Recap Ethereum Smart Contracts

Blockchain-Based Systems Engineering

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Definition

- Solidity is a **high-level language** to write **smart contracts** for **Ethereum.**

- **Contracts**[1] can be defined as **encapsulated units**, similar to classes in traditional **object-oriented** programming languages like Java.

- A **contract** has **its own, persistent state** on the blockchain which is **defined by state variables** in the contract.

- **Functions** are **used to change** the **state** of the contract or to **perform** other **computations.**

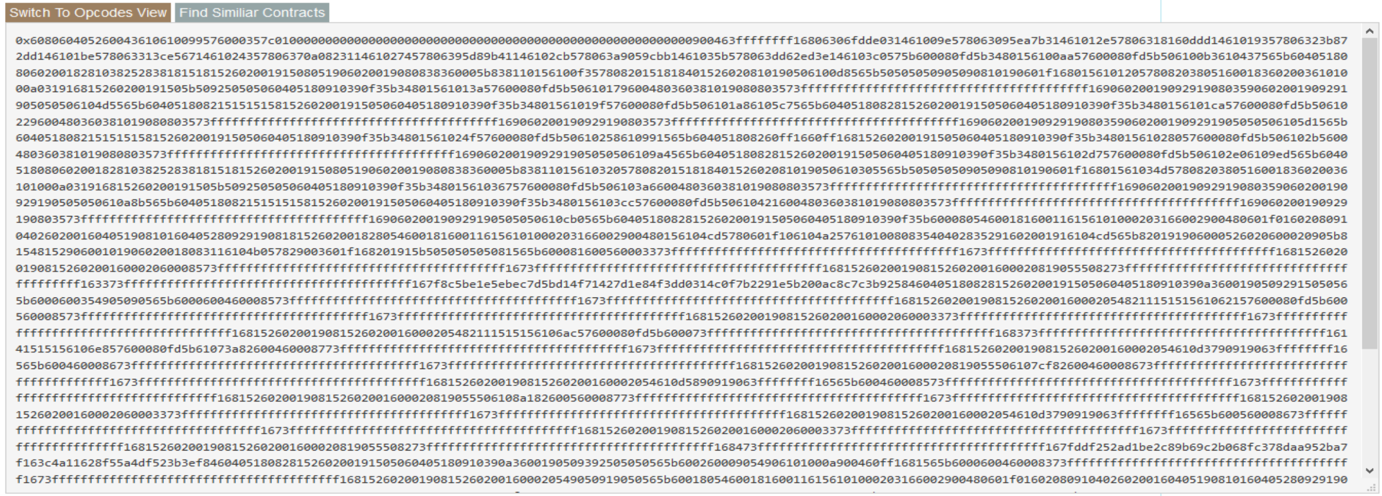
- Solidity is **compiled to bytecode** which is **persistent and immutable** once deployed to the blockchain:
  ➔ **No patch deployment** possible
  ➔ **Smart contracts** must be **perfect before** using them in **production**!

[1] "Contract" is used as a short form of "smart contract".

Source Code

- Source code is typically not stored on the blockchain, only byte code.
- Without further analysis, the purpose of this smart contract is unclear.

- Source code can be made publicly available.
- Etherscan.io is the only service which verifies source codes and the respective byte code.



```
0x608060405260043610610099576000357c0100000000000000000000000000000000000000000000000000000000900463ffffffff16806306fdde031461009e578063095ea7b31461012e57806318160ddd1461019357806323b87
2dd146101be578063313ce5671461024357806370a082311461027457806395d89b41146102cb578063a9059cbb1461035b578063dd62ed3e146103c0575b600080fd5b3480156100aa57600080fd5b506100b3610437565b60405180
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f1673ffffffffffffffffffffffffffffffffffffffff16815260200190815260200160002054905091905056 5b6001805460018160011615610100020316600290048060 1f0160208091040260200160405190810160405280929190
```
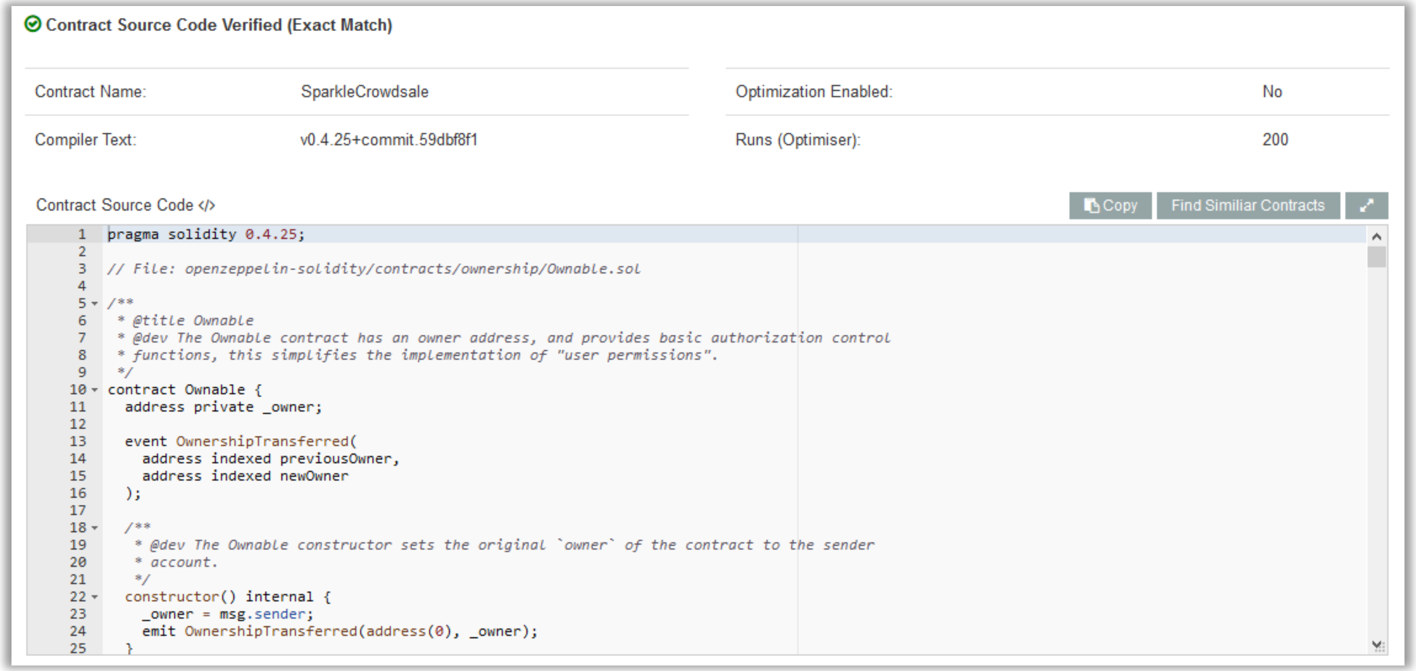



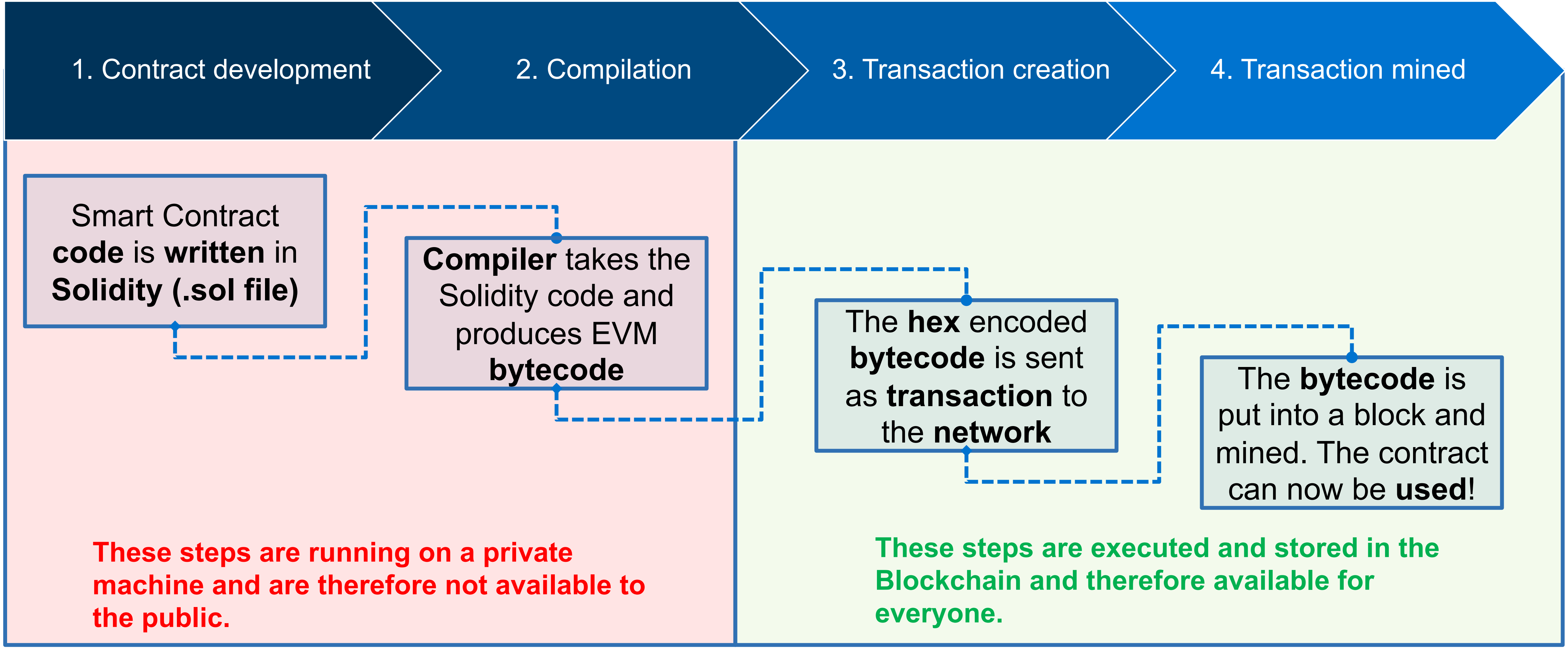
Contract Source Code Verified (Exact Match)

Contract Name:	SparkleCrowdsale	Optimization Enabled:	No
Compiler Text:	v0.4.25+commit.59dbf8f1	Runs (Optimiser):	200

Contract Source Code </>

```
pragma solidity 0.4.25;

// File: openzeppelin-solidity/contracts/ownership/Ownable.sol

/**
 * @title Ownable
 * @dev The Ownable contract has an owner address, and provides basic authorization control
 * functions, this simplifies the implementation of "user permissions".
 */
contract Ownable {
  address private _owner;

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

  /**
   * @dev The Ownable constructor sets the original `owner` of the contract to the sender
   * account.
   */
  constructor() internal {
    _owner = msg.sender;
    emit OwnershipTransferred(address(0), _owner);
  }
```

From Solidity Source Code to a Deployed Smart Contract



1. Contract development

2. Compilation

3. Transcation creation

4. Transaction mined

Smart Contract **code** is **written** in **Solidity (.sol file)**

Compiler takes the Solidity code and produces EVM **bytecode**

The **hex** encoded **bytecode** is sent as **transaction** to the **network**

The **bytecode** is put into a block and mined. The contract can now be **used**!

These steps are running on a private machine and are therefore not available to the public.

These steps are executed and stored in the Blockchain and therefore available for everyone.

Anatomy of a Solidity Smart Contract File

File: **BBSE.sol**

```
contract BBSE {

    struct Tutor {
        string firstName;
        string lastName;
    }
    mapping (address => Tutor) tutors;
    address professor;

    modifier onlyProfessor {
        require(msg.sender == professor);
        _;
    }

    constructor() public {
        professor = msg.sender;
    }

    function getProfessor() view returns (address) {
        return professor;
    }

    // This function adds a new tutor
    function addTutor(address tutorAddress,
    string firstName, string lastName) onlyProfessor {
        Tutor tutor = tutors[tutorAddress];
        tutor.firstName = firstName;
        tutor.lastName = lastName;
    }

}
```

State variables

- State variables are permanently stored in the contract’s storage.
- Changing the state requires a transactions and therefore costs ether.
- Reading the state of a contract is free and does not require a transaction.

Anatomy of a Solidity Smart Contract File (cont.)

File: **BBSE.sol**

```
contract BBSE {

    struct Tutor {
        string firstName;
        string lastName;
    }
    mapping (address => Tutor) tutors;
    address professor;

    modifier onlyProfessor {
        require(msg.sender == professor);
        _;
    }

    constructor() public {
        professor = msg.sender;
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        tutor.firstName = firstName;
        tutor.lastName = lastName;
    }

}
```

Function modifiers

- Function modifiers are a convenient way to reuse pieces of code.
- Changes the behavior of a function.
- Can execute code either before and/or after the actual function execution.
- The low dash _ indicates where the actual function code is injected.
- Often used for authentication.

Anatomy of a Solidity Smart Contract File (cont.)

File: **BBSE.sol**

```
contract BBSE {

    struct Tutor {
        string firstName;
        string lastName;
    }
    mapping (address => Tutor) tutors;
    address professor;

    modifier onlyProfessor {
        require(msg.sender == professor);
        _;
    }

    constructor() public {
        professor = msg.sender;
    }

    function getProfessor() view returns (address) {
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    }

    // This function adds a new tutor
    function addTutor(address tutorAddress,
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        Tutor tutor = tutors[tutorAddress];
        tutor.firstName = firstName;
        tutor.lastName = lastName;
    }

}
```

Constructor

- The constructor function is executed once when the contract is created through a transaction.
- The function cannot be called after the creation of the contract.
- Usually used to initialize the state of a contract.
- Execution costs gas and more complex constructors lead to higher deployment costs.

Anatomy of a Solidity Smart Contract File (cont.)

File: **BBSE.sol**

```
contract BBSE {

    struct Tutor {
        string firstName;
        string lastName;
    }
    mapping (address => Tutor) tutors;
    address professor;

    modifier onlyProfessor {
        require(msg.sender == professor);
        _;
    }

    constructor() public {
        professor = msg.sender;
    }

    function getProfessor() view returns (address) {
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        Tutor tutor = tutors[tutorAddress];
        tutor.firstName = firstName;
        tutor.lastName = lastName;
    }

}
```

Functions

- Functions are used to change the state of a contract.
- Can also be used to read the state of the contract.
- Consist of a name, a signature, a visibility, a type, a list of modifiers, and a return type.

Formal definition:

```
function (<parameter types>)
{internal|external|public|private}
[pure|constant|view|payable]
[(modifiers)]
[returns (<return types>)]
```

Language Features Overview

Solidity is **inspired by JavaScript** and comes with a very similar syntax. Furthermore, it implements the standard set of features for high-level (object-oriented) programming languages. Compared to the dynamically-typed JavaScript, Solidity uses static types.

Built-in data types

int, uint, bool, array, struct, enum, mapping

Built-in first level objects

block, msg, tx, address

Built-in functions

Error handling: assert(), require(), revert()
Math & Crypto: addmod(), mulmod(), sha3(), keccak256(), sha256(), ripemd160(), ecrecover()
Information: gasleft(), blockhash()
Contract related: selfdestruct()

A set of literals

Solidity comes with some Ethereum specific literals (like eth for units, e.g., int a = 5 eth)

Flow control

if, else, do, while, break, continue, for, return, ? … : … (ternary operator)

Function and Variable Visibility

In Solidity, functions can be declared with four different visibility types.

External
External methods can be called by other contracts and via transactions issued by a certain wallet. Methods declared as external **are always publicly visible** and **can’t be called directly by the contract itself**.

Public
Public can **be called internally** by the contract itself but also **externally** by other contracts and via transactions. **State variable** which are defined as public will **by default have getter** method created automatically by the compiler.

Internal
Internal methods can only be accessed by the contract itself or by any contract derived from it. They are not callable from other contracts nor via transactions.

Private
Private methods can **only** be called **internally** by the contract who owns the method. **Derived contracts cannot access** a private method of their parent contract.

Special Function Types (cont.)

Payable function
By default, it is not possible to send ether to a function because the function will by default revert the transaction. The behavior is intentional, it should prevent Ether that is accidentally sent from being lost. However, sometimes it is necessary to pay a contract, e.g. in case of an ICO. Therefore, Solidity implements so-called *payable* functions.

Example

```
function buyInICO() public payable { /* … */ }
```

- The keyword payable is also required for declaring constructors and addresses that can receive Ether (e.g., constructor payable { /* … */ }, function withdraw (address payable _to) public { /* … */ }).

- While implicit conversions are allowed from address payable to address, a casting function called payable (<address>) must be used for conversions from address to address payable.

```
address public customer;

function transfer (uint amount) public {
    payable(customer). transfer(amount);
}
```

Address Class

Some contracts may require information about a specific account, e.g. the current account balance. Solidity implements a special type for accounts called *address*. Any Ethereum account, i.e. externally owned, as well as, contract, can be represented as address object.

An address can be directly defined via a valid 20 byte hex code representation.

```
address a = 0xd5e7726990fD197005Aae8b3f973e7f2A65b4c18
```

An address that can receive Ether must either be defined as address payable or it should be cast with payable (<address>) function while sending Ether to it.

Furthermore, any contract object can be explicitly casted to an address.

```
contract A {
  function f() {}
}
contract B {
     function g() {
        A a = new A();
        address contract_a = address(a);
        address self = address(this);
     }
}
```

Address Class

<address>.balance
The balance of the address in Wei returned as 256 bit unsigned integer

<address>.transfer(uint256 value)
Transfers the amount passed as *value* in Wei to the *<address>.* The function throws on failure. Forwards 2300 gas to *<address>*. (**NOTE**: Must keep in mind that the called smart contract can quickly run out of gas and make the transfer impossible)

<address>.send(uint256 value)
Same as *<address>.transfer(uint256 value)* but returns false on failure

<address>.call(…)
A Low-level function that can be used to invoke functions but also to send Ether. The function returns false on failure and, by default, forwards all gas to *<address>* (**NOTE**: The called contract can execute complex operations that can spend all of the forwarded gas, causing more cost to the caller). If there is no receive function defined in the called contract (i.e., if the fallback gets triggered upon Ether received), then, only 2300 gas is forwarded.

<address>.delegatecall(…)
A low-level function that can be used to call a function at *<address>* in the context/state of the current contract (i.e., *caller contract delegates the use of its storage to the receiving contract*). This function returns false on failure. (**NOTE**: Caller contract needs to trust the receiving contract)

Message Object

Some contracts may require information about the caller of a function, e.g. for authentication purposes. Solidity provides the global msg object that contains information about the caller. It does not matter whether the caller of the function was an externally owned account or another contract.

The object refers to the last account that was responsible for invoking the function. This can either be a contract or an externally owned account.

msg.sender
The account address of the function’s caller, which has type address (**NOTE**: Needs to be cast to address payable when calling *transfer*, *send*, or *call*).

msg.data
The complete payload of the message/transaction

msg.sig
The function’s hash signature so that the EVM knows which function is called

msg.value
The amount of Wei that is sent with the message

Block Object

Some contracts may require information about the latest mined block, e.g. when a specific function should be time locked. Solidity provides a global variable called `block` to access the most recent block of the blockchain.

block.coinbase

The account address of the current block's miner

block.difficulty

The current mining difficulty as unsigned integer

block.gaslimit

The current block's gaslimit (by the miner)

block.timestamp

The UNIX timestamp of the block (in theory, can by manipulated by the miner)