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Blockchain Documentation

Brief description of our project

The aim of our work was to create a recent security mechanism, which is more and more used in the computing universe, known as the blockchain. In this project, we put in place algorithms and security measures, which will prevent data from being modified by other users or anyone. We are also going to put in place a user interface to enable us to perform certain operations on our blockchain. These operations are described more in details below.

Important variables

For a better comprehension of this documentation, here are important variables and data structure names used in our code.

1. Blockchain: Our list of chains
2. Open transactions: The transactions not yet mined
3. Public key: The public key of node
4. Private key: The private key of a node
5. Signature: The signature of a node

NB: A node is a member of our blockchain network

The 10 essential functions

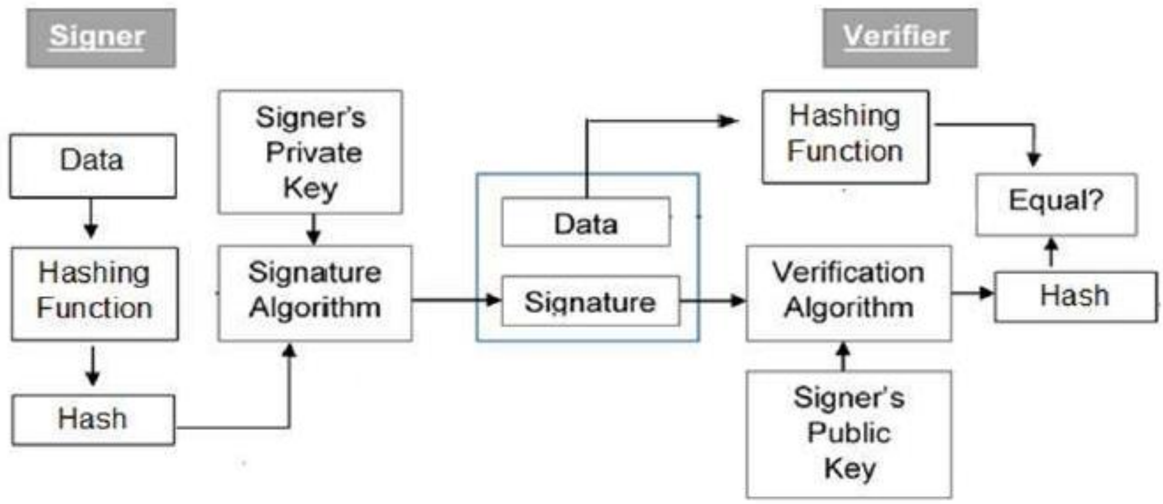
In the following, there is a list of important and crucial functions to our blockchain, listed in a chronological order, so that the lecturer can better understand what is being done.

1. **Hash_block :** The hash_block function is the function responsible to hash our blocks. After adding the different transactions, they are stored in the open_transactions list and need to be added to the blockchain (during the mining process). This function makes use of the **hashlib** package of python and the **SHA256** hashing method**.** The **sha256** creates a 64 character hash. Values accepted are just strings. So, since the block is a dictionary, we can convert it to a string with the **JSON** method, which is imported from the **JSON** package of python. JSON encodes objects and data structures as a string. The **Encode()** method is used to ensure that the string is converted in UTF-8. The hash generated is not a string, but a byte hash. The **hexdigest()** method returns the string version of the hash.

Syntax: hashlib.sha256(json.dumps(block).encode())

Note: We are not using a hash because we want to hide the data. The data must be publicly available and read from anyone. We use the hash in order to store a large amount of data in a small amount of space.

- **Generate_keys:** Each member in our blockchain is called a Node. These Nodes need identifiers in order to be identified on the node. They also need public and private keys in order to be able to sign a transaction as described below. Pycryptodome is an external module used to generate private and public keys. It is not shipped with python but it can be installed using either pip or anaconda. We are going to generate our public and private keys using the RSA algorithm. To import this package, we type: from Crypto.PublicKey import RSA. We also import a package that will generate a random number such as randint of python. The private key is generated randomly with the **RSA.generate()** method of the RSA class which takes the wished length of the key and a random number as parameters and the public key is calculated from the randomly generated private key using the **public_key()** function of **pycryptodome**.
- **Sign_transaction:** When new transactions are added, they are stored in a list waiting to be mined in order to be added in the blockchain. During this time, they can be hacked and modified since there are no security measures on it. In order to prevent this, the transactions are signed by the sender by the time it is emitted. The algorithm used to generate these signatures is PKCS1_v1_5 from the package pycryptodome. A digital signature is a key generated from some data (the data we wish to keep authentic) and a key known only by the user (private key).



Since we need data and a key that just the user knows, these data will be the combinations of the sender's id, amount sent and recipient's id. The key will be the private key. Here in creating the signatures, we actually do the reverse operation of when we generate a key in order to have the private key in binary form. After having generated the signature, we add this to the transaction dictionary as a data of the transaction.

- **Verify_signature:** Since the signature is used as a security measure, it needs to be verified when this is necessary, like when we add a new transaction. To verify the signatures, there exists a verify method of the pycryptodome package which takes in as parameters the hash of the data used and the binary version of the transaction's signature. So, this function gets the value of the public key of our node and convert it from string to binary data. It also gets the signature of the transaction and the other values that where used **sign_transaction** to generate this signature. The **verify** method of the **pycryptodome** package is used and these data are passed as argument. This function returns True if the transaction is correct and False if it was being modified.
- **Mine_block:** Mining blocks should be challenging, i.e, it must require a great amount of time. This is:
  - To control the rate at which new groups of transactions (blocks) are added to the network.
  - For security. The comparism of the hash of the previous block and the current block was already a security measure, but it is still possible to overcome it by changing the data in a block and adjust the hash of subsequent blocks so that it can accept the modification. The prove of work basically prevents this because the modifications of just one of the blocks will require a great amount of time and computing power to recalculate the proof.

This function starts by verifying if we have an owner. If it is the case, it verifies if the transactions in the open transactions are correct. This is with the help of **verify_signature**. If it is again the case, the proof is then calculated by using the **proof_of_work_rec** function and its value is added to the block's field, **proof.** When everything is done successfully, we empty the open transactions list and return True but if something goes wrong, we return False.

- **Proof_of_work_env:** Proof_of_work_env is our recursive function. It is used to protect the chain against a mass attack as described above. This function is an envelop function which returns **Proof_of_work.** The function proof_of_work() is recursive. This function initializes a variable proof with 0 and calls **valid_proof** recursively and each time increments proof until it returns True. What does **valid_proof** does? Valid_proof concatenates the open transactions, the last hash and the proof variable and returns the hash of the string formed. The two first values of this hash are verified, and we check if it's equal to two zeros, three or four depending on the time we want the mining process to take. When our condition is satisfied, we return True and when not, we return False. The **proof** number generated by **proof_of_work** is used to verify a block. This verification method is described below

- **Verify chain:** In order to mine a block, we should ensure that the chain we are having is valid. This is verified with the **verify_chain()** method. This method goes through every block in the blockchain and for each block, it concatenates the transactions in this block with the previous hash and the proof stored in the block. If this concatenated chain generates a hash with two, three, four or more leading zeros depending on our decided condition, then, this block is valid.
- **Load_keys() and load_data():** As described above, we have different data for our blockchain. These data are the blockchain, the open transactions, the public and private keys. When a new node is being added on the blockchain, we need to generate keys for them and initialize the blockchain and the open transaction list. This function is responsible for this and is made up of an error handling method. In the **try** block of these functions, we try to have access to the files called **wallet** for the function **load_keys()** and **blockchain** for the **load_data()** function which are stored on the server and contains our public key, private key, blockchain and open transactions in case it is already created. If this file doesn't exist (which is the case for a new user), the **except** block plays it role. It initializes the public and private key with the help of **generate_keys** and the blockchain with the genesis block and the open transactions as an empty list. In the other case, if it exists, it reads the file with the help of the **readlines** function of python and initializes the public, private key, blockchain and open transactions with the data stored in this file.
- **Save_keys() and save_data():** When we create our keys, we need to save them. **Save_keys()** just save them in a file. **Save_data()** save the blockchain and the open transactions each time they are modified. These are modified when we add a transaction and mine a block.

Libraries used

1. Json: JSON (Javascript object notation) is a package used to store or transfer some particular data structures in order to be used later or in other projects. It is also used to convert these data structures into strings and from strings back to these structures. It has two principal methods: **dumps and loads,** which are respectively used to convert data to string and back to what they were. JSON is used in our project to hash data which are not strings. It is also used to write our blockchain, open transactions, public and private key in a file. The responses when we add requests and routes are done with JSON but this time from the jsonify package of Flask.
2. Hashlib : Hashlib contains different hashing methods. The one we used is SHA256 because it is the most stable today. We need a hash function when hashing our blocks during the mining and the verification process. The hash function is also used to generate a signature.
3. Pycryptodome : Pycryptodome is a package used in python to generate private and public keys. These keys are generated as explained above in **generate_keys().**
4. PKCS1_v1_5 : This package is contains methods such as **sign()** and **verify()** which generates respectively a signature and verifies later if this signature and the data stored are correct.
5. Binascii : Binascii is used to convert binary data types from binary to ascii strings and vice versa. This is used when returning the generated keys and signatures, because they need to be returned as strings and not as binary data. When these keys are verified, they need to be in binary form again, and hence need Binascii once more.
6. Flask : Flask is a framework and a class of python which is indispensable when dealing with requests and routes. The Flask package was used to launch functions written in our blockchain file from an html page and javascript code. The html, css and bootstrap were used to design the page as shown below. Javascript was now used to insert events on buttons which will trigger some functions dans will establish our request and receive the responses. The main method used in javascript was **axios** as well as try and catch blocks to collect possible errors and respond correctly them.
7. Request : Request was used to establish POST requests that required an additional data. For example, a **mine** request (request to mine a block) is

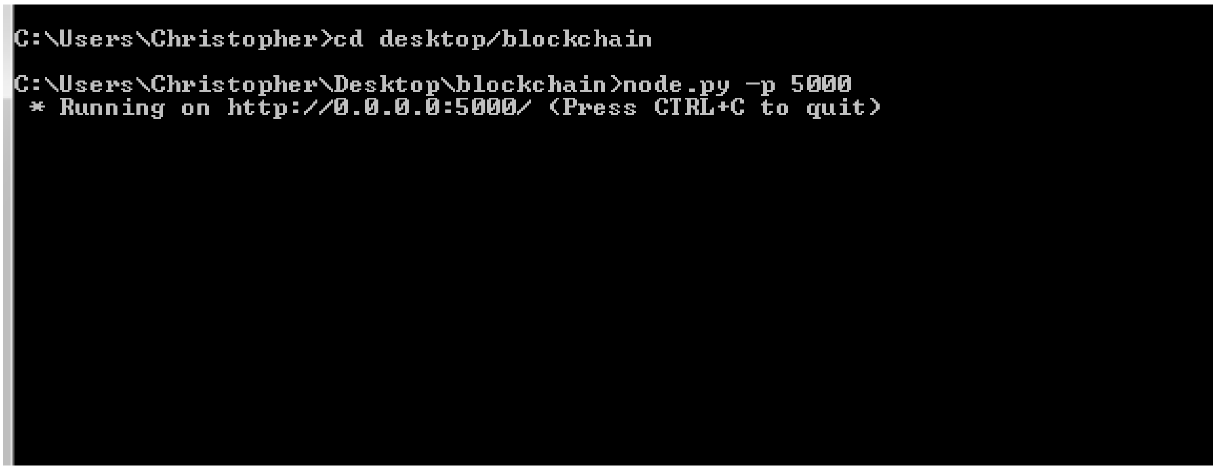
a POST request (since we are adding data to our server). But to mine, we just need to call this function and it is all. To add a transaction for example is also a POST request, but here we need to say who is the recipient and what is the amount. The **request** method of Flask allows us to that.

8. Argsparse(): Used to get the port on which to run a node.

Our application in action

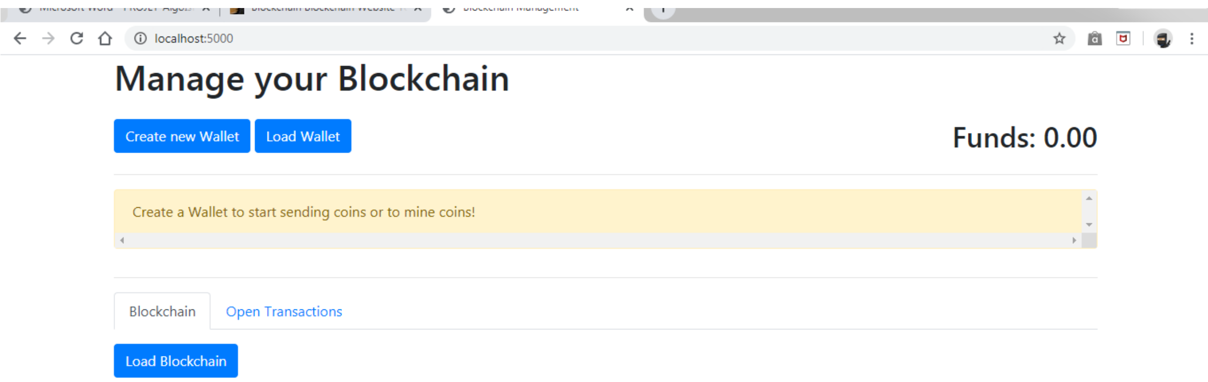
Starting a node.

To start a node, we can pass through the command line, then go to the location of our **node.py** file and launch it indicating the port on which to run with the option -p.

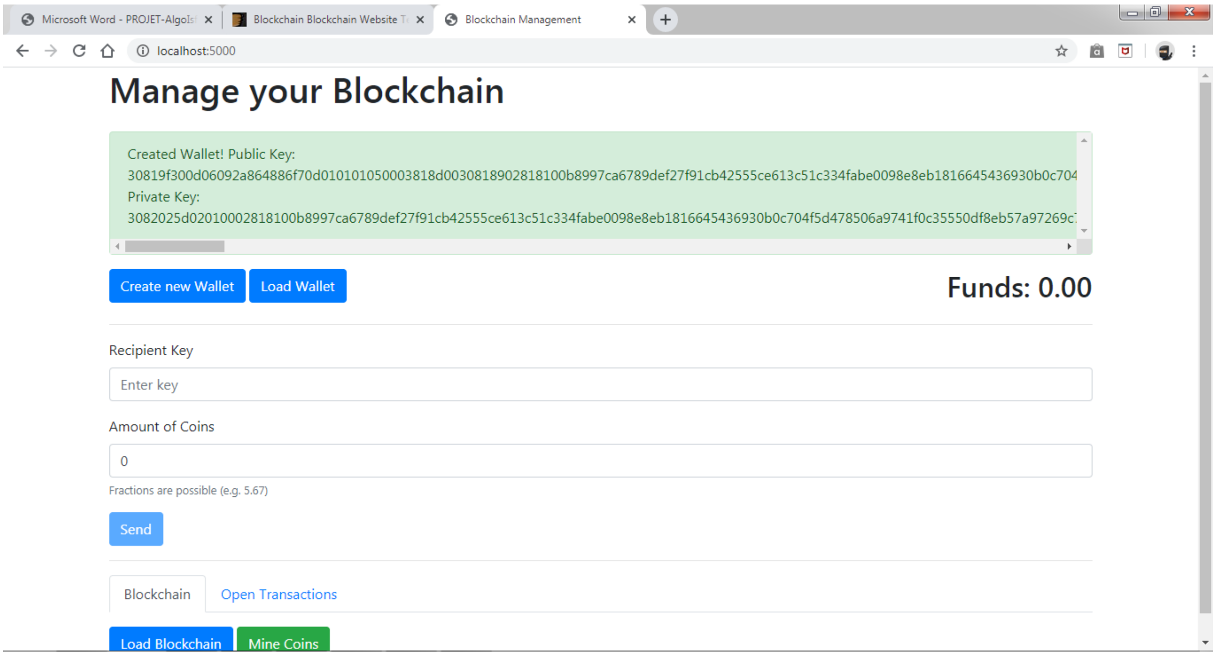


Launching the web interface

As seen on the image, our application is running on the address http://0.0.0.0:5000. We type this on our navigator's address bar and obtain the page below.

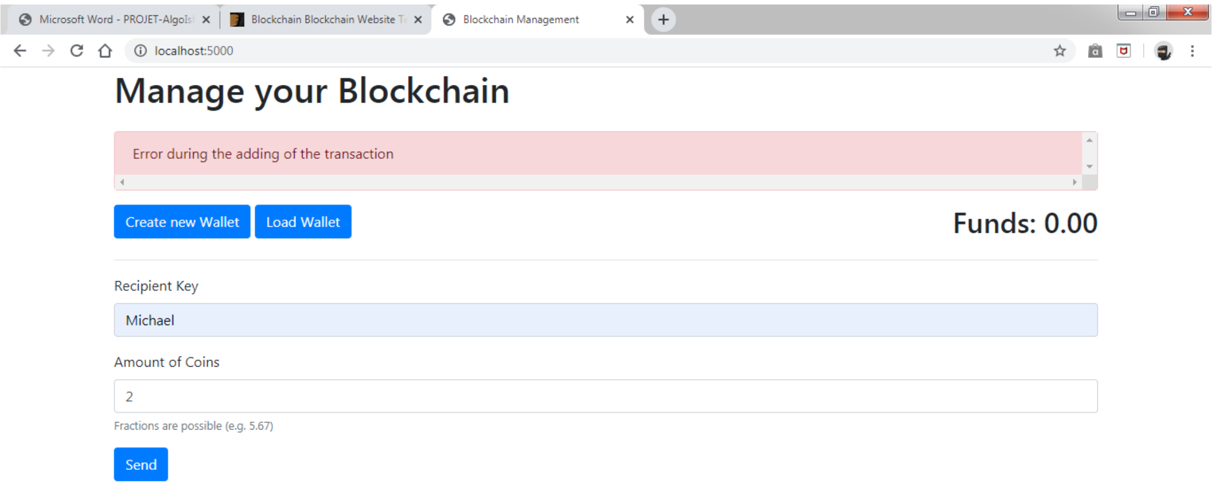


As we can read on the image, we should first create a new Wallet. This will consist of generating a public and private key for this node. When everything goes fine, we have the image below on the green board, telling us that the wallet has been created successfully.

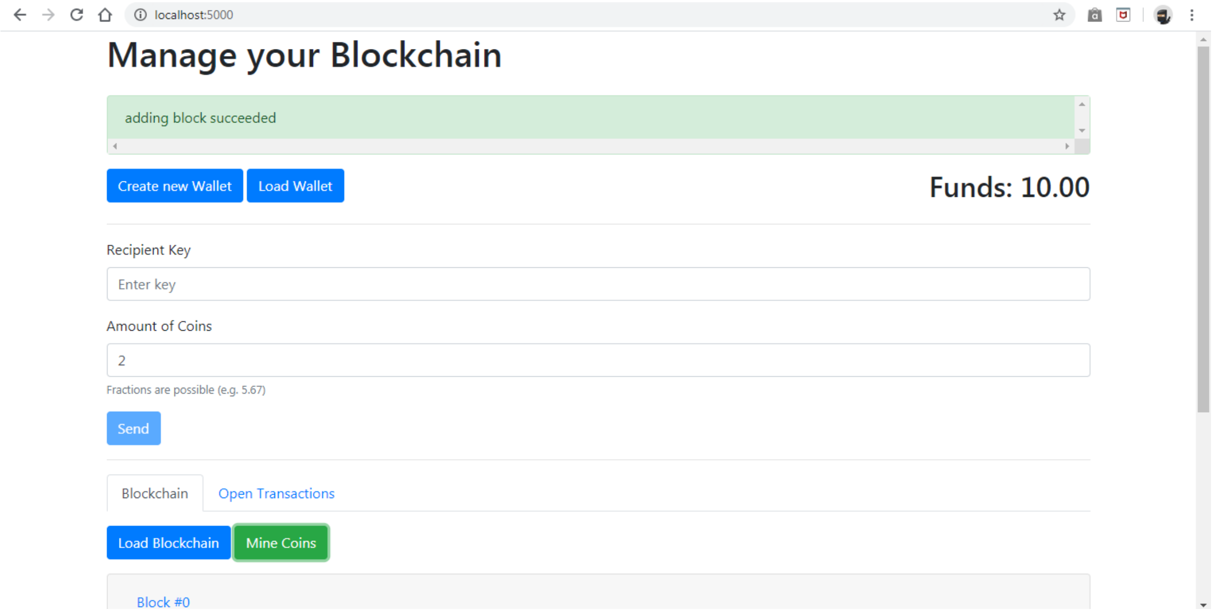


We then have a form that can allow us to operate a transaction.

On the image below, we see that our fund is 0. If we try to add a transaction this will fail as shown below because our funds are insufficient.

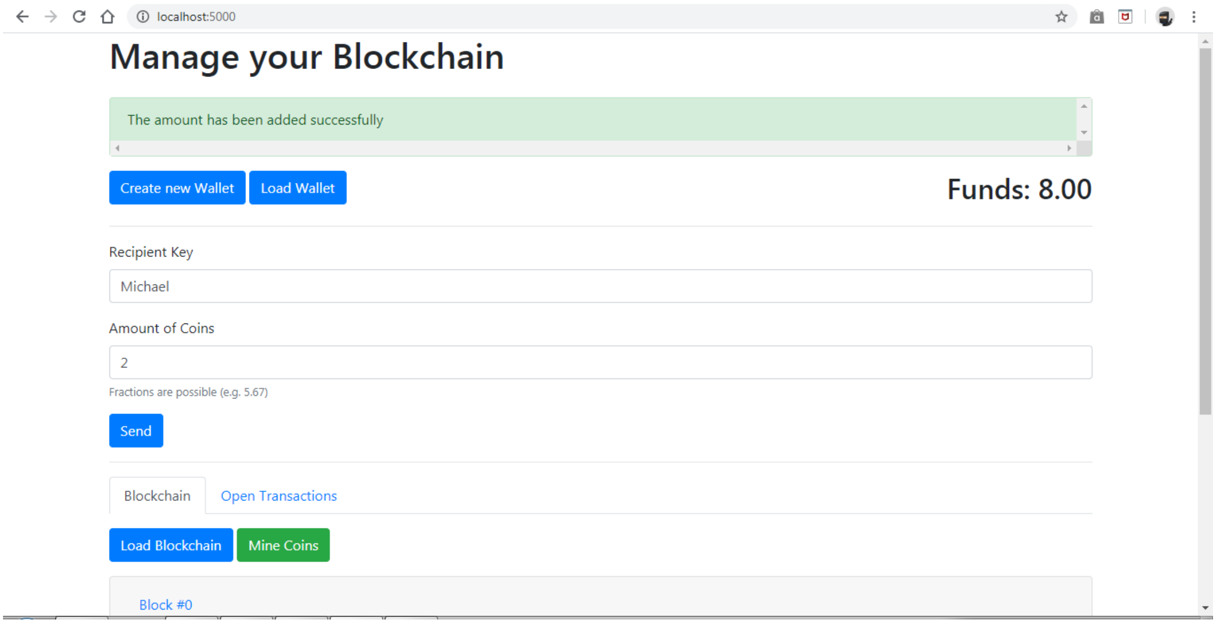


In order to have an amount, we should mine the block, which will inturn reward us with 10 coins.



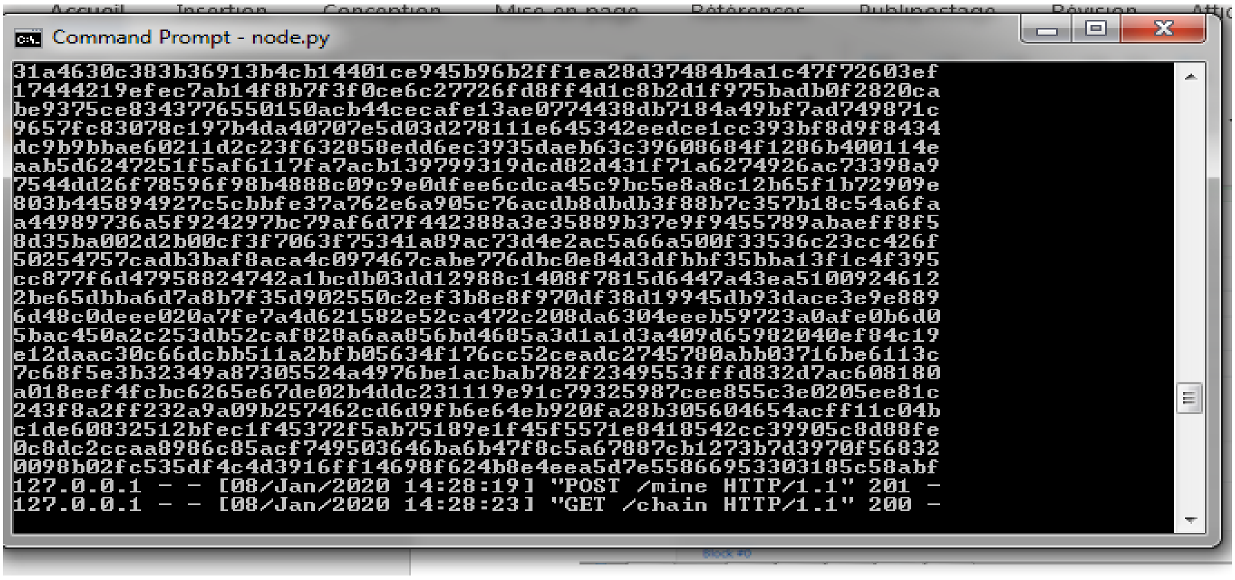
We see that the block has been added successfully and the funds are updated to 10 coins.

Let us now repeat the sending operation and send 2 coins to Michael.

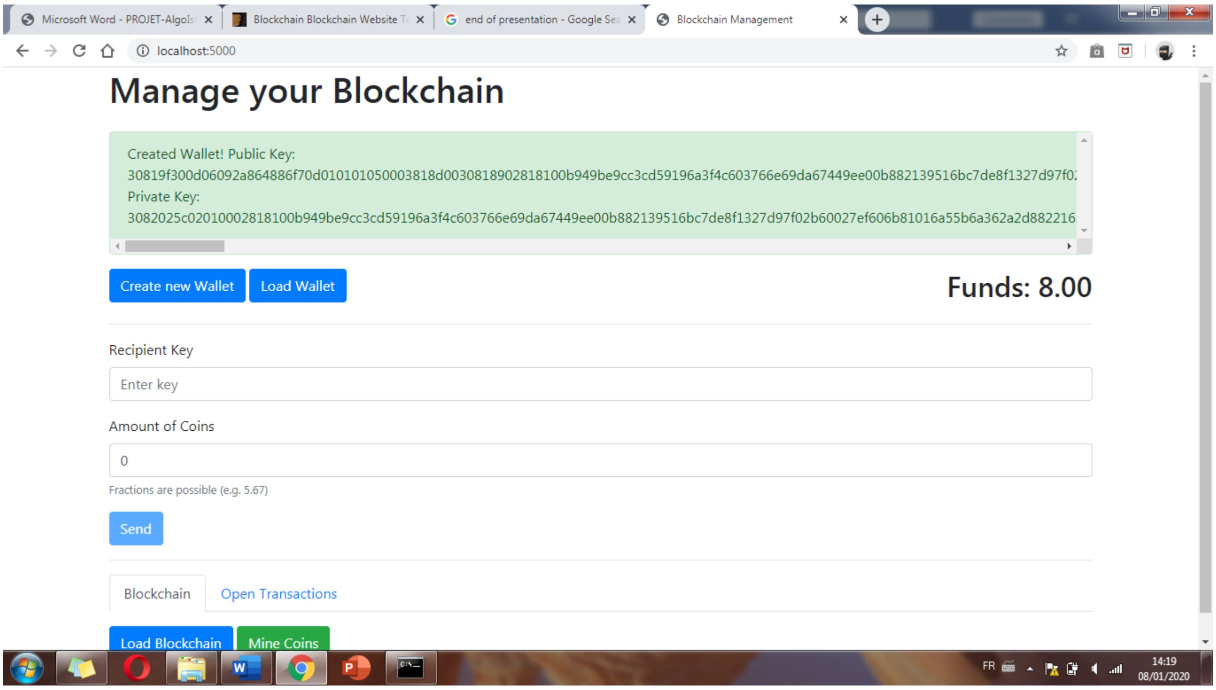


We see that the amount has been added successfully and our fund is now 8.

After adding this transaction, we can decide to mine the block once more so that it can enter in the blockchain. We can also perform more transactions before mining them. If we click on mine coins and have a look in the console or command line, we see how the proof of work is calculated. By looking the last hash, we see that it starts with 2 leading zeros.



If we quit and launch the node again through the command line on the same port, launch the web page, then click on **load wallet**, we get our pair of public and private keys, the funds and everything back as we left.



Our blockchain confronted to security measure

When we perform what ever operation we want to perform on the blockchain, it stores it in blockchain_port.txt. If a data in this file is modified, further mining of blocks is no more possible.

N.B: For the modifications made directly in the blockchain_port.txt file to be taken in consideration, we should relaunch the application.

Running multiple nodes

To run multiple nodes, we just need to launch the app in the console by giving a different port number with the -p option and typing the address in the address bar of the navigator.

For example: node.py -p 5001

In the navigator: localhost:5001

General URL: localhost:port

Problems encountered

There were important logical errors that prevented us from easily attaining our goals. These errors were being located thanks to the powerful text editor **visual studio code**, which gave us a debug mode which allows to execute our code step by step as in **python tutor** and to have the state of each variable at each step. This helped us enormously to locate and correct our errors.

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