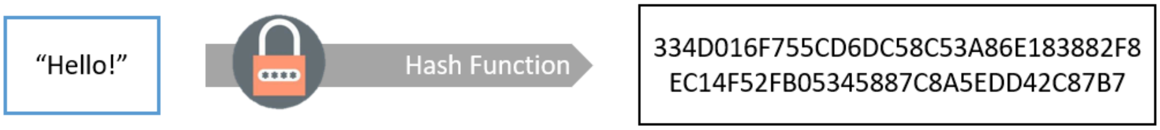
Practical 2

Aim: To create a blockchain using Python.

Theory

Cryptographic Hash Function

Hashing is converting an original piece of data into a digest or hash. The process uses cryptographic hash functions for the irreversible conversion of the message.



Cryptographic hash functions are irreversible. That means it's a 1-way function, and one can't generate the message back using the digest. There are a bunch of cryptographic hash functions. For example, SHA-224, SHA-256, SHA-512, KECCAK-256, Whirlpool, etc.

Merkle Tree

Merkle trees, also known as Binary hash trees, are a prevalent sort of data structure in computer science. In bitcoin and other cryptocurrencies, they're used to encrypt blockchain data more efficiently and securely. It's a mathematical data structure made up of hashes of various data blocks that summarize all the transactions in a block. It also enables quick and secure content verification across big datasets and verifies the consistency and content of the data.

Benefits of Merkle Tree

- Validate the data's integrity: It can be used to validate the data's integrity effectively.
- Takes little disk space: Compared to other data structures, the Merkle tree takes up very little disk space.
- Tiny information across networks: Merkle trees can be broken down into small pieces of data for verification.
- Efficient Verification: The data format is efficient, and verifying the data's integrity takes only a few moments.

Cryptographic Puzzle

A cryptographic puzzle in proof-of-work blockchains is a mathematical challenge miners must solve to add a new block to the chain. To solve the puzzle, miners must find a block with a hash value that starts with a specific number of zeros, known as mining difficulty. They do this by trying different numbers, called nonces, until they get a hash that meets the difficulty requirement. The first miner to solve the puzzle gets to add the block to the blockchain and earn a reward. This process helps secure the blockchain and control the rate at which new blocks are added.

Working of Merkle Trees

A Merkle tree totals all transactions in a block and generates a digital fingerprint of the entire set of operations, allowing the user to verify whether it includes a transaction in the block.

- Merkle trees are made by hashing pairs of nodes repeatedly until only one hash remains; this hash is known as the Merkle Root or the Root Hash.
- They're built from the bottom, using Transaction IDs, which are hashes of individual transactions.
- Each non-leaf node is a hash of its previous hash, and every leaf node is a hash of transactional data.

Mining in blockchain

Mining is the process that Bitcoin and several other cryptocurrencies use to generate new coins and verify new transactions.

Mining in blockchain involves using computers to solve complex mathematical problems that validate and record transactions on the blockchain. When a miner successfully solves these problems, they add a new block of transactions to the blockchain and are rewarded with cryptocurrency. This process ensures the integrity and security of the blockchain by preventing fraud and double-spending.

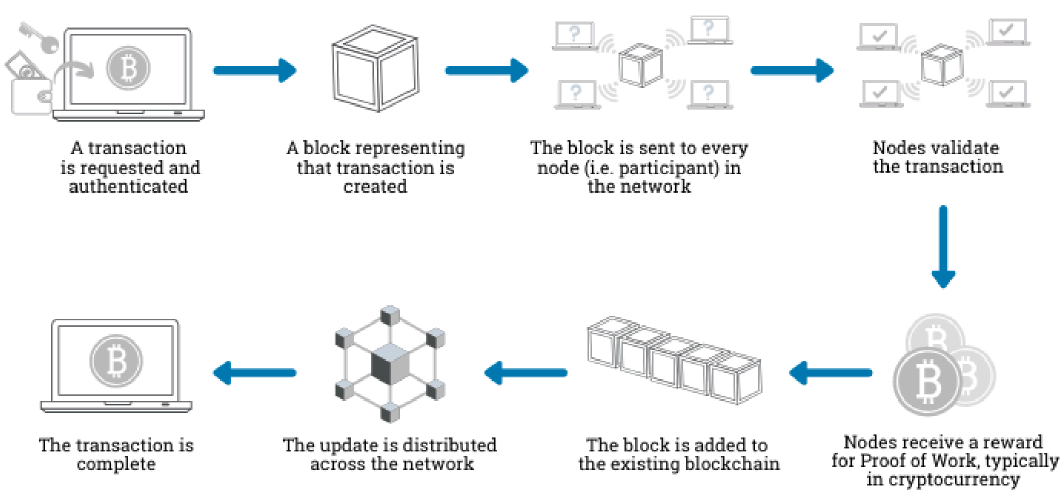
Checking validity of the blockchain

To check the validity of blocks, nodes verify that each block's hash matches the expected value, confirm that all transactions within the block are legitimate and follow the blockchain's rules, and ensure the block's previous hash correctly references the previous block. This ensures the integrity and continuity of the blockchain.

Challenges in P2P network

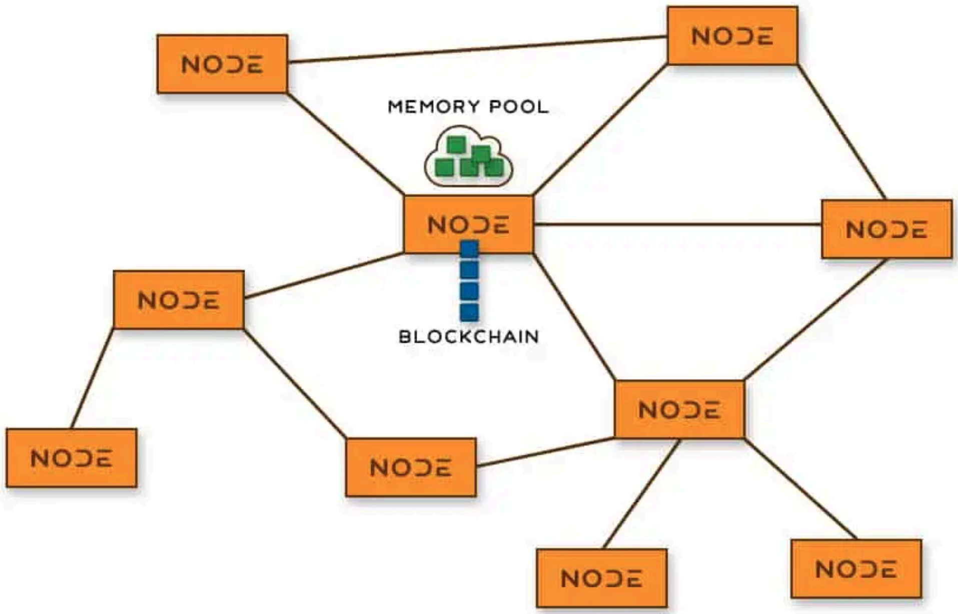
Peer-to-peer (P2P) networks face challenges such as managing data consistency and synchronization, dealing with network security and privacy issues, handling varying node reliability and performance, and addressing scalability as the number of nodes increases.

How are transactions performed on a network?



What is mempool?

A mempool, or memory pool, is where unconfirmed transactions are stored before being included in a block. It acts as a waiting area where transactions are kept until they are validated by miners and added to the blockchain.



Libraries and tools used during implementation

datetime: Essential for timestamping transactions and blocks to ensure accurate recording of when events occur on the blockchain. For instance, blocks might include timestamps to record when they were mined or transactions were initiated.

jsonify: Useful for creating responses in web APIs that interact with blockchain nodes. For example, it can be used to format blockchain data, like transaction details or block information, into JSON to be sent over HTTP.

hashlib: Critical for creating cryptographic hashes of blocks and transactions. Hashing ensures data integrity by generating unique, fixed-size representations of variable-size input data. In blockchain, hashes are used to link blocks and secure transaction data.

uuid4: Useful for creating unique IDs for transactions or blocks. This helps avoid duplication and ensures that each transaction or block has a distinct identifier, which is important for tracking and referencing in the blockchain.

urlparse: Helps in handling and processing URLs in blockchain applications, such as when interacting with APIs or network nodes. It allows for easier extraction and manipulation of URL components needed for network communication.

request: Facilitates communication between different blockchain nodes or between a client and server. It is used to send and receive data over the internet, such as querying block data from a node or sending transaction information.

Code

```
import datetime
import hashlib
import json
from flask import Flask, jsonify, request

# Part 1 - Building a Blockchain
class Blockchain:
    def __init__(self):
        self.chain = []
        self.transactions = []
        self.create_block(self.proof_of_work(self.get_temp_block('0')))

    def create_block(self, block):
        self.chain.append(block)
        self.transactions = self.transactions[5:]
        return block

    def get_previous_block(self):
        return self.chain[-1]

    def hash(self, block):
        encoded_block = json.dumps(block, sort_keys = True).encode()
        return hash(encoded_block)

    def proof_of_work(self, temp_block):
        new_proof = 1
        check_proof = False
        while check_proof is False:
            temp_block['nonce'] = new_proof
            hash_operation = self.hash(temp_block)
            if hash_operation.startswith('000'):
                check_proof = True
            else:
                new_proof += 1
        return temp_block

    def create_transaction(self, sender, receiver, amount):
        self.transactions.append({'sender': sender, 'receiver': receiver,
                                  'amount': amount})
        previous_block = self.get_previous_block()
        return "Your transaction has been added to pool."

    def is_chain_valid(self, chain):
        previous_block = chain[0]
        block_index = 1
        while block_index < len(chain):
            block = chain[block_index]
            if block['previous_hash'] != self.hash(previous_block):
                return False
            if not self.hash(block).startswith('000'):
                return False
            previous_block = block
            block_index += 1
        return True
```

```
    def get_temp_block(self, previous_hash):
        block = {'index': len(self.chain) + 1,
                 'nonce': 1,
                 'timestamp': str(datetime.datetime.now()),
                 'previous_hash': previous_hash,
                 'transactions': self.transactions[:5],
                 'merkle_root': get_merkle_root(self.transactions[:5])}
        return block

# Create merkle tree
def get_merkle_root(transactions):
    if len(transactions) == 0:
        return None
    if len(transactions) == 1:
        return hash(transactions[0])
    # hash all transactions before building merkle tree
    hashed_transactions = []
    for i in range(len(transactions)):
        hashed_transactions.append(hash(transactions[i]))
    # build merkle tree
    level = 0
    while len(hashed_transactions) > 1:
        if len(hashed_transactions) % 2 != 0:
            hashed_transactions.append(hashed_transactions[-1])

        new_transactions = []
        for i in range(0, len(hashed_transactions), 2):
            combined = hashed_transactions[i] + hashed_transactions[i+1]
            hash_combined = hash(combined)
            new_transactions.append(hash_combined)
        hashed_transactions = new_transactions
        level += 1
    return hashed_transactions[0]

# Helper function to hash
def hash(value):
    return hashlib.sha256(str(value).encode('utf-8')).hexdigest()

# Part 2 - Mining our Blockchain
app = Flask(__name__)
b = Blockchain()

# Mining a new block
@app.route('/mine_block', methods = ['GET'])
def mine_block():
    if len(b.transactions) > 0:
        previous_block = b.get_previous_block()
        previous_hash = b.hash(previous_block)
        temp_block = b.proof_of_work(b.get_temp_block(previous_hash))
        block = b.create_block(temp_block)
        response = {'message': 'Congratulations, you just mined a block!',
                    'index': block['index'], 'timestamp': block['timestamp'],
                    'nonce': block['nonce'],
                    'previous_hash': block['previous_hash']}
    else:
        response = {'message': 'No transactions to mine'}
    return jsonify(response), 200
```

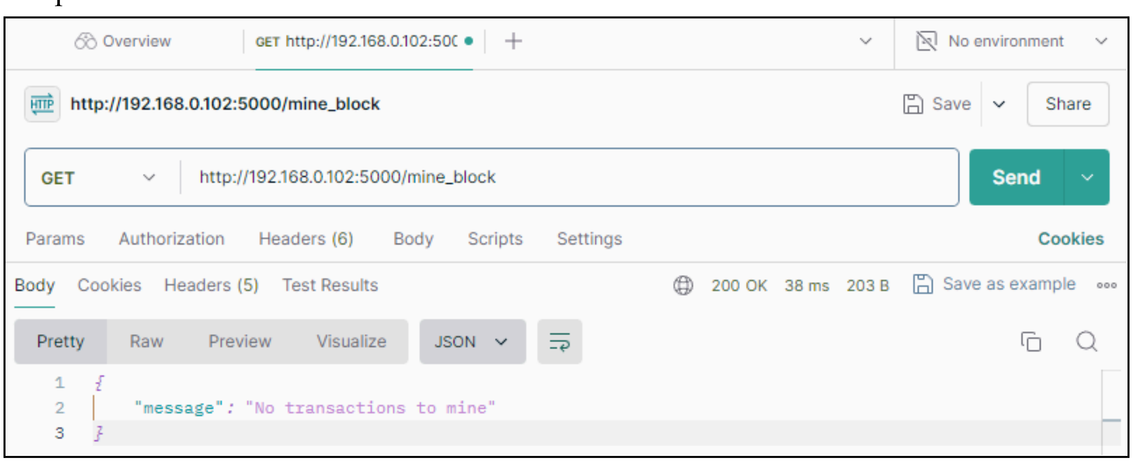
```python
# Getting the full Blockchain
@app.route('/get_chain', methods = ['GET'])
def get_chain():
    response = {'chain': b.chain, 'length': len(b.chain)}
    return jsonify(response), 200

# Checking if the Blockchain is valid
@app.route('/is_valid', methods = ['GET'])
def is_valid():
    is_valid = b.is_chain_valid(b.chain)
    if is_valid:
        response = {'message': 'All good. The Blockchain is valid.'}
    else:
        response = {'message': 'Houston, we have a problem.
                                 The Blockchain is not valid.'}
    return jsonify(response), 200

@app.route('/add_transaction', methods = ['POST'])
def add_transaction():
    # Method to create transaction in the b
    json = request.get_json()
    sender = json['sender']
    receiver = json['receiver']
    amount = json['amount']
    response = {'message': b.create_transaction(sender, receiver, amount)}
    return jsonify(response), 201

@app.route('/get_transactions', methods = ['GET'])
def get_transactions():
    response = {'transactions': b.transactions}
    return jsonify(response), 200
# Running the app
app.run(host = '0.0.0.0', port = 5000)
```

Outputs

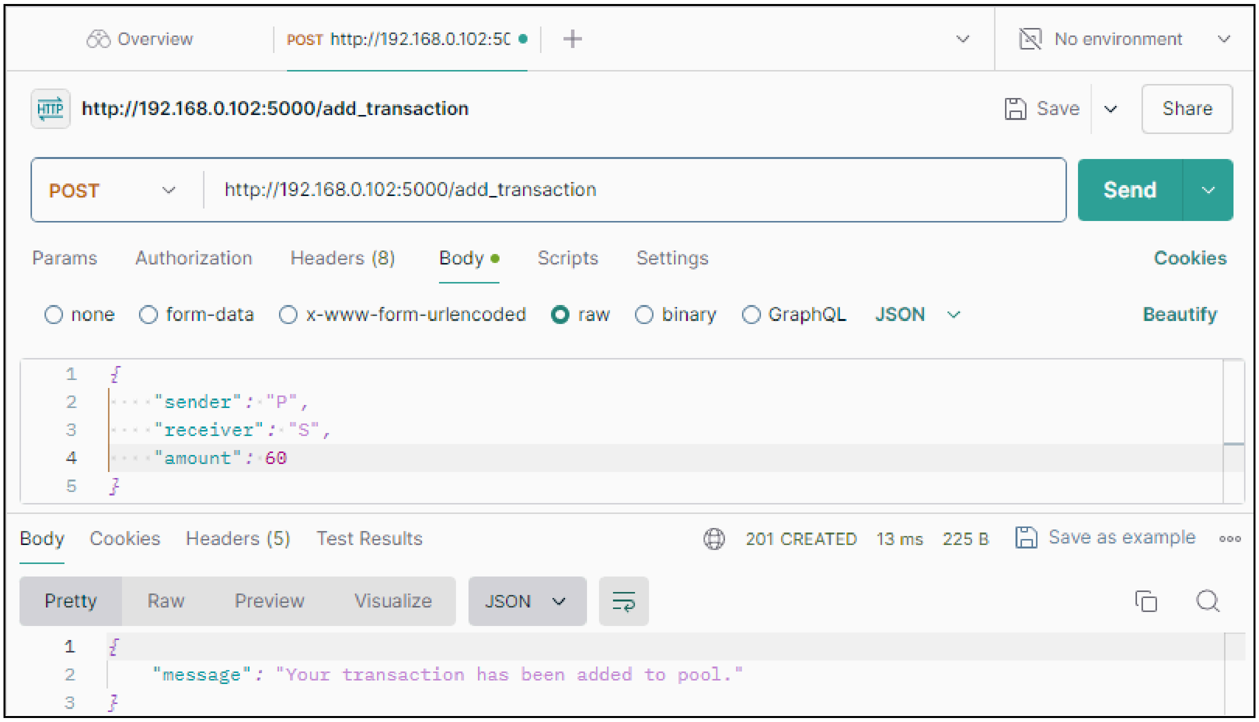
Execute flask application

```
PS D:\B. E. CMPN\Seventh sem\BC> python blockchain.py
 * Serving Flask app 'blockchain'
 * Debug mode: off
WARNING: This is a development server. Do not use it in
 * Running on all addresses (0.0.0.0)
 * Running on http://127.0.0.1:5000
 * Running on http://192.168.0.102:5000
```

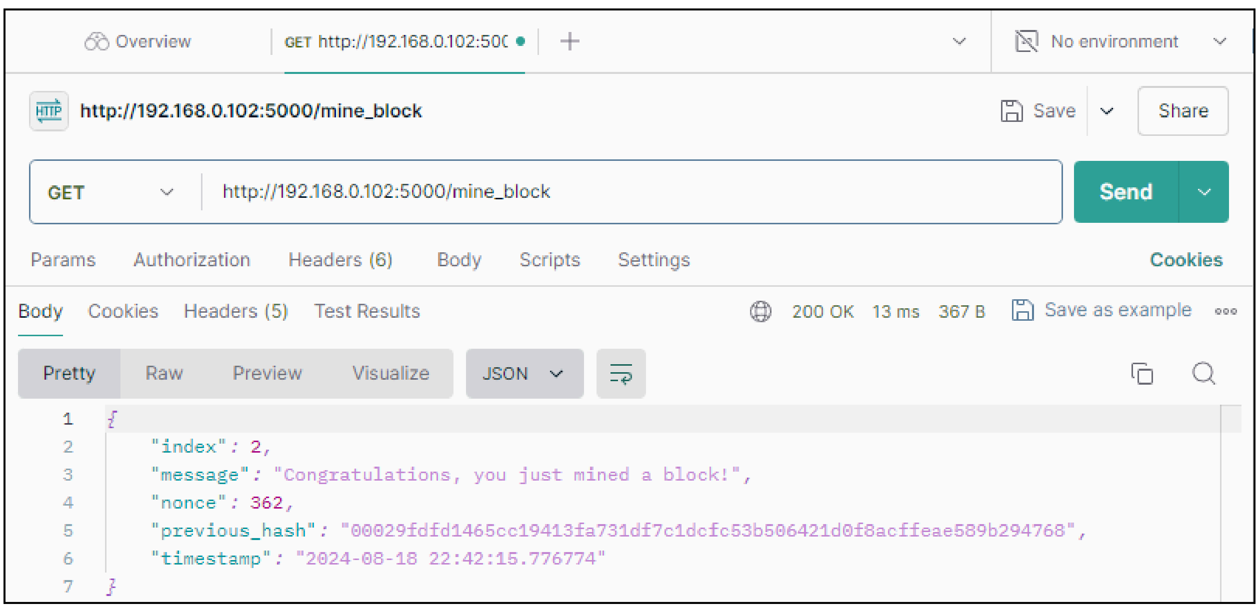
Make request to the API



Add few transactions to blockchain

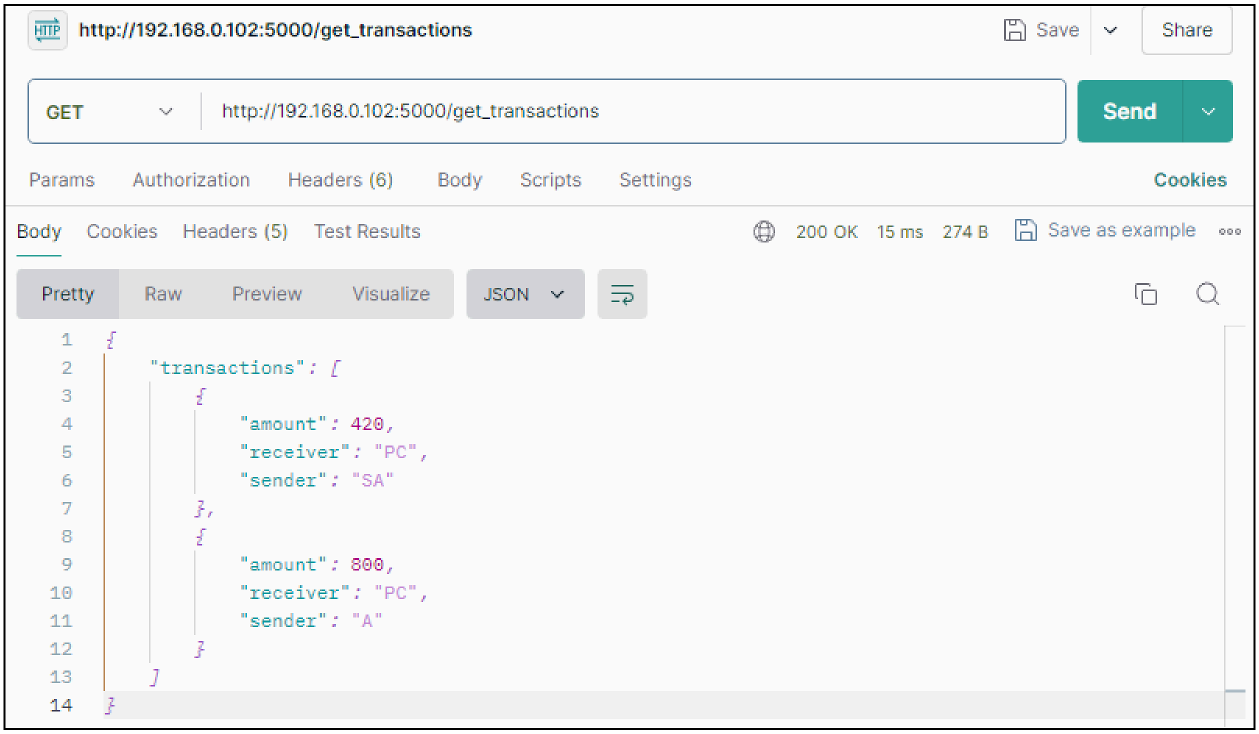


Mine block



Check if blockchain is valid

Viewing transactions in mempool

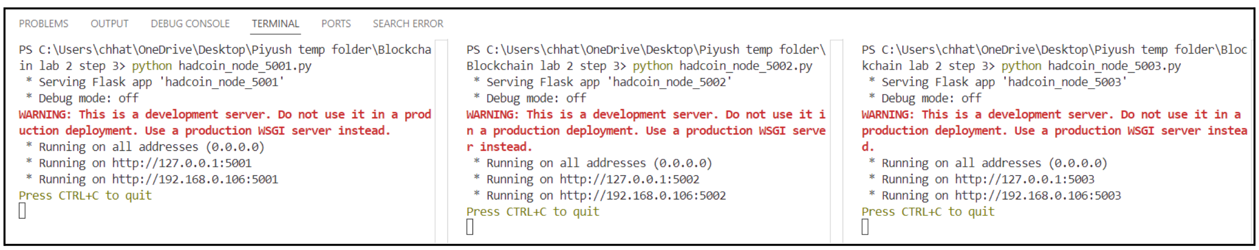


Viewing the chain at http://192.168.0.102:5000/get_chain

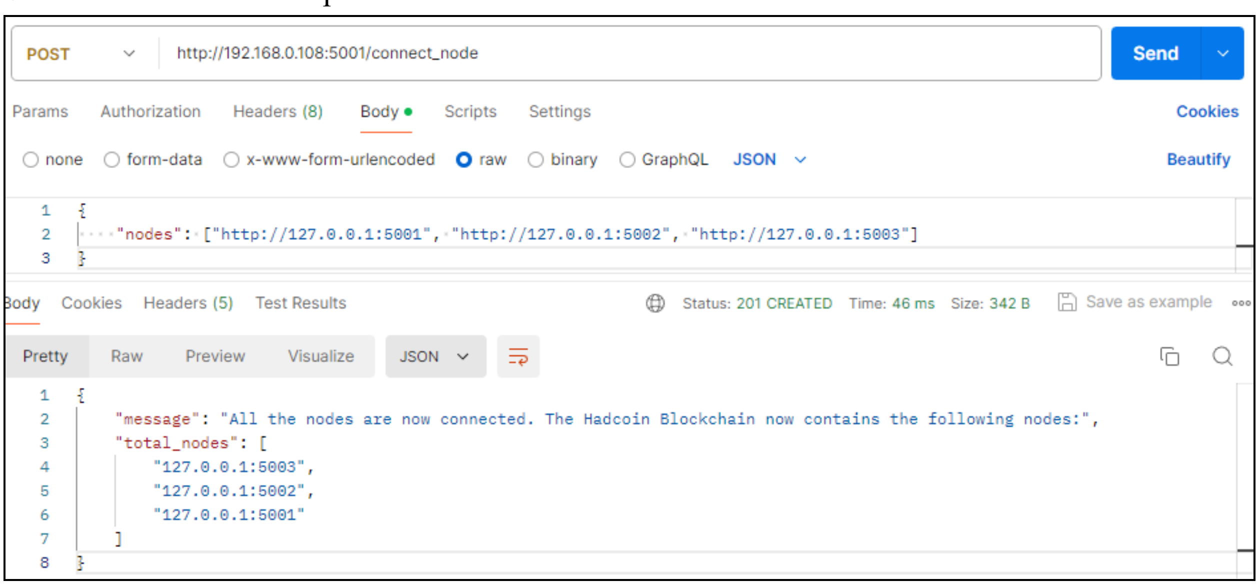

```
{
    "chain": [
        {
            "index": 1, "merkle_root": null, "nonce": 1995,
            "previous_hash": "0", "timestamp": "2024-08-18 22:36:01.669454",
            "transactions": []
        },
        {
            "index": 2, "nonce": 362,
            "merkle_root":
            b335f26f17941cc0372d5795f3de3a8300083c98931ec2d0a10c9d4b294659b3,
            "previous_hash":
            00029fdfd1465cc19413fa731df7c1dcfc53b506421d0f8acffeae589b294768,
            "timestamp": "2024-08-18 22:42:15.776774",
            "transactions": [
                {
                    "amount": 60, "receiver": "S", "sender": "P"
                },
                {
                    "amount": 120, "receiver": "Shop", "sender": "S"
                },
                {
                    "amount": 100, "receiver": "A", "sender": "P"
                }
            ]
        },
        {
            "index": 3, "nonce": 3117,
            "merkle_root":
```

```
                bf2128b4769f631f5ec97c156b6a635c87f4e53f554a6490249bd3f4121be8ad,
                "previous_hash":
                000a1ea954e2997ddc9dc128b84dd2543f92e41abdf8dac865c17b327f26e516,
                "timestamp": "2024-08-18 22:51:15.778886",
                "transactions": [
                    {
                        "amount": 420,
                        "receiver": "PC",
                        "sender": "SA"
                    },
                    {
                        "amount": 800,
                        "receiver": "PC",
                        "sender": "A"
                    }
                ]
            }
        ],
        "length": 3
}
```


Running a blockchain with 3 peer nodes

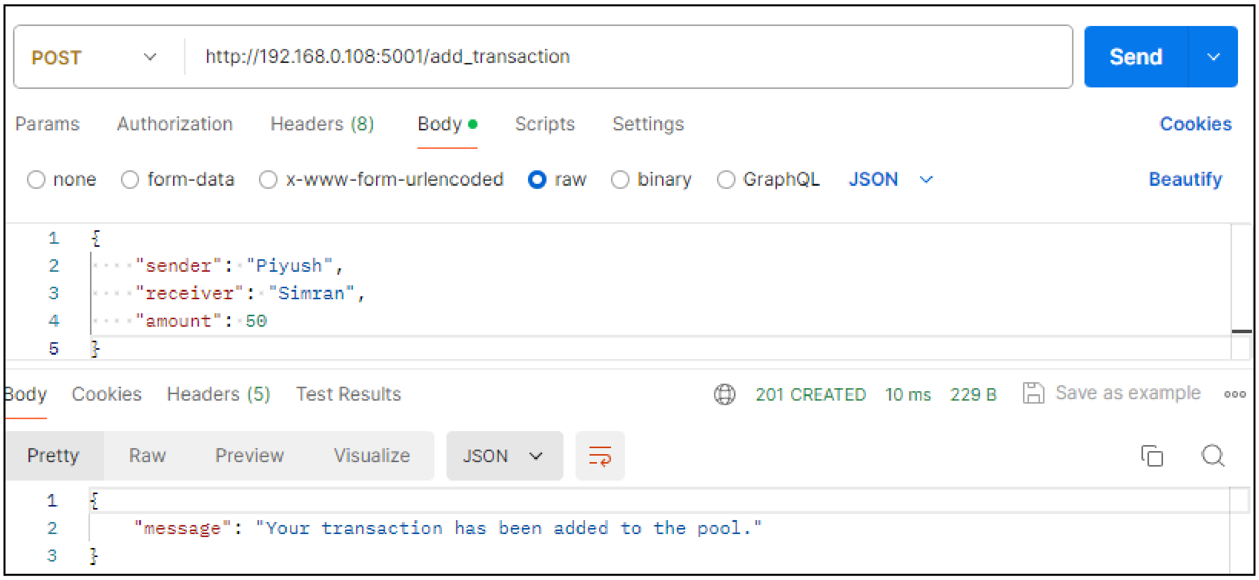


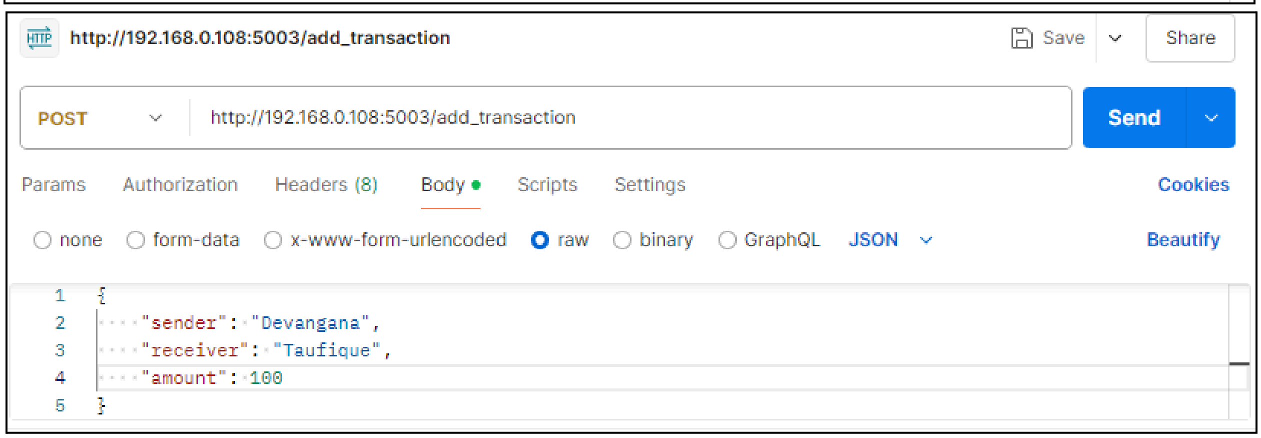
Connect node 5001 with peer nodes



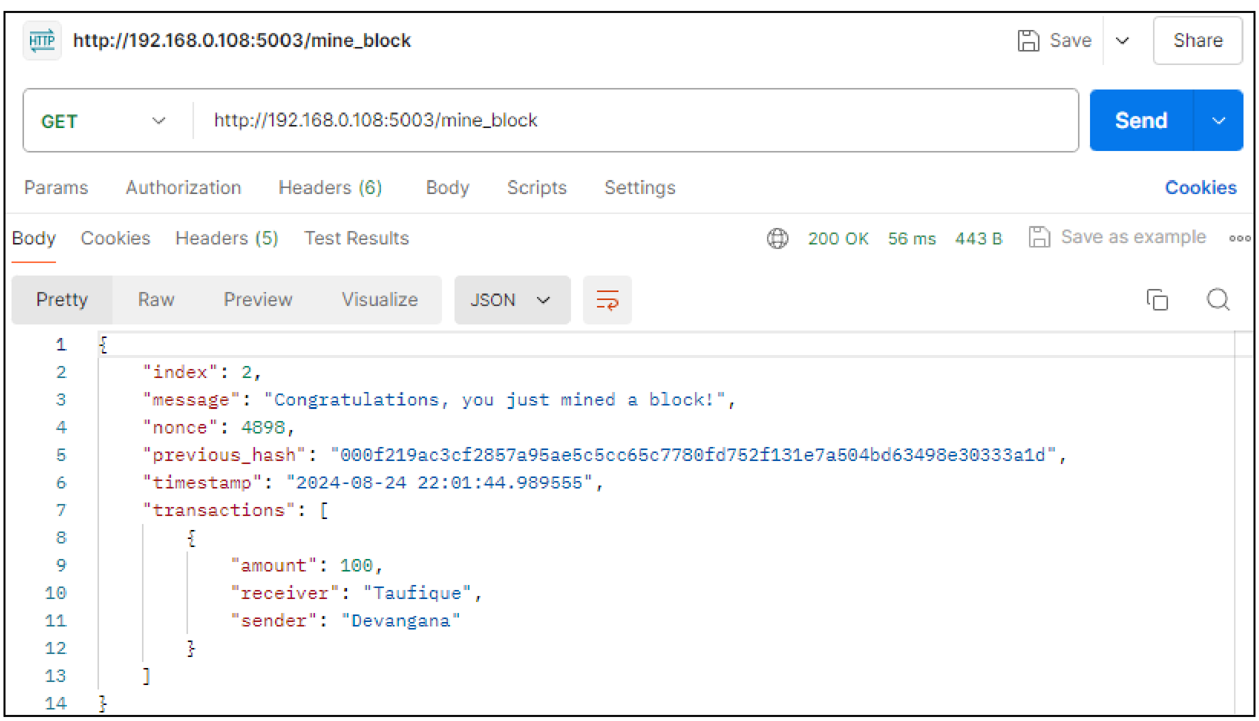
Call same for nodes 5002 and 5003

Add different transactions to all blockchain nodes

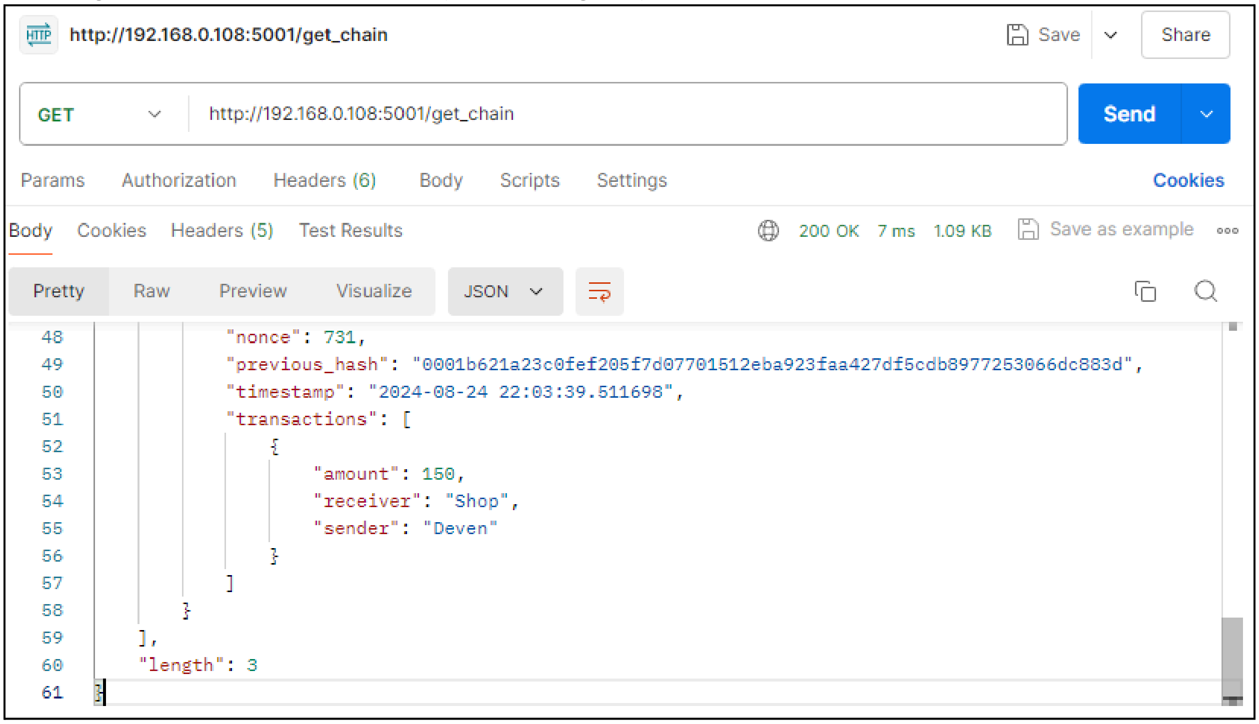




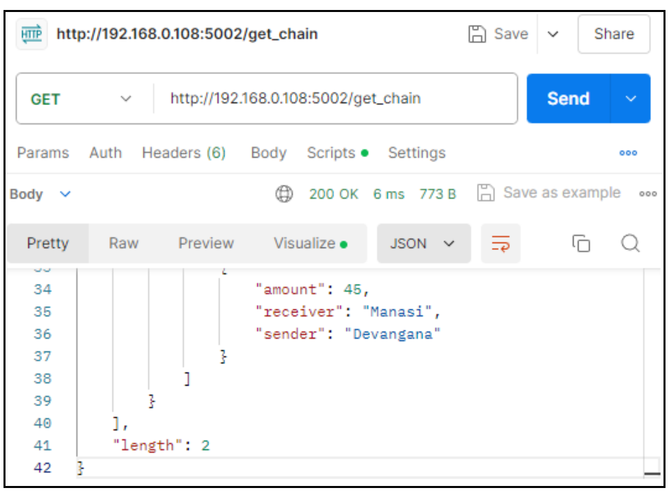
Mine blocks on all nodes



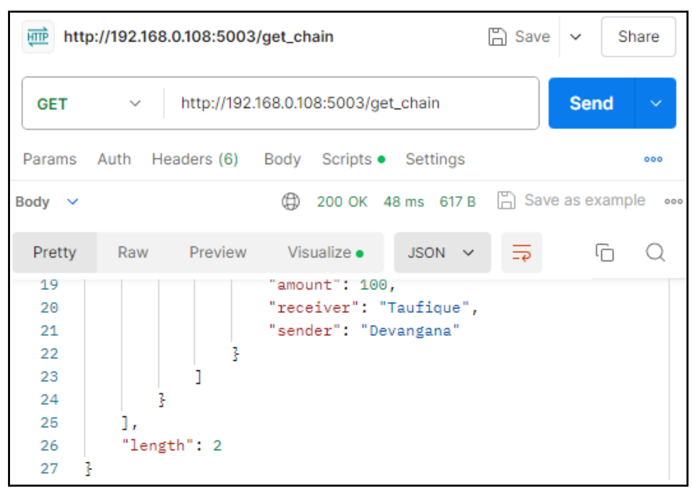
Viewing the blockchain at node 1 (it is of length 3)



Blockchain at node 2 (length 2)



Blockchain at node 3 (length 2)



As the nodes have different blockchains, let us replace it with the biggest chain amongst the 3 which is with node 1.

Blocks have different chains, replace chain in block 2 and 3 with longest one

Replaced chain:


```
{
  "chain": [{
      "index": 1, "merkle_root": null, "nonce": 403, "previous_hash": "0",
      "timestamp": "2024-08-24 21:53:59.239844", "transactions": []},
    {
      "index": 2, "nonce": 2018, "timestamp": "2024-08-24 22:02:37.294951",
      "previous_hash":
      000d2b1e26214b0841d989dec13df308b5dcff33346d700764bf5f0a127c73fc,
      "merkle_root":
      69d78d68061a1ac4a043b4e2e336a7530fe52f173967adbb068ab421ab5884f4,
      "transactions": [
        {"amount": 50, "receiver": "Simran", "sender": "Piyush"},
        {"amount": 100, "receiver": "Shop", "sender": "Simran"},
        {"amount": 500, "receiver": "Manraj", "sender": "Sakshi"},
        {"amount": 50, "receiver": "Manraj", "sender": "Deven"},
        {"amount": 1500, "receiver": "Shop", "sender": "Manraj"}]},
    {
      "index": 3, "nonce": 731, "timestamp": "2024-08-24 22:03:39.511698",
      "merkle_root":
      6f35076bb095707c9420012d9234a8b2d3bc16dc3ef3134ee6439d3e726f4344,
      "previous_hash":
      0001b621a23c0fef205f7d07701512eba923faa427df5cdb8977253066dc883d,
      "transactions": [
        {"amount": 150, "receiver": "Shop", "sender": "Deven"}]}],
  "length": 3}
```


Conclusion

Understood the challenges in P2P networks, how transactions are performed and how a miner mines a block to be added in a blockchain. Implemented a Cryptocurrency in Python using Flask, Postman and Python libraries such as datetime, jsonify, hashlib, uuid4, urlparse, request. Successfully mined the blocks among a P2P network with 3 nodes. Performed transactions via the network. Successfully updated the block across the network.