Pharmaceutical Supply Chain Management using Blockchain

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Abstract: **The pharmaceutical industry faces different challenges, such as extensive drug counterfeits, lack of transparency, and poor supply chain management. This paper introduces a Decentralized Application (DApp) based on blockchain technology, which improves the transparency, traceability, and trust levels in the supply chain. This DApp uses tools such as Ethereum, Solidity, Web3.js, and React for smart contracts that guarantee secure and tamper-proof records of transactions. The application will then enable the various stakeholders involved—the manufacturers, distributors, transporters, and retailers—to track the pharmaceutical products from the time of manufacture to the point of delivery. This would give stakeholders a tamper-resistant digital ledger of every product through the entire supply chain process, which would improve visibility and accountability at every point. In a simulated environment, it has proven to reduce risks, create trust, and adhere to regulatory requirements.**

Keywords— **Blockchain, Ethereum, Smart Contracts, Supply Chain, Transparency, DApp**

I. Introduction

A. Background

Major challenges facing the pharmaceutical and supply chain industries include counterfeit drugs, inefficient processes, and lack of transparency. It is estimated that approximately 10% of medicines sold globally are either substandard or counterfeit, posing serious health risks and adding billions of dollars to annual healthcare fraud [1]. Despite the use of traditional systems such as barcodes and RFID tags, they often fail to ensure the integrity and traceability of pharmaceutical products [1][4]. The blockchain technology is revolutionary in its decentralized and immutable nature and can revolutionize pharmaceutical supply chains in terms of transparency, building trust, and increasing operational efficiency [1]. This helps implement security for sensitive information, tracking the origin of products and offering real-time visibility about improving compliance on counterfeited drugs and risks.

B. Problem Statement

Despite the improvements made by current efforts, the existing systems still lack transparency when it comes to tracing the medicines. There is also a scarcity of solutions that will offer the pharmaceuticals authenticity and discourage fraudulent trading. This paper suggests a blockchain framework to fill the gap by enhancing traceability and ensuring product integrity while increasing efficiency in the whole supply chain operations.

C. Scope of Work

This research aims at developing a DApp on blockchain that creates more transparency, traceability, and efficiency in the pharmaceutical supply chain. It hopes to put into practice using a blockchain mainly based on Ethereum, which guarantees the safe and immovable tracking of pharmaceutical products from producers all through consumers. A user-friendly DApp will be implemented that allows stakeholders - manufacturers, distributors, and retailers to interact with the blockchain system to track medicines in real-time and understand their movements. The solution will allow end-to-end traceability of drugs to prevent counterfeits and ensure that drugs are authentic. In addition, the DApp will streamline supply chain processes, making them more efficient and reducing delays.

II. Related Work

The incorporation of blockchain technology in the pharmaceutical supply chain has received considerable interest because of its capacity to improve traceability, transparency, and security. Ghadge et al. [1] offer a conceptual framework aimed at the application of blockchain in pharmaceutical supply chains, underscoring its essential function in combating counterfeiting, ensuring adherence to regulatory standards, and promoting comprehensive traceability throughout the process. In addition, the study illustrates the synergistic integration of blockchain with IoT and digital twins and gives a transforming view to enhance operations. Lingayat et al. [2] have further discussed the efficacy of blockchain in securing pharmaceutical supply chains by demonstrating how decentralized ledgers enhance authentication and data integrity and establish robust systems against counterfeit drugs.

In a broader context, Sharabati and Jreisat [5] examine blockchain's application across supply chain management, emphasizing its ability to create immutable records that enhance operational efficiency and trust among stakeholders. Their review underscores blockchain's versatility and scalability in addressing industry-specific challenges, including pharmaceuticals. Tamboli et al. [6] extensively examine blockchain technologies within the pharmaceutical sector, exploring characteristics such as decentralized data storage, immutable transactions, and real-time monitoring. They highlight the critical necessity of maintaining cold chain compliance for pharmaceuticals that may be sensitive to temperature variations.

Other studies discuss the possible integration of blockchain with new technologies like artificial intelligence and cloud computing [3][4]. These studies underscore the advancements required for extensive deployment, illustrating the revolutionary potential of blockchain in resolving critical pharmaceutical supply chain issues, maintaining product integrity, and fostering ethical behaviors within global networks.

III. Proposed Methodology

This paper proposes a Decentralized Application (DApp), based on blockchain technology to manage and secure the pharmaceutical supply chain, ensuring transparency, traceability, and security regarding medications. The proposed framework involves several stakeholders, including the Owner, Manufacturer, Distributor, Transporter, and Retailer, and utilizes Ethereum-based blockchain technology to record every transaction securely and irreversibly.

The design of the architectural aspect of the proposed system for pharmaceutical supply chain management will enable seamless communication among all the parties involved; it will, however, conserve the integrity and transparency of information. The key elements of its architecture include the following:

1) Blockchain Network (Ethereum and Ganache): The Ethereum blockchain [8] acts as a distributed ledger providing security, immutability, and transparency for all the transactions happening in the supply chain. Ganache [9] is a personal Ethereum blockchain that allows simulating the actual Ethereum network locally for development and testing objectives.

2) Smart Contracts (Solidity): Smart contracts, written in Solidity - a programming language used to develop contracts on the Ethereum blockchain are created for each user role: Owner, Manufacturer, Distributor, Transporter, and Retailer. These contracts automate processes like user creation, medicine requests, and shipment verification, ensuring role-based functionality and efficient, trust less operations.

3) User Interface (React): The frontend of the system is built using React, and it makes an interface that is easy for all stakeholders to interact with the blockchain. This interface allows users to perform actions such as creating medicine requests, approving shipments, and verifying deliveries.

4) Web3.js and MetaMask Integration: Web3.js [7] acts as an interface between the frontend and the Ethereum blockchain, enabling communication with the blockchain and smart contracts. MetaMask [10] is integrated with this for secure authentication of the user and transaction signing, making access decentralized.

5) Role-Based Access Control: Each individual participating in the system is assigned specific roles and permissions:

a) Owner: creates and manages user accounts within the system.

b) Manufacturer: Creates medicines, and approves and verifies requests from the Distributor.

c) Distributor: Requests medicines from the Manufacturer, verifies shipments from the Transporter, and approves Retailer requests.

d) Transporter: Verifies and transports medicines between stakeholders, maintaining shipment accuracy.

e) Retailer: Requests medicines from the Distributor and verifies shipments from the Transporter.

6) Transaction cost: All actions, such as creating, requesting, and receiving medicines, etc are recorded as transactions on the blockchain. The cost associated with every transaction is compensated in Ether (ETH), the native cryptocurrency of Ethereum. The transaction cost depends upon factors like gas consumption and the gas price, hence making sure that every single operation in the supply chain is transparent, traceable, and secure within a cost-provable framework.

Fig. 1 shows the system architecture of the proposed blockchain-based pharmaceutical supply chain management system.

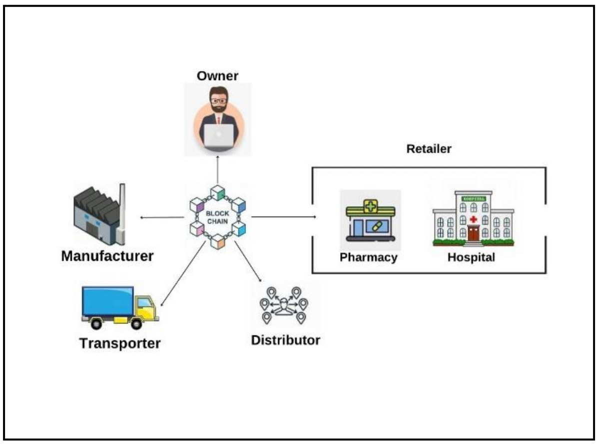

Fig. 1: System Architecture

IV. System Implementation

The System operates within the integrated smart contracts network specially configured to each user role-in particular, Owner, Manufacturer, Distributor, Transporter, and Retailer. Central to this framework is the Supply Chain Contract, which acts as the main contract that connects all role-specific agreements, thereby facilitating smooth interaction among the various stakeholders.

The implementation process starts with the Owner deploying all smart contracts onto the Ethereum blockchain network utilizing Truffle [9]. Following the deployment, the Owner establishes user accounts for each participant within the supply chain, designating roles - Manufacturer, Distributor, Transporter, and Retailer. Users whose accounts are established along with their associated roles are recorded on the blockchain.

The Manufacturer continues the process by creating medicine records, which are recorded on the blockchain. The Distributor accesses information regarding the medicines produced by the Manufacturer and submit requests for specific medicines. Once a request is received, the Manufacturer verifies and approves it, subsequently assigning a Transporter to handle the shipment of the requested medicine package. The assigned Transporter then verifies the shipment details and transports the medicine to the Distributor. Upon receiving the shipment, the Distributor verifies the delivery and records it on the blockchain.

Similarly, the Retailer can view the medicines available at the Distributor and submit requests for specific medicines. Upon receiving a request from the Retailer, the Distributor verifies and approves it, assigning a Transporter to handle the delivery. The Transporter, as before, verifies and transports the medicines to the Retailer. Once the Retailer receives and verifies the shipment, the transaction is recorded on the blockchain.

During the entire process, every transaction, including user registration, pharmaceutical requests, authorizations, and distributions, is meticulously recorded on the blockchain. This ensures transparency, traceability, and accountability at each phase of the supply chain, in addition to protecting the integrity of the data.

Fig. 2 shows the Process Flow Diagram of the proposed blockchain-based pharmaceutical supply chain management system.

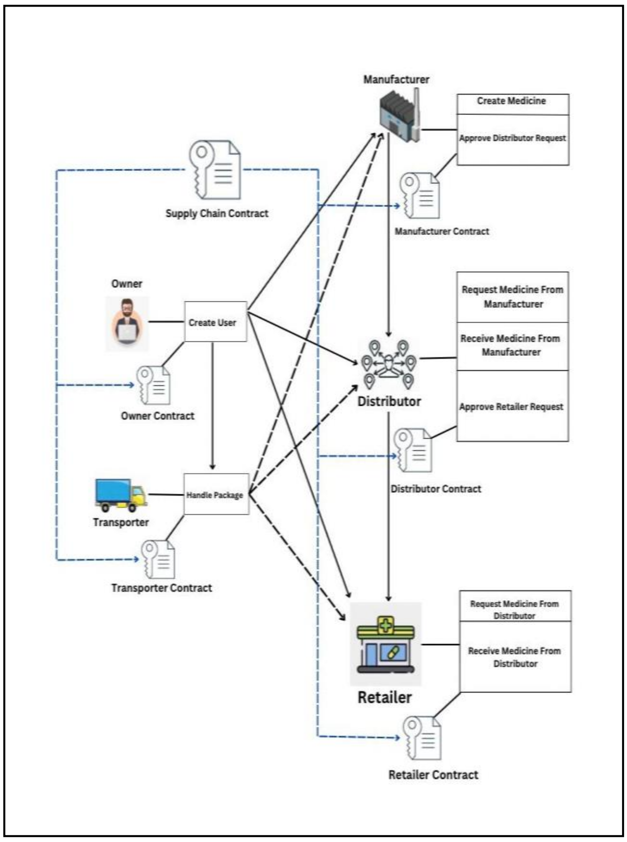

Fig. 2: Process Flow Diagram

V. Result & Discussion

A pharmaceutical supply chain blockchain-based decentralized application was implemented successfully. The smart contract was written in Solidity, was successfully compiled, and deployed on the Ethereum blockchain using Truffle with Ganache for testing. A user interface built with React was connected to the blockchain using Web3.js for seamless interaction with smart contracts. The system effectively integrated real-time monitoring of medicine movement through the supply chain, thereby allowing stakeholders to monitor the status of shipments and deliveries at any moment. The role-based functionality has been achieved by allowing stakeholders to perform specific functions based on their assigned roles. All operational capabilities, starting from the development of medicines, request approval, shipment monitoring, and delivery validation are operating correctly. All the transactions are properly recorded in the blockchain and displayed in Ganache, therefore ensuring full transparency and tracing of every stage of the supply chain.

The system provides a decentralized framework that ensures safe, transparent, and traceable activities carried out by each stakeholder. The combination of smart contracts with blockchain technology adequately meets the objectives of the project, which shows its ability to improve the management of the pharmaceutical supply chain.

Fig. 3 shows the details of the deployed smart contract including the transaction hash, the contract address, the block number, gas consumption, and total deployment cost, thus confirming the successful deployment on the Ethereum blockchain.

Fig. 3: Transaction Details of the deployed smart contract

Fig. 4 depicts the transaction for registering a user by the Owner, as recorded in Ganache., which shows how effectively supply chain operations are registered on the blockchain for transparency and traceability.

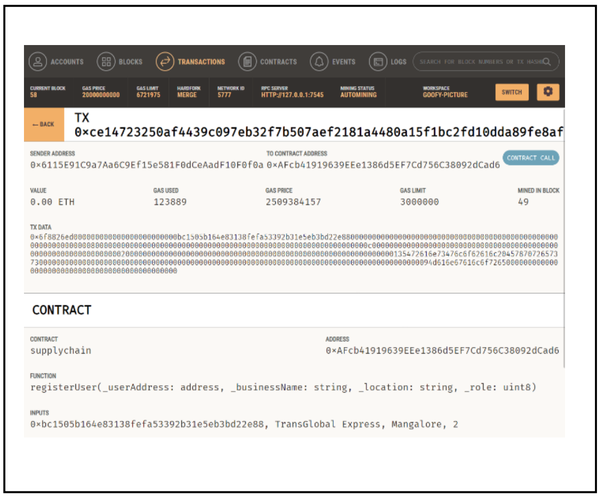

Fig. 4: Transaction for User Registration, recorded in Ganache

Fig. 5 depicts the front-end page for medicine creation, where manufacturers can enter essential details. This interface allows for seamless interaction with the blockchain.

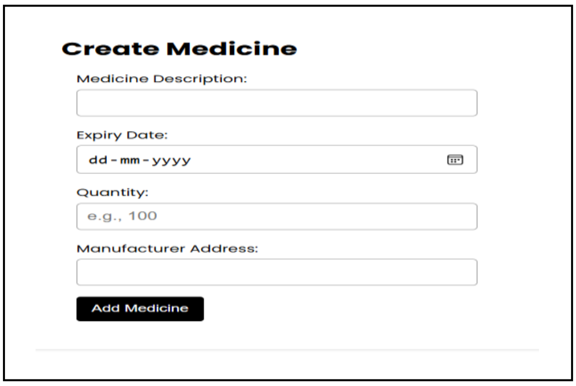

Fig. 5: Create Medicine Front-end Page

VI. Conclusion

In summary, the blockchain-based decentralized pharmaceutical supply chain system effectively enhances transparency, traceability, and security along the supply chain. The smart contracts used with Ethereum blockchain technology make it easy to monitor pharmaceuticals from production to distribution with great security. Role-specific functionalities and real-time monitoring of medicines allow all parties involved to carry out their respective tasks with total accountability while ensuring smooth engagement with the blockchain.

For further improvement, the incorporation of QR codes in the system will help to give any stakeholder well-rounded information about the drug in a more streamlined manner, including origin, transit history, and present status within the supply chain. Furthermore, an added price control mechanism, it will deter any party in the chain from selling drugs at astronomically high prices so that drugs may stay affordable and accessible, while at the same time, fairness would remain in the system. Moreover, these improvements will improve integrity in the system and gain even wider acceptance in pharmaceutical fields.

References

[1] Ghadge, M. Bourlakis, S. Kamble, and S. Seuring, "Blockchain implementation in pharmaceutical supply chains: A review and conceptual framework," *International Journal of Production Research*, vol. 61, no. 19, pp. 6633–6651, 2022. doi: 10.1080/00207543.2022.2125595.

[2] V. Lingayat, I. Pardikar, S. Yewalekar, S. Khachane, and S. Pande, "Securing pharmaceutical supply chain using blockchain technology," *in ITM Web of Conferences*, vol. 37, p. 01013, 2021. doi: 10.1051/itmconf/20213701013.

[3] N. Zakari, M. Al-Razgan, A. Alsaadi, H. Alshareef, H. Al-Saigh, L. Alashaikh, M. Alharbi, R. Alomar, and S. Alotaibi, "Blockchain technology in the pharmaceutical industry: A systematic review," *PeerJ Computer Science*, vol. 8, p. e840, 2022. doi: 10.7717/peerj-cs.840.

[4] C. Singh, R. Thakkar, and J. Warraich, "Blockchain in Supply Chain Management," *European Journal of Engineering and Technology Research*, vol. 7, no. 5, pp. 60–69, Oct. 2022. doi: 10.24018/ejeng.2022.7.5.2888.

[5] A.-A. A. Sharabati and E. R. Jreisat, "Blockchain technology implementation in supply chain management: A literature review," *Sustainability*, vol. 16, no. 7, p. 2823, 2024. doi: 10.3390/su16072823.

[6] F. Tamboli, M. Zade, A. Salunkhe, M. Kore, D. Bhusnar, K. Dikole, and D. Mane, "Blockchain technologies in pharmaceutical industry: A comprehensive overview," *IP International Journal of Comprehensive and Advanced Pharmacology*, vol. 9, pp. 24–30, 2024. doi: 10.18231/j.ijcaap.2024.004.

[7] Web3.js, "Web3.js Documentation," *Web3.js*. [Online]. Available: https://docs.web3js.org/. [Accessed: Dec. 3, 2024].

[8] Ethereum Foundation, "Geth Documentation," *Ethereum*. [Online]. Available: https://geth.ethereum.org/docs. [Accessed: Dec. 3, 2024].

[9] Truffle Suite, "Truffle Documentation," *Truffle Suite*. [Online]. Available: https://archive.trufflesuite.com/docs/. [Accessed: Dec. 3, 2024].

[10] MetaMask, "MetaMask," *MetaMask*. [Online]. Available: https://metamask.io/. [Accessed: Dec. 3, 2024].