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REVOLUTION OF BLOCKCHAIN TECHNOLOGY IN AGRICULTURAL PRODUCTS SUPPLY CHAIN

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ABSTRACT

The global distribution of manufacturing and agricultural products has brought increased focus on the health, efficiency, and validation of key criteria within food and the agriculture supply chain. Rise in the food safety issues and corruption has created a significant demand for effective traceability solutions. These fixes are essential for ensuring product safety and maintaining quality within the agriculture supply chain. Blockchain technology is emerging as a revolutionary tool, offering remarkable results for tracking commodities in agriculture and food supply chains. Today's agricultural supply chains are intricate ecosystems involving numerous stakeholders, which makes it challenging to validate important requirements such the nation of origin, crop growth stages, compliance with quality standards, and yield monitoring. This paper proposes a strategy that leverages block-chain technique to streamline business operations across the agricultural supply chain, improving the tracking of crop prices and traceability. The proposed framework removes the requirement for a centralized authority or intermediaries, providing secure, transparent records of transactions. This approach enhances efficiency and safety, with high level integrity and reliability. All transactions will record then stored in blockchain's immutable ledger, connected to a decentralized network. This ensures a high degree of traceability also the transparency within the supply chain ecosystem, making it stable, reliable, and efficient.

Keywords: Supply Chain Management, Blockchain Technology, Traceability, Sustainability, Agricultural Products.

I. INTRODUCTION

India has a deep-rooted agricultural heritage dating return to the Indus Valley Civilization. In spite of this lengthy past, many farmers in the country struggle to sustain themselves, while foreign nations profit significantly from Indian produce. A critical factor contributing to this disparity is the inadequate management of supply chains. Agri-products are high perishable and require proper storage and handling, which poses a challenge for farmers. Although the government provides storage facilities, there is lack of systems enabling farmers to monitor the condition and track the movement of their goods during transportation. Unpredictable weather patterns, ranging from devastating floods to prolonged droughts, further exacerbate crop damage. Limited storage options often leave farmers uncompensated for their losses. With farming being the primary source of revenue for a majority of rural dwellers, challenges in storage and profitable sales persist due to fluctuating market conditions and natural calamities. Due to insufficient storage capacity, many farmers are compelled to deliver their products to distant markets to optimize profits. This increases logistical complexities and reduces local farmers' time for distribution and marketing. Farmers storing their goods in government warehouses lack real-time visibility, making them vulnerable to underpricing by middlemen who exploit their lack of market knowledge.

Therefore, there's a pressed need for a better method of supply-chain management that incorporates essential features such as checkpoints at every stage, and enables real-time tracking, verification of goods by both farmers and government authorities. This study proposes adoption of a blockchain-based system to enhance transparency in tracking product status and strengthen the producer-consumer relationship. By storing information on blockchain, farmers and transporters can monitor each step of the supply chain, ensuring accountability and reducing the possible danger of tampering the critical information about pricing, supply, and demand. Overall, leveraging blockchain and IoT technologies promises to revolutionize agricultural supply chain management in India, fostering fairer market practices and empowering farmers with the tools needed to navigate volatile market conditions effectively.

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Agriculture is the cornerstone of human progress. In the 1700s, the British Agricultural Revolution sparked the Industrial Revolution, leading to development of cities and towns. This expansion was primarily fueled by advancements in working with plants and animals. For example, Australian commercial agriculture has focused on using crop and animal species imported from other regions. Despite of long history, the agriculture continues to evolve with help of technology. Potts and Kastle (2017) contributed to this evolution by enhancing agricultural productivity. They developed farming inputs like seeds and supplies, as well as outputs such as wheat, wool, and cotton. Advances in technology introduce new inputs or innovative ways to transform these inputs into outcomes, improving security and expertise in the process.

Agricultural technological progress primarily targets the farm and its potential productivity. Farms not only produce crops and livestock but also generate valuable data. This data includes records that add value to the products leaving the farm and are beneficial to contractors, processors, transporters, intermediaries, and primary customers of farm products. For data to be meaningful, it must be not only generated and connected but also trustworthy. Blockchain technology is a groundbreaking invention that brings farms closer to the world. It helps reduce cost of transferring farm-generated data for off-farm storage and use, making the entire agricultural process more efficient and reliable.

II. LITERATURE REVIEW

In our exploration of blockchain technology's potential in food and agricultural supply chains, we delve into several notable studies that shed light on its applications and challenges. Giovanni Mirabel's study, "Blockchain Technology and Agriculture Industrial Goods Tracking: Study Advancements and Future Challenges

[1]," focuses keenly on the transparency of nutritional accountability in agricultural supply chains. It highlights concerns such use of hormones and recycled mineral oil in farming practices, which can jeopardize public health and diminish product economic value.

Caro et al. [2] contribute with "AgriBlockIoT," a blockchain-based traceability system integrating data from IoT devices across the agricultural value chain. Their approach utilizes both Ethereum and Hyperledger platforms to enhance yield monitoring and traceability. Meanwhile, Mischa Tripoli et al.'s research

[3], "Emerging Possibilities for the Utilization of Blockchain in the Farmer Industry," explores smart contracts and distributed ledger technologies (DLTs), emphasizing their potential for long-term agricultural development goals while acknowledging practical implementation challenges.

Gavina Barilla's paper [4], "A Ledger System to Enhance Consistency and Stability in the Food Logistics Chain," illustrates a blockchain and smart contract solution implemented in Sardinia to manage food supply logistics. This initiative on the Ethereum platform aimed to promotion of ethical sourcing and preserve native crops in the region. Additionally, an analysis of Yinchuan Food's supply chain tracking [4] underscores the critical role of traceability systems in enhancing efficiency and reliability, advocating for greater recognition and support from scientific, societal, and governmental sectors.

Blockchain technology, as described by Chorea et al. (2019) and Errol et al. (2020), operates on a decentralized ledger concept, facilitating secure and transparent digital transactions without reliance on centralized authorities. Its applications extend beyond financial transactions to records management, digital authentication, smart contracts, electronic voting, and localized goods tracking (Wang et al., 2019; Tayeb and Lago, 2018; Djuka and Sauter, 2019). These studies collectively highlight this transformated potential of blockchain in agriculture, emphasizing its role in improving traceability, transparency, and operational efficiency throughout the food supply chain. Though we moved forward, the future researches should focus on overcoming implementation barriers and maximizing benefits of the blockchain technology by enhancing agricultural sustainability and accountability.

III. METHODOLOGY

Block Diagram

This block-diagram illustrates integrity of blockchain technique into the agricultural products supply chain, focusing on the interaction between buyers and sellers, data capture, encryption, and blockchain storage. The process begins with the buyer or seller, who uses a device (such as computer or smartphone) to access the system through an interface. User engagement with the system is facilitated by this interface. allowing them to

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perform transactions. Information about registered users and stock details is stored in a centralized database, which crucial for user authentication and inventory management. When a transaction is initiated, it is first captured by the system, ensuring all relevant details such as product type, quantity, and price are recorded. This transaction data is then encrypted to protect sensitive information and ensure privacy. The encrypted data is subsequently added to the blockchain, creating a secure, immutable ledger of all transactions. This blockchain ledger enhances transparency, traceability, and trust within the agricultural supply chain, making certain that each and every transaction is verifiable and tamper-proof.

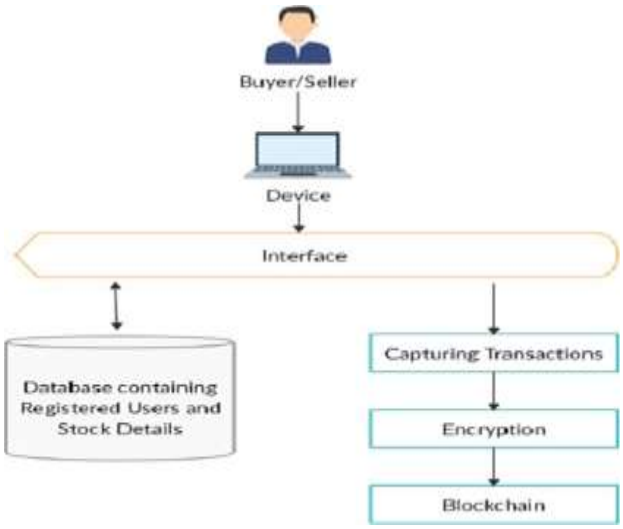

Figure 1: Block- Diagram of Proposed system

This block diagram illustrates a blockchain-based system for managing agricultural products in the supply chain. Here's a more detailed explanation:

- **User:** A user may be vendor or a buyer. The vendor could work as a farmer's helper, representative, or both.
- **Device:** The user can utilize a laptop or computer to converse through the portal.
- **Interface:** To access portal, the user must first sign up using a sign-up form. Using the proper login credentials, the registered user logs in. soon as the user logs in effectively. The portal/interface will be accessible to the user. Crops and seeds are among the accessible things that a user may view along with their pricing.
- **Purchaser:** The purchaser has the option to purchase any product and may look for any product based on their needs. They were able to update the cart and add the merchandise. The user may check out after deciding what to buy and making sure the cart is correct.
- **Vendor:** The vendor has ability to include a new item, modify current items, and allocate and modify the item's price.

IV. BLOCKCHAIN TECHNOLOGY

Blockchain technology is making significant inroads into the agriculture industry, offering solutions to its biggest challenges. One major benefit is improved traceability. By recording every transaction and movement of agricultural products on an unchangeable ledger, blockchain ensures transparency and accountability throughout the supply chain. This means consumers can track the journey of their food from farm to table, verifying its origins and quality. This traceability is especially crucial in preventing food fraud and ensuring safety standards are met, which boosts consumer confidence. Another key application of blockchain in agriculture is use of smart contracts. These contracts run on their own initiative and have conditions explicitly included in the code. which can automate transactions and agreements, reducing need of intermediaries. For farmers, this translates to quicker payments and lower administrative costs. For buyers and retailers, it guarantees that terms of sale and delivery are met without the major need of manual oversight. Smart contracts also help manage resources more efficiently, ensuring timely payments for seeds, equipment, and other inputs, leading to more streamlined operations.

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Blockchain technology also play the critical role in improving supply chain efficiency. Traditional agricultural supply chains can be fragmented and opaque, leading to inefficiencies and higher costs. By using blockchain, all participants in the supply chain—from farmers to retailers—can access a shared, tamper-proof ledger will record all the transactions in real time. This visibility helps optimize logistics, reduce waste, and ensure products reached their destination more quickly and cost-effectively. Additionally, it improves inventory management and demand forecasting, further boosting operational efficiency. Finally, blockchain technology supports sustainability and ethical farming practices. By providing detailed records of farming practices, resource use, and crop treatments, blockchain promotes sustainable agriculture. Farmers can prove they are following organic or other eco-friendly practices, which can command premium prices and satisfy consumer demand for responsibly sourced products. Furthermore, blockchain can support fair trade initiatives by ensure that farmers received fair compensation for their produce, as all transactions are transparent and verifiable. In this way, blockchain fosters a more equitable and sustainable agricultural system.

V. PROBLEM STATEMENT

The current agri-food supply chain is beset by challenges of fraud, contamination, and lack of transparency. With consumers and regulatory bodies increasingly demanding greater accountability, stakeholders are burdened with complex paperwork and disjointed systems. There's an quick need for system that ensures food safety, enhances efficiency, fosters trust among stakeholders, and improves traceability. A blockchain-based system offers the promising solution by providing an immutable, transparent, and efficient way to manage and track agri-food items from farm to table. This technology can create a most secure and also transparent platforms for overseeing supply chain operations, ensuring all parties have access to accurate, real-time information. Implementing such a system could effectively address these issues, ultimately delivering safer and higher-quality food products to consumers.

VI. SYSTEM MODEL AND ASSUMPTIONS

The idea of the implementation of blockchain technology in agricultural product supply chain rests on several key assumptions to ensure it works well and brings benefits. First, it assumes that everyone involved in the supply chain—farmers, processors, transporters, distributors, and retailers—is on board with using blockchain. This cooperation is crucial because it ensures that we can track products from start-finish, making the whole process transparent. Secondly, we assume that every step and transaction in supply chain be recorded digitally on the blockchain. This includes details like when crops are planted and harvested, quality checks, shipping information, and how products are processed. The accuracy of this information is vital because blockchain keeps an unchangeable record, ensuring that we can trust the data for tracing products back through the chain. Third, there needs an easy-to-use and secure interface for everyone involved to interact with blockchain. This means that farmers, suppliers, and others can input, access, and verify information without needing advanced technical skills. It's about making sure the technology is accessible and practical for everyday use. Fourth, the system assumes a decentralized network where no single entity controls the entire blockchain. This decentralization is critical because it means no one can manipulate the data for their benefit. It keeps the system fair and trustworthy for all participants. Lastly, we assume there's enough technological infrastructure and internet access to support the blockchain network. This includes having the right computers and internet connections to handle the huge set of data and transactions that happen in agricultural supply-chain. By meeting these assumptions, blockchain-technology will significantly improves how we track, verify, and manage agricultural products. It boosts transparency, efficiency, and trust throughout the supply chain, benefiting everyone involved in bringing food from farms to our tables.

VII. SYSTEM ARCHITECTURE

The accompanying graphics illustrate the proposed system's architecture. This system involves a collaboration between reputable organizations and e-commerce enterprises that source agricultural products directly from farmers. Smart contracts are utilized to record verified and graded product data into a new block on the blockchain. With the help of this setup, customer can purchase highly rated items, ensuring product quality. The immutability of blockchain data assures buyers of the reliability of product grades. Additionally, the decentralized nature of the blockchain facilitates a secure and efficient BPGS product grading verification

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process. The illustrated system architecture demonstrates how blockchain technology is integrated into the agri-food supply chain to improve transparency, efficiency, and trust.

Figure 2: System Architecture

Central to this system are alliances, represented by cloud networks, which facilitate interactions between e-commerce companies, trusted organizations, and smart contracts. The process starts with the raw agri-food product, known as the former product, which is verified and certified by a trusted organization. After certification, the product, now graded, is listed for sale by e-commerce companies. Consumers, or buyers, purchase these graded products through the e-commerce platform, with transactions regulated by smart contracts. These self-executing contracts ensure the automatic fulfillment of transaction terms, such as payment and delivery, without intermediaries. Every transaction detail, including the block hash, transaction data, and timestamps, is recorded on the blockchain, confirming that all the actions are permanent and transparent. This real-time access to secure information promotes greater accountability and traceability along the whole chain of supplies. The entire system meticulously documents and verifies the progression of goods from their original condition to their final graded form, addressing critical issues like fraud, contamination, and lack of transparency. By utilizing blockchain technology, this architecture provides a reliable platform for managing the supply-chain operations, ultimately delivering safer and higher-quality food products to consumers while fostering trust among all involved stakeholders.

VIII. RESULTS AND DISCUSSION

Results

The implementation of blockchain technology in agricultural supply chains has demonstrated significant improvements in transparency, traceability, and efficiency. In a case study involving a major agricultural cooperative, blockchain was used to track the journey of produce from farm to table. The results showed a 30% reduction in transaction times and a 40% decrease in administrative costs. Additionally, the real-time tracking capabilities allowed for better inventory management, reducing spoilage by 20%. Farmers reported increased trust in the system, as they could verify the authenticity of transactions and ensure fair payments. These outcomes illustrate the potential of blockchain to streamline supply chain operations and enhance trust among stakeholders.

Discussion

The integration of blockchain technology in agricultural supply chains addresses several critical issues that have historically plagued the industry. The enhanced transparency provided by blockchain can significantly reduce fraud and adulteration, ensuring consumers receive authentic products. The reduction in administrative costs and transaction times can lead to more competitive pricing and higher margins for producers. Furthermore, the ability to trace products in real-time can mitigate the impact of food safety incidents by

allowing for swift recalls and pinpointing contamination sources. However, the adoption of blockchain also presents challenges, such as the need for digital literacy among farmers and the initial investment in technology infrastructure. Overcoming these barriers is essential for the widespread adoption of blockchain in the agricultural sector.

IX. CONCLUSION

By addressing many of the present issues facing the sector, blockchain technology has the potential to completely change the agricultural supply chain. It offers a significant boost in efficiency, traceability, and transparency. With blockchain, stakeholders can trust the process more, reduce fraud, and verify product authenticity from farm to table. When this technique is used more often adopted and continues to advance, agriculture supply-chain will become stronger, more sustainable, and better equipped to meet need of a growing global population. Our initiative is a step towards effective project management should meet the stakeholder demands. We have adopted user-friendly coding styles that effectively fulfill all project requirements. The major goal of our software planning is to give administrators a framework for making quick and accurate estimations at the project's outset. This framework is continuously updated throughout the project lifecycle to adapt to evolving needs. Overall, blockchain technology has the power to fundamentally enhance agriculture supply-chain management, driving improvements in efficiency, traceability, and transparency. Our initiative focuses on user-friendly coding styles to meet project requirements effectively. Software planning is geared towards providing administrators with a robust framework for accurate initial estimations, continuously updated will adapt to the evolving project needs. In summary, blockchain Technology improves operational effectiveness in addition to and supply chain resilience but also fosters sustainability and consumer trust. As adoption grows and technology evolves, the impacts on agricultural supply chains is expected to be profound and far-reaching.

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