



PAKISTAN BLOCKCHAIN INSTITUTE

Class-3

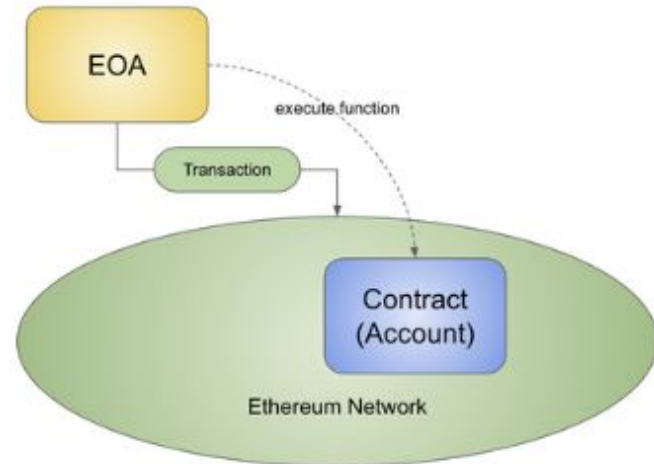
MODULE-3

ETHEREUM 2.0 EXPLAINER

Raja Rizwan Saleem
Lead Blockchain Trainer



TRANSACTION EXECUTION POS



HOW A TRANSACTION GETS EXECUTED IN ETHEREUM POS

1. A user creates and signs a transaction with their private key. This is usually handled by a wallet or a library such as [ether.js](#), [web3js](#), [web3py](#) etc but under the hood the user is making a request to a node using the Ethereum JSON-RPC API. The user defines the amount of gas that they are prepared to pay as a tip to a validator to encourage them to include the transaction in a block. The tips get paid to the validator while the base fee gets burned.
2. The transaction is submitted to an Ethereum execution client which verifies its validity. This means ensuring that the sender has enough ETH to fulfill the transaction and they have signed it with the correct key.
3. If the transaction is valid, the execution client adds it to its local mempool (list of pending transactions) and also broadcasts it to other nodes over the execution layer gossip network. When other nodes hear about the transaction they add it to their local mempool too. Advanced users might refrain from broadcasting their transaction and instead forward it to specialized block builders such as [Flashbots Auction](#). This allows them to organize the transactions in upcoming blocks for maximum profit (MEV).

HOW A TRANSACTION GETS EXECUTED IN ETHEREUM POS

4. One of the nodes on the network is the block proposer for the current slot, having previously been selected pseudo-randomly using RANDAO.

This

node is responsible for building and broadcasting the next block to be added to the Ethereum blockchain and updating the global state. The node is made up of three parts: an execution client, a consensus client and a validator client. The execution client bundles transactions from the local mempool into an "execution payload" and executes them locally to generate a state

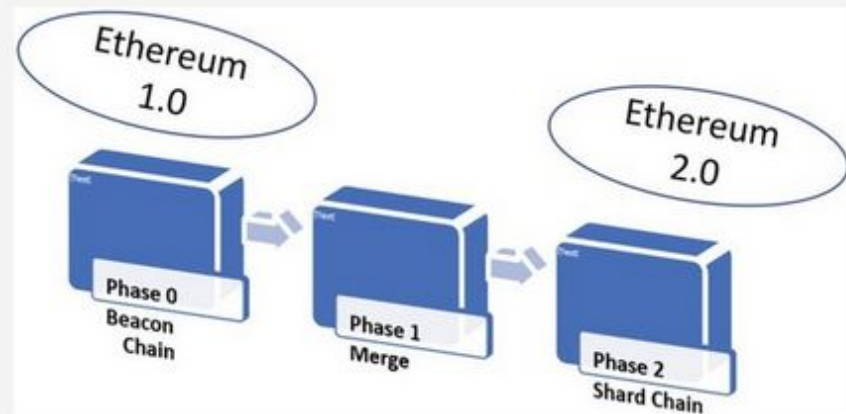
change. This information is passed to the consensus client where the

execution payload is wrapped as part of a "beacon block" that also contains information about rewards, penalties, slashings, attestations etc. that enable the network to agree on the sequence of blocks at the head of the chain

HOW A TRANSACTION GETS EXECUTED IN ETHEREUM POS

5. Other nodes receive the new beacon block on the consensus layer gossip network. They pass it to their execution client where the transactions are re-executed locally to ensure the proposed state change is valid. The validator client then attests that the block is valid and is the logical next block in their view of the chain (meaning it builds on the chain with the greatest weight of attestations as defined in the [fork choice rules](#)). The block is added to the local database in each node that attests to it.
6. The transaction can be considered "finalized" if it has become part of a chain with a "supermajority link" between two checkpoints. Checkpoints occur at the start of each epoch and they exist to account for the fact that only a subset of active validators attest in each slot, but all active validators attest across each epoch. Therefore, it is only between epochs that a 'supermajority link' can be demonstrated (this is where 66% of the total staked ETH on the network agrees on two checkpoints).

ETHEREUM 2.0 PHASES



Sharding Phase -1

- Validator Manager Contract (VMC) hosted on the Beacon Chain responsible for coordinating the sharding process
- Prospective ETH2 validators are required to lock up 32 ETH into the smart contract before getting added to the pool of eligible validators
- VMC assigns validators to shards at intervals to validate and process transaction collations to the consensus chain
- Shards only serve as "data depots" to increase data processing abilities of the Ethereum network.

Sharding Phase -II

- Shards move from being data layers to code execution layers—each shard has an independent “state”, (i.e. a unique set of smart contracts, account balances, and addresses.)
- Each shard acts like the Ethereum Mainnet with full smart contract and dApp support
- Cross-shard communication allows users on different shard chains to exchange value.
- dApps running on different shard chains can "talk" and interact with each other using cross-shard communication, improving Ethereum's scalability functionality.

Ethereum 2.0 Phases

Ethereum 2.0 has three phases:

Phase 0 – Beacon Chain

Phase 1 – shards

Phase 2 – execution

An analogy with the human body:

Phase 0 – heart

Phase 1 – limbs

Phase 2 – brain

An analogy with an orchestra that's tough to beat:

Phase 0 – conductor

Phase 1 – instruments

Phase 2 – musicians

Ethereum 2.0 Phases

All phases are integral to the system and have different characteristics. Phase 0 is part of Ethereum 2020. Phase 1 is generally more inanimate and static than the other phases. Phase 2 is generally about action and agency.

Ethereum 2.0 Phases

Phase 0: Beacon Chain (PoS Implementation)

The Beacon Chain is the foundational component of Ethereum 2.0. It operates as a separate PoS blockchain that introduces validators and staking. The main goals of Phase 0 are to establish the PoS system and prepare for the subsequent phases. Key features of Phase 0 include:

- Launch of the Beacon Chain.
- Introduction of validator nodes that participate in consensus by proposing and attesting to blocks.
- Validators stake Ether as collateral to participate and secure the network.
- Beacon Chain manages the PoS consensus and coordination of shard chains.

Purpose of the Beacon Chain

- Store information about validators and their stakes, while ensuring that all validators have a minimum 32 ETH staked
- Select block proposers for each shard in each slot Organize validators into committees to vote on the validity of proposed blocks
- Distributing rewards and imposing penalties to validators. The Beacon Chain is also responsible for monitoring the behavior of the validators. Rewards are given to the validators as an incentive for acting in line with the rules. On the other hand, malicious behaviors, such as voting on two chains at once, will lead to a penalty (slashing) where some of their staked collateral is deducted. In egregious cases, they can even get thrown out of the system entirely.
- Establish the mechanism to determine finality and enable crosslinks between shards. The current state of each shard is recorded in a Beacon Chain block as a crosslink. When the Beacon Chain block has been finalized, the corresponding shard block is considered finalized. The other shards can depend on it for cross-shard transactions

Ethereum 2.0 Phases

Phase 1: Shard Chains (Data Sharding)

Phase 1 focuses on introducing shard chains to Ethereum blockchain. Sharding involves dividing the Ethereum network into smaller chains (shards), each capable of processing its own transactions and smart contracts. However, in Phase 1, these shard chains primarily focus on data storage rather than full smart contract execution. Key features of Phase 1 include:

- Introduction of shard chains, each responsible for storing data.
- Shards work in parallel, enhancing the overall capacity to process transactions.
- Cross-links connect the Beacon Chain to shard chains, allowing data availability and secure communication.

Ethereum 2.0 Phases

Phase 1.5: Eth1-Eth2 Merger (PoS Mainnet)

Phase 1.5 marks the transition from the current Ethereum PoW mainnet to the PoS-based Ethereum 2.0 network. This phase involves merging the existing Ethereum 1.0 mainnet into the Ethereum 2.0 framework. The PoW chain becomes one of the shard chains, while the Beacon Chain continues to manage PoS consensus. Key features of Phase 1.5 include:

- Transition from PoW to PoS for the main Ethereum network.
- Eth1 chain becomes a shard within the Eth2 framework.
- Validators secure the network, and PoS is fully operational.

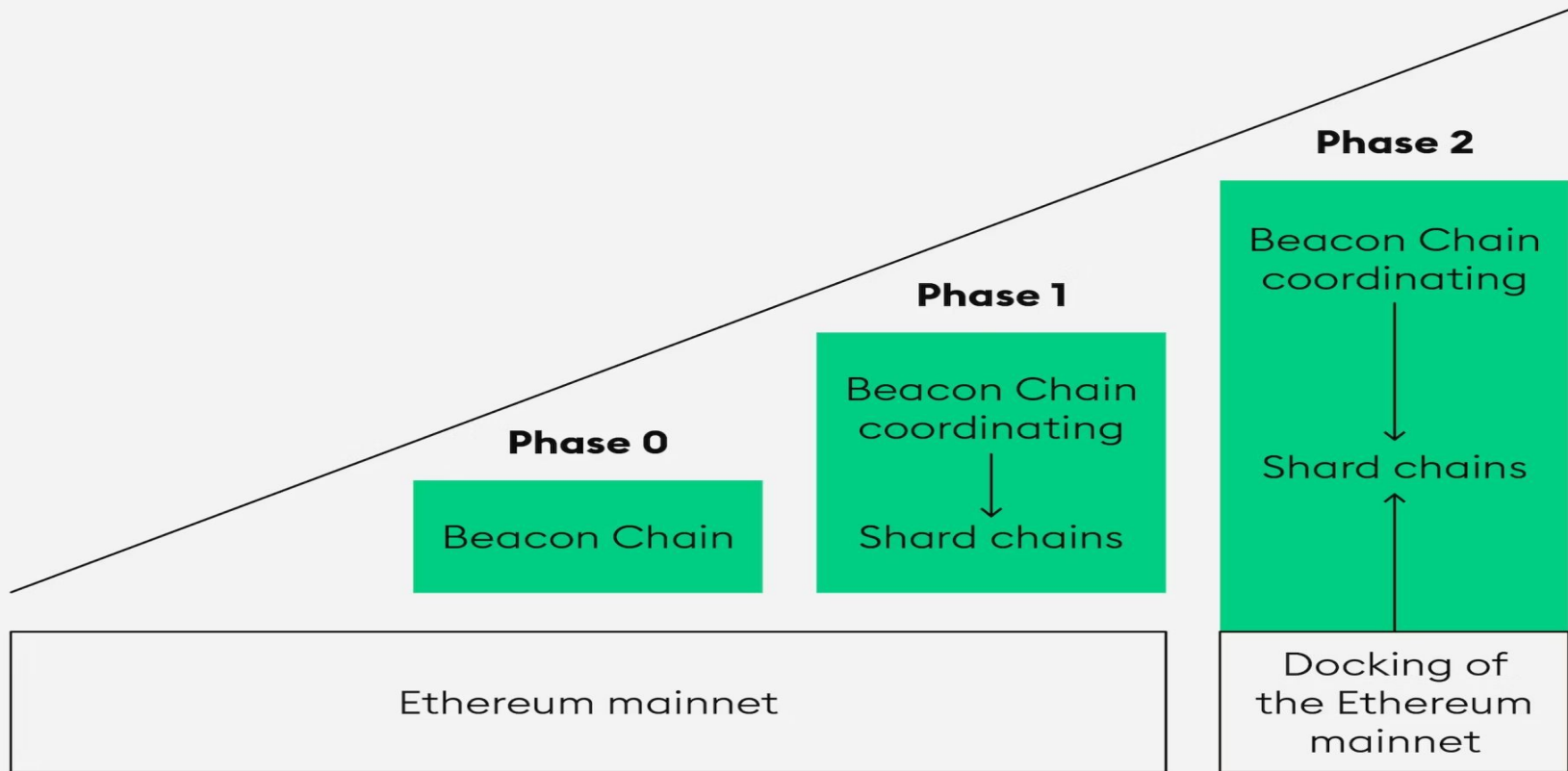
Ethereum 2.0 Phases

Phase 2: Full Sharding and Execution Environments

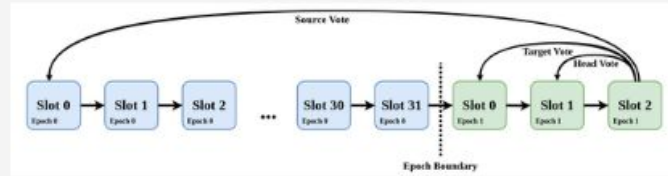
Phase 2 is the most extensive and ambitious phase of Ethereum 2.0. It aims to complete the transition to full sharding and implement execution environments on shard chains. In this phase, shard chains become capable of executing smart contracts and transactions more akin to the current Ethereum mainnet. Key features of Phase 2 include:

- Full execution environments on shard chains, enabling smart contract execution.
- Cross-shard communication and coordination mechanisms.
- Enhanced scalability, efficiency, and throughput.

It's important to note that these phases represent a general roadmap for Ethereum 2.0. The actual development and deployment process might involve adjustments, optimizations, and improvements based on research, community feedback, and technical considerations. The Ethereum community and developers work collaboratively to achieve the goals set out in these phases.



SLOTS AND EPOCHS



Slot & Epoch

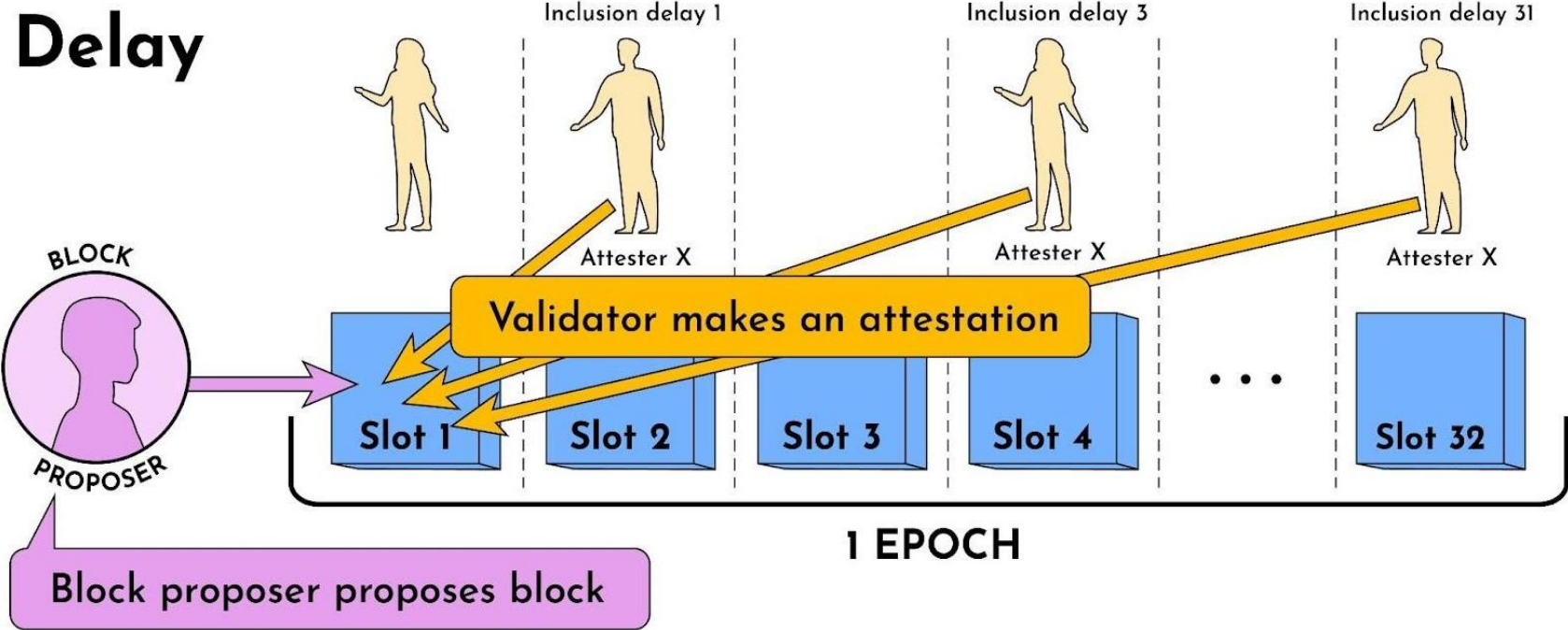
In the context of Ethereum 2.0 and its Proof of Stake (PoS) consensus mechanism, "slots" and "epochs" are important concepts that relate to the operation and organization of the network.

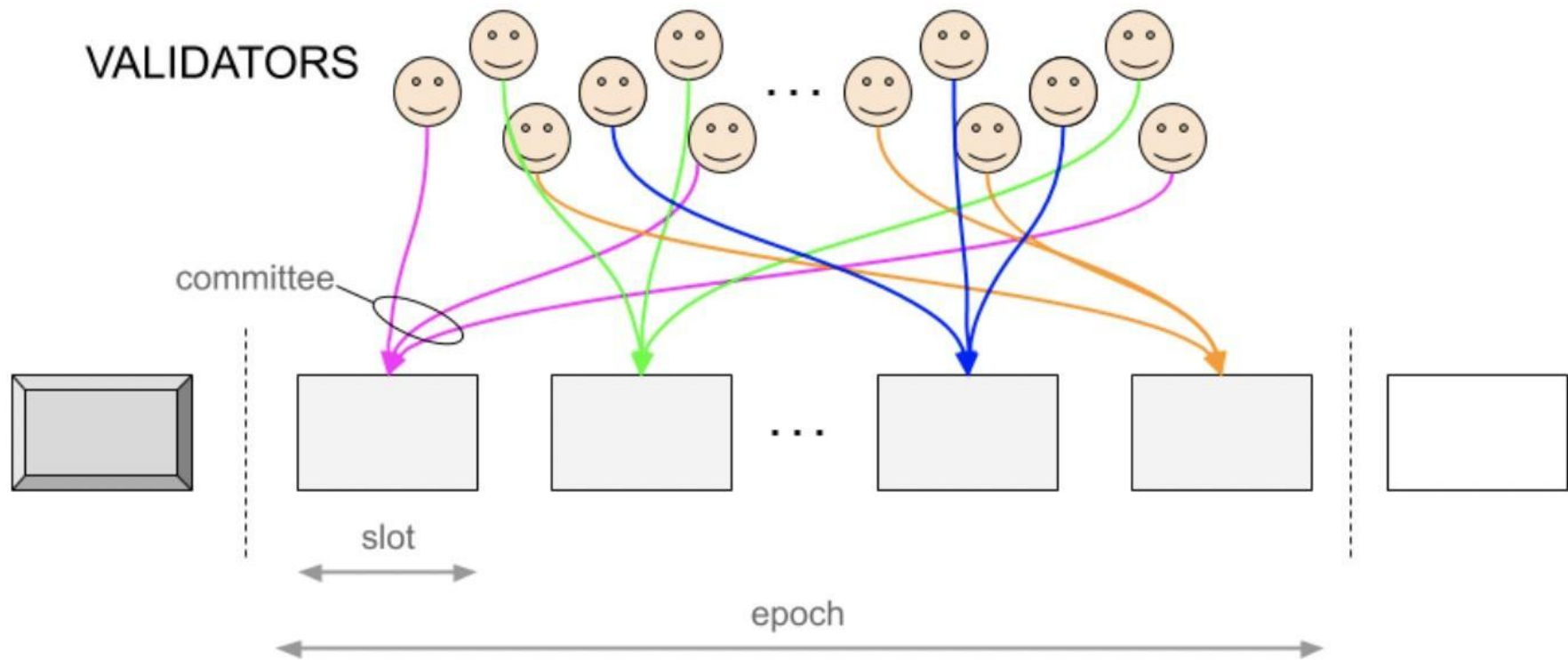
Slots

32 Slots = 1 Epoch A time period of **12 seconds** in which a randomly chosen validator has time to propose a block. Each slot may or may not have a block in it. The total number of validators is split up in committees and one or more individual committees are responsible to attest to each slot. One validator from the committee will be chosen to be the aggregator, while the other 127 validators are attesting. After each Epoch, the validators are mixed and merged to new committees. There is a minimum of 128 validators per committee.

Slots

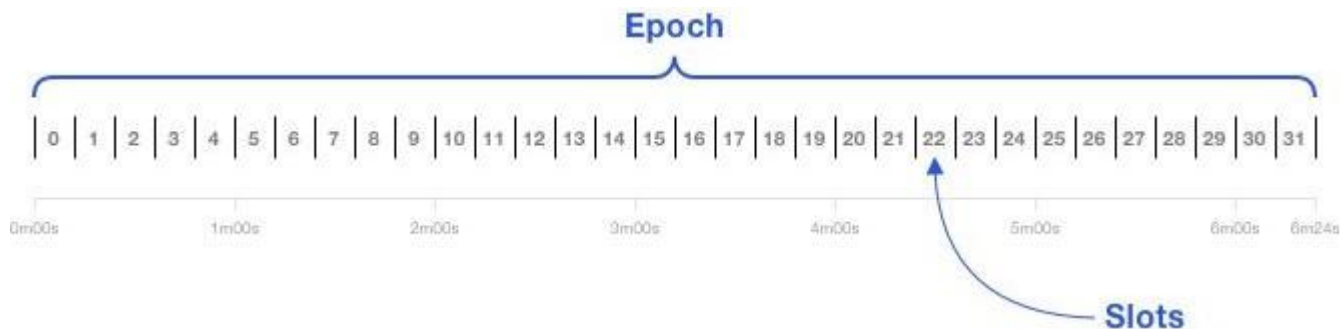
Inclusion Delay





Slot and Epochs

The Beacon Chain provides the heartbeat to Ethereum 2.0. It provides the tempo and rhythm for the system's harmony and consensus. Each slot is 12 seconds and an epoch is 32 slots: 6.4 minutes.



Slot and Epochs

A slot is a chance for a block to be added to the Beacon Chain and shards. You can imagine that the Beacon Chain and shard chains are choreographed in lockstep. Every 12 seconds, one beacon (chain) block and 64 shard blocks are added when the system is running optimally. Validators do need to be roughly [synchronized with time](#).

A slot is like the block time, but slots can be empty. Genesis blocks for the Beacon Chain and shards are at Slot 0. Shards will start at a future epoch than the Beacon Chain's Epoch 0, but will have their own Epoch 0 that includes their genesis blocks.

Slot and Epochs

- Validators take turns proposing blocks in consecutive slots.
- A validator chance to propose a block is determined by their weight, which is influenced by the amount of Ether they have staked and other factors.
- Once a validator proposes a block in a slot, that block contains transactions and attestations from other validators, indicating agreement on the state of the network.
- If a validator misses their turn or behaves maliciously, they might lose a portion of their staked Ether as a penalty.

Epochs

Represents the number of 32 slots and takes approximately **6.4 minutes**. Epochs play an important role when it comes to the [validator queue](#) and [finality](#).

An epoch is a larger unit of time in Ethereum 2.0, composed of a fixed number of slots. Each epoch consists of 32 slots. An epoch is approximately 6.4 minutes long (32 slots * 12 seconds per slot). The concept of epochs helps organize various activities and processes within the Ethereum 2.0 network. Some key aspects related to epochs include:

Epochs

- **Validator Rotation:** Validators are shuffled and reorganized at the beginning of each epoch. This process helps distribute the opportunity to participate in block proposing and attesting more fairly.
- **Reward Distribution:** Rewards and penalties for validators are calculated at the end of each epoch. This includes rewards for proposing blocks, attesting correctly, and penalties for misbehavior.
- **State Transitions:** Certain state transitions, such as updating the active validator set, occur at the boundary between epochs. This ensures smooth network operations.
- **Slashing:** Slashing refers to the penalty imposed on validators who behave maliciously or contradict the consensus rules. Slashing is applied based on evidence from multiple validators and can result in a loss of staked Ether.



End of Module-3 (Class-3)

Thank You!