BLOCKCHAIN-ENABLED SUPPLY CHAIN FOR AGRICULTURAL PRODUCTS

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ABSTRACT

Supply chain management is a vital aspect of modern business operations, ensuring the seamless flow of goods and services from origin to consumption. However, traditional supply chain systems face persistent challenges related to data integrity, transparency, inefficiencies, and security vulnerabilities. The advent of blockchain technology offers a transformative solution to these issues, providing a decentralized, immutable, and transparent ledger for tracking transactions and product movements. By leveraging blockchain, businesses can significantly enhance visibility, traceability, and trust throughout the supply chain while mitigating risks such as fraud and data manipulation. This paper explores how blockchain technology can revolutionize supply chain processes, including product traceability, provenance tracking, inventory management, and the automation of contracts via smart contracts [1][2][3]. The advantages of adopting blockchain for improved supply chain efficiency, security, and operational transparency, as well as its potential to redefine the future of supply chain management, are discussed

Keyword: - *supply chain management, blockchain technology, data integrity, transparency, inefficiencies, security vulnerabilities, decentralized ledger, immutable ledger, product traceability, provenance tracking, inventory management, smart contracts, fraud mitigation, data manipulation, operational transparency, supply chain efficiency, blockchain adoption, future of supply chain.*

INTRODUCTION

Supply chain management is integral to the global movement of goods and services, linking suppliers, manufacturers, distributors, and consumers. Its primary objective is to optimize the flow of products by tracking production, shipping, and delivery, while minimizing costs and ensuring timely availability. However, modern supply chain systems often struggle with inefficiencies, lack of visibility, fraud, and the involvement of intermediaries. These challenges are particularly prominent in industries like agriculture, where a significant portion of produce is wasted due to ineffective supply chain management [1][2].

Blockchain technology has emerged as a potential game-changer for supply chain management. By decentralizing control and removing the need for intermediaries, blockchain provides stakeholders with a single, transparent source of truth that can be securely accessed in real-time [1][4]. Blockchain's tamper-proof nature ensures that data is immutable, enabling stakeholders to trust the system without requiring direct trust in one another [2][5].

First introduced by Satoshi Nakamoto in 2008 for Bitcoin, blockchain introduced the idea of a decentralized network where data could be recorded and verified by multiple independent participants instead of relying on a centralized authority [3]. Its structure, where blocks are cryptographically linked, forms an immutable chain of records. Additionally, blockchain networks utilize smart contracts, which are self-executing contracts with terms embedded directly into code. These can play a pivotal role in optimizing supply chain processes, such as managing supplier agreements and automating payments [4].

LITERATURE SURVEY

Blockchain-Based Agri-Food Supply Chain Systems: Shahid et al. propose a blockchain-based solution tailored to the challenges of managing supply chains in the agriculture and food sector. By leveraging Ethereum smart contracts and decentralized storage (IPFS), the system enhances traceability, accountability, and trust [1].

Soybean Traceability Using Blockchain: Salah et al. present a blockchain-based soybean traceability system, which uses Ethereum smart contracts and IPFS for decentralized storage. However, limitations include insufficient accountability and auditability, crucial for ensuring end-to-end transparency [2].

Improved Storage and Traceability for Agricultural Products: Hao et al. propose an efficient storage scheme using blockchain and IPFS, focusing on agricultural products. A key drawback is the reliance on secondary databases, which introduces vulnerability to failures [3].

Smart Contracts for Physical Asset Delivery: Wang et al. develop auditable protocols for fair payment and secure delivery. Despite improving transparency, the system does not address the credibility of merchants, a critical factor in fostering trust [4].

Decentralized Storage for Blockchain-Based Supply Chains: Wang, Zhang, and Zhang propose a blockchain framework for decentralized storage with fine-grained access control. While effective in securing sensitive data, computational overhead remains a challenge in IoT scenarios [5].

METHODOLOGY

The proposed system leverages Ethereum blockchain technology to manage the agricultural supply chain, providing a decentralized and transparent platform. The steps include:

Smart Contracts Development: Smart contracts, written in Solidity, automate key processes such as product registration, ownership transfer, and quality assurance.

These contracts enforce predefined rules without requiring intermediaries, ensuring secure and transparent operations.

Decentralized Data Storage: The InterPlanetary File System (IPFS) is utilized for decentralized file storage, ensuring scalability and fault tolerance for large datasets.

Data is hashed and stored on IPFS, while references are recorded on the blockchain for immutability and integrity.

System Architecture: The architecture comprises a React.js frontend, Web3.js middleware, and an Ethereum private blockchain.

The frontend interacts with smart contracts via Web3.js, facilitating seamless communication between the user interface and blockchain.

Stakeholder Integration: Different stakeholders, including manufacturers, third-party sellers, delivery hubs, and consumers, are assigned roles through blockchain-based identity management. Stakeholders interact with the system using MetaMask for secure wallet integration and transaction execution.

WORKFLOW

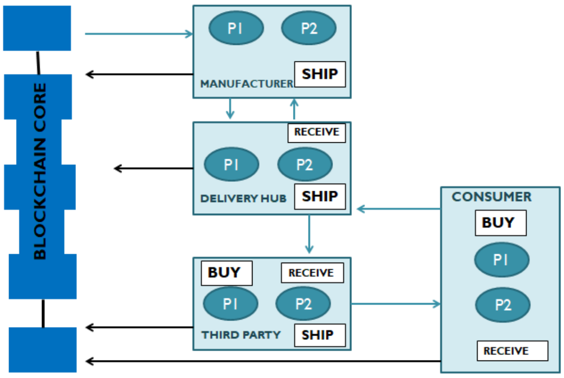

Fig: Workflow diagram of blockchain-enabled supply chain

1. Product Manufacturing

The manufacturer uses the system to register the product via the manufactureProduct() function. Inputs include product details like the name, category, batch number, manufacturing date, location (latitude and longitude), and production specifications. A unique identifier (UID) is generated and stored immutably on the blockchain. A new record is added to the product's history, marking its creation. Smart contracts validate the data to ensure compliance with predefined rules. Establishes the product's digital footprint from the source. Ensures initial quality control and provenance for subsequent stages.Enables accountability for the manufacturer.

2. Third-Party Purchase

Third-party sellers access the system to view available products. They purchase the desired product using the purchasedByThirdParty() function, transferring ownership from the manufacturer. The blockchain updates the ownership details and transaction timestamp. Ownership transfer is securely recorded as a blockchain transaction.
The product’s history is updated with the seller's details and purchase event. Enables secure and transparent transfer of products without intermediaries. Reduces delays and paperwork often associated with traditional supply chains.

3. Shipping by Manufacturer

The manufacturer ships the purchased product to the third-party seller. This event is logged using the shipToThirdParty() function. Shipment details, including dispatch date and transportation mode, are recorded. Updates the product’s status to "Shipped by Manufacturer." Records the tracking data and ensures traceability during transit. Allows real-time monitoring of product movement. Ensures that any discrepancies during shipping are traceable to the source.

4. Reception by Third Party

The third-party seller confirms the receipt of the shipped product via the receiveByThirdParty() function. The seller also logs details such as the location coordinates (latitude and longitude) and date of receipt. Updates the product’s state to "Received by Third Party." Appends location and time data to the product history for end-to-end traceability.

5. Customer Purchase

The third-party seller lists the product for customers, who can purchase it through the system. Once a customer buys the product using the purchasedByCustomer() function, ownership is transferred to the customer. Logs the transaction, updating the ownership details and timestamp. Adds the customer’s details to the product history.

6. Delivery Hub Process

After purchase, the product is shipped to a delivery hub by the third-party seller. The hub logs the receipt using receiveByDeliveryHub() and initiates further shipping via shipByDeliveryHub(). At each checkpoint, the location, timestamp, and condition of the product are recorded. Tracks every checkpoint in the distribution process. Updates the product's status at each stage.

7. Final Delivery to Customer

The delivery hub ships the product to the customer. The customer logs the receipt using receiveByCustomer(), completing the product's lifecycle on the blockchain. Marks the product's final state as "Delivered to Customer." Records the delivery event and timestamp immutably.

RESULTS AND DISCUSSION

1. **Improved Transparency and Traceability**: Real-time product tracking from production to final delivery ensures reduced fraud and enhanced consumer confidence [1][2].
2. **Efficiency Gains**: Automation via smart contracts reduces paperwork and manual intervention, cutting down delays and operational costs [4][5].
3. **Enhanced Security:** Blockchain's immutability and cryptographic hashing ensure tamper-proof data, addressing concerns of data manipulation and fraud [3].

CONCLUSION

Blockchain technology has the potential to revolutionize supply chain management by addressing core challenges of transparency, traceability, and efficiency. This study demonstrates the successful implementation of a blockchain-based system for agricultural products, with smart contracts ensuring process automation and trust among stakeholders [1][3][5]. While challenges such as scalability and regulatory compliance persist, advancements in blockchain, IoT, and AI promise further optimization. By fostering greater transparency and accountability, blockchain is poised to redefine supply chain management, contributing to a more sustainable and trustworthy global economy.

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