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INTERPLANETARY FILE SYSTEM FOR CUSTOM LOGGING SYSTEM INTEGRATED WITH SMART CONTRACT

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ABSTRACT

The agricultural sector faces challenges in managing dynamic data during transactions, particularly price quotations between farmers and buyers. Traditional smart contract systems often lack the flexibility to handle real-time data changes. This research proposes a customized logging system that integrates smart contracts with the InterPlanetary File System (IPFS) within a web application. By storing data references (hashes) on the blockchain and actual logs on IPFS, the system ensures reliable data recording, flexibility in updating transaction logs, and improved storage efficiency. This integration enhances the system's ability to manage fluctuating agricultural transactions. The proposed method aims to create a robust framework for managing price quotations, which can be extended to other industries with similar requirements.

Keyword: Blockchain, IPFS, Smart Contract, Web Application, Integration.

INTRODUCTION

Blockchain technology has emerged as a groundbreaking innovation with significant impacts across multiple industries, including agriculture, where it is revolutionizing conventional practices through decentralization, transparency, and enhanced data security (Burgess et al., 2024), (Duan et al., 2024). One of its key applications is the use of smart contracts—self-executing programs stored on the blockchain. These contracts operate based on pre-defined conditions, eliminating intermediaries and making them particularly useful for sectors reliant on trust and dynamic interactions, such as agriculture(Kiani & Sheng, 2024), (Lopez-Barreiro et al., 2024). However, despite their advantages, implementing smart contracts effectively in agriculture faces obstacles, particularly concerning the management of flexible and continuously changing data.

Agricultural supply chains are inherently fluid, influenced by factors such as fluctuating customer demand, seasonal variations, climatic conditions, and produce quality. For example, price negotiations between farmers and buyers frequently shift due to external economic factors and market volatility (Friedman et al., 2024), (Reardon et al., 2024). Consequently, there is a need for a system that can not only record transactions but also dynamically adapt to real-time changes. Conventional blockchain-based data recording mechanisms are often rigid, depending on static structures that fail to accommodate the fluid nature of agricultural price agreements. Additionally, traditional on-chain data storage results in inefficiencies, including high costs and limited scalability (Öztürk, 2024), (Khan et al., 2021), (Fernández-Iglesias et al., 2024). Addressing these challenges necessitates innovative approaches to designing a more adaptive and cost-efficient data recording framework.

The InterPlanetary File System (IPFS) presents a promising alternative for overcoming the limitations associated with traditional blockchain storage. As a distributed file system, IPFS disperses large datasets across a decentralized network rather than relying on centralized servers or storing data directly on the blockchain. It employs content-based addressing, where cryptographic hashes identify and retrieve files, ensuring both data authenticity and security (Bin Saif et al., 2024a), (Lin et al., 2024). This architecture makes IPFS particularly well-suited for managing vast, dynamic datasets. Instead of storing data directly on the blockchain, IPFS allows only file references (hashes) to be recorded on-chain, significantly reducing storage costs while preserving security and reliability (Liang et al., 2024), (Tmeizeh et al., 2024).

Integrating IPFS with smart contracts provides a robust framework for developing a dynamic logging system tailored to agricultural price quotations. The proposed system capitalizes on IPFS's decentralized nature and scalability to enable flexible transaction data recording while allowing real-time updates without compromising data integrity. By keeping actual transaction logs in IPFS and only storing file references

on the blockchain, the approach enhances efficiency while ensuring immutability (Westphal et al., 2023), (Mughal et al., 2022). This hybrid model not only alleviates the high costs of on-chain storage but also strengthens the system's capability to handle substantial volumes of agricultural market data.

Ensuring transparency is crucial in agricultural supply chains, where trust between farmers, buyers, and intermediaries is often fragile. Unreliable data can lead to pricing disputes and hinder long-term collaborations. By leveraging blockchain and IPFS for logging price quotations and transactions, this research promotes transparency, verifiability, and immutability in data management (Kumar C & Selvaprabhu, 2023), (Hasan et al., 2020), (Cocco et al., 2021). With a decentralized structure, all stakeholders can independently verify records, minimizing the risk of disputes and fostering greater trust. Furthermore, removing centralized control points enhances system resilience and reliability.

Despite its advantages, developing a seamless interaction between smart contracts and IPFS presents several challenges. Ensuring efficient data retrieval and maintaining integrity verification require meticulous system design. Additionally, latency in data access could affect real-time operations, posing a challenge for industries like agriculture that rely on instant updates (Yu et al., 2024). Overcoming these technical difficulties demands a deep understanding of both blockchain and IPFS, as well as their potential for innovative data management applications.

Beyond agriculture, the proposed IPFS-integrated logging system has broader implications. Various industries, such as logistics, healthcare, and manufacturing, face similar challenges in handling extensive and dynamic datasets while ensuring data security. The principles introduced in this research can serve as a model for addressing these issues across different domains (Huang et al., 2020), (Battah et al., 2020). For instance, the system could be adapted for tracking shipments in logistics, maintaining electronic health records, or managing production data in manufacturing environments (Bin Saif et al., 2024b).

This research contributes to the expanding knowledge base on blockchain and decentralized technologies by presenting a novel framework for managing agricultural price quotations. Unlike existing methods that depend solely on on-chain storage or centralized databases, the proposed approach integrates blockchain with IPFS to create a hybrid system that is both adaptable and efficient. By specifically addressing the complexities of handling dynamic price quotations, this study introduces a scalable and transparent solution aligned with the evolving needs of the agricultural sector. Moreover, the methodologies proposed have the potential to drive technological advancements in other industries, reinforcing the broader applicability of decentralized data management solutions.

RESEACH GAP

Blockchain technology has been extensively examined for its potential to enhance transparency, security, and efficiency across various sectors, including agriculture. Research indicates that it can provide tamper-proof data recording, improve stakeholder trust, and automate processes via smart contracts. However, challenges remain in applying blockchain to dynamic and data-intensive agricultural systems, particularly for real-time price quotations and supply chain data management.

The agricultural industry faces unique challenges, such as price volatility, seasonal demand, and complex supply chains. Blockchain has been proposed as a solution to ensure transparency and accountability. (Ellahi et al., 2024) highlighted the significance of blockchain in sustainable food supply chains by enabling stakeholders to trace the origin and quality of products. (Bosona & Gebresenbet, 2023) discussed how blockchain improves food safety by providing reliable tracking and validation of supply chain events. Despite these advantages, the agricultural sector needs dynamic systems that can adapt to frequent updates, like market price fluctuations. Traditional blockchain implementations, with their rigid data structures and limited storage, struggle with this flexibility. (Charatsari et al., 2023) identified these limitations in agrifood value chains and called for innovative systems to efficiently manage dynamic data. Although blockchain holds promise, it also faces significant criticisms in agriculture. High implementation costs and complex integration pose barriers, especially for small and medium-sized farmers with limited resources. Additionally, scalability issues make it difficult to handle the high volume of transactions typical in dynamic supply chains. Furthermore, the reliance on robust digital infrastructure creates disparities, as many rural areas in developing countries lack the necessary connectivity and technological resources for effective adoption.

Smart contracts have emerged as transformative tools for automating processes and reducing intermediaries. In agriculture, they have been used to

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automate tasks such as pricing agreements, payment settlements, and contract enforcement. (Sakib, 2024) explored the use of smart contracts for managing complex transactions and highlighted their ability to reduce operational inefficiencies. However, vulnerabilities in smart contract designs limit their reliability in dynamic systems. For price quotation management, smart contracts offer a promising solution by automating agreement execution based on predefined criteria. Nevertheless, (Egunjobi et al., 2024) noted that smart contracts alone cannot overcome blockchain's storage limitations, especially for applications requiring frequent updates. This underscores the need for hybrid architectures that integrate off-chain storage solutions. While smart contracts provide significant benefits, their adoption in agriculture is not without challenges. A major issue is the lack of standardization in contract templates, leading to interoperability problems across different platforms and systems. Additionally, relying on oracles to feed real-world data into the blockchain poses security risks, as compromised oracles can result in incorrect contract execution. The steep learning curve associated with developing and managing smart contracts can also deter smaller agricultural stakeholders with limited technical expertise. Addressing these challenges requires collaborative efforts to develop secure, user-friendly, and standardized solutions tailored to agriculture's unique needs.

Integrating the InterPlanetary File System (IPFS) with blockchain has been proposed to address storage limitations. IPFS offers decentralized storage for large datasets, while blockchain stores only references or data hashes. (Haque et al., 2024) demonstrated the scalability and efficiency of this approach, with IPFS managing off-chain data and blockchain ensuring data integrity through cryptographic hashing. Similarly, (Widayat et al., 2023) highlighted the security advantages of IPFS, especially in scenarios requiring distributed data storage and retrieval. In agriculture, this hybrid approach is particularly relevant due to the large volume of data generated by IoT sensors, market analysis systems, and supply chain operations. (Ortega et al., 2022) introduced a decentralized agro-food planning system, showcasing the potential of blockchain-IPFS integration to manage complex agricultural data. However, their study primarily focused on static data storage and did not address real-time data updates, leaving a gap for further exploration.

To address the gaps, this study proposes a customized logging system that combines blockchain, IPFS, and smart contracts specifically for agricultural price quotation management. Unlike traditional systems, this approach enables real-time updates, automates pricing processes, and ensures scalability by leveraging IPFS for off-chain storage. By addressing the unique challenges of dynamic agricultural data, this study aims to contribute a novel framework that enhances efficiency and transparency in supply chains.

RESEARCH METHODOLOGY

This section outlines the framework, design, and implementation steps for developing a blockchain-IPFS-based system tailored to agricultural price quotation management. The proposed methodology integrates blockchain technology, smart contracts, and the InterPlanetary File System (IPFS) to address the unique challenges of dynamic data management and transparency in the agricultural supply chain. Figure 1 is showing the flow between farmer and buyer via smart contract integrated with IPFS.

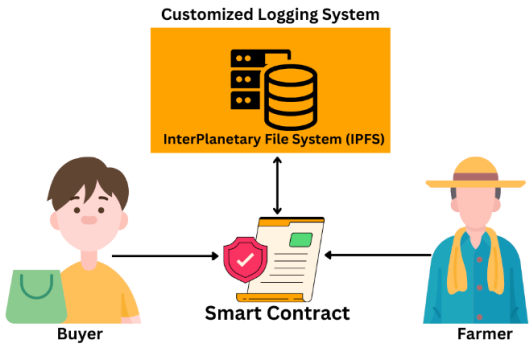

Figure 1. Interplanetary File System Integration with Smart Contract

This study develops a blockchain-IPFS-based system for agricultural price quotation management, integrating blockchain for transparency, IPFS for scalable storage, and smart contracts to automate transactions. The system follows a hybrid architecture where a private Ethereum blockchain is used to record critical data references and manage smart contracts, ensuring secure and verifiable transactions. Meanwhile, IPFS provides decentralized storage for large datasets such as price logs and transaction histories, assigning each file a unique content identifier (CID) to maintain data integrity. Smart contracts facilitate price quotation management by automating processes and enabling seamless interaction between

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blockchain and IPFS. A web-based dashboard serves as the user interface, allowing stakeholders, including farmers, traders, and suppliers, to access, update, and monitor data in real time. Figure 2 is showing how the custom logging system built to store information including logging data.

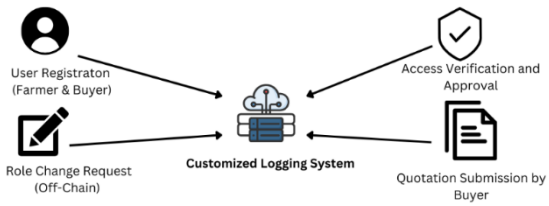

Figure 2. Customized Logging System using IPFS

For implementation, smart contracts play a crucial role in securely linking transaction data to IPFS. Before storage, data is hashed to prevent unauthorized modifications, ensuring transparency and security. The development process involves several tools to support system functionality. Ganache is used as a local blockchain environment to simulate transactions before deployment. Node.js manages backend operations, handling user requests such as registration, role changes, and access verification. MetaMask serves as a crypto wallet for managing private keys and authorizing transactions, while Helia is utilized for off-chain role management, optimizing system efficiency. Solidity is employed to develop smart contracts that enforce business logic, including access control, activity logging, and quotation submission, ensuring secure and transparent execution of system operations.

Integration with IPFS ensures secure storage and retrieval of price quotation logs. The system hashes the data before storing it on IPFS, with the smart contract recording the generated hash as a verifiable reference. This approach guarantees that stored data remains tamper-proof while enabling efficient data management. By leveraging blockchain and IPFS, the system enhances security, transparency, and efficiency in managing agricultural price quotations, reducing risks associated with data loss and manipulation.

RESULTS AND DISCUSSION

The implementation of a blockchain-based platform for managing role-based functionalities and quotation creation offers several advantages. One key benefit is ensuring transparency and traceability in interactions between farmers and buyers. Figure 3 illustrates the user interface designed to assign roles and create quotations. Users begin by selecting their role, such as "Farmer" or "Buyer," from a dropdown menu and confirming it by clicking the "Assign Role" button. This role assignment process ensures that only authorized users can access specific features, thus maintaining the platform's integrity.

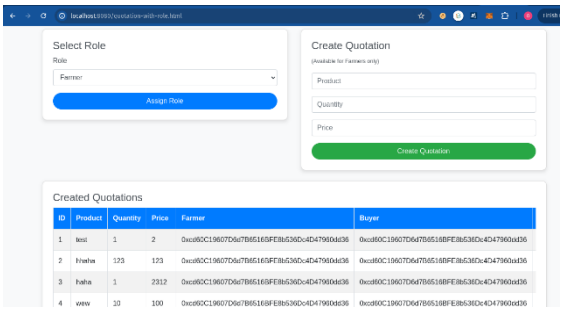

Figure 3. Select role and Quotation

Farmers, for instance, are granted access to the "Create Quotation" feature, where they can enter product details such as name, quantity, and price. This feature simplifies the process of generating offers for their products. Upon completing the input, users submit the quotation by clicking the "Create Quotation" button, after which the data is securely stored within the blockchain system. The table displayed below the input fields dynamically updates to show all created quotations, including details such as quotation ID, product name, quantity, price, and the blockchain addresses of both farmers and buyers, promoting transparency and accountability.

The role-based access ensures that buyers can only view existing quotations, facilitating efficient interaction without compromising data security. Figure 4 complements this process by showcasing the retrieval of user data from the InterPlanetary File System (IPFS). The data includes the user's blockchain address, assigned role, and timestamp, which are critical for validating role assignments and maintaining a decentralized yet immutable record of user actions.

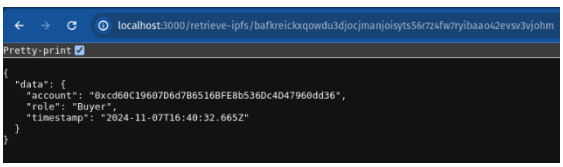

Figure 4. IPFS Data Retrieval

Together, Figures 4 and 5 highlight a seamless integration of role-based user interaction and decentralized data storage. The IPFS-based system ensures that all role assignments and created quotations are tamper-proof and verifiable. These features not only

enhance operational efficiency but also foster trust among users by providing transparency and secure data management. While some challenges may arise in the system's implementation and scaling, the benefits of using blockchain technology to create a secure and transparent agricultural marketplace are clear.

CONCLUSION

This research successfully integrates IPFS and smart contracts to manage price quotations in the agricultural supply chain. The system provides an efficient and scalable solution for storing and retrieving large datasets while ensuring data integrity and transparency. By utilizing IPFS for off-chain storage and referencing data hashes in smart contracts, the system enhances security and immutability, fostering trust among stakeholders. The results demonstrate that the system can effectively handle volumes of data, offering a cost-efficient approach to managing dynamic price quotations. The combination of IPFS scalability and smart contract transparency makes it highly suitable for the agricultural industry, where real-time access to accurate pricing information is essential for decision-making. However, some limitations remain, particularly regarding the availability of IPFS nodes and potential delays in data retrieval. Future research could focus on improving smart contract consensus mechanisms and enhancing IPFS data availability and redundancy. Despite these challenges, this study represents a significant advancement in improving the efficiency, transparency, and security of agricultural supply chain management through blockchain and IPFS technology.

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