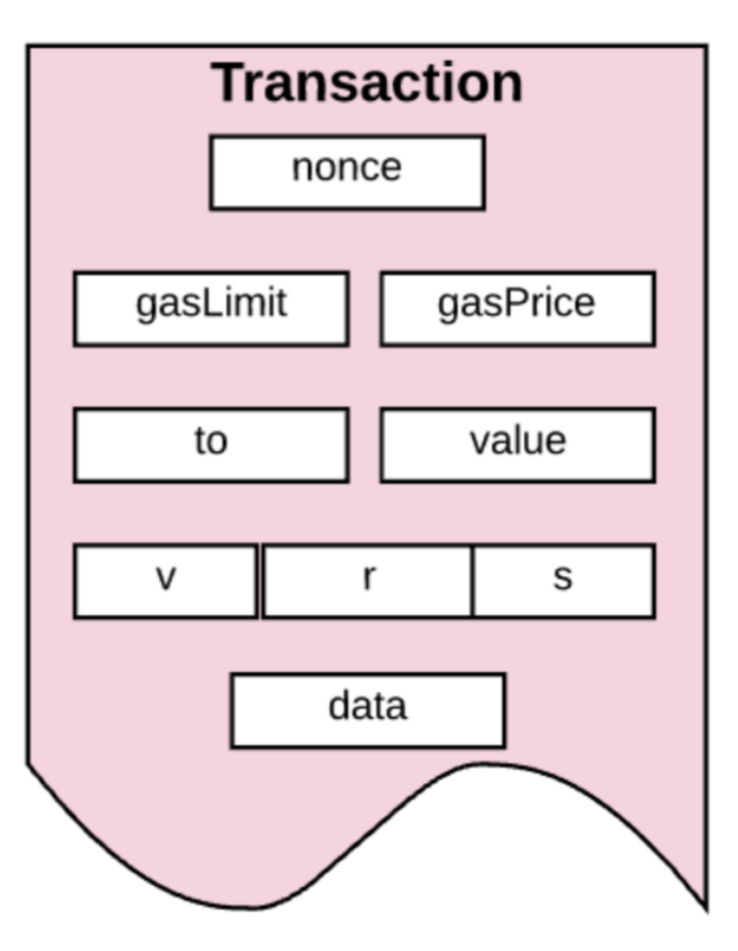
- Like Bitcoin, there are three major sub-components in the Ethereum blockchain
  - Transactions
  - Blocks
  - Blockchain

Ethereum transactions

- On Ethereum there are mainly two transactions
  - External transactions
  - Internal transactions
- An external transaction
  - is generated by a user, serialised and sent to the Ethereum network, put on the blockchain (just like Bitcoin)
  - Includes payment (regular) transactions and contract creation & contract call (execution) transactions

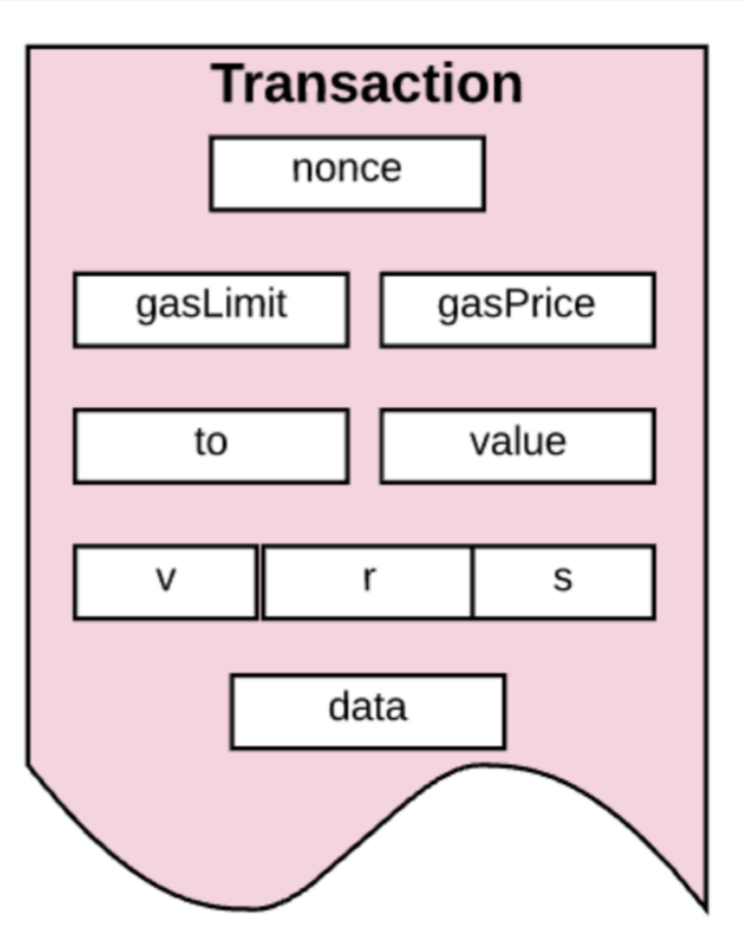
Ethereum external transactions: structure

- nonce: A count of the number of transactions sent by the sender (EOA) number, used to prevent message replay
- gasPrice: The price of gas (in wei) the originator (sender) is willing to pay
- gasLimit: The maximum amount of gas the originator is willing to buy for this transaction



Ethereum transactions

- to: Recipient's/contract address
- value: Amount of Wei transferred from the sender to the receiver
- v,r,s: The three components of an ECDSA digital signature of the originating EOA
- data: optional field to include code to create a contract or data for calling a function of an existing contract



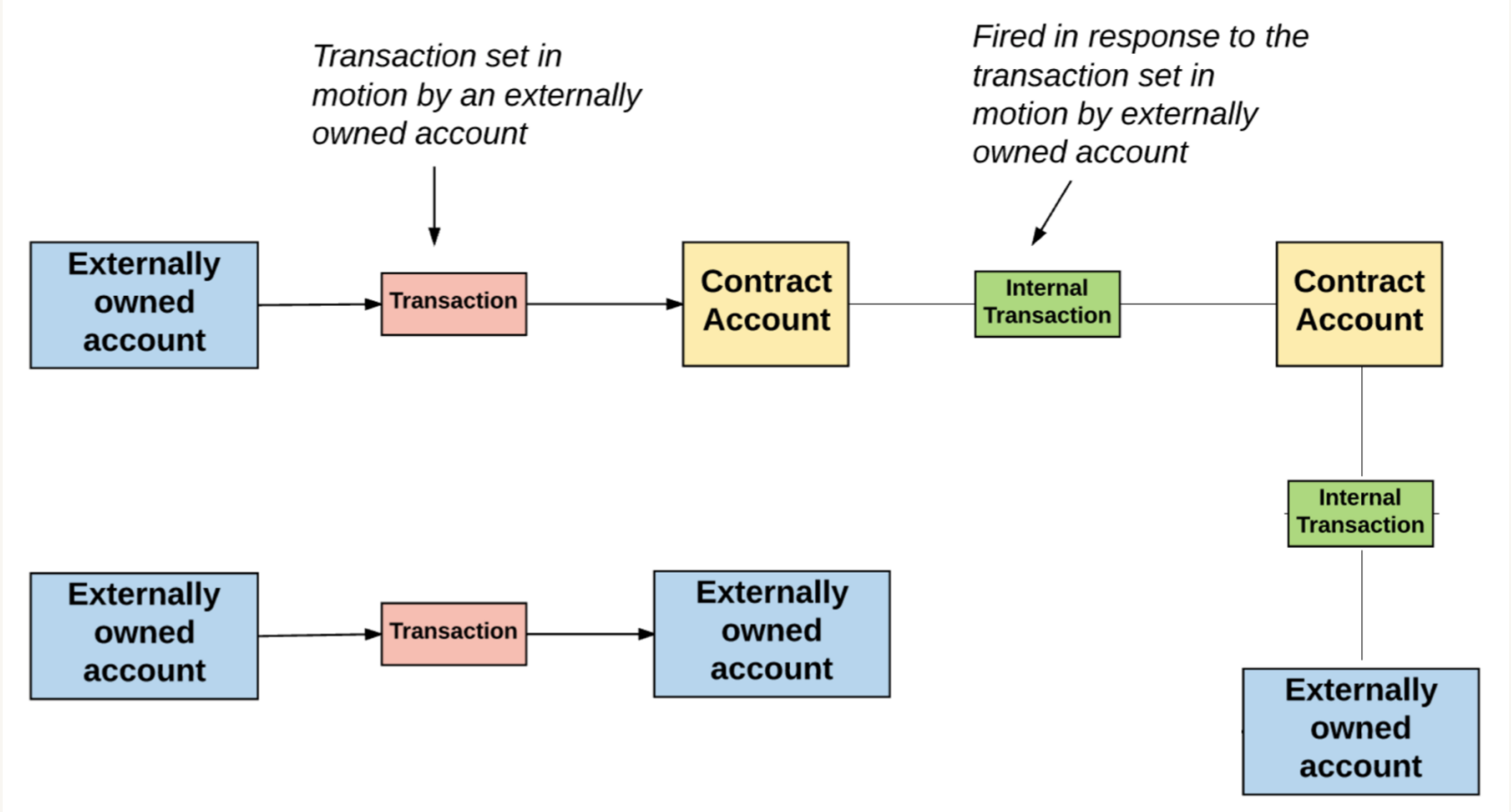
Ethereum external transactions

- Regular transactions
  - a transaction from one account to another (either to an EOA or to a contract account)
  - A 'to' address in this transaction denotes to receiver’s address
- Contract deployment transactions:
  - to deploy a smart-contract
  - a transaction without a 'to' address, where the data field is used for the contract code
- Execution of a contract:
  - a transaction that interacts with a deployed smart contract
  - In this case, 'to' address is the smart contract address
  - Data field contains the relevant value for the contract (function)

Ethereum transactions types

- Internal transactions
  - Contracts A can call a function in Contract B
  - These are not serialised and not put on the blockchain!
  - When these transactions transfer value (Eth) to another account, the account update is stored in the blockchain

Ethereum transactions types



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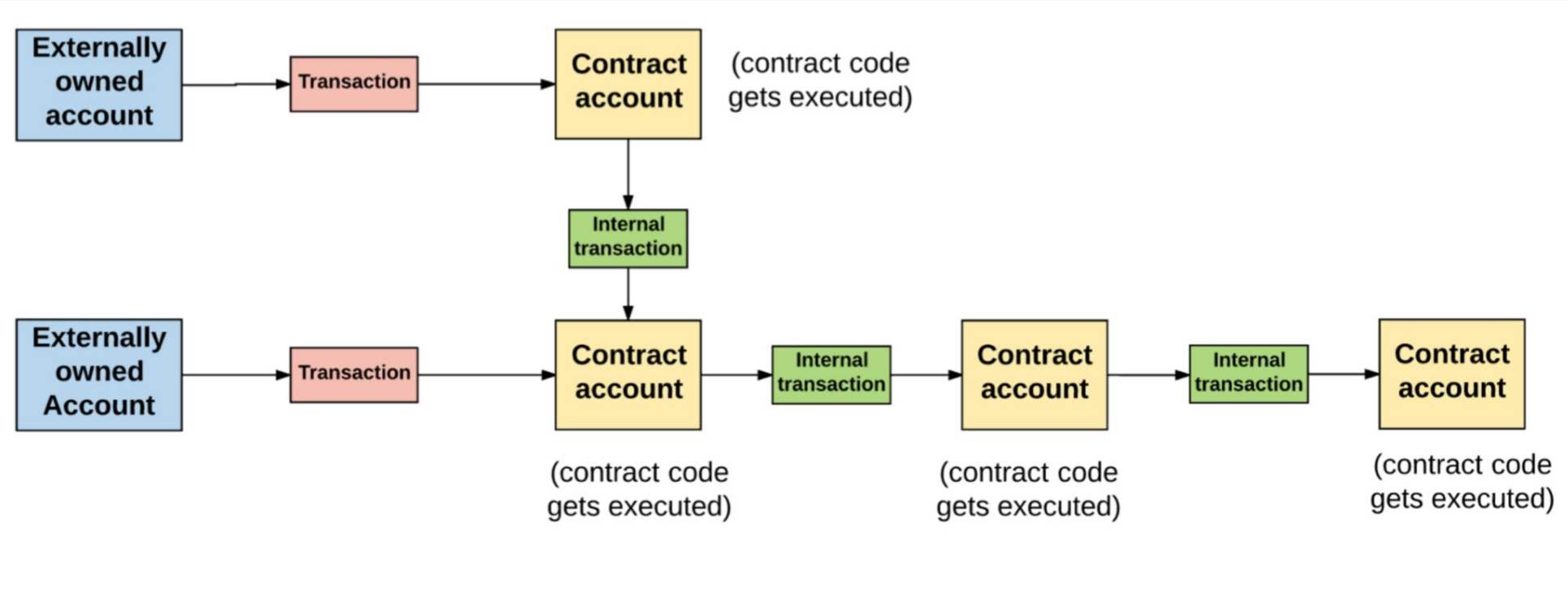
Ethereum transactions types



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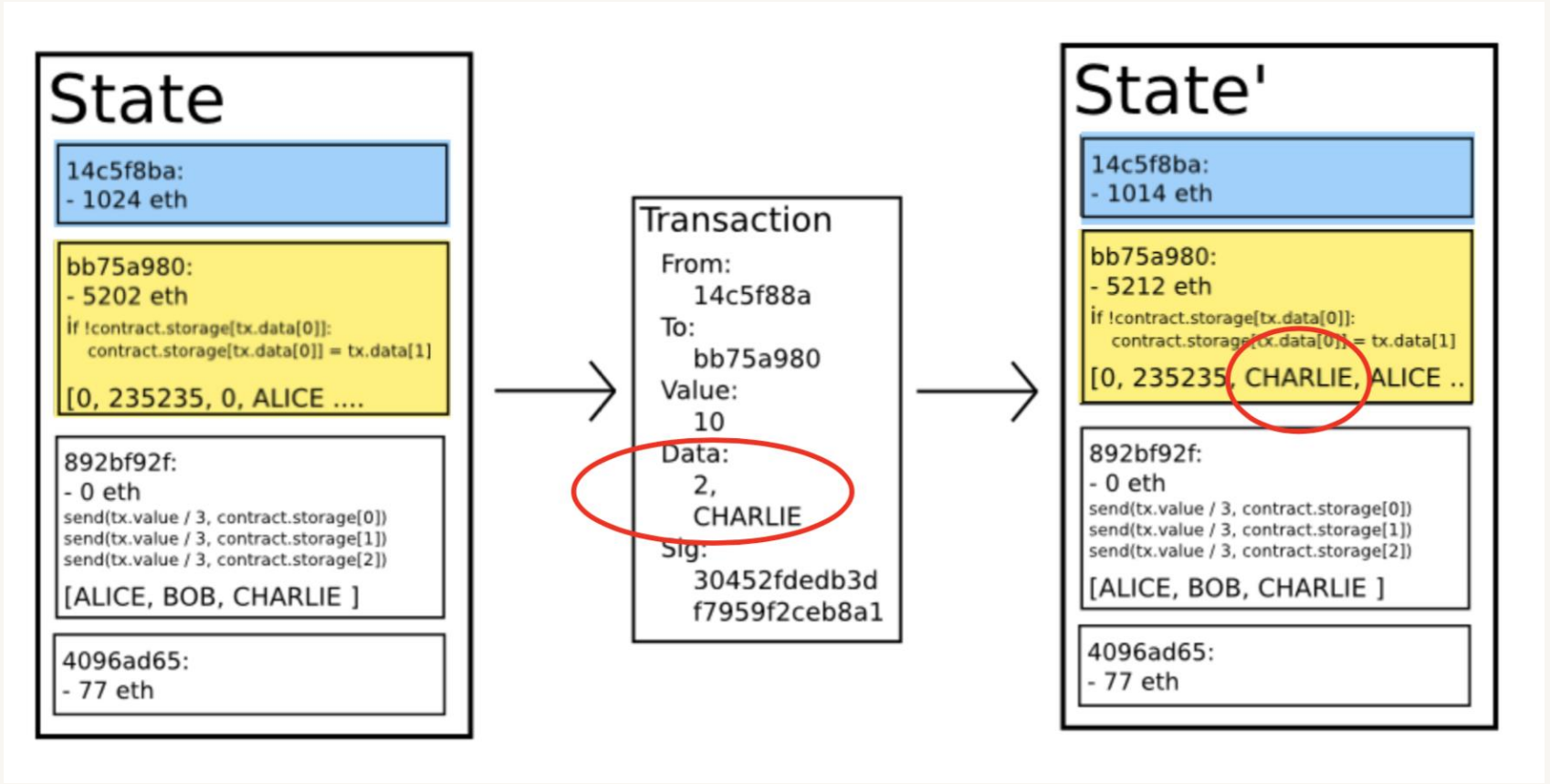
Ethereum transaction execution



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Ethereum DoS protection

- EVM code is “Turing complete", e.g., has loops and may not halt
- In order to ensure safety, a type of DoS protection, the concept of fee is used
- Ethereum utilises a “pay as you execute” model
  - Meaning users need to pay for both computation and storage of data
- This payment is collected by the respective miner

Ethereum gas and gas price

- Each transaction contains a “gas limit”, and a “gas price” which is the price the sender will pay per unit of gas, denominated in ETH (currency)
- Along with sufficient ETH to pay the fee
- But, how much do you need to pay?
- It depends on how much unit of work, i.e. code execution, is carried out or the amount of data stored in the network
  - The unit of work in Ethereum is defined with the concept of Gas
  - Ether buys GAS to fuel the EVM, like hour(s) of labour

Ethereum gas and gas price

- Each operation in Ethereum utilises some amount of gas
- For example:
  - If you add two numbers, 3 gas is used
  - If you multiply two numbers, 5 gas is used
  - One hash call requires 30 gas
- Ethereum also uses gas for contract creation
- By calculating total operations, we can estimate how much gas it might require
- It is difficult to know the exact gas required for contract execution
  - So, set a higher limit using the notion of gasLimit, that implies the maximum amount of gas you are willing to buy

Ethereum gas and gas price

- But, still we don't know how much Ether we have to pay to the miners
- That is determined by Gas Price, which is like the hourly labour rate: 500 taka/hour
- Fee for computation in Ether = gasLimit x gasPrice;
  - gasLimit (gas) and gasPrice are specified in the transaction
  - The calculated Fee is placed in Escrow
- Gas price is determined by the sender
- If gasPrice is too low, no miner will bother about processing a transaction

Ethereum gas and gas price

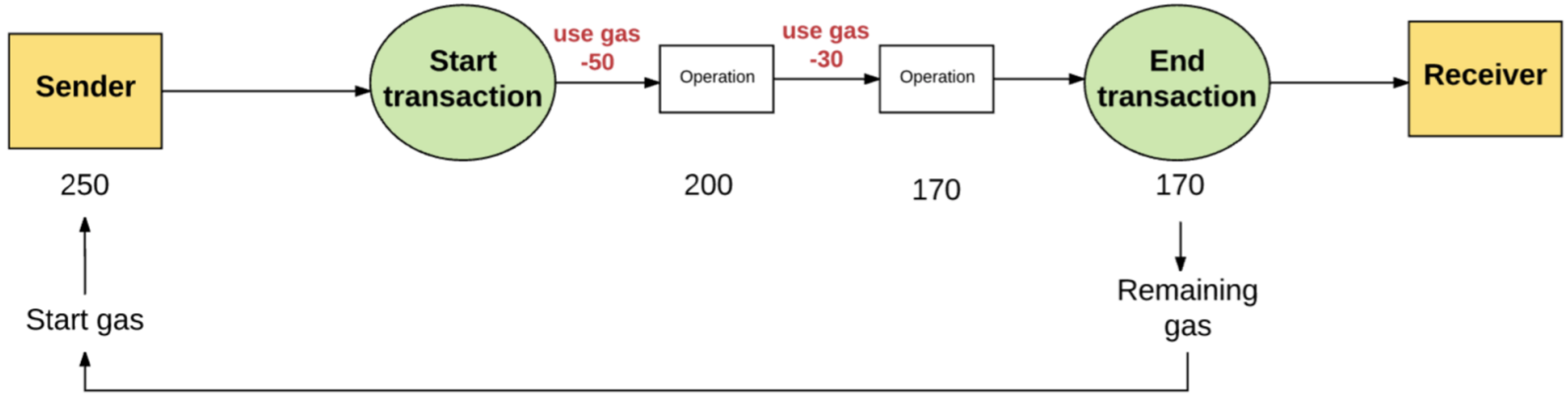
- If the fee is less than required, gas runs out before a transaction is completed
  - State is reverted back to the previous state
  - Fee is consumed from the escrowed Ether
- If execution completes
  - consumed gas x gasPrice is paid to the miner
  - Remaining gas (gasLimit – consumed gas) x gasPrice is returned back to the caller
- The higher the gas price you set, the sooner your transaction gets mined
  - Most miners tend to choose transactions with higher fees
- If price is relatively low, your transaction will eventually get included in the block but you might have to wait for a bit

Ethereum gas and gas price

- Gas limit: Max no. of computational steps the transaction is allowed.
- Gas Price: Max fee the sender is willing to pay per computation step.

Ethereum gas and gas price

The sender is refunded for any unused gas at the end of the transaction.



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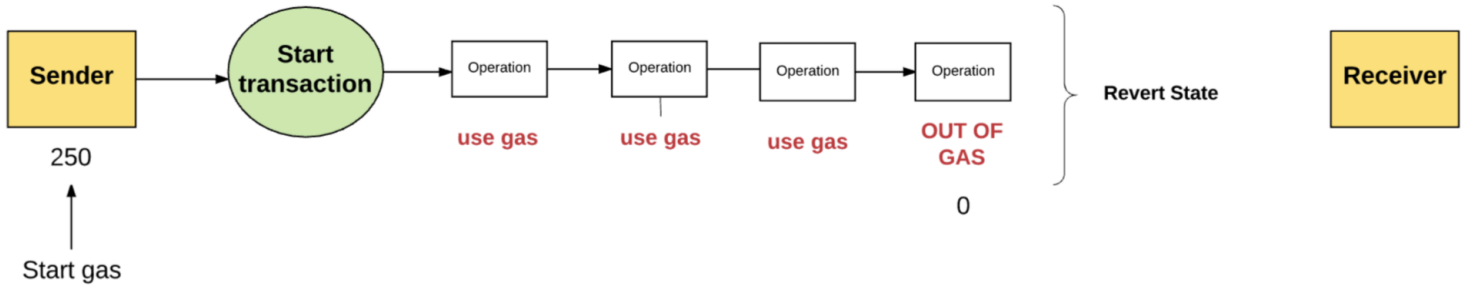
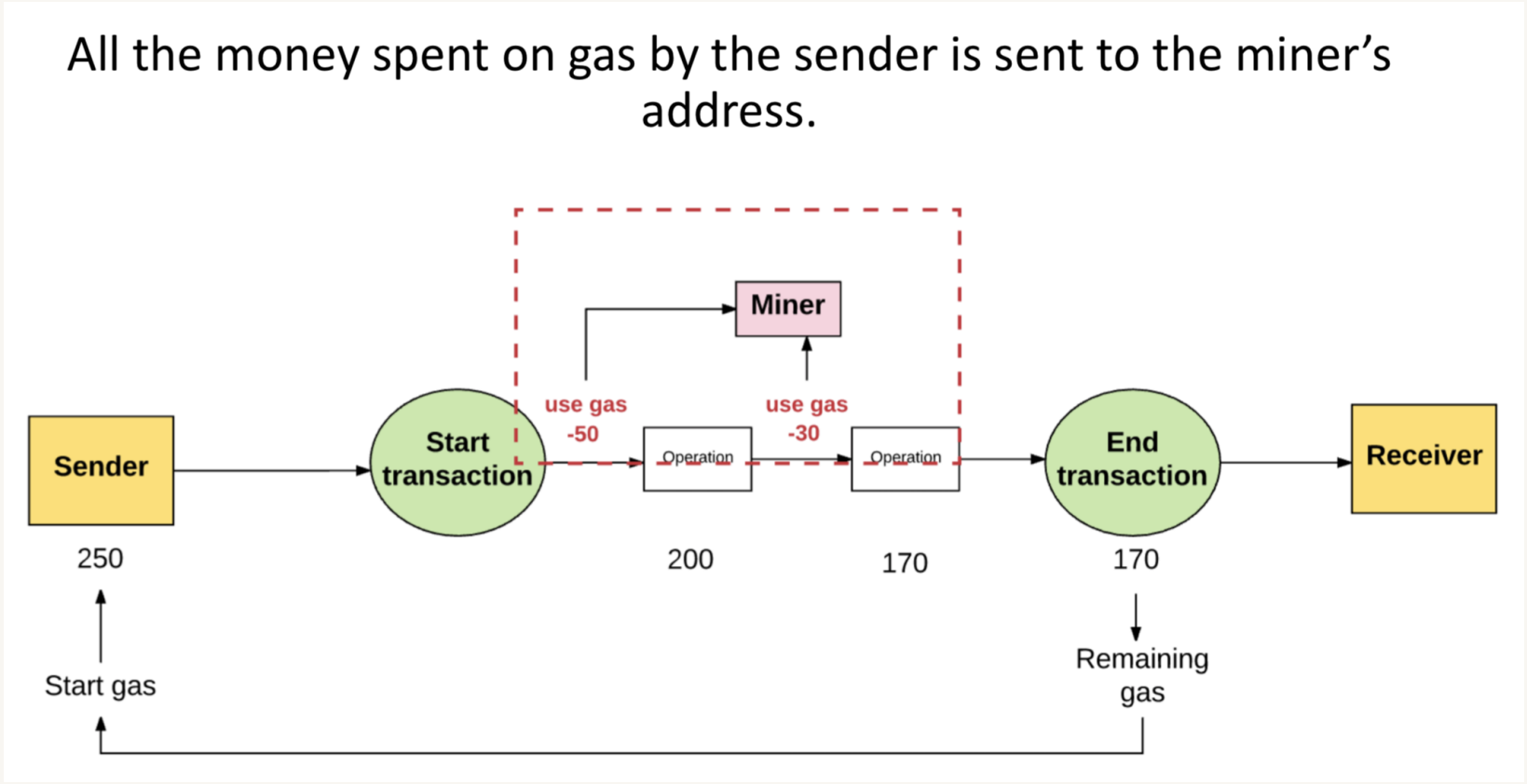
Ethereum gas and gas price

If sender does not provide the necessary gas to execute the transaction, the transaction runs “out of gas” and is considered invalid.



- The changes are reverted.
- None of the gas is refunded to the sender.

Ethereum gas and gas price



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Question?