Namespace Storage

(for now and for a Verkle EVM)

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The grammar of storage layouts

Given the linearized contract ...

... take all the variables in order ...

... and follow the grammar (with root 0)

$$
\begin{aligned}
L_{root} := \quad & root \\
& \mid L_{root} + n \\
& \mid \texttt{keccak256}(L_{root}) \\
& \mid \texttt{keccak256}(H(k) \oplus L_{root}) \\
& \mid \texttt{keccak256}(L_{root} \oplus H(k))
\end{aligned}
$$

Storage matters … when performing upgrades

Upgradeable smart contract needs to preserve a similar view of the storage layout across upgrades.

A lot can potentially go wrong:

- Inserting a variable that shift the layout
- Resize a variable (sometimes it's ok, not always)
- Reorder variables in a contract
- Reorder inheritance

The gap approach

Used in

`@openzeppelin/contracts-upgradeable`

3.x – 4.x

```solidity
/**
 * @dev Context variant with ERC2771 support.
 */
abstract contract ERC2771ContextUpgradeable is Initializable, ContextUpgradeable {
    /// @custom:oz-upgrades-unsafe-allow state-variable-immutable
    address private immutable _trustedForwarder;

    /// @custom:oz-upgrades-unsafe-allow constructor
    constructor(address trustedForwarder) {
        _trustedForwarder = trustedForwarder;
    }

    function isTrustedForwarder(address forwarder) public view virtual returns (bool) {
        return forwarder == _trustedForwarder;
    }

    function _msgSender() internal view virtual override returns (address sender) {
        if (isTrustedForwarder(msg.sender) && msg.data.length >= 20) {
            // The assembly code is more direct than the Solidity version using `abi.decode`.
            /// @solidity memory-safe-assembly
            assembly {
                sender := shr(96, calldataload(sub(calldatasize(), 20)))
            }
        } else {
            return super._msgSender();
        }
    }

    function _msgData() internal view virtual override returns (bytes calldata) {
        if (isTrustedForwarder(msg.sender) && msg.data.length >= 20) {
            return msg.data[:msg.data.length - 20];
        } else {
            return super._msgData();
        }
    }

    /**
     * @dev This empty reserved space is put in place to allow future versions to add new
     * variables without shifting down storage in the inheritance chain.
     * See https://docs.openzeppelin.com/contracts/4.x/upgradeable#storage_gaps
     */
    uint256[50] private __gap;
}
```

The namespace approach

Used in

`@openzeppelin/contracts-upgradeable`

5.x

```solidity
abstract contract OwnableUpgradeable is Initializable, ContextUpgradeable {
    /// @custom:storage-location erc7201:openzeppelin.storage.Ownable
    struct OwnableStorage {
        address _owner;
    }

    // keccak256(abi.encode(uint256(keccak256("openzeppelin.storage.Ownable")) - 1)) & ~bytes32(uint256(0xff))
    bytes32 private constant OwnableStorageLocation = 0x9016d09d72d40fdae2fd8ceac6b6234c7706214fd39c1cd1e609a0528c199300;

    function _getOwnableStorage() private pure returns (OwnableStorage storage $) {
        assembly {
            $.slot := OwnableStorageLocation
        }
    }

    /**
     * @dev The caller account is not authorized to perform an operation.
     */
    error OwnableUnauthorizedAccount(address account);

    /**
     * @dev The owner is not a valid owner account. (eg. `address(0)`)
     */
    error OwnableInvalidOwner(address owner);

    event OwnershipTransferred(address indexed previousOwner, address indexed newOwner);

    /**
     * @dev Initializes the contract setting the address provided by the deployer as the initial owner.
     */
    function __Ownable_init(address initialOwner) internal onlyInitializing {
        __Ownable_init_unchained(initialOwner);
    }

    function __Ownable_init_unchained(address initialOwner) internal onlyInitializing {
        if (initialOwner == address(0)) {
            revert OwnableInvalidOwner(address(0));
        }
        _transferOwnership(initialOwner);
    }

    /**
     * @dev Throws if called by any account other than the owner.
     */
    modifier onlyOwner() {
        _checkOwner();
        _;
    }

    /**
     * @dev Returns the address of the current owner.
     */
    function owner() public view virtual returns (address) {
        OwnableStorage storage $ = _getOwnableStorage();
        return $._owner;
    }
```

ERC-7201

ERC-7201: derivation of a new (safe) root

```
21    abstract contract OwnableUpgradeable is Initializable, ContextUpgradeable {
22        /// @custom:storage-location erc7201:openzeppelin.storage.Ownable
23        struct OwnableStorage {
24            address _owner;
25        }
26
27        // keccak256(abi.encode(uint256(keccak256("openzeppelin.storage.Ownable")) - 1)) & ~bytes32(uint256(0xff))
28        bytes32 private constant OwnableStorageLocation = 0x9016d09d72d40fdae2fd8ceac6b6234c7706214fd39c1cd1e609a0528c199300;
29
30        function _getOwnableStorage() private pure returns (OwnableStorage storage $) {
31            assembly {
32                $.slot := OwnableStorageLocation
33            }
34        }
```

Going back to the grammar

What is not in the grammar for a root 0 ?

$$
\begin{aligned}
L_{root} := \quad & root \\
& \mid L_{root} + n \\
& \mid \texttt{keccak256}(L_{root}) \\
& \mid \texttt{keccak256}(H(k) \oplus L_{root}) \\
& \mid \texttt{keccak256}(L_{root} \oplus H(k))
\end{aligned}
$$

If *n* is small enough, and if *keccak256* is a good hashing function, we just need to find a location that is not in L_{root}, and use that as our new root.

ERC-7201 derivation explained

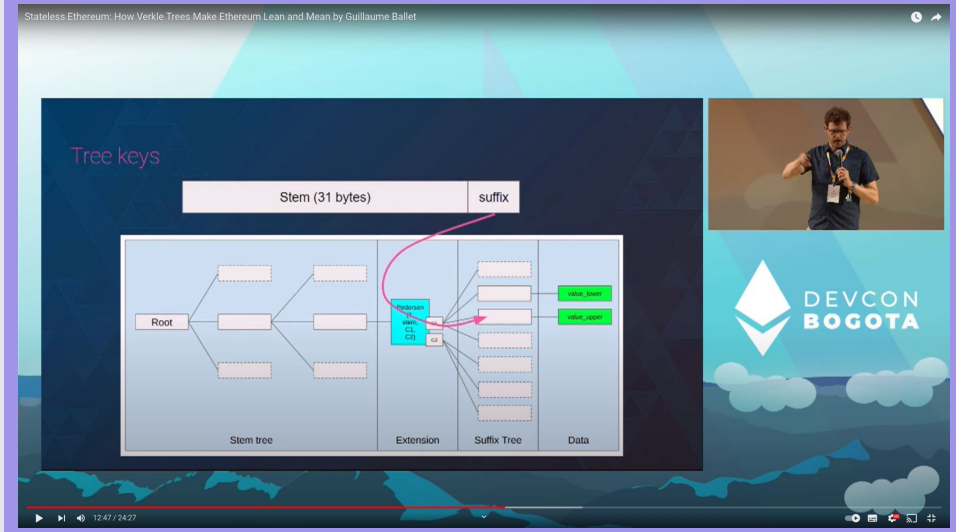
```
keccak256(keccak256("openzeppelin.storage.Ownable") - 1) & ~0xFF
```

`"openzeppelin.storage.Ownable"`	Seed
`keccak256(...) - 1`	Hash of the seed might collide if the seed matches a valid storage location is L_0, so we subtract 1 to exit L_0
`keccak256(...)`	Get a completely new space (so doing "+n") don't bring us back into L0
`... & ~0xFF`	Clean the last byte so our namespace starts at the beginning of a bucket

What is a bucket?

Should Solidity (& Vyper) change their grammar?

Maybe!



Stateless Ethereum: How Verkle Trees Make Ethereum Lean and Mean by Guillaume Ballet
https://www.youtube.com/watch?v=Q7rStTKwuYs

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