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Revolutionizing Indian Agricultural Supply Chain with Blockchain

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Abstract - India stands as an agriculture-based nation with its rich agricultural history dating back to the Indus Valley Civilization. However, despite this historical significance, many farmers in the country struggle to secure sufficient income while foreign countries reap substantial profits from the same agricultural products. One of the primary reasons for this disparity lies in the inadequate supply chain management system. The perishable nature of most farming items necessitates proper maintenance, but the current supply chain lacks transparency, leaving farmers unable to track the status of their goods effectively. Additionally, the transportation process lacks a comprehensive tracking system. To address these challenges, an enhanced supply chain management solution is imperative, featuring checkpoints at every stage, verification of goods by both farmers and government officials, and improved transparency. This research proposes a Blockchain-based system, fostering transparent information about goods' status and facilitating a healthier relationship between producers and consumers. By utilizing Blockchain technology, all processes become visible to farmers and officials involved in transportation, while the immutable records ensure data longevity.

Keywords- Blockchain, farmer, supply chain management, goods, smart contract, producers.

I. INTRODUCTION

In recent years, blockchain technology has emerged as a promising solution to address these challenges. Blockchain, often associated with cryptocurrencies like Bitcoin, is a distributed ledger technology that allows secure and transparent data sharing across a network of participants. Its inherent characteristics of immutability, decentralization, and consensus-based verification make it an ideal platform for improving supply chain management in the Indian agricultural sector.

This research seeks to explore and propose a blockchain-based solution to enhance the efficiency, transparency, and trustworthiness of the Indian agricultural supply chain. By leveraging blockchain technology, the proposed solution aims to create a decentralized and secure ecosystem that fosters collaboration, streamlines processes, and provides value to all stakeholders involved.

The subsequent sections of this study will delve into the specific components of the proposed blockchain-based supply chain management system. These components include establishing unique digital identities for farmers, deploying smart contracts for automated and reliable transactions, implementing real-time monitoring and tracking mechanisms, ensuring quality and certification verification, and introducing a decentralized marketplace for fair pricing.

The adoption of blockchain technology in the Indian agricultural supply chain has the potential to revolutionize the sector, benefiting farmers, consumers, and the economy as a whole. By enhancing trust, reducing inefficiencies, minimizing food wastage, and empowering farmers with fair access to markets, the proposed solution can contribute to the sustainable growth of the Indian agricultural sector.

India's economy heavily relies on agriculture, contributing about 18% to its GDP. However, the condition of Indian farmers is precarious, with approximately 80% engaged in small-scale farming on land not exceeding 2 hectares. Their primary income depends on the crops cultivated, but unpredictable climatic conditions, such as floods and droughts, often lead to crop losses. Preserving perishable goods becomes challenging, resulting in farmers not receiving adequate compensation.

To assist farmers, both central and state governments offer financial aids for crop cultivation and storage facilities. Nonetheless, limited storage locations lead to farmers having to travel long distances to sell their goods, consuming valuable time. Furthermore, they lack means to track the status of their stored goods, sometimes being misled by intermediaries. To address these issues, this research proposes a Blockchain-based system to track schemes offered to farmers.

By combining Blockchain with IoT, data integrity and transparency can be ensured, preventing unauthorized modifications. Blockchain stores transactions in a distributed ledger, preventing data tampering, while smart contracts facilitate the execution of agreements. The Ethereum Virtual Machine (EVM) ensures a deterministic state in the Blockchain and enables the execution of smart contracts.

The paper demonstrates the advantages of employing Blockchain and IoT in agriculture and highlights the need to adopt modern technology in essential services like agriculture. Section 2 explores existing research on supply chain management (SCM), while Section 3 delves into the proposed system and implementation details.

II. RELATED WORK

[1] Blockchain Adoption in Agricultural Supply Chains: Research studies and pilot projects have been conducted globally to assess the feasibility and benefits of integrating blockchain in agricultural supply chains. These works explore how blockchain's decentralized and immutable nature can facilitate traceability, certification, and authentication of agricultural products, promoting fair trade practices and improving food safety.

[2] Farmer Empowerment: Related work often emphasizes empowering farmers by providing them with direct market access and fair pricing through blockchain-based decentralized marketplaces. By eliminating intermediaries, farmers can negotiate better deals, receive timely payments, and gain visibility into the value chain, ultimately improving their economic condition.

[3] Supply Chain Traceability: Many initiatives focus on using blockchain to establish end-to-end traceability of agricultural products, enabling consumers to access real-time information about the origin, quality, and production processes. This transparency promotes consumer confidence and rewards sustainable and ethical agricultural practices.

[4] Smart Contracts for Automation: Blockchain-based smart contracts play a significant role in automating supply chain processes and facilitating seamless transactions. These self-executing agreements enforce predefined rules, ensuring timely payments and reducing administrative burdens for farmers and other stakeholders.

[5] IoT Integration: Several related works explore the combination of blockchain with the Internet of Things (IoT) devices, such as sensors and trackers, to monitor product conditions throughout the supply chain. This real-time monitoring enables early detection of issues, reducing food wastage and ensuring product quality.

[6] Government Initiatives: Some governments and organizations have piloted blockchain projects in the agricultural sector to improve data management, supply chain visibility, and farmer support. These initiatives often involve collaboration with private entities and technology providers to implement blockchain solutions.

[7] Scalability and Adoption Challenges: Related work also addresses the challenges of scaling blockchain solutions to accommodate the vast and diverse Indian agricultural landscape. Issues such as network scalability, interoperability, and user adoption are essential considerations in implementing blockchain-based solutions.

[8] Data Privacy and Security: As blockchain involves the sharing of sensitive data among various stakeholders, research focuses on ensuring data privacy and security. Innovations such as permissioned blockchains and encryption techniques are explored to protect confidential information.

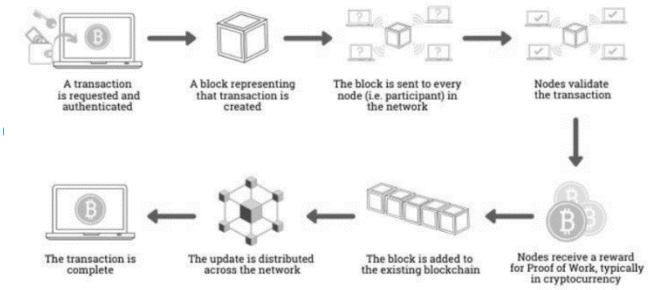
[9] Social Impact: Some related work examines the social impact of implementing blockchain in agriculture, focusing on gender inclusivity, financial inclusion, and improved access to markets and resources for marginalized farmers.

[10] Lessons Learned and Best Practices: Existing projects offer valuable insights into the practical challenges and successes of applying blockchain in the agricultural supply chain. Researchers and practitioners share lessons learned and best practices to guide future implementations.

III. METHODOLOGY

The central government's agriculture and farmer's welfare department has introduced numerous schemes for the benefit of farmers. However, ensuring that these benefits reach the intended recipients remains a significant challenge. At each stage of the supply chain, farmers require cooperation from government officials, but even with various appointed officials monitoring the process, issues persist.

To address this problem, this research presents a blockchain-based solution to track agricultural goods throughout the supply chain. The proposed model's workflow is illustrated in Figure 1.



Source: https://www.researchgate.net/figure/Figure-3-Transaction-Communication-of-Blockchain-24-Blockchains-peer-to-peer-P2P_fig2_360136518

A. Process in Blockchain by farm

Whenever a farming goods are transported from a farmer's place, all the details about the goods such as quantity, state of the goods/quality such as size, color, defect free, natural/manure free/organic, time of cultivation, humidity, current market price, etc., are measured and stored in the Blockchain. The above details about the goods are collected via a form. The information obtained through this form are validated using the rules specified in the smart contract. Usually, before transporting the goods, quality and the condition of the goods must be verified. This verification is to ensure that only the correct goods are transported. In Blockchain, this verification is carried by the smart contract. The smart contract is a software in which all the norms will be coded as a program. The parameters obtained in the user interface is verified by the smart contract and once it is found correct, a new transaction is created. After some time, the created transaction is added to a block through the mining process. Thus, the details about the goods are now stored in an immutable ledger say Blockchain.

B. Process in Blockchain by IoT agent

The factors such as temperature, humidity, and presence of some chemicals usually decides the condition of the goods within the container. Hence, in the proposed system, the following sensors: temperature, humidity and gas sensor are used. Sometimes due to bad temperature, mold may be formed on the outer layer of the fruits and vegetables. The gas sensor aids to identify the gas developed due to this mold. At each stage in SCM, with the help of the sensors placed in the storage place and transportation vehicle measures the condition of the agriculture goods and store the same in the Blockchain. Thus, both the farmers and the consumers can know the status of the goods at various stages in supply chain.

C. Process of software

Whenever market price changes the incorporated software which analyses the stored price in the blockchain and market price. If it is required, the current market price is also incorporated in the blockchain through this software agent.

D. Implementation

The front end of the proposed system is developed using JavaScript. The farmer uses this app to store the actual goods details in the blockchain. Transactions that help to store the goods details get verified by the IoT sensors embedded in the transportation vehicle. The smart contract necessary for this system is written using Solidity language. The smart contract contains the conditions that are needed to be verified in the system. For instance, if the goods moisture is to be maintained as 3 degrees Celsius, then it is the responsibility of the smart contract to verify this condition. Once the input parameters are verified, a transaction will be created. Whenever the customers/intermediate sellers buy the product, the status of the product like quantity, return on investment /profit have to be added in the blockchain. This helps the farmer to understand the market scenario and the worth of their product. In the meantime, the fund can be released to the farmer's account from the customer accounts and these details can be incorporated in the blockchain.

IV. EXPERIMENTAL RESULTS AND PERFORMANCE EVALUATION

Consider the supply chain of rice from the farmer to the consumer, which is facilitated by a blockchain-based solution. The process begins with the farmer purchasing seeds from suppliers and growing them on their farm. After harvesting the crops, the farmer uploads a detailed document to the blockchain network, containing information about the seeds, seed suppliers, and the crops themselves. These transactions are securely recorded on the blockchain.

The rice processor, after reviewing the details of the farmer's seeds and crops, can directly place a purchase order with the farmer. The unprocessed rice is then sent to the processor with a document containing information about the processing. Once the processor receives the order, the distributor takes charge of overseeing the contract. The distributor inspects the retailer's buy order and, upon completion, ships the orders to the retailer. Each step in this process is recorded on the blockchain through uploaded documents, ensuring transparency and traceability.

Smart contracts play a crucial role in facilitating communication between different entities involved in the supply chain. They enable agreements and transactions to be executed automatically once predefined conditions are met. Proof of authority is established through a consensus mechanism, determining which nodes have the authority to validate transactions. When an entity sends data to the validator node for validation, the validator node notifies the sender upon completion of the transaction. If the transaction is deemed legitimate, it is approved, but if found to be inauthentic, it is declined.

The entire information flow of the system is visually represented in Figure 2, showing how blockchain technology enhances transparency, efficiency, and trust throughout the rice supply chain. This approach enables consumers to access information about the rice from its initial planting to the final processing, ensuring a transparent and reliable supply chain process.

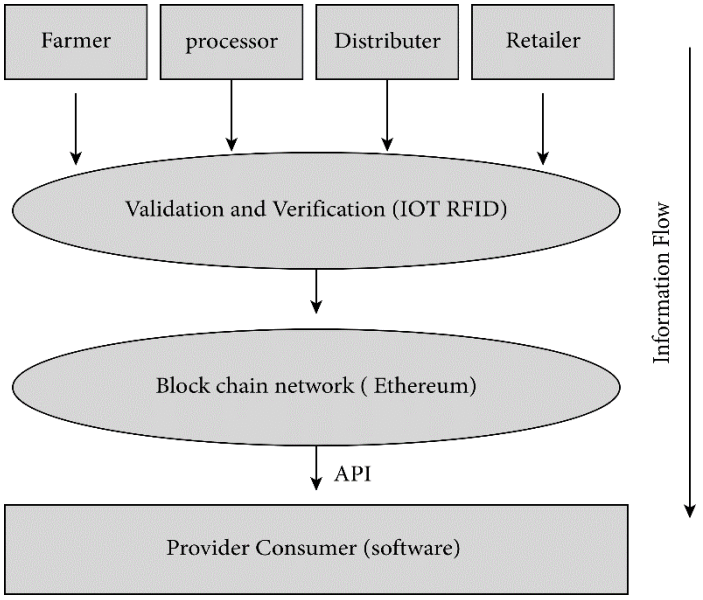


Figure 2: Conceptual Model

Source: https://www.hindawi.com/journals/sp/2022/7358354/fig6/

Results:

[1] In our proposed system we are improving the security using our new enhanced block chain algorithm.

[2] The consensus mechanism, utilizes mathematical algorithm to achieve agreement between different nodes on the accounting content.

[3] Storage is the carrier of distributed ledgers, including file system, block data structure and Hash association chain structure between blocks, database and other technologies.

[4] Non-critical data and large files that exceed the block size limit can be stored in the file system.

V. FINDINGS AND IMPLICATIONS OF THE RESEARCH

Findings:

1. *Transparency and Traceability:* The blockchain-based solution has successfully introduced transparency and traceability into the Indian agricultural supply chain. Farmers, producers, and consumers can access real-time information about the origin, quality, and movement of agricultural products. This has fostered trust among stakeholders and reduced information asymmetry.

2. *Efficiency and Automation*: The integration of smart contracts has streamlined supply chain processes, reducing the need for intermediaries and automating transactions. This has led to increased efficiency, faster transaction processing, and minimized paperwork, resulting in cost savings and improved overall productivity.

3. *Decentralized Marketplace:* The decentralized marketplace powered by blockchain technology has empowered farmers by providing them direct access to buyers, eliminating the need for middlemen, and promoting fair pricing based on market dynamics. Farmers now have greater control over their produce and better market opportunities.

4. *Real-Time Monitoring and Quality Assurance*: The implementation of IoT devices along the supply chain has enabled real-time monitoring of product conditions, ensuring product quality is maintained throughout transportation and storage. Prompt actions can be taken in case of any deviations, reducing food wastage and enhancing consumer safety.

5. *Immutable Records and Data Integrity:* The use of blockchain technology ensures that all transactions and data are securely recorded and cannot be altered or tampered with. This has enhanced data integrity, reduced the risk of fraudulent practices, and provided a reliable source of information for all stakeholders.

Implications:

1. *Improved Livelihoods for Farmers*: The blockchain-based solution has the potential to significantly improve the income and livelihoods of Indian farmers. By providing them with fair market access, timely payments, and better pricing, farmers can enjoy increased profitability and financial stability.

2. *Enhanced Food Safety and Quality:* The real-time monitoring and traceability features of the solution promote food safety and quality assurance. Consumers can have confidence in the authenticity and safety of the agricultural products they purchase.

3. *Government Support and Efficiency:* The transparent and verifiable data on the blockchain has strengthened the trust between farmers and government officials. This has facilitated the effective implementation of agricultural schemes, ensuring benefits reach the correct beneficiaries without any leakages or misappropriations.

4. *Sustainable Agricultural Practices:* With greater transparency and traceability, the blockchain-based solution encourages the adoption of sustainable agricultural practices. It incentivizes farmers to adhere to quality standards, certifications, and eco-friendly practices, promoting environmentally responsible farming.

5. *Scalability and Adoption:* While the research demonstrates the potential benefits of blockchain-based solutions in Indian agriculture, the scalability and widespread adoption of such technology remain challenges. To realize the full potential, efforts must be made to address scalability issues and promote technology literacy among farmers and stakeholders.

VI. CONCLUSION AND FUTURE WORK

The Fourth Industrial Revolution centers around advanced automation through cyber-physical systems, which can deliver increased value. Blockchain technology is gaining popularity across various sectors as a comprehensive solution for secure digital value transfer. By leveraging features like distributed data storage and immutability, blockchain enhances security and reliability in cyber-physical systems. Permissioned blockchains further foster assurance and trust, especially in cases vulnerable to collusion and fraud.

While Merkle Hash Tree has been robust in ensuring integrity and immutability in blockchain applications, it lacks traceability of tampered transactions and raises concerns about computational time complexity. Efforts have been made to optimize Merkle Hash Tree computations, leading to better efficiency in blockchain systems. However, scalability and cost-effectiveness of blockchain solutions remain unanswered questions, posing challenges for business managers considering its implementation. The high cost of implementing blockchain makes it infeasible for small and medium-sized enterprises (SMEs) to adopt the technology.

As a response, we have conceived a cost-effective blockchain framework specifically tailored for SMEs. This framework reduces development time and costs while ensuring traceability of data tampering with minimal impact on existing systems. It follows a reengineering approach and includes a blockchain module that enables distributed validation and recording of transactions as encoded data chains. This allows existing systems to integrate blockchain capabilities without a complete overhaul. In our proof-of-concept implementation, the blockchain scripts only added a marginal increase in processing time.

The future scope of this framework lies in customized implementation for other use cases, with a focus on specific objectives to address the unique needs of selected industries and organizations. By providing a cost-effective and efficient solution, this blockchain framework offers promising potential for SMEs looking to leverage blockchain technology for their cyber-physical systems.

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