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Drug Inventory and Supply Chain Tracking

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Abstract

Drug Inventory and Supply Chain Management is a crucial aspect of the pharmaceutical industry that ensures the efficient tracking, storage, and distribution of medicines. This project aims to develop a web-based application using Python, Django, and SQLite/MySQL to streamline the management of drug inventory from manufacturers to pharmacists. The proposed system provides a centralized plat form for tracking medicine stock, managing orders, and enhancing supply chain visibility. The platform allows different stakeholders, including administrators, manufacturers, distributors, suppliers, and pharmacists, to efficiently manage their respective roles. By integrating QR code-based tracking and automated order pro cessing, the system improves accuracy, reduces wastage, and prevents stock short ages.

Keywords: *Blockchain-Inspired Architecture, SHA-256 Hashing, Order IntegrityAtomic Transactions (Django).*

Introduction

Managing drug inventory and supply chains is a significant challenge in the pharmaceu tical industry. Traditional systems are often manual, leading to inefficiencies, human errors, and delays in drug distribution. The increasing demand for timely medicine availability necessitates a reliable system that ensures transparency and efficiency. This project introduces a web-based Drug Inventory and Supply Chain Management system that automates the tracking of medicines from manufacturers to endusers. The system integrates various roles such as administrators, manufacturers, distributors, suppliers, and pharmacists, ensuring smooth order processing, inventory tracking, and order fulfil

ment. The healthcare supply chain is one of the most complex systems involving many stakeholders, and this complexity often leads to confusion in tracking the supplies and allowing counterfeit drugs to enter into the system. Counterfeit drugs contain no or even incorrect active pharmaceutical ingredients and are the cause of significant health haz ards, especially in developing countries, where they constitute as much as 30 percent of sold medicines and are the biggest killer of children. This problem also results in consid- erable economic losses, to the tune of 200 billion dollars annually, according to the U.S. estimates. Traceability of drugs is one of the important requirements through regulation, such as DSCSA in the United States and similar initiatives are ongoing in China. Decentralized, tamper-proof ledger technology, such as that with blockchain technology, has proven promising to better traceability and reduction in the instances of counterfeit drugs through its capabilities in securely tracking transactions all along the chain of drug distribution from raw materials to end users[1]

Counterfeit drugs take advantage of gaps in the pharmaceutical supply chain. In cases of drug shortages, the demand for them tends to be high, especially on expensive pre scription drugs like AIDS and cancer treatments. Falsified medicines may not work, may cause harm, or even kill the user, especially in low-income countries where antibiotics and anti-malaria drugs are mostly counterfeited.Other challenges in the pharmaceutical supply chain include poor inventory management

drug shortage, adverse drug reactions, contaminated manufacturing, poor and inappropriate cold chain management, , which is so difficult and expensive to tell from the real ones; drugs make up one in every ten medical products sold globally in low-and- middle income countries. India, a major player in the pharmaceutical industry, also faces significant counterfeit drug issues, driven by the difficulty of detection and gaps in regulation. Blockchain technology offers potential solutions by enhancing traceability and transparency across the supply chain.[2] Effective management of drug inventories in hospitals is very critical in tackling drug shortages, over-provisioning, expensive storage, and wastage. Generally, safety stock strategies have been employed to counter these shortages in most hospitals; however, they result in inefficiency and expense when considering storage and expiration constraints on specific drugs. The proposed system provides near-optimal solutions to large-scale inventory problems, allowing hospitals to improve operational efficiency while balancing costs and demand [3]. The key innovations include smart contracts for au tomated transactions, RFID tags for product tracking, and a bi-objective mathematical model to minimize costs and reduce product damage during transportation. The pro posed solution demonstrates an improved response time, reduced latency, and enhanced sustainability, thus providing a secure and transparent framework for healthcare logis tics.[4] A supply chain is defined as the process of acquiring a product from its manufacturer and delivering it to the end-user (customer). A supply chain can be for any product, such as an automobile, clothing, medical supply chain, etc.Like other supply chains, the healthcare supply chain has many stakeholders, starting with the raw material supplier and progressing to the manufacturer, then a wholesaler and distributor, and finally the pharmacist .2 When we examine healthcare supply chains, we see that they have a large and complex structure and numerous stakeholders. Traceability, transparency, depend ability, cost efficiency, integrity, and sustainability are all lacking in earlier versions of supply chains that were not digitally advanced. There is no proper method for tracking the history of medicine transitions [a]nd ownership from their origin to the patients. Due to a lack of traceability and transparency, there is uncertainty about the medicine's originality and security, which leads to issues related to drug counterfeiting and falsification. In addition, the lack of these critical features leads to black-marketing of medicines, the intermediary falsifies the actual drugs and sells the irrelevant drugs at a lower price. These activities do not stop at lowering the prices of fake products; instead, black marketers raise the prices of original products to such an unpayable level that people in need are forced to switch to them. These actions not only cause a slew of health problems for the people, but they also result in a large number of casualties at times, which can cause panic among the people in times such as the Covid-19 pandemic. [5] The e-LMIS is a very key means through which the medicine supply chain in Singida District Council, Tanzania, is to be improved. The data management, procurement, and distribution will be streamlined, thus increasing access to essential medicines in public health facilities. The system allows health providers and decision-makers better communication that will lead to a betterinformed decision in regard to medicine stock levels and resource allocation. [6] A strong drug inventory and supply chain tracking system is an essential remedy for overcoming

the challenges posed by the pharmaceutical industry. It would be possible through integration of the latest technology to increase the efficiency in operation, minimize wastage, and make the drugs most crucial available when needed the most. Such advancements would benefit not only the healthcare sector but also pa tient outcomes by assuring the delivery of such critical drugs where and when they are needed the most[7]. Manual inventory management relies heavily on paper-based records or spreadsheets for tracking drug quantities and locations. This outdated approach of ten results in errors, delays, and inefficiencies in maintaining accurate records. Limited visibility further exacerbates the problem, as there is a lack of real-time information on drug availability and movement. Inefficient procurement processes depend on manual methods and communication through phone or email, making them slow and prone to miscommunication [8]. Paper-based documentation is another challenge, with manual tracking of purchase orders, invoices, and delivery receipts creating unnecessary delays and a higher risk of errors. Manual distribution adds to the inefficiency, relying on physical transportation and manual tracking of shipments, which can result in delays and lost shipments. Limited quality control due to manual inspection and testing of drugs further compromises the 3 effectiveness of the supply chain. [9] Issues related to raw material shortages, manufacturing disruptions, and regulatory barriers exacerbate drug shortages that significantly impact the quality of inpatient care. However, pediatric patients are impacted the most. Children present specific challenges with limited alternatives available for therapeutics and an increased risk of adverse effects from substituting drugs.. Increased demand, supply chain disruption, and estimating pediatric drug usage with vial fractionation and varying concentrations further complicate medication inven tory management during emergencies such as global pandemics. However, the problem of limited resources and solutions designed for pediatric hospitals still remains. [11]

2. Methodology

The system employs a blockchain-inspired approach to ensure data integrity and im mutability within the order management process. At its core, the OrderModel integrates SHA-256 hashing to establish a verifiable chain of records. For each new order entry, the system computes a unique hash-signature using SHA-256, derived from the order's data combined with the previous-hash of the preceding order. This cryptographic linkage forms a tamperevident chain, making it computationally infeasible to alter any order without invalidating the entire subsequent chain. The concept of blockchain is implemented structurally by including a previoushash field in each order record. This allows the system to mimic the behavior of a traditional blockchain, ensuring chronological ordering and integrity across transactions. Any modi f ication attempt would be detected due to the mismatch in hash values, thus safeguarding against data manipulation or unauthorized changes. Additionally, all database operations related to orders—such as additions, updates, and deletions—are encapsulated within atomic transactions using Django's transaction.atomic()-context manager. This guarantees atomicity, meaning each operation is executed com pletely or not at all. This transactional integrity is crucial in preventing partial updates Collectively, this methodology provides a lightweight yet secure mechanism for tracking order history with cryptographic assurance and transactional reliability, enhancing the overall integrity and transparency of the supply chain system.

Hashing (SHA-256): Ensures data integrity in the Order_Model by hashing order data along with the previous block's hash to create a blockchain-like chain.

Blockchain Concept: Implements a chain of records by storing previous-hash and generating a new hash-

signature for each order.

Transactions: Ensures atomic operations using transactionatomic () so that add/update/delete operations either complete fully or not at all. (Figure 1).

3. System Architecture

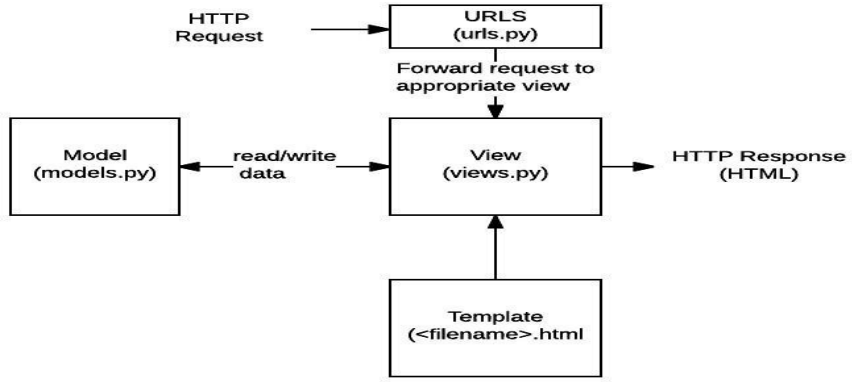

Figure 1 System Architecture

4. Results and Discussion

Web application serves as a blockchain-integrated pharmaceutical inventory and supply chain management system. It is designed to facilitate secure, traceable, and role-specific operations among multiple stakeholders—manufacturers, distributors,

suppliers, pharmacists, and administrators. The system's backend is structured around four main models: UserModel, MedicineModel, OrderModel, and MessageModel, enabling user authentication, medicine cataloging, order tracking, and communication, (Figure 2)

Figure 2 Registration Page

The medicine management module allows manufacturers to add medicines with de tailed information such as name, brand, expiry date, description, pricing, and quantity.

Each medicine entry is tagged with a status (e.g.:"pending", "approved") to indicate acceptance in the supply chain.The user registration and login system ensures only au thorized users can access the platform, with role-based dashboards controlling what each user can see and do. (Figure 3)

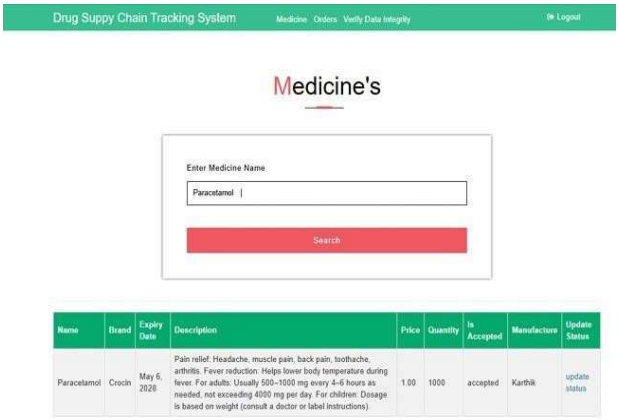

Figure 3 Admin Page

The ordering process begins when a distributor selects a medicine and initiates an order through a dedicated interface. The system calculates the total price based on

quantity, and the user is redirected to a simulated payment page for confirmation. Once confirmed,OrderModel instance is created with associated data like medicine

reference, manufacturer details, quantity, price, assigned distributor,and the current timestamp (Figure 4,5)

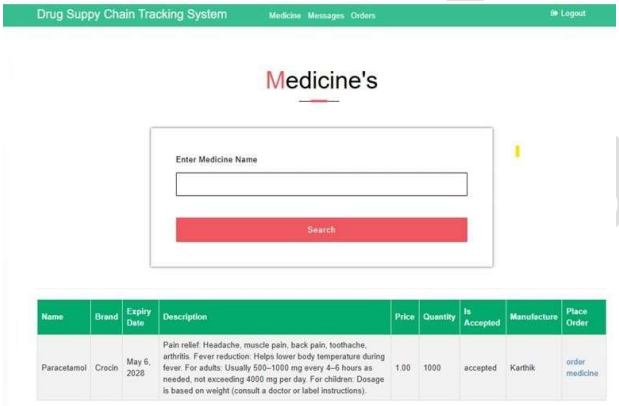

Figure 4 Distributor Ordering

Figure 5 Distributor Payment Page

Figure 6 Distributor Assigning

A key feature of the platform is its integration of blockchain principles. Each order includes a previous-hash and hash-signature to create a tamperevident chain of transactions. These hashes are computed using SHA-256 and are updated across all records when a new order is placed or modified. This ensures that any unauthorized change to an order disrupts the entire chain, which can be detected using the integrity verification function provided in the system. After placing an order, confirmation and assignment follow. Admins or higher-level users (like manufacturers) can assign orders to suppliers and pharmacists, updating their respective fields in the database.

Distributors can also update the price (i.e., distributor-specific pricing), and any user involved can update the order status as it progresses through the supply

chain(e.g.,"Pending","Shipped",

"Delivered"). (Figure 7)

Figure 7 Supplier Updating Order Details

To enhance communication, users can exchange messages with others in the system. This feature helps coordinate logistics, confirm actions, and report updates. (Figure 8)

Figure 8 Pharmacist Checking Order

At any point, users can verify the blockchain integrity through a dedicated function that re-computes and compares all hash signatures. If the chain has been altered, the system alerts the user to a potential integrity breach. Otherwise, it confirms that the blockchain is valid, thus reinforcing trust, accountability, and security in the supply chain.

Conclusion

This work developed on Django-based web application provides a robust solution for managing the pharmaceutical supply chain by integrating blockchain technology for enhanced security and transparency. It supports a full lifecycle of medicine handling— from registration, inventory management, ordering, and payment confirmation to multi-role coordination involving manufacturers, distributors, suppliers, and pharmacists. The platform's core is built around structured Django models (User_Model, Medicine_Model, Order_Model, and Message_Model) and includes comprehensive features like role-based dashboards, secure order placement, real-time messaging, and blockchain integrity verification. The ordering and confirmation flow ensures that transactions are traceable, tamperresistant, and auditable, reducing the risk of fraud. By combining a traditional inventory system with cryptographic hash chains (via SHA-256), the system ensures that each transaction remains secure and verifiable. Any changes in the transaction history are immediately detectable, thus promoting trust. Project not only addresses common pain points in the pharmaceutical supply chain—such as data manipulation, miscommunication, and tracking inefficiencies but also demonstrates the practical application of blockchain concepts in real-world systems. As a result, it serves as a solid foundation for future enhancements such as smart contract integration, real-time logistics tracking, or AI-based
inventory predictions

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