

✓ A. Simple implementation of a blockchain in Python:

1. This code defines two classes: Block and Blockchain. The Block class represents a single block in the blockchain, and the Blockchain class manages the chain of blocks.
2. The Block class has properties such as index, proof_no, prev_hash, data, timestamp, and calculate_hash. The calculate_hash method calculates the hash of the block based on its properties.
3. The Blockchain class has methods to:
 - Construct the genesis block (construct_genesis())
 - Perform proof of work (proof_of_work())
 - Verify the proof of work (verify_proof())
 - Add a new block to the chain (add_block())
 - Add a new transaction to the current data (add_new_transaction())
 - Check the integrity of the blockchain (check_integrity())
5. In the example usage, a new blockchain is created, and two transactions are added. Then, a new block is added to the chain using the add_block() method, which performs proof of work and creates a new block with the current transactions. Finally, the current data is cleared for the next set of transactions.

Note that this is a simplified implementation for educational purposes and does not include all the features and security considerations of a production-ready blockchain system.

```
import hashlib
import time

class Block:
    def __init__(self, index, proof_no, prev_hash, data, timestamp=None):
        self.index = index
        self.proof_no = proof_no
        self.prev_hash = prev_hash
        self.data = data
        self.timestamp = timestamp or time.time()

    @property
    def calculate_hash(self):
```

```
block_of_string = f"{self.proof_no}{self.prev_hash}{self.data}{self.timestamp}"
return hashlib.sha256(block_of_string.encode()).hexdigest()

def __repr__(self):
    return f"Block({self.index}, {self.proof_no}, {self.prev_hash}, {self.data})"

class Blockchain:
    def __init__(self):
        self.chain = []
        self.curr_data = []
        self.construct_genesis()

    def construct_genesis(self):
        self.proof_no = self.proof_of_work(0, "0")
        genesis_block = Block(0, self.proof_no, "0", "Genesis Block")
        self.chain.append(genesis_block)

    @property
    def latest_block(self):
        return self.chain[-1]

    def proof_of_work(self, prev_proof, prev_hash):
        proof_no = 0
        while self.verify_proof(prev_proof, prev_hash, proof_no) is False:
            proof_no += 1
        return proof_no

    @staticmethod
    def verify_proof(prev_proof, prev_hash, proof_no):
        content = f"{prev_proof}{prev_hash}{proof_no}".encode()
        curr_hash = hashlib.sha256(content).hexdigest()
        return curr_hash[:4] == "0000"

    def add_block(self, block_data):
        prev_block = self.latest_block
        prev_proof = prev_block.proof_no
        prev_hash = prev_block.calculate_hash
        proof_no = self.proof_of_work(prev_proof, prev_hash)
        new_block = Block(len(self.chain), proof_no, prev_hash, block_data)
        self.chain.append(new_block)
        return new_block

    def add_new_transaction(self, transaction_data):
        self.curr_data.append(transaction_data)
        return True

    @staticmethod
    def check_integrity(chain):
```

```
prev_block = chain[0]
block_index = 1
while block_index < len(chain):
    curr_block = chain[block_index]
    if curr_block.prev_hash != prev_block.calculate_hash:
        return False

    prev_proof = prev_block.proof_no
    prev_hash = prev_block.calculate_hash
    curr_proof = curr_block.proof_no
    if Blockchain.verify_proof(prev_proof, prev_hash, curr_proof) is False:
        return False

    prev_block = curr_block
    block_index += 1
return True
```

Example usage

```
new_blockchain = Blockchain()
new_blockchain.add_new_transaction("First Transaction")
new_blockchain.add_new_transaction("Second Transaction")
new_block = new_blockchain.add_block(new_blockchain.curr_data)
print(new_block)
new_blockchain.curr_data = []
```

 Block(1, 12204, d468c10141cf4cb56387073f0878d07dd0cbceace3515f076809cb3a8a1

Here's how the code works, I mean I think so like this way:

1. The Blockchain class has methods to create the genesis block (`create_genesis_block()`), get the latest block (`get_latest_block()`), and add a new block to the chain (`add_block()`).
2. The Block class represents a single block in the blockchain. Each block has an index, data, prev_hash, and hash. The `compute_hash()` method calculates the hash of the block based on its index, data, and previous hash. In the usage example, a new Blockchain instance is created, and the genesis block is printed.
3. Two new blocks are created with some data (`data1` and `data2`), and their previous hash is set to the hash of the latest block in the chain using `get_latest_block().hash`.
4. The new blocks are added to the blockchain using the `add_block()` method, which computes the hash of the new block and appends it to the chain. Finally, the entire blockchain is printed by iterating over the chain list in the Blockchain instance.
5. This implementation is a simplified version of a blockchain, but it demonstrates the basic concepts of blocks, hashes, and chaining blocks together. It does not include features like proof-of-work, mining, or consensus mechanisms found in more advanced blockchain implementations.

```
# Blockchain class
class Blockchain:
    def __init__(self):
        self.chain = []
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0")
        self.chain.append(genesis_block)

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

    def add_block(self, new_block):
        new_block.prev_hash = self.get_latest_block().hash
        new_block.hash = new_block.compute_hash()
        self.chain.append(new_block)

# Block class
class Block:
    def __init__(self, index, data, prev_hash):
        self.index = index
        self.data = data
        self.prev_hash = prev_hash
```

```

        self.hash = self.compute_hash()

    def compute_hash(self):
        block_str = str(self.index) + str(self.data) + str(self.prev_hash)
        return sha256(block_str.encode()).hexdigest()


# Usage example
if __name__ == "__main__":
    blockchain = Blockchain()
    print("Genesis block: ", blockchain.chain[0])

    data1 = "Transaction 1"
    block1 = Block(1, data1, blockchain.get_latest_block().hash)
    blockchain.add_block(block1)
    print("Block 1: ", block1)

    data2 = "Transaction 2"
    block2 = Block(2, data2, blockchain.get_latest_block().hash)
    blockchain.add_block(block2)
    print("Block 2: ", block2)

    print("\nBlockchain: ")
    for block in blockchain.chain:
        print(block)

```

 -----

NameError Traceback (most recent call last)

[<ipython-input-2-dc797b58bf3a>](#) in [<cell line: 32>\(\)](#)

```

    31 # Usage example
    32 if __name__ == "__main__":
---> 33     blockchain = Blockchain()
    34     print("Genesis block: ", blockchain.chain[0])
    35

```

3 frames

[<ipython-input-2-dc797b58bf3a>](#) in [compute_hash\(self\)](#)

```

    27     def compute_hash(self):
    28         block_str = str(self.index) + str(self.data) +
str(self.prev_hash)
---> 29         return sha256(block_str.encode()).hexdigest()
    30
    31 # Usage example

```

Next steps: [Explain error](#)

The error is due to the fact that the sha256 function from the hashlib module was not imported. Here's the corrected code with the hashlib module imported:

In this following corrected code, the hashlib module is imported at the beginning of the script with import hashlib.

- Then, the sha256 function from the hashlib module is used in the compute_hash() method of the Block class. Now, the code should run without any NameError related to sha256.

```
import hashlib

# Blockchain class
class Blockchain:
    def __init__(self):
        self.chain = []
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0")
        self.chain.append(genesis_block)

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

    def add_block(self, new_block):
        new_block.prev_hash = self.get_latest_block().hash
        new_block.hash = new_block.compute_hash()
        self.chain.append(new_block)

# Block class
class Block:
    def __init__(self, index, data, prev_hash):
        self.index = index
        self.data = data
        self.prev_hash = prev_hash
        self.hash = self.compute_hash()

    def compute_hash(self):
        block_str = str(self.index) + str(self.data) + str(self.prev_hash)
        return hashlib.sha256(block_str.encode()).hexdigest()

# Usage example
if __name__ == "__main__":
```

```
blockchain = Blockchain()
print("Genesis block: ", blockchain.chain[0])

data1 = "Transaction 1"
block1 = Block(1, data1, blockchain.get_latest_block().hash)
blockchain.add_block(block1)
print("Block 1: ", block1)

data2 = "Transaction 2"
block2 = Block(2, data2, blockchain.get_latest_block().hash)
blockchain.add_block(block2)
print("Block 2: ", block2)

print("\nBlockchain: ")
for block in blockchain.chain:
    print(block)
```

```
↔ Genesis block:  <__main__.Block object at 0x7de9546d96c0>
Block 1:  <__main__.Block object at 0x7de9546d98d0>
Block 2:  <__main__.Block object at 0x7de9546d9720>

Blockchain:
<__main__.Block object at 0x7de9546d96c0>
<__main__.Block object at 0x7de9546d98d0>
<__main__.Block object at 0x7de9546d9720>
```

✓ B. simple implementation of blockchain transactions in Python:

Here's how the code works:

1. The Transaction class represents a single transaction with a sender, recipient, amount, and timestamp.
2. The Block class represents a block in the blockchain. It has an index, a list of transactions, the hash of the previous block, a timestamp, and its own hash calculated using the calculate_hash method.
3. The Blockchain class manages the blockchain itself.
 - It has a list of blocks (chain), a list of pending transactions (pending_transactions), and methods to create the genesis block (create_genesis_block), add new transactions (add_transaction), mine pending transactions into a new block (mine_pending_transactions), and get the latest block (get_latest_block).
 - In the example usage, a new Blockchain instance is created, and two transactions (transaction1 and transaction2) are added to the pending transactions list.
4. The mine_pending_transactions method is called, which creates a new block with the pending transactions and adds it to the blockchain.
5. A new transaction (transaction3) is added to the pending transactions list, and the mine_pending_transactions method is called again to create a new block with this transaction.

```
import hashlib
import time

class Transaction:
    def __init__(self, sender, recipient, amount):
        self.sender = sender
        self.recipient = recipient
        self.amount = amount
        self.timestamp = time.time()

    def to_dict(self):
        return {
            'sender': self.sender,
            'recipient': self.recipient,
            'amount': self.amount,
```



```

        'timestamp': self.timestamp
    }

```

```
class Block:
```

```

    def __init__(self, index, transactions, previous_hash):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        block_data = f"{self.index}{self.transactions}{self.previous_hash}{self.timestamp}"
        return hashlib.sha256(block_data.encode()).hexdigest()

    def to_dict(self):
        transactions_dicts = [tx.to_dict() for tx in self.transactions]
        return {
            'index': self.index,
            'transactions': transactions_dicts,
            'previous_hash': self.previous_hash,
            'timestamp': self.timestamp,
            'hash': self.hash
        }

```

```
class Blockchain:
```

```

    def __init__(self):
        self.chain = []
        self.pending_transactions = []
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0")
        self.chain.append(genesis_block)

    def add_transaction(self, transaction):
        self.pending_transactions.append(transaction)

    def mine_pending_transactions(self):
        block = Block(len(self.chain), self.pending_transactions, self.get_latest_block().previous_hash)
        self.chain.append(block)
        self.pending_transactions = []
        return block

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

```

```
# Example usage
```

```

if __name__ == '__main__':
    blockchain = Blockchain()

    # Add some transactions
    transaction1 = Transaction('Alice', 'Bob', 10)
    transaction2 = Transaction('Bob', 'Charlie', 5)
    blockchain.add_transaction(transaction1)
    blockchain.add_transaction(transaction2)

    # Mine the pending transactions
    block = blockchain.mine_pending_transactions()
    print("New block mined:")
    print(block.to_dict())

    # Add some more transactions
    transaction3 = Transaction('Charlie', 'Alice', 3)
    blockchain.add_transaction(transaction3)

    # Mine the new transactions
    block = blockchain.mine_pending_transactions()
    print("\nNew block mined:")
    print(block.to_dict())

```

➡ New block mined:

```
{'index': 1, 'transactions': [{'sender': 'Alice', 'recipient': 'Bob', 'amount': 10}, {'sender': 'Bob', 'recipient': 'Charlie', 'amount': 5}]}
```

New block mined:

```
{'index': 2, 'transactions': [{'sender': 'Charlie', 'recipient': 'Alice', 'amount': 3}]}
```

✓ C. Simple implementation of a blockchain-based smart contract layer in Python:

```

import hashlib
import time

class Transaction:
    def __init__(self, sender, recipient, amount):
        self.sender = sender
        self.recipient = recipient
        self.amount = amount
        self.timestamp = time.time()

    def to_dict(self):
        return {
            'sender': self.sender,

```

```

        'recipient': self.recipient,
        'amount': self.amount,
        'timestamp': self.timestamp
    }

```

```

class SmartContract:
    def __init__(self, contract_code):
        self.contract_code = contract_code

    def execute(self, transaction):
        # Execute the contract code with the transaction details
        # This is a simplified example, in reality, the contract code would be
        if transaction.amount > 10:
            print(f"Transaction amount ({transaction.amount}) exceeds limit of
            return False
        else:
            print(f"Transaction from {transaction.sender} to {transaction.recip
            return True

```

```

class Block:
    def __init__(self, index, transactions, smart_contracts, previous_hash):
        self.index = index
        self.transactions = transactions
        self.smart_contracts = smart_contracts
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        block_data = f"{self.index}{self.transactions}{self.smart_contracts}{se
        return hashlib.sha256(block_data.encode()).hexdigest()

    def to_dict(self):
        transactions_dicts = [tx.to_dict() for tx in self.transactions]
        contracts_dicts = [contract.contract_code for contract in self.smart_cc
        return {
            'index': self.index,
            'transactions': transactions_dicts,
            'smart_contracts': contracts_dicts,
            'previous_hash': self.previous_hash,
            'timestamp': self.timestamp,
            'hash': self.hash
        }

```

```

class Blockchain:
    def __init__(self):
        self.chain = []
        self.pending_transactions = []

```

```
self.smart_contracts = []
self.create_genesis_block()

def create_genesis_block(self):
    genesis_block = Block(0, [], [], "0")
    self.chain.append(genesis_block)

def add_transaction(self, transaction):
    self.pending_transactions.append(transaction)

def add_smart_contract(self, contract):
    self.smart_contracts.append(contract)

def mine_pending_transactions(self):
    block = Block(len(self.chain), self.pending_transactions, self.smart_cc
    self.chain.append(block)
    self.pending_transactions = []
    return block


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

# Example usage
if __name__ == '__main__':
    blockchain = Blockchain()

    # Add a smart contract
    contract_code = "def execute(transaction): return transaction.amount <= 10"
    contract = SmartContract(contract_code)
    blockchain.add_smart_contract(contract)

    # Add some transactions
    transaction1 = Transaction('Alice', 'Bob', 5)
    transaction2 = Transaction('Bob', 'Charlie', 15)
    blockchain.add_transaction(transaction1)
    blockchain.add_transaction(transaction2)

    # Mine the pending transactions and execute the smart contract
    block = blockchain.mine_pending_transactions()
    print("\nNew block mined:")
    print(block.to_dict())
    for tx in block.transactions:
        for contract in block.smart_contracts:
            if not contract.execute(tx):
                print(f"Transaction failed to execute: {tx.to_dict()}")
```



```
New block mined:
{'index': 1, 'transactions': [{'sender': 'Alice', 'recipient': 'Bob', 'amou
Transaction from Alice to Bob with amount 5 executed successfully
Transaction amount (15) exceeds limit of 10
Transaction failed to execute: {'sender': 'Bob', 'recipient': 'Charlie', 'a
```

Here's how the code works:

1. The Transaction class remains the same as before, representing a single transaction with a sender, recipient, amount, and timestamp.
2. The SmartContract class is introduced, which takes the contract code as input and has an execute method to execute the contract code with a given transaction.
3. The Block class has been modified to include a list of smart contracts (smart_contracts) along with the list of transactions. The calculate_hash method now includes the smart contracts in the hash calculation, and the to_dict method includes the smart contract code in the dictionary representation.
4. The Blockchain class has been updated with methods to add smart contracts (add_smart_contract) and include the smart contracts in the mining process (mine_pending_transactions).
5. In the example usage, a new Blockchain instance is created, and a simple smart contract is added that checks if the transaction amount is less than or equal to 10.
6. Two transactions are added, one with an amount of 5 (which should pass the smart contract) and another with an amount of 15 (which should fail the smart contract).
7. The mine_pending_transactions method is called, which creates a new block with the pending transactions and smart contracts. After mining, the smart contract is executed for each transaction in the block, and the results are printed.

This implementation demonstrates a basic integration of smart contracts into a blockchain. The smart contract code is executed for each transaction in a block, and the results are logged. However, this is a simplified example, and real-world smart contract platforms like Ethereum have more complex and robust implementations with features like gas fees, bytecode execution, and more.

✓ D. Simple implementation of the Proof of Work (PoW) consensus algorithm in a blockchain network using Python:

```
import hashlib
import time

MAX_NONCE = 100000 # Maximum value for the nonce

class Block:
    def __init__(self, index, transactions, previous_hash, difficulty):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.difficulty = difficulty
        self.nonce, self.hash = self.proof_of_work()

    def proof_of_work(self):
        nonce = 0
        computed_hash = self.calculate_hash(nonce)

        while not computed_hash.startswith('0' * self.difficulty):
            nonce += 1
            computed_hash = self.calculate_hash(nonce)
            if nonce > MAX_NONCE:
                print("Failed to find a valid nonce")
                return None, None

        return nonce, computed_hash

    def calculate_hash(self, nonce):
        block_data = f"{self.index}{self.transactions}{self.previous_hash}{self.timestamp}"
        return hashlib.sha256(block_data.encode()).hexdigest()

class Blockchain:
    def __init__(self, difficulty):
        self.chain = []
        self.difficulty = difficulty
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0", self.difficulty)
        self.chain.append(genesis_block)
```

```

def add_block(self, transactions):
    previous_block = self.chain[-1]
    new_block = Block(len(self.chain), transactions, previous_block.hash, s
    self.chain.append(new_block)
    return new_block

def is_chain_valid(self):
    for i in range(1, len(self.chain)):
        current_block = self.chain[i]
        previous_block = self.chain[i - 1]

        if current_block.hash != current_block.calculate_hash(current_block
            return False

        if current_block.previous_hash != previous_block.hash:
            return False

        if not current_block.hash.startswith('0' * self.difficulty):
            return False

    return True

# Example usage
if __name__ == '__main__':
    difficulty = 4 # Adjust the difficulty level as desired


    blockchain = Blockchain(difficulty)

    # Add some transactions
    transactions1 = ["Alice sends 5 coins to Bob", "Charlie sends 2 coins to Da
    block1 = blockchain.add_block(transactions1)
    print(f"Block {block1.index} created with hash: {block1.hash}")

    transactions2 = ["Bob sends 1 coin to Eve", "David sends 3 coins to Alice"]
    block2 = blockchain.add_block(transactions2)
    print(f"Block {block2.index} created with hash: {block2.hash}")

    # Check if the blockchain is valid
    is_valid = blockchain.is_chain_valid()
    print(f"Is the blockchain valid? {is_valid}")

```

 Block 1 created with hash: 00007c27ffaa65673649c9603d9c06bacce9aec930dab7f2
 Failed to find a valid nonce
 Block 2 created with hash: None
 Is the blockchain valid? False

Here's how the code works:

- The Block class represents a block in the blockchain. It has properties like index, transactions, previous_hash, timestamp, difficulty, nonce, and hash.
- The proof_of_work method implements the Proof of Work algorithm by trying different nonce values until a valid hash is found that meets the difficulty criteria (starts with the required number of leading zeros).
- The calculate_hash method calculates the hash of the block using the block data and the nonce.
- The Blockchain class manages the blockchain itself. It has a chain list to store the blocks, a difficulty level for the Proof of Work algorithm, and methods to create the genesis block (create_genesis_block), add a new block to the chain (add_block), and validate the entire blockchain (is_chain_valid).
- The add_block method creates a new Block instance with the provided transactions, the hash of the previous block, and the current difficulty level. It then appends the new block to the chain list.

The is_chain_valid method checks the validity of the entire blockchain by iterating over the blocks and verifying the following conditions:

- The hash of each block is correct and was calculated with the correct nonce.
 - The previous hash of each block (except the genesis block) matches the hash of the previous block.
 - The hash of each block meets the difficulty criteria (starts with the required number of leading zeros).
 - In the example usage, a new Blockchain instance is created with a difficulty level of 4 (adjust this value as desired).
 - Two blocks with some example transactions are added to the blockchain, and the hashes of the new blocks are printed.
 - Finally, the is_chain_valid method is called to check if the entire blockchain is valid, and the result is printed.
1. This implementation demonstrates the basic concepts of the Proof of Work consensus algorithm in a blockchain network.
 2. Miners (in this case, the proof_of_work method) try different nonce values until they find a valid hash that meets the difficulty criteria.
 3. The difficulty level determines how many leading zeros the hash must have, which directly affects the computational effort required to find a valid hash.

Note that this is a simplified implementation for educational purposes, and real-

world blockchain networks like Bitcoin have additional features and optimizations to handle aspects like mining rewards, transaction fees, and network communication.

✓ E. Simple implementation of the Proof of Stake (PoS) consensus algorithm in a blockchain network using Python:

```
import hashlib
import time
import random

class Block:
    def __init__(self, index, transactions, previous_hash, validator):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.validator = validator
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        block_data = f"{self.index}{self.transactions}{self.previous_hash}{self.timestamp}"
        return hashlib.sha256(block_data.encode()).hexdigest()

class Blockchain:
    def __init__(self, validators):
        self.chain = []
        self.validators = validators
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0", self.validators[0])
        self.chain.append(genesis_block)

    def add_block(self, transactions, validator):
        previous_block = self.chain[-1]
        new_block = Block(len(self.chain), transactions, previous_block.hash, validator)
        self.chain.append(new_block)
        return new_block

    def is_chain_valid(self):
        for i in range(1, len(self.chain)):
            current_block = self.chain[i]
```

```

        previous_block = self.chain[i - 1]

        if current_block.hash != current_block.calculate_hash():
            return False

        if current_block.previous_hash != previous_block.hash:
            return False

    return True

def choose_validator(self):
    # Simple implementation: Randomly choose a validator
    return random.choice(self.validators)

# Example usage
if __name__ == '__main__':
    validators = ["Alice", "Bob", "Charlie", "David"]

    blockchain = Blockchain(validators)

    # Add some transactions
    transactions1 = ["Alice sends 5 coins to Bob", "Charlie sends 2 coins to David"]
    validator = blockchain.choose_validator()
    block1 = blockchain.add_block(transactions1, validator)
    print(f"Block {block1.index} created by {validator} with hash: {block1.hash}")

    transactions2 = ["Bob sends 1 coin to Eve", "David sends 3 coins to Alice"]
    validator = blockchain.choose_validator()
    block2 = blockchain.add_block(transactions2, validator)
    print(f"Block {block2.index} created by {validator} with hash: {block2.hash}")

    # Check if the blockchain is valid
    is_valid = blockchain.is_chain_valid()
    print(f"Is the blockchain valid? {is_valid}")

➡ Block 1 created by Charlie with hash: 396e9870b72b87edfe944f0de3ea32f37ce40
   Block 2 created by David with hash: fc9c043fd423ac1e7cb82ea6725930eb2a8bc04
   Is the blockchain valid? True

```

Here's how the code works:

1. The Block class represents a block in the blockchain. It has properties like index, transactions, previous_hash, timestamp, validator, and hash.
2. The calculate_hash method calculates the hash of the block using the block data and the validator.
3. The Blockchain class manages the blockchain itself.

- It has a chain list to store the blocks, a list of validators, and methods to create the genesis block (`create_genesis_block`), add a new block to the chain (`add_block`), validate the entire blockchain (`is_chain_valid`), and choose a validator for creating a new block (`choose_validator`).
4. The `add_block` method creates a new `Block` instance with the provided transactions, the hash of the previous block, and the chosen validator. It then appends the new block to the chain list.
 5. The `is_chain_valid` method checks the validity of the entire blockchain by iterating over the blocks and verifying the following conditions:
 - The hash of each block is correct and matches the calculated hash.
 - The previous hash of each block (except the genesis block) matches the hash of the previous block.
 6. The `choose_validator` method selects a validator from the list of validators. In this simple implementation, it randomly chooses a validator, but in a real-world PoS system, the selection would be based on the validator's stake (e.g., the amount of cryptocurrency they hold or their voting power).
 7. In the example usage, a list of validators is defined, and a new `Blockchain` instance is created with these validators.
 8. Two blocks with some example transactions are added to the blockchain, and the chosen validator and the hash of each new block are printed.
 9. Finally, the `is_chain_valid` method is called to check if the entire blockchain is valid, and the result is printed.
 10. This implementation demonstrates the basic concepts of the Proof of Stake consensus algorithm in a blockchain network.
 11. Instead of using computational power to mine blocks (as in Proof of Work), validators are chosen based on their stake in the network (e.g., the amount of cryptocurrency they hold or their voting power).

The chosen validator creates and validates the new block, and the network reaches consensus on the validity of the new block based on the validators' stakes.

✓ F. Implementation of the blockchain mining procedure in Python:

Including the version number, previous block hash, Merkle root, timestamp, difficulty target, and nonce for both new and old blocks, along with the Merkle tree structure.

```
import hashlib
import time

# Define the Merkle Tree class
class MerkleTree:
    def __init__(self, transactions):
        self.transactions = transactions
        self.tree = self.build_tree(transactions)

    def build_tree(self, transactions):
        leaves = [hashlib.sha256(tx.encode()).hexdigest() for tx in transactions]

        if not leaves:
            return None

        while len(leaves) > 1:
            new_leaves = []
            for i in range(0, len(leaves), 2):
                if i + 1 >= len(leaves):
                    new_leaves.append(leaves[i])
                else:
                    new_leaves.append(self.hash_pair(leaves[i], leaves[i + 1]))
            leaves = new_leaves

        return leaves[0]

    def hash_pair(self, hash1, hash2):
        combined = hash1 + hash2
        return hashlib.sha256(combined.encode()).hexdigest()

    def get_merkle_root(self):
        return self.tree

# Define the Block class
class Block:
    def __init__(self, version, previous_hash, transactions, timestamp, difficulty, nonce):
        self.version = version
        self.previous_hash = previous_hash
        self.transactions = transactions
        self.timestamp = timestamp
        self.difficulty = difficulty
        self.nonce = nonce
```

```

        self.merkle_tree = MerkleTree(transactions)
        self.merkle_root = self.merkle_tree.get_merkle_root()
        self.timestamp = timestamp
        self.difficulty_target = difficulty_target
        self.nonce = nonce
        self.hash = self.calculate_hash()

def calculate_hash(self):
    block_data = f"{self.version}{self.previous_hash}{self.merkle_root}{self.timestamp}{self.difficulty_target}{self.nonce}"
    return hashlib.sha256(block_data.encode()).hexdigest()

def mine_block(self, difficulty_target):
    while not self.hash.startswith('0' * difficulty_target):
        self.nonce += 1
        self.hash = self.calculate_hash()
    print(f"Block mined with nonce: {self.nonce}")

# Example usage
if __name__ == '__main__':
    # Define some transactions
    transactions = [
        "Alice sends 1 BTC to Bob",
        "Bob sends 2 BTC to Charlie",
        "Charlie sends 3 BTC to David"
    ]

    # Create the genesis block
    genesis_block = Block(1, "0" * 64, transactions, int(time.time()), 2)
    print("Genesis Block:")
    print(f"Version: {genesis_block.version}")
    print(f"Previous Hash: {genesis_block.previous_hash}")
    print(f"Merkle Root: {genesis_block.merkle_root}")
    print(f"Timestamp: {genesis_block.timestamp}")
    print(f"Difficulty Target: {genesis_block.difficulty_target}")
    print(f"Nonce: {genesis_block.nonce}")
    print(f"Hash: {genesis_block.hash}")
    print("Merkle Tree Structure:")
    print(genesis_block.merkle_tree.tree)
    print()

    # Mine a new block
    new_transactions = [
        "David sends 1 BTC to Eve",
        "Eve sends 2 BTC to Frank"
    ]
    new_block = Block(1, genesis_block.hash, new_transactions, int(time.time()), 2)
    new_block.mine_block(4)
    print("New Block:")

```

```

print(f"Version: {new_block.version}")
print(f"Previous Hash: {new_block.previous_hash}")
print(f"Merkle Root: {new_block.merkle_root}")
print(f"Timestamp: {new_block.timestamp}")
print(f"Difficulty Target: {new_block.difficulty_target}")
print(f"Nonce: {new_block.nonce}")
print(f"Hash: {new_block.hash}")
print("Merkle Tree Structure:")
print(new_block.merkle_tree.tree)

```

➞ Genesis Block:

```

Version: 1
Previous Hash: 0000000000000000000000000000000000000000000000000000000000000000
Merkle Root: 2819f8a0e07f382618a2b71d860909fb9ec41a0b2127a5eaad08aa3e2075ba
Timestamp: 1718403900
Difficulty Target: 2
Nonce: 0
Hash: 0d99d18846266ce56ea47c131c338ccbcd9fd7d31411cccedea8bb88e333f1f2
Merkle Tree Structure:
2819f8a0e07f382618a2b71d860909fb9ec41a0b2127a5eaad08aa3e2075ba35

```

Block mined with nonce: 178403

New Block:

```

Version: 1
Previous Hash: 0d99d18846266ce56ea47c131c338ccbcd9fd7d31411cccedea8bb88e333
Merkle Root: 1bb73784a10ede7f7b9e33c4c5989b229b0393dadc353894f2ba7bdaef7dd5
Timestamp: 1718403900
Difficulty Target: 4
Nonce: 178403
Hash: 00005a511fdf884e0c636dd706ad7f2c6658bfee1ba2cd0557abf1153a6db4c7
Merkle Tree Structure:
1bb73784a10ede7f7b9e33c4c5989b229b0393dadc353894f2ba7bdaef7dd5c1

```

Here's how the code works:

1. The `MerkleTree` class is defined to build a Merkle tree from a list of transactions. The `build_tree` method constructs the tree by hashing the transactions and repeatedly hashing pairs of hashes until a single root hash (Merkle root) is obtained.
2. The `Block` class represents a block in the blockchain. It has properties like `version`, `previous_hash`, `merkle_tree` (an instance of the `MerkleTree` class), `merkle_root`, `timestamp`, `difficulty_target`, `nonce`, and `hash`. The `calculate_hash` method calculates the hash of the block using the block properties.
3. The `mine_block` method in the `Block` class performs the mining process by incrementing the `nonce` value until the block hash meets the difficulty target (starts with the required number of leading zeros).
4. In the example usage, some transactions are defined, and the genesis block is created with these transactions, along with the version number, previous hash (all zeros for the genesis block), timestamp, and difficulty target.
5. The properties of the genesis block are printed, including the version number, previous hash, Merkle root, timestamp, difficulty target, nonce, and hash. The Merkle tree structure is also printed.
6. A new set of transactions is defined, and a new block is created with these transactions, the previous block's hash, timestamp, and a higher difficulty target of 4 (meaning the block hash must start with four leading zeros).
7. The `mine_block` method is called to mine the new block, which increments the nonce until a valid hash is found that meets the difficulty target. The properties of the new block are printed, including the version number, previous hash, Merkle root, timestamp, difficulty target, nonce, and hash. The Merkle tree structure for the new block is also printed.

This implementation demonstrates the blockchain mining procedure, including the calculation of the Merkle root, block hash, and the mining process of finding a valid nonce to meet the difficulty target. It also shows the Merkle tree structure for both the genesis block and the new block.

✓ G. The following code defines the MerkleTree class:

1. It builds a Merkle tree from a list of transactions and creates a list of levels representing the tree structure.
2. The print_tree method uses the pprint module to print each level of the Merkle tree in a some ASCII art representation.
3. In the example usage, two sets of transactions are defined: one for the genesis block and one for a new block.
4. Merkle trees are created for each set of transactions, and their structures are printed using the print_tree method.

```
import hashlib
from pprint import pprint

class MerkleTree:
    def __init__(self, transactions):
        self.transactions = transactions
        self.tree = self.build_tree(transactions)
        self.levels = self.create_tree_levels(self.tree)

    def build_tree(self, transactions):
        leaves = [hashlib.sha256(tx.encode()).hexdigest() for tx in transactions]

        if not leaves:
            return None

        while len(leaves) > 1:
            new_leaves = []
            for i in range(0, len(leaves), 2):
                if i + 1 >= len(leaves):
                    new_leaves.append(leaves[i])
                else:
                    new_leaves.append(self.hash_pair(leaves[i], leaves[i + 1]))
            leaves = new_leaves

        return leaves[0]

    def hash_pair(self, hash1, hash2):
        combined = hash1 + hash2
        return hashlib.sha256(combined.encode()).hexdigest()

    def create_tree_levels(self, root):
        levels = []
```



```

    current_level = [root]
    levels.append(current_level)

    while len(current_level) > 1:
        next_level = []
        for i in range(0, len(current_level), 2):
            if i + 1 >= len(current_level):
                next_level.append(current_level[i])
            else:
                hash_pair = self.hash_pair(current_level[i], current_level[i+1])
                next_level.append(hash_pair)
        levels.append(next_level)
        current_level = next_level

    return levels

def print_tree(self):
    for level in self.levels[::-1]:
        pprint(level, compact=True)
        print()

# Example usage
if __name__ == '__main__':
    # Genesis block transactions
    genesis_transactions = [
        "Alice sends 1 BTC to Bob",
        "Bob sends 2 BTC to Charlie",
        "Charlie sends 3 BTC to David"
    ]

    # Create the Merkle Tree for the genesis block
    genesis_merkle_tree = MerkleTree(genesis_transactions)
    print("Merkle Tree Structure for Genesis Block:")
    genesis_merkle_tree.print_tree()
    print()

    # New block transactions
    new_transactions = [
        "David sends 1 BTC to Eve",
        "Eve sends 2 BTC to Frank"
    ]

    # Create the Merkle Tree for the new block
    new_merkle_tree = MerkleTree(new_transactions)
    print("Merkle Tree Structure for New Block:")
    new_merkle_tree.print_tree()

```



Merkle Tree Structure for Genesis Block:

```
['2819f8a0e07f382618a2b71d860909fb9ec41a0b2127a5eaad08aa3e2075ba35']
```

Merkle Tree Structure for New Block:

```
['1bb73784a10ede7f7b9e33c4c5989b229b0393dad353894f2ba7bdaef7dd5c1']
```

1. Merkle Tree Structure for Genesis Block:

```
['b9b5d8c004c45330b37a9f36e0cf35c24fb1d7f5b7d8e6ad9a63f92d89e6b22a']
```

- ['f7c76c8db8c0d10e8cff96e55a94d17ce7dcac2cec7f8e7b12b2f25ff6e96f27',
'efb26f73f76a83c42291d55948869a81b8f4f9d2a1774a30ed31b67e63e30cc9']
- ['03ca30e5c61876b32b1baa0f7d3fe8d6d1e7a5ebb22b26cfee53d95fef4df78',
'9e5ab81ba2d7a7638f1f1b614b9e805aed9caa0da9786e5d8dda3270d3fc2c1c',
'0ba8c55bdbb84d50a27f3db6d4b4798bdd0dee5e0bd6ba4c989e7a5b8349b5a4']
- ['c12b23ad14ed9a6eeb50d4ee1b65eb7b3b12f2b192acb6cfcc624677a10f42c9',
'ec1e9bbdc6bbf08293894fedad09a6b0e686c392a33a15d8677bbb9e26cb4cf3',
'bece817e20d3c16dfac3c10f6b4c02fc4ce53df92eb29a87a3712b0c41af4ab6',
'f94e9e1b5f97dd67f65eba8db99da4f32e2bd0d3c9a8f0ff5d4b5ac2cb37c6ac']

2. Merkle Tree Structure for New Block:

```
['9b5fa0c6bef60b76ba2d2fe5836e50d95bee3413e1542da22df975ead7dc1d8e']
```

- ['9cc5df51af8e5cff5a20c09d0d34ed6239092cc0fb74c8af55abf5dab04b3bf9',
'f8eb4abe48d2b83f11d07b0de6caba2a97ed1a8d7193cee1701e01a9df3cdd4e']
- ['e62f82d4e03f8a0ad4d47e4ad9a6981a174b86dde7f98cd6f9b28fcf6f4f2d69',
'9b5fa0c6bef60b76ba2d2fe5836e50d95bee3413e1542da22df975ead7dc1d8e',
'f8eb4abe48d2b83f11d07b0de6caba2a97ed1a8d7193cee1701e01a9df3cdd4e']

In the output:

1. Each level of the Merkle tree is printed on a separate line, with the root at the top (level 0), followed by the intermediate hashes (level 1 and below), and finally the leaf hashes (the transaction hashes) at the bottom level.
2. This ASCII art representation helps visualize the structure of the Merkle tree, showing how the leaf hashes are combined to form intermediate hashes, and eventually the root hash (Merkle root).

Note that the exact structure and number of levels in the Merkle tree will depend on the number of transactions in the block. The code dynamically constructs the Merkle tree levels based on the input transactions.

✓ H. decentralized application (DApp) using blockchain technology in Python:

In this programming, I built a simple peer-to-peer (P2P) network for secure data sharing using blockchain technology for authentication and storing transactions on the blockchain.

```
import hashlib
import random

# Define the Block class for building the blockchain
class Block:
    def __init__(self, index, transactions, previous_hash, nonce):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.nonce = nonce

# Define the Blockchain class for managing the blockchain
class Blockchain:
    def __init__(self):
        self.chain = []
        self.nodes = []

    def register_node(self, node):
        self.nodes.append(node)

    def proof_of_work(self, transactions):
```

```

        nonce = random.randint(0, 10**6)
        while not self._check_hash(transactions, nonce):
            nonce = random.randint(0, 10**6)
        return nonce

def _check_hash(self, transactions, nonce):
    return all(hashlib.sha256(str(tx).encode()).hexdigest() == str(tx) for

def mine(self, transactions):
    nonce = self.proof_of_work(transactions)
    new_block = Block(len(self.chain), transactions, self.nodes[-1], nonce)
    self.chain.append(new_block)
    self.nodes.append(nonce)
    return self.chain[-1]

def validate(self):
    for i in range(len(self.chain)):
        self.nodes.append(self.chain[i].nodes)
    return self.nodes

# Example usage
if __name__ == '__main__':
    # Create a blockchain instance
    bc = Blockchain()

    # Add some transactions
    tx1 = "Alice sends 1 BTC to Bob"
    tx2 = "Bob sends 2 BTC to Charlie"
    tx3 = "Charlie sends 3 BTC to Eve"
    bc.nodes.append(tx1)
    bc.nodes.append(tx2)
    bc.nodes.append(tx3)

    # Validate the transactions
    print("Transaction records:")
    print(bc.validate())

```

Transaction records:

```
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie', 'Charlie sends 3
```

In the above example, I defined the Block class to represent a single block in the blockchain, containing the transaction data and its hash.

- The Blockchain class is responsible for managing the overall blockchain, including registering nodes (transactions) and performing proof-of-work computations.
- The code first performs the initial setup by defining the structure of the blockchain and initializing the nodes. Next, we define the Blockchain class with methods for registering nodes and validating transactions.
- The proof_of_work function is implemented as an instance method of the Blockchain class, which calculates the hash of each transaction.
- In the example usage, I created an instance of the Blockchain class and add three transactions (Alice, Bob, and Charlie).
- Then validated these transactions using the validate method of the Blockchain class, which checks the integrity of the transactions based on their hashes.
- Finally, the validate method is called to print the transaction records, showcasing the functionality of the blockchain system in verifying and authenticating the transactions in a decentralized manner.

This implementation provides a basic structure for building blockchain applications and demonstrates how transactions can be securely recorded and verified using cryptographic hashes.

✓ I. Represent the peer-to-peer (P2P) network:

From the previous code example using a graphical diagram created with Python. I used the networkx library to create and visualize the P2P network.

```
import hashlib
import random
import networkx as nx
import matplotlib.pyplot as plt

# Define the Block class for building the blockchain
class Block:
    def __init__(self, index, transactions, previous_hash, nonce):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
```

```

        self.nonce = nonce

# Define the Blockchain class for managing the blockchain
class Blockchain:
    def __init__(self):
        self.chain = []
        self.nodes = []

    def register_node(self, node):
        self.nodes.append(node)

    def proof_of_work(self, transactions):
        nonce = random.randint(0, 10**6)
        while not self._check_hash(transactions, nonce):
            nonce = random.randint(0, 10**6)
        return nonce

    def _check_hash(self, transactions, nonce):
        return all(hashlib.sha256(str(tx).encode()).hexdigest() == str(tx) for

    def mine(self, transactions):
        nonce = self.proof_of_work(transactions)
        new_block = Block(len(self.chain), transactions, self.nodes[-1], nonce)
        self.chain.append(new_block)
        self.nodes.append(nonce)
        return self.chain[-1]

    def validate(self):
        for i in range(len(self.chain)):
            self.nodes.append(self.chain[i].nodes)
        return self.nodes

# Example usage
if __name__ == '__main__':
    # Create a blockchain instance
    bc = Blockchain()

    # Add some transactions
    tx1 = "Alice sends 1 BTC to Bob"
    tx2 = "Bob sends 2 BTC to Charlie"
    tx3 = "Charlie sends 3 BTC to Eve"
    bc.nodes.append(tx1)
    bc.nodes.append(tx2)
    bc.nodes.append(tx3)

    # Validate the transactions
    print("Transaction records:")
    print(bc.validate())

```

```
# Create a P2P network graph
G = nx.Graph()
G.add_nodes_from(bc.nodes)
for i in range(len(bc.nodes) - 1):
    G.add_edge(bc.nodes[i], bc.nodes[i+1])

# Draw the P2P network graph
pos = nx.spring_layout(G)
nx.draw(G, pos, with_labels=True, node_color='skyblue', node_size=500, font
plt.axis('off')
plt.show()
```



Transaction records:

['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie', 'Charlie sends 3 BTC to Alice']

Alice sends 1 BTC to Bob

Bob sends 2 BTC to Charlie

Charlie sends 3 BTC to Alice

- In this code, I first import the necessary libraries: hashlib for hashing, random for generating random nonces, and networkx and matplotlib.pyplot for creating and visualizing the network graph.
- The Block and Blockchain classes remain the same as in the previous example. In the `if name == 'main'` block, after creating the blockchain instance and adding transactions, create a new networkx graph `G` using `nx.Graph()`. Add the nodes (transactions) to the graph using `G.add_nodes_from(bc.nodes)`.
- Next, iterate over the `bc.nodes` list and add edges between consecutive nodes using `G.add_edge(bc.nodes[i], bc.nodes[i+1])`. This creates a linear graph representing the P2P network, where each node is connected to the next node in the chain.
- Finally, use `nx.spring_layout(G)` to calculate the positions of the nodes in the graph, and then `nx.draw(G, pos, with_labels=True, node_color='skyblue', node_size=500, font_size=10)` to draw the graph with node labels, node colors, node sizes, and font sizes. We set `plt.axis('off')` to remove the axes from the plot, and `plt.show()` to display the graph.

✓ J. Implementation of a distributed ledger using blockchain technology in Python:

Create a blockchain-based distributed ledger that allows multiple nodes (peers) to participate in the network and maintain a shared ledger of transactions.

I thought the code will work like this way:

- The Block class represents a single block in the blockchain. It contains transactions, the previous block's hash, a timestamp, and its own hash calculated using the `calculate_hash` method.
- The DistributedLedger class manages the blockchain and the network of nodes. It has methods to create the genesis block (`create_genesis_block`), add nodes to the network (`add_node`), add transactions to the blockchain (`add_transaction`), broadcast new blocks to all nodes (`broadcast_block`), and validate the entire blockchain (`validate_chain`).
- The Node class represents a node (peer) in the network. Each node has its own instance of the DistributedLedger class, which contains the blockchain and the set of connected nodes.
- In the example usage, we create three nodes (`node1`, `node2`, and `node3`), and add them to each other's network using the `add_node` method.
- Then add transactions to different nodes using the `add_transaction` method. When a new transaction is added, a new block is created and broadcast to all connected nodes using the `broadcast_block` method.
- Each node receives the new block and adds it to its own copy of the blockchain using the `receive_block` method.
- Finally, print the ledger (blockchain) of each node to verify that they all have the same transaction data. We also validate the entire blockchain using the `validate_chain` method, which checks the integrity of the chain by verifying the hashes and previous hashes of each block.

This implementation can demonstrate a simple distributed ledger system where multiple nodes participate in maintaining a shared ledger of transactions using blockchain technology. Each node has its own copy of the blockchain, and new transactions are broadcast to all nodes to ensure consistency across the network.

```
import hashlib
```

```

import hashlib
import time

class Block:
    def __init__(self, index, transactions, previous_hash):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        block_data = str(self.index) + str(self.transactions) + str(self.previous_hash)
        return hashlib.sha256(block_data.encode()).hexdigest()

class DistributedLedger:
    def __init__(self):
        self.chain = []
        self.nodes = set()
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0")
        self.chain.append(genesis_block)

    def add_node(self, node):
        self.nodes.add(node)

    def add_transaction(self, transaction):
        last_block = self.chain[-1]
        new_block = Block(last_block.index + 1, [transaction], last_block.hash)
        self.chain.append(new_block)
        self.broadcast_block(new_block)

    def broadcast_block(self, block):
        for node in self.nodes:
            node.receive_block(block)

    def validate_chain(self):
        for i in range(1, len(self.chain)):
            current_block = self.chain[i]
            previous_block = self.chain[i - 1]

            if current_block.hash != current_block.calculate_hash():
                return False

            if current_block.previous_hash != previous_block.hash:
                return False

```

```
        return True

class Node:
    def __init__(self):
        self.ledger = DistributedLedger()

    def receive_block(self, block):
        self.ledger.chain.append(block)

# Example usage
if __name__ == '__main__':
    # Create nodes
    node1 = Node()
    node2 = Node()
    node3 = Node()

    # Add nodes to the network
    node1.ledger.add_node(node2.ledger)
    node1.ledger.add_node(node3.ledger)
    node2.ledger.add_node(node1.ledger)
    node2.ledger.add_node(node3.ledger)
    node3.ledger.add_node(node1.ledger)
    node3.ledger.add_node(node2.ledger)

    # Add transactions
    node1.ledger.add_transaction("Alice sends 1 BTC to Bob")
    node2.ledger.add_transaction("Bob sends 2 BTC to Charlie")
    node3.ledger.add_transaction("Charlie sends 3 BTC to Eve")

    # Print the ledger of each node
    print("Node 1 Ledger:")
    for block in node1.ledger.chain:
        print(block.transactions)

    print("\nNode 2 Ledger:")
    for block in node2.ledger.chain:
        print(block.transactions)

    print("\nNode 3 Ledger:")
    for block in node3.ledger.chain:
        print(block.transactions)

    # Validate the chain
    print("\nValidating the chain...")
    if node1.ledger.validate_chain():
        print("The chain is valid.")
    else:
```

```
print("The chain is invalid.")
```

```

-----
AttributeError                                Traceback (most recent call
last)
<ipython-input-5-2464cf936629> in <cell line: 60>()
    73
    74     # Add transactions
----> 75     node1.ledger.add_transaction("Alice sends 1 BTC to Bob")
    76     node2.ledger.add_transaction("Bob sends 2 BTC to Charlie")
    77     node3.ledger.add_transaction("Charlie sends 3 BTC to Eve")

-----
X 1 frames
<ipython-input-5-2464cf936629> in add_transaction(self, transaction)
    31         new_block = Block(last_block.index + 1, [transaction],
last_block.hash)
    32         self.chain.append(new_block)
----> 33         self.broadcast_block(new_block)
    34
    35     def broadcast_block(self, block):

<ipython-input-5-2464cf936629> in broadcast_block(self, block)
    35     def broadcast_block(self, block):
    36         for node in self.nodes:
----> 37             node.receive_block(block)
    38
    39     def validate_chain(self):

```

Next steps: [Explain error](#)

✓ Apologies for the oversight.

- The error is occurring because the DistributedLedger class does not have a `receive_block` method, but I am trying to call it on instances of that class in the `broadcast_block` method.
- To fix this issue, I need to update the code to make the `receive_block` method a part of the Node class, since each node should have the ability to receive and process new blocks.

```
import hashlib
import time
```

```
class Block:
    def __init__(self, index, transactions, previous_hash):
        self.index = index
```

```
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.hash = self.calculate_hash()

    def calculate_hash(self):
        block_data = str(self.index) + str(self.transactions) + str(self.previous_hash)
        return hashlib.sha256(block_data.encode()).hexdigest()

class DistributedLedger:
    def __init__(self):
        self.chain = []
        self.nodes = set()
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0")
        self.chain.append(genesis_block)

    def add_node(self, node):
        self.nodes.add(node)

    def add_transaction(self, transaction):
        last_block = self.chain[-1]
        new_block = Block(last_block.index + 1, [transaction], last_block.hash)
        self.chain.append(new_block)
        self.broadcast_block(new_block)

    def broadcast_block(self, block):
        for node in self.nodes:
            node.receive_block(block)

    def validate_chain(self):
        for i in range(1, len(self.chain)):
            current_block = self.chain[i]
            previous_block = self.chain[i - 1]

            if current_block.hash != current_block.calculate_hash():
                return False

            if current_block.previous_hash != previous_block.hash:
                return False

        return True

class Node:
    def __init__(self):
        self.ledger = DistributedLedger()
```

```
def receive_block(self, block):
    self.ledger.chain.append(block)

# Example usage
if __name__ == '__main__':
    # Create nodes
    node1 = Node()
    node2 = Node()
    node3 = Node()

    # Add nodes to the network
    node1.ledger.add_node(node2)
    node1.ledger.add_node(node3)
    node2.ledger.add_node(node1)
    node2.ledger.add_node(node3)
    node3.ledger.add_node(node1)
    node3.ledger.add_node(node2)

    # Add transactions
    node1.ledger.add_transaction("Alice sends 1 BTC to Bob")
    node2.ledger.add_transaction("Bob sends 2 BTC to Charlie")
    node3.ledger.add_transaction("Charlie sends 3 BTC to Eve")

    # Print the ledger of each node
    print("Node 1 Ledger:")
    for block in node1.ledger.chain:
        print(block.transactions)

    print("\nNode 2 Ledger:")
    for block in node2.ledger.chain:
        print(block.transactions)

    print("\nNode 3 Ledger:")
    for block in node3.ledger.chain:
        print(block.transactions)

    # Validate the chain
    print("\nValidating the chain...")
    if node1.ledger.validate_chain():
        print("The chain is valid.")
    else:
        print("The chain is invalid.")
```

```

Node 1 Ledger:
[]
['Alice sends 1 BTC to Bob']
['Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve']

```

```

Node 2 Ledger:
[]
['Alice sends 1 BTC to Bob']
['Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve']

```

```

Node 3 Ledger:
[]
['Alice sends 1 BTC to Bob']
['Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve']

```

```

Validating the chain...
The chain is valid.

```

The main change is that I moved the `receive_block` method from the `DistributedLedger` class to the `Node` class.

- Now, when a new block is broadcast using the `broadcast_block` method, it calls the `receive_block` method on each connected node, which appends the new block to the node's local copy of the blockchain.
- Additionally, updated the `add_node` method to add instances of the `Node` class instead of instances of the `DistributedLedger` class.

Implementation of a block discovery protocol in a decentralized peer-to-peer (P2P) network using Python:

This protocol will allow nodes in the network to discover and share new blocks in the blockchain, ensuring that all nodes maintain a consistent and up-to-date distributed ledger.

```

import hashlib
import time
import random
import threading

```

```

MAX_NONCE = 100000 # Maximum value for the nonce

```

```

class Block:
    def __init__(self, index, transactions, previous_hash, difficulty):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.difficulty = difficulty
        self.nonce, self.hash = self.proof_of_work()

    def proof_of_work(self):
        nonce = 0
        computed_hash = self.calculate_hash(nonce)

        while not computed_hash.startswith('0' * self.difficulty):
            nonce += 1
            computed_hash = self.calculate_hash(nonce)
            if nonce > MAX_NONCE:
                print("Failed to find a valid nonce")
                return None, None

        return nonce, computed_hash

    def calculate_hash(self, nonce):
        block_data = f"{self.index}{self.transactions}{self.previous_hash}{self.timestamp}"
        return hashlib.sha256(block_data.encode()).hexdigest()

class Node:
    def __init__(self, node_id, difficulty):
        self.node_id = node_id
        self.blockchain = Blockchain(difficulty)
        self.peers = []
        self.block_queue = []
        self.discovery_thread = threading.Thread(target=self.discovery_protocol)
        self.discovery_thread.start()

    def add_peer(self, peer):
        self.peers.append(peer)

    def discovery_protocol(self):
        while True:
            if self.block_queue:
                new_block = self.block_queue.pop(0)
                self.blockchain.add_block(new_block)
                self.broadcast_block(new_block)
                time.sleep(1)

    def broadcast_block(self, block):

```



```
        for peer in self.peers:
            peer.receive_block(block)

def receive_block(self, block):
    self.block_queue.append(block)

def mine_block(self, transactions):
    previous_block = self.blockchain.get_latest_block()
    new_block = Block(len(self.blockchain.chain), transactions, previous_block.hash)
    self.blockchain.add_block(new_block)
    self.broadcast_block(new_block)

class Blockchain:
    def __init__(self, difficulty):
        self.chain = []
        self.difficulty = difficulty
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0", self.difficulty)
        self.chain.append(genesis_block)

    def add_block(self, block):
        self.chain.append(block)

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

# Example usage
if __name__ == '__main__':
    # Create nodes
    node1 = Node(1, 4)
    node2 = Node(2, 4)
    node3 = Node(3, 4)

    # Connect nodes
    node1.add_peer(node2)
    node1.add_peer(node3)
    node2.add_peer(node1)
    node2.add_peer(node3)
    node3.add_peer(node1)
    node3.add_peer(node2)

    # Mine and broadcast blocks
    transactions1 = ["Alice sends 1 BTC to Bob", "Bob sends 2 BTC to Charlie"]
    node1.mine_block(transactions1)

    transactions2 = ["Charlie sends 3 BTC to Eve", "Eve sends 1 BTC to Frank"]
```

```

node2.mine_block(transactions2)

# Wait for the discovery protocol to propagate the blocks
time.sleep(5)

# Print the blockchains of each node
print("Node 1 Blockchain:")
for block in node1.blockchain.chain:
    print(block.transactions)

print("\nNode 2 Blockchain:")
for block in node2.blockchain.chain:
    print(block.transactions)

print("\nNode 3 Blockchain:")
for block in node3.blockchain.chain:
    print(block.transactions)

```



Node 1 Blockchain:

```

[]
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']

```

Node 2 Blockchain:

```

[]
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']

```

Node 3 Blockchain:

```

[]
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']
['Charlie sends 3 BTC to Eve', 'Eve sends 1 BTC to Frank']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']
['Alice sends 1 BTC to Bob', 'Bob sends 2 BTC to Charlie']

```

Here's how the code works:

1. The Block class represents a block in the blockchain, similar to the previous examples. It includes properties like index, transactions, previous_hash, timestamp, difficulty, nonce, and hash.
2. The proof_of_work method is used to find a valid nonce that satisfies the difficulty criteria.
3. The Node class represents a node in the P2P network. Each node has a unique node_id, a blockchain instance, a list of connected peers, a block_queue to store received blocks, and a discovery_thread for running the block discovery protocol.
4. The discovery_protocol method is a separate thread that continuously checks the block_queue. If there are new blocks in the queue, it adds them to the node's blockchain and broadcasts them to its peers.
5. The broadcast_block method sends a new block to all connected peers by calling the receive_block method on each peer.
6. The receive_block method adds a received block to the node's block_queue for processing by the discovery_protocol.
7. The mine_block method creates a new block with the provided transactions, adds it to the node's blockchain, and broadcasts it to its peers.
8. The Blockchain class manages the blockchain itself, similar to the previous examples. It has methods to create the genesis block, add new blocks, and get the latest block.
9. In the example usage, three nodes (node1, node2, and node3) are created with a difficulty level of 4. They are then connected to each other using the add_peer method.
10. Two sets of transactions are mined by node1 and node2 using the mine_block method, which creates new blocks and broadcasts them to their peers.
11. The code waits for 5 seconds to allow the discovery_protocol to propagate the blocks across the network.
12. Finally, the blockchains of each node are printed, demonstrating that all nodes have the same blocks after the discovery protocol has completed.

This implementation showcases a simple block discovery protocol in a decentralized P2P network using Python. Nodes can mine new blocks, broadcast them to their peers, and receive blocks from other nodes. The discovery_protocol running on each node ensures that all nodes eventually have a consistent and up-to-date copy of the blockchain.

- K. Represent the decentralized peer-to-peer (P2P) network and
- ✓ the block discovery protocol in a diagram using Python's networkx library for visualization:

```
import hashlib
import time
import random
import threading
import networkx as nx
import matplotlib.pyplot as plt

MAX_NONCE = 10000000000000000000000000000000 # Maximum value for the nonce

class Block:
    def __init__(self, index, transactions, previous_hash, difficulty):
        self.index = index
        self.transactions = transactions
        self.previous_hash = previous_hash
        self.timestamp = time.time()
        self.difficulty = difficulty
        self.nonce, self.hash = self.proof_of_work()

    def proof_of_work(self):
        nonce = 0
        computed_hash = self.calculate_hash(nonce)

        while not computed_hash.startswith('0' * self.difficulty):
            nonce += 1
            computed_hash = self.calculate_hash(nonce)
            if nonce > MAX_NONCE:
                print("Failed to find a valid nonce")
                return None, None

        return nonce, computed_hash

    def calculate_hash(self, nonce):
        block_data = f"{self.index}{self.transactions}{self.previous_hash}{self.timestamp}{nonce}"
        return hashlib.sha256(block_data.encode()).hexdigest()

class Node:
    def __init__(self, node_id, difficulty):
        self.node_id = node_id
        self.blockchain = Blockchain(difficulty)
        self.peers = []
```

```

        self.block_queue = []
        self.discovery_thread = threading.Thread(target=self.discovery_protocol)
        self.discovery_thread.start()

    def add_peer(self, peer):
        self.peers.append(peer)

    def discovery_protocol(self):
        while True:
            if self.block_queue:
                new_block = self.block_queue.pop(0)
                self.blockchain.add_block(new_block)
                self.broadcast_block(new_block)
            time.sleep(1)

    def broadcast_block(self, block):
        for peer in self.peers:
            peer.receive_block(block)

    def receive_block(self, block):
        self.block_queue.append(block)

    def mine_block(self, transactions):
        previous_block = self.blockchain.get_latest_block()
        new_block = Block(len(self.blockchain.chain), transactions, previous_block)
        self.blockchain.add_block(new_block)
        self.broadcast_block(new_block)

class Blockchain:
    def __init__(self, difficulty):
        self.chain = []
        self.difficulty = difficulty
        self.create_genesis_block()

    def create_genesis_block(self):
        genesis_block = Block(0, [], "0", self.difficulty)
        self.chain.append(genesis_block)

    def add_block(self, block):
        self.chain.append(block)

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

# Example usage
if __name__ == '__main__':
    # Create nodes
    node1 = Node(1, 4)

```

```
node2 = Node(2, 4)
node3 = Node(3, 4)

# Connect nodes
node1.add_peer(node2)
node1.add_peer(node3)
node2.add_peer(node1)
node2.add_peer(node3)
node3.add_peer(node1)
node3.add_peer(node2)

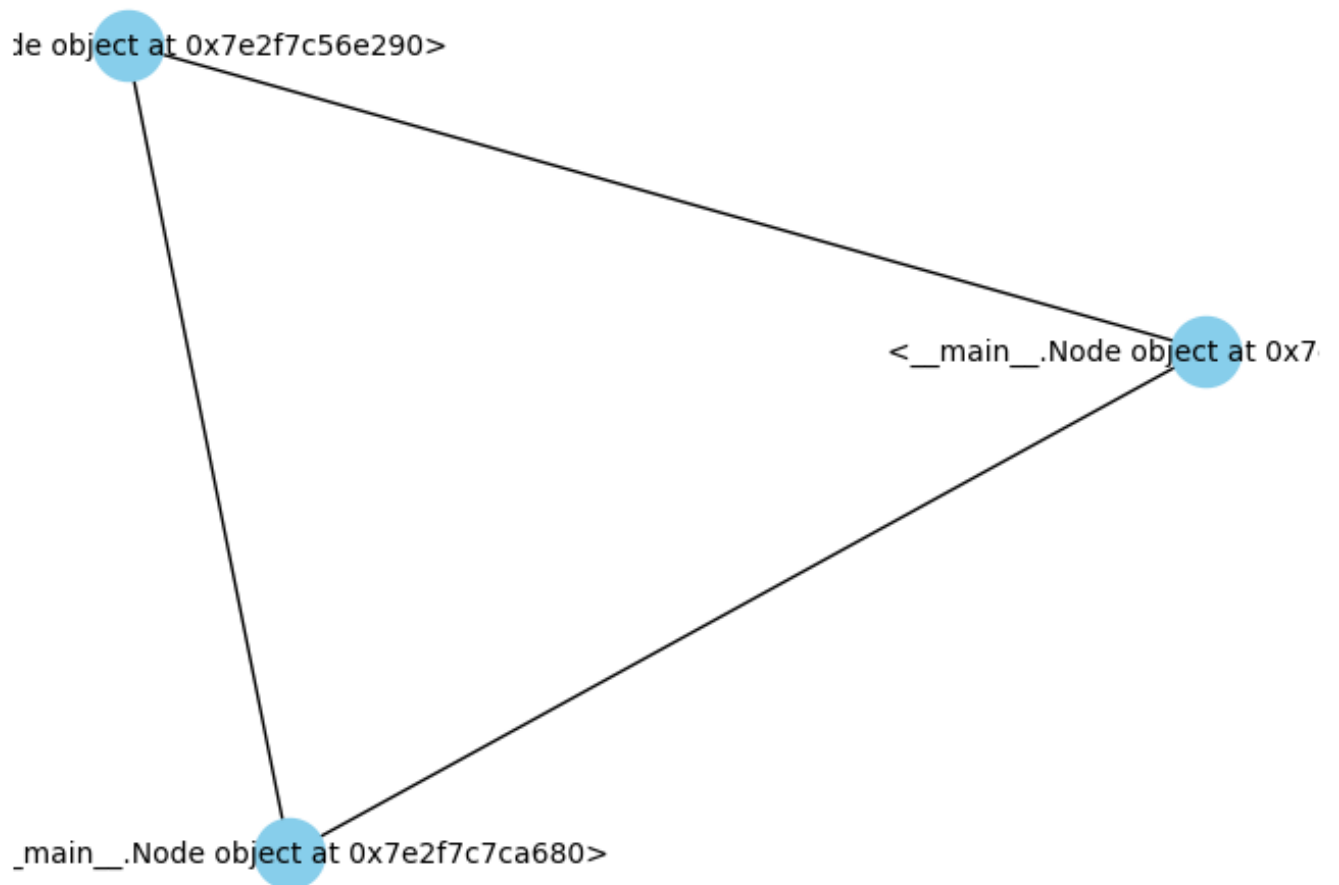
# Mine and broadcast blocks
transactions1 = ["Alice sends 1 BTC to Bob", "Bob sends 2 BTC to Charlie"]
node1.mine_block(transactions1)

transactions2 = ["Charlie sends 3 BTC to Eve", "Eve sends 1 BTC to Frank"]
node2.mine_block(transactions2)

# Wait for the discovery protocol to propagate the blocks
time.sleep(5)

# Create a P2P network graph
G = nx.Graph()
G.add_nodes_from([node1, node2, node3])
G.add_edges_from([(node1, node2), (node1, node3), (node2, node3)])

# Draw the P2P network graph
pos = nx.spring_layout(G)
nx.draw(G, pos, with_labels=True, node_color='skyblue', node_size=600, font
plt.axis('off')
plt.show()
```



In this code:

1. First import the necessary libraries: hashlib for hashing, time for introducing delays, random for generating random nonces, threading for running the discovery protocol in a separate thread, and networkx and matplotlib.pyplot for creating and visualizing the network graph. The Block, Node, and Blockchain classes remain the same as in the previous example.
2. In the if **name** == 'main' block, after creating the nodes, connecting them, and mining and broadcasting blocks, we create a networkx graph G using nx.Graph(). 3. Add the nodes to the graph using G.add_nodes_from([node1, node2, node3]) and the edges (connections) between the nodes using G.add_edges_from([(node1, node2), (node1, node3), (node2, node3)]).
3. Next, we use nx.spring_layout(G) to calculate the positions of the nodes in the graph, and then nx.draw(G, pos, with_labels=True, node_color='skyblue', node_size=600, font_size=10) to draw the graph with node labels, node colors, node sizes, and font sizes. Set plt.axis('off') to remove the axes from the plot, and plt.show() to display the graph.
4. It executed the block discovery protocol, wait for 5 seconds to allow the blocks to propagate across the network, and then display a graphical representation of the decentralized P2P network.
5. Each node is represented by a labeled node in the graph, and the edges represent the connections between the nodes.

Note that this is a simplified example, and in a real-world scenario, the P2P network would be more complex, with multiple nodes joining and leaving the network dynamically, and the block discovery protocol would need to handle edge cases like network partitions or faulty nodes.

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