Blockchain Empowered: Revolutionizing Agro-Based Supply Chain Management

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Abstract

Agriculture, the mainstay of rural India, provides livelihoods to 70% of the rural populace. However, it is beleaguered by supply chain inefficiencies, leading to losses of up to 5.99% in cereals and a whopping 60% yield loss for farmers. The prevailing supply chains are often shrouded in obscurity, with a scant 6% of businesses having complete visibility. This lack of transparency culminates in inefficient processes and potential delays in order fulfilment, engendering customer dissatisfaction and financial losses. The emergence of blockchain technology, however, offers a beacon of hope. Blockchain provides a transparent platform where all stakeholders can access and verify the movement of goods. This transparency not only bolsters customer trust but also enhances their satisfaction levels. Moreover, blockchain technology optimises inventory management and logistics, thereby reducing waste and boosting productivity. These enhancements translate into substantial cost savings. The advent of blockchain could revolutionise agricultural supply chains in India. By providing a transparent and efficient system for tracking the movement of goods, blockchain could eliminate many of the current inefficiencies. This would not only lead to increased profits for farmers but also ensure that consumers have access to fresh and high-quality produce. Furthermore, the use of blockchain could also promote sustainable farming practices by making it easier to track and verify the use of environmentally friendly methods. In conclusion, blockchain technology has the potential to transform the agricultural sector in India, making it more efficient, transparent, and sustainable.

I. INTRODUCTION

This pioneering project stands as a testament to innovation in agro-based supply chain management, leveraging blockchain's security and SHA-256's cryptographic prowess. It aims to dismantle the barriers of inefficiency and opacity that have long hindered the agricultural sector's potential. By embedding a quality assistant within the system, it ensures an unparalleled level of transparency, allowing stakeholders to monitor the lifecycle of agricultural products with precision. The SHA-256 algorithm fortifies each transaction, cementing trust and upholding integrity across the supply chain. More than a mere enhancement, this project represents a bold stride towards a future where clarity in the agricultural supply chain is paramount, protecting the interests of both producers and consumers. It sets a new benchmark for the industry, heralding a blueprint for a fairer, more efficient, and transparent agricultural economy, energised by the latest technological advancements. This initiative is poised to redefine the agricultural landscape, fostering a more sustainable and prosperous future for all involved in the cultivation and distribution of the world's essential sustenance. The addition of a quality assistant tool further enhances this vision, providing stakeholders with real-time insights and quality checks addition of a quality assistant tool further enhances this vision, providing stakeholders with real-time insights and quality checks. This project is a step towards an empowered agricultural sector where technology and tradition converge to create a harmonious and prosperous future.

II RELATED WORKS

Shruti Jadon, Anagha Rao, Thanushree R., Netra Jagadish, and Prasad B. Honnavalli [1] present a comprehensive survey on the application of blockchain technology in the electronics industry for enhancing supply chain management. The paper, published in 2024, discusses the usage of blockchain technology in the electronic industry to provide a decentralized architecture. Additionally, they compare the different types of blockchain networks used, the security of frameworks, and the cost of implementation.

Jan Pennekamp, Fritz Alder, Lennart Bader, Gianluca Scopelliti, Klaus Wehrle, and Jan Tobias Mühlberg [2] in their 2024 publication explore the opportunities and designs for securing sensing in supply chains. They propose innovative solutions using building blocks to enhance security measures, ensuring the integrity and authenticity of the data in the supply chain. They also highlight relevant pitfalls and challenges, providing a comprehensive study of four scenarios that lead to end-to-end-secured sensing in complex IoT-based supply chains.

Marco Fiore and Marina Mongiello [3] offer in their 2023 publication a comprehensive review of how blockchain technology can support agri-food supply chains. They address various challenges, such as traceability, food safety, and waste reduction, and discuss how blockchain can enhance efficiency and transparency in the agri-food sector. Their work also identifies the lack of training for industries and stakeholders, the involvement of additional technologies (i.e., big data and edge computing), and the absence of supporting tools for developers as key research directions.

Nima Afraz, Francesc Wilhelmi, Hamed Ahmadi, and Marco Ruffin [4] in their 2023 publication, analyze the requirements versus cost for implementing blockchain and smart contracts in telecommunications. They discuss how these technologies can enhance security and efficiency, and provide a cost-benefit analysis to guide implementation decisions. They also study two prominent use cases: one proposing a distributed marketplace solution for 5G slice brokering and another one on the decentralization of federated learning (FL) through blockchain.

Abubakar Mohammed, Vidyasagar Potdar, Mohammed Quaddus, and Wendy Hui [5] in their 2023 publication provide a systematic literature review on the enablers, benefits, and barriers associated with adopting blockchain technology within food supply chains. They discuss various factors that influence the adoption of blockchain and how it can benefit the food supply chain by improving traceability, reducing fraud, and enhancing consumer trust. Their work also provides a conceptual framework for blockchain adoption within the food supply chain.

XIN XU AND SHAOJIE ZHOU [6] propose a technique that considers out-of-stock aversion risk and waste aversion risk in cross-border e-commerce supply chain decision-making. They examine the risk preferences of cross-border e-commerce platforms and overseas warehouses based on prospect theory. They construct a cross-border e-commerce supply chain decision-making model with four different risk preference combinations under the Stackelberg game decision-making model.

Vinoth Kumar C. and Poongundran Selvaprabhu [7] examine distributed and decentralised systems for trustworthy control of supply chains. They propose a blockchain-based inventory sharing approach based on smart contracts using a private Ethereum network to link suppliers and retailers. Their approach combines blockchain technology with decentralised storage to increase the transparency, trust, and security of supply chain transactions.

Pratyush Kumar Patro, Raja Jayaraman, Khaled Salah, and Ibrar Yaqoob [8] propose a blockchain-based traceability system for the fishery supply chain. They present a generalised mechanism for secure information sharing that includes comprehensive algorithms to capture supply chain stakeholder interactions that enhance trust among participating entities.

Atima Tharatipyakul and Suporn Pongnumkul [9] review the user interface of blockchain-based agri-food traceability applications. They analyse existing research and literature to uncover the latest advancements and potential future breakthroughs in this area.

Ilhaam A. Omar, Raja Jayaraman, Mazin S. Debe, Haya R. Hasan, Khaled Salah, and Mohammed Omar [10] propose a solution for supply chain inventory sharing using the Ethereum blockchain and smart contracts. They present a detailed cost analysis for various stakeholder transactions in the supply chain. Their solution demonstrates that a blockchain-based approach reduces inefficiencies, is economical, is commercially viable, and provides improved information connectivity among supply chain stakeholders in a trusted and secure way.

III BACKGROUND WORK

The study aims to demonstrate that a blockchain-based approach for supply chain inventory sharing is efficient, cost-effective, commercially viable, and enhances stakeholder connectivity and trust.

Blockchain technology is making waves across various sectors due to its decentralised structure, transparency, and security. It's particularly influential in supply chain management, enhancing traceability, and minimising fraud. Numerous researchers have suggested ways to utilise blockchain in this field. For example, techniques have been proposed that take into account the risks associated with out-of-stock and waste aversion in decision-making for cross-border e-commerce supply chains. Others have explored distributed and decentralised systems for reliable control of supply chains and suggested a blockchain-based approach for sharing inventory. Proposals have also been made for a blockchain-based traceability system for the fishery supply chain, and reviews have been conducted on the user interface of blockchain-based applications for tracing agri-food. Solutions have been proposed for sharing supply chain inventory using the Ethereum blockchain and smart contracts. These studies highlight the potential of blockchain technology to enhance supply chain management in various sectors. However, challenges remain, including implementation costs, the need for industry and stakeholder training, and the requirement for developer support tools. This project seeks to build on these studies and address these challenges to further the application of blockchain technology in supply chain management.

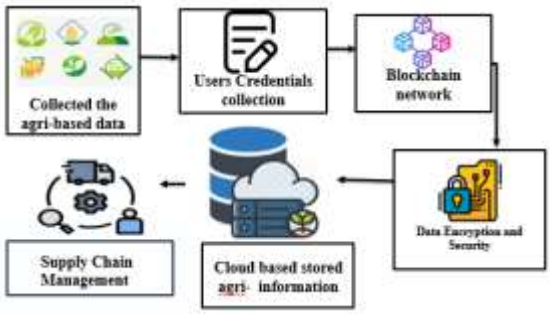

Figure 3.1: Model Diagram of workflow

IV. Our Proposed Model

The system employs blockchain to ensure the traceability of agricultural products, offering solutions to manage heavy loads effectively. It encompasses the entire journey of agricultural products from production, through processing and logistics, to sales. In the production phase, it meticulously records crucial data such as seedling specifics, cultivation details, environmental conditions, and transactional information during key activities like planting, transplanting, watering, fertilising, and harvesting. The research delves into the prevalent issues with the traceability of agricultural products and suggests innovative solutions. To circumvent the excessive power consumption linked to the computational intensity of the nodes, the researchers have introduced a Proof of Stake (POS) mechanism that operates independently of computational power, alongside a Delegated Proof of Stake (DPOS) system. The PBFT consensus mechanism is designed to achieve consensus within a distributed system, even in the presence of a minority of malicious nodes. A web application facilitates interaction with the blockchain network and smart contracts,

providing a seamless interface for partners to monitor and manage their inventory. The application employs cryptographic techniques like digital signatures, signature verification, and hashing to guarantee secure, unalterable message transmission, safeguarding against tampering, counterfeiting, and repudiation. To further enhance the system, a quality assistant has been implemented. This assistant is pivotal in verifying the quality of the products, thereby bolstering reliability and trust among consumers. It acts as a guardian of standards, ensuring that every product meets the stringent criteria set forth, which not only improves the overall quality but also fortifies the confidence of all stakeholders in the supply chain. This comprehensive approach to traceability, powered by blockchain technology, marks a significant advancement in the agricultural sector, promising greater efficiency, transparency, and trust in the processes that bring food from farm to table.

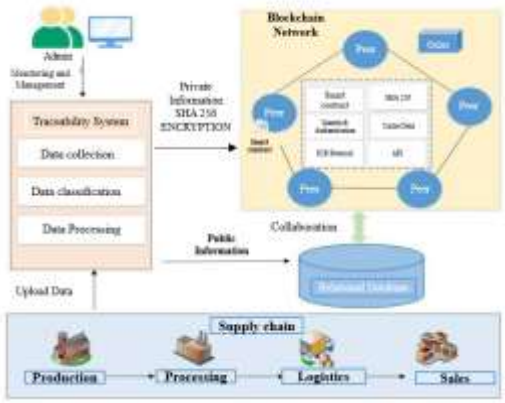

Figure 4.1 CNN WORKFOLW

V .IMPLEMENTATION

5.1 Module Description

- Admin module
- Agro-based data collection
- Blockchain network
- Data encryption and security
- Supply chain management
- Buyer module

5.1.1 Admin module

The Admin Module is designed to provide a robust authentication framework for system administrators, enabling secure login and registration processes. It guarantees verified entry to essential system functionalities, such as comprehensive data management and real-time operational surveillance. Additionally, this module simplifies the integration process for new administrators, allowing them to access and manage the system's extensive array of tools and services efficiently. This ensures a streamlined administrative experience and maintains the integrity and security of the system's operations.

5.1.2 Agro-based data collection

The agro-based data collection module plays a crucial role in compiling agricultural information. It meticulously captures a wide range of data, from quality benchmarks to production volumes, and detailed product identifiers like names and categories, including grains, fruits, and vegetables. This rich dataset is sourced from a network of contributors, including cultivators, processors, and supply chain intermediaries, ensuring a comprehensive aggregation of agricultural insights. This module is essential for maintaining a detailed ledger of agricultural activities and outputs, serving as a foundational tool for informed decision-making and strategic planning in the agricultural sector. It embodies a systematic approach to data gathering, reflecting the multifaceted nature of agriculture.

5.1.3 Blockchain network

The Blockchain Network module is pivotal in setting up and sustaining a blockchain network, capitalising on its decentralised and unalterable features for the secure preservation of data and handling of transactions. It meticulously logs each transaction concerning agricultural commodities, spanning from their inception in production to their final point of sale. This diligent record-keeping on the blockchain fosters an environment of openness and traceability, reinforcing the security and integrity of data associated with agricultural transactions. The module enhances collaboration among stakeholders, fostering a unified ecosystem for efficient and transparent

agricultural supply chain management. This module also ensures compliance with global data protection regulations, contributing to the legal and ethical use of blockchain in agriculture.

5.1.4 Data encryption and security

The Data Encryption and Security module is dedicated to the protection of sensitive agricultural data, employing robust encryption methods to shield it against unauthorized intrusion and manipulation. By integrating state-of-the-art encryption technologies, the module fortifies data confidentiality throughout its lifecycle, encompassing both storage and transfer phases within the blockchain infrastructure. This ensures that all agricultural data, deemed critical for the integrity of the supply chain, remains secure and unaltered, thereby upholding the trust and reliability essential to the network's stakeholders. The module's focus on encryption not only preserves the sanctity of data but also reinforces the blockchain's core principles of decentralisation and immutability, making it a cornerstone of the network's security strategy.

5.1.5 Supply chain management

The Supply Chain Management module oversees the entire journey of agricultural goods within the supply chain, ensuring traceability and transparency. It meticulously monitors the progression of products from their creation phase through distribution. Every transaction and procedural step is recorded on a blockchain, ensuring data integrity and accessibility. The incorporation of smart contracts into the blockchain elevates this module's efficiency. These self-executing contracts with coded terms facilitate, automate, and enforce agreements among stakeholders without intermediaries. This not only expedites transactions but also mitigates inefficiencies, fostering a streamlined, accountable, and transparent supply chain that is responsive to real-time demands and challenges.

5.1.6 Buyer module

The Buyer Module is a comprehensive platform designed for buyers, including wholesalers and retailers. It provides access to information about available agricultural products. Through a blockchain-powered system, buyers can transparently view details such as product origin, quality standards, available quantity, and pricing. This module allows buyers to initiate purchases securely, with confidence in the integrity and traceability of the offered products. This innovative approach ensures that buyers are equipped with real-time data that is both reliable and traceable, enabling informed decision-making processes. This amalgamation of transparency, integrity, security, and accessibility defines the Buyer Module as an indispensable asset for every buyer in the agricultural sector.

VI CONCLUSION AND FUTURE ENHANCEMENT

The integration of blockchain technology into agricultural supply chain management is a game-changer, offering transparency, security, and efficiency. Blockchain's decentralised and tamper-proof nature ensures reliable recording of agricultural data, enhancing supply chain transparency. The added benefits of increased security, automated processes via smart contracts, and reduced fraud risk make this innovative approach a pillar of integrity for the agricultural supply chain. It also lays the groundwork for a sustainable and technologically advanced future in agriculture. The adoption of blockchain is set to redefine stakeholder engagement in the agricultural ecosystem, marking a significant stride towards a more resilient and efficient industry. The disease classification could be expanded to include a variety of vegetables and fruits for increased accuracy. Developing a user-friendly interface for the system would make it more accessible to farmers and agricultural specialists, allowing them to easily input data and understand the results.

The deployment of digital technologies like the Internet of Things (IoT), big-data analytics, artificial intelligence (AI), and other ICTs is pivotal in modern industries. They offer crucial insights, boost decision-making, enhance operational efficiency, and enable communication and information exchange, thereby transforming various sectors, including agro-supply chain management. When these technologies are combined with blockchain, they can enhance the efficiency, transparency, and resilience of the supply chain.

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