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Agritech: Blockchain Based Agri-Food Supply Chain Management

Mrs. K Padmaja [1], Nikhil Tagare [2], Pannaga [3], Rajkumar [4], Sameer [5]

[1]*K Padmaja, Asst. Prof, Dept. of ISE, East West Institute Of Technology, Bengaluru*
[2]*Nikhil Tagare, Dept. of ISE, East West Institute Of Technology, Bengaluru*
[3]*Pannaga, Dept. of ISE, East West Institute of Technology, Bengaluru*
[4]*Rajkumar, Dept. of ISE, East West Institute of Technology, Bengaluru*
[5]*Sameer, Dept. of ISE, East West Institute of Technology, Bengaluru*

Abstract - The contemporary agri-food supply chain is plagued by fragmentation, inefficiency, and a critical lack of transparency. This opacity makes end-to-end traceability difficult, leading to food fraud, inefficient recalls, and diminished consumer trust. This project presents a Blockchain-Based Agri-Food Supply Chain Management System designed to create a single, immutable source of truth for all stakeholders. By utilizing a permissioned blockchain architecture and smart contracts, the system will create a permanent, auditable, and tamper-proof record for every product at each stage of its journey—from farm to table. The primary objective is to enhance traceability, improve food safety, and ensure data integrity by capturing real-time data from farmers, distributors, and retailers. This solution will streamline operations, reduce fraud, and build verifiable trust among all participants, ultimately empowering consumers with authentic, traceable product information

Keywords-- Blockchain, Supply Chain Management, Agri-Food, Traceability, Transparency, Smart Contracts, Food Safety, Provenance

1. INTRODUCTION

The food supply chain plays a vital role in ensuring the availability, safety, and quality of food products from their origin to the final consumer. However, traditional food supply chain management systems face numerous challenges, including inefficiencies in tracking, fraudulent practices such as food mislabeling and adulteration, and delays in identifying contamination sources. These issues arise due to the reliance on centralized databases and manual record-keeping, which often lead to data manipulation and fragmented information sharing among stakeholders. In a conventional supply chain, multiple intermediaries are involved in verifying product authenticity, leading to increased operational costs and slower decision-making processes. Additionally, foodborne illness outbreaks and contamination incidents require swift identification of affected batches, yet traditional systems struggle with prompt traceability, resulting in significant health risks and financial losses.

2. RELATED WORK

Significant body of work has emerged to address the challenges of opacity and fraud in agri-food supply chains. This related work can be categorized into three key areas: existing industry platforms, the role of smart contracts in automation, and the critical challenge of data storage.

1.Existing Industry Platforms The most prominent real-world application of blockchain in this sector is **IBM Food Trust**. Leveraged by major retailers like **Walmart**, this platform (which utilizes Hyperledger Fabric) creates a shared, permissioned ledger that allows stakeholders to trace food products in seconds rather than days. Walmart's successful pilot in tracing mangoes and pork demonstrated the system's ability to ensure food safety and reduce waste by rapidly identifying product origins. Similarly, platforms like **Ripe.io** and **AgriDigital** use blockchain to connect farmers, distributors, and consumers. Ripe.io integrates IoT sensors to track the food journey and verify quality, while AgriDigital focuses on using smart contracts to process complex agricultural transactions and provide real-time payments to growers.

2. Smart Contracts for Automation and Quality Assurance Related research highlights the use of **smart contracts** as self-executing digital agreements that automate supply chain processes. These contracts are critical for enforcing predefined conditions for quality and compliance. For example, by integrating with IoT sensors that monitor temperature and humidity, a smart contract can be automatically triggered if a shipment's temperature exceeds a safe threshold. This can send an immediate alert, reject the batch, or automatically hold payment, thereby minimizing disputes and ensuring handling standards are met without human intermediaries. This automation

streamlines operations and enforces accountability among participants.

3. Data Storage Models: On-Chain vs. Off-Chain A primary challenge identified in existing literature is managing the large volume of data (e.g., from IoT sensors) generated by a supply chain. Storing all data **on-chain** is prohibitively expensive and slow, as blockchains are not designed for large datasets. The most accepted best practice is a **hybrid approach**. In this model, only small, critical, and high-trust data—such as ownership records, transaction timestamps, and compliance certificates—is stored directly on the blockchain. Large, bulky data (like high-resolution images or detailed sensor logs) is stored **off-chain** in a separate system, such as a decentralized file system like IPFS or a traditional cloud database. A **cryptographic hash** (a unique digital fingerprint) of the off-chain data is then stored on-chain. This method ensures the large data is tamper-evident (since the hash can't be changed) while keeping the blockchain itself lightweight, scalable, and cost-effective.

3.OBJECTIVES OF THE PROJECT

The primary objective of this project is to design and develop a **blockchain-based application for managing the agri-food supply chain**, ensuring end-to-end visibility, transparency, and efficiency. The system aims to empower farmers, protect consumers, and improve supply chain performance using decentralized technologies. The key objectives are as follows:

1. **Develop a Transparent Blockchain-Based Platform:** To create a decentralized and immutable digital ledger for recording all transactions and movements in the agri-food supply chain, ensuring accountability and eliminating data tampering.
2. **Implement Smart Contracts for Automation:** To deploy smart contracts that automatically handle payment settlements, order confirmations, and compliance checks without the need for intermediaries.
3. **Enhance Traceability and Product Authenticity:** To provide a complete product journey — from farm to fork — that can be accessed by scanning a QR code, helping consumers verify the product's origin, quality, and authenticity.
4. **Empower Farmers through Direct Payments:** To ensure farmers receive timely and fair compensation by removing middlemen and automating transactions via blockchain-based smart contracts.
5. **Improve Efficiency and Reduce Costs:** To streamline the entire supply chain process by reducing paperwork, manual verification, and delays, thereby increasing operational efficiency and cost-effectiveness.
6. **Enhance Consumer Trust and Food Safety:** To improve consumer confidence in food products by making all data transparent

4. SYSTEM ANALYSIS

The agriculture and food supply chain faces several critical challenges such as lack of transparency, delayed payments, product counterfeiting, and inefficient information flow between stakeholders. Traditional systems rely heavily on intermediaries and centralized databases, which often result in delayed processes, reduced accountability, and limited visibility across the chain. To overcome these challenges, the proposed system introduces a **Blockchain-Based Agri-Food Supply Chain Management Platform** — a secure, transparent, and decentralized application that connects farmers, distributors, retailers, and consumers in a unified digital ecosystem.

The proposed system leverages the power of **blockchain technology** to store every transaction or movement of goods in a tamper-proof and immutable ledger. By integrating **smart contracts**, **peer-to-peer (P2P) communication**, and **SHA-256 encryption**, the system ensures the authenticity, integrity, and transparency of all data records. This eliminates the dependency on intermediaries, promotes fair trade practices, and enables direct, verifiable transactions between producers and buyers.

The system is designed to be implemented as a web-based decentralized application (DApp) that operates on the **Ethereum blockchain network**. It employs smart contracts written in **Solidity** that automate payment transfers, validate transactions, and enforce agreements without the need for manual oversight. The frontend of the application is developed using **React.js**, offering an interactive and user-friendly interface, while the backend is handled through **Node.js and Express.js**, which act as middleware between the user interface and blockchain layer.

Each participant in the supply chain — including farmers, distributors, transporters, wholesalers, and retailers — is registered in the system and assigned a unique blockchain identity. Once a product (for example, a batch of grains or vegetables) is harvested, the farmer records it on the blockchain, including critical details such as product type, quantity, date, and farm location. These details become

part of an immutable digital record that can be accessed by authorized participants throughout the product's journey.

When the product is transferred to another stakeholder, such as a distributor or retailer, the transaction is logged into the blockchain, creating a transparent and traceable record of the entire process. Each handoff is recorded through a **smart contract**, which ensures that payments are automatically triggered and securely transferred once the product delivery is confirmed. This automation removes payment delays and prevents disputes between parties.

To further enhance the system, the application can be integrated with **Internet of Things (IoT)** devices and sensors to record environmental parameters such as temperature, humidity, and transportation conditions. These IoT inputs are stored on the blockchain, providing additional layers of traceability and quality assurance. This integration ensures that perishable products, such as fruits, dairy, or meat, are stored and transported under optimal conditions, improving both safety and customer confidence.

From the consumer's perspective, the system allows buyers to verify product authenticity and origin by scanning a unique **QR code** attached to each product. The QR code retrieves the complete journey of the item from farm to table, including timestamps, storage data, and handling details. This traceability not only enhances consumer trust but also encourages ethical sourcing and sustainable farming practices.

The system also supports a **feedback and rating mechanism**, allowing end-users to share reviews about product quality and supplier reliability. This data is stored on-chain, creating a decentralized reputation system that benefits trustworthy farmers and suppliers while discouraging malpractice.

By incorporating all these features, the proposed blockchain-based system aims to revolutionize the existing agricultural supply chain by ensuring **transparency, efficiency, accountability, and fairness** across all stakeholders.

System analysis plays a vital role in developing a robust and efficient application. It involves studying the existing manual or traditional system, identifying the challenges, and analyzing how a new technological solution can overcome those issues. For the **Blockchain-Based Agri-Food Supply Chain Management System (AgriTech)**, system analysis helps in understanding the structure of the agricultural supply chain, the flow of information among participants, and how blockchain technology can enhance transparency, traceability, and trust among all stakeholders.

The process of analysis included evaluating user requirements, technical constraints, and operational feasibility to ensure that the new system meets both business and functional objectives. The ultimate goal is to create a decentralized, transparent, and secure ecosystem where all transactions are recorded immutably on the blockchain.

The primary purpose of system analysis is to gain a complete understanding of how the current agricultural supply chain operates and to design a system that resolves its inefficiencies.
In the existing model, information is fragmented, transactions are delayed, and farmers are often unaware of market trends or product movement. Through system analysis, the AgriTech platform aims to:

- Map data flow from farmers to consumers.
- Identify bottlenecks in the existing process.
- Determine suitable blockchain-based solutions for automation.
- Define the requirements for integrating web, backend, and blockchain layers.

By carefully analyzing these aspects, the proposed system ensures that each stakeholder's needs are met effectively.

In the traditional agricultural supply chain, farmers, distributors, and retailers operate independently, maintaining separate records for transactions. There is **no unified platform** for sharing real-time information. This leads to several drawbacks:

- **Lack of transparency:** Stakeholders cannot verify data authenticity.
- **Dependence on intermediaries:** Farmers rely on agents for selling produce.
- **Data duplication:** Manual records are often inconsistent or tampered with.
- **Limited consumer trust:** End-users cannot verify product source or handling conditions.

Flow of Data:

1. Farmers register and upload product details.

2. Distributors update transportation and storage information.

3. Retailers confirm product reception and initiate payments.

4. Smart contracts record and execute these operations automatically.

5. Consumers retrieve verified product information using the product's QR code.

Fig: System Architecture

5.IMPLEMENTATION

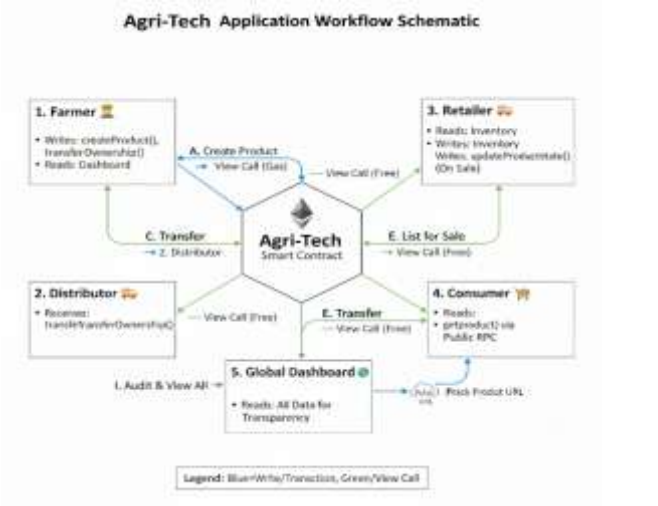

Fig: Implementation

6. Result

Fig: Home page

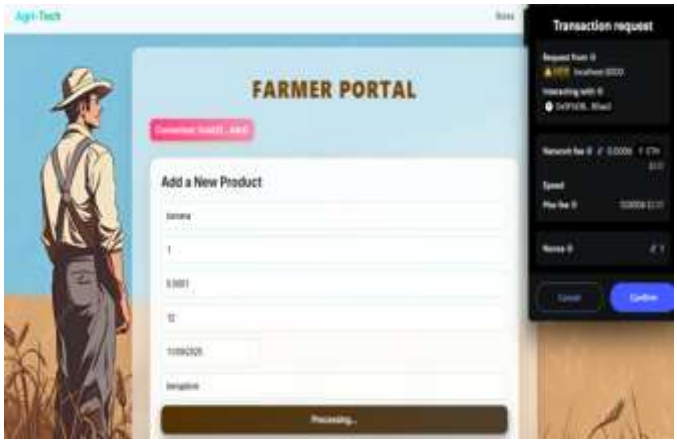

Fig: Farmer Dashboard

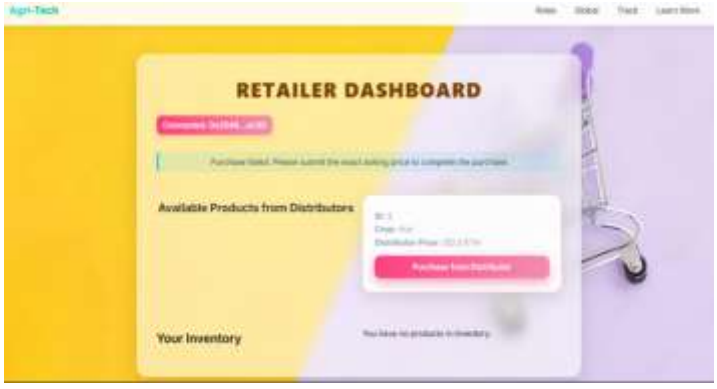

Fig: Retailer Dashboard

Fig: Distributor Dashborad

Fig: Comsumer Dashboard

7. Conclusion

Successful completion of the Blockchain-Based Agri-Food Supply Chain Management System (AgriTech) marks an important milestone in the use of decentralized technologies to improve agricultural transparency, product traceability, and stakeholder trust.

This project demonstrates how modern blockchain frameworks, smart contracts, and web technologies can work together to create a transparent, tamper-proof, and efficient digital ecosystem for farmers, distributors, retailers, and consumers.

Through careful planning, research, development, and testing, the system achieved its primary objective — enabling a trustworthy, automated, and traceable agri-supply chain that ensures product authenticity and fair compensation to producers.Blockchain technology has gained significant traction in various industries, with food supply chain management being one of the most promising applications. The fundamental advantage of blockchain is its ability to create a decentralized ledger, ensuring that transactions recorded within the network remain immutable and transparent. This feature is especially crucial in food supply chain management, where tracking the movement of products from farm to fork is essential. Blockchain eliminates the traditional reliance on centralized systems, enabling a more efficient, secure, and trustworthy framework that benefits all stakeholders. Since food supply chains involve multiple entities—such as producers, distributors, retailers, and consumers—having a unified and immutable ledger ensures that every participant can verify the authenticity and integrity of the food they handle or consume. The decentralized nature of blockchain allows real-time monitoring of products, preventing unethical practices like food fraud, supply chain manipulation, and misrepresentation. One of the most compelling applications of blockchain technology in food supply chain management is improving food safety and recall efficiency. In conventional supply chains, identifying the source of contamination often requires extensive manual verification, leading to delays that can cause widespread health concerns. Blockchain addresses this issue by ensuring real-time traceability, allowing stakeholders to pinpoint contamination sources within seconds. For example, Walmart successfully integrated blockchain in its food supply chain to track leafy greens, reducing the time required to trace contamination from several days to mere seconds. This capability is invaluable, especially when handling perishable products where immediate action is necessary to prevent foodborne illnesses.

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