

Blockchain Based Drug Security

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Overall, a blockchain-based drug security system creates an

Abstract - The pharmaceutical industry faces significant challenges due to counterfeit drugs, inefficient supply chains, and limited transparency. Counterfeit medicines threaten public health, cause financial losses, and reduce trust in healthcare systems. To address these issues, this project proposes a blockchain-based drug security system that ensures secure, transparent, and tamper-proof tracking of drugs throughout the supply chain. Each drug package is assigned a unique digital identity, such as a QR code, which records its complete lifecycle on a distributed ledger. Smart contracts automate secure drug transfers, while optional IoT integration enables monitoring of storage and transportation conditions. Consumers can verify drug authenticity by scanning the QR code through a mobile or web application. The proposed system enhances traceability, reduces counterfeit drug circulation, improves regulatory oversight, and strengthens trust across the pharmaceutical ecosystem.

Key Words: Blockchain, QR Code, Medicines, Drug Security, Transparency, Decentralized Ledger

1. INTRODUCTION

Recent advancements in medicine and pharmaceuticals have greatly improved healthcare quality and life expectancy. However, access to timely medical care remains a challenge, especially for the elderly, homebound, or busy individuals. A critical aspect of healthcare is drug monitoring and security, as the traditional supply chain—from manufacturers to pharmacies—faces issues such as counterfeit drugs, expired or diverted medicines, and lack of transparency. Centralized tracking systems are vulnerable to tampering, single-point failures, and cyberattacks. Blockchain technology offers a decentralized, tamper-proof solution, enabling secure recording of every transaction in the drug supply chain.

Each drug can be assigned a unique digital identity (QR code), allowing stakeholders to verify authenticity in real time. Smart contracts automate authorized transfers, while IoT sensors monitor storage and transportation conditions. This blockchain-based system ensures end-to-end transparency, reduces counterfeit circulation, improves patient safety, and fosters trust among manufacturers, distributors, regulators, and consumers

end-to-end transparent, efficient, and tamper-proof pharmaceutical ecosystem. It reduces the circulation of counterfeit drugs, improves patient safety, enhances regulatory oversight, and fosters trust among manufacturers, distributors, regulators, and consumers. By combining blockchain, smart contracts, and IoT monitoring, the system strengthens drug security and promotes a reliable healthcare environment.

2. LITERATURE SURVEY

1] Mazin Debe et al. proposed a blockchain-based framework using Ethereum to track returned and reusable pharmaceutical products. The system integrates smart contracts to automatically validate transactions and manage the lifecycle of drugs within the supply chain. By storing drug information on a decentralized ledger, the framework ensures data immutability, traceability, and transparency among stakeholders such as manufacturers, distributors, pharmacies, and regulators. Experimental evaluation showed that the proposed system achieved low execution cost and efficient smart-contract deployment while maintaining strong resistance against malicious activities such as counterfeit drug insertion and unauthorized modification of records.

2] Ahmad Musamih and co-authors introduced a decentralized blockchain-based pharmaceutical supply chain management system aimed at addressing the issue of counterfeit drugs and lack of transparency in traditional systems. The proposed architecture records every transaction related to drug manufacturing, distribution, and delivery on the blockchain ledger. This ensures that each drug can be tracked from its origin to the end consumer. The system also improves data integrity and auditability, since records cannot be altered once stored on the blockchain. Their research demonstrated that the approach provides cost efficiency, transparency, and protection against integrity attacks, making it a reliable solution for secure pharmaceutical supply chains.

3] Aysha Alnuaimi and her team proposed a private blockchain architecture for managing prescription drug insurance claims. The system combines smart contracts with the InterPlanetary File System (IPFS) to securely store and share healthcare records among authorized

stakeholders such as hospitals, pharmacies, insurance companies, and regulatory authorities. Smart contracts automate the claim verification and approval process, reducing manual intervention and fraud. The use of IPFS enables distributed storage of large medical data files, improving scalability and privacy. The proposed framework enhances security, decentralization, and transparency while addressing key challenges such as data immutability, patient confidentiality, and trust among multiple entities.

4] Ghaleb A. Husseini and colleagues investigated the application of deep learning techniques in optimizing controlled drug delivery systems. Their work focused on drug carriers such as liposomes and metal-organic frameworks, which are commonly used in targeted cancer therapy. By applying deep learning algorithms, the researchers were able to model and predict the behavior of drug release under different environmental conditions. This approach helps in designing more precise and efficient drug delivery mechanisms, minimizing side effects and improving treatment outcomes. Their research demonstrates the potential of artificial intelligence in biomedical engineering and personalized medicine.

5] Ryan Sebastian and his team studied transdermal drug delivery using hollow microneedle technology. Microneedles are tiny needle-like structures that penetrate the outer layer of the skin without causing significant pain. Their research analyzed how different infusion strategies and delivery parameters influence the efficiency of drug transport through the skin. The study concluded that infusion rate and pressure significantly affect the accuracy of dosage and delivery efficiency. This technology offers a promising alternative to conventional injection methods by providing minimally invasive, painless, and controlled drug administration.

6] Tania Islam and co-researchers proposed molecular communication models for nanoscale drug delivery systems. In this approach, drug molecules act as information carriers that travel through biological environments to reach target cells. The researchers designed communication schemes that minimize drug delivery time errors and energy consumption. Their findings highlight how advanced communication models can improve the reliability and efficiency of nanomedicine-based drug delivery systems, especially for targeted therapies where precise timing and dosage are crucial.

7] Roya Paridar and colleagues applied a queuing theory model to analyze molecular interactions involved in drug delivery. The model considers factors such as receptor activity, molecular movement, and arrival rates of drug

molecules at the target site. Using this mathematical framework, the researchers were able to estimate **safe** and effective drug dosage ranges while minimizing the risk of overdose or ineffective treatment. This approach provides a theoretical basis for optimizing drug administration strategies in nanomedicine.

8] Theocharis Nikiforos Iordanidis and his team developed a MEMS (Micro-Electro-Mechanical Systems) based microimplant device for controlled drug delivery. The implant is capable of releasing drugs at specific target locations inside the body using ultrasonic signals for activation. This technology allows physicians to precisely control when and where the drug is released, improving treatment effectiveness while reducing side effects. Such microimplant systems represent a significant advancement in implantable medical devices and targeted therapy.

9] Krishna K. Ramajayam and collaborators studied different hyperthermia techniques for enhancing drug delivery using temperature-sensitive liposomes (TSL). Their research compared methods such as infrared laser heating and water bath hyperthermia. The results showed that infrared laser heating provides more precise and efficient temperature control, which improves the release of drugs from liposomes at targeted sites. In contrast, water bath hyperthermia, although widely used in laboratory experiments, was found to be less effective for controlled drug release.

10] Jonghyun Lee and his research group developed ChemBERTa, a transformer-based language model trained on large datasets of drug-like molecular structures. The model applies techniques from natural language processing to understand and generate chemical representations of molecules. Their experiments showed that pre-training on molecular data significantly improves molecular representation learning, prediction accuracy, and molecule generation tasks. The model achieved competitive performance on MoleculeNet benchmark datasets, particularly in predicting clinical toxicity and chemical properties, demonstrating the usefulness of AI models in drug discovery and pharmaceutical research.

3. PROPOSED METHODOLOGY

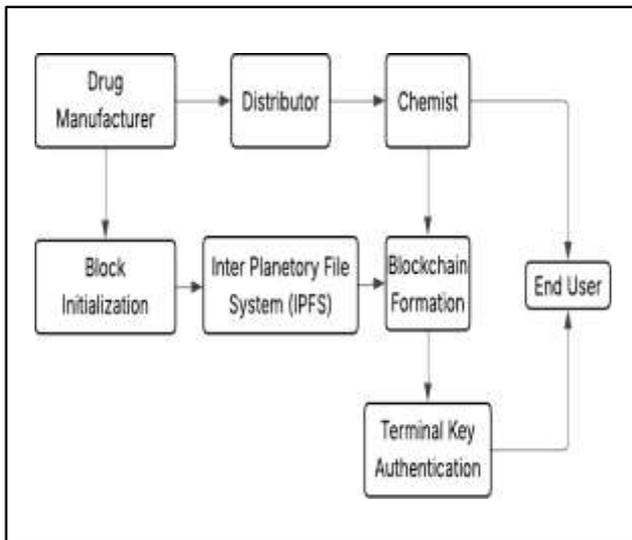


Figure 1. System overview

The proposed Blockchain-Based Drug Security System is designed to provide secure drug distribution, shipment tracking, and verification of medicines throughout the pharmaceutical supply chain. The architecture integrates blockchain technology, decentralized storage, authentication mechanisms, and a scanning-based verification system to prevent counterfeit drugs and ensure transparency. The system involves several stakeholders including drug manufacturers, distributors, chemists (pharmacies), and end users.

1. Drug Manufacturer

The process starts with the drug manufacturer who produces pharmaceutical products and registers them in the system. Each drug batch is assigned a unique identification code such as a QR code or barcode. This code will later be used for scanning and verifying the authenticity of the drug.

Important details like drug name, batch number, manufacturing date, expiry date, manufacturer ID, and shipment information are entered into the system. These details form the initial data that will be stored and secured through the blockchain network. The manufacturer acts as the first trusted entity responsible for creating the digital record of the drug in the system.

2. Block Initialization

After the drug data is entered by the manufacturer, the system performs block initialization. In this stage, the collected drug information is structured into a block of data. This block contains information such as drug details, batch number, timestamp, and manufacturer credentials.

The purpose of block initialization is to prepare the data before adding it to the blockchain. During this stage, the system may also generate hash values to maintain data integrity and prevent tampering.

3. InterPlanetary File System (IPFS)

The system uses the InterPlanetary File System for decentralized storage of detailed drug data. Instead of storing all information directly on the blockchain, which could increase storage cost and slow down the system, the detailed drug data is stored in IPFS. IPFS generates a unique cryptographic hash known as a content identifier for every stored file. This hash acts as a reference to retrieve the data from IPFS. Only this hash value is stored on the blockchain.

This approach improves system performance because the blockchain stores only the reference hash while the larger data files remain securely stored in IPFS. It also increases scalability and reduces storage overhead.

4. Blockchain Formation

After the data is stored in IPFS, the system creates a blockchain record. During blockchain formation, the IPFS hash and transaction details are added to a block in the blockchain network.

The blockchain maintains a distributed ledger that records every transaction related to the drug lifecycle. Each block contains the previous block hash, the IPFS data hash, transaction details, timestamp, and digital signatures.

This structure ensures that once the data is recorded it cannot be modified. The blockchain therefore provides immutability, transparency, and traceability. Any attempt to modify stored drug information will break the hash chain and be immediately detected.

5. Distributor

Once the drug is registered in the blockchain network, it is shipped to the distributor. The distributor receives the shipment and verifies the drug information stored in the blockchain.

The distributor then updates the system with shipment details such as shipment ID, transport information, distributor identity, and delivery timestamp. These details are recorded as a new blockchain transaction. This step ensures that the movement of drugs between different supply chain participants is properly tracked.

6. Chemist

After distribution, the drugs reach the chemist or pharmacy. The chemist verifies the shipment details using the blockchain system before accepting the drugs. The chemist updates the blockchain ledger confirming that the medicines have been received. This stage helps maintain accurate inventory tracking and ensures that only verified medicines are sold to consumers.

7. Terminal Key Authentication

To maintain system security, terminal key authentication is implemented. Each authorized participant such as manufacturers, distributors, and chemists is assigned a unique cryptographic key.

This key is used for authentication and secure access to the blockchain network. Only users with valid keys can perform operations such as updating shipment records or verifying drug information. This mechanism prevents unauthorized access and ensures secure transactions.

8. End User Verification

The final stage involves the end user who purchases the medicine from the chemist. The user can scan the QR code or barcode present on the drug packaging using a mobile scanner or application.

Once scanned, the system retrieves the drug identifier and checks the blockchain record using the IPFS reference. If the data matches the stored blockchain record, the drug is verified as genuine. If the record is missing or does not match, the system identifies the drug as potentially counterfeit.

This verification process enables consumers to confirm the authenticity of the medicine before using it, thereby increasing trust and safety.

4. RESULTS AND DISCUSSIONS

The proposed Blockchain-Based Drug Security system was implemented to track pharmaceutical shipments and verify drug authenticity using a scanning mechanism. The system integrates blockchain technology with decentralized storage and a QR/barcode scanning process to improve transparency and security in the pharmaceutical supply chain.

During system testing, the drug registration process was successfully performed by the manufacturer. Each drug batch was assigned a unique identification code and the associated drug information was securely stored using the InterPlanetary File System. The generated IPFS hash was recorded in the blockchain ledger, ensuring that the stored information remained tamper-proof and immutable.

The shipment tracking module allowed the movement of drugs to be monitored from the manufacturer to the distributor and then to the chemist. Each stage of the supply chain generated a new transaction that was recorded in the blockchain. The recorded information included shipment ID, timestamp, sender, and receiver details. This provided complete traceability of the drug lifecycle and ensured transparency among all stakeholders.

The scanning-based drug verification feature was tested using QR code scanning at the chemist and end-user level. When the code on the drug package was scanned, the system retrieved the corresponding record from the

blockchain using the IPFS hash. If the scanned drug information matched the blockchain record, the system confirmed that the medicine was authentic and part of the verified supply chain.

The system was also evaluated for its ability to detect invalid or unregistered drugs. When a QR code that did not exist in the blockchain ledger was scanned, the system successfully identified the drug as invalid or potentially counterfeit. This demonstrates the capability of the system to prevent the circulation of fake medicines in the market.

The blockchain architecture ensured that once the drug information and shipment details were recorded, they could not be modified or deleted. This provided a secure and reliable audit trail for pharmaceutical distribution. Additionally, the use of decentralized storage through the InterPlanetary File System reduced the storage burden on the blockchain and improved data retrieval efficiency.

Overall, the results demonstrate that the proposed system effectively tracks pharmaceutical shipments and verifies drug authenticity through scanning. The integration of blockchain technology with decentralized storage and QR-based verification improves transparency, enhances security, and helps reduce the risk of counterfeit drugs entering the supply chain.

5. CONCLUSIONS

The implementation of a blockchain-based drug security system provides a robust solution to the growing problem of counterfeit drugs in the pharmaceutical industry. By leveraging the decentralized and immutable nature of blockchain technology, the system ensures that every drug's journey from the manufacturer to the end consumer is accurately recorded and verifiable. This significantly reduces the risk of tampering, fraud, and counterfeiting, which are major concerns for patient safety and public health. The system enhances traceability, allowing manufacturers, distributors, pharmacies, and regulatory authorities to monitor drug movements in real-time. This transparency builds trust among stakeholders and improves the accountability of the entire supply chain. Moreover, the use of smart contracts automates verification processes, reducing human error and administrative overhead, which streamlines operations and cuts costs. By storing critical drug information securely on the blockchain, the system guarantees data integrity, ensuring that all records are permanent and cannot be altered without detection. This feature is crucial in maintaining compliance with regulatory standards and provides legal protection in cases of disputes. Additionally, consumers can verify the authenticity of their medicines using simple interfaces, which empowers them to make safe choices and reinforces confidence in pharmaceutical

products. The integration of blockchain technology in drug supply chains also promotes collaboration between different stakeholders. Hospitals, pharmacies, and manufacturers can share verified data seamlessly, enabling better inventory management, faster recalls in case of defective drugs, and improved planning for demand and supply. The system can further be enhanced with IoT sensors and AI analytics to monitor storage conditions, predict shortages, and detect anomalies in the supply chain proactively. In conclusion, a blockchain-based drug security system addresses critical challenges in the pharmaceutical sector by ensuring authenticity, enhancing transparency, and safeguarding public health. Its adoption represents a significant step toward a safer, more reliable, and technologically advanced supply chain. As counterfeit drugs continue to threaten communities worldwide, such systems not only protect consumers but also strengthen the credibility and efficiency of pharmaceutical companies, regulators, and healthcare providers. With continuous development, this approach can serve as a global standard for drug security, setting new benchmarks for safety, trust, and innovation in healthcare.

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