Enhancing Trust and Traceability in Supply Chains through Blockchain and Machine Learning

Project report submitted for the requirement for the degree of

Bachelor of Technology

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Certificate

This is to certify that this project entitled **Enhancing Trust and Traceability in Supply Chains through Blockchain and Machine Learning** is done by **JIVANJYOTI BHATTACHARYYA**, **DIPJYOTI KASHYAP**, **HEMA GOHAIN** and **TAJKIRATUL QUBRA** Roll No **190710007028**, **200750007002**, **200750007003** and **200750007007** . Under the guidance and supervision in a benefited student of the Department of Computer Science & Engineering has carried this project as fulfillment of the requirement of a B.tech in Computer Science & Engineering and this work is presented in this report has presented for academic purpose.

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Date:- 26/06/2023

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Abstract

Traditional supply chain models in the agricultural and food sectors frequently struggle with issues of lack of transparency, interoperability, and traceability, resulting in erroneous reporting and problems with quality assurance. The management and optimization of supply chains, however, have the potential to revolutionize with the introduction of disruptive technologies like blockchain and machine learning (ML).In this regard, the proposed project "Enhancing Trust and Traceability in Supply Chains through Blockchain and Machine Learning" offers an all-encompassing solution that makes use of the immutability and transparency of blockchain technology as well as the analytical power of ML algorithms to enhance traceability, transparency, and sustainability in the agriculture and food supply chains. The project seeks to monitor a product's complete life cycle, from production and harvesting to processing, packaging, and distribution. utilizing a decentralized and secure blockchain network, more especially Hyperledger Fabric, for storage and delivery. This makes it possible to track and document each transaction and activity in the supply chain effectively, removing middlemen and streamlining the procedure for reduced costs and increased efficiency.

The project also seeks to advance sustainable agriculture and food supply chain practices. Customers can make informed decisions by receiving clear information regarding farming practices. Customers can choose products that suit their interests for those that are socially and environmentally responsible.

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Chapter 1

Introduction

1.1 Overview

The supply chains for the agriculture and food industries are complicated since they involve several stakeholders, processes, and transactions. These traditional supply chain models usually run into issues with quality verification, delays, and inefficiencies, as well as a lack of transparency, interoperability, and traceability that can lead to inaccurate reports. The use of disruptive technologies like blockchain and machine learning (ML) to improve and change the management of agriculture and food supply chains has gained popularity in recent years. A secure, decentralized platform for tracking and recording each transaction and activity along the supply chain can be provided by blockchain technology, which is recognized for its immutability, transparency, and security. Blockchain reduces the need for intermediaries, and accelerates the process, using a distributed ledger ensures that captured is open and impervious to manipulation. On the other hand, machine learning algorithms can go through the vast amount of data saved on the blockchain to provide intelligent analysis and forecasts that will improve supply chains. Agriculture and food supply chains may now be more transparent, traceable, sustainable, and effective than ever thanks to blockchain technology and machine learning.

We propose "Enhancing Trust and Traceability in Supply Chains through Blockchain and Machine Learning", a comprehensive strategy for reshaping the food and agriculture supply chains utilizing blockchain technology and machine learning. The objective of this strategy is to maximize the advantages of both technologies to improve efficiency, sustainability, and transparency in the agriculture and food sectors. We will examine the main advantages of using blockchain technology and machine learning in the food and agricultural supply chains, as well as how they might help solve some of the problems that traditional supply chains have. The transparency that blockchain technology offers is one of its main advantages. Customers have access to specifics about the complete process a product has undergone, including information about the seeds' place of origin and the fertilizers used. This encourages food safety and quality by giving consumers the power to make knowledgeable decisions about the products they buy. Additionally, farmers and food producers can use the data gathered on the blockchain to enhance their procedures and increase efficiency, resulting in greater product quality and higher yields. The project includes ML algorithms at different points along the supply chain process in addition to transparency. Large-scale blockchain data may be analyzed by ML algorithms, which can then produce insightful forecasts and predictions that can be used to optimize supply chain operations. To better irrigation, fertilization, and pest management, for instance, ML algorithms may analyze weather data, soil conditions, and crop health information. This results in increased crop yields and sustainable farming techniques. To identify potential quality problems and implement preventive actions, ML algorithms can also analyze data on product quality, and transportation routes. This ensures that only high-quality products are delivered to the final consumers.

The suggested method includes machine learning algorithms at multiple points along the supply chain process in addition to transparency. The massive amounts of data stored on the blockchain may be analyzed by machine learning algorithms to produce insightful forecasts and recommendations for improving supply chain operations. To better irrigation, fertilization, and pest management, for instance, machine learning algorithms may analyze weather data, soil conditions, and crop health information. This results in increased agricultural yields and sustainable farming techniques. To identify potential quality problems and implement preventive actions, ML algorithms can also analyze data on product quality, and transportation routes. This ensures that only high-quality products are delivered to the final consumers.

Customers can make decisions that are in line with their preferences for ecologically sustainable and socially responsible products by being given transparent information about farming practices. To make sure that the items match the specified sustainability requirements, the proposed approach can also aid in monitoring and verifying sustainability certificates. The proposed strategy influences numerous parties involved in the agriculture and food supply chains. Increased transparency, traceability, and access to useful data can help farmers improve their farming methods and boost yields. By being open and honest about their products, food producers may streamline their operations, guarantee the quality of their goods, and increase consumer trust. Utilizing transparent and effective supply chain management technology, importers and retailers may improve customer satisfaction while reducing expenses.

Customers can choose products that fit their tastes for quality, sustainability, and social responsibility by making informed judgments about what they buy. In addition, regulatory agencies and certifying bodies can profit from blockchain's transparency and immutability, which can help with compliance monitoring and certification verification.

Nevertheless, despite the potential advantages, using blockchain and machine learning in the agriculture and food supply chains has its share of difficulties. These difficulties include technical hurdles, such as blockchain's scalability and interoperability problems, as well as issues with data privacy and security. As numerous stakeholders with varying degrees of technological readiness and knowledge are involved in the agriculture and food supply chains, there are additional difficulties with adoption and integration. Our suggested strategy includes a broad framework that integrates blockchain and machine learning technologies, data governance and privacy measures, interoperability standards, and stakeholder engagement tactics to address these issues. We will give a thorough analysis of each element and explain how it affects the overall transformation of the food and agricultural supply chains. In conclusion, by improving transparency, sustainability, and efficiency, the combined use of blockchain with machine learning has the potential to transform agriculture and food supply chains. Our proposed approach strategy intends to take advantage of these technologies advantages to address the problems with conventional supply chains and develop a more open, sustainable, and effective system.

1.2 Problem Statement

Multiple parties in supply chains participate in complicated networks with a variety of interests, roles, and responsibilities. The current supply chain system's lack of transparency and traceability frequently leads to problems including mislabeling, contamination, and fraud, raising customer concerns and posing dangers to food safety. Additionally, while handling, storage, or transit, goods frequently become ruined, wasted, or destroyed, costing supply chain participants a lot of money. The integrity of supply chain data is compromised by existing systems that rely on centralized databases and paper-based records because they are open to data manipulation, theft, and unauthorized access.

Given the variation in product quality and the possibility of fraudulent actions, standard techniques of quality prediction and fraud detection may also be inefficient and inaccurate. It can be difficult to coordinate and manage interactions among stakeholders, which can lead to delays, disagreements, and inefficiencies in the supply chain operation.

1.3 Need of the Study

There are various advantages to implementing a blockchain-based supply chain in agricultural products. Transparency is provided by allowing stakeholders to track and verify each step of the supply chain. Traceability is also enabled by technology, ensuring the authenticity and quality of items while adhering to rules. By promptly identifying and recalling contaminated products, blockchain improves food safety. It promotes quality assurance by documenting cultivation and storage practices. Furthermore, blockchain streamlines processes lowers costs, and improves access to funding. Overall, it results in a more reliable and resilient ecosystem for agricultural goods.

Chapter 2

Literature Review

2.1 Introduction

The goal of this literature review is to investigate the state of current research on sustainable supply chain management practices and the use of blockchain and machine learning in this field. Recent years have seen a substantial increase in interest in sustainable supply chain management because of its potential to reduce environmental impact, increase social responsibility, and boost economic performance.

In order to perform this assessment, we looked at a number of academic publications and articles that explicitly look into supply chain sustainability, blockchain integration, and machine learning. The selected research addresses various facets of these subjects and offers insightful information on their consequences and efficacy.

2.2 Related Work

- Tian proposed a food supply chain traceability system based on Hazard Analysis and Critical Control Points (HACCP) using blockchain and Internet of Things (IoT). Tian also discussed the advantages and disadvantages of RFID and blockchain for agriculture food supply chain traceability in a previous work. Caro et al. presented AgriBlockIoT, a blockchain-based traceability solution that integrates data from IoT devices along the value chain, with implementation comparisons using both Ethereum and Hyperledger. Tse et al. discussed at a high abstract level how blockchain technology can be applied to food supply chains and compared it with traditional solutions. They also highlighted key aspects related to security, integrity, and trust. Lin et al. reviewed blockchain concepts for Agri-ICT systems and presented a model ICT system for agriculture using blockchain technology.

- Tripoli and Schmidhuber discussed the application of distributed ledger technologies (DLT) and smart contracts for increasing efficiency and providing traceability in agriculture. The authors identified technical challenges and barriers to adoption and concluded that DLTs have significant potential in achieving sustainable development goals. Mao and Dianhui presented a blockchain-based credit evaluation system via smart contracts for efficient management in food supply chains. Galves et al. reviewed challenges and potential uses of blockchain for assuring traceability and authenticity in food supply chains. Mao et al. proposed a consortium blockchain approach to an efficient food trading system and validated it using a case study in Shandong province, China. Lucena et al. presented an approach for grain quality measurement using blockchain and smart contracts and implemented a solution for a real life case that resulted in 15% added valuation for genetically modified (GM)-free soy grain exports from Brazil. Chinaka studied how implementing a blockchain based solution can facilitate value transfer in small-scale agriculture in Africa by translating farmer's assets such as livestock, farmlands, and produce . Schneider designed a prototype blockchain system to enhance transparency and automate processes in the agricultural sector. Holmberg and Aquist studied the challenges in implementing a blockchain-based traceability solution in the dairy industry.

- Agridigital's use of Ethereum to ease the exchange of wheat in Australia is one recent example of a blockchain trial application in the food and agriculture supply chains, as are Walmart's food traceability pilots with IBM Hyperledger. Additionally, the first-ever blockchain-based commodities trade of US soybeans to China's Shangong Bohi Industry was successfully conducted by Louis Dreyfus, a significant commodity trader.

- The adoption of blockchain technology for improved information security, transparency, and authentication in different parts of food and agricultural supply chains is on the rise, as is shown from these connected works. While lacking particular implementation frameworks or methodologies, a sizable amount of the literature continues to concentrate on the conceptual application of blockchain in agricultural supply chains. Our project contributes to the growing literature on blockchain applications by proposing an efficient, reliable, secure, and decentralized trace and track solution for supply chains. We leverage the power of blockchain technology, machine learning, and Hyperledger Fabric smart contracts to create a comprehensive system. Our work includes detailed information on the system's architecture, metadata, sequence diagrams and interactions, applied to various scenarios involving agricultural supply chains with multiple stakeholders. This addition to the existing literature on blockchain applications in agriculture will provide valuable insights and contribute to the advancement of the field.

The literature demonstrates an increasing adoption of blockchain technology in food and agriculture supply chains to enhance information security, transparency, and authentication. While some works focus on conceptual applications, our project contributes by proposing an efficient, secure, decentralized trace and track solution for products in supply chains. Leveraging blockchain technology, machine learning, and Hyperledger Fabric smart contracts, our comprehensive system includes architecture, metadata, sequence diagrams, and stakeholder interactions. This contribution adds valuable insights to the existing literature on blockchain applications in agriculture and advances the field as a whole.

Chapter 3

Feasibility Study

3.1 Introduction

We conducted a feasibility study to assess the viability and potential benefits of implementing a blockchain-based supply chain management system. Our goal was to determine whether adopting blockchain technology is feasible and advantageous for our supply chain management process. We evaluated various aspects, including technical, economic, operational, and organizational factors, to make an informed decision.

3.1.1 Technical Feasibility

We evaluated the technical capabilities and requirements of implementing a blockchain solution in our existing supply chain infrastructure. We assessed the compatibility of the blockchain technology with our current IT systems and software. We also considered the scalability, security, and performance aspects of the blockchain network to ensure it can handle our supply chain transactions.

3.1.2 Economic Feasibility

We conducted a comprehensive cost-benefit analysis to determine the financial viability of implementing a blockchain-based supply chain management system. We assessed the initial setup costs, including hardware, software, and infrastructure requirements. Additionally, we analyzed the potential cost savings and efficiency gains that could be achieved through enhanced transparency, traceability, and reduced intermediaries in our supply chain process. Based on this analysis, we determined the return on investment (ROI) and payback period for implementing the blockchain solution.

3.1.3 Operational Feasibility

We assessed the impact of implementing a blockchain system on our day-to-day supply chain operations. We identified the potential operational benefits, such as real-time tracking, improved inventory management, and streamlined logistics. We also considered the training and skill requirements for our employees to adapt to the new technology and ensure a smooth adoption and implementation process. Throughout this assessment, we analyzed any potential disruptions or challenges that may arise during the transition phase and developed strategies to mitigate risks.

Based on our feasibility study, we concluded that implementing a blockchain-based supply chain management system is feasible and beneficial for a organization. The study provided valuable insights into the technical, economic, operational, and organizational aspects, enabling us to make informed decisions and plan for the adoption of blockchain technology in our supply chain management processes.

Chapter 4

Methodology

4.1 Introduction

The methodology employed in implementing the proposed strategy for enhancing trust and traceability in supply chains through blockchain and machine learning involves a comprehensive approach that integrates various components to address the challenges and achieve the desired outcomes in the agriculture and food sectors.

The methodology begins with a thorough analysis of the existing supply chain processes, identifying the key pain points, inefficiencies, and areas where transparency and traceability are lacking. This analysis helps in understanding the specific needs and requirements of the supply chains, laying the foundation for the implementation of blockchain and machine learning technologies.

The first step in the methodology is the integration of blockchain technology into the supply chains. This involves designing and developing a secure and decentralized platform that can track and record each transaction and activity along the supply chain. The platform ensures immutability, transparency, and security of the captured data, reducing the need for intermediaries and accelerating the overall process. Technical challenges related to scalability and interoperability are addressed during this phase, ensuring the seamless integration of blockchain into the existing infrastructure.

Next, machine learning algorithms are incorporated into the system to leverage the vast amount of data stored on the blockchain. These algorithms are designed to analyze the data and provide intelligent analysis, forecasts, and recommendations for improving supply chain operations. For instance, weather data, soil conditions, and crop health information can be analyzed to optimize irrigation, fertilization, and pest management, leading to increased crop yields and sustainable farming practices. Additionally, data on product quality and transportation routes can be analyzed to identify potential issues and implement preventive actions, ensuring the delivery of high-quality products to consumers.

Data governance and privacy measures are implemented as an integral part of the methodology to address concerns related to data security and privacy. Robust protocols are established to ensure the confidentiality and integrity of the data stored on the blockchain, while also complying with relevant regulations and standards. This instills trust among stakeholders and facilitates the adoption and acceptance of the technology.

Interoperability standards are defined and implemented to enable seamless data exchange and integration between different stakeholders along the supply chain. This ensures that information flows smoothly, enhancing collaboration and coordination among farmers, producers, importers, retailers, regulatory agencies, and certifying bodies.

Stakeholder engagement tactics form a crucial part of the methodology. It involves educating and training the various stakeholders on the benefits and functionalities of the blockchain and machine learning technologies. This helps in overcoming resistance to change and promoting widespread adoption and integration of the new system. Collaboration among stakeholders is fostered, encouraging transparency, sharing of information, and continuous improvement of the supply chains.

Throughout the implementation process, regular monitoring and evaluation are conducted to assess the effectiveness of the strategy. Key performance indicators are defined to measure the improvements in efficiency, sustainability, transparency, and customer satisfaction. Feedback from stakeholders is collected and analyzed to identify any further refinements or adjustments needed in the system.

In conclusion, the methodology for enhancing trust and traceability in supply chains through blockchain and machine learning encompasses a comprehensive approach that integrates various components. It involves the integration of blockchain technology, implementation of machine learning algorithms, establishment of data governance and privacy measures, adoption of interoperability standards, and engagement of stakeholders. By following this methodology, the goal of transforming agriculture and food supply chains into more transparent, sustainable, and efficient systems can be achieved

4.2 Objective

In our project, we developed a supply chain management application based on blockchain and machine learning using a strict and iterative methodological approach. Our objective was to create a scalable and adaptable system that addresses the challenges and constraints associated with traditional supply chain management methods. By combining the advantages of blockchain technology with machine learning algorithms, we hoped to change supply networks.

4.3 Data Collection Method

To ensure the adequacy of data for our study, we adopted a dual approach to data collection, utilizing both primary and secondary methods. Our primary data collection involved conducting interviews and surveys with various individuals closely associated with the supply chain domain, including experts, industry practitioners, and potential end-users. These interactions provided us with valuable firsthand information regarding their specific needs, challenges, and expectations related to supply chain management. By engaging with these stakeholders directly, we gained a deep understanding of the intricacies and complexities of the field. Furthermore, we complemented our primary data with secondary data from diverse sources. We extensively reviewed research papers, case studies, and industry reports to obtain additional insights into the latest trends and best practices in supply chain management. This secondary data enabled us to enrich our understanding of the subject matter, validate our primary findings, and acquire a broader perspective on the current state of the industry. By combining primary data obtained through interviews and surveys with secondary data derived from research papers, case studies, and industry reports, we ensured a comprehensive and well-informed approach to our study. This dual data collection methodology allowed us to capture a wide range of perspectives, validate our findings, and present a thorough analysis of the supply chain landscape.

The decision to integrate blockchain and machine learning into our supply chain management app was driven by several key factors. One of the main drivers was the recognition of the need for improved transparency, traceability, and security in supply chain operations. By incorporating blockchain technology, we aimed to create a decentralized and immutable ledger that would ensure data integrity and enhance trust among all stakeholders involved in the supply chain.

Blockchain technology provides a transparent and tamper-resistant platform where all transactions and information are securely recorded. This enables real-time visibility into the movement of goods, from the point of origin to the final destination. With the use of smart contracts, we can automate and enforce contractual agreements, ensuring compliance and reducing the risk of fraud or error.

Chapter 5

System Design and Architecture

5.1 Introduction

The system design and architecture are of utmost importance when it comes to the implementation of a supply chain management system using blockchain technology. A well-designed system ensures the efficient and secure management of the supply chain, leveraging the unique capabilities offered by blockchain. To effectively design the system architecture for a blockchain-based supply chain management system, several key aspects need to be considered. These include:

5.1.1 Hyperledger Fabric

The Fabric network comprises three organizations (Manufacturer, Middle Men, and Consumer) with five peers, one orderer, and one channel. Each organization has its own Fabric CA for managing digital certificates. The network uses Fabric CA as the Certificate Authority for secure authentication and authorization. The peers maintain a copy of the shared ledger and execute chaincode for smart contracts. The Orderer validates and orders transactions, ensuring consistency. The Fabric network with Fabric CA provides a secure, transparent, and efficient solution for managing the operations.

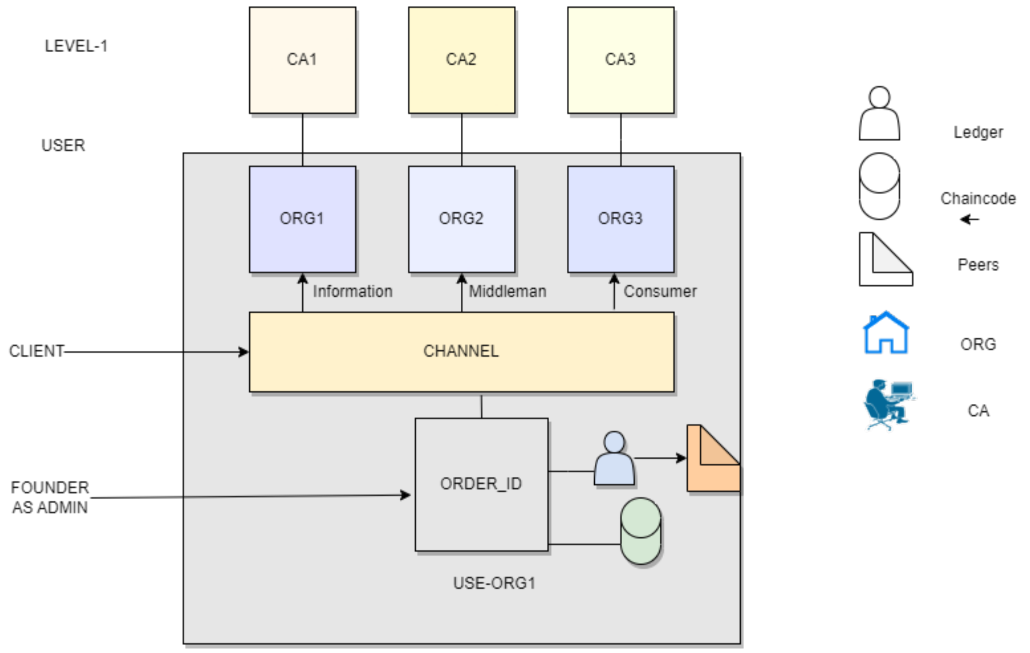


FIGURE 5.1: Hyperledger Fabric network Architecture

The Fabric network comprises three organizations (Manufacturer, Middle Men, and Consumer) with five peers, one orderer, and one channel. Each organization has its own Fabric CA for managing digital certificates. The network uses Fabric CA as the Certificate Authority for secure authentication and authorization. The peers maintain a copy of the shared ledger and execute chain code for smart contracts. The Orderer validates and orders transactions, ensuring consistency. The Fabric network with Fabric CA provides a secure, transparent, and efficient solution for managing operations.

- Admin: all the organization.

- Manufacturer: Org1.

- Middleman: Org2.
- Consumer: Org3.

5.1.2 Membership and Access Control

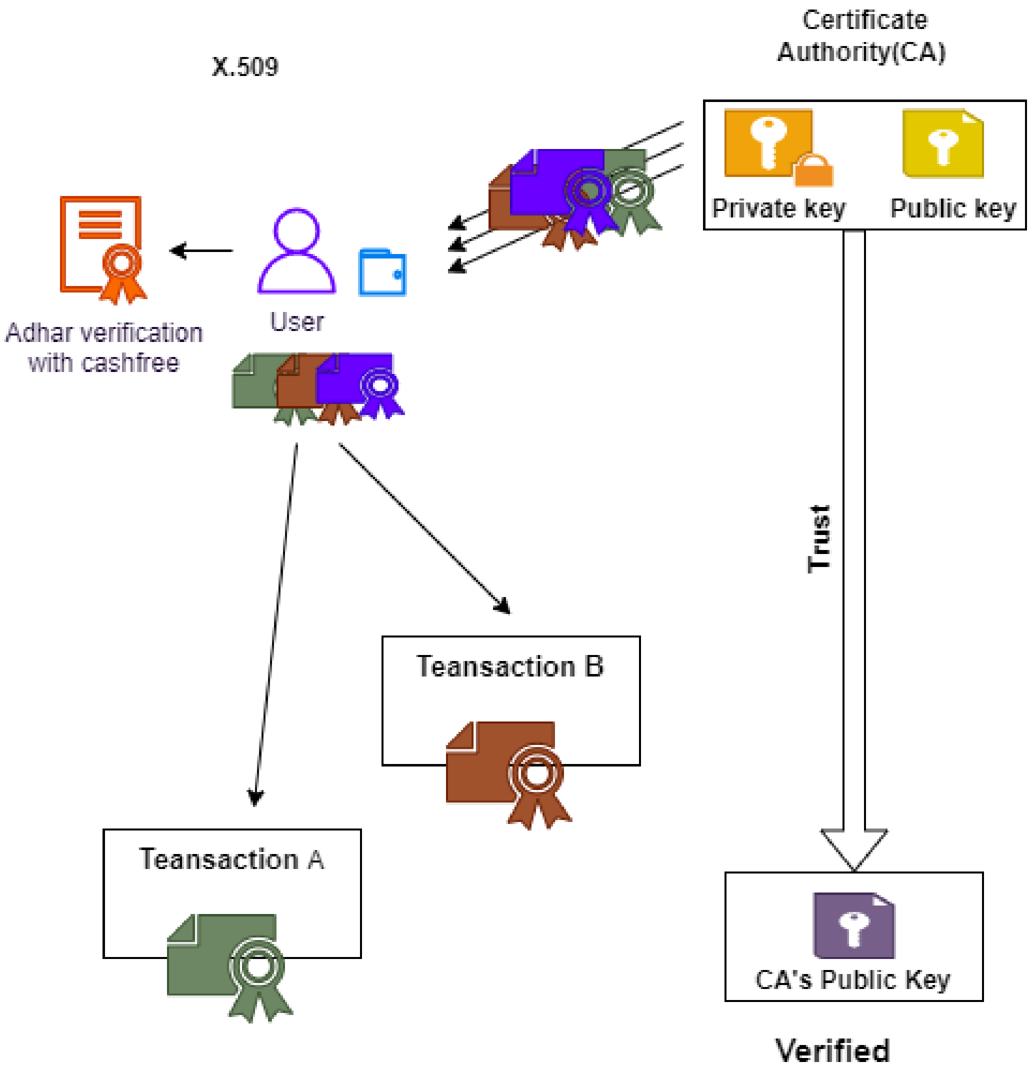


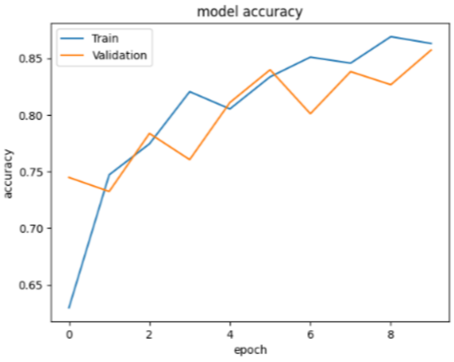
FIGURE 5.2: X.509 Identity Management

5.2 shows that there is a CA that issues a certificate to the user, and this X.059 certificate has multiple attributes whenever the user performs a transaction, it signs using this certificate and also checks for Aadhar verification status. Any other entity in the system that can view these transactions will be able to see their attributes, thereby knowing that the transaction was performed by the particular user to ensure trustworthy of each user in the network.

5.1.3 Machine Learning

The developed solution presents a machine learning (ML) model for detecting the freshness of fruits using a Convolutional Neural Network (CNN) algorithm. The model is trained using TensorFlow, an open-source library for deep learning and machine learning tasks, and is supported by other libraries such as NumPy, Pandas, and Matplotlib for data handling, data cleaning, and visualization. The dataset used for training the model is imported, and its length is verified to be 10901. The model is trained with a sequential model using different layers, including convolutional, activation, dropout, max pooling, flattening, and dense, each serving a specific function in the training process. Keras, a popular library for building neural networks, is used to create the final layers of the CNN model.

The model is compiled with the Adamax optimizer, a commonly used optimizer in ML models. During training, the data is traversed multiple times using epochs, with an epoch value of 30 in this case. A validation-data of validation-generator with verbose 1 used and a batch size of 15 is used in the model training process. The proposed approach combines various libraries, algorithms, and tools to develop an ML model for detecting the freshness of fruits based on their condition, which can be beneficial in tracking the quality of products in supply chains. The solution contributes to the expanding body of literature on blockchain applications by providing an effective, dependable, secure, and decentralized trace and track solution using ML and blockchain technologies.



(A) Model Accurecy

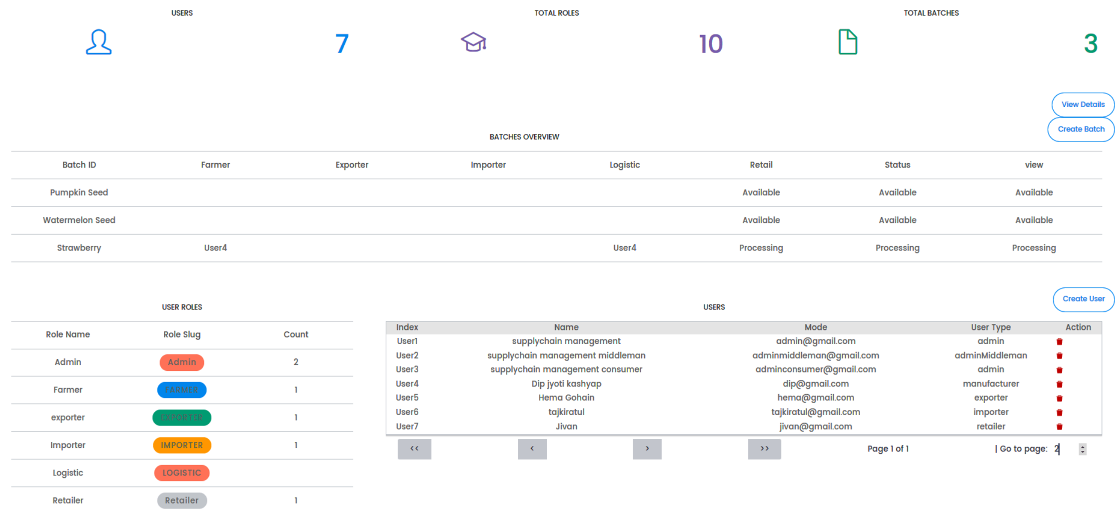
(B) Validation loss

FIGURE 5.3: Main caption

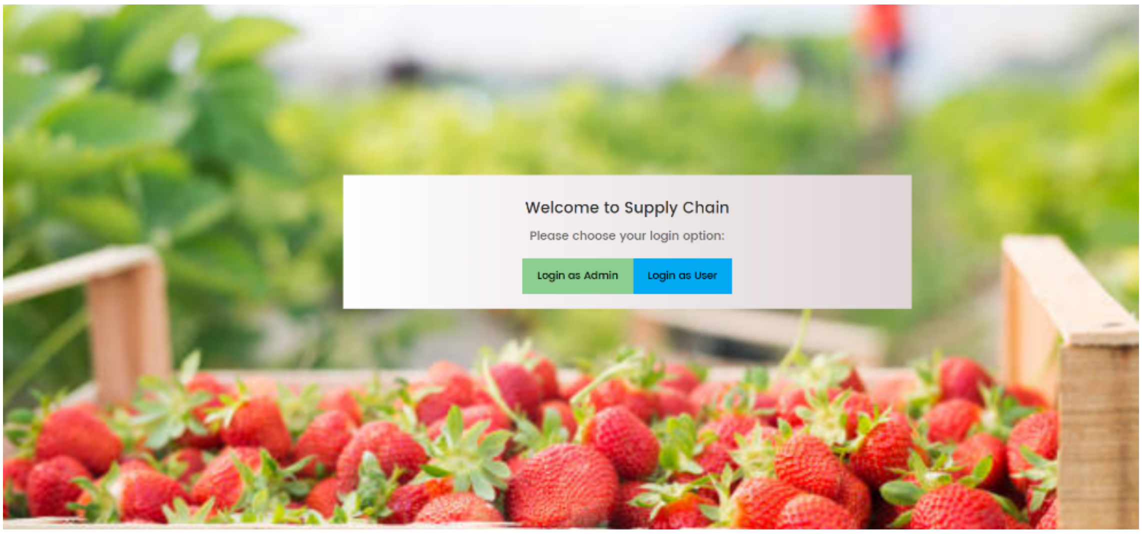
5.3 (a) shows the training accuracy and Validation accucy.Train graph shows the overall model's Training accuracy and validation accuracy shows the Subset of the training data .It is seen that with each epoch Model is giving more accuracy also validation accuracy too. Validation accuracy is calculated by using subset of the whole Training dataset.The final accuracy of the Model is found to be 88.5%. 5.3 (b) shows the output result that our model provides.It can be seen That our model is providing us the correct output.For a rotten Fruit it predicts the fruit as rotten and for a fresh it predicts as fresh.

5.1.4 Webapp

The frontend application is developed using React.js, providing a user-friendly interface for capturing product images, interacting with the supply chain system, and receiving real-time quality predictions. The application allows authorized participants to capture product images using a camera and sends transaction proposals to the appropriate peers in the Hyperledger Fabric network for further processing.



(A) Admin Dashboard



(B) Login Screen

FIGURE 5.4: Main caption

5.1.5 REST API Layer

shows the API endpoints build using express.js implemented using Node.js to handle requests and responses between the frontend application and the Hyperledger Fabric network. The APIs facilitate the communication between the frontend application and the smart contracts deployed on the peers for transaction submission, endorsement, and validation such as managing users, goods, orders, and asset tracking, asset transfer which are part of the Supply Chain Management Chaincode. The "Admin" role is intended to utilize the "createUser" method to add new users to the system. Users can log in and authenticate their credentials using the "sign in" feature. The "Manufacturer" role has access to the "createProduct" method, which lets them add new goods to the blockchain. The "Manufacturer," "Exporter," "Importer," and "Retailer" roles can change a product's information and status as it passes through the supply chain by using the "update product" function. As items are delivered from one supply chain entity to another, the functions "sendToExporter," "sendToImporter," and "sendToRetailer" are used to update the asset transfer status of those products. Then at last a consumer can buy the product from a retailer.

5.2 Proposed system

The details of the participation of the network are displayed in Figure 10. Each participant has a unique identity number in the network that is generated by the system using which a participant can participate in the network and each asset has its own unique identity to identify and process at each stage. Also, some additional attributes vary according to the nature of the product and stage.

shows our proposed architecture using hyper ledger fabric and an ML model that checks the quality of the product before passing it to the next participant. Each participant is interconnected and each of them maintains a peer along with the ledger in their given organization. Each participant has to take a membership and later be verified by Aadhar to participate in the network. The membership service

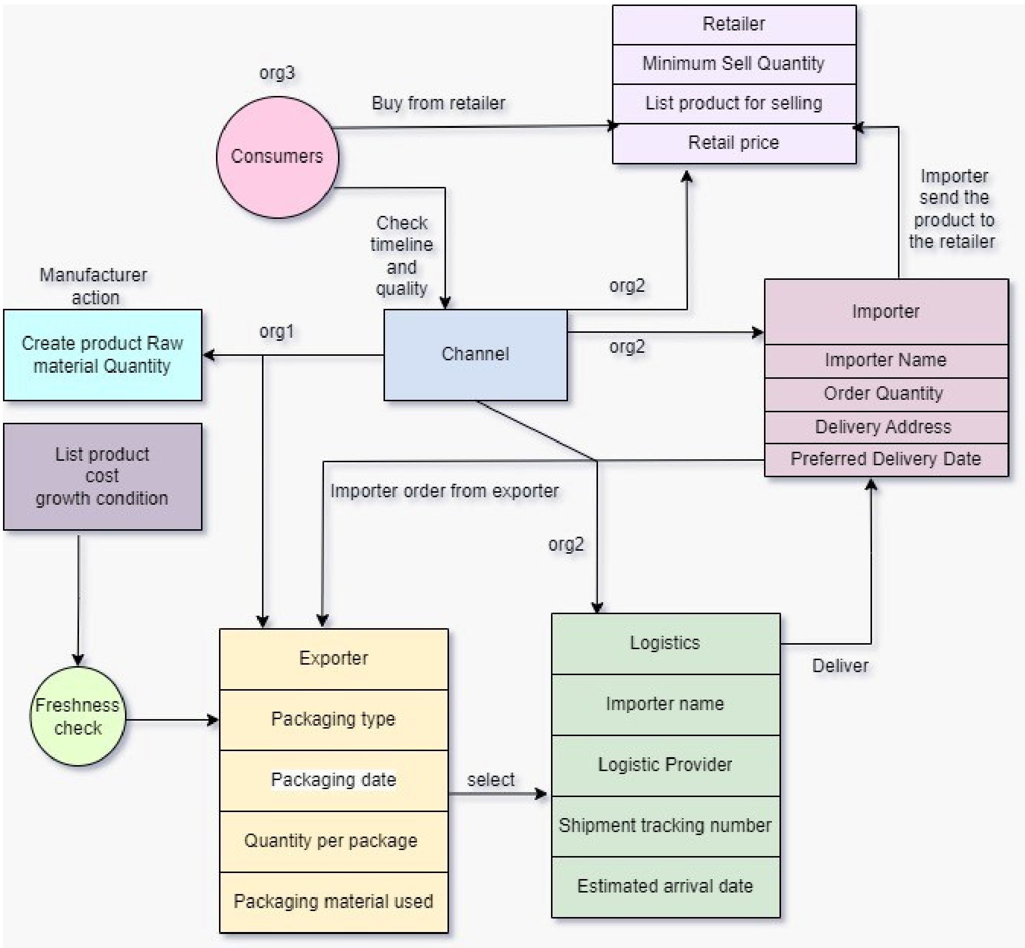


FIGURE 5.5: Class Diagram

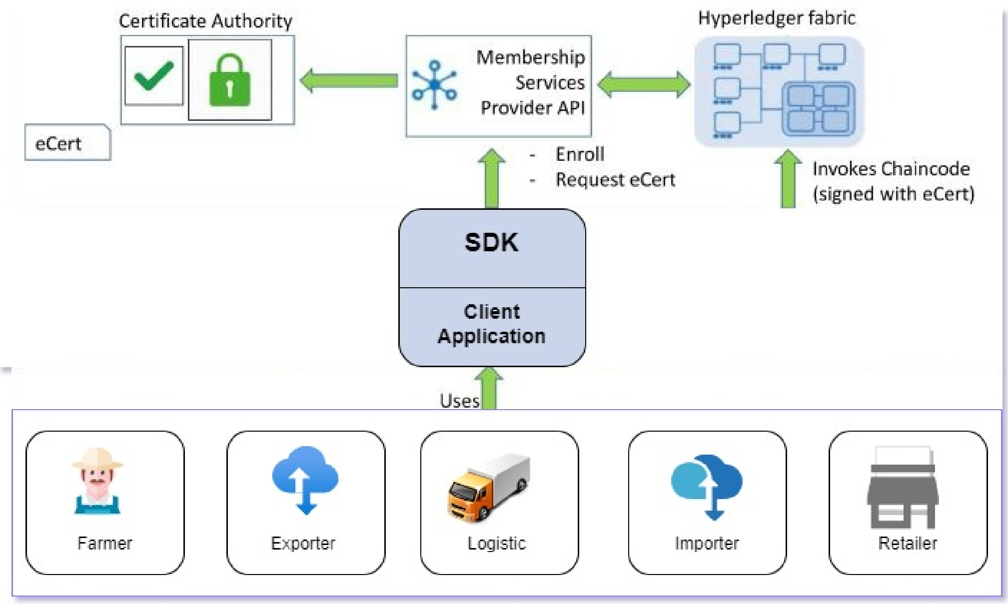


FIGURE 5.6: proposed system Architecture

provider issues certificates, ECert (Enrollment Certificates), through the CA (Certificate Authority) to the requested peers. These certificates act as identities for the peers. To execute transactions in the Hyperledger Fabric environment, chaincode procedures are called. Chaincode procedures are initiated by any authenticated peer and executed by all peers in the network.

5.2.1 Product Management

The proposed system is simulated by product management and verification. where a product with a unique identification id and credential contains all the information about its producer, manufacturer, importer, exporter, and retailer. and its management is achieved by creating product update products and querying products.

- Admin is in charge of generating user accounts and authorizing access to the system, as well as enrolling people in the network, Manufacturer is allowed to generate new ones within the system.
- The exporter, who serves as a middleman in the supply chain, receives a new product once it is made by the Manufacturer. The Exporter is in charge of getting the item from the Manufacturer and getting it to the Importer, who is the next supply chain participant.
- The importer is in charge of delivering the goods to the Retailer, who is the following party in the supply chain, after receiving it from the Exporter.
- Logistics is in charing of carrying out the shipment and delivery of the product from one participant to another.
- The retailer is responsible for selling the product to the end consumer, who can place an order for the desired product.

Once the product is delivered to the consumer, they can mark it as "Delivered" in the system, indicating that the product has been received. This helps in tracking the status of the product delivery and ensures transparency and accountability in the supply chain process. At each step of the supply chain, the ML model check the product's condition and quality and if it's found to be damaged then the product is rejected and it will not move to the next step of the supply chain.

Chapter 6

Implementation

6.1 Introduction

During the implementation phase, we, as a team, focused on translating the design and requirements into a functional and robust system. This phase involved the actual development and deployment of the supply chain management solution using blockchain technology. We encountered various challenges along the way, but through collaboration and perseverance, we were able to overcome them and achieve successful results.

One of the key aspects of the implementation was the adoption of a microservice architecture using Docker. This allowed us to modularize the system and deploy different components in separate Docker containers. By leveraging Docker, we ensured scalability, flexibility, and portability of our solution. Each organization in the network, including peers and orderers, was hosted within its own Docker container, providing an isolated and consistent environment for running the Hyperledger Fabric nodes.

The Hyperledger Fabric framework served as the foundation for our blockchain implementation. It provided us with the necessary tools and protocols for building a secure and decentralized supply chain management system. By leveraging the features of Hyperledger Fabric, such as smart contracts and consensus mechanisms, we were able to create a transparent and tamper-proof ledger for tracking and verifying supply chain transactions.

6.2 Experimental Setup

6.2.1 Blockchain Network Setup

In the initial step, we will set up the network infrastructure by installing and configuring the necessary dependencies such as Hyperledger Fabric, Docker, and Node.js. Then, we'll establish the network topology, consisting of three organizations (Org1, Org2, and Org3) and a single orderer node. Each organization will have its own cryptographic material generated using the Fabric CA, ensuring secure communication and authentication.

6.2.2 Channel configuration

Next, we configured the channel, which involves defining the channel structure and membership. The channel acts as a private communication pathway between the organizations, providing confidentiality and restricted access to transactions and data. We utilize the configtxgen tool to generate the required channel artifacts, including the genesis block. This block serves as the starting point for the channel and contains the initial configuration information.

6.2.3 Chaincode Development

In this project, we developed a smart contract using the Fabric Contract API package and the Node.js SDK in Hyperledger Fabric. By leveraging the Fabric Contract API and Node.js SDK, we can simplify the contract development process and interact with the blockchain network seamlessly. In this section, we will define the contract logic, handle transactions, manage the ledger state, and interact with other network participants. The combination of the Fabric Contract API and Node.js SDK empowers us to build efficient and scalable smart contracts for decentralized applications.

6.2.3.1 User Registration

```
input name, email, userType, address, password, profilePic
newUserID=generateUserID()
Store(newUserID, user)
incrementCounter('UserCounterNO')
return user
```

Listing 6.1: User register

The create user process initiated by admin involves registering a new user while incorporating the Certificate Authority (CA) authority and Know Your Customer (KYC) procedures. During registration, the user provides essential information such as name, email, user type, address, password, and profile picture. The information is validated for accuracy and completeness, and a unique user ID is generated. The user's identity is verified by the CA, which issues a digital certificate, establishing their authenticity within the network. Additionally, KYC procedures may be implemented, requiring users to submit identification documents and undergo verification to ensure compliance and mitigate fraud risks. By integrating CA authority and

KYC procedures, the create user process enhances the trust, security, and regulatory compliance within the Hyperledger network.

6.2.3.2 User Signin

```
Input userId, password:
if userId andr password exist:
User <-Get(eId);
if User.Password is equal to password:
return Success
```

Listing 6.2: User signin

The signIn function checks the provided user ID and password for emptiness. If either of them is empty, an error response is returned. The function then retrieves the user's data from the system's state using the provided user ID. If the user data is not found, an error response is returned indicating that the entity (user) cannot be found. The function compares the provided password with the password stored in the user's data. If they do not match, an error response is returned indicating that either the ID or password is wrong. If the password matches, relevant user data such as address, email, name, user ID, user type, and profile picture are extracted from the entityUser object. Finally, a success response is returned with status 200 and the extracted user data, indicating a successful sign-in.

6.2.3.3 create product

```
input name, mid, price, quantity:
User <- Get(mid)
if mid exist in the network:
If User.type == ‘manufacturer‘:
productCounter <- Get(productCounter);
newProduct id <- generateProductId(productCounter);
timestampget <- Get(timestamp);. product = (name, mid, price, quantity);
```

```
Store(newProductId , Product , time );
incrementProductCounter(Product);
return success;
```

Listing 6.3: Create product

The create product process includes several steps. First, the input parameters are validated to ensure their correctness. Then, the system verifies the manufacturer's existence and user type. The price is converted to a numeric format. A unique product ID is generated, and the current timestamp is obtained. An invoice is created, and the product object is constructed with relevant details. It is then stored in the system's database or ledger using the generated ID. The product counter is incremented to maintain uniqueness. Finally, a success response is returned to indicate the successful creation of the product.

6.2.3.4 product listing

```
input pid,uid,pprice,climate,soil type
if pid & uid exists in the network:
users <- Get(uid);
if user.type == ‘manufacture‘:
product_price=price+raw_product_amount;
product(amount = price,production_data.climate=climate,production_data.soil_type=soil_type,status‘
if user.type ==‘exporter‘:
product_price=price+product.price;
product(amount=price,production_data.selectLogistic,status‘ Available‘ ,product.availableFor=‘impo
if user.type ==‘importer‘:
product_price=price+ product.price;
product(amount=price,production_data.delivered=true,status‘Processing‘)
if user.type ==‘logistic‘:
product(amount=price,production_data.climate=climate,production_data.soil_type=soil_type,status‘Av
if user.type==‘retailer‘:
product_price=price+ product.price;
product(amount=price,production_data.climate=climate,production_data.soil_type=soil_type,status‘Av
updatedProductAsBytes= serializeToBytes(product);
```

```
return success== updatedProductAsBytes;
```

Listing 6.4: product listing

The product listing process to be ready for export involves several steps. First, the relevant product details are retrieved from the system using the product ID. The system verifies the existence of the product and ensures that it is in the appropriate status for export. The necessary product information, such as type, origin, owner, quantity, price, production date, and availability for exporter, is updated accordingly. Additionally, the producer's status is updated to reflect that the product is available for export. The updated product object is serialized and stored back into the system. This process ensures that the product is listed and marked as ready for export, allowing exporters to view and initiate export transactions. The specific implementation may vary based on the system requirements and the desired level of validation and persistence.

6.2.3.5 send to exporter

```
input pId,eId:
if pId or eId exists in the network:
User <-Get(eId);
if user.type != ‘exporter‘’:
product=Get(eId);
txTimestamp=Get(timestamp);
invoice=[name:product.name,price:product.product.price,quantity:product.product.quantity]
product.exporter.id= eId;
product(availablefor==‘importer‘’,status==‘processing‘’,exporter status==‘processing‘’);
return success;
```

Listing 6.5: send to exporter

The "sendToExporter" function facilitates the process of sending a product to an exporter. It takes the product ID and exporter ID as inputs. The function performs several verifications to ensure the validity of the inputs. It checks if the product and exporter exist in the system and verifies that the exporter has the appropriate user type. Once the verifications are successful, the function retrieves the product details and validates if the product has already been sent to an the stackholder. If the product is available, the function proceeds to create an invoice and update the necessary product and information. The stackholder ID, export date, product owner, available status, and invoice details are updated accordingly. The updated product object is serialized and stored back into the system. This process ensures that the product is successfully sent to the exporter and marked as "Processing" for further export-related activities.

6.2.3.6 invoice creation

```
input product,from:
if product exists in the network:
productobj <-Get(productId);
sellerId <- productObj.product.owner
existingproduct <- Find(sellerId,ProductId);
if existingproduct is not NULL:
existingProduct.quantity += parseInt(product.quantity);
invoidedate <- GetTimestamp(ctx);
From seller Get invoicecounter,invoiceid,invoice;
save(newinvoiceId,invoice);
Push(sellerId,productId,invoicenumber);
return invoice;
```

Listing 6.6: invoice creation

The createInvoice takes in a product, which is parsed as a JSON object. It performs validations to ensure that at least one product is provided and that the manufacturer ID is provided. It then processes each product, grouping them by seller and calculating the total price for each seller's products. The function generates a unique invoice ID, creates an invoice object, and saves it to the ledger. Finally, it returns an array of invoices containing information such as the seller ID, product IDs, and invoice number.

6.2.3.7 query

```
Input type, recordElement, recordValue
productbyType<-GET(Type)
if productByTypeExist:
assetCounter = parseInt(getCounter(assetType));
startKey = assetType + '1';
endKey = assetType + (assetCounter + 1);
resultsIterator=getStateByRange(startKey, endKey);
const buffer = [];
while (true)
Record = resultIterator.next()
if Record.product.type !== type):
if Record[recordElement].id === recordValue:
buffer.push({ Key, Record });
return { success: buffer  };
```

Listing 6.7: User query

The query function takes the input parameters include the type of product, the element to be searched , and its corresponding value . Then, the code attempts to retrieve products by their type using a GET request . If the products of the specified type exist, the code proceeds to fetch the asset counter for that type .Then the startKey and endKey are defined to set the range of assets to be retrieved. A resultsIterator is created to iterate through the state and obtain records falling within the specified range .A buffer is initialized to store the matching records . The code enters a loop , and within each iteration, it retrieves the next record . If the record's product type does not match the desired type , the loop continues to the next iteration. If the record's specified element matches the provided value , the record is added to the buffer.Finally, the function returns the buffer containing the matching records , providing the result of the operation as a success along with the retrieved records.

Chapter 7

Conclusion and Future Scope

7.1 Conclusion

In conclusion, a noteworthy development in the agriculture sector is the adoption of a blockchain-based farming system that combines supply chain management with machine learning algorithms to track and evaluate food quality. By ensuring transparency, traceability, and improved food safety, this novel concept transforms conventional farming methods.

The solution gives customers access to an immutable, decentralised ledger of all farming and supply chain activity by utilising blockchain technology. The ability to trace the path of their food from farm to table gives consumers the power to make knowledgeable decisions about the products they buy. The blockchain's immutability shields users from fraud, manipulation, and the introduction of fake items into the supply chain. The system is further advanced because to the incorporation of machine learning models. These algorithms are able to analyse a variety of factors, including farming methods, environmental factors, and quality indicators, to evaluate the overall quality of the food by utilising enormous amounts of data. This enables prompt responses to reduce these risks and aids in the identification of potential hazards like contamination or spoiling. In the end, it makes sure that consumers have access to high-quality, safe food products. All parties involved will profit greatly from the farming system's integration of blockchain and machine learning. Farmers may boost productivity, allocate resources more efficiently, and obtain insights into their farming practises. Distributors and retailers may increase customer trust while reducing waste and managing their inventory more effectively. On the other side, customers can relax knowing that they have open access to information on the food they eat.

Overall, the blockchain-based farming system augmented by machine learning system raises industry standards for food safety, supply chain effectiveness, and consumer empowerment. It is a key step towards creating a food ecosystem that is safer and more sustainable, and it encourages everyone to take responsibility for their actions.

7.2 Future Scope

The integration of blockchain-based farming systems with supply chain management and machine learning algorithms opens up a promising future for the agriculture industry. Here are some potential futurescopes for this innovative concept:

1. Enhanced Food Safety and Quality Assurance: As the technology continues to evolve, the integration of blockchain and machine learning can further enhance food safety and quality assurance measures. Advanced sensors and IoT devices can be integrated into the system to continuously monitor and collect real-time data on

various parameters such as temperature, humidity, and soil conditions. This data can be analyzed by machine learning models to detect potential risks and ensure proactive interventions, thereby minimizing the occurrence of foodborne illnesses and maximizing food quality.

2. Expansion of Traceability and Certification: The blockchain-based farming system can extend its traceability capabilities by incorporating smart contracts and digital certifications. Smart contracts can automatically verify and enforce compliance with specific farming standards and regulations. Digital certifications, issued through blockchain, can provide a trustworthy and immutable record of organic, fair trade, or other specific product attributes. This expansion of traceability and certification will empower consumers with even more information about the origin, production practices, and authenticity of the food they purchase.

3. Integration with IoT and Automation: The integration of the farming system with the Internet of Things (IoT) and automation technologies holds immense potential. IoT devices such as drones, sensors, and autonomous machinery can be used to collect data, monitor crop health, and automate farming processes. These devices can interface with the blockchain system, recording and verifying data in real-time, while machine learning algorithms can analyze the data to optimize resource allocation, predict crop yields, and enable more efficient farming practices.

4. Consumer Engagement and Education: The blockchain-based farming system can serve as a platform for consumer engagement and education. Through mobile applications or web interfaces, consumers can access detailed information about the food they consume, including farming practices, environmental impact, and nutritional profiles. Educational resources, such as tutorials on sustainable farming or healthy eating, can be integrated into the system, promoting awareness and empowering consumers to make conscious food choices.

5. Global Collaboration and Standards: The adoption of blockchain-based farming systems can foster global collaboration and the establishment of common standards in the agriculture industry. By providing a transparent and decentralized platform, stakeholders from different regions and countries can collaborate, share best practices, and collectively work towards sustainable and efficient food production. This collaboration can lead to the development of globally recognized standards for farming practices, supply chain management, and quality assurance, promoting harmonization and trust across international markets.

In conclusion, the future of blockchain-based farming systems combined with supply chain management and machine learning is promising. With continued advancements and innovations, we can expect improved food safety, expanded traceability, increased automation, enhanced consumer engagement, and global collaboration in the agriculture industry. This technology-driven future holds the potential to create a more sustainable, transparent, and secure food ecosystem for the benefit of all stakeholders involved.

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