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ENSURING DATA INTEGRITY IN HEALTHCARE SUPPLY CHAINS: A BLOCKCHAIN-POWERED METHODOLOGY

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Abstract: The supply chain for healthcare is a complicated web of separate businesses, including manufacturers, distributors, pharmacies, hospitals, patients, and suppliers of raw materials. Due to a number of reasons, such as centralised control, conflicting stakeholder behaviour, and a lack of information, tracking supply across this network is not simple. Medical supply chains are intricate networks that go over many organisational and geographic borders and serve as the foundation for services that are essential to daily living. Such systems' intrinsic complexity might bring impurities such restricted data provenance, opaqueness, and erroneous information. One effect of these restrictions in current supply chains is the emergence of counterfeit medications, which not only seriously harms public health but also severely undercuts the healthcare sector financially. In this study, we propose a decentralised off-chain storage system and blockchain-based methodology for effective tracking of goods in the supply chain of medical products. The smart contract ensures the provenance of data, does away with the need for middlemen, and gives all parties involved a safe, unchangeable record of transactions.

Keywords: Healthcare Supply Chain, Medical Products, Smart Contracts, Decentralized Systems, Traceability.

1. Introduction

The supply chain for healthcare is a complicated web of several separate organisations, including manufacturers, distributors, pharmacies, hospitals, patients, and suppliers of raw materials. Due to centralised management, conflicting stakeholder conduct, and a lack of information, tracking supply across this network is difficult. In addition to creating problems like those brought to light by the COVID-19 pandemic [1], such complexity can make it more difficult to combat counterfeit medications since they can readily infiltrate the supply chain for health care.

Products that are purposefully and fraudulently manufactured and/or mislabelled with regard to identification and/or source to give the impression that they are authentic are known as counterfeit pharmaceuticals [2][3]. These prescriptions may include contaminants, repackaged expired goods, an erroneous amount of active pharmaceutical ingredients (API), a drug of low grade, or no drug ingredient at all. It's possible that some fake drugs are even made under unsatisfactory circumstances and with wrong formulations [4].

A new approach to building applications has been made possible by blockchain technology, and it is mostly predicated on the Bitcoin application's effective data structure implementation. The basic idea behind the format of blockchain data is comparable to that of a linked list, meaning that all nodes in the network share it and each node maintains a local copy of every block (connected to the longest chain) beginning with its genesis block. In a variety of fields, including e-government,

e-document management, and the Web of Things, numerous real-world uses have recently been created [5]. The self-cryptographic verification mechanism among transactions (using hashes) and the publicly accessible public ledger of recorded transactions in a peer-to-peer network are two advantages of blockchain technology that are utilised in these applications. It is extremely difficult to alter the records when a chain of blocks is created and linked by cryptographic structures (hashes), as doing so would require reworking every transaction from the beginning to the most recent block.

One of the first attempts at blockchain-based traceability for the supply chain of drugs is presented here. We take a comprehensive approach to the pharmaceutical supply chain, offering an end-to-end solution for drug traceability, even though our solution is similar to this effort because it uses blockchain technology and focusses on the pharmaceutical supply chain [19]. First off, unlike other approaches that just include suppliers, manufacturers, and wholesalers as stakeholders, ours recognises and involves the FDA, supplier, supplier, retailer, pharmacists, and patient—the main players in the medication supply chain. As a result, unlike in an actual medication supply chain, the chemists are portrayed as an external entity. Second, we specifically work to define and identify the connections between smart contracts, decentralised storage systems, on-chain resources, and stakeholders that are needed. Additionally, because stakeholder interactions are important, we have added clear definitions to eliminate any confusion, even if they haven't been included in the definition. Thirdly, in order to reduce human interaction and thus undesirable delays, we employ smart contract technology to accomplish real-time, seamless tracking with push alerts.

The drug industry has made several attempts to address the well-known problem of attaining traceability in order to reduce the risk of imitation drugs.

2. Literature Survey

As per Mettler, the blockchain technology has demonstrated significant flexibility as several industry sectors have tried to integrate its capabilities into their operations. Although the primary emphasis has so far been on the financial services sector, several studies in other service-related fields, such as healthcare, indicate a shift is commencing. This research focusses on several applications of Blockchain technology in the healthcare sector.

Yan et al. examine the applications of blockchain technology and see how it may improve pharmaceutical supply chain operations. They also explore the potential integration of blockchain technology into Bayer's pharmaceutical supply chain. They start by defining smart contracts, blockchain technology, and the pharmaceutical supply chain. They go over involved entities, flow of data, contracts, settlements, transportation, openness, product security, blockchain facilities, and governance while talking about the advantages and implementation. Blockchain technology can benefit Bayer and the sector. Blockchain enables information sharing without revealing trade secrets, as well as quick, safe, and confidential transactions and consumer transparency.

Mettler et al. suggested that blockchain technology may be used to combat counterfeit medications in the pharmaceutical sector. Kurki shared on the advantages and recommendations for

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applying blockchain technology to the pharmaceutical supply chain. Though they provided few technical information on how they apply the practical workflow with blockchain, Archa et al. revealed their ideas on merging the GDPIoT architecture with Tendermint blockchain for medication distribution traceability.

Thejaswini et al. proposed a system to verify medications in a supply chain that involved producers, distributors, wholesalers, chemists, and consumers, an application was created. It used a smart contract to generate QR codes for verification, but only a small group of individuals were able to check their legitimacy, and it wasn't made to give out the drug's data.

3. Implementation

Using blockchain technology, the suggested drug traceability system offers a safe, transparent, and impenetrable record of drug interactions across the supply chain. The design of this system is based on decentralised elements, mainly smart contracts, a decentralised storage system, and on-chain resources, all of which are accessed through a Decentralised Application (DApp), which serves as a conduit for communication between stakeholders.

3.1 System Components

Smart contracts, the central component of this system, automated and regulate the rules governing stakeholder interactions. The smart contract is accessible to each stakeholder according to their function, allowing them to execute actions that are consistent with their place in the medication supply chain. By permanently logging every transaction that occurs, smart contracts preserve openness and guarantee responsibility and accountability for each medication unit handled.

Through the **DApp**, which serves as the front-end layer, stakeholders interface with the blockchain network. Stakeholders have an easy way to access data, start predefined smart contract actions, and examine logs thanks to this app's API integration with on-chain resources and decentralized storage.

The methodology of the proposed system is represented Figure 1.

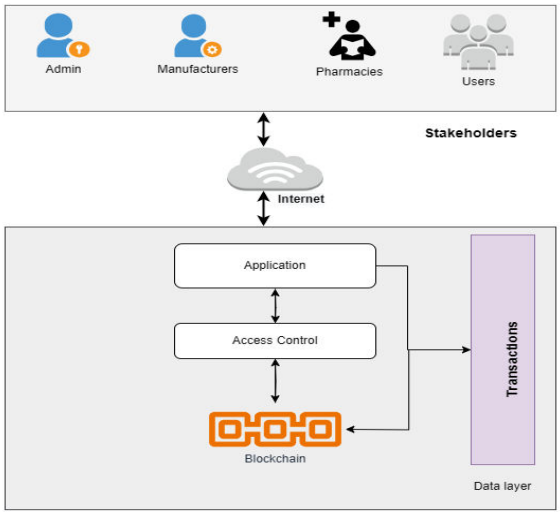

Figure 1. Proposed methodology

Each of the four main groups involved in the system—administrators, producers, pharmacies, and end-users—has certain responsibilities and access levels. The supply chain, stakeholder access management, and transaction auditing capabilities are all accessible to administrative and regulatory bodies with higher-level rights. Production data can be recorded by manufacturers and medication origins can be authenticated. Pharmacies may update distribution drug transaction information, and end-users can check the legitimacy of their drugs.

In their designated capacities, stakeholders are able to efficiently and safely maintain medication records through interaction with the smart contracts for pre-authorized function calls. Interactions with on-chain resources make crucial information, like as transaction logs and audit trails, accessible

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to stakeholders, fostering transparency and traceability.

4. Discussion and Results

This is a high-level architecture for the proposed drug traceability system, which includes the stakeholders and the interactions that they have with the smart contract. It is envisioned that stakeholders will be able to access the smart contract, the decentralised storage system, and the on-chain resources by means of software devices that have a front-end layer that is denoted by a DApp (Decentralised Application). This DApp is connected to the smart contract, the on-chain resources, and the decentralised storage system through an application program interface (API) that includes Solidity, Web3, Ganache and Django framework. A smart contract will be used to facilitate interactions between the various parties in order to begin pre-authorized track transactions in the supply chain.

A blockchain-based drug traceability system that will monitor the flow of medications across the healthcare supply chain is currently being developed. The healthcare supply chain involves several organisations, such as manufacturers, distributors, suppliers, hospitals, pharmacies, and so on. There is a chance that one of the parties will mislabel or counterfeit the drug while it is being given to the patient or client by the manufacturer. We advise integrating smart contract technology, which offers push connect with ganache, into our system to help address this. The implementation of solidity program is mentioned in Figure 2.

Ganache

With Ganache, an Ethereum development tool, developers can test distributed smart contracts and replicate a blockchain environment locally. With Ganache, you can create, implement, and test your DApps in a secure and predictable environment across the whole development cycle. The implementation of Ganache transactions of the proposed system is mentioned in Figure 3.

DApp

For participants, this acts as the front-end interface. Accessing blockchain features and interacting with the system's back-end elements, including as the smart contract, on the network resources, and decentralised storage, is made simple by the DApp. Using Django API developed the DApp and shown in Figure 4.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract DrugTraceability {
  struct DrugTransaction {
    uint256 id;
    string drugName;
    string batchNumber;
    string manufacturer;
    string receiver;
    uint256 timestamp;
  }

  DrugTransaction[] public transactions;

  event TransactionAdded(uint256 id, string drugName, string batchNumber, string manufacturer, string receiver, uint256 timestamp);

  function addTransaction(
    string memory _drugName,
    string memory _batchNumber,
    string memory _manufacturer,
    string memory _receiver
  ) public {
    uint256 transactionId = transactions.length;
    transactions.push(DrugTransaction(transactionId, _drugName, _batchNumber, _manufacturer, _receiver, block.timestamp));

    emit TransactionAdded(transactionId, _drugName, _batchNumber, _manufacturer, _receiver, block.timestamp);
  }

  function getTransaction(uint256 _id) public view returns (DrugTransaction memory) {
    return transactions[_id];
  }
}
```

Figure 2. Solidity contract

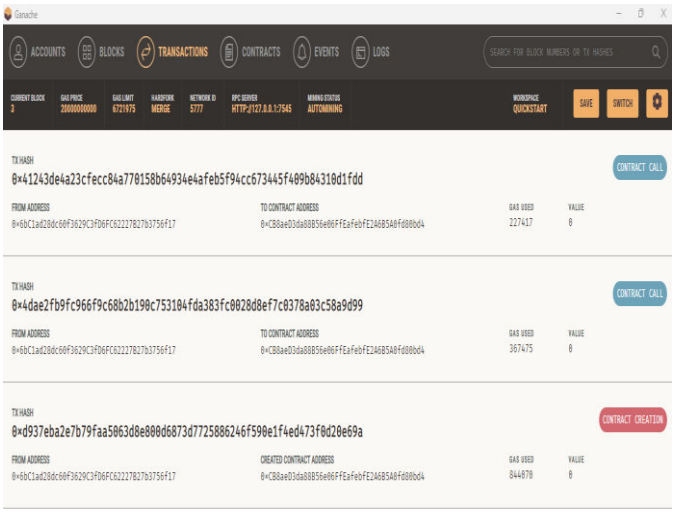

Figure 3. Ganache transactions

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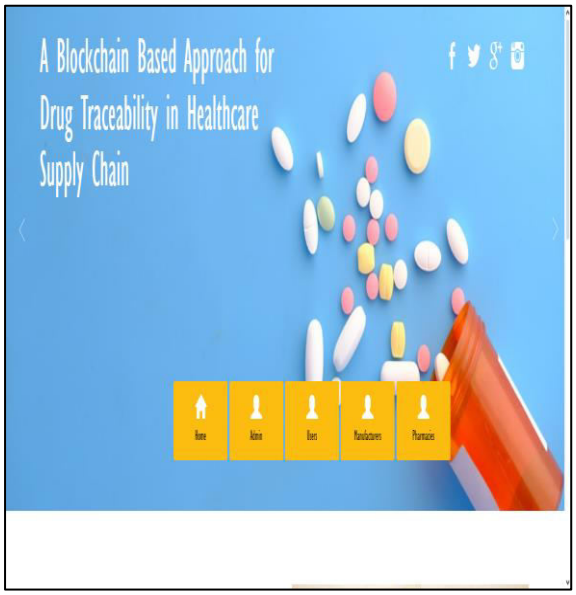

Figure 4. DApp using Django

5. Conclusions

In conclusion, the proposed blockchain-based drug tracing system provides a transparent and safe way to fight fake medications in the supply chain. This system allows producers, pharmacies, and regulatory bodies to track medication transactions in an unchangeable and verifiable way by utilising decentralised technology. The blockchain securely records every transaction, guaranteeing data integrity and providing authorised users with real-time audit trails. The technology increases stakeholder trust and improves traceability by utilising smart contracts and decentralised storage, giving end users assurance about the legitimacy of their prescription drugs. In terms of improving medication supply chain transparency and protecting public health, this methodology is a major advancement.

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