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DRUG SUPPLY CHAIN ON A DECENTRALIZED NETWORK: A SURVEY PAPER

Dr. Swapnaja Ubale, Aryan Hamine, Sharwari Akre, Yash Ghan, Anisha Kango
Information Technology Department, Marathwada Mitra Mandal College of Engineering, Pune

Abstract—The modern markets heavily rely on the principles of supply and demand, necessitating the implementation of effective processes to ensure product quality. Supply chains encompass a series of activities involving multiple stakeholders like manufacturers, suppliers, and transporters working together to produce a desired product. The drug supply chain specifically focuses on the manufacturing and distribution of pharmaceuticals, where traceability plays a vital role in ensuring transparency among stakeholders and ultimately benefiting end-users. Enhancing traceability in drug supply chains enables meticulous monitoring and compliance with regulatory standards. Leveraging blockchain technology for drug supply chains appears to be a promising solution due to its inherent characteristics. In this research project, we aim to establish and operate drug supply chains using the Ethereum blockchain. Our objective is to offer organizations solutions that enhance supply chain management. By utilizing blockchain technology, transactions within the supply chain can be securely recorded and traced, leading to robust traceability and reliable record-keeping. The implementation of blockchain technology revolutionizes the efficiency and effectiveness of supply chain operations, thereby positively impacting various aspects of the process.
Key Words— Supply Chain, Blockchain, Pharmaceutical, Transparency, Immutability.

I. INTRODUCTION

HEALTHCARE supply chain is a complex network consisting of multiple independent entities, including raw material suppliers, manufacturers, distributors, pharmacies, and ultimately, patients. This intricate system poses various challenges due to its inherent complexity, such as the introduction of impurities, inaccurate information, lack of transparency, and limited data provenance. One significant consequence of these limitations within the existing healthcare supply chains is the proliferation of counterfeit drugs. Counterfeit drugs not only have a detrimental impact on human health but also cause significant economic losses to the healthcare industry.

Tracking supplies throughout this intricate network is a non-trivial task, primarily due to several factors. One key challenge is the lack of comprehensive information exchange among the different entities involved in the supply chain. This lack of information sharing hampers visibility and traceability, making it difficult to identify the origin and movement of drugs. Additionally, centralized control within the supply chain creates dependencies and information bottlenecks, further complicating the tracking process. Furthermore, competing behavior among stakeholders, such as manufacturers, distributors, and pharmacies, can hinder effective collaboration and information sharing, impeding the ability to track and trace drugs accurately.

The forementioned challenges exacerbate the problem of counterfeit drugs and drug misplacement within the healthcare supply chain. Counterfeit drugs can easily infiltrate the supply chain, posing serious risks to patient safety and public health. Similarly, drug misplacement can lead to inefficiencies, delays, and potential errors in patient treatment.

To address these issues, there is a growing recognition of the need for a robust, end-to-end track and trace system for pharmaceutical supply chains. In this research paper, we propose an Ethereum blockchain-based approach to enhance product traceability in the healthcare supply chain. The utilization of blockchain technology offers several advantages, including decentralization, immutability, and transparency. By leveraging smart contracts and decentralized off-chain storage, we aim to establish a secure and reliable system for tracking and tracing pharmaceutical products. This approach ensures that each transaction and movement within the supply chain is securely recorded, enabling stakeholders to verify the authenticity, origin, and movement of drugs.

Implementing an Ethereum blockchain-based solution for healthcare supply chain traceability holds the potential to significantly mitigate the risks associated with counterfeit drugs and drug misplacement. By enhancing transparency and data integrity, this approach can help ensure the safety and effectiveness of pharmaceutical products, benefiting both patients and the healthcare industry as a whole.

II. LITERATURE SURVEY

In recent years, there has been growing interest in leveraging blockchain technology to enhance transparency, security, and efficiency in various domains, including healthcare supply chain management. Several studies have explored the potential applications of blockchain in automating procurement contracts and drug traceability within the healthcare supply chain. Omar et al. [1] proposes a framework for automating procurement contracts in the healthcare supply chain using blockchain smart contracts. The study highlights the potential of blockchain technology to streamline the procurement process and reduce reliance on intermediaries. By utilizing blockchain smart contracts, transparency and efficiency can be enhanced in procurement operations. Musamih et al. [2] presents a blockchain-based approach for drug traceability in the healthcare supply chain. They address the challenges of counterfeit drugs and supply chain transparency by leveraging blockchain technology. The proposed system allows for the tracking and verification of drug information at each stage of the supply chain, ensuring the authenticity and integrity of drugs. To facilitate drug traceability and regulation, Huang et al. [3] introduces Drugledger, a practical blockchain system. This system enables secure and transparent tracking of drug-related information, such as production, distribution, and sale. By leveraging blockchain technology, the authors aim to enhance drug safety, reduce counterfeiting, and improve regulatory compliance within the healthcare supply chain. Blockchain technology in the healthcare supply chain management has gained attention due to its potential benefits. Moulouki et al. [4] provides an overview of the state of the art, challenges, and opportunities in implementing blockchain in health supply chain management. They emphasize the increased transparency, efficiency, and security that blockchain can offer to

supply chain operations. The paper also highlights the key considerations and challenges for successful implementation in the healthcare context. In a smart hospital setting, Jamil et al. [5] proposes a novel medical blockchain model for drug supply chain integrity management. Their model utilizes blockchain technology, incorporating smart contracts, secure data sharing, and auditing mechanisms. The goal is to enhance drug traceability, reduce counterfeit drugs, and improve patient safety within the smart hospital environment. A systematic literature review conducted by Chang and Chen [6] explores the current development and potential applications of blockchain in the supply chain domain. The review provides an overview of existing research and identifies various use cases, challenges, and opportunities of integrating blockchain technology in supply chain management. The potential benefits of blockchain, such as improved traceability, transparency, and efficiency, are highlighted. Overall, these studies demonstrate the potential of blockchain technology in addressing challenges within the healthcare supply chain, including procurement automation, drug traceability, and supply chain transparency. The proposed frameworks and models provide valuable insights for future research and implementation in this domain.

III. GAPS IN KNOWLEDGE

The blockchain-based approach for drug traceability in the healthcare supply chain presented by Musamih et al. [2] provides valuable insights into addressing the challenges of counterfeit drugs and enhancing supply chain transparency. However, the scalability of the proposed system may be a potential limitation. Our proposed system aims to potentially overcome the challenge of scalability by utilizing the strategies such as Layered or off-chain solutions, also known as sidechains, state channels, or payment channels, can be implemented to reduce the burden on the main blockchain and increase overall throughput. Sharding, which involves partitioning the blockchain network into smaller subsets called shards, enables parallel processing of transactions and distributed computational and storage requirements across multiple nodes. Consensus algorithm optimization, such as adopting Proof of Stake (PoS) or Delegated Proof of Stake (DPoS) algorithms, can enhance scalability by improving throughput and reducing resource requirements compared to traditional Proof of Work (PoW) algorithms. Network optimization, including improving peer-to-peer communication, utilizing efficient data synchronization mechanisms, and employing advanced network protocols and technologies, can also contribute to scalability improvements. Additionally, upgrading the underlying hardware infrastructure, such as utilizing more powerful processing units and increasing storage capacity, can enhance the system's ability to handle a larger volume of transactions. By considering these strategies, the scalability limitations of the blockchain-based approach for drug traceability can be addressed, leading to a more robust and scalable solution.

IV. PROPOSED METHODOLOGY

A. System Design

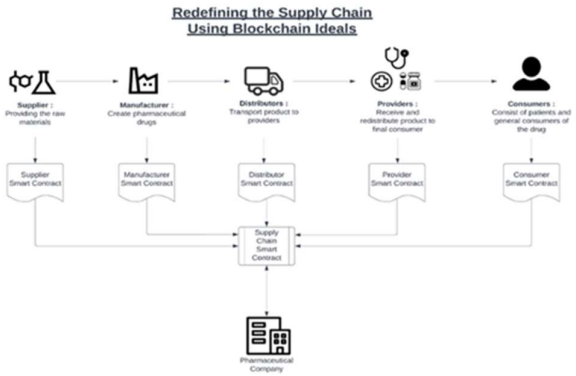

Fig. 1. Redefining the pharmaceutical supply chain using ideals of blockchain

The proposed research introduces a blockchain-based approach to redefine the pharmaceutical supply chain, aiming to enhance transparency and traceability. The high-level workflow, as depicted in Figure 1, illustrates the utilization of blockchain and smart contracts to connect various actors and entities involved in the supply chain. In this system, the Pharmaceutical Company, seeking to maintain immutable records of their supply chain, registers on the application and adds relevant actors to the network. To ensure transparency and accountability, a smart contract is created for each actor, enabling them to update records at each stage of the supply chain. These smart contracts are integrated into a pre-defined Supply Chain Smart Contract. The application accesses the data and records stored within the smart contract through an API, facilitating their visualization on the graphical user interface (GUI) of the application.

B. System Components

1) Actors in the supply chain

The supply chain consists of various stakeholders, including manufacturers, distributors, pharmacy admins, suppliers and consumers. These actors participate in the system and are assigned specific roles and functions based on their position in the supply chain. They are granted access to supply chain resources, such as log information and data, enabling them to track transactions and perform their designated tasks.

2) Decentralized Storage System

The system employs a decentralized storage mechanism to ensure the reliability, accessibility, and integrity of supply chain transaction data. The blockchain's decentralized nature allows for the secure storage of data. Each uploaded file is assigned a unique hash, and these hashes are stored on the blockchain. The decentralized storage system is accessed through the smart contract, and any modifications made to the uploaded files are reflected in the associated hash, ensuring data integrity.

3) Ethereum Smart Contract

The Ethereum smart contract plays a central role in managing the supply chain operations. It facilitates the deployment of the supply chain system and tracks the history of transactions. The

smart contract interacts with the decentralized storage server, managing the hashes associated with the stored data. Functions specific to different stakeholders within the supply chain are defined within the smart contract, ensuring that only authorized actors can access and perform their designated functions.

In summary, the proposed system includes actors representing different entities in the supply chain, a decentralized storage system to ensure data reliability, and an Ethereum smart contract that manages the supply chain operations and controls access to the system's functionalities.

C. High-Level Architecture

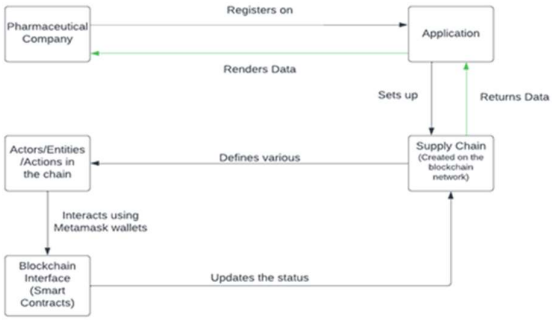

Fig. 2. High level system architecture of pharmaceutical supply chain web-based application

Figure 2 depicts the High-Level Workflow of the application, illustrating the sequential steps involved in the system. To initiate the process, the Pharmaceutical Company engages with the application by either providing the required information or logging into their existing accounts. Once the company is registered, the application proceeds to establish the supply chain framework. This includes creating and defining the actors and entities involved in the pharmaceutical supply chain.

The actors and entities within the supply chain interact with the system through the utilization of MetaMask Wallets, which serve as a gateway to access the smart contracts. These smart contracts play a pivotal role in facilitating the interactions and transactions within the supply chain. They enable the updating of the product statuses and records as the supply chain progresses.

The information recorded within the supply chain, including the status of products and relevant records, can be easily accessed and queried by authorized actors or the pharmaceutical company itself. This access ensures transparency and accountability throughout the supply chain, allowing stakeholders to retrieve relevant information as needed.

In summary, the workflow outlined in Figure 2 begins with the Pharmaceutical Company's registration on the application, followed by the establishment of the supply chain framework. The actors and entities interact with the system using MetaMask Wallets, leveraging smart contracts to update and retrieve product statuses and records within the supply chain.

V. FUTURE SCOPE

1.Enhanced Transparency and Traceability

Blockchain can provide an immutable and transparent ledger that enables real-time tracking and tracing of products throughout the supply chain. Future directions involve the integration of Internet of Things (IoT) devices, sensors, and smart contracts to automate data collection and verification, ensuring greater transparency and traceability.

2. Supply Chain Optimization:

Blockchain can streamline supply chain operations by reducing paperwork, eliminating intermediaries, and automating processes through smart contracts. Future trends include the use of machine learning and artificial intelligence to analyze blockchain data and optimize supply chain processes, such as inventory management, demand forecasting, and route optimization.

3. Quality Assurance and Counterfeit Prevention:

Blockchain can help ensure product authenticity and prevent counterfeiting by creating a tamper-proof record of every transaction and movement within the supply chain.

4. Efficient Supplier Management:

Blockchain can streamline supplier management by creating a decentralized and secure database of supplier information, certifications, and performance data. Future scope includes the implementation of blockchain-based reputation systems and smart contracts to automate supplier selection, verification, and payment processes.

5. Collaborative Networks and Trust:

Blockchain can facilitate trust and collaboration among multiple stakeholders in a supply chain network by providing a decentralized and secure platform for data sharing and consensus. Scope can be enhanced by facilitating the development of blockchain-based consortiums and ecosystems, where partners can securely share data, execute transactions, and collaborate on shared objectives.

These emerging trends and future directions demonstrate the potential of blockchain technology to revolutionize supply chain management by improving transparency, efficiency, trust, and sustainability across various industries.

VI. CONCLUSION

In conclusion, the development of this application caters to the creation of elaborate supply chains, ensures transparency and authenticity, eliminates the need for intermediaries, and keeps track of all transactions, processes and events in an immutable ledger which can greatly benefit the pharmaceutical industry. This platform for pharmaceutical companies to create, track, and streamline their product chains, can minimize the losses incurred due to mismanagement and enable a more efficient and reliable supply chain. This application can lead to increased trust and confidence in the pharmaceutical industry, ultimately benefiting all stakeholders involved.

Furthermore, the use of blockchain technology in the pharmaceutical industry can also improve the safety and security of the supply chain by reducing the risk of counterfeit drugs and ensuring compliance with regulatory standards. The immutable nature of the blockchain ledger allows for easy tracing and auditing of the entire supply chain, from the production of raw materials to the distribution of finished products. Moreover, the decentralized nature of blockchain ensures that there is no single point of failure in the system, making it more resilient to cyber-attacks and ensuring the continuity of operations even in the face of disruptive events. The adoption of blockchain technology in the pharmaceutical industry can revolutionize the supply chain management process by enhancing transparency, security, and efficiency. This can translate into significant cost savings, better compliance, and ultimately, improved patient outcomes.

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