SnapshotEngine

> This project is not audited
>
> If you want to use this project, perform your own verification or send an email to admin@cmta.ch.

The **SnapshotEngine** is a smart contract designed to perform on-chain snapshots, making it easier to distribute dividends or other token-based rewards directly on-chain.

It is intended to work with any standard ERC-20 token (for example, **CMTAT**).

If you want to integrate it into another contract—such as one for distributing dividends—you can access balance and state information through the `ISnapshotState` interface, defined in `ISnapshotState.sol`.

The codebase is modular, allowing you to use or extend only the components you need. Thus, instead of using the `SnapshotEngine` as an external contract called by the ERC-20 token, you can integrate the relevant modules directly in the token smart contract. This repository provides an example with CMTAT, see `CMTAT deployment version`.

How to include it

While it has been designed for the CMTAT, the `SnapshotEngine` can be used with other ERC-20 contracts to perform on-chain snapshots.

To use it, import in your contract the interface `ISnapshotEngine` which declares the function `operateOnTransfer`.

This interface can be found in CMTAT/contracts/interfaces/engine

```
/*
* @dev minimum interface to define a SnapshotEngine
*/
interface ISnapshotEngine {
   /**
```

```
    * @notice Records balance and total supply snapshots before any token transfer occurs.
    * @dev This function should be called inside the {_update} hook so that
    * snapshots are updated prior to any state changes from {_mint}, {_burn}, or {_transfer}.
    * It ensures historical balances and total supply remain accurate for snapshot queries.
    *
    * @param from The address tokens are being transferred from (zero address if minting).
    * @param to The address tokens are being transferred to (zero address if burning).
    * @param balanceFrom The current balance of `from` before the transfer (used to update snapshot).
    * @param balanceTo The current balance of `to` before the transfer (used to update snapshot).
    * @param totalSupply The current total supply before the transfer (used to update snapshot).
    */
    function operateOnTransfer(address from, address to, uint256 balanceFrom, uint256 balanceTo, uint256 totalSupply) external;
}
```

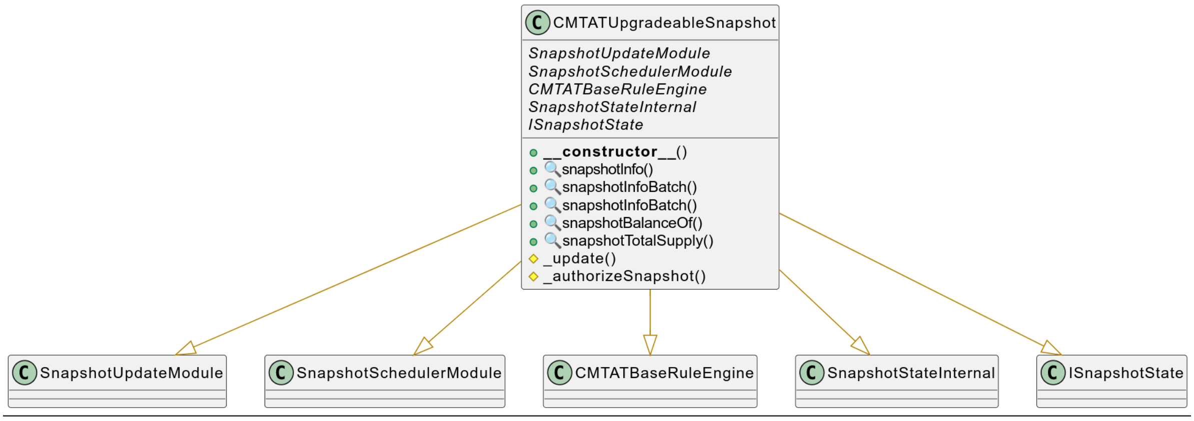
During each ERC-20 transfer, before updating the balances and total supply, your contract must call the function `operateOnTransfer` which is the entrypoint for the SnapshotEngine.

CMTAT deployment version

This repository also contains a CMTAT deployment version with the required snapshot modules integrated called `CMTATUpgradeableSnapshot`.

The CMTAT features are included by inheriting from the CMTAT base contract `CMTATBaseRuleEngine` and overriding the internal `update` function (from OpenZeppelin's ERC20) to call `_snapshotUpdate`. This internal function is responsible for updating balances and total supply whenever a snapshot is detected.

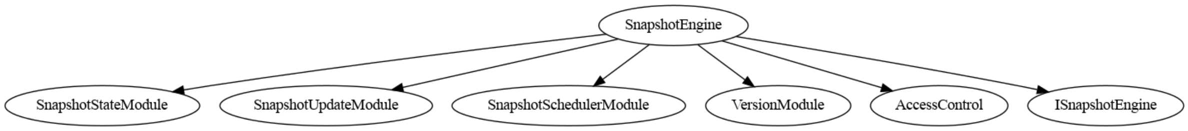
For each ERC-20 transfer, the `_update` function is called, and a snapshot is taken if required. Since the snapshot logic is integrated directly into the token, there is no need for an external `SnapshotEngine` contract.



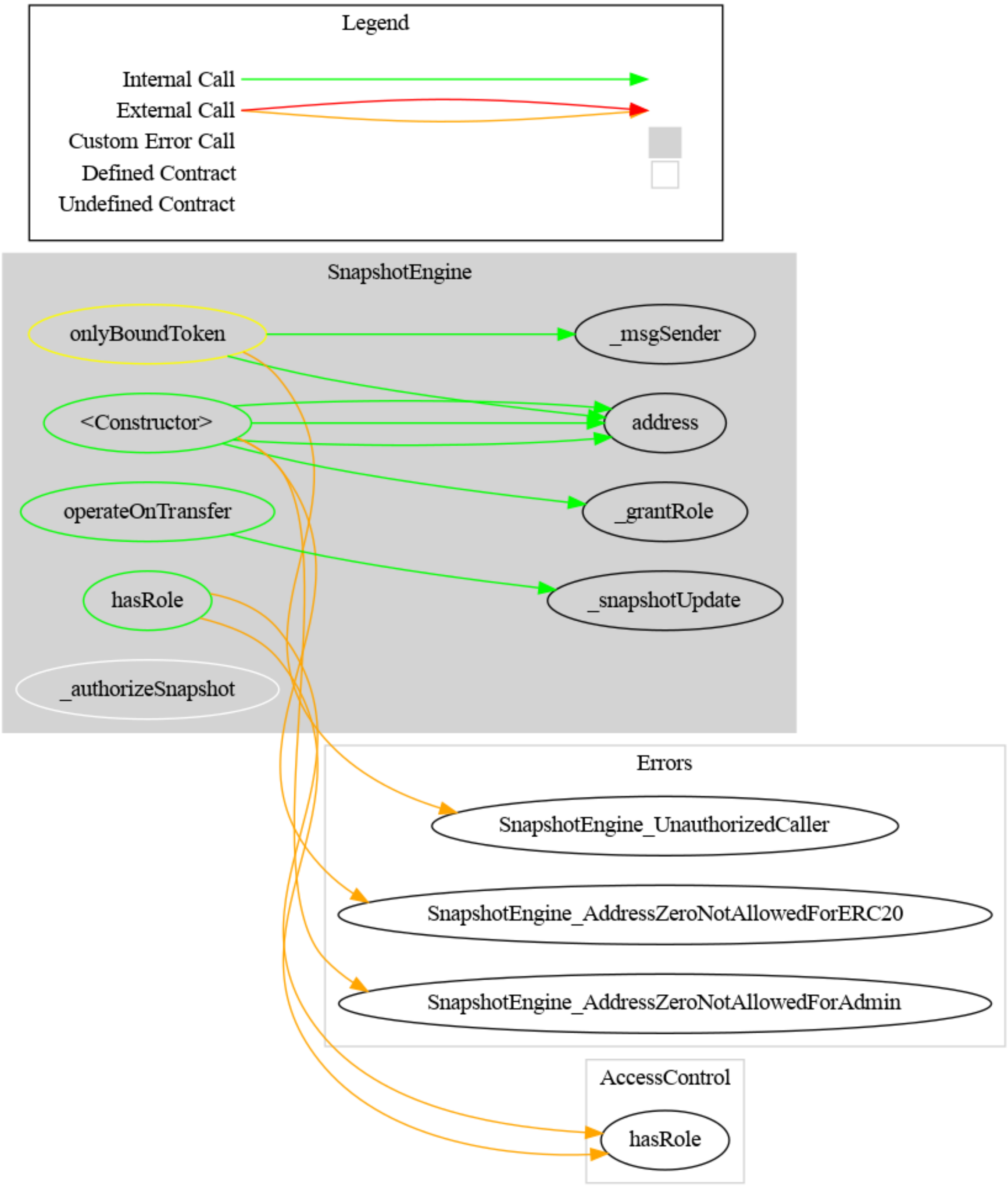
Schema

The main contract is `SnapshotEngine`

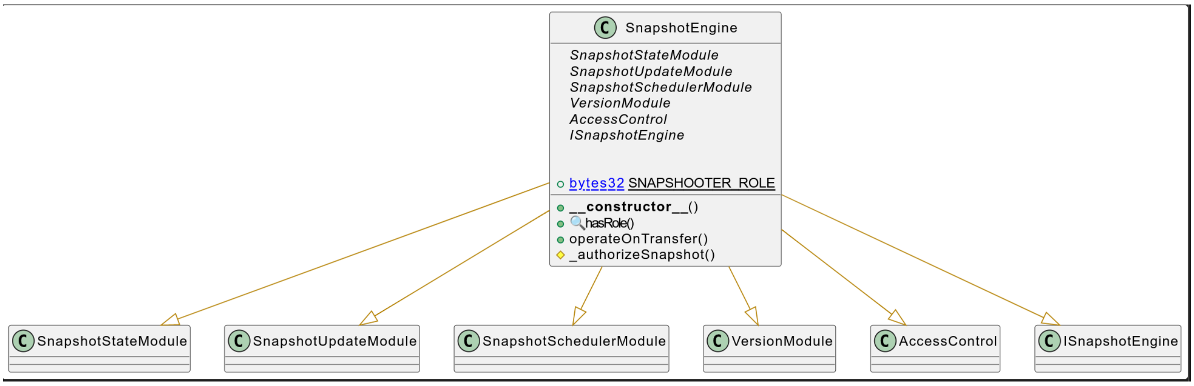
Inheritance



Graph



UML



Technical

Complexity

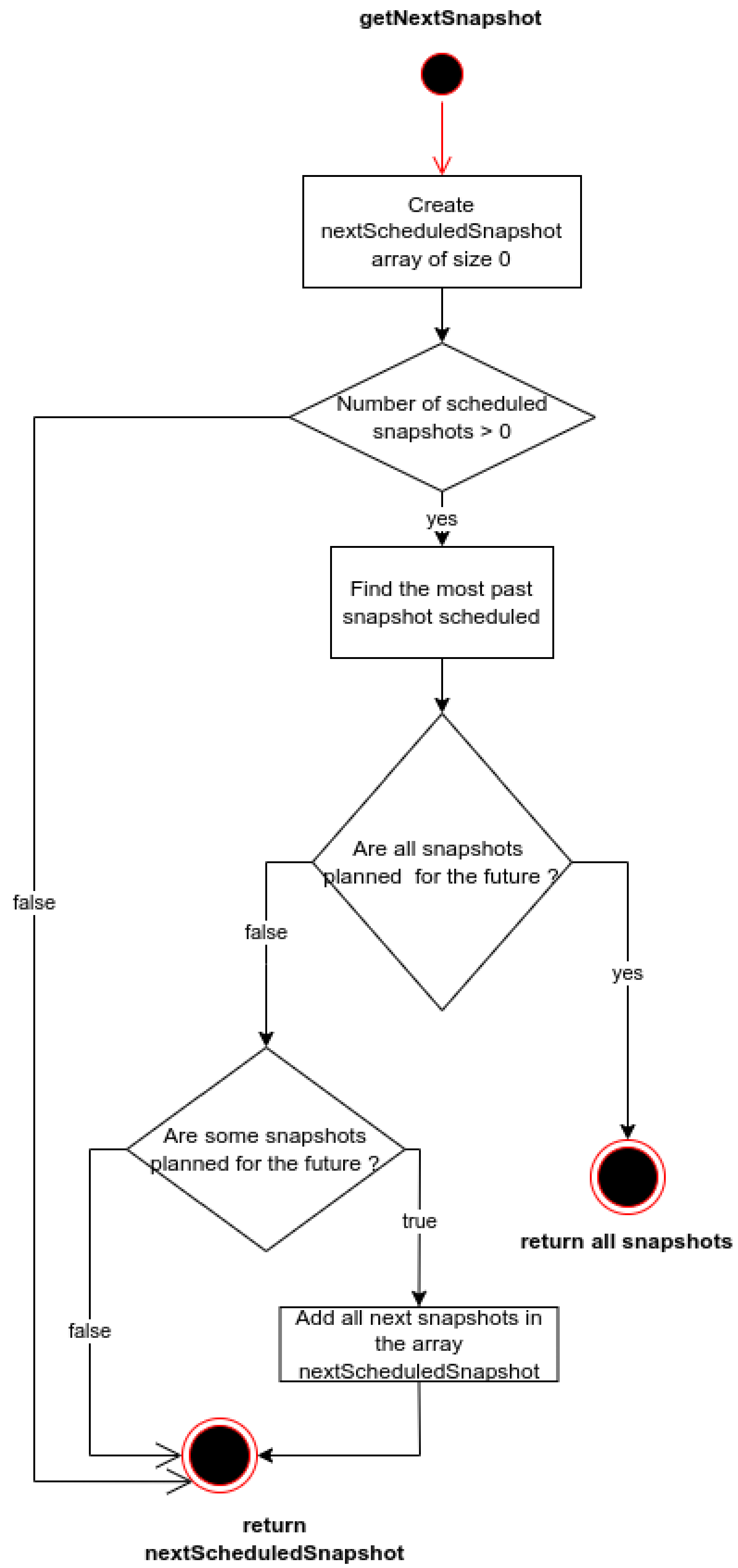
Name	Function	Description	Implemented [yes, no]	Complexity	Best case	Worst case
Schedule snapshot in the future, after all current snapshots	`scheduleSnapshot`	-	☑	O(1)		
Schedule a snapshot at a random place in the future	`scheduleSnapshotNotOptimized`	-	☑	O(N)	O(1)	O(N)
Schedule snapshot in the past	-	-	☒	O(N)	O(1)	O(N)
Reschedule a snapshot (in the future)	`_rescheduleSnapshot`	The new time is in the range between the previous snapshot and the next snapshot	☑	O(1)		
Reschedule a snapshot (in the future)	-	The new time can be after or before another existent snapshot	☒	O(N)	O(1)	O(N)
Reschedule a snapshot (in the past)	-	The new time can be in the past	☒	-		
Unschedule the last snapshot	`_unscheduleSnapshot`	-	☑	O(1)		
Unschedule a random snapshot in the past	`_unscheduleNotOptimized`	-	☑	O(N)	O(1)	O(N)
Unschedule a random snapshot in the future	`_unscheduleNotOptimized`	-	☑	O(N)	O(1)	O(N)
Set the current snapshot	`_setCurrentSnapshot`	-	☑	Same as `_findScheduledMostRecentPastSnapshot`		
Update snapshots of the balance of an account	`_updateAccountSnapshot`	-	☑	Same as `_updateSnapshot`		
Update snapshots of the total Supply	`_updateTotalSupplySnapshot`	-	☑	Same as `_updateSnapshot`		
Get the last snapshot time inside a snapshot ids array	`_lastSnapshot`	-	☑	O(1)		

Name	Function	Description	Implemented [yes, no]	Complexity	Best case	Worst case
Find a snapshot	`_findScheduledSnapshotIndex`	Find the snapshot index at the specified time	☑	O(log2(N)) We use a binary search to find the value at the specified time		
Find the mot recent past snapshot	`_findScheduledMostRecentPastSnapshot`	-	☑	O(1) We only have a O(N) complexity (worst case) if all next scheduled snapshot are situated in the past but no update of the current snapshot has been made.	O(1)	O(N)
Update balance and/or total supply snapshots before the values are modified	`_update` `transferred`	Call before each transfer. It is very important to have a low complexity because this function is called very often.	☑	The complexity depends of th functions `_setCurrentSnapshot` `_updateAccountSnapshot` `_updateTotalSupplySnapshot`		
Get the next scheduled snapshotd	`getNextSnapshots`	-	☑	O(N) Nevertheless, we maintain a pointer on the actual snapshot to avoid loop through past snapshot		
Get all snapshot	`getAllSnapshots`	-	☑	O(1) We directly return the array		
Get the balance of an tokenHolder st the time specified	`snapshotBalanceOf`	Return the number of tokens owned by the given tokenHolder at the time when the snapshot with the given time was created.	☑	O(log2(N)) We use a binary search to find the value at the snapshot time		
Get the total supply at the time specified	`snapshotTotalSupply`	-	☑	O(log2(N)) We use a binary search to find the value at the snapshot time		

Schema

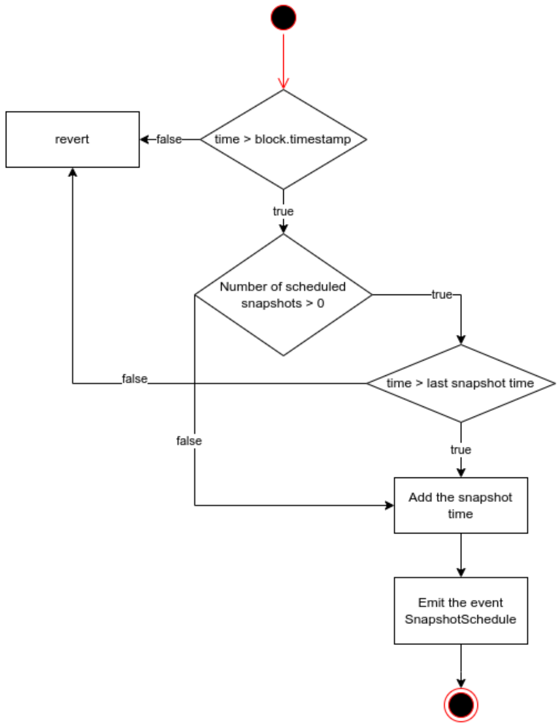
Here are several schema to explain the main functions

Get next snapshot


getNextSnapshot
Create nextScheduledSnapshot array of size 0
Number of scheduled snapshots > 0
yes
false
Find the most past snapshot scheduled
Are all snapshots planned for the future ?
false
yes
Are some snapshots planned for the future ?
true
false
return all snapshots
Add all next snapshots in the array nextScheduledSnapshot
return nextScheduledSnapshot

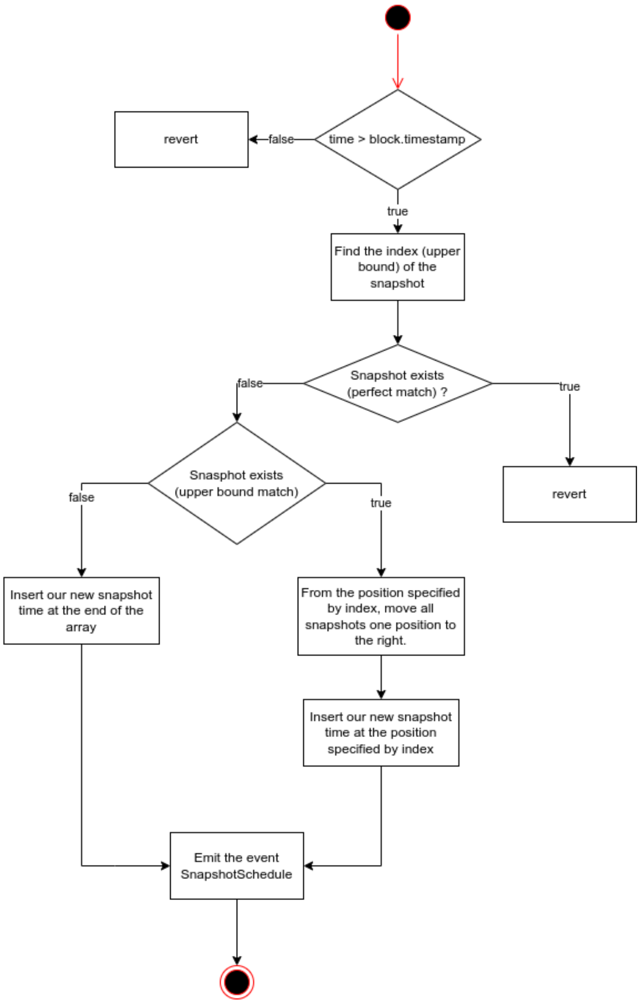
Schedule a snapshot

_scheduleSnapshot(uint256 time)



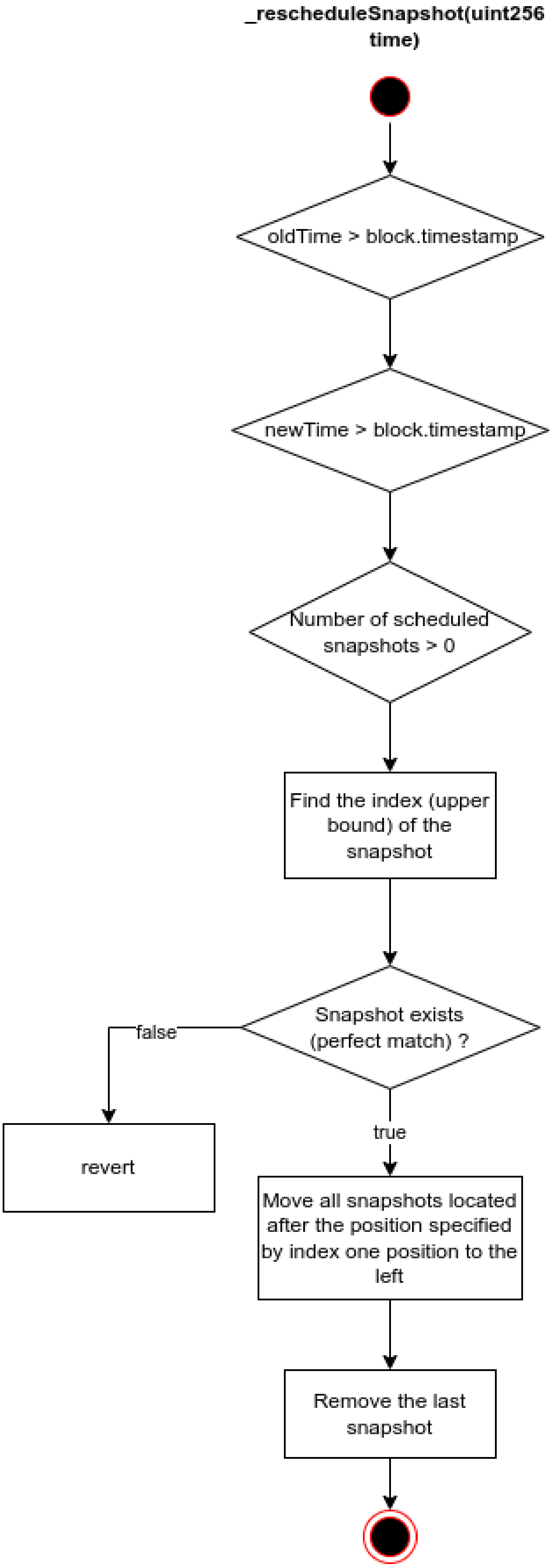
revert
false
time > block.timestamp
true
Number of scheduled snapshots > 0
true
false
time > last snapshot time
false
true
Add the snapshot time
Emit the event SnapshotSchedule

_scheduleSnapshotNotOptimized(uint256 time)

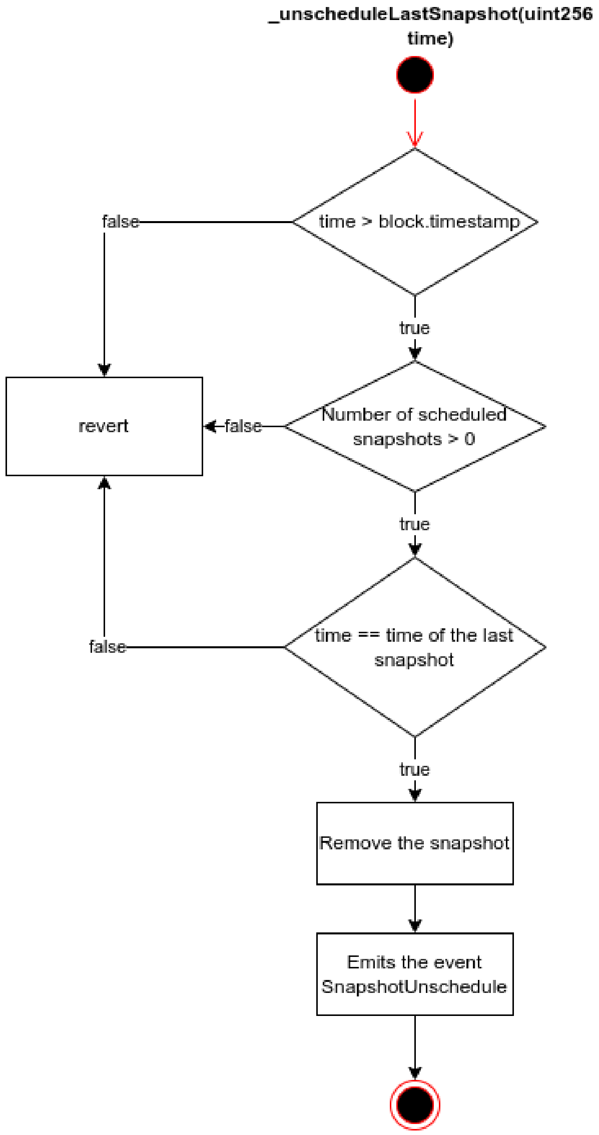


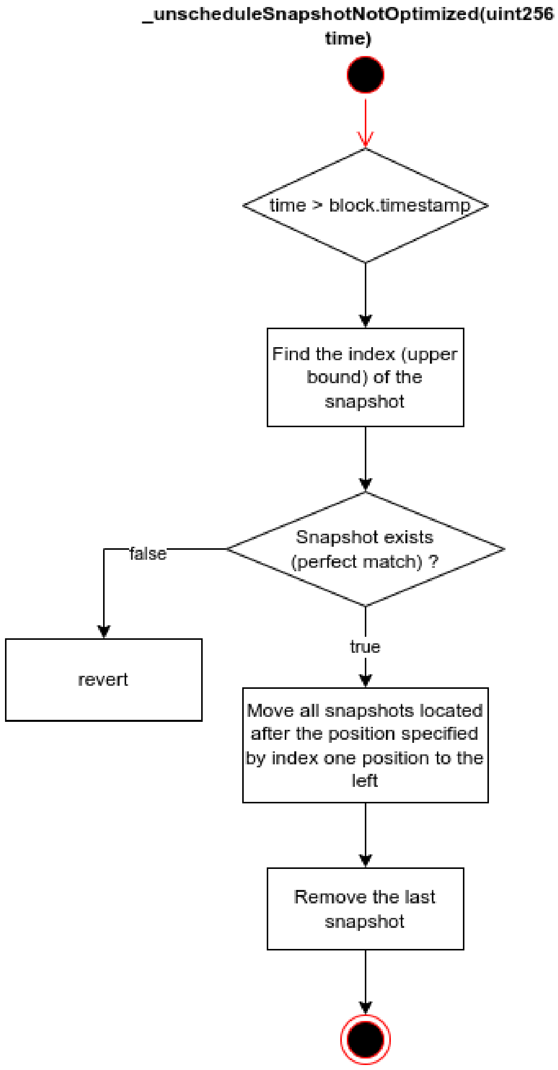
revert
false
time > block.timestamp
true
Find the index (upper bound) of the snapshot
false
Snapshot exists (perfect match) ?
true
Snasphot exists (upper bound match)
false
true
revert
Insert our new snapshot time at the end of the array
From the position specified by index, move all snapshots one position to the right.
Insert our new snapshot time at the position specified by index
Emit the event SnapshotSchedule

Reschedule a snapshot


_rescheduleSnapshot(uint256 time)
oldTime > block.timestamp
newTime > block.timestamp
Number of scheduled snapshots > 0
Find the index (upper bound) of the snapshot
Snapshot exists (perfect match) ?
false
revert
true
Move all snapshots located after the position specified by index one position to the left
Remove the last snapshot

Unschedule a snapshot


_unscheduleLastSnapshot(uint256 time)
time > block.timestamp
false
true
revert
Number of scheduled snapshots > 0
false
true
time == time of the last snapshot
false
true
Remove the snapshot
Emits the event SnapshotUnschedule


_unscheduleSnapshotNotOptimized(uint256 time)
time > block.timestamp
Find the index (upper bound) of the snapshot
Snapshot exists (perfect match) ?
false
revert
true
Move all snapshots located after the position specified by index one position to the left
Remove the last snapshot

Access Control

RBAC Role list

Here is the list of roles and their 32 bytes identifier.

	Defined in	32 bytes identifier
DEFAULT_ADMIN_ROLE	OpenZeppelin AccessControl	0x0000000000000000000000000000000000000000000000000000000000000000
SNAPSHOOTER_ROLE	`SnapshotScheduler`	0x809a0fc49fc0600540f1d39e23454e1f6f215bc7505fa22b17c154616570ddef

ERC-20 token bound

The ERC-20 bounds to the Snapshot Engine is set at deployment and can not be changed after that.

Only the ERC-20 token contract can called the function `operateOnTransfer` defined in the main contract `SnapshotEngine`.

Ethereum API

SnapshotBase

Base contract for snapshot engines, providing common errors and read-only functions to query snapshots.

Events

SnapshotSchedule(uint256, uint256)

```
SnapshotSchedule(uint256 indexed oldTime, uint256 indexed newTime)
```

Emitted when a snapshot is scheduled for the first time or rescheduled.

Input Parameters:

Name	Type	Description
oldTime	uint256	The previous scheduled timestamp (0 if newly scheduled).
newTime	uint256	The new scheduled timestamp for the snapshot.

SnapshotUnschedule(uint256)

```
SnapshotUnschedule(uint256 indexed time)
```

Emitted when a previously scheduled snapshot is canceled.

Input Parameters:

Name	Type	Description
time	uint256	The timestamp of the snapshot that was unscheduled.

Errors

SnapshotEngine_SnapshotScheduledInThePast(uint256, uint256)

```
SnapshotEngine_SnapshotScheduledInThePast(uint256 time, uint256 timestamp)
```

Thrown when attempting to schedule a snapshot at a time earlier than the current block timestamp.

Input Parameters:

Name	Type	Description
time	uint256	The snapshot time requested.
timestamp	uint256	The current block timestamp.

SnapshotEngine_SnapshotTimestampBeforeLastSnapshot(uint256, uint256)

```
SnapshotEngine_SnapshotTimestampBeforeLastSnapshot(uint256 time, uint256
lastSnapshotTimestamp)
```

Thrown when a snapshot timestamp is earlier than the last snapshot timestamp.

Input Parameters:

Name	Type	Description
time	uint256	The snapshot time requested.
lastSnapshotTimestamp	uint256	The timestamp of the most recent snapshot.

SnapshotEngine_SnapshotTimestampAfterNextSnapshot(uint256, uint256)

```
SnapshotEngine_SnapshotTimestampAfterNextSnapshot(uint256 time, uint256
nextSnapshotTimestamp)
```

Thrown when a snapshot timestamp is later than the next scheduled snapshot timestamp.

Input Parameters:

Name	Type	Description
time	uint256	The snapshot time requested.
nextSnapshotTimestamp	uint256	The timestamp of the next scheduled snapshot.

SnapshotEngine_SnapshotTimestampBeforePreviousSnapshot(uint256,uint256)

```
SnapshotEngine_SnapshotTimestampBeforePreviousSnapshot(uint256 time, uint256
previousSnapshotTimestamp)
```

Thrown when a snapshot timestamp is earlier than the previous snapshot timestamp.

Input Parameters:

Name	Type	Description
time	uint256	The snapshot time requested.
previousSnapshotTimestamp	uint256	The timestamp of the previous snapshot.

SnapshotEngine_SnapshotAlreadyExists()

Thrown when attempting to schedule a snapshot that already exists.

SnapshotEngine_SnapshotAlreadyDone()

Thrown when attempting to execute or schedule a snapshot that has already been taken.

SnapshotEngine_NoSnapshotScheduled()

Thrown when attempting to unschedule or interact with a snapshot when no snapshot is currently scheduled.

SnapshotEngine_SnapshotNotFound()

Thrown when querying or modifying a snapshot that cannot be found.

Functions

getAllSnapshots() -> (uint256[] memory)

Get all snapshots that have been created.

Return Values:

Name	Type	Description
snapshots	uint256[]	Array of timestamps of all existing snapshots.

---

getNextSnapshots() -> (uint256[] memory)

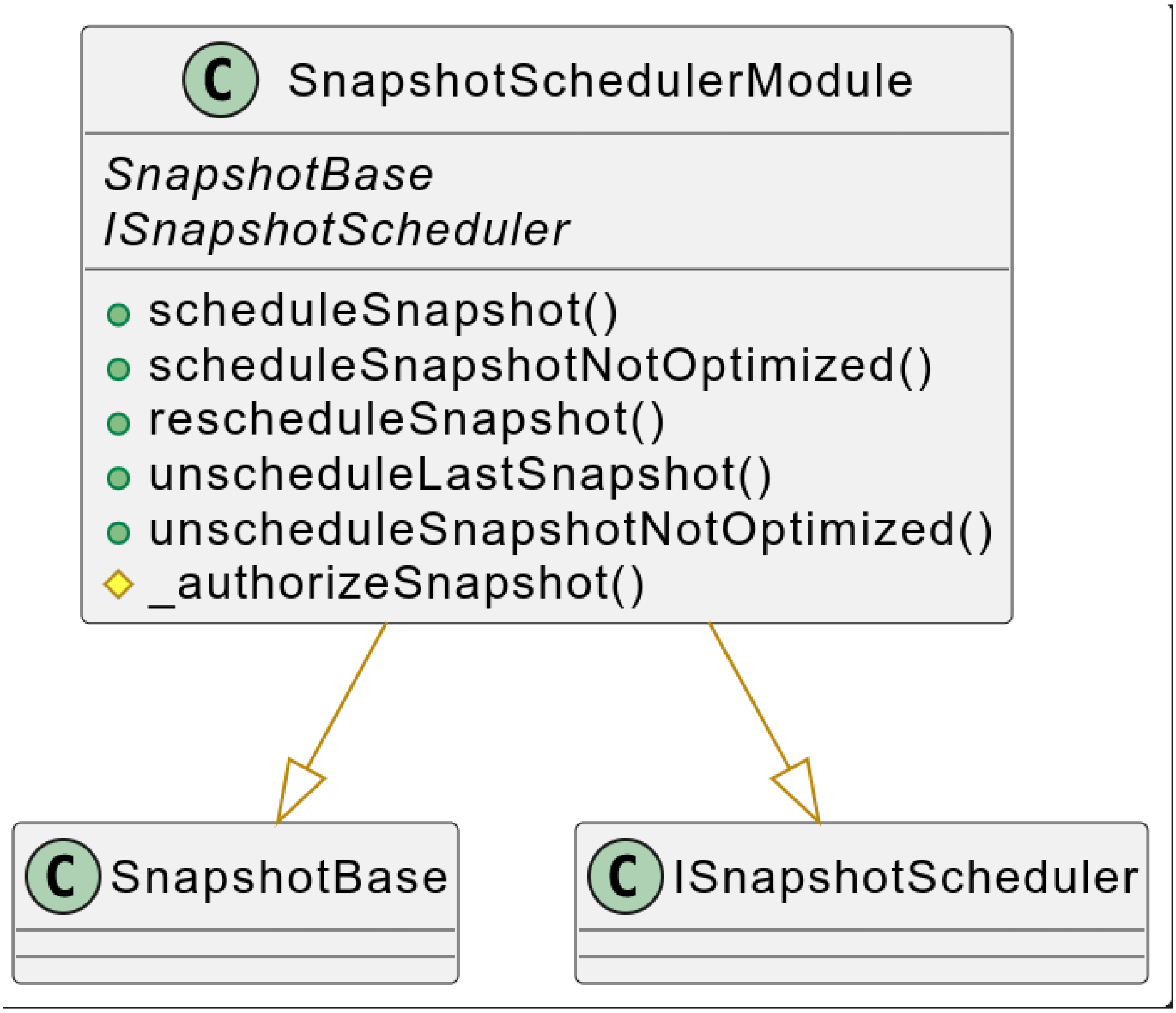
Get the next scheduled snapshots that have not yet been created.

Return Values:

Name	Type	Description
nextSnapshots	uint256[]	Array of timestamps of all future scheduled snapshots.

SnapshotScheduler

Abstract contract for scheduling, rescheduling, and canceling snapshots.
Provides methods to manage snapshot times (expressed in seconds since epoch) with role-based access control via `SNAPSHOOTER_ROLE`.



Functions

scheduleSnapshot(uint256)

```
function scheduleSnapshot(uint256 time)
public onlyRole(SNAPSHOOTER_ROLE)
```

Schedules a snapshot at the given time (in seconds since epoch).

Details:

- The scheduled time cannot be before the latest scheduled but not yet created snapshot.
- Access is restricted to accounts with `SNAPSHOOTER_ROLE`.

Input Parameters:

Name	Type	Description
time	uint256	The scheduled time of the snapshot.

scheduleSnapshotNotOptimized(uint256)

```
function scheduleSnapshotNotOptimized(uint256 time)
public onlyRole(SNAPSHOOTER_ROLE)
```

Schedules a snapshot at the given time (non-optimized version).

Details:

- The scheduled time cannot be before the latest scheduled but not yet created snapshot.
- Access is restricted to accounts with `SNAPSHOOTER_ROLE`.

Input Parameters:

Name	Type	Description
time	uint256	The scheduled time of the snapshot.

---

rescheduleSnapshot(uint256 oldTime, uint256 newTime)

```
function rescheduleSnapshot(uint256 oldTime,uint256 newTime)
public onlyRole(SNAPSHOOTER_ROLE)
```

Reschedules a snapshot from `oldTime` to `newTime`.

Details:

- The new time cannot be before the previous scheduled snapshot or after the next scheduled snapshot.
- Access is restricted to accounts with `SNAPSHOOTER_ROLE`.

Input Parameters:

Name	Type	Description
oldTime	uint256	The original scheduled time of the snapshot.
newTime	uint256	The new scheduled time of the snapshot.

---

unscheduleLastSnapshot(uint256 time)

```
function unscheduleLastSnapshot(uint256 time)
public onlyRole(SNAPSHOOTER_ROLE)
```

Cancels the creation of the last scheduled snapshot at the given time.

Details:

- There must not be any other snapshots scheduled after this one.
- Access is restricted to accounts with `SNAPSHOOTER_ROLE`.

Input Parameters:

Name	Type	Description
time	uint256	The scheduled time of the snapshot to cancel.

---

unscheduleSnapshotNotOptimized(uint256 time)

```
function unscheduleSnapshotNotOptimized(uint256 time)
public onlyRole(SNAPSHOOTER_ROLE)
```

Cancels the creation of a scheduled snapshot at the given time (non-optimized version).

Details:

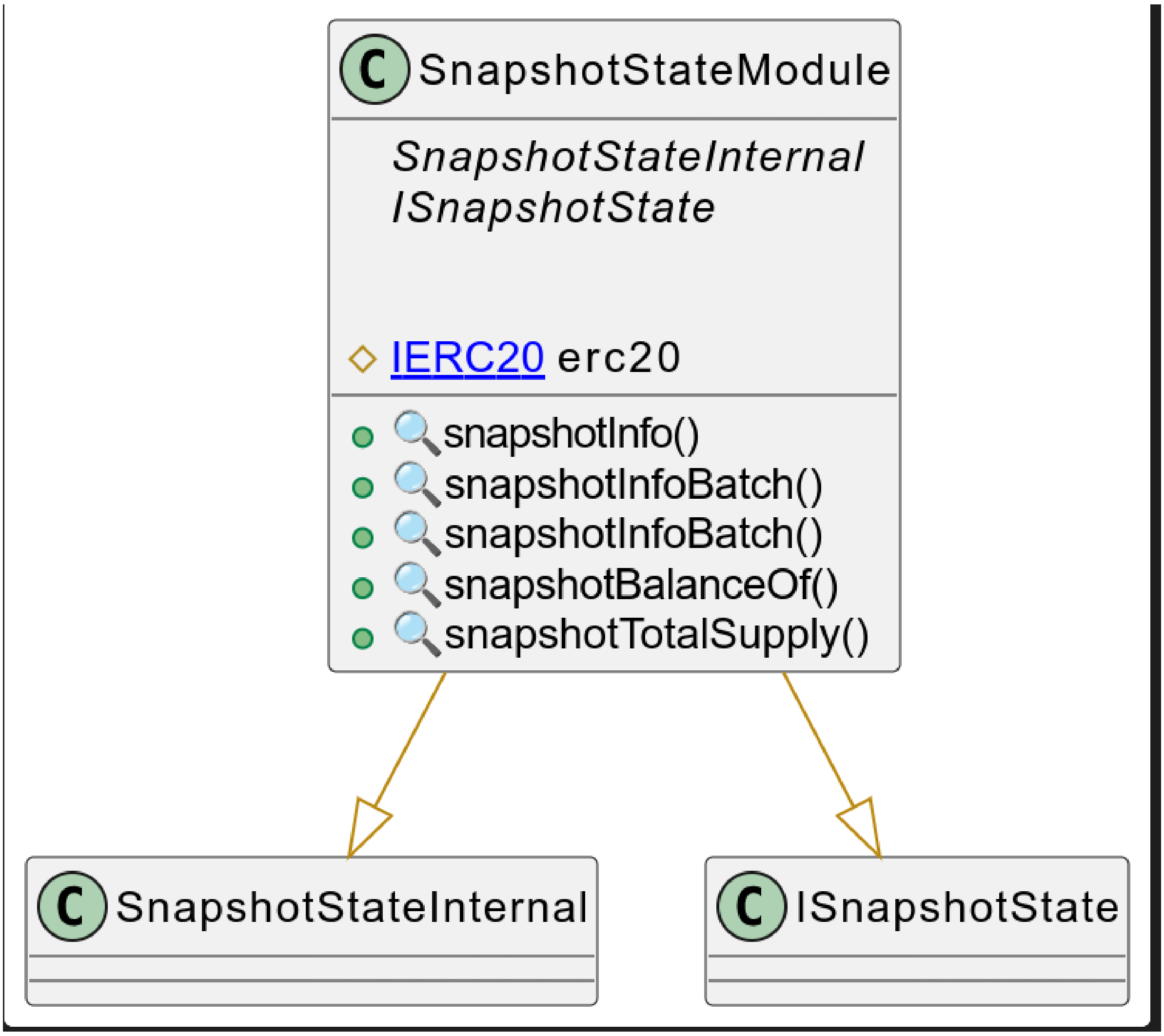
- Access is restricted to accounts with `SNAPSHOOTER_ROLE`.

Input Parameters:

Name	Type	Description
time	uint256	The scheduled time of the snapshot to cancel.

SnapshotState

Minimal interface for contracts (e.g. SnapshotEngine or CMTAT) supporting historical balance and total supply queries using snapshots.
Provides read-only methods to retrieve account balances and total token supply at specific timestamps, either individually or in batch.



Functions

snapshotBalanceOf(uint256, address) -> (uint256)

```
function snapshotBalanceOf(uint256 time,address tokenHolder)
external view returns (uint256 tokenHolderBalance);
```

Gets the balance of a specific account at the snapshot corresponding to a given timestamp.

Input Parameters:

Name	Type	Description
time	uint256	The timestamp identifying the snapshot to query.
tokenHolder	address	The address whose balance is being requested.

Return Values:

Name	Type	Description
balance	uint256	The recorded balance at the snapshot, or the current balance if no snapshot exists for that timestamp.

snapshotTotalSupply(uint256) -> (uint256)

```
function snapshotTotalSupply(uint256 time)
public view override(ISnapshotState)
returns (uint256 totalSupply)
```

Gets the total token supply at the snapshot corresponding to a given timestamp.

Input Parameters:

Name	Type	Description
time	uint256	The timestamp identifying the snapshot to query.

Return Values:

Name	Type	Description
supply	uint256	The recorded total supply at the snapshot, or the current total supply if no snapshot exists for that timestamp.

snapshotInfo(uint256, address) -> (uint256, uint256)

```
function snapshotInfo(uint256 time, address tokenHolder)
public view override(ISnapshotState)
returns (uint256 tokenHolderBalance, uint256 totalSupply)
```

Retrieves both an account's balance and the total supply at the snapshot for a given timestamp in a single call.

Input Parameters:

Name	Type	Description
time	uint256	The timestamp identifying the snapshot to query.
tokenHolder	address	The address whose balance is being requested.

Return Values:

Name	Type	Description
tokenHolderBalance	uint256	The recorded balance of the tokenHolder at the snapshot, or current balance if no snapshot exists.
totalSupply	uint256	The recorded total supply at the snapshot, or current total supply if no snapshot exists.

snapshotInfoBatch(uint256, address[]) -> (uint256[], uint256)

```
function snapshotInfoBatch(uint256 time, address[] calldata addresses)
public view override(ISnapshotState)
returns (uint256[] memory tokenHolderBalances, uint256 totalSupply)
```

Retrieves balances of multiple accounts and the total supply at a snapshot for a given timestamp in a single call.

Input Parameters:

Name	Type	Description
time	uint256	The timestamp identifying the snapshot to query.
addresses	address[]	The array of addresses to query balances for.

Return Values:

Name	Type	Description
tokenHolderBalances	uint256[]	Array containing each address's balance at the snapshot, or current balance if no snapshot exists.
totalSupply	uint256	The recorded total supply at the snapshot, or current total supply if no snapshot exists.

snapshotInfoBatch(uint256[], address[]) -> (uint256, uint256)

```
function snapshotInfoBatch(uint256[] calldata times, address[] calldata
addresses)
public view override(ISnapshotState)
returns (uint256[][] memory tokenHolderBalances, uint256[] memory totalSupply)
```

Retrieves balances of multiple accounts at multiple snapshots, as well as the total supply at each snapshot.

Input Parameters:

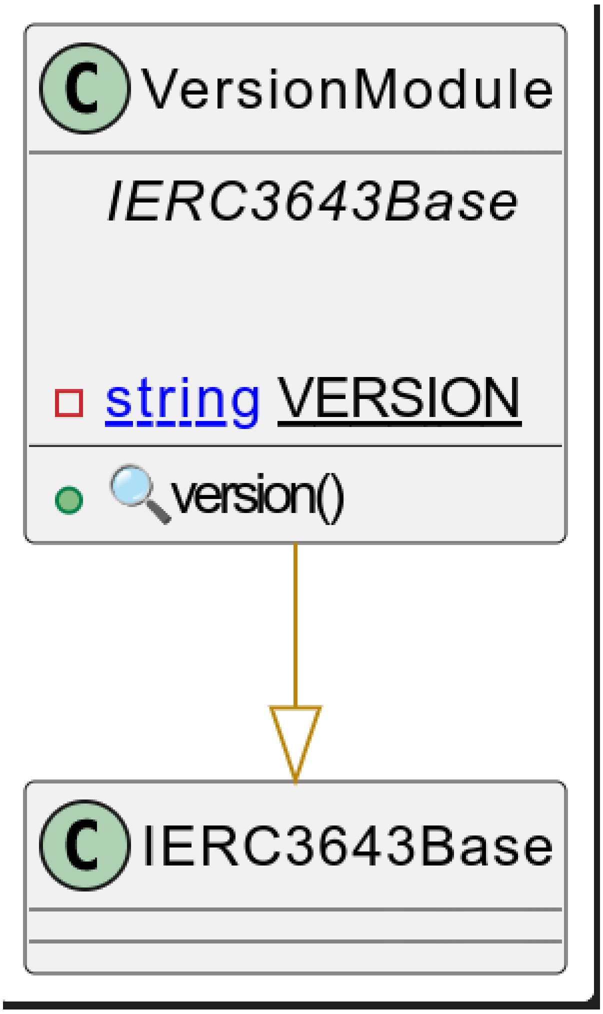
Name	Type	Description
times	uint256[]	Array of timestamps identifying each snapshot to query.
addresses	address[]	Array of addresses to query balances for at each snapshot.

Return Values:

Name	Type	Description
tokenHolderBalances	uint256[][]	2D array where each row corresponds to the balances of all provided addresses at a given snapshot.

Name	Type	Description
totalSupplies	uint256[]	Array containing the total supply at each snapshot, or current supply if no snapshot exists.

VersionModule



Storage management (ERC-7201)

While SnapshotEngine can not be deployed with a proxy, modules implement ERC-7201 to allow them to be directly used by a potential CMTAT deployment version.

Usage instructions

Dependencies

The toolchain includes the following components, where the versions are the latest ones that we tested:

- Development
  - npm 10.2.5
  - Hardhat ^2.22.7
  - Node 20.5.0
- Compilation

- Solidity v0.8.30
- CMTAT v3.0.0-rc7
- OpenZeppelin
  - OpenZeppelin Contracts (Node.js module) v5.4.0
  - OpenZeppelin Contracts Upgradeable (Node.js module) v5.4.0 (to compile CMTAT)

Installation

- Clone the repository

Clone the git repository, with the option `--recurse-submodules` to fetch the submodules:

```
git clone git@github.com:CMTA/SnapshotEngine.git  --recurse-submodules
```

- Node.js version

We recommend to install the Node Version Manager `nvm` to manage multiple versions of Node.js on your machine. You can then, for example, install the version 20.5.0 of Node.js with the following command: `nvm install 20.5.0`

The file .nvmrc at the root of the project set the Node.js version. `nvm use` will automatically use this version if no version is supplied on the command line.

- node modules

To install the node modules required by SnapshotEngine, run the following command at the root of the project:

```
npm install
```

Hardhat

> To use Hardhat, the recommended way is to use the version installed as part of the node modules, via the `npx` command:

```
npx hardhat
```

Alternatively, you can install Hardhat globally:

```
npm install -g hardhat
```

See Hardhat's official documentation for more information.

Contract size

You can get the size of the contract by running the following commands.

- Compile the contracts:

```
npx hardhat compile
```

- Run the script:

```
npm run-script size
```

The script calls the plugin hardhat-contract-sizer with Hardhat.

Testing

Tests are written in JavaScript by using web3js and run **only** with Hardhat as follows:

`npx hardhat test`

To use the global hardhat install, use instead `hardhat test`.

Please see the Hardhat documentation for more information about the writing and running of Hardhat.

Code style guidelines

We use linters to ensure consistent coding style. If you contribute code, please run this following command:

For JavaScript:

```
npm run-script lint:js
npm run-script lint:js:fix
```

For Solidity:

```
npm run-script lint:sol
npm run-script lint:sol:fix
```

Generate documentation

Surya

To generate documentation with surya, you can call the three bash scripts in doc/script

Task	Script	Command exemple
Generate graph	script_surya_graph.sh	npx surya graph -i contracts/*/.sol npx surya graph contracts/SnapshotEngine.sol
Generate inheritance	script_surya_inheritance.sh	npx surya inheritance contracts/modules/SnapshotEngine.sol -i npx surya inheritance contracts/modules/SnapshotEngine.sol
Generate report	script_surya_report.sh	npx surya mdreport -i surya_report.md contracts/modules/SnapshotEngine.sol npx surya mdreport surya_report.md contracts/modules/SnapshotEngine.sol

In the report, the path for the different files are indicated in absolute. You have to remove the part which correspond to your local filesystem.

Coverage

Code coverage for Solidity smart-contracts, installed as a hardhat plugin

```
npm run-script coverage
```

Docgen (Solidity API)

```
npm run-script docgen
```

Security

Vulnerability disclosure

Please see SECURITY.md (CMTAT main repository).

Audit

This project is not audited !

Tools

Slither

Slither is a Solidity static analysis framework written in Python3

```
slither .  --checklist --filter-paths "openzeppelin-contracts-upgradeable|openzeppelin-contracts|@openzeppelin|test|CMTAT|mock" > slither-report.md
```

Aderyn

Here is the list of report performed with Aderyn

```
aderyn -x mock --output aderyn-report.md
```

Further reading

You can find a prototype to distribute on-chain dividend based on on-chain snapshot here:

- Taurus - Equity Tokenization: How to Pay Dividend On-Chain Using CMTAT
- CMTAT IncomeVault

Note that this project used snapshots when they were performed directly inside CMTAT, see CMTAT v2.4.0, not through the `SnapshotEngine` but the principle is similar.

Intellectual property

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