

AccountingOracle

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info It's advised to read [What is Lido Oracle mechanism](#) before

What is AccountingOracle

AccountingOracle is a contract which collects information submitted by the off-chain oracles about state of the Lido-participating validators and their balances, the amount of funds accumulated on the protocol vaults (i.e., [withdrawal](#) and [execution layer rewards](#) vaults), the number [exited and stuck](#) validators, the number of [withdrawal requests](#) the protocol is able to process and distributes node-operator rewards.

Report cycle

The oracle work is delineated by equal time periods called frames. In normal operation, oracles finalize a report in each frame (the frame duration is 225 Ethereum Consensus Layer epochs, each frame starts at ~12:00 noon UTC). Each frame has a reference slot and processing deadline. Report data is gathered by looking at the world state (both Ethereum Execution and Consensus Layers) at the moment of the frame's reference slot (including any state changes made in that slot), and must be processed before the frame's processing deadline.

Reference slot for each frame is set to the last slot of the epoch preceding the frame's first epoch. The processing deadline is set to the last slot of the last epoch of the frame.

It's worth noting that frame length [can be changed](#). And if oracle report is delayed it does not extend the report period, unless it's missed. In this case, the next report will have the report period increased.

The frame includes these stages:

- Waiting:
- oracle starts as [daemon](#)
- and wakes up every 12 seconds (by default) in order to find the last finalized slot, trying to collate with it with the expected reference slot;
- Data collection:
- oracles monitor the state of both the execution and consensus layers and collect the data for the successfully arrived finalized reference slot;
- Hash consensus:
- oracles analyze the data, compile the report and submit its hash to the [HashConsensus](#)
- smart contract;
- Core update report:
- once the [quorum](#)
- of hashes is reached, meaning more than half of the oracles submitted the same hash (i.e., 5 of 9 oracle committee members at the moment of writing), one of the oracles chosen in turn submits the actual report to the [AccountingOracle](#)
- contract, which triggers the core protocol state update, including the token rebase, distribution of node operator rewards, finalization of withdrawal requests, and the protocol mode decision: whether to go in the bunker mode, and
- Extra data report:
- an additional report carrying additional information that is not vital for the core update is submitted to the AccountingOracle, can be submitted in chunks (e.g, node operator key states and reward distribution data).

note As it was said, daily oracle reports shouldn't be taken for granted. Oracle daemons could stop pushing their reports for extended periods of time in case of no [finality](#) on the Ethereum Consensus Layer. This would ultimately result in no oracle reports and no stETH rebases for this whole period.

Report processing

The [submission](#) of the main report to AccountingOracle triggers the next processes in order, although within a single tx:

1. Update exited validators counts for each StakingModule in StakingRouter;
2. Update bunker mode status for WithdrawalQueue;
3. Handle function on the Lido contract which performs the main protocol state change.
4. Store information about ExtraData

The diagram shows the interaction with contracts.

Report data

The function `submitReportData()` accepts the following `ReportData` structure.

struct

`ReportData`

```
{ uint256 consensusVersion ; uint256 refSlot ; uint256 numValidators ; uint256 clBalanceGwei ; uint256 [ ]  
stakingModuleIdsWithNewlyExitedValidators ; uint256 [ ] numExitedValidatorsByStakingModule ; uint256  
withdrawalVaultBalance ; uint256 elRewardsVaultBalance ; uint256 sharesRequestedToBurn ; uint256 [ ]  
withdrawalFinalizationBatches ; uint256 simulatedShareRate ; bool isBunkerMode ; uint256 extraDataFormat ; bytes32  
extraDataHash ; uint256 extraDataItemsCount ; } Oracle consensus info
```

- `consensusVersion`
 - — Version of the oracle consensus rules. A current version expected by the oracle can be obtained by calling `getConsensusVersion()`
- `refSlot`
 - — Reference slot for which the report was calculated. The state being reported must include all state changes resulting from the all blocks up to this reference slot (inclusive). The epoch containing the slot must be finalized prior to calculating the report.

CL values

- `numValidators`
 - — The number of validators on the Ethereum Consensus Layer that were ever deposited via Lido as observed at the reference slot.
- `clBalanceGwei`
 - — Cumulative balance nominated in gwei of all Lido validators on the Ethereum Consensus Layer as observed at the reference slot.
- `stakingModuleIdsWithNewlyExitedValidators`
 - — Ids of staking modules that have more exited validators than the number stored in the respective staking module contract as observed at the reference slot.
- `numExitedValidatorsByStakingModule`
 - — Number of ever exited validators for each of the staking modules from the `stakingModuleIdsWithNewlyExitedValidators`
- array as observed at the reference slot.

EL values

- `withdrawalVaultBalance`
 - — Ether balance of the Lido [withdrawal vault](#)
 - as observed at the reference slot.
- `elRewardsVaultBalance`
 - — Ether balance of the Lido [execution layer rewards vault](#)
 - as observed at the reference slot.
- `sharesRequestedToBurn`
 - — The shares amount requested to burn through [Burner](#)
 - as observed at the reference slot. The value can be obtained in the following way:

(`coverSharesToBurn` , `nonCoverSharesToBurn`)

=

`IBurner (burner) . getSharesRequestedToBurn () sharesRequestedToBurn = coverSharesToBurn + nonCoverSharesToBurn` Withdrawals finalization decision

- `withdrawalFinalizationBatches`
 - — The ascendingly-sorted array of withdrawal request IDs obtained by the oracle daemon on report gathering via calling [WithdrawalQueue.calculateFinalizationBatches](#)
 - . An empty array means that no withdrawal requests to be finalized.
- `simulatedShareRate`
 - — The share rate (i.e., [total pooled ether](#)
 - divided by [total shares](#)
 -) with the 10^{27} precision (i.e., multiplied by 10^{27}) that would be effective as the result of applying this oracle report at the reference slot, with `withdrawalFinalizationBatches`
 - set to empty array and `simulatedShareRate`
 - set to 0. To estimate `simulatedShareRate`
 - one should perform a view call [Lido.handleOracleReport](#)
 - directly via [eth_call](#)

- JSON-RPC API and calculate as follows:

simulatedShareRate

(postTotalPooledEther *

10 ** 27)

/ postTotalShares where postTotalPooledEther and postTotalShares were retrieved as return values from the performed view call

- isBunkerMode
- — Whether, based on the state observed at the reference slot, the protocol must be in the bunker mode or the turbo (regular) mode.

note

Extra data

Extra data — the oracle information that allows asynchronous processing, potentially in chunks, after the main data is processed. The oracle doesn't enforce that extra data attached to the same data report is processed in full before the processing deadline expires or a new data report starts being processed, but enforces that no processing of extra data for a report is possible after its processing deadline passes or a new data report arrives.

Extra data is an array of items, each item being encoded as follows:

3 bytes 2 bytes X bytes | itemIndex | itemType | itemPayload |

- itemIndex
- is a 0-based index into the extra data array;
- itemType
- is the type of extra data item;
- itemPayload
- is the item's data which interpretation depends on the item's type.

Items must be sorted ascendingly by the (itemType, ...itemSortingKey) compound key where itemSortingKey calculation depends on the item's type (see below).

itemType=0 (EXTRA_DATA_TYPE_STUCK_VALIDATORS): stuck validators by node operators.

The itemPayload field has the following format:

| 3 bytes | 8 bytes | nodeOpsCount * 8 bytes | nodeOpsCount * 16 bytes | | moduleId | nodeOpsCount | nodeOperatorIds | stuckValidatorsCounts |

moduleId is the staking module for which exited keys counts are being reported.

nodeOperatorIds contains an array of ids of node operators that have total stuck validators counts changed compared to the staking module smart contract storage as observed at the reference slot. Each id is a 8-byte uint, ids are packed tightly.

nodeOpsCount contains the number of node operator ids contained in the nodeOperatorIds array. Thus,

nodeOpsCount = byteLength(nodeOperatorIds) / 8

stuckValidatorsCounts contains an array of stuck validators total counts, as observed at the reference slot, for the node operators from the nodeOperatorIds array, in the same order. Each count is a 16-byte uint, counts are packed tightly. Thus,

byteLength(stuckValidatorsCounts) = nodeOpsCount * 16

nodeOpsCount must not be greater than maxAccountingExtraDataListItemsCount specified in the [OracleReportSanityChecker](#) contract. If a staking module has more node operators with total stuck validators counts changed compared to the staking module smart contract storage (as observed at the reference slot), reporting for that module should be split into multiple items.

Item sorting key is a compound key consisting of the module id and the first reported node operator's id:

itemSortingKey = (moduleId, nodeOperatorIds[0:8])

itemType=1 (EXTRA_DATA_TYPE_EXITED_VALIDATORS): exited validators by node operators.

The payload format is exactly the same as for itemType=EXTRA_DATA_TYPE_STUCK_VALIDATORS , except that, instead

of stuck validators counts, exited validators counts are reported. The `itemSortingKey` is calculated identically.

The oracle daemon must report exited/stuck validators counts ONLY for those `(moduleId, nodeOperatorId)` pairs that contain outdated counts in the staking module smart contract as observed at the reference slot.

Extra data array can be passed in different formats, see below. * `extraDataFormat` * - Format of the extra data. Currently, only the `EXTRA_DATA_FORMAT_EMPTY=0` * and `EXTRA_DATA_FORMAT_LIST=1` * formats are supported. See the constant defining a specific data format for more info. * `extraDataHash` * - Hash of the extra data. See the constant defining a specific extra data format for the info on how to calculate the hash. Must be set to a zero hash if the oracle report contains no extra data. * `extraDataItemsCount` * - Number of the extra data items. Must be set to zero if the oracle report contains no extra data.

Access and permissions

Access to lever methods is restricted using the functionality of the [AccessControlEnumerable](#) contract and a bunch of [granular roles](#).

Constants

LIDO()

Returns an address of the [Lido](#) contract

address

public immutable LIDO

LOCATOR()

Returns an address of the [LidoLocator](#) contract

ILidoLocator public immutable LOCATOR

LEGACY_ORACLE()

Returns an address of the [LegacyOracle](#) contract

address

public immutable LEGACY_ORACLE

SECONDS_PER_SLOT()

See <https://ethereum.org/en/developers/docs/blocks/#block-time>

note always returns 12 seconds due to [the Merge](#) uint256

public immutable SECONDS_PER_SLOT

GENESIS_TIME()

See <https://blog.ethereum.org/2020/11/27/eth2-quick-update-no-21>

note always returns 1606824023 (December 1, 2020, 12:00:23pm UTC) or [Mainnet](#) uint256

public immutable GENESIS_TIME

EXTRA_DATA_TYPE_STUCK_VALIDATORS()

This type carries the details of [stuck](#) validator(s).

uint256

public

constant EXTRA_DATA_TYPE_STUCK_VALIDATORS =

EXTRA_DATA_TYPE_EXITED_VALIDATORS()

This type contains the details of [exited](#) validator(s).

uint256

public

constant EXTRA_DATA_TYPE_EXITED_VALIDATORS =

2

EXTRA_DATA_FORMAT_EMPTY()

The extra data format used to signify that the oracle report contains no [extra data](#) .

Sends as a part of the Oracle's [Phase 3](#) .

This format uses when there are no new [stuck](#) or [exited](#) validators on report period.

uint256

public

constant EXTRA_DATA_FORMAT_EMPTY =

0

EXTRA_DATA_FORMAT_LIST()

The list format for the extra data array. Used when all extra data processing fits into a single transaction.

Extra data is passed within a single transaction as a bytearray containing all data items packed tightly.

Hash is akeccak256 hash calculated over the bytearray items. The Solidity equivalent of the hash calculation code would bekeccak256(array) , wherearray has thebytes type.

uint256

public

constant EXTRA_DATA_FORMAT_LIST =

1

ProcessingState

struct

ProcessingState

{ uint256 currentFrameRefSlot ; uint256 processingDeadlineTime ; bytes32 mainDataHash ; bool mainDataSubmitted ; bytes32 extraDataHash ; uint256 extraDataFormat ; bool extraDataSubmitted ; uint256 extraDataItemsCount ; uint256 extraDataItemsSubmitted ; } * currentFrameRefSlot * - Reference slot for the current reporting frame. * processingDeadlineTime * - The last time at which a data can be submitted for the current reporting frame. * mainDataHash * - Hash of the main report data. Zero bytes if consensus on the hash hasn't been reached yet for the current reporting frame. * mainDataSubmitted * - Whether the main report data for the current reporting frame has already been submitted. * extraDataHash * - Hash of the extra report data. Should be ignored unlessmainDataSubmitted * is true. * extraDataFormat * - Format of the extra report data for the current reporting frame. Should be ignored unlessmainDataSubmitted * is true. * extraDataSubmitted * - Total number of extra report data items for the current reporting frame. Should be ignored unlessmainDataSubmitted * is true. * extraDataItemsSubmitted * - How many extra report data items are already submitted for the current reporting frame.

View methods

getConsensusContract()

Returns the address of the [HashConsensus](#) contract instance used byAccountingOracle .

function

getConsensusContract ()

external

view

returns

(address)

getConsensusReport()

Returns the last consensus report hash and metadata.

function

getConsensusReport ()

external

view

returns

(bytes32 hash , uint256 refSlot , uint256 processingDeadlineTime , bool processingStarted)

Returns

Name Type Description hash bytes32 The last reported hash refSlot uint256 The frame's reference slot: if the data the consensus is being reached upon includes or depends on any onchain state, this state should be queried at the reference slot. The state being reported must include all state changes resulting from all blocks up to this reference slot (inclusive). processingDeadlineTime uint256 Timestamp of the last slot at which a report can be reported and processed processingStarted bool Has the processing of the report been started or not

getConsensusVersion()

Returns the current consensus version expected by the oracle contract.

note Consensus version must change every time consensus rules change, meaning that an oracle looking at the same reference slot would calculate a different hash. function

getConsensusVersion ()

external

view

returns

(uint256)

getContractVersion()

Returns the current contract version.

function

getContractVersion ()

public

view

returns

(uint256)

getLastProcessingRefSlot()

Returns the last reference slot for which processing of the report was started.

function

getLastProcessingRefSlot ()

external

view

returns

(uint256)

getProcessingState()

Returns data processing state for the current reporting frame. See the docs for the [ProcessingState](#) struct.

function

getProcessingState ()

external

view

returns

(ProcessingState memory result)

Methods

submitReportData()

Submits report data for processing.

function

submitReportData (ReportData calldata data ,

uint256 contractVersion)

Parameters

Name	Type	Description
data	ReportData	The data. See the ReportData structure's docs for details.
contractVersion	uint256	Expected version of the oracle contract.

Reverts

For more information about reverts, see a separate section [here](#)

submitReportExtraDataEmpty()

Triggers the processing required when no extra data is present in the report, i.e. when extra data format equals EXTRA_DATA_FORMAT_EMPTY.

function

submitReportExtraDataEmpty ()

Reverts

- Reverts withSenderNotAllowed()
- if sender doesn't have aSUBMIT_DATA_ROLE
- role and sender is not a consensus member.

submitReportExtraDataList()

Submits report extra data in the EXTRA_DATA_FORMAT_LIST format for processing.

function

submitReportExtraDataList (bytes

calldata items)

Parameters

Name Type Description items bytes The extra data items list. See docs for the [EXTRA_DATA_FORMAT_LIST](#) constant for details.

Reverts

- Reverts with `SenderNotAllowed()`
- if sender doesn't have a `SUBMIT_DATA_ROLE`
- role and sender is not a consensus member.

submitConsensusReport()

Called by [AccountingOracle HashConsensus](#) contract to push a consensus report for processing.

note Note that submitting the report doesn't require the processor to start processing it right away, this can happen later (see [getLastProcessingRefSlot](#)). Until processing is started, HashConsensus is free to reach consensus on another report for the same reporting frame and submit it using this same function, or to lose the consensus on the submitted report, notifying the processor via `discardConsensusReport` . function

submitConsensusReport (bytes32 reportHash ,

uint256 refSlot ,

uint256 deadline)

Parameters

Name Type Description reportHash bytes32 Hash of the data calculated for the given reference slot. refSlot uint256 The reference slot the data was calculated for. Reverts if doesn't match the current reference slot. deadline uint256 The timestamp of the last slot at which the report can be processed by the report processor contract.

discardConsensusReport()

Called by HashConsensus contract to notify that the report for the given ref. slot is not a consensus report anymore and should be discarded. This can happen when a member changes their report, is removed from the set, or when the quorum value gets increased.

Only called when, for the given reference slot:

1. there previously was a consensus report; AND
2. processing of the consensus report hasn't started yet; AND
3. report processing deadline is not expired yet; AND
4. there's no consensus report now (otherwise [submitConsensusReport](#)
5. is called instead).

Can be called even when there's no submitted non-discarded consensus report for the current reference slot, i.e. can be called multiple times in succession.

function

discardConsensusReport (uint256 refSlot)

setConsensusContract()

function

setConsensusContract (address addr)

setConsensusVersion()

Sets the consensus version expected by the oracle contract.

function

setConsensusVersion (uint256 version)

Permissions

SUBMIT_DATA_ROLE()

An ACL role granting the permission to submit the data for a committee report.

bytes32

public

constant SUBMIT_DATA_ROLE =

keccak256 ("SUBMIT_DATA_ROLE") ;

MANAGE_CONSENSUS_CONTRACT_ROLE()

An ACL role granting the permission to set the consensus contract address by calling setConsensusContract.

bytes32

public

constant MANAGE_CONSENSUS_CONTRACT_ROLE =

keccak256 ("MANAGE_CONSENSUS_CONTRACT_ROLE") ;

MANAGE_CONSENSUS_VERSION_ROLE()

An ACL role granting the permission to set the consensus version by calling setConsensusVersion.

bytes32

public

constant MANAGE_CONSENSUS_VERSION_ROLE =

keccak256 ("MANAGE_CONSENSUS_VERSION_ROLE") ;

Events

ExtraDataSubmitted()

Emits when any extra report data for the current reporting frame has been submitted.

ExtraDataSubmitted (uint256

indexed refSlot ,

uint256 itemsProcessed ,

uint256 itemsCount)

WarnExtraDataIncompleteProcessing()

Emits when try to submit the same report, but not all items are processed yet.

event

WarnExtraDataIncompleteProcessing (uint256

indexed refSlot , uint256 processedItemsCount , uint256 itemsCount)

ConsensusHashContractSet()

Emits when a contract hash value is changed.

event

ConsensusHashContractSet (address

indexed addr ,

address

indexed prevAddr)

ConsensusVersionSet()

Emits when a consensus version value is changed.

event

ConsensusVersionSet (uint256

indexed version ,

uint256

indexed prevVersion)

ReportSubmitted()

Emits when a new consensus report hash is submitted

event

ReportSubmitted (uint256

indexed refSlot ,

bytes32 hash ,

uint256 processingDeadlineTime)

ReportDiscarded()

Emits when consensus report is discarded.

event

ReportDiscarded (uint256

indexed refSlot ,

bytes32 hash)

ProcessingStarted()

Emits when report data is submitted

event

ProcessingStarted (uint256

indexed refSlot ,

bytes32 hash)

WarnProcessingMissed()

Emits on [submitConsensusReport](#) when refSlot != prevSubmittedRefSlot && prevProcessingRefSlot != prevSubmittedRefSlot

event

WarnProcessingMissed (uint256

indexed refSlot)

Reverts

submitReportData()

To ensure that the reported data is within possible values, the handler function performs a number of sanity checks. When checking, reverts may occur in different contracts.

AccountingOracle and BaseOracle contracts

- Reverts withSenderNotAllowed()
- if caller doesn't have aSUBMIT_DATA_ROLE
- role and is not a member of the oracle committee.
- Reverts withUnexpectedContractVersion(expectedVersion, version)
- if provided contract version is different from the current one.
- Reverts withUnexpectedConsensusVersion(expectedConsensusVersion, consensusVersion)
- if provided consensus version is different from the expected one.
- Reverts withUnexpectedRefSlot(report.refSlot, refSlot)
- if provided reference slot differs from the current consensus frame's one.
- Reverts withUnexpectedDataHash(report.hash, hash)
- if keccak256 hash of the ABI-encoded data is different from the last hash.
- Reverts withNoConsensusReportToProcess()
- if report hash data is 0.
- Reverts withRefSlotAlreadyProcessing()
- if report reference slot is equal to previous processing reference slot.
- Reverts withUnexpectedExtraDataHash(bytes32(0), data.extraDataHash)
- ifdata.extraDataFormat
- isEXTRA_DATA_FORMAT_EMPTY
- anddata.extraDataHash
- is 0
- Reverts withUnexpectedExtraDataItemsCount(0, data.extraDataItemsCount)
- ifdata.extraDataFormat
- isEXTRA_DATA_FORMAT_EMPTY
- anddata.extraDataItemsCount
- is not 0
- Reverts withUnsupportedExtraDataFormat(data.extraDataFormat)
- ifdata.extraDataFormat
- is notEXTRA_DATA_FORMAT_EMPTY
- and notEXTRA_DATA_FORMAT_LIST
- Reverts withExtraDataItemsCountCannotBeZeroForNonEmptyData()
- ifdata.extraDataFormat
- isEXTRA_DATA_FORMAT_LIST
- anddata.extraDataItemsCount
- is 0
- Reverts withExtraDataHashCannotBeZeroForNonEmptyData()
- ifdata.extraDataFormat
- isEXTRA_DATA_FORMAT_LIST
- anddata.extraDataHash
- is 0
- Reverts withInvalidExitedValidatorsData()
- if provided exited validators data doesn't meet safety checks.

OracleReportSanityChecker

- Reverts withMaxAccountingExtraDataItemsCountExceeded(uint256 maxItemsCount, uint256 receivedItemsCount)
- error when check is failed, more[here](#)
- Reverts withExitedValidatorsLimitExceeded(uint256 limitPerDay, uint256 exitedPerDay)
- if provided exited validators data doesn't meet safety checks. (OracleReportSanityChecker)

StakingRouter

- Reverts withArraysLengthMismatch(_stakingModuleIds.length, _exitedValidatorsCounts.length)
- if provided exited validators data doesn't meet safety checks. (StakingRouter)
- Reverts withExitedValidatorsCountCannotDecrease()
- if provided exited validators data doesn't meet safety checks. (StakingRouter)
- Reverts withReportedExitedValidatorsExceedDeposited(uint256 reportedExitedValidatorsCount, uint256 depositedValidatorsCount)
- if provided exited validators data doesn't meet safety checks. (StakingRouter)

Other reverts onLido.handleOracleReport() [Edit this page](#) [Previous EIP712StETH](#) [Next ValidatorsExitBusOracle](#)