upgrade contract

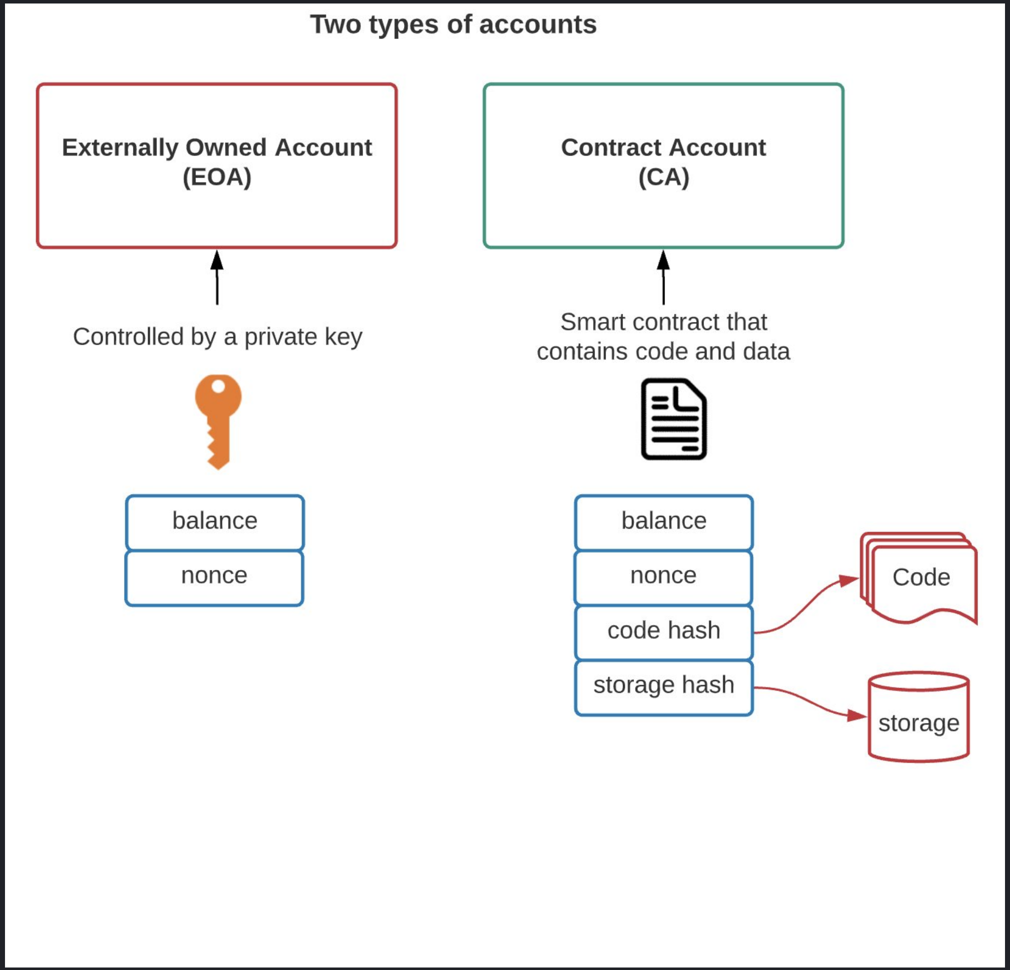
@seven

outline

- introduce smart contract
- upgrade pattern
- writing upgradeable contracts

Accounts

EOA VS Contract



Two types of accounts
Externally Owned Account (EOA)
Contract Account (CA)
Controlled by a private key
Smart contract that contains code and data
balance
nonce
balance
nonce
code hash
storage hash
Code
storage

smart contract

- value
- storage
- code
  - immutable

exception

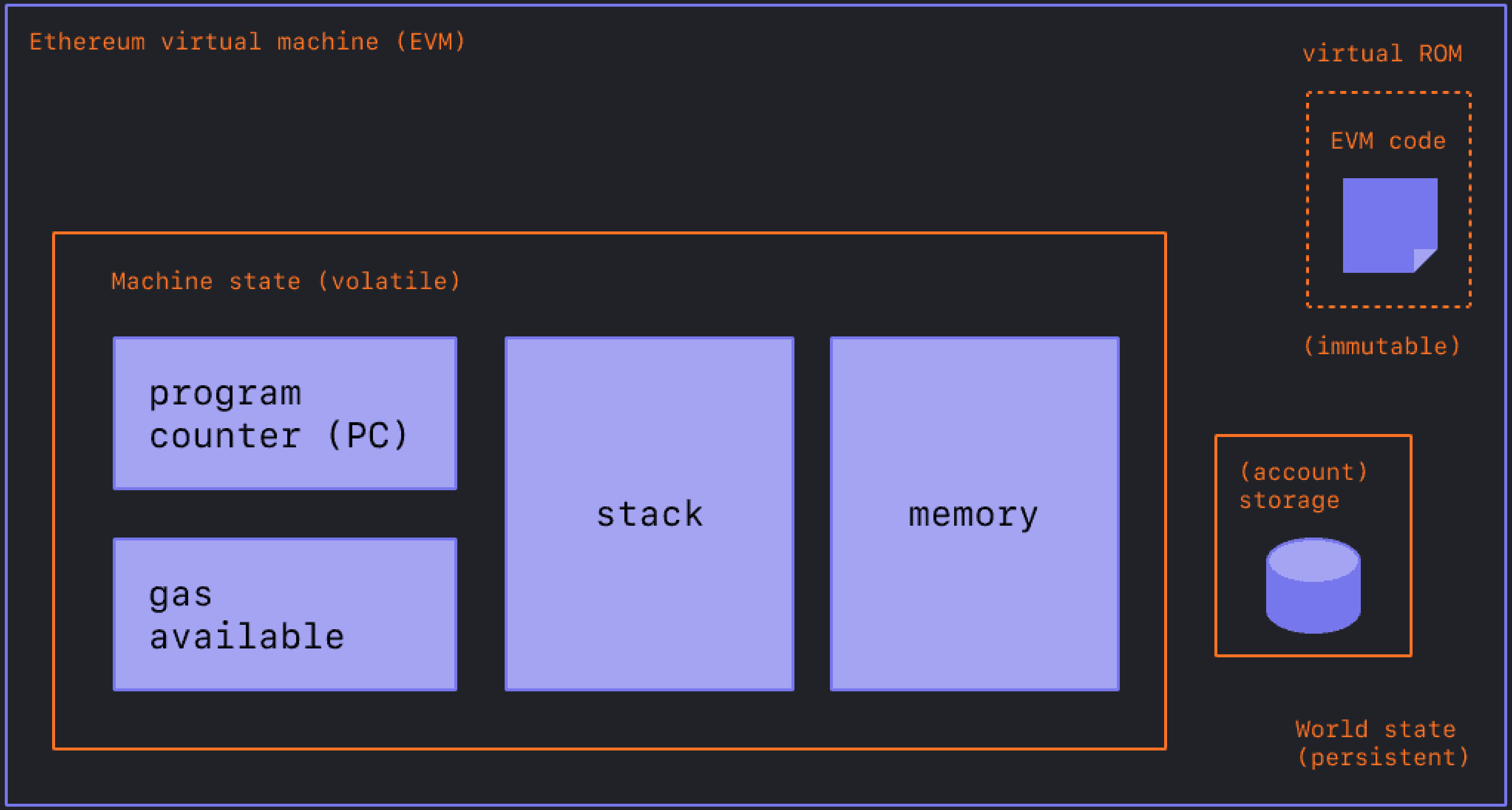
- selfdustruct: delete code, storage and transfer value

storage

low level: evm

high level: solidity

EVM


Ethereum virtual machine (EVM)
virtual ROM
EVM code
(immutable)
Machine state (volatile)
program counter (PC)
gas available
stack
memory
(account) storage
World state (persistent)

- a simple stack based vm
- code execute from zero
- memory is temporary: lifetime is limited to an external function call
- storage is sustained: limited to the lifetime of a contract

storage ops

- sload
- sstore

storage structure

- map:
  - key and value are both 256 bits
- slot

solidity code

demo code

```
contract Demo {
    string public name;

    constructor(string memory _name) payable {
        name = _name;
    }

    function hello() public view returns (string memory) {
        return name;
    }
}
```

```
npx hardhat run scripts/deploy_demo.js
```

How to execute in solidity

- no main function
- bin Vs lib

solidity

- no main function
- execute code from zero
- how to execute different function?

function selector

- if match: jump to the code

```
❯ cast sig "transfer(address,uint256)"
0xa9059cbb
```

- selector clash

solidity storage layout

Layout of State Variables in Storage

storage slot demo

```
contract Storage {
    uint public a = 1;
    uint128 internal b = 2;
    uint128 internal _c;
    uint internal _d;
    uint[] public e = [1, 2, 3];
    mapping(uint => uint) public f;
    uint public g = 5;
}
```

```
cd demo
npx hardhat run --network local scriptss/depoly_storage.js
cast storage --help
```

array address

```
❯ cast keccak 0x000000000000000000000000000000000000000000000000000000
0xc2575a0e9e593c00f959f8c92f12db2869c3395a3b0502d05e2516446f71f85b

❯ cast storage -r http://127.0.0.1:8545 0x1291Be112d480055DaFd8a610b7d1
0x0000000000000000000000000000000000000000000000000000000000000001
```

map address

```
# hash(key.slot)
❯ cast keccak 0x000000000000000000000000000000000000000000000000000000
0xabd6e7cb50984ff9c2f3e18a2660c3353dadf4e3291deeb275dae2cd1e44fe05

❯ cast storage -r http://127.0.0.1:8545 0x1291Be112d480055DaFd8a610b7d1
0x0000000000000000000000000000000000000000000000000000000000000002

❯ cast keccak 0x000000000000000000000000000000000000000000000000000000
0x91da3fd0782e51c6b3986e9e672fd566868e71f3dbc2d6c2cd6fbb3e361af2a7

❯ cast storage -r http://127.0.0.1:8545 0x1291Be112d480055DaFd8a610b7d1
0x0000000000000000000000000000000000000000000000000000000000000004
```

pattern

- parameters configuration
- contracts register
- strategy pattern
- pluggable modules
- **upgrade pattern**

parameters configuration

- simply tuning a set of parameters in contract
- not really update the code

contracts registry

- central registry
- state need migrate mannully
- external client need to call into the registry before interacting with the contract

strategy pattern

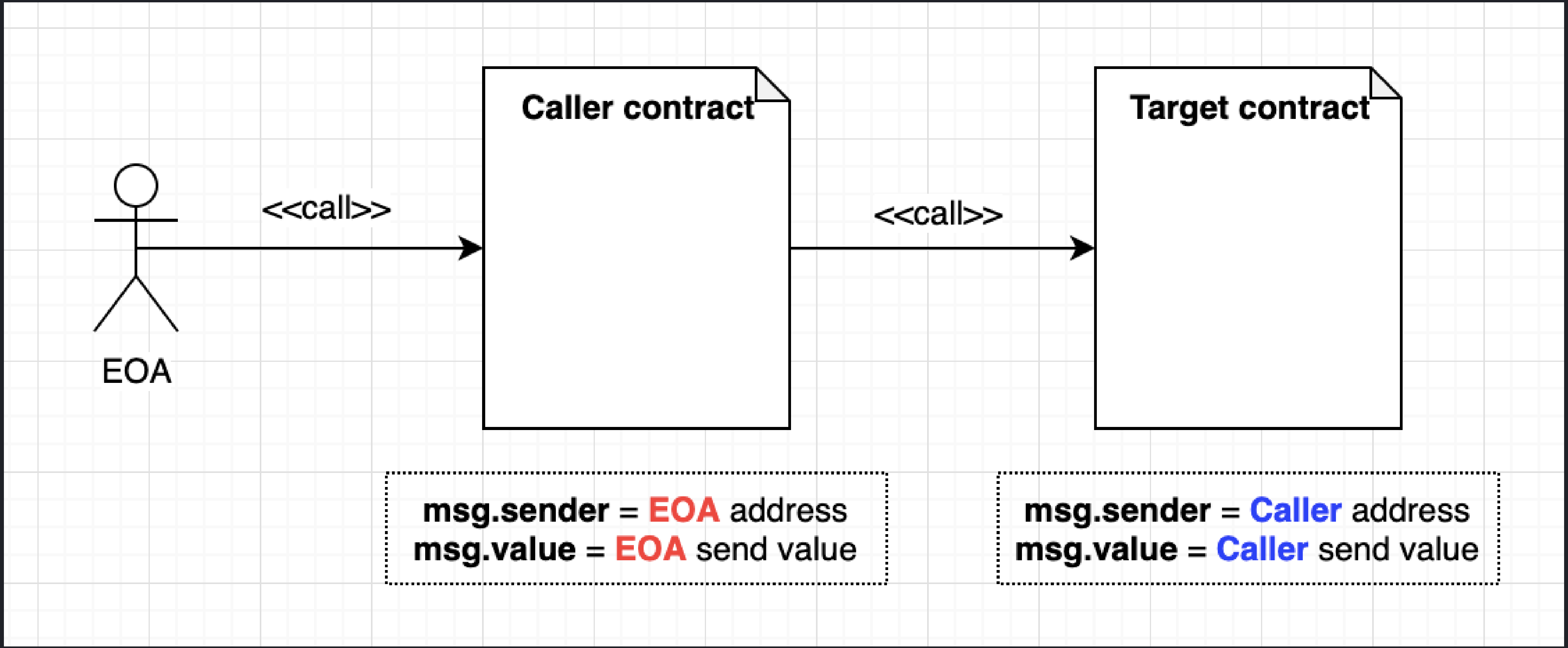
- Instead of implementing a function in your contract to take care of a specific task, you call into a separate contract to take care of that – and by switching implementations of that contract, you can effectively switch between different strategies
- only read state

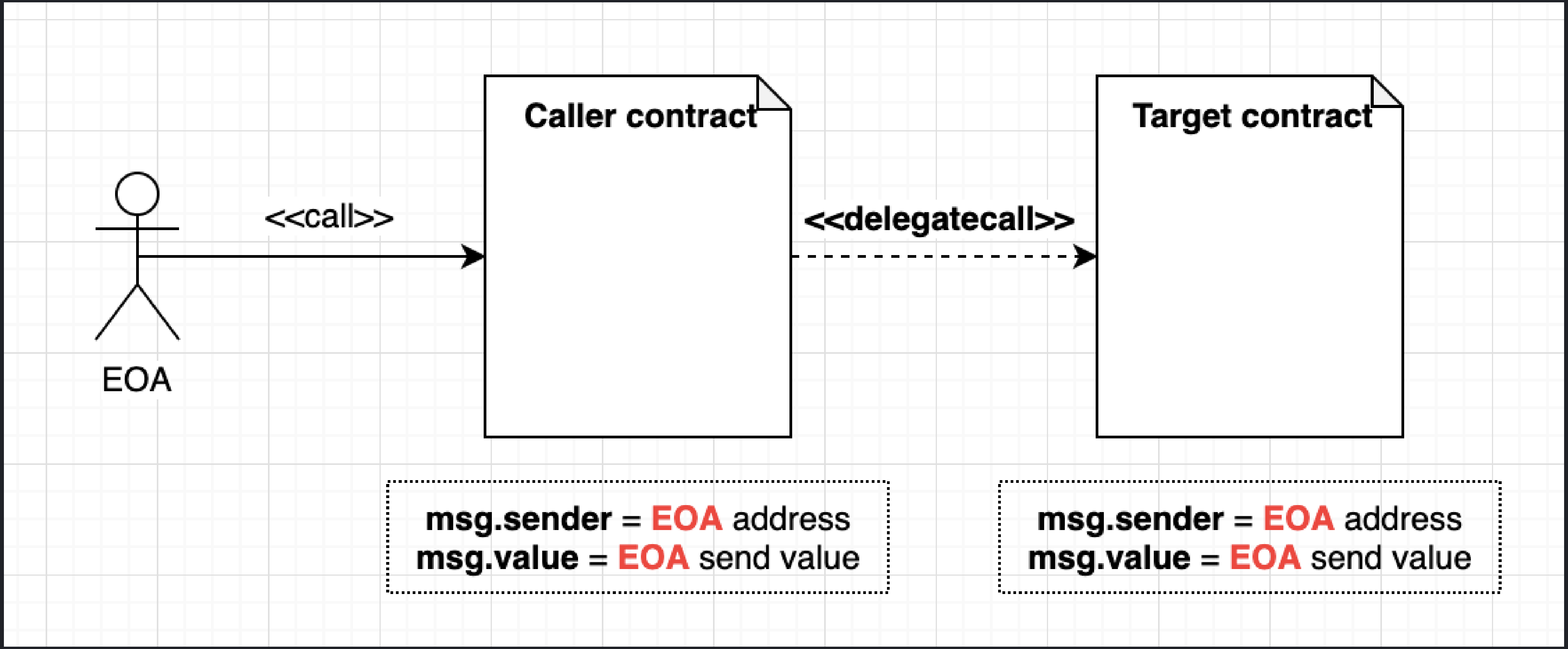
pluggable modules

- core immutable features
- most common in wallets
- can't fix core contract bug

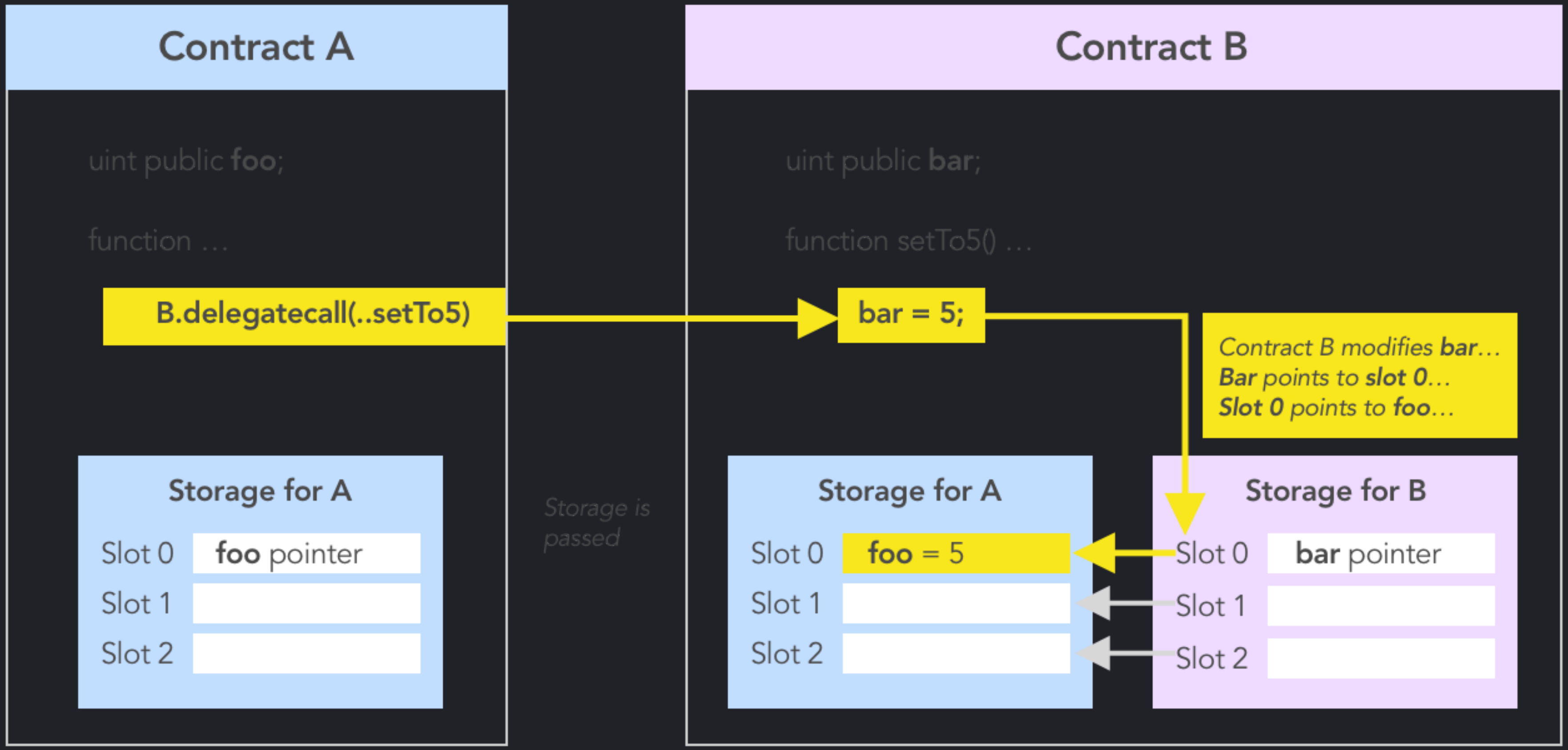
upgrade pattern

- library
- call Vs delegatecall

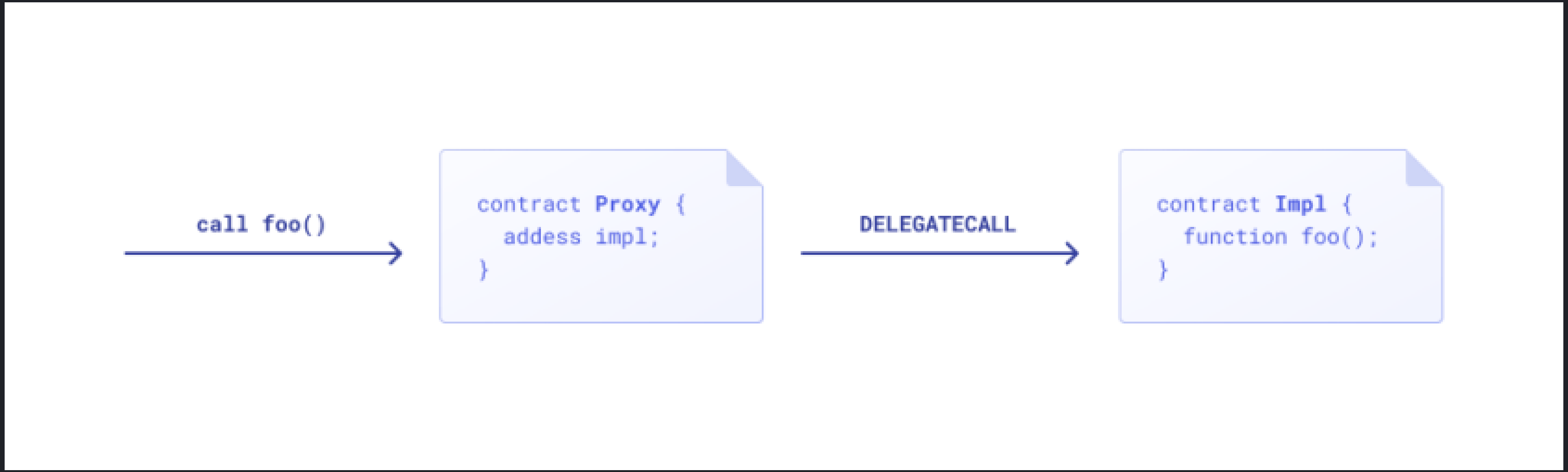

Caller contract
Target contract
<<call>>
<<call>>
EOA
msg.sender = EOA address
msg.value = EOA send value
msg.sender = Caller address
msg.value = Caller send value


Caller contract
Target contract
<<call>>
<<delegatecall>>
EOA
msg.sender = EOA address
msg.value = EOA send value
msg.sender = EOA address
msg.value = EOA send value

How Storage Works on Delegatecall()



Proxy



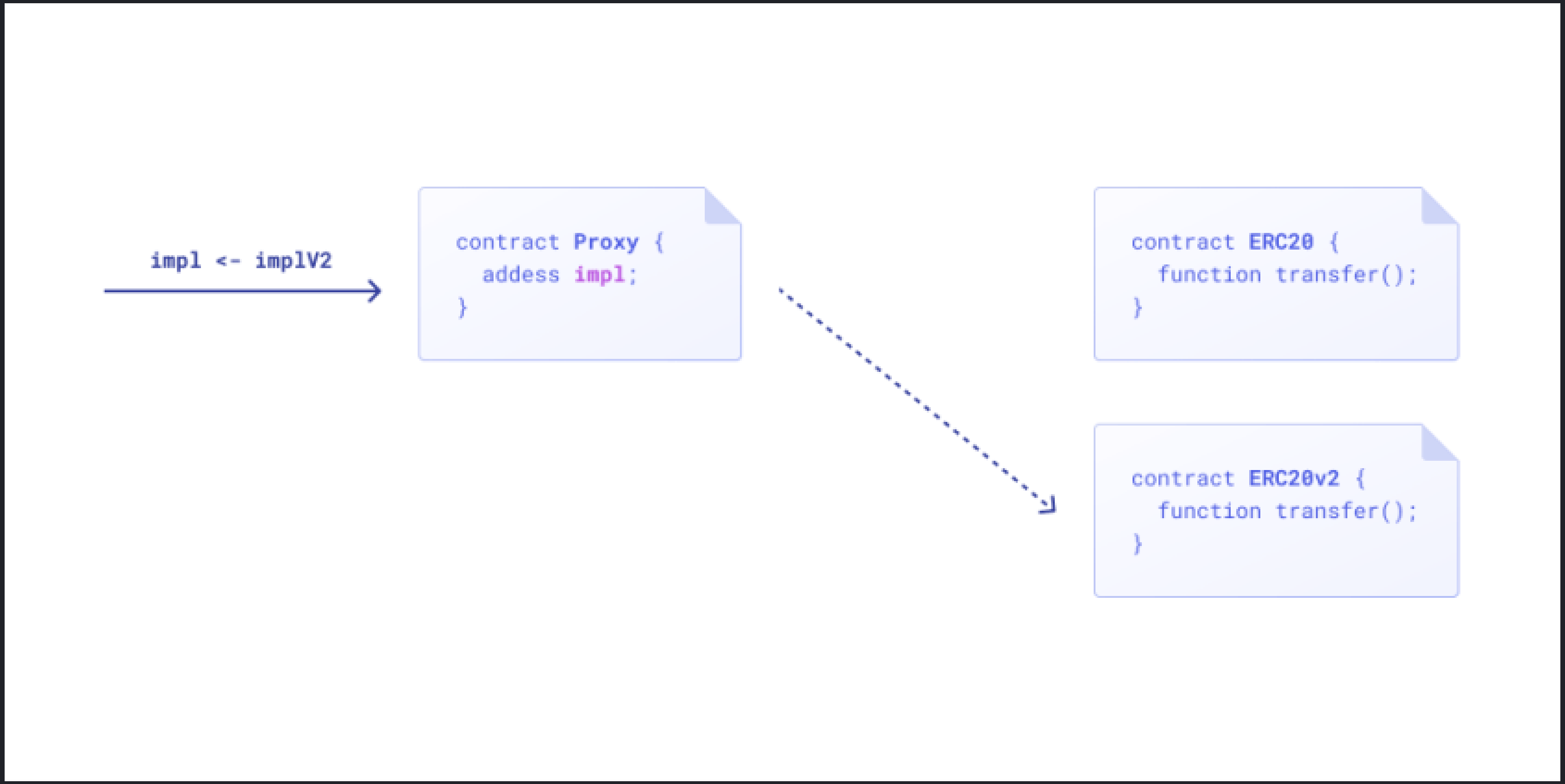
```
contract Proxy {
    address implementation;

    fallback() external payable {
        (bool res, ) = implementation.delegatecall(msg.data);
        require(res, "Failed to delegatecall");
    }
}
```

demo

```
❯ npx hardhat run --network localhost scripts/deploy_proxy.js
```

upgradable



```
contract Proxy {
  addess impl;
}
```

```
contract ERC20 {
  function transfer();
}
```

```
contract ERC20v2 {
  function transfer();
}
```

upgradablee(continue)

```
contract AdminUpgradeableProxy {
    address implementation;
    address admin;

    fallback() external payable {
        (bool res, ) = implementation.delegatecall(msg.data);
        require(res, "Failed to delegatecall");
    }

    receive() external payable {}

     function upgrade(address newImplementation) external {
        require(msg.sender == admin);
        implementation = newImplementation;
    }
}
```

problem 1

- proxy vs logic function selector confict

```
contract Foo {
    function collate_propagate_storage(bytes16) external { }
    function burn(uint256) external { }
}
```

transparent proxy

```
// Sample code, do not use in production!
contract TransparentAdminUpgradeableProxy {
    address implementation;
    address admin;
    fallback() external payable {
        require(msg.sender != admin);
        implementation.delegatecall.value(msg.value)(msg.data);
    }
    function upgrade(address newImplementation) external {
        if (msg.sender != admin) fallback();
        implementation = newImplementation;
    }
}
```

Admin Contract

- create an admin contract

downside

- gas cost. Each call requires an additional read from storage to load the admin address
- contract itself is expensive to deploy

Universal upgradeable proxy

```
// Sample code, do not use in production!
contract UUPSProxy {
    address implementation;
    fallback() external payable {
        implementation.delegatecall(msg.data);
    }
}
abstract contract UUPSProxiable {
    address implementation;
    address admin;
    function upgrade(address newImplementation) external {
        require(msg.sender == admin);
        implementation = newImplementation;
    }
}
```

benefit:

- no select clashes
- proxy is small
- less read from storage (check admin)

downside:

- may lock the logic contract

unstructured storage pattern

- proxy vs logic storage conflict

```
/**
 * @dev Storage slot with the address of the current implementation
 * This is the keccak-256 hash of "eip1967.proxy.implementation" su
 * validated in the constructor.
 */
bytes32 internal constant _IMPLEMENTATION_SLOT = 0x360894a13ba1a321
```

logic contracts storage confict after upgrade

- storage variable append only, never delete
- padding reserve
- eternal storage pattern (proposal: solidity language direct support)

```
// Sample code, do not use in production!
contract EternalStorage {
    mapping(bytes32 => uint256) internal uintStorage;
    mapping(bytes32 => string) internal stringStorage;
    mapping(bytes32 => address) internal addressStorage;
    mapping(bytes32 => bytes) internal bytesStorage;
    mapping(bytes32 => bool) internal boolStorage;
    mapping(bytes32 => int256) internal intStorage;
}
contract Box is EternalStorage {
    function setValue(uint256 newValue) public {
        uintStorage[‘value’] = newValue;
    }
}
```

limit

- can't use constructors, use initializer

EIP2535(Diamond Contract)

```
// Sample code, do not use in production!
contract Proxy {
    mapping(bytes4 => address) implementations;
    fallback() external payable {
        address implementation = implementations[msg.sig];
        return implementation.delegatecall(msg.data);
    }
}
```

Beacons

```
// Sample code, do not use in production!
contract Proxy {
    address immutable beacon;
    fallback() external payable {
        address implementation = beacon.implementation();
        return implementation.delegatecall.value(msg.value)(msg.data);
    }
}
contract Beacon is Ownable {
    address public implementation;
    function upgrade(address newImplementation) public onlyOwner {
        implementation = newImplementation;
    }
}
```

Abusing CREATE2 with Metamorphic Contracts

- create2
- selfdestruct

openzepplin upgrade guide

example

- bas
- demo

Upgrade Governance

- EOA
- mulit-sig
- timelock
- pausable
- escape hatches
- commit-reveal upgrades
- voting

refenence

The State of Smart Contract Upgrades

Proxy Upgrade Pattern

EIP-1967: Proxy Storage Slots

EIP-1822: Universal Upgradeable Proxy Standard (UUPS)

EIP-2535: Diamonds, Multi-Facet Proxy