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PH360 – Special Projects in Physics
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HW 2 – Question 2
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Tutorial – Building a Blockchain

Representing a blockchain

The tutorial represents the blockchain as a class. The class contains the methods that can be used on the class to accomplish the various tasks required of the chain. The methods described are:

1. *Initialisation*
   Initialisation entails creating the chain. It creates two empty lists – one to store the blockchain, the other to store transactions which are used to created blocks.

2. *New Block Creation*
   The `.new_block` method creates a new block, and then adds it to the end of the blockchain. The transactions will be compiled from the list, added to the block, and then the block will be added to the chain, with all the required properties.

3. *New Transaction Creation*
   A `new_transaction` with all the required information is created and added to the list of transactions.

Using these methods, the blockchain can be created and subsequently manipulated as required. Given that each method is explored in detail, for now, a simple placeholder definition of the class is sufficient, as seen below:

```
class Blockchain(object):
    def __init__(self):
        self.chain = []
        self.current_transactions = []

    def new_block(self):
        # Creates a new Block and adds it to the chain
        pass

    def new_transaction(self):
        # Adds a new transaction to the list of transactions
        pass

    @staticmethod
    def hash(block):
        pass

    @property
    def last_block(self):
        # Returns the last Block in the chain
        pass
```

The final part of the placeholder is a static method which computes the hash of the block, by using sha256 as a hash function, and a property which allows the user to see the last block in the chain. This is useful functionality that is applied later.

Structure of a Block

Every block comprises the following parts:

1. Index – the block identification index.
2. Timestamp – the Unix timestamp of the block's creation/verification
3. Transaction list
4. "Proof" – proof of work, discussed later
5. Hash pointer to the previous block

```
block = {
    'index': 1,
    'timestamp': 1506057125.900785,
    'transactions': [
        {
            'sender': "8527147fe1f5426f9dd545de4b27ee00",
            'recipient': "a77f5cdfa2934df3954a5c7c7da5df1f",
            'amount': 5,
        }
    ],
    'proof': 324984774000,
    'previous_hash': "2cf24dba5fb0a30e26e83b2ac5b9e29e1b161e5c1fa7425e73043362938b9824"
```

The transactions are added to the block using a combination of the `.new_block` and the `.new_transaction` methods. By encoding the `previous_hash` into the block, the previous block is "set in stone". The idea is that the hash is computed using the static method `hash`, which uses *all* the data in the block. If a block is edited or modified in any way, the hash algorithm will not match, and a subsequent rehash of the edited block will result in a new hash value. However, since the original hash was encoded in the new block, it will be apparent that the edited block has been tampered with, and all the subsequent blocks will contain incorrect hashes[1].

Creating a New Transaction

The new transaction is one of the "helper methods" in the tutorial. It accomplishes three tasks:

1. It creates a transaction with sender, recipient and amount fields.
2. It adds this transaction to a list of transactions which will make up the next block
3. It then returns the index of the block that will contain the transaction being added – which is the *next block that will be mined.*

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[1] Conceivably, one could go and rehash *the entire blockchain beyond the tampered block*, but this would be cryptographically difficult. While it may be possible in the case of this simple example, it would not work in a stable system like Bitcoin, which depends on verification of the chain.

```
def new_transaction(self, sender, recipient, amount):
        """
        Creates a new transaction to go into the next mined Block
        :param sender: <str> Address of the Sender
        :param recipient: <str> Address of the Recipient
        :param amount: <int> Amount
        :return: <int> The index of the Block that will hold this transaction
        """

        self.current_transactions.append({
            'sender': sender,
            'recipient': recipient,
            'amount': amount,
        })

        return self.last_block['index'] + 1
```

`current_transactions` is the list of transactions that will comprise the next block.

Creating a New Block

Creating a new block has various facets to it. It needs to initialise a block, index it, link it to the predecessor, and add the transactions.

```
def new_block(self, proof, previous_hash=None):
        """
        Create a new Block in the Blockchain
        :param proof: <int> The proof given by the Proof of Work algorithm
        :param previous_hash: (Optional) <str> Hash of previous Block
        :return: <dict> New Block
        """

        block = {
            'index': len(self.chain) + 1,
            'timestamp': time(),
            'transactions': self.current_transactions,
            'proof': proof,
            'previous_hash': previous_hash or self.hash(self.chain[-1]),
        }

        # Reset the current list of transactions
        self.current_transactions = []

        self.chain.append(block)
        return block
```

Proof of Work

The example in the tutorial uses a much-simplified model. While the `valid_proof` static method requires that the first four digits of the hash be 0 – the same as the example in class (the live blockchain at blockchain.mit.edu), the difference lies in the `proof_of_work` algorithm. The proof of work in the tutorial calculates the proof based on the proof of the last block only.

```
def proof_of_work(self, last_proof):
        """
        Simple Proof of Work Algorithm:
         - Find a number p' such that hash(pp') contains leading 4 zeroes, where p is the
           previous p'
         - p is the previous proof, and p' is the new proof
        :param last_proof: <int>
        :return: <int>
        """

        proof = 0
        while self.valid_proof(last_proof, proof) is False:
            proof += 1

        return proof


@staticmethod
    def valid_proof(last_proof, proof):
        """
        Validates the Proof: Does hash(last_proof, proof) contain 4 leading zeroes?
        :param last_proof: <int> Previous Proof
        :param proof: <int> Current Proof
        :return: <bool> True if correct, False if not.
        """

        guess = f'{last_proof}{proof}'.encode()
        guess_hash = hashlib.sha256(guess).hexdigest()
        return guess_hash[:4] == "0000"
```

Essentially, the algorithm hashes together the proof of the last block together with the proof of the current block, and then checks whether the first four digits of the resulting hash are 0. If they are, then the proof is returned, if not, the proof of the current block is incremented by 1, and so on, until the condition is met.

The MIT website, however, hashes together the data in the block, the *hash of the previous block*, and the proof (which is referred to as 'nonce'), and then checks the resulting hash to see whether the first four digits are 0 or not.

Python Flask Framework

`/transactions/new`
Creates a new transaction and adds to the next block to be mined. Essentially this endpoint calls the `new_transaction` method in python. It is a `POST` method, in which the transaction is posted to the client.

`/mine`
Mines the next block at the given node. Essentially calculates the proof brute force such that a hash condition is met. This is a `GET` method – it receives information from the client.

`/chain`
Returns the chain as it currently stands on the node in question. This is also a `GET` method.

Endpoints:

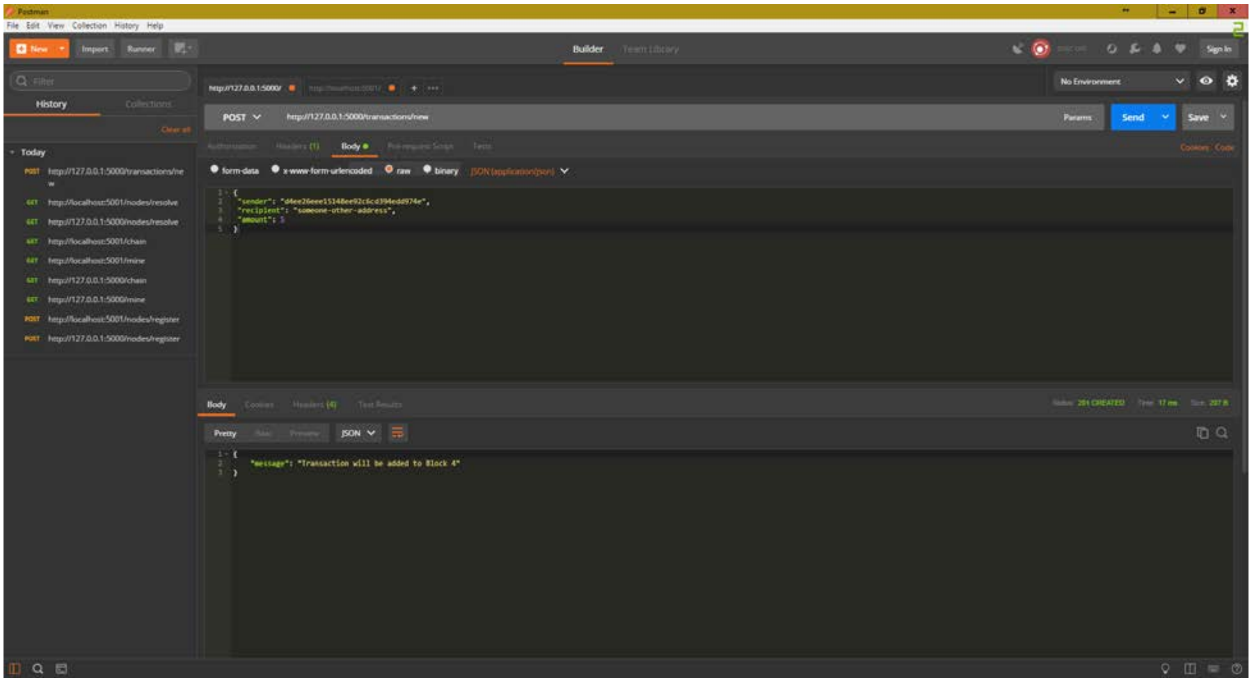
Endpoints are the unique urls which are used as pointers. Here, the endpoints point to Python functions, which are requested by the HTTP client (Postman). So, when the method `/mine` is called, it acts as a `GET` request from the endpoint, receives the function and executes it to mine the block.

Implementation

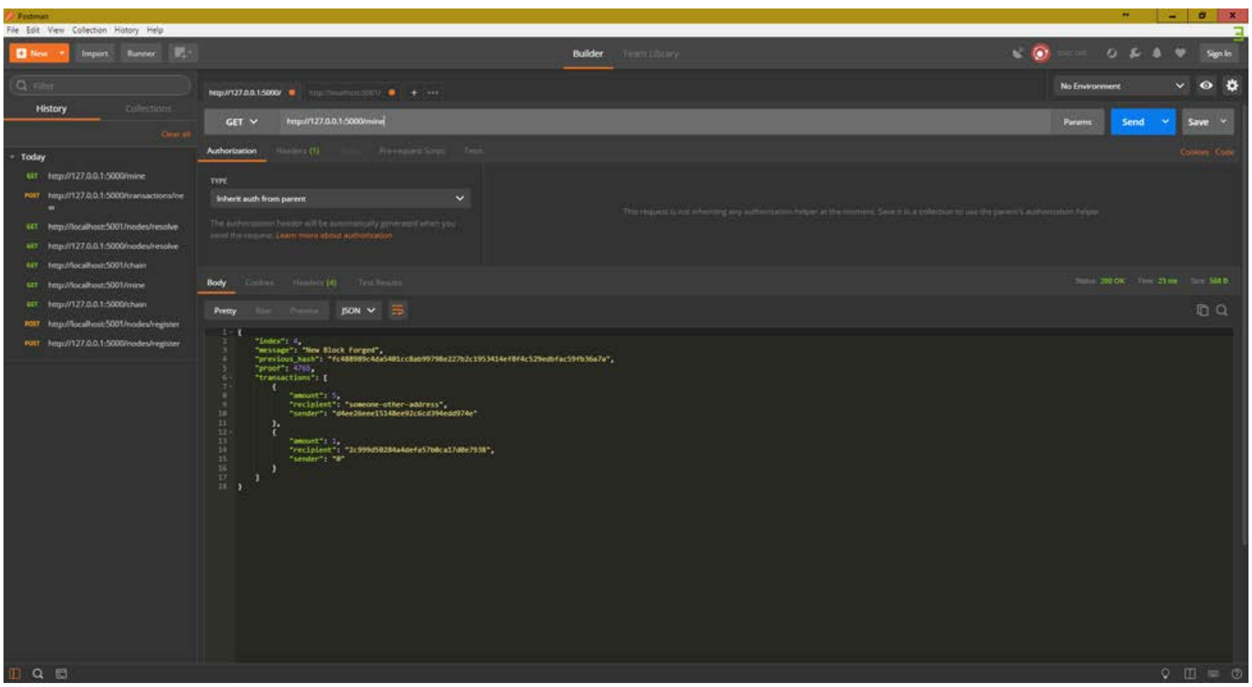
The implementation for the next sections – using Postman to GET and POST requests to the chain, was done by initialising the node on a computer using Spyder from the Anaconda Suite. Spyder allows for multiple consoles, which allowed for simultaneous execution of two separate files – simulating two nodes on ports 5000 and 5001 of the `localhost`.

It is to be noted that this entire process, which combined Spyder and Postman could be replaced by a simple terminal prompt and cURL. Similarly, the nodes could be extended to any number of machines, provided that they are on the same network.

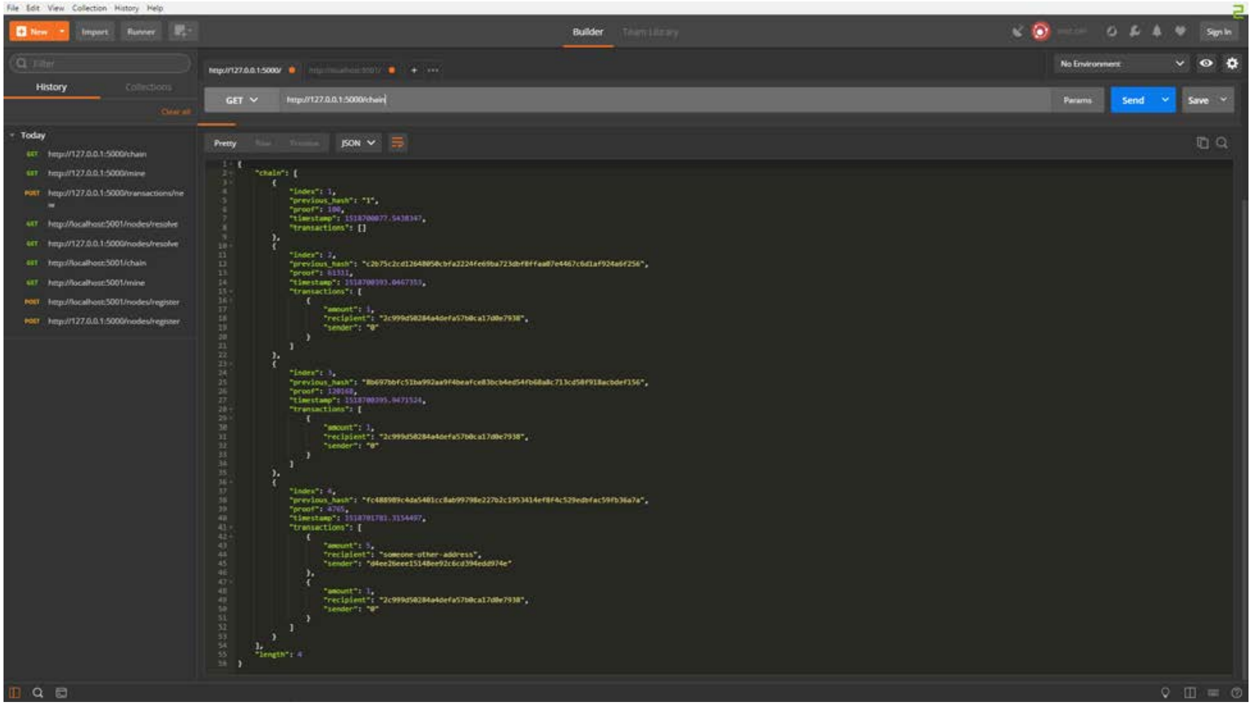
Posting a Transaction



Mining a Block



Calling for the entire blockchain



Consensus

The algorithm is incredibly basic in that it only searches for one parameter, and based on a binary result, proceeds with resolution of conflicts. The method is resolve_conflicts:

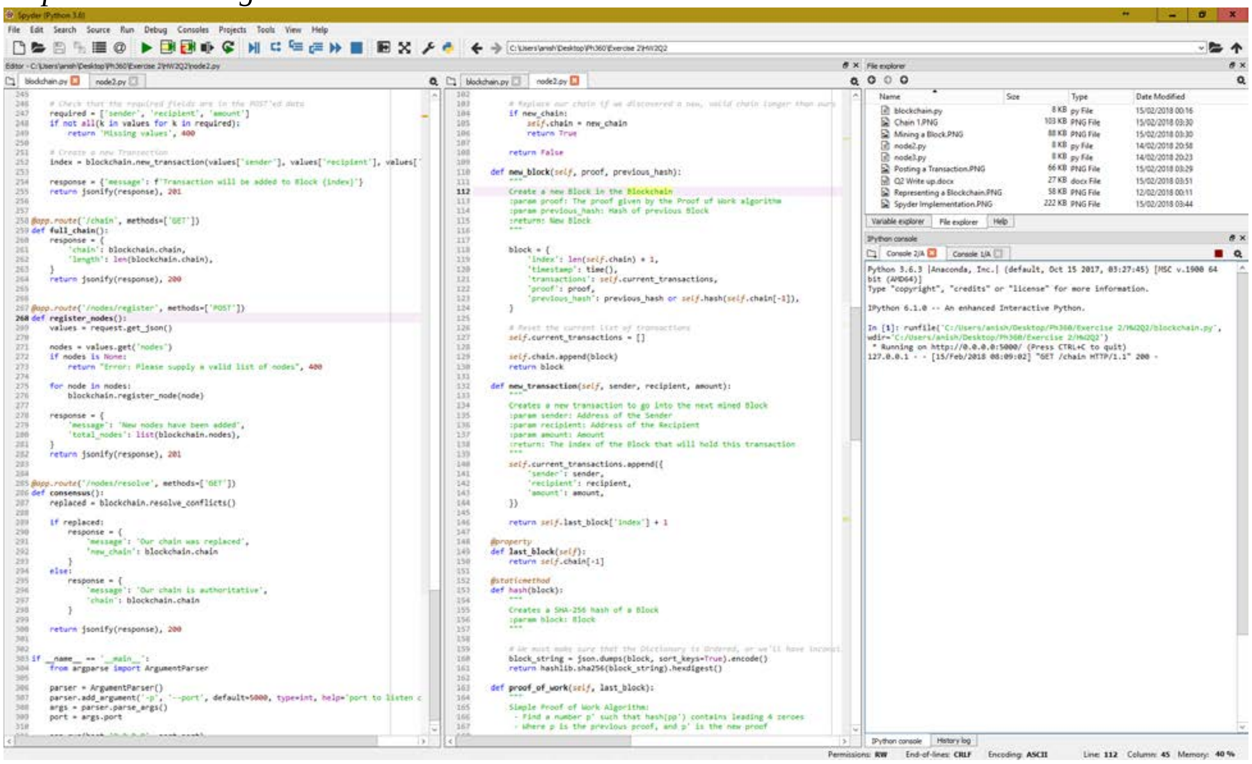
```
def resolve_conflicts(self):
        """
        This is our consensus algorithm, it resolves conflicts
        by replacing our chain with the longest one in the network.

        :return: True if our chain was replaced, False if not
        """
        # pdb.set_trace()
        neighbours = self.nodes
        new_chain = None

        # We're only looking for chains longer than ours
        max_length = len(self.chain)

        # Grab and verify the chains from all the nodes in our network
        for node in neighbours:
            response = requests.get(f'http://{node}/chain')

            if response.status_code == 200:
                length = response.json()['length']
                chain = response.json()['chain']

                # Check if the length is longer and the chain is valid
                if length > max_length and self.valid_chain(chain):
                    max_length = length
                    new_chain = chain

        # Replace our chain if we discovered a new, valid chain longer than ours
        if new_chain:
            self.chain = new_chain
            return True

        return False
```

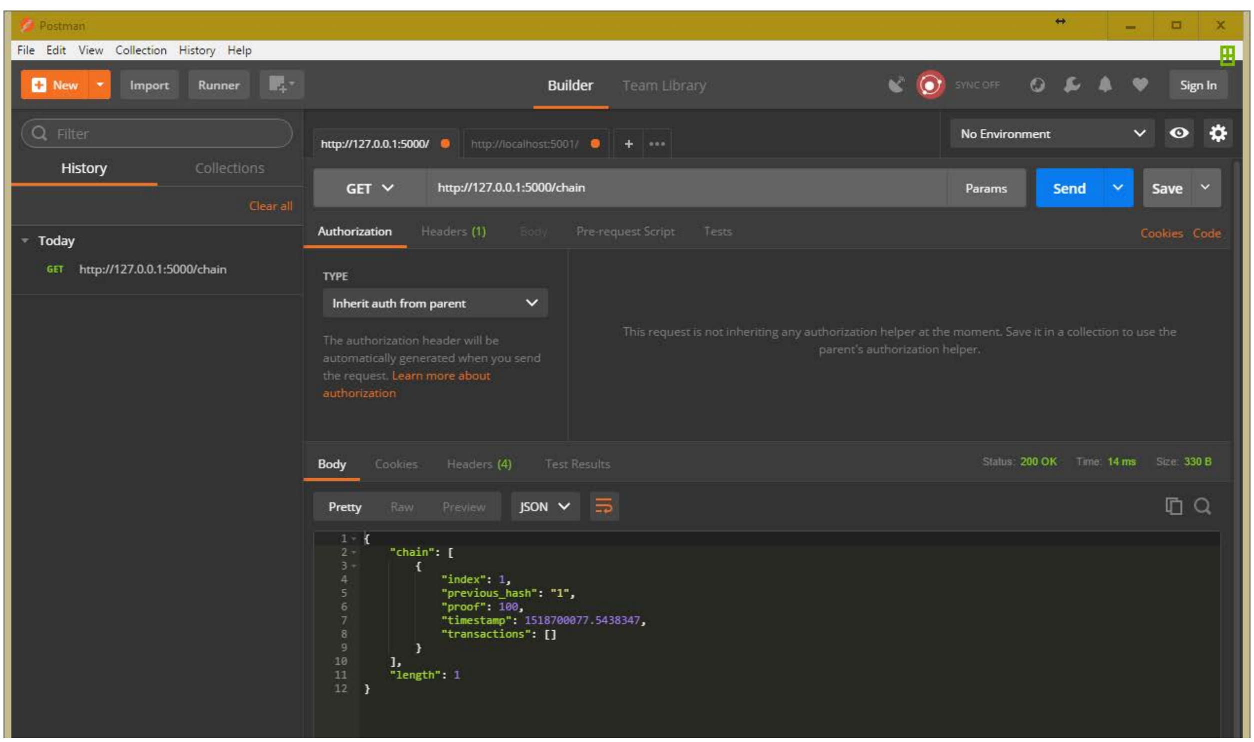
The method first finds the length of the chain at the node where the method is called. It then compares the length of the chain of the nodes that are its neighbours. After catching the longest chain, it checks validity and returns true or false based on the outcome.

NOTE: It was found that there was an issue in the `valid_chain` method, where the original code called for the `previous_hash` of the `last_block`, instead of the current `block`. This is currently an open issue on the GitHub ([Issue #66]) and by editing `last_block` to `block`, the `resolve_conflicts` method did not resolve incorrectly, defaulting to authoritative no matter the length of the chain. We used a `pdb` trace to verify this issue independently.

Consensus, as seen in code

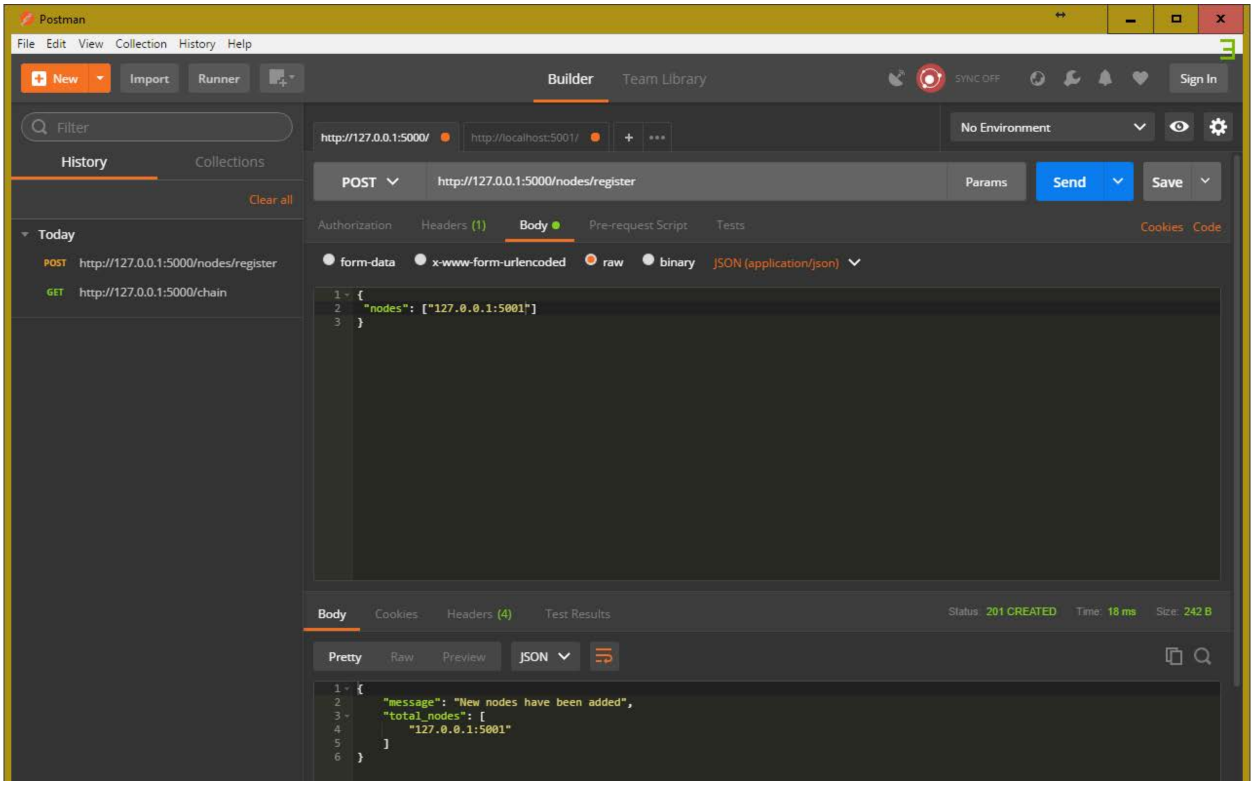
Step 1 – Initialising both nodes

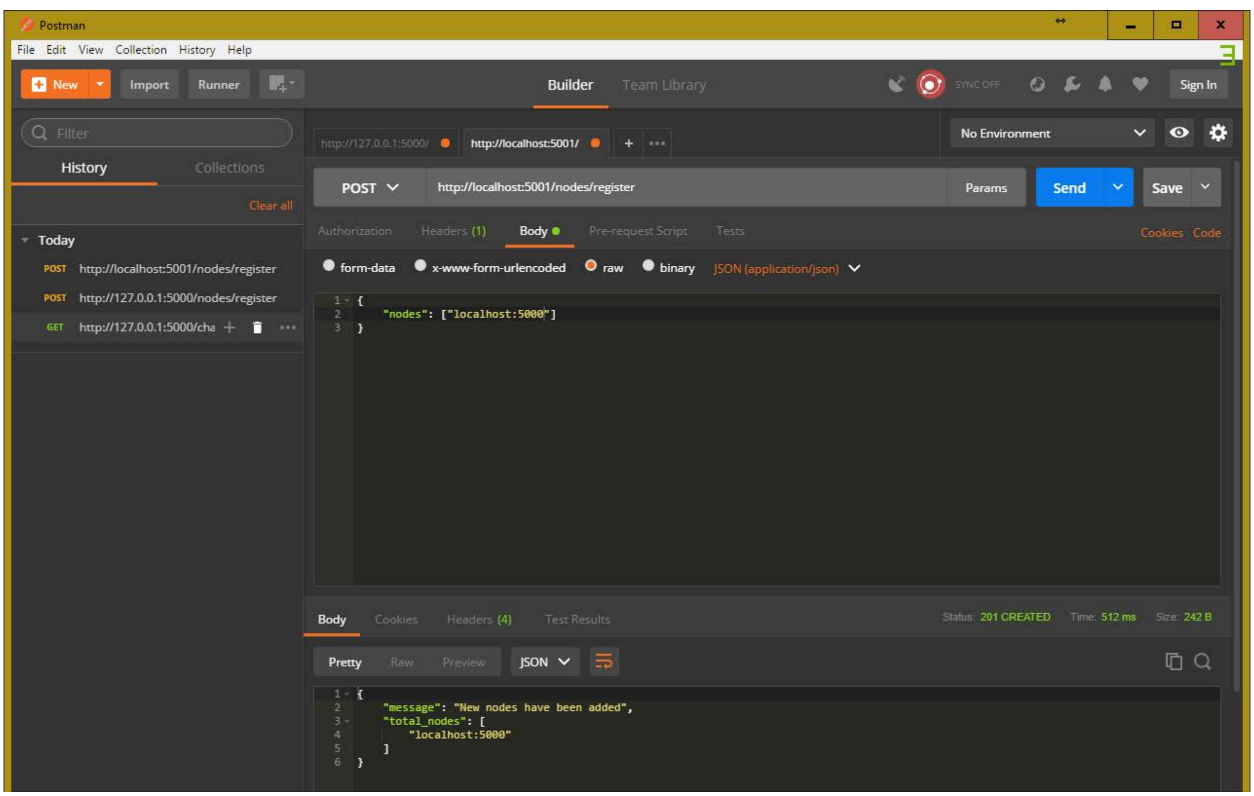




The two nodes are simultaneously running in separate console windows 1(A) and 2(A). In Postman, the two tabs are used to interact with them independently.

Step 2 – Node Registration

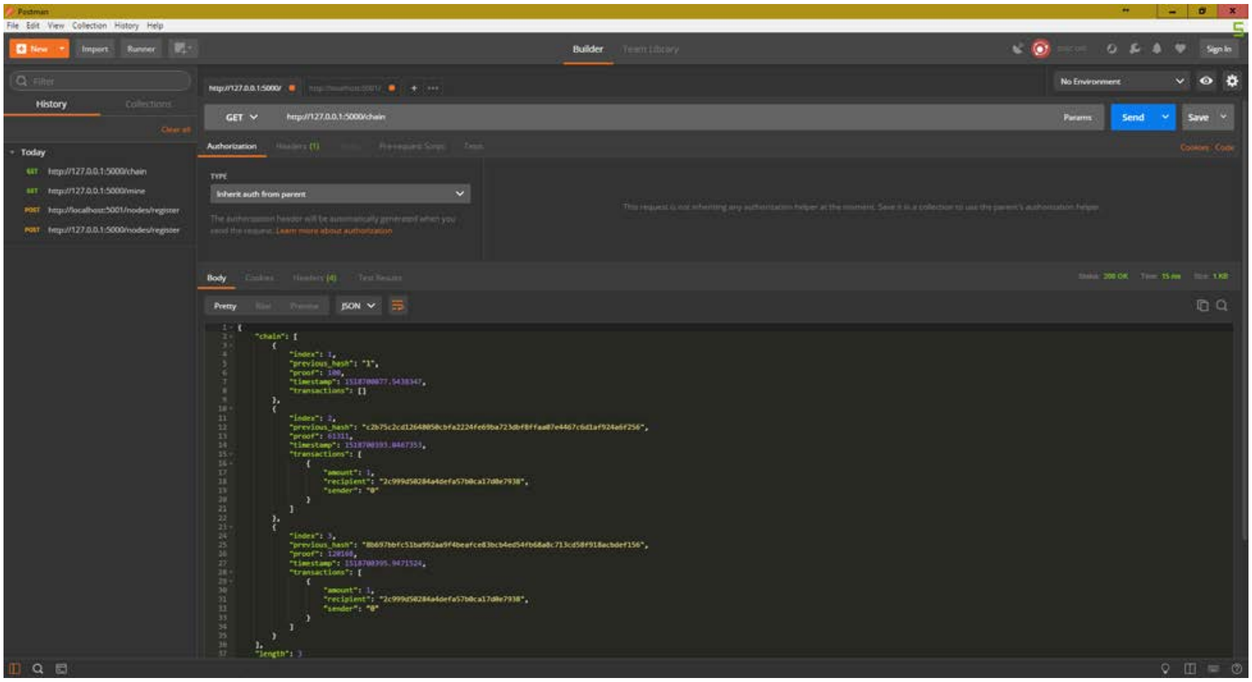


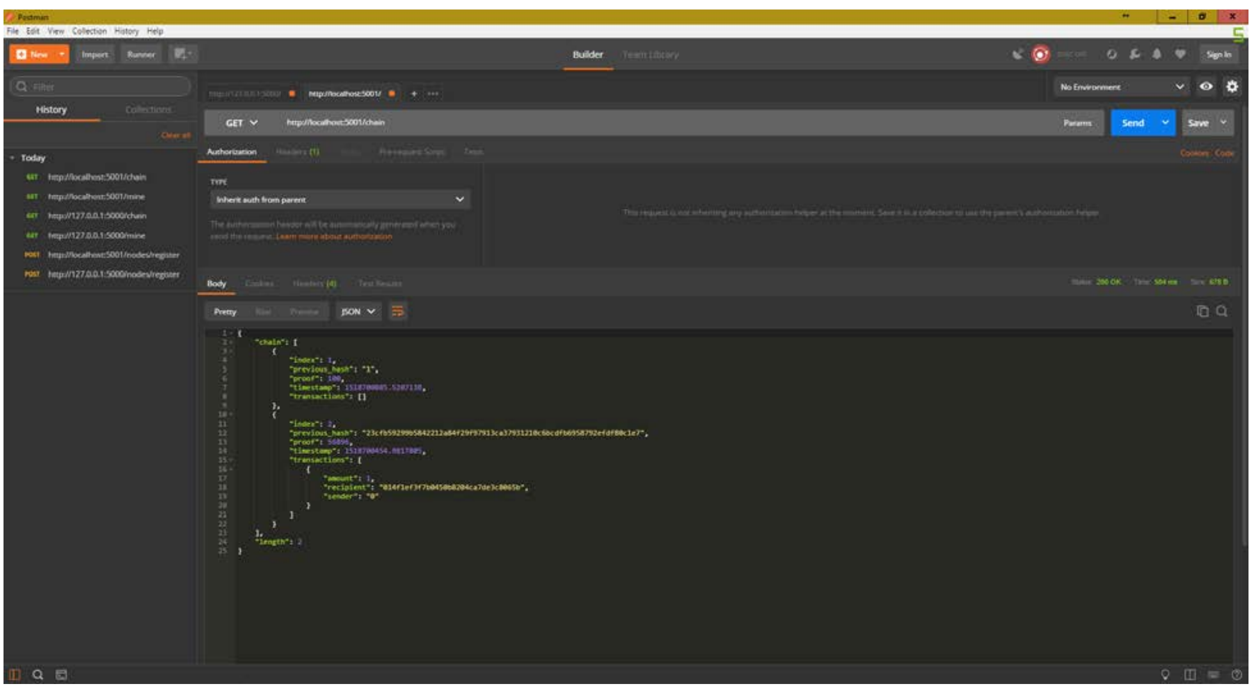


Both nodes are made aware of the other's presence using the `/nodes/register` method.

Step 3 – Mining blocks

Two additional blocks are mined on node 1 and one additional block on node 2. This way, there is a conflict in which node has the longer chain.

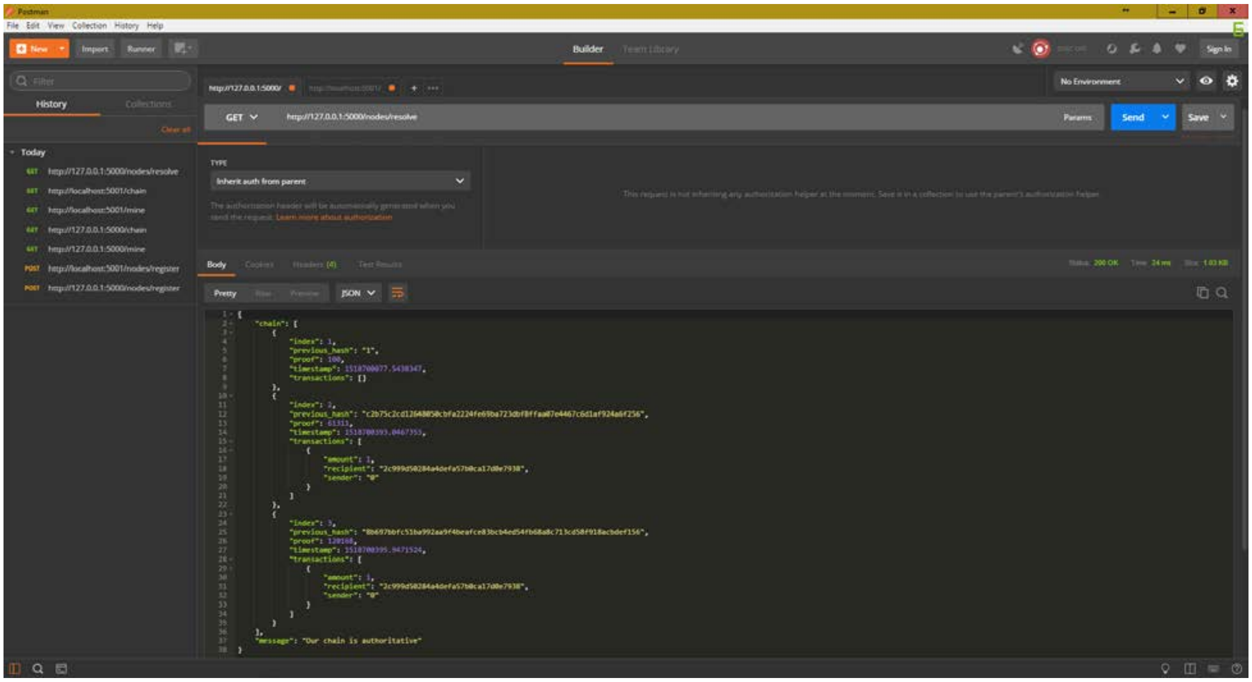


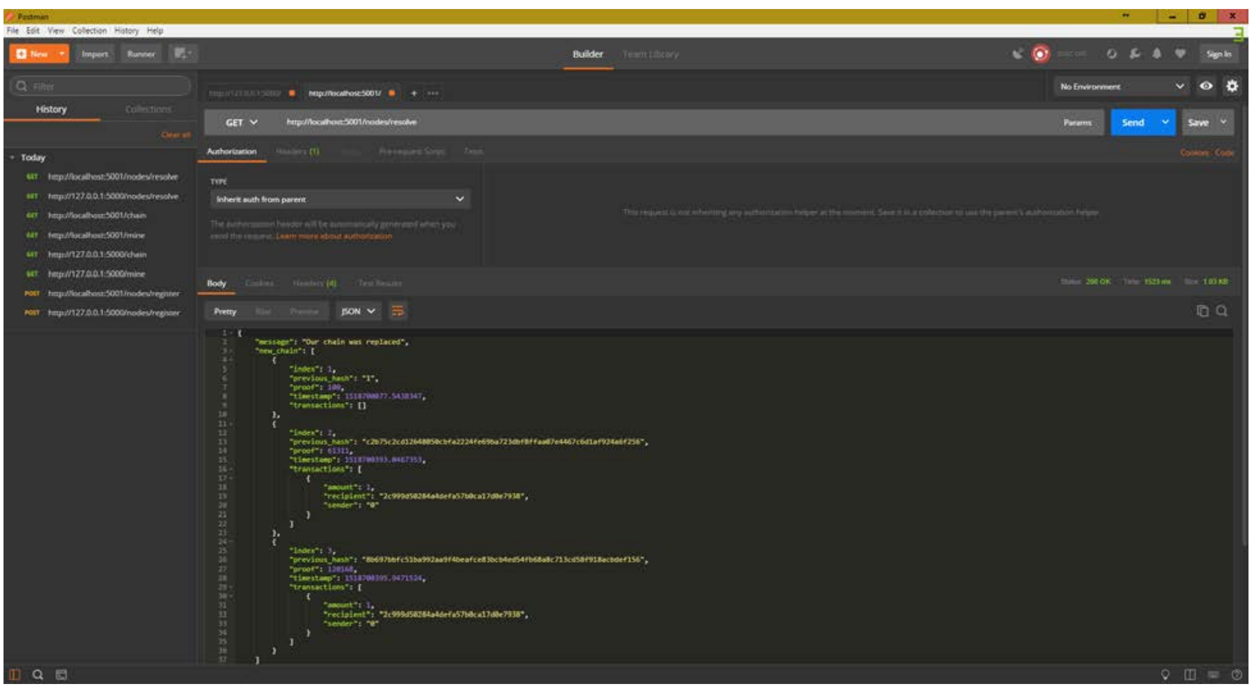


The idea here is that once the conflict is detected, the shorter chain will be replaced by the longer, while the longer stays the same, unifying the network.

Step 4 – Consensus Resolution

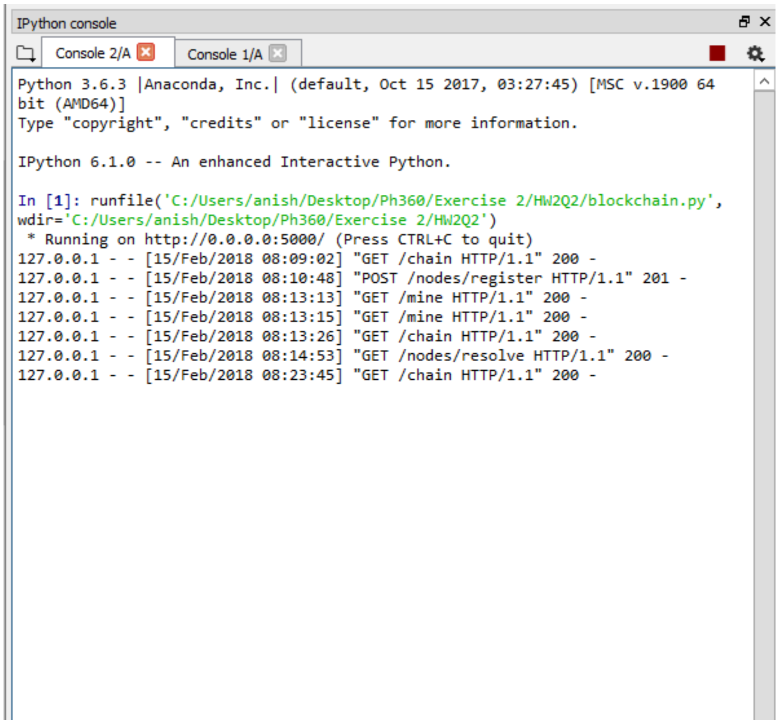
The `/nodes/resolve` method is used to detect and resolve conflict on both chains. On applying to node 1 (`PORT 5000`), it changes little, the existing chain is declared to be authoritative. However, on node 2 (`PORT 5001`), the existing chain is replaced, and simultaneously checked for validity.





This is the end console appearance for each node in Spyder.

Node 1:



Node 2: