

Block Chain Big Data Supply Chain for Pharma Authentication

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ABSTRACT

The pharmaceutical industry is highly vulnerable to counterfeit drugs, supply chain inefficiencies, and lack of transparency, which can severely affect patient safety and healthcare quality. Traditional supply chain systems are often centralized, making them prone to tampering, delays, and inaccurate data management. With the increasing complexity of pharmaceutical distribution and the vast amount of data generated at each stage from manufacturing to delivery there is a pressing need for a secure, transparent, and intelligent system to ensure drug authenticity. This study proposes an integrated Blockchain and Big Data approach to address these challenges. Blockchain technology provides a decentralized and tamper-proof ledger for recording all transactions within the supply chain, ensuring traceability and accountability at every stage. Big Data analytics enables real-time monitoring, predictive insights, and anomaly detection, optimizing inventory management, logistics, and overall operational efficiency. Smart contracts automate verification processes, reducing human errors and ensuring compliance with regulatory standards. The proposed system also incorporates IoT-enabled devices for continuous monitoring of storage conditions, transportation, and handling of pharmaceutical products. By combining secure data storage, analytics, and real-time monitoring, the system ensures that every drug can be verified for authenticity from production to end-user delivery. Implementing this Blockchain-Big Data integrated supply chain is expected to significantly reduce counterfeit drug incidents, enhance transparency, and improve efficiency across the pharmaceutical industry. This approach not only strengthens trust among stakeholders but also contributes to safer healthcare outcomes and better regulatory compliance, demonstrating a transformative potential for the future of pharmaceutical supply chain management.

KEYWORDS : To meet the objectives stated above the system brings together a wide variety of high-order technical and functional components. Each component is

very vital as far as ensuring the functionality of the platform and its security:

- Immutable Distributed Ledger Technology (DLT):

that is it cannot be deleted or/and modified by anyone including administrators of such a system. Accordingly the purpose of this element is mainly to ensure the authenticity of information related to a drug's pedigree through its supply chain.

- V Smart Contract Automation:

The system relies on self-executable code called These are programmed protocols the drug delivery from the manufacturer to the distributor only if the distributor digitally signs that they have accepted the delivery and if IoT sensors establish that the drug was transported within the required temperature ranges.

- Big Data Predictive Analytics Module:

In the case of a sensitive drug like a vaccine or insulin temperature regulation is critical. The technology is integrated with the packaging container in ships. Environmental information is recorded continuously. This information is hashed and marked permanently in the blockchain allowing the buyer to confirm that the drug has been stored at the right temperatures throughout the entire process. In the case of a temperature violation the drug is labeled "compromised."

INTRODUCTION

conceptualized model of "Blockchain Big Data Supply Chain for Pharma Authenticity" is The considered an innovation in the form of infrastructure development and it aims at unlocking the present secrecy in the pharmacological logistics chain worldwide. In short this project aims at unlocking the present inconformity existing in the data transmission process and the actual pharmacological product. Presently the data associated with the manufacturing process conditions of transportation and transactions at the point of custody

is present in various standalone systems maintained by biopharmaceutical firms third-party logistics firms and pharmacological distributors. Therefore this creates certain points in the pharmacological chain called “blind spots” through which substandard and poor-quality drugs enter the pharmacological chain leading to the livelihood risk of the patients.

I LITERATURE REVIEW

In the existing operational model these entities largely operate in silos. Each stakeholder maintains its own internal system or database (centralized ledgers). When one stakeholder to another (e.g. from Manufacturer to Wholesaler) the transfer of information is often disconnected from the transfer of goods. Information is shared via Electronic Data Interchange (EDI) emails paper invoices or PDFs. Currently "track and trace" capabilities are limited to "one up one down." A distributor knows who they bought from (one up) and who they sold to (one down) but they lack visibility into the origin of the raw materials or the final destination of the product. This disjointed approach relies heavily on trust. If a manufacturer claims a drug was produced on a certain date downstream actors must trust that paper certificate. There is no single shared. Furthermore the existing system relies on reactive validation. Verification of a drug's authenticity usually only happens after a problem is detected—such as a patient adverse reaction or a regulatory audit. In the event of a product recall the process is manual and slow often taking weeks to notify all affected parties and physically locate the specific batches by which time the compromised drugs may have already been consumed.

I. EXISTING SYSTEM

The reliance on centralized siloed databases and manual processes introduces significant vulnerabilities and inefficiencies:

- **Single Point of Failure:** Centralized databases are vulnerable to hacking data corruption and insider threats. If a central server is compromised the entire data history can be manipulated or held for ransom.
- **Lack of End-to-End Visibility (opacity):** Not all stakeholders are able to trace the life journey of the product. Both of these enable the entry of counterfeits at different points within the stream without being traceable since it becomes difficult to ascertain the origin at first system; sometimes resulting in errors and delay.
- **Slow and Inefficient Recalls:** Taking into consideration

the scenario whereby the “defective” batch of certain medicine has been discovered traceability of each and every package of that particular batch would be an enormous burden on the system and would be nightmarish enough by virtue of the delay entailed with regards to the recall of the drug and that would pose an immense threat to the notion of public Susceptibility to Document Fraud: The common means of ensuring compliance with requirements is the use of paper documents and easily editable documents in .pdf format. This makes it easy to counterfeit and substandard and expired drugs are thus “laundry”-ed back into the market .

- **Lack of Ability to Track Integrity in the Cold Chain:** In the existing system the temperature reports are downloaded manually at the end of each transport. This would mean that if any violation took place in the middle of the transport it could be masked by the transporter in order to escape blame leading to the patient receiving spoiled medication.

II PROPOSED SYSTEM

The proposed system is a decentralized data-driven ecosystem designed to replace the linear chain of the past with a dynamic interconnected network. It proposes a multi-layer architecture consisting of the Blockchain Layer the Big Data/Storage Layer and the Application Layer.

The Blockchain Layer: This layer uses a permissioned blockchain framework-such as Hyperledger Fabric or Enterprise Ethereum. In contrast to a public blockchain such as Bitcoin a permissioned chain restricts participation to authorized actors only. In this the "Genesis Block" forms when the manufacturer creates the drug. In its movement "transactions" are recorded. A transaction infers change of ownership or state. This layer manages the "Hash" of the data ensuring the integrity of the data without mirroring the network with heavy files.

The Big Data Layer: Recognizing that storing images detailed sensor logs and massive logistical datasets on the blockchain is impractical the proposed system uses an off-chain Big Data repository (using This layer stores the heavy data. It sends a cryptographic hash-a digital fingerprint-of the data onto the Blockchain. In this case if someone changed the data in the Big Data layer then the hash no longer would match the hash that's anchored on the Blockchain and the tampering is immediately evident. This layer does the heavy lifting of analytics-processing millions of expiration composition) is hashed and stored on the Blockchain.

1. **Logistics:** Sensors of the IoT transmit information on the temperature and location of the

consignment to the Big Data cloud. At defined intervals a summary hash is committed to the Blockchain via Smart Contract. 1. Distribution: Handover is authenticated via digital signatures. The Smart Contract verifies that the previous custodian has released the goods and the new custodian has accepted them. 2. Pharmacy/Retail: The pharmacy scans the incoming stock. The system verifies that this stock was legitimately transferred from the distributor. 3. Consumption: The patient scans the product. The system displays the full history and marks the serial number as "Consumed" on the ledger to prevent bottle refilling fraud.

Advantages of Proposed System

1 Real-Time Traceability and Provenance: Stakeholders can trace the movement of drugs in real-time. It makes sure that the provenance of the drug is always known from its production line down to the retail store by offering granular visibility. In practice this would make it almost impossible for counterfeit drugs to be introduced into the legitimate supply chain without such anomalies being flagged.

2. Fast Pinpointed Recalls: In case of a safety concern manufacturers can query the ledger to identify the precise location of every unit in the affected batch. It enables surgical recalls that remove only the affected products rather than recalling the entire market inventory saves billions in costs and preserves brand reputation.

3 Automated Compliance and Efficiency: Smart contracts automate administrative tasks such as payments compliance checks and ownership transfers. This reduces paper works minimizes human errors and accelerates supply chains..

4. Cold Chain Assurance: Using the Blockchain in conjunction with IoT provides irrefutable proof of storage conditions. Stakeholders could prove the cold chain was never broken ensuring the biological efficacy of their medication.

5. Data-Driven Decision Making: Big Data is a crucial factor that permits businesses to analyze the aggregate data on route optimization

SYSTEM ARCHITECTURE

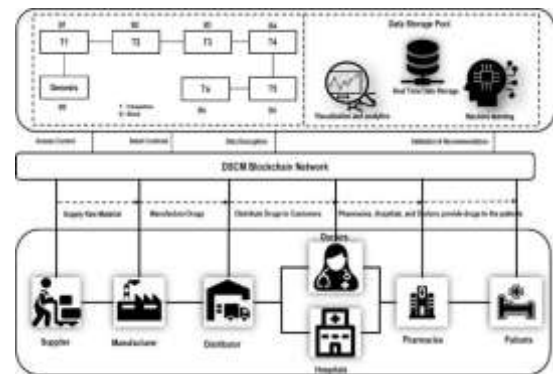


Figure : shows that Architecture Diagram

III EXPERIMENTAL RESULTS

- Integration with Artificial Intelligence (AI) and Machine Learning:

Future iterations could deepen the integration of AI. Machine Learning models could analyze the Big Data stored off-chain to predict supply chain disruptions (e.g. weather impacting shipping routes) or dynamic pricing models based on real-time demand. AI could also be used for more sophisticated image recognition to detect counterfeit packaging visuals that human inspectors might miss.

- Cross-Border Interoperability (Blockchain Interoperability):

Currently different regions may use different blockchains (e.g. Europe might use Ethereum Asia might use Hyperledger). Future work involves developing "Atomic Swaps" or "Bridges" that allow data to flow seamlessly between different blockchain networks creating a truly global borderless tracking standard.

- Tokenization and Supply Chain Finance:

The system could be expanded to include financial layers. By "tokenizing" the inventory manufacturers could use their stock on the blockchain as collateral for instant financing. Smart contracts could automate payments releasing funds to the supplier the exact second the distributor signs for the delivery revolutionizing cash flow management.

- Consumer Reward and Feedback Loop:

To encourage consumers to scan products (which helps the ecosystem detect fakes) a loyalty program could be implemented. Users could earn crypto-tokens or loyalty points for every scan which could

be redeemed for healthcare discounts. Additionally the app could allow patients to report side effects directly to the manufacturer via the blockchain creating a direct channel for pharmacovigilance.

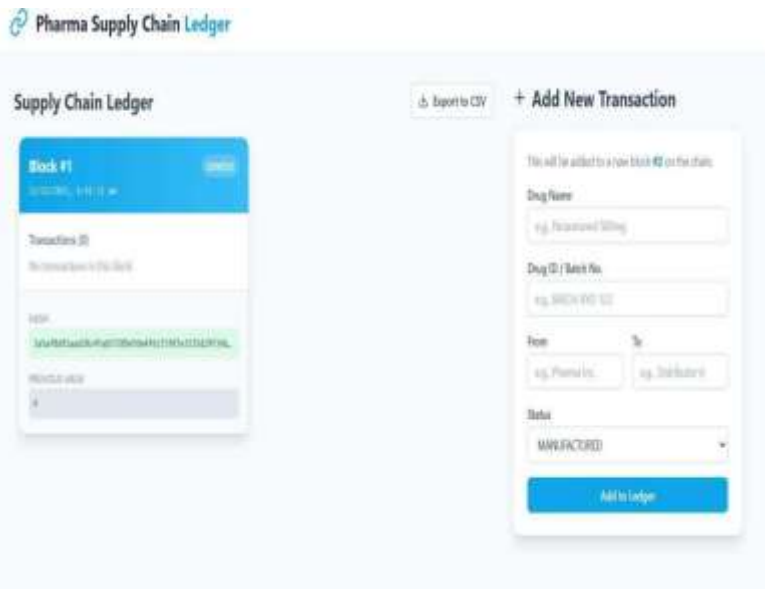


Figure 8.1.1: above figure shows Dashboard of Pharma Supply Chain Ledger

IV CONCLUSION

The "Blockchain-Big Data Supply Chain for Pharma Authenticity" project represents a pivotal advancement in the fight against pharmaceutical counterfeiting and supply chain inefficiency. By successfully integrating the immutable trust of Blockchain technology with the analytical power of Big Data this project addresses the critical vulnerabilities inherent in traditional centralized supply chain models.

The system successfully establishes a transparent secure and verifiable ecosystem where every drug unit is tracked from the raw material phase to the end consumer. The implementation of smart contracts automates compliance reduces human error and ensures that safety protocols (such as cold chain integrity) are strictly adhered to. The Big Data component transforms the vast amounts of logistical data into actionable intelligence allowing for proactive decision-making and rapid anomaly

detection.

Ultimately this project serves a higher purpose beyond technical innovation: it safeguards public health. by empowering patients to verify their medication and enabling regulators to audit the supply chain in real-time the system restores trust in the pharmaceutical industry. It moves the industry towards a future where counterfeit drugs are eliminated recalls are surgical and swift and patient safety is guaranteed by cryptographic truth rather than blind faith.

V REFERENCES

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