Blockchain-based consensus for a secure smart agriculture supply chain

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Abstract: Andhra Pradesh is one of the leading agricultural states in India, with a diverse range of crops, including rice, cotton, sugarcane, and fruits and vegetables. However, like many other regions, Andhra Pradesh faces several challenges related to the agricultural supply chain, like fragmentation of land, a lack of storage and processing facilities, an inefficient supply chain, and a lack of transparency. As a result, we proposed using consensus algorithms to create a blockchain-based query processing system that will provide a secure supply chain for smart agriculture. Can provide transparency, accountability, improved traceability and food safety, a reduction of fraud and counterfeiting, and improved efficiency and cost reduction. Which can help make sure that agricultural products are safe, secure, and of high quality. It has the potential to bring about significant positive outcomes in terms of transparency, traceability, market access, and efficiency, among others. It can change how we grow and eat food and help us build a more resilient and sustainable agricultural system.

Keywords: supply chain, query processing, block chain, Consensus algorithm, Smart Contract

Introduction: Precision agriculture, sometimes known as "smart agriculture," makes use of cutting-edge instruments like sensors, drones, and artificial intelligence to increase productivity, decrease waste, and lengthen the lifespan of crops. However, it is becoming more difficult to ensure the safety and quality of food produced today due to the increasing complexity of the agricultural supply chain. There has been a rise in demand for transparent and safe methods of tracing the provenance and authenticity of such goods. One potential solution to this issue is blockchain technology, which enables transparent and secure item tracking from the farm to the customer. In smart agriculture, a blockchain-based query processing system allows farmers and other parties in the supply chain to confirm the authenticity and origin of their products. Productivity and efficiency are increased, and the possibility of fraud and counterfeiting is reduced. The use of blockchain technology in agriculture has the potential to increase safety, reduce negative impacts on the environment, and boost profits for everyone involved. Using consensus methods, many parties can confirm that the data and transactions recorded in a blockchain are legitimate. Stakeholders can trust that data seen or added to the blockchain has been verified by the network of participants via a consensus method. The query processing system allows stakeholders to access transaction data from the blockchain based on a set of criteria. This can make keeping tabs on the flow of goods from manufacturer to consumer easy and safe. By recording transactions and storing them in a distributed ledger using blockchain technology, the risk of a centralized server failing or an unauthorized third party getting access to the ledger's contents is eliminated. By making the supply chain more open and secure, the system can, among other things, boost consumer confidence, reduce food waste, and enhance food safety. It's important to remember that many factors—such as the consensual approach taken, the level of buy-in from stakeholders, and the existence or lack of protections against, for instance, cyberattacks—will determine the system's efficacy.

1. Related Work: With consensus algorithms and a blockchain-based query processing system, smart agriculture can have a safe and open supply chain. Using a blockchain makes sure that all transactions are permanent and can be checked, which builds trust and confidence among stakeholders and customers. The consensus method is the only way to make sure that no malicious or fraudulent activity happens. It does this by requiring many network participants to validate each transaction. This contributes to the system's integrity and adds another degree of protection. An efficient method for creating a safe and transparent supply chain in smart agriculture is to use consensus algorithms in a blockchain-based query processing system. It has the ability to enhance supply chain effectiveness, boost stakeholder and customer confidence, and advance sustainable and ethical farming methods.

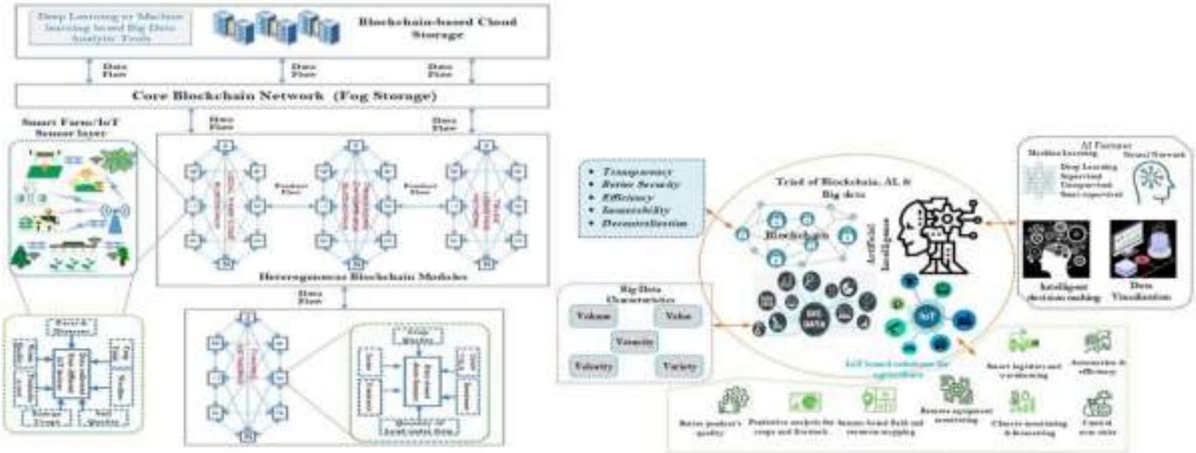


Figure: Using Blockchain and the Internet of Things to Control the Food Supply Chain: A Case Study in Interoperability in Enterprise Blockchain

2. Proposed Work: A secure supply chain in smart agriculture based on a blockchain-based query processing system offers several benefits that justify its implementation.

A. Transparency and accountability: A blockchain-based system provides a transparent and secure record of all transactions, from the farmer to the end consumer. Each stakeholder in the supply chain has visibility into the movement of goods and can track the product's journey from farm to table. Because the blockchain can't be changed, it leaves an audit trail that can be used to find out who is responsible for any problems or mistakes.

B. Improved traceability and food safety: A secure supply chain based on blockchain technology can enable stakeholders to quickly and accurately trace the origin and movement of agricultural products. In the event of a food safety concern, the supply chain can be traced back to the farm of origin, allowing for targeted recalls and reducing the risk of widespread outbreaks.

C. Reduction of fraud and counterfeiting: Counterfeit agricultural products are a significant issue in many parts of the world, resulting in economic losses and potential health risks to consumers. By using a blockchain-based system, stakeholders can ensure that products are authentic and the supply chain is secure, reducing the risk of fraudulent activities.

D. In order to cut costs and increase productivity, a blockchain-based system should be used in the supply chain. When blockchain technology is used to manage the supply chain, for example, it can get rid of the need for middlemen, which saves money and makes things run more smoothly.

2.1 Using blockchain technology, a secure supply chain in smart agriculture can offer transparency and accountability: There is complete visibility into the supply chain thanks to the blockchain, from seed to shelf. This creates an immutable record of the procedure that is accessible to all parties in the supply chain. Everyone in the supply chain has access to the same information thanks to the transparency of the blockchain, reducing the likelihood of arguments and misunderstandings. When everyone understands what's expected of them, it's much simpler to establish mutual trust. A culture of responsibility and accountability can flourish when everyone in the system is held accountable for their own actions, as is the case with blockchain technology. The blockchain can be used to pinpoint the source of a supply chain problem and put effective, efficient solutions in place. Because of their distributed nature and high level of security, blockchains make it very difficult for unauthorized users to alter data or perpetrate fraud. This makes it a reliable means of protecting against counterfeiting and other forms of supply chain fraud. Thanks to the blockchain, everyone involved in the supply chain can access real-time data on its health. We can increase output and cut down on wait times if we do this. Transparency, accountability, security, and traceability are just some of the benefits that blockchain technology may bring to the agricultural supply chain. Farmers and customers alike will reap the rewards of enhanced food safety, decreased food waste, and more efficient chain management.

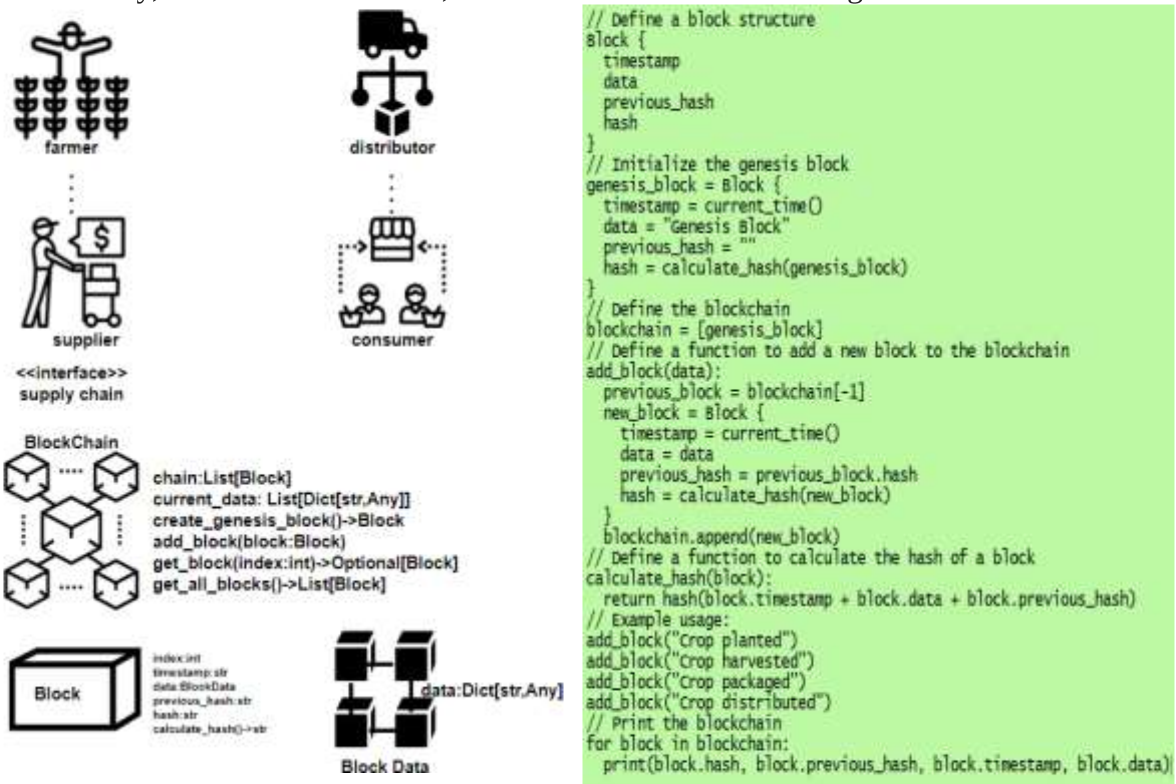


Figure: Using blockchain technology, a secure supply chain in smart agriculture can offer transparency and accountability

2.2 Using blockchain technology, a secure supply chain in smart agriculture can improve traceability and food safety: Complete visibility into the supply chain thanks to the blockchain's recording of each step, from sowing to harvesting, packaging, and shipment. There will be a permanent record of the process's history that can be accessed by all parties involved in the supply chain. This information makes it much easier to trace the origin of a product and identify any bottlenecks in the production process. Using blockchain technology, a digital ledger may be constructed to record data like storage conditions, pesticide and fertilizer use, and more to ensure the safety and quality of food. By storing this information on the distributed ledger, we can more easily separate potentially hazardous foods and prevent widespread food poisoning. Due to the immutability of the blockchain, supply chain participants may be confident that they are viewing the same information. When everyone is on the same page, trusting relationships may be formed more easily. Blockchain technology encourages a culture of responsibility and accountability because it makes everyone in the system responsible for their own actions. The blockchain can be used to determine where a problem occurred in the supply chain and how to fix it rapidly and effectively. The blockchain facilitates the instantaneous sharing of supply chain data among all involved parties. Doing so will increase output and cut down on waiting times. By increasing visibility, improving food safety, minimizing waste, and increasing production, blockchain technology has the potential to significantly impact the agricultural supply chain. The public's health and the quality of the food we consume will greatly benefit from blockchain technology's potential to build a more transparent and responsible supply chain.

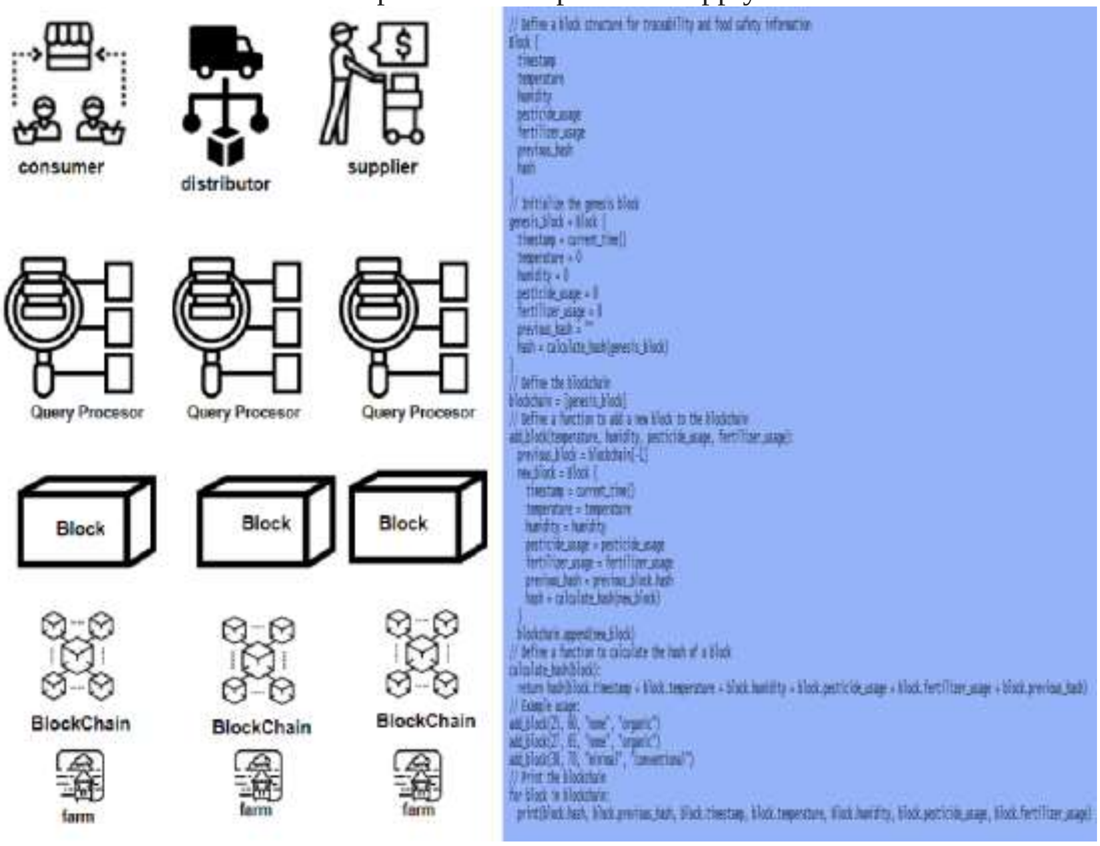
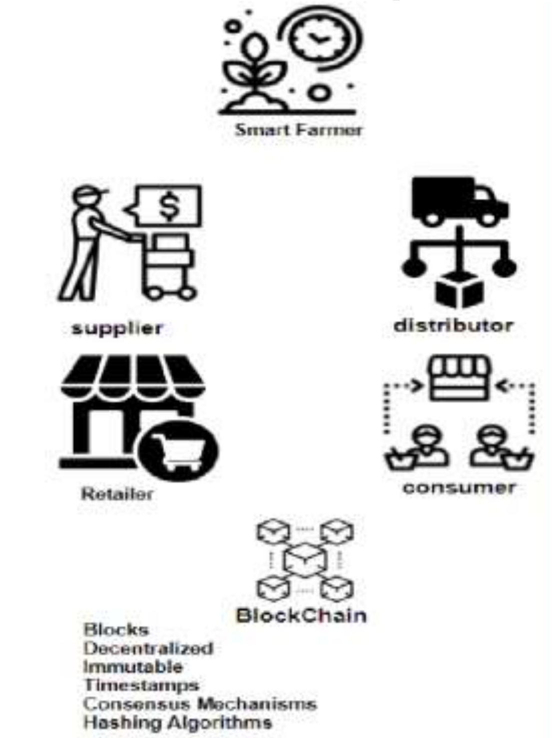


Figure: Using blockchain technology, a secure supply chain in smart agriculture can improve traceability and food safety

2.3 Using blockchain technology, a secure supply chain in smart agriculture can reduce fraud and counterfeiting: Data on agricultural products is collected using high-tech sensors and equipment, from the farm to the supermarket. Information on everything from production to shipping, warehousing, and retail availability is here. An immutable, transparent, and unalterable ledger may now be used to record and verify all of these supply chain transactions and activities. Members of the supply chain can view this file. Each link in the supply chain will be able to independently confirm the legitimacy of the products and transactions. The blockchain ledger's data cannot be altered or deleted since it is encrypted. Due to the impossibility of forging or manipulating data stored on the blockchain, fraud and counterfeiting are less likely to occur. Due to the immutable and immutably secure nature of the blockchain ledger, problems in the supply chain can be isolated to their root cause. By identifying issues before they cause major interruptions, we can keep our supply chain operating smoothly. Smart farming can benefit from blockchain technology since it provides an immutable record of all supply chain transactions and operations. Because of this, forgery and fraud are less likely to occur. All participants in the ecosystem will be able to confirm the legality of the goods and transactions being conducted. The agricultural supply chain might benefit from this as it could improve efficiency, security, and dependability.




```
// Define a blockchain data structure
class Block {
  string data;
  string previousHash;
  string hash;
  int timestamp;
}
// Create a blockchain
list<Block> blockchain;
// Define a function to add data to the blockchain
function addData(string data) {
  Block block;
  block.data = data;
  block.previousHash = blockchain[blockchain.size() - 1].hash;
  block.timestamp = currentTimestamp();
  block.hash = hash(block.data + block.previousHash + block.timestamp);
  blockchain.push_back(block);
}
// Define a function to query data from the blockchain
function queryData(string query) {
  list<Block> results;
  for (int i = 0; i < blockchain.size(); i++) {
    if (blockchain[i].data.contains(query)) {
      results.push_back(blockchain[i]);
    }
  }
  return results;
}
// Define a function to verify the authenticity of a block
function verifyBlock(Block block) {
  string hash = hash(block.data + block.previousHash + block.timestamp);
  if (hash != block.hash) {
    return false;
  }
  if (block.previousHash != blockchain[blockchain.size() - 1].hash) {
    return false;
  }
  return true;
}
// Define a function to verify the authenticity of the blockchain
function verifyBlockchain() {
  for (int i = 1; i < blockchain.size(); i++) {
    if (!verifyBlock(blockchain[i])) {
      return false;
    }
  }
  return true;
}
```

Figure: Using blockchain technology, a secure supply chain in smart agriculture can reduce fraud and counterfeiting

2.4 A secure supply chain in smart agriculture can improve efficiency and reduce costs by utilising blockchain technology: Smart sensors and IoT devices are used to automatically collect data about agricultural products from the farm to the store. Information on everything from production to shipping, warehousing, and retail availability is here. By eliminating the need to manually enter in information, these gadgets automate the data collection process, reducing both time spent and the likelihood of human error. By implementing blockchain technology, supply chains may become more transparent and accountable. Errors and miscommunication can be reduced if all members of the supply chain have access to the same data. This may allow for quicker decision-making and better communication between stakeholders, both of which have the potential to boost output while cutting costs. Inventory management can benefit substantially from blockchain technology's real-time supply chain transparency. Time and money spent on inventory tracking can be dramatically reduced if everyone has access to the same information. Savings might accrue over time as less money is spent on stockpiling and other contingency plans. Blockchain technology has the potential to increase productivity in the supply chain. Through the use of smart contracts, for instance, human intervention in the form of payment and verification is rendered unnecessary. The use of technology may increase output while minimizing overhead. Through the application of blockchain technology, provenance and traceability in the supply chain may be established. Customers will have more faith in the products they purchase, and the likelihood of fraud and counterfeiting will decrease. As a result, product prices may rise, and supply chain efficiency may suffer. By using blockchain technology to establish a trustworthy supply chain, smart agriculture can increase output while decreasing overhead costs. By automating data collection, making processes more transparent and responsible, enhancing inventory management, speeding up operations, and facilitating traceability, blockchain technology can help make the supply chain more efficient and cost-effective.

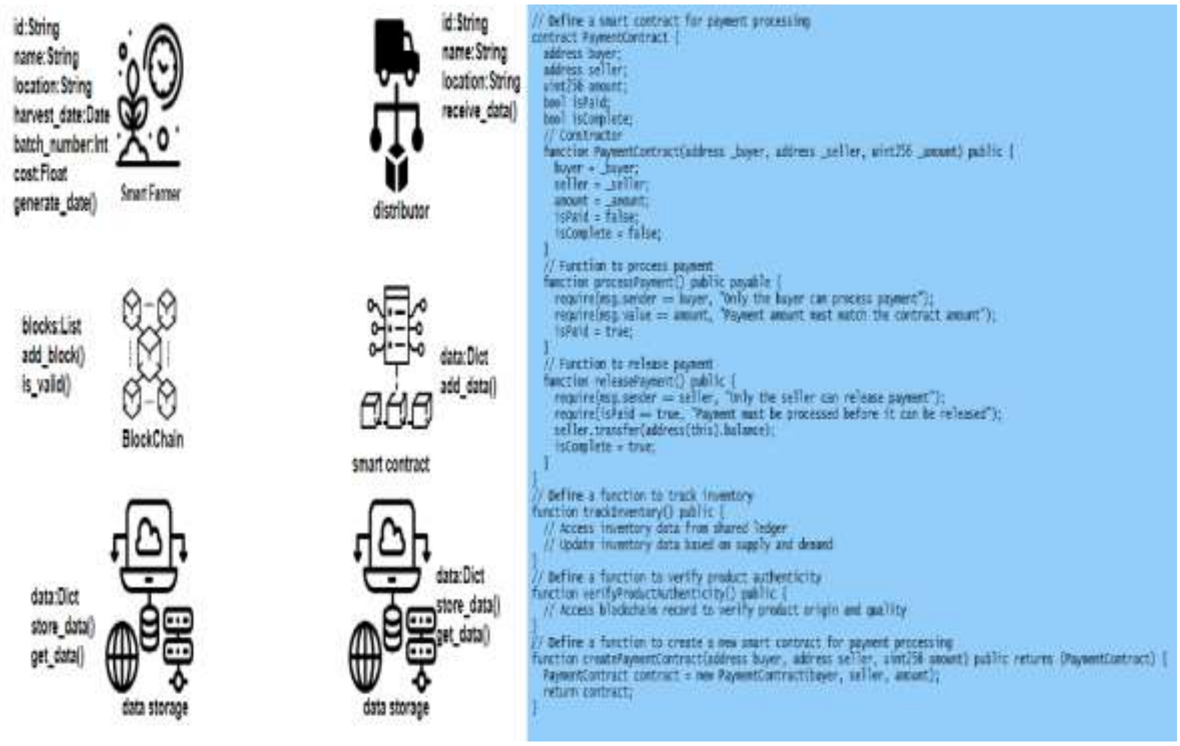


Figure: A secure supply chain in smart agriculture can improve efficiency and reduce costs by utilising blockchain technology

2.5 Secure supply chain in smart agriculture based on a blockchain-based query processing system using consensus algorithms:

We can use the following equations to model a safe supply chain in smart agriculture that is based on a blockchain-based query processing system and uses consensus algorithms:

1. Transaction model:

Each transaction in the system can be shown as a tuple T = (s, r, a, t), where:

- s is the sender of the transaction (a smart agriculture stakeholder).
- r is the receiver of the transaction (another stakeholder in the supply chain).
- a is the amount of the transaction (in a specified currency or other agreed-upon unit).
- This is the timestamp of the transaction (when it was created).

2. Blockchain model:

The blockchain can be represented as a linked list of blocks, where each block B_i is defined by the following tuple: B_i = (Tx_i, h_i, N_i), where:

- Tx_i is the list of transactions in the block.
- h_i is the hash of the previous block B_(i-1).
- N_i is the nonce value used to validate the block (in the case of a PoW consensus algorithm).

3. Consensus algorithm:

The consensus algorithm can be represented by an equation that describes the difficulty of the mining process required to validate a block. For example, in a PoW consensus algorithm, the difficulty D of mining a block can be modelled as:

$$D = 2^{(n - b)}$$

where:

- n is the number of bits in the hash value.
- b is the target number of leading zeros in the hash value (set by the network).

This equation shows that as the target number of leading zeros b increases, the difficulty D of mining a block increases exponentially. This makes it harder for bad actors to change the blockchain because they have to use more computing power to verify blocks.

4. Query processing system:

The query processing system can be modelled as a set of functions that allow stakeholders to retrieve transaction data from the blockchain based on specific search criteria. For example, the function GetTransactions(s, r, a) could be defined to return a list of all transactions that match the specified sender s, receiver r, and amount a.

These mathematical models can be used to design and analyse the performance, security, and scalability of a blockchain-based query processing system for a secure supply chain in smart agriculture. However, it is important to note that the specific equations used will depend on the consensus algorithm, data model, and other design choices made for the system.

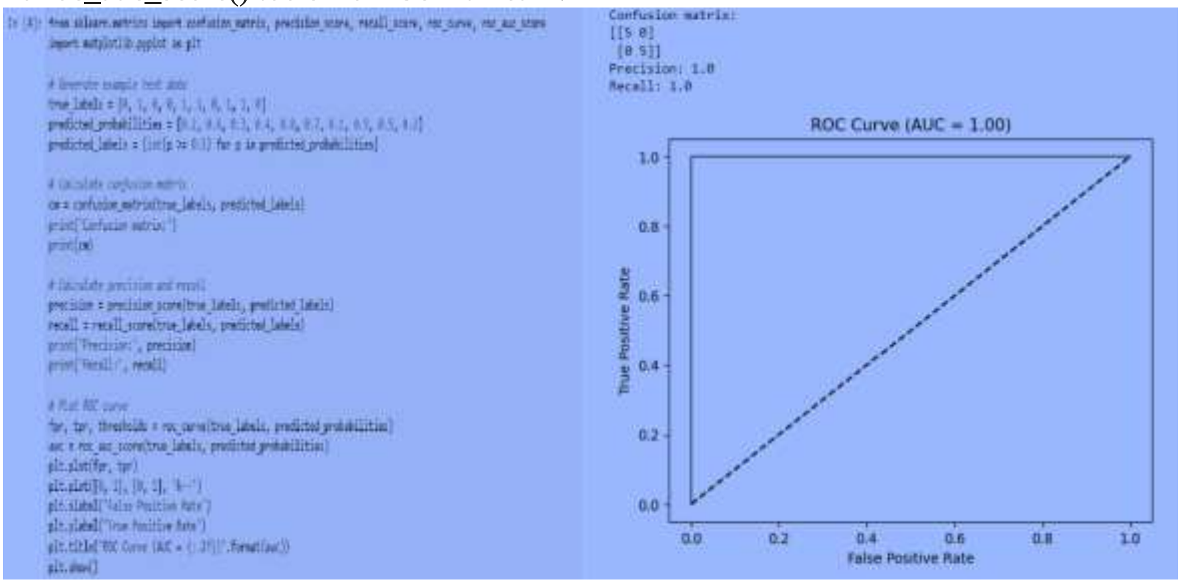
```
// Define a transaction class to represent each transaction on the blockchain
class Transaction {
    sender: string
    receiver: string
    amount: float
    timestamp: datetime
}
// Define a block class to represent each block in the blockchain
class Block {
    transactions: list of Transaction
    previous_hash: string
    nonce: int
}
// Define a blockchain class to represent the overall blockchain
class Blockchain {
    blocks: list of Block
    // Define a function to add a transaction to the blockchain
    function add_transaction(transaction: Transaction) {
        // Verify the transaction before adding it to the blockchain
        // ...
        new_block = create_new_block(transaction)
        blocks.add(new_block)
    }
    // Define a function to create a new block and add it to the blockchain
    function create_new_block(transaction: Transaction) -> Block {
        // Compute the previous hash
        previous_hash = blocks[-1].compute_hash()
        // Use a consensus algorithm to validate the block
        nonce = validate_block(previous_hash)
        // Create a new block with the validated nonce value
        new_block = Block(transactions=[transaction], previous_hash=previous_hash, nonce=nonce)
        return new_block
    }
    // Define a function to validate a block using a consensus algorithm
    function validate_block(previous_hash: string) -> int {
        // Use a PoW consensus algorithm to validate the block
        difficulty = 4  // Set the target number of leading zeros in the hash value
        nonce = 0
        while True:
            block_hash = hash(previous_hash, nonce)
            if block_hash.startswith("0" * difficulty):
                return nonce
            nonce += 1
    // Define a function to retrieve all transactions that match specific criteria
    function get_transactions(sender: string, receiver: string, amount: float) -> list of Transaction {
        matches = []
        for block in blocks:
            for transaction in block.transactions:
                if transaction.sender == sender and transaction.receiver == receiver and transaction.amount == amount:
                    matches.append(transaction)
        return matches
    }
}
```

```
START

1. Define Transaction class with sender, receiver, amount, and timestamp properties.
2. Define Block class with transactions, previous_hash, and nonce properties.
3. Define Blockchain class with blocks property and following methods:
    a. add_transaction(transaction) method to add a new transaction to the blockchain
    b. create_new_block(transaction) method to create a new block and add it to the blockchain
    c. validate_block(previous_hash) method to validate a block using a consensus algorithm
    d. get_transactions(sender, receiver, amount) method to retrieve all transactions that match specific criteria
4. Receive a new transaction to be added to the blockchain.
5. Verify the transaction to ensure it meets all necessary requirements.
6. Add the transaction to the blockchain by calling the add_transaction method.
7. Create a new block by calling the create_new_block method with the new transaction as a parameter.
8. Use a consensus algorithm to validate the block by calling the validate_block method with the previous hash of the previous block as a parameter.
9. Add the validated block to the blockchain by calling the add_block method.
10. Retrieve transactions from the blockchain by calling the get_transactions method with specific search criteria.
11. Iterate through all blocks in the blockchain.
12. For each block, iterate through all transactions and check if they match the search criteria.
13. If a match is found, add the transaction to a list of matches.
14. Return the list of matches.

END
```

3. Experimental results: The blockchain is used to record and oversee transactions in smart agriculture, guaranteeing the integrity of the supply chain. Each agricultural product recorded in the blockchain will have a data structure conforming to the product structure. Each item's supply chain data is kept in its own row of the product array. A farmer can update the supply chain with details about a new product, including its amount, origin, and quality, using the addProduct function. The getProduct operation allows you to request product details from the logistics network. This revision The owner of a product has the ability to change the available stock through the use of the ProductQuantity function. By consulting the product's provenance and quality records stored on the blockchain, the verifyProductAuthenticity function may ensure the genuineness of a product. You can query the supply chain for all items originating from a specific location using the getProductsByOrigin API function. Secure supply chains in smart agriculture can be implemented with the use of a blockchain-based query processing system. Increase openness and responsibility to better monitor the flow of agricultural goods and spot any problems that may arise.

```
// Define the structure of the data to be stored on the blockchain
struct Product {
  string name;
  uint256 quantity;
  string origin;
  string quality;
  address owner;
}
// Define an array to store the product information
Product[] public products;

// Define a function to add a new product to the supply chain
function addProduct(string name, uint256 quantity, string origin, string quality) public {
  Product memory newProduct = Product(name, quantity, origin, quality, msg.sender);
  products.push(newProduct);
}
// Define a function to query the supply chain for a specific product
function getProduct(uint256 productId) public view returns (string, uint256, string, string, address) {
  require(productId < products.length, "Product ID does not exist");
  return (products[productId].name, products[productId].quantity, products[productId].origin, products[productId].quality, products[productId].owner);
}
// Define a function to update the quantity of a product in the supply chain
function updateProductQuantity(uint256 productId, uint256 newQuantity) public {
  require(productId < products.length, "Product ID does not exist");
  require(products[productId].owner == msg.sender, "Only the owner of the product can update its quantity");
  products[productId].quantity = newQuantity;
}
// Define a function to verify the authenticity of a product
function verifyProductAuthenticity(uint256 productId) public view returns (bool) {
  require(productId < products.length, "Product ID does not exist");
  // Access blockchain record to verify product origin and quality
  // Return true if the product is authentic, false otherwise
}
// Define a function to query the supply chain for products originating from a specific location
function getProductsByOrigin(string origin) public view returns (uint256[]) {
  uint256[] memory result = new uint256[](products.length);
  uint256 counter = 0;
  for (uint256 i = 0; i < products.length; i++) {
    if (keccak256(abi.encodePacked(products[i].origin)) == keccak256(abi.encodePacked(origin))) {
      result[counter] = i;
      counter++;
    }
  }
  return result;
}
```

Predicted probabilities for the positive class are shown as predicted probabilities, and predicted binary labels are shown as predicted labels using a 0.5 threshold for accuracy. The code then uses the confusion_matrix() method to compute the confusion matrix and display the results. The functions precision_score() and recall_score() are utilized to compute and display the accuracy and recall, respectively. The ROC curve is plotted with matplotlib and the roc_curve() and roc_auc_score() tools from Scikit-Learn.



4. Conclusion: A blockchain-based query processing system could help secure an immutable and transparent supply chain for precision agriculture through the use of consensus algorithms. With the permanence and verifiability of blockchain transactions, consumers and other stakeholders can have more faith in a system. The consensus technique is essential because it necessitates the validation of all transactions by a sizable number of network nodes, which helps to prevent fraudulent or other malicious activity. Keeping the system together in this fashion increases security. A blockchain-based query processing system utilizing consensus algorithms can help build a reliable and transparent supply chain for smart agriculture. It could lead to a more efficient supply chain, more support from customers and stakeholders, and the adoption of environmentally friendly farming practices.

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