GETTING STARTED WITH

Ethereum Private Blockchain

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INTRODUCTION

BACKGROUND

A blockchain is a distributed computing architecture where every node runs in a peer-to-peer topology, where each node executes and records the same transactions. These transactions are grouped into blocks. Each block contains a one-way hash value. Each new block is verified independently by peer nodes and added to the chain when a consensus is reached. These blocks are linked to their predecessor blocks by the unique hash values, forming a chain. In this way, the blockchain's distributed dataset (a.k.a. distributed ledger) is kept in consensus across all nodes in the network. Individual user interactions (transactions) with the ledger are append-only, immutable, and secured by strong cryptography. Nodes in the network, in particular the public network, that maintain and verify the transactions (a.k.a. mining) are incentivized by mathematically enforced economic incentives coded into the protocol. All mining nodes will eventually have the same dataset throughout.

Ethereum is an open-source blockchain platform that allows anyone to build and use decentralized applications running on blockchain technology. Ethereum is a programmable blockchain - it allows users to create their own operations. These operations, coded as Smart Contracts, are deployed and executed by the Ethereum Virtual Machine (EVM) running inside every node.

The public blockchain is open to anyone who wants to deploy smart contracts and have their executions performed by public mining nodes. Bitcoin is one of the largest public blockchain networks today. As such, there is limited privacy in the public blockchain. Mining nodes in the public blockchain requires a substantial amount of computational power to maintain the distributed ledger at a large scale. In the Ethereum public blockchain, compiled versions of smart contract codes can be viewed openly.

A private blockchain can be set up within the safety confines of a private network within an organization. Hence, nodes participating in transactions are authenticated and authorized machines within the organizational network.

The following text of this Refcard highlights fundamental information on the Ethereum Blockchain and the basic steps to get a private blockchain up and running. At the end of this Refcard, you should be able to set up two running nodes on one local machine.

FURTHER READING:
- ethdocs.org/en/latest/introduction/what-is-ethereum.html
- bitsonblocks.net/2016/10/02/a-gentle-introduction-to-ethereum

ACCOUNTS AND CONTRACTS

There are 2 types of accounts in Ethereum:

- **External Account**, which stores ETH balance – This contains the address of the User that was created using the Web3.js API, e,g, personal.newAccount(...). These accounts are used for executing smart contract transactions. ETH is your incentive received for using your account to mine transactions. The address of the account is the public key, and the password of the account is the private key.

  A public example of an External account that stores ETH can be found here.

- **Contract Account**, which stores ETH balance and has codes – This contains the address of an instance of Smart Contract codes. Instance(s) of smart contracts can be created programmatically or via Browser-Solidity using Web3 APIs.

  A public example of a contract account that has a smart contract can be found here.

FURTHER READING:
- github.com/ethereum/go-ethereum/wiki/Contracts-and-Transactions
- github.com/ethereum/go-ethereum/wiki/Managing-your-accounts

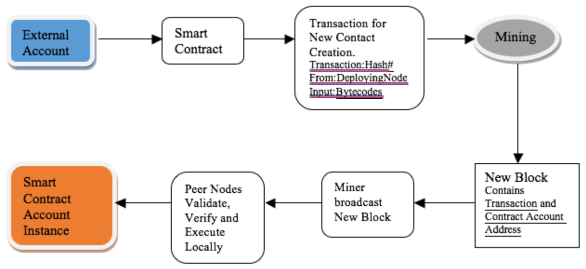
SMART CONTRACT CREATION

Smart Contracts contain the program codes to be executed, and are analogous to a C++, C#, or Java class. It contains:

- States variables
- Functions
- Events

FURTHER READING:
- solidity.readthedocs.io/en/develop/contracts.html?highlight=constructor#creating-contracts

Smart Contracts are compiled to bytecodes. These bytecodes are deployed as instances of Smart Contracts in the Ethereum Virtual Machine (EVM).

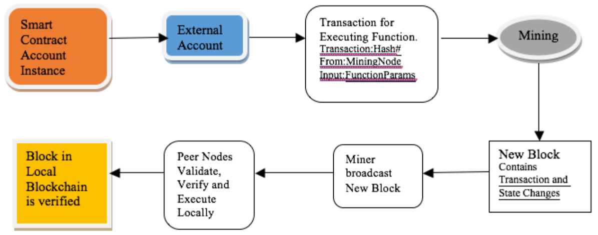


An instance of a Smart Contract is created by an External Account (or by the default account of the executing node):

- The creation process triggers a Transaction.
- The Transaction has to be mined to take effect. For example, later sections will show that you can check pending transactions using the API `eth.pendingTransactions()`.
- Mining is "competitively performed" by peer nodes. For example, later sections will show this by using the API `miner.start()`.
- On successful mining by a node, a new Block is created, which contains the Transaction and Contract Address.
- The mining node will broadcast the new Block to peer nodes.
- The new block will be validated and verified by peer nodes to be become an official block in their local blockchains.
- The new instance of the Smart Contract contains a unique address. This address must be saved, recorded, or registered. It will be retrieved for subsequent "contract execution."

SMART CONTRACT EXECUTION

A Smart Contract contains functions that can be executed by an External Account or a Decentralized Application (DAPP). In the case of a DAPP, the executing node would have a default External Account.


Smart Contract Account Instance
External Account
Transaction for Executing Function.
Transaction:Hash#
From:MiningNode
Input:FunctionParams
Mining
New Block
Contains
Transaction and
State Changes
Miner broadcast New Block
Peer Nodes Validate, Verify and Execute Locally
Block in Local Blockchain is verified

- To execute a function defined in the Smart Contract, the DAPP retrieves a unique instance of the Smart Contract by its address.
  E.g.
  ```
  > var address = 
  "0xc7caf784fae5840bdc893b03b7391fce6efb6190"
  ```
  ```
  > var myContract = eth.contract(abi).at(address)
  ```
- Functions that change the state(s) of a contract will trigger a Transaction.
  E.g.
  ```
  > myContract.setTimeIn("08:45")
  ```
- The Transaction has to be mined to take effect. For example, later sections will show that you can check pending transactions using the API `eth.pendingTransactions()`.
- Mining is "competitively performed" by peer nodes. For example, later sections will show this by using the API `miner.start()`.
- On successful mining by a node, a new Block is created, which contains the Transaction.
- The mining node broadcasts the new Block to peer nodes.
- The new block will be validated, verified, and its transaction executed locally by peer nodes to be become an official block in their local blockchains.

GETH

Geth is an implementation of a full Ethereum node written in the Go programming language. It is a command line process.

Automated builds are available for stable releases and the unstable master branch. Binary archives are published here.

You will be executing geth from the command line. Set your search PATH accordingly. For example, my geth was installed in a sub-directory, **geth-alltools-windows-amd64-1.6.5-cf87713d**. I set my path as:

```
set PATH=%PATH%;C:\dev\ethereum\geth-alltools-
windows-amd64-1.6.5-cf87713d
```

CREATING YOUR PRIVATE BLOCKCHAIN

Assuming our current working folder is C:\dev\ethereum, create the following 3 sub-folders:

- `C:\dev\ethereum\geth\data\00` ← This folder contains the default Genesis block data.
- `C:\dev\ethereum\geth\data\01` ← This is the folder for the first geth node.
- `C:\dev\ethereum\geth\data\02` ← This is the folder for the second geth node.

THE GENESIS BLOCK

The Genesis block is the root block, i.e. the first block in the blockchain.

The default genesis block can be provided in the form of a JSON file, as shown below.

Store the below JSON data in the file `C:\dev\ethereum\geth\data\00\DefaultGenesis.json`:

```
{
    "config":{
      "homesteadBlock":10
    },
    "nonce": "0x0000000000000042",
    "timestamp": "0x00",
    "parentHash": "0x00000000000000000000000000000000000000
    00000000000000000000000000",
    "extraData": "0x00",
    "gasLimit": "0x8000000",
    "difficulty": "0x400",
    "mixhash": "0x000000000000000000000000000000000000000
    000000000000000000000000",
    "coinbase": "0x33333333333333333333333333333333333333
    333",
    "alloc": {}
}
```

DATA DIRECTORIES

If your data directories are not yet created, create a data directory for each node in your private blockchain.

For instance, below are two data directories for two running nodes in one machine.

`C:\dev\ethereum\geth\data\01` ← This is the folder for the first geth node.

`C:\dev\ethereum\geth\data\02` ← This is the folder for the second geth node.

Each data directory will therefore store an individual node's blockchain data.

INITIALIZING THE DATA DIRECTORY

Before starting up the geth nodes, their data directories must be initialized.

Below are the command lines to initialize the nodes with the default genesis data.

To initialize node 1:

```
geth --datadir "C:\dev\ethereum\geth\data\01" init "C:\
dev\ethereum\geth\data\00\ DefaultGenesis.json"
```

To initialize node 2:

```
geth --datadir "C:\dev\ethereum\geth\data\02" init "C:\
dev\ethereum\geth\data\00\ DefaultGenesis.json"
```

STARTING GETH NODE INSTANCES

Below is the command line to start node 1. The default listening port is **30303**, and the default rpc port is **8545**. The **ipcpath** name must be a unique pipe name.

Note that **--rpc** and **--rpccorsdomain** must be specified. This is so that the geth node will accept the RPC protocol.

```
geth --datadir "C:\dev\ethereum\geth\data\01"
--ipcpath geth01 --nodiscover --networkid 1234 --rpc
--rpccorsdomain "*" console 2> "C:\dev\ethereum\geth\
data\01\console.log"
```

For node 2, the listening port **30304** and the **rpc port** must be explicitly specified.

```
geth --datadir "C:\dev\ethereum\geth\data\02" --ipcpath
geth02 --port 30304 --nodiscover --networkid 1234 --rpc
--rpcport 8546 --rpccorsdomain "*" console 2> "C:\dev\
ethereum\geth\data\02\console.log"
```

ATTACHING TO GETH NODE INSTANCES

With both nodes started up, they are running as a server process, waiting for events and commands to be executed. You should not interrupt the server process by entering commands in its console window. Instead, you should send commands to it from another client process.

This is achieved by starting another geth process as a client and connecting it to the geth server process.

Once attached, you can then send interactive commands to the server process. You can do this by first attaching your geth client to a geth server process.

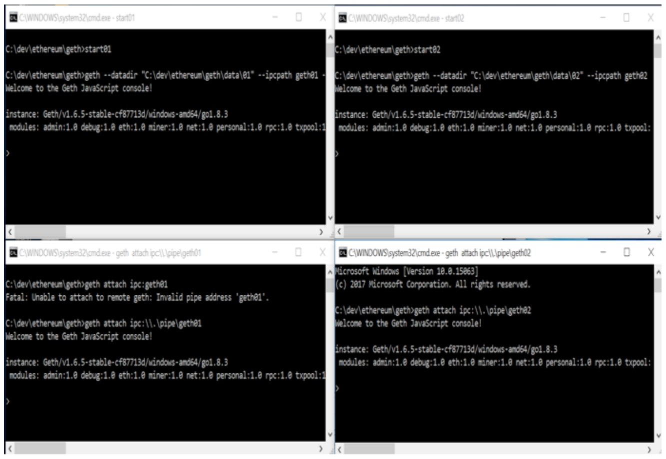
This command line attaches to geth node 1 via namepipe:

```
geth attach ipc:\\.\pipe\geth01
```

Attaching to geth node 2 via namepipe:

```
geth attach ipc:\\.\pipe\geth02
```

Below are four screenshots, where the top two console windows are geth server processes and the bottom two console windows are the geth clients.


C:\WINDOWS\system32\cmd.exe - start01
C:\WINDOWS\system32\cmd.exe - start02
C:\WINDOWS\system32\cmd.exe - geth attach ipc:\\.\pipe\geth01
C:\WINDOWS\system32\cmd.exe - geth attach ipc:\\.\pipe\geth02

```
C:\dev\ethereum\geth>start01

C:\dev\ethereum\geth>geth --datadir "C:\dev\ethereum\geth\data\01" --ipcpath geth01 -
Welcome to the Geth JavaScript console!

instance: Geth/v1.6.5-stable-cf87713d/windows-amd64/go1.8.3
 modules: admin:1.0 debug:1.0 eth:1.0 miner:1.0 net:1.0 personal:1.0 rpc:1.0 txpool:1

>
```

```
C:\dev\ethereum\geth>start02

C:\dev\ethereum\geth>geth --datadir "C:\dev\ethereum\geth\data\02" --ipcpath geth02
Welcome to the Geth JavaScript console!

instance: Geth/v1.6.5-stable-cf87713d/windows-amd64/go1.8.3
 modules: admin:1.0 debug:1.0 eth:1.0 miner:1.0 net:1.0 personal:1.0 rpc:1.0 txpool:

>
```

```
C:\dev\ethereum\geth>geth attach ipc:geth01
Fatal: Unable to attach to remote geth: Invalid pipe address 'geth01'.

C:\dev\ethereum\geth>geth attach ipc:\\.\pipe\geth01
Welcome to the Geth JavaScript console!

instance: Geth/v1.6.5-stable-cf87713d/windows-amd64/go1.8.3
 modules: admin:1.0 debug:1.0 eth:1.0 miner:1.0 net:1.0 personal:1.0 rpc:1.0 txpool:1

>
```

```
Microsoft Windows [Version 10.0.15063]
(c) 2017 Microsoft Corporation. All rights reserved.

C:\dev\ethereum\geth>geth attach ipc:\\.\pipe\geth02
Welcome to the Geth JavaScript console!

instance: Geth/v1.6.5-stable-cf87713d/windows-amd64/go1.8.3
 modules: admin:1.0 debug:1.0 eth:1.0 miner:1.0 net:1.0 personal:1.0 rpc:1.0 txpool:

>
```

ADDING PEER NODES MANUALLY

The two running nodes do not know each other even though we have specified that they are in the same network, with id 1234. For now, we are not bootstrapping nodes on startup, i.e. not configuring known static nodes on startup. We will add a peer node manually.

To get the node information of node 1, enter the function *admin.nodeInfo* from the node 1 client console:

```
> admin.nodeInfo
{
  enode: "enode://b71b3f6e23f33a07d30b862dd53f3364e46057b
85183b4d0d856a4f7…831ab@[::]:30303?discport=0",
```

To get the node information of node 2, enter the function admin.nodeInfo from the node 2 client console:

```
> admin.nodeInfo
{
  enode: "enode://
deb200d8ea9c67dd9675b920072145576311d20cb229e80e544…
eb7a131ee@[::]:30304?discport=0",
...
```

In node 1, you can add node 2 by using the *admin.addPeer* function by specifying the entire enode data of node 2 as below. This function will return "true":

```
>admin.addPeer("enode://
deb200d8ea9c67dd9675b920072145576311…b8eb7a131ee@
[::]:30304?discport=0")
true
>
```

Once added, both nodes will recognize each other. You can verify this using the admin.peers function.

From node 1:

```
> admin.peers
[{
    caps: ["eth/63"],
    id: "deb200d8ea9c67dd9675b920072145576311d20cb229e8
0e….3b9cbbf580ca261f85c3c642fbb7b8eb7a131ee",
```

From node 2:

```
> admin.peers
[{
    caps: ["eth/63"],
    id: "b71b3f6e23f33a07d30b862dd53f3364e46057b85183b4…
db399c0c227ec9158512a5a8e2d883efab7831ab",
```

ADD A NEW ACCOUNT

We have to add our first account to the blockchain of node 1 so that the account can be used for executing transactions. This is the External account, owned by a person.

From node 1, enter the function personal.newAccount and provide your password. This function will return the address of the newly created account.

```
> personal.newAccount(<".....you password here.....">)
"0x4799c873f6574b299854bfd831ae99ad2e664e30"
```

The string of numbers and letters is the address of the new account in node 1.

Important: There is no way to restore your account if you forget your password. Never forget your password. Keep it in a safe place, and do not store it on your machine.

EVENTUAL CONSISTENCY

Below is a demonstration of eventual consistency between the two nodes.

Start mining on node 1 by using the function miner.start(1), where 1 refers to the number of threads. Note that the miner.start(n) function will always return "null." Unless you have many CPU cores, keep the thread number low to avoid high CPU usage. Note that mining without any pending transaction can still earn your default account incentive (ETH). It creates empty blocks, thus strengthening the integrity of the blockchain tree.

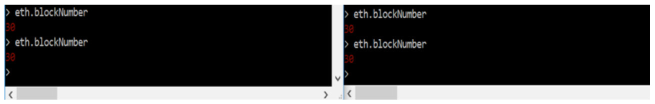
```
> miner.start(1)
null
> eth.blockNumber
8
> eth.blockNumber
8
> eth.blockNumber
9
> eth.blockNumber
10
...
```

Stop mining on node 1 by using the function *miner.stop()*. This function returns "true":

```
> miner.stop()
true
```

Both nodes will have the same number of blocks in their blockchain.

From either node, as shown below, you can query the number of blocks by using the function `eth.blockNumber`.



```
> eth.blockNumber
30
> eth.blockNumber
30
>
```

```
> eth.blockNumber
30
> eth.blockNumber
30
>
```

Both nodes will get the same block per block number, e.g. hash shown below, being mined by node 1:

```
> eth.getBlock(30)
{
  difficulty: 132864,
  extraData:
"0xd983010605846765746887676f312e382e338777696e646f7773",
  gasLimit: 130340787,
  gasUsed: 0,
  hash: "0xab2afb75d7082e0f62432ed518e6596643e158343c83a
f4a6b20f60a08480f75",
  logsBloom: "0x00000000000000000000000000000000…00000
0000000000000000000000000000000000000000",
  miner: "0x4799c873f6574b299854bfd831ae99ad2e664e30",
```

Alternatively, you can pass in the last block number to the *eth.getBlock* function and get the miner address directly:

```
> eth.getBlock(eth.blockNumber).miner
"0x4799c873f6574b299854bfd831ae99ad2e664e30"
```

For any node to start mining, it requires an external account.

Hence, we now add a new external account in node 2's client console:

```
> personal.newAccount(<"…your password here…">)
"0x5be060fa31a851a20a4739dc8d45619f6d292461"
```

The string of numbers and letters is the address of the new account in node 2. Once again, there is no way to restore your account if you forget your password. Keep it in a safe place, not stored on your machine.

Node 2 can start mining as per node 1. Effectively, both nodes can now compete to mine new blocks.

While both nodes have been issued the *miner.start(1)* function, you can query the last block's miner from either the node 1 client or node 2 client console:

```
> eth.getBlock(eth.blockNumber).miner
"0x5be060fa31a851a20a4739dc8d45619f6d292461"
← mined by node 2 account
> eth.getBlock(eth.blockNumber).miner
"0x5be060fa31a851a20a4739dc8d45619f6d292461"
> eth.getBlock(eth.blockNumber).miner
"0x5be060fa31a851a20a4739dc8d45619f6d292461"
> eth.getBlock(eth.blockNumber).miner
"0x4799c873f6574b299854bfd831ae99ad2e664e30"
←  mined by node 1 account
> eth.getBlock(eth.blockNumber).miner
"0x4799c873f6574b299854bfd831ae99ad2e664e30"
```

FURTHER READING:

- github.com/ethereum/go-ethereum/wiki/Private-network

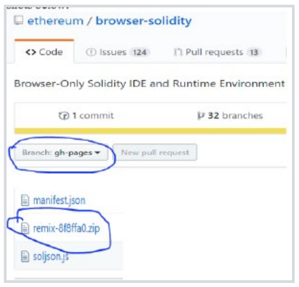
BROWSER-SOLIDITY: PREPARING YOUR FIRST SMART CONTRACT

Solidity is the programming language used to write smart contract codes.

Browser-Solidity is a Web IDE environment to write smart contract codes, as well as compile and deploy them to your geth nodes.

You can download the built version from github.com/ethereum/browser-solidity.

From the Branch drop-down button, select "gh-pages" and download the zip file. See the screen shots below.



BUILDING BROWSER-SOLIDITY FROM SOURCE

You may want to build Browser-Solidity if you find that the above downloaded zip does not work as expected. For example, there was a bug concerning "Gas Limit" and the fix may not have made it to the published zip file. The latest source would have contained the fix.

I manually built from the master by following the README.md instructions in the Master Branch.

The pre-requisites to build are to have npm and Node.js installed on your machine.

Refer to docs.npmjs.com/getting-started/installing-node, and then the following steps (assuming my working directory is C:\dev\ethereum):

- `git clone https://github.com/ethereum/browser-solidity`
- `cd browser-solidity`
- `npm install` - fetches dependencies and executes `npm run prepublish` to build the application.

STARTING BROWSER-SOLIDITY

To start Browser-Solidity, run `npm start` and open `http://127.0.0.1:8080` in your browser as shown below (assuming Browser-Solidity has been git cloned and built in the directory C:\dev\ethereum\browser-solidity):

```
cd C:\dev\ethereum\browser-solidity

C:\dev\ethereum\browser-solidity>npm start
> browser-solidity@0.0.0 start C:\dev\ethereum\browser-
solidity
> npm-run-all -lpr serve watch onchange

[serve    ]
[serve    ] > browser-solidity@0.0.0 serve C:\dev\
ethereum\browser-solidity
[serve    ] > execr --silent http-server .
...
[onchange] > browser-solidity@0.0.0 lint C:\dev\ethereum\
browser-solidity
[onchange] > standard | notify-error
[onchange]
[onchange] standard: Use JavaScript Standard Style
(http://standardjs.com)
[onchange]   C:\dev\ethereum\browser-solidity\src\app.
js:61:7: 'settingsView' is assigned a value but never
used.
[onchange]   C:\dev\ethereum\browser-solidity\src\
universal-dapp.js:287:5: Move function declaration to
function body root.
```

Now open `http://127.0.0.1:8080` in your browser.

Alternatively, you can also open `C:\dev\ethereum\browser-solidity\index.html` directly in your browser.

YOUR FIRST SMART CONTRACT

This section describes the steps to write and deploy a simple smart contract to node 1.

A sample code of a Solidity smart contract named `BillPayment.sol` is given below. You can save it locally and open it from Browser-Solidity.

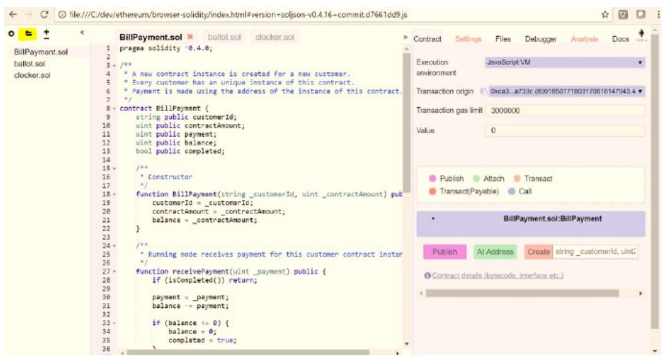
```
pragma solidity ^0.4.0;

/**
 * A new contract instance is created for a new customer.
 * Every customer has an unique instance of this
contract.
 * Payment is made using the address of the instance of
this contract.
 */
contract BillPayment {
    string public customerId;
      uint public contractAmount;
      uint public payment;
      uint public balance;
      bool public completed;

    /**
     * Constructor
     */
    function BillPayment(string _customerId, uint _
contractAmount) public {
        customerId = _customerId;
         contractAmount = _contractAmount;
         balance = _contractAmount;
    }

    /**
     * Running node receives payment for this customer
contract instance.
    */
    function receivePayment(uint _payment) public {
        if (isCompleted()) return;

  payment = _payment;
         balance -= payment;

         if (balance <= 0) {
               balance = 0;
               completed = true;
         }
    }

    /**
     * Get the customer ID.
     */
    function getCustomerId() constant returns (string) {
        return customerId;
    }

    /**
     * Get the contract amount.
     */
    function getContractAmount() constant returns (uint)
{
        return contractAmount;
    }

    /**
     */
    function getPayment() constant returns (uint) {
        return payment;
    }

    /**
     * Indicates if contract is fully received.
     */
    function isCompleted() constant returns (bool) {
      return completed;
    }
}
```

FURTHER READING:

- solidity.readthedocs.io/en/develop/introduction-to-smart-contracts.html

DEPLOY YOUR FIRST SMART CONTRACT

Open the `BillPayment.sol` smart contract code file from Browser-Solidity using the file open icon. Please note that you will need to be connected to the Internet, because Browser-Solidity will attempt the retrieve the latest solidity compiler.

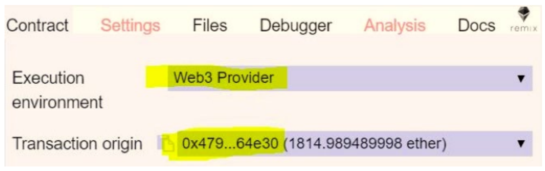

file:///C:/dev/ethereum/browser-solidity/index.html#version=soljson-v0.4.16+commit.d7661dd9.js

BillPayment.sol ballot.sol clocker.sol

```
pragma solidity ^0.4.0;

/**
 * A new contract instance is created for a new customer.
 * Every customer has an unique instance of this contract.
 * Payment is made using the address of the instance of this contract.
 */
contract BillPayment {
    string public customerId;
    uint public contractAmount;
    uint public payment;
    uint public balance;
    bool public completed;

    /**
     * Constructor
     */
    function BillPayment(string _customerId, uint _contractAmount) pub
        customerId = _customerId;
        contractAmount = _contractAmount;
        balance = _contractAmount;
    }

    /**
     * Running node receives payment for this customer contract instar
     */
    function receivePayment(uint _payment) public {
        if (isCompleted()) return;

        payment = _payment;
        balance -= payment;

        if (balance <= 0) {
            balance = 0;
            completed = true;
```

Execution environment: JavaScript VM
Transaction origin: 0xca3...a733c (8301850771803170616147543.4
Transaction gas limit: 3000000
Value: 0

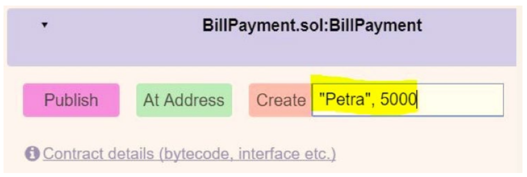
To deploy the smart contract to node 1, change the Execution environment drop-down selection to “Web3 Provider” as shown below. Accept the default Web3 Provider endpoint as localhost:8545


Execution environment: Web3 Provider
Transaction origin: 0x479...64e30 (1814.989489998 ether)

Once switched, it uses the first account address for transaction execution (see Transaction origin).

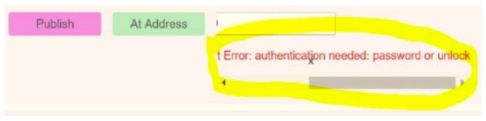
CREATE YOUR FIRST SMART CONTRACT INSTANCE

Our BillPayment smart contract constructor requires two parameters: the _customerId string and _contractAmount integer. To create an instance, you can provide these values in the textbox shown below, then click on the Create button.


"Petra", 5000

BillPayment.sol:BillPayment
Publish
At Address
Create
Contract details (bytecode, interface etc.)

Notice the authentication Error message as displayed below. To create a new instance, you will have to provide the account address and its password.


Error: authentication needed: password or unlock

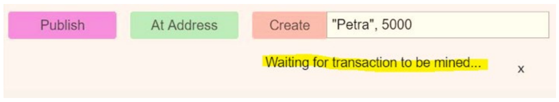
From the node 1 client console, enter `eth.accounts`. This function will return a list of accounts, which we created earlier (in this case, we created only one external account).

```
> eth.accounts
["0x4799c873f6574b299854bfd831ae99ad2e664e30"]
```

We will unlock this account with its password in quotes " " using the `personal.unlockAccount` function.

```
> personal.unlockAccount(eth.accounts[0], <"...your
password...">)
true
```

Once unlocked, click on the Create button again.



Waiting for transaction to be mined...

Now the new message "Waiting for transaction to be mined..." appears. Although our geth server processes for node 1 and node 2 are up and running, they are not actively mining any transaction(s). You can pass in parameters when starting the geth server so that mining threads are also started automatically.

To better understand blockchain mechanisms, we will do this manually and interactively. Follow the next section on "Mining your first Blockchain Transaction."

MINING YOUR FIRST BLOCKCHAIN TRANSACTION

This section will describe the steps to mine a blockchain transaction manually.

First, let's query our pending transaction using the `eth.pendingTransactions` function.

From the node 1 client console, enter `eth.pendingTransactions`. It will return a list of transactions:

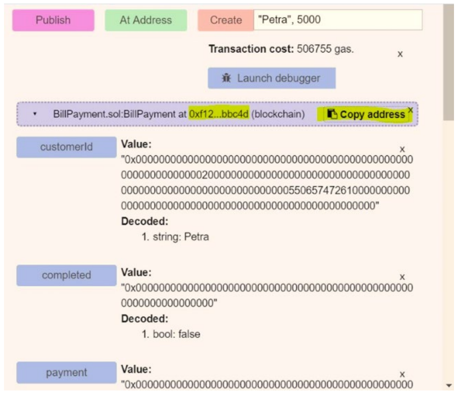
```
> eth.pendingTransactions
[{
    blockHash: null,
    blockNumber: null,
    from: "0x4799c873f6574b299854bfd831ae99ad2e664e30",
    gas: 506756,
    gasPrice: 18000000000,
    hash: "0xf325f2a174571511329752367 34bb8c6a0f387c9fe
    ee4e05c325a7f99afa14fe",
    input: "0x6060604052341561000f57600080fd5b604051610
    6a03803806106a083398101…46101bc5780639d9…",
    nonce: 16,
    r: "0xf3800b099aaad5a4197eaca1dbff0dcc16b9ddc0f46a95
    bdd591ac4698bd8be9",
    s: "0x884d4e4995beedb7844b4a7060c24c917804f54597d2fc
    e02f3f6e82a71c55a",
    to: null,
    transactionIndex: 0,
    v: "0x1b",
    value: 0
}]
>
```

Now enter `miner.start(1)`, where 1 is the number of threads used for mining transactions.

Query `eth.pendingTransactions` again. If it returns an empty list [], it means the above transaction has been mined. Issue the `miner.stop()` function to stop mining.

```
> miner.start(1)
null
…
> eth.pendingTransactions
[]
> miner.stop()
true
```

Notice that Browser-Solidity will refresh, with the BillPayment contract address displayed (see highlight below).



Transaction cost: 506755 gas.

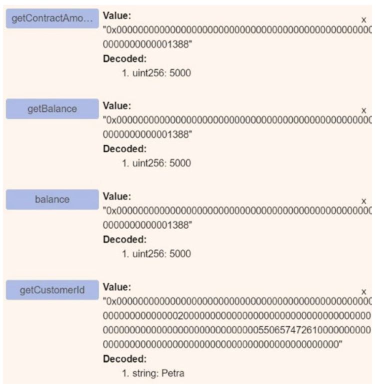
BillPayment.sol:BillPayment at 0xf12...bbc4d (blockchain)

```
customerId
Value:
"0x0000000000000000000000000000000000000000000000
00000000000002000000000000000000000000000000000
00000000000000000000000000055065747261000000000
0000000000000000000000000000000000000000000"
Decoded:
    1. string: Petra

completed
Value:
"0x0000000000000000000000000000000000000000000000
000000000000000"
Decoded:
    1. bool: false

payment
Value:
"0x0000000000000000000000000000000000000000000000
```

Again, we are doing these steps manually to demonstrate the procedures involved.

The first thing to do is to click on the 'Copy address' button to copy the Contract address "0xf125233002884fd827947d21b1fa377d4b6bbc4d." **Save this address in a text file for later use.**

In Browser-Solidity, scroll until you see that the values of the contract instance properties initialized (as shown below).



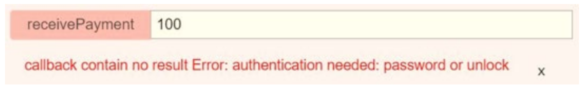
```
getContractAmo...
Value:
"0x0000000000000000000000000000000000000000000000000
0000000000001388"
Decoded:
    1. uint256: 5000

getBalance
Value:
"0x0000000000000000000000000000000000000000000000000
0000000000001388"
Decoded:
    1. uint256: 5000

balance
Value:
"0x0000000000000000000000000000000000000000000000000
0000000000001388"
Decoded:
    1. uint256: 5000

getCustomerId
Value:
"0x0000000000000000000000000000000000000000000000000
00000000000002000000000000000000000000000000000
00000000000000000000000000055065747261000000000
0000000000000000000000000000000000000000000"
Decoded:
    1. string: Petra
```

CHANGING THE STATE OF A CONTRACT INSTANCE

Let us now try to change or update the state data of our contract instance.

Our BillPayment contract has a *receivePayment* function that accepts an integer amount.

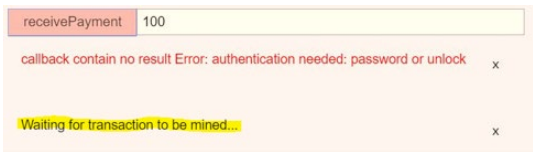
From Browser-Solidity, scroll to the *receivePaymen*t function and enter 100 in its textbox and click on the function button.



callback contain no result Error: authentication needed: password or unlock

An authentication error is displayed again because changing the state of a smart contract instance will trigger a new transaction. You can unlock the account using the function personal.`unlockAccount` again (refer to the section, “Create Your Smart First Contract Instance”).

```
> personal.unlockAccount(eth.accounts[0], <"...your
password...">)
true
```



receivePayment 100

callback contain no result Error: authentication needed: password or unlock ×

Waiting for transaction to be mined... ×

Upon successfully unlocking your account, there is a transaction waiting to be mined again (see highlighted message above).

From the node 1 client console, you can query the pending transaction as shown:

```
> eth.pendingTransactions
[{
    blockHash: null,
    blockNumber: null,
    from: "0x4799c873f6574b299854bfd831ae99ad2e664e30",
    gas: 47193,
    gasPrice: 18000000000,
    hash: "0x2c3f24e19b8efb0c4d85705392f45bdf07c32492b72
    ab566c8c9feee31a8ced0",
    input: "0xe2eab48300000000000000000000000000000000000
    0000000000000000000000000064",
    nonce: 17,
    r: "0x91b6ac27df4d9ef372e1d28287e9f5f636fce6a62b23a01
    5b0be9a98c41b83a",
    s: "0x6b148b18a7bfc814c3440757a7d8095fdf30821013fed8d
    35427f0e638a8732a",
    to: "0xf125233002884fd827947d21b1fa377d4b6bbc4d",
    transactionIndex: 0,
    v: "0x1c",
    value: 0
}]
true
```

To mine the transaction, enter the `miner.start(1)` function. Once successfully mined, stop the mining using `miner.stop()`.

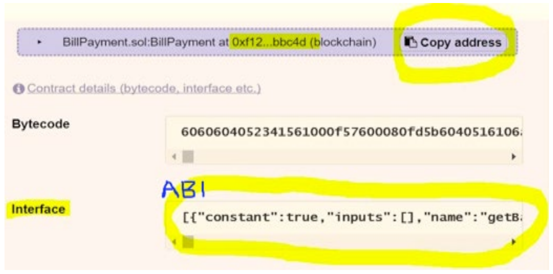
```
> miner.start(1)
…
> eth.pendingTransactions
[]
> miner.stop()
```

RETRIEVING AN INSTANCE OF A CONTRACT

You have created an instance of a smart contract in Browser-Solidity. This section describes how you can retrieve it to query or update its state values.

Previously, at the end of “Mining Your First Blockchain Transaction,” you copied the address of the contract (e.g. in my example, the contract address is “0xf125233002884fd827947d21b1fa377d4b6bbc4d”).

In Browser-Solidity, scroll to the section below.



BillPayment.sol:BillPayment at 0xf12...bbc4d (blockchain) Copy address

Contract details (bytecode, interface etc.)

Bytecode 6060604052341561000f57600080fd5b6040516106

ABI

Interface [{"constant":true,"inputs":[],"name":"getB

From the **Interface** textbox, copy the **ABI**.

ABI stands for Application Binary Interface. This is the interface between solidity contracts and the EVM (Ethereum Virtual Machine). The interface contains the properties and method signatures of a contract.

You can retrieve the contract instance using the **contract address** and its **ABI**.

From the node 1 client console, paste the ABI to a variable shown below.

```
> var abi
[{"constant":true,"inputs":[],"name":"getBalance",
"outputs
……………………
…:"nonpayable","type":"constructor"}]
```

Set the address variable from your copied/saved contract address.

```
> var myContractAddr =
"0xf125233002884fd827947d21b1fa377d4b6bbc4d"
Undefined
```

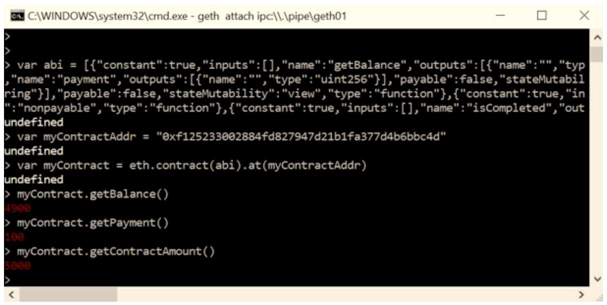
Now, retrieve your contract using the below functions.

```
> var myContractAddr =
"0xf125233002884fd827947d21b1fa377d4b6bbc4d"
Undefined
```

Finally, you can query the states of your contract instance as shown below. Note that read-only functions do not create any transactions as they do not change state.

```
> myContract.getBalance()
4900
> myContract.getPayment()
100
> myContract.getContractAmount()
5000
```

The screenshot below shows the function statements in the node 1 client console in its entirety.



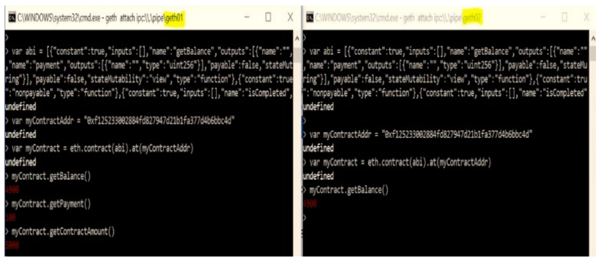
```
C:\WINDOWS\system32\cmd.exe - geth  attach ipc:\\.\pipe\geth01
>
>
> var abi = [{"constant":true,"inputs":[],"name":"getBalance","outputs":[{"name":"","typ
,"name":"payment","outputs":[{"name":"","type":"uint256"}],"payable":false,"stateMutabil
ring"}],"payable":false,"stateMutability":"view","type":"function"},{"constant":true,"in
":"nonpayable","type":"function"},{"constant":true,"inputs":[],"name":"isCompleted","out
undefined
> var myContractAddr = "0xf125233002884fd827947d21b1fa377d4b6bbc4d"
undefined
> var myContract = eth.contract(abi).at(myContractAddr)
undefined
> myContract.getBalance()
4900
> myContract.getPayment()
100
> myContract.getContractAmount()
5000
>
```

CREATE A TRANSACTION FROM ANOTHER NODE

This section describes and demonstrates that mining nodes in your private blockchain network is synchronized and that it competes for mining transactions. Again, we will show this manually by:

- Creating a transaction from node 2.
- Mining the transaction from node 1.
- Verifying the result from node 2.

From both the node 1 and node 2 client consoles, which are attached to their respective server processes, enter the command functions shown in the screenshot below.



```
C:\WINDOWS\system32\cmd.exe - geth  attach ipc:\\.\pipe\geth01
>
> var abi = [{"constant":true,"inputs":[],"name":"getBalance","outputs":[{"name":"",
,"name":"payment","outputs":[{"name":"","type":"uint256"}],"payable":false,"stateMut
ring"}],"payable":false,"stateMutability":"view","type":"function"},{"constant":true
":"nonpayable","type":"function"},{"constant":true,"inputs":[],"name":"isCompleted",
undefined
> var myContractAddr = "0xf125233002884fd827947d21b1fa377d4b6bbc4d"
undefined
> var myContract = eth.contract(abi).at(myContractAddr)
undefined
> myContract.getBalance()
4900
> myContract.getPayment()
100
> myContract.getContractAmount()
5000
```

```
C:\WINDOWS\system32\cmd.exe - geth  attach ipc:\\.\pipe\geth02
>
> var abi = [{"constant":true,"inputs":[],"name":"getBalance","outputs":[{"name":""
,"name":"payment","outputs":[{"name":"","type":"uint256"}],"payable":false,"stateMu
ring"}],"payable":false,"stateMutability":"view","type":"function"},{"constant":tru
":"nonpayable","type":"function"},{"constant":true,"inputs":[],"name":"isCompleted"
undefined
>
> var myContractAddr = "0xf125233002884fd827947d21b1fa377d4b6bbc4d"
undefined
> var myContract = eth.contract(abi).at(myContractAddr)
undefined
> myContract.getBalance()
4900
>
```

Both nodes retrieve the same instance of a smart contract, and both nodes have the same contract balance amount (using the `getBalance()` function).

CREATE A TRANSACTION FROM NODE 2

We use node 2 to receive a payment of 200 via the smart contract function, `receivePayment()`. Note that the `receivePayment()` function can accept a **second parameter** for the account address that is used to create this transaction. (Note that you can also set `web3.eth.defaultAccount = "<…account address…>"`, after which you can just call `receivePayment`(200) with one parameter.)

The authentication error is highlighted and we resolve it by unlocking the account with its password.

```
> myContract.receivePayment(200, {from:eth.accounts[0]})
Error: authentication needed: password or unlock
    at web3.js:3104:20
    at web3.js:6191:15
    at web3.js:5004:36
    at web3.js:4061:16
    at apply (<native code>)
    at web3.js:4147:16
    at <anonymous>:1:1

> personal.unlockAccount(eth.accounts[0], <"...your
password...">)
true
```

We call the *receivePayment()* function again, and this time it successfully returns a transaction hash value, "**0x42…**," as shown below.

```
> myContract.receivePayment(200, {from:eth.accounts[0]})
"0x42bdf8d4ee6bc3ad7189989c0b266cdea9695a0865b10ecf6348
f3493d5ab69c"
>
```

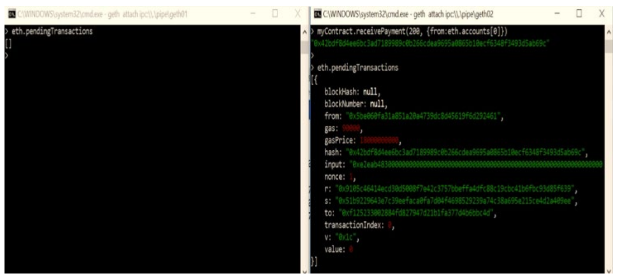
You can verify this transaction hash by looking at the hash value from the pending transactions.

```
> eth.pendingTransactions
[{
    blockHash: null,
    blockNumber: null,
    from: "0x5be060fa31a851a20a4739dc8d45619f6d292461",
    gas: 90000,
    gasPrice: 18000000000,
    hash:
"0x42bdf8d4ee6bc3ad7189989c0b266cdea9695a0865b10ecf6348
f3493d5ab69c",
    input: "0xe2eab48300000000000000000000000000000000000
00000000000000000000000000c8",
    nonce: 1,
    r: "0x9105c46414ecd30d5008f7e42c3757bbeffa4dfc88c19
cbc41b6fbc93d85f639",
    s: "0x51b9229643e7c39eefaca0fa7d04f4698529239a74c38
a695e215ce4d2a409ee",
    to: "0xf125233002884fd827947d21b1fa377d4b6bbc4d",
    transactionIndex: 0,
    v: "0x1c",
```

Node 2 has now created the transaction, and is waiting to be mined.

MINE THE TRANSACTION FROM NODE 1

Since the transaction is created by node 2, it is pending only on node 2, not node 1. The screenshot below demonstrates this.



```
C:\WINDOWS\system32\cmd.exe - geth  attach ipc:\\.\pipe\geth01
> eth.pendingTransactions
[]
>
```

```
C:\WINDOWS\system32\cmd.exe - geth  attach ipc:\\.\pipe\geth02
> myContract.receivePayment(200, {from:eth.accounts[0]})
"0x42bdf8d4ee6bc3ad7189989c0b266cdea9695a0865b10ecf6348f3493d5ab69c"
>
> eth.pendingTransactions
[{
    blockHash: null,
    blockNumber: null,
    from: "0x5be060fa31a851a20a4739dc8d45619f6d292461",
    gas: 90000,
    gasPrice: 18000000000,
    hash: "0x42bdf8d4ee6bc3ad7189989c0b266cdea9695a0865b10ecf6348f3493d5ab69c",
    input: "0xe2eab4830000000000000000000000000000000000000000000000000000000000000
    nonce: 1,
    r: "0x9105c46414ecd30d5008f7e42c3757bbeffa4dfc88c19cbc41b6fbc93d85f639",
    s: "0x51b9229643e7c39eefaca0fa7d04f4698529239a74c38a695e215ce4d2a409ee",
    to: "0xf125233002884fd827947d21b1fa377d4b6bbc4d",
    transactionIndex: 0,
    v: "0x1c",
    value: 0
}]
```

However, any node in the same private blockchain network can compete to mine the transaction. To demonstrate this, we let node 1 do the mining by issuing `miner.start(1)` on node 1.

```
> miner.start(1)
null
```

VERIFY THE RESULTS USING NODE 2

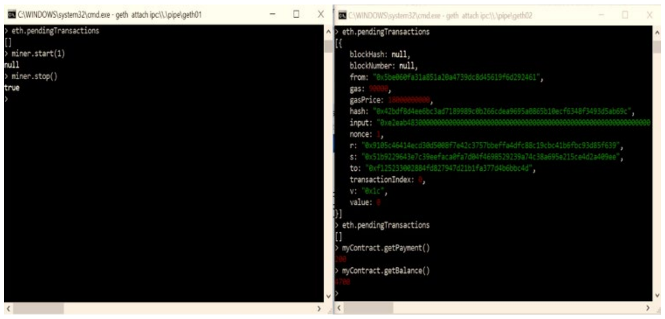
Once node 1 has mined the transaction, we can verify the result in node 2.

From the node 2 client console, we check that its pending transaction is gone (check again by using eth.pendingTransactions), and we verify the expected values of the last payment and remaining balance of our contract (using our smart contract functions getPayment() and getBalance() respectively) are indeed correct.

```
> eth.pendingTransactions
[{
    blockHash: null,
    blockNumber: null,
    from: "0x5be060fa31a851a20a4739dc8d45619f6d292461",
    gas: 90000,
    gasPrice: 18000000000,
    hash: "0x42bdf8d4ee6bc3ad7189989c0b266cdea9695a0865
b10ecf6348f3493d5ab69c",
    input: "0xe2eab483000000000000000000000000000000000
000000000000000000000000000c8",
    nonce: 1,
    r: "0x9105c46414ecd30d5008f7e42c3757bbeffa4dfc88c
 19cbc41b6fbc93d85f639",
    s: "0x51b9229643e7c39eefaca0fa7d04f4698529239a74c
38a695e215ce4d2a409ee",
    to: "0xf125233002884fd827947d21b1fa377d4b6bbc4d",
    transactionIndex: 0,
    v: "0x1c",
    value: 0
}]
> eth.pendingTransactions
[]
> myContract.getPayment()
200
> myContract.getBalance()
4700
>
```

TIP: For any other node to mine a transaction, admin.peers must reflect the nodes are in the same network. If you have re-started your system, use admin.addPeer to add your node to the current peer again.

The final screenshot below shows node 1 and node 2 in their entirety.



```
C:\WINDOWS\system32\cmd.exe - geth attach ipc:\\.\pipe\geth01
> eth.pendingTransactions
[]
> miner.start(1)
null
> miner.stop()
true
>
```

```
C:\WINDOWS\system32\cmd.exe - geth attach ipc:\\.\pipe\geth02
> eth.pendingTransactions
[{
    blockHash: null,
    blockNumber: null,
    from: "0x5be060fa31a851a20a4739dc8d45619f6d292461",
    gas: 90000,
    gasPrice: 18000000000,
    hash: "0x42bdf8d4ee6bc3ad7189989c0b266cdea9695a0865b10ecf6348f3493d5ab69c",
    input: "0xe2eab4830000000000000000000000000000000000000000000000000000000000
    nonce: 1,
    r: "0x9105c46414ecd30d5008f7e42c3757bbeffa4dfc88c19cbc41b6fbc93d85f639",
    s: "0x51b9229643e7c39eefaca0fa7d04f4698529239a74c38a695e215ce4d2a409ee",
    to: "0xf125233002884fd827947d21b1fa377d4b6bbc4d",
    transactionIndex: 0,
    v: "0x1c",
    value: 0
}]
> eth.pendingTransactions
[]
> myContract.getPayment()
200
> myContract.getBalance()
4700
>
```

SUMMARY

Read-only function calls do not create new Transactions. These functions do not change the state(s) of the contract instance. Therefore, as long as nodes have the address of the contract instance, they can call as many times as they want to retrieve the states.

Functions that change the state(s) of the contract instance require Transactions. Each invocation will create a new Transaction, waiting to be mined. Once mined, the new Block is broadcast. Peer nodes will validate and execute it to update its local blockchain.

This is yet another take on "distributed transactions," or in our case, ***a distributed-deferred-transaction with eventual consistency***. All mining nodes will have the same copy of distributed ledgers.

ABOUT THE AUTHOR

SEBASTIAN L.K. MA has been a software craftsman in Singapore and Germany. Having been through the trenches in software development and designing service oriented architecture for distributed systems in C++, Java, C#, and Erlang, Sebastian still enjoys hands-on technical roles. Blockchain and Smart Contracts have added a positive revolution on decentralization and Sebastian now plays multiple roles as Blockchain researcher, designer and developer at TNO.