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Medicine Supply Chain using Blockchain

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Abstract: *This paper presents a Blockchain-Powered Medicine Supply Chain System aims to improve and enhance transparency, security, and authenticity in pharmaceutical products. This system was developed on a local device using Java and Java Servlet/JSP as the front-end, and JDBC for database connectivity, with MySQL data storage. It applies blockchain technology's decentralized and immutable structure to create a trusted network among diverse stakeholders within the supply chain. This means that in a peer-to-peer blockchain model in which the nodes are connected for the registration of each transaction, no record can be altered or tampered with. It actually scans the QR codes and verifies the product at every level within the supply chain in real time. That way, only authenticated drugs can have a transaction completed while preventing counterfeit drugs from reaching consumers. Its decentralized blockchain network further helps mitigate the issues with the possibility of data tampering or a single point of failure, hence making the system secure against multiple security threats. The system further uses cryptographic methods, such as digital signing and double encryption, to ensure integrity and anonymity to users. This paper discusses technology, system design, and how this blockchain solution offers an efficient supply chain toward the demands of the pharmaceutical industry for safe dispensation of drugs for which consumers eventually gain confidence in later stages.*

Keywords: Blockchain, Medicine Supply Chain, Java, Java Servlet, JSP, JDBC, MySQL, Decentralization, Product Validation, QR Code, Peer-to-Peer Blockchain, Double Encryption, Transparency, Security

I. INTRODUCTION

Blockchain technology, known for its decentralized and secure approach to data management, has become a significant focus of research across industries that require transparency, security, and authenticity. The pharmaceutical sector is one such area where blockchain can make a transformative impact, particularly in addressing the issue of counterfeit medicines infiltrating supply chains. Counterfeit drugs not only pose health risks but also undermine consumer trust, making it imperative to create a robust, transparent supply chain for pharmaceuticals [1], [2]. This paper introduces a blockchain-based medicine supply chain system designed to operate independently on localized devices, offering a secure, transparent, and verifiable chain of custody for medicines without relying on cloud infrastructure. Deploying this system on a localized device ensures that data remains within the local environment, promoting privacy and security by reducing dependence on external networks and cloud servers[5].

The proposed system leverages a peer-to-peer blockchain architecture, ensuring that all data transactions are validated and securely recorded by nodes operating within a local network. This setup not only maintains data integrity but also prevents tampering, creating an immutable record of each transaction in the supply chain[3][4]. By eliminating the need for internet connectivity and cloud infrastructure, this approach allows the system to operate independently in regions where network access may be limited or intermittent, ensuring high reliability and adaptability to different deployment environments. This independence from external infrastructure enables sensitive pharmaceutical data to be securely managed within localized networks, avoiding potential vulnerabilities associated with cloud-based storage and remote data breaches [7].

A notable feature of this system is its QR code scanning functionality, integrated to verify product authenticity at each stage of the supply chain. Each medicine package contains a unique QR code, which is scanned and verified against blockchain records. By scanning these codes at various points in the distribution process, users can cross-check the authenticity of each product in real-time. This feature is particularly crucial, as it guarantees that only authenticated and validated products proceed through the supply chain, providing a direct solution to the counterfeit drug issue that

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plagues the pharmaceutical industry. This localized authentication system ensures that stakeholders, from manufacturers to end-consumers, can trust the integrity of the medicines without needing access to a centralized database[10].

Operating on localized devices also has practical advantages for system performance and scalability. By keeping all operations and data storage local, the system maintains high processing speeds and low latency, as it does not rely on internet connectivity or third-party cloud services. This localized approach reduces the risk of network bottlenecks or delays that could arise from cloud-based interactions, making it highly efficient for environments that demand quick access to information. Additionally, this decentralized structure can scale to accommodate more users or devices within the local network, allowing small-scale distributors, clinics, and pharmacies to implement the system without the overhead costs associated with cloud storage[5].

This paper will examine the design, functionality, and implementation of this blockchain-based system for medicine supply chains, providing insights into its potential to reshape pharmaceutical distribution. By focusing on localized deployment, the system offers a unique, self-contained solution that enhances security, transparency, and product verification at every stage of the supply chain. This approach serves as a promising model for developing resilient supply chain solutions that safeguard against counterfeit products, build trust among stakeholders, and deliver authentic medicines to consumers without the need for cloud-dependent architecture. The research highlights the advantages and challenges of using blockchain in localized device settings, demonstrating a new way forward in secure pharmaceutical supply chain management[9].

II. LITERATURE SURVEY

Blockchain technology has recently become a promising solution for giving patients greater control over their medical records, addressing longstanding issues related to data privacy, accessibility, and security. In one study, blockchain was applied to a personal health record (PHR) system to decentralize the management of medical data, empowering patients to control access permissions directly[4]. This patient-centered approach means that patients can grant or revoke access to their records without involving a central authority, thus enhancing security by decentralizing patient-doctor interactions. The blockchain's distributed ledger and its inherent immutability ensure that records cannot be tampered with or misused. Consequently, this method builds a secure, accessible, and more transparent framework that allows patients to interact with healthcare providers without relying on centralized storage, which is prone to unauthorized access risks.

In another approach, researchers implemented a combined blockchain and Interplanetary File System (IPFS) architecture to secure electronic medical records (EMRs) with advanced encryption protocols[1]. This method leverages attribute-based encryption (ABE) within IPFS, a peer-to-peer file-sharing protocol, to securely store and share medical records. By applying ABE, this model customizes access to patient data based on specified attributes, meaning only authorized entities can decrypt the information. Blockchain in this system works to record access logs in a tamper-proof manner, enhancing data sharing efficiency and privacy. Utilizing IPFS as a decentralized storage solution, this system reduces dependence on single centralized servers, which can suffer from downtimes and pose data security risks. The approach also ensures seamless data retrieval and effective storage solutions, especially in network-restricted scenarios, proving its utility in complex medical environments[3].

Health record management systems have explored blockchain for its capacity to streamline healthcare data processing while maintaining data integrity[4]. Another study implemented smart contracts to automate core processes, including data validation and record creation. By integrating smart contracts into the system, repetitive tasks are automated, thus enhancing operational efficiency and reducing human error. This design enables secure record sharing across health institutions and facilitates easy tracking and validation of interactions. The use of blockchain-based smart contracts enables healthcare providers to access shared medical records more securely, providing a level of transparency that conventional centralized databases cannot achieve. By eliminating intermediaries, the system minimizes delays in data transmission and supports a real-time, automated update mechanism that enhances the accuracy and reliability of patient data.

A privacy-focused solution for medical data protection proposed a blockchain-based method that assigns unique pseudo-identities to patients and healthcare institutions. This model aims to strengthen privacy by substituting real

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patient identities with pseudonymous identifiers, allowing secure data processing while safeguarding actual identities[9]. During initial registration, healthcare providers receive pseudo-IDs, which remain consistent in all subsequent interactions, enabling a robust privacy shield across the network. This pseudonymous identity system helps comply with privacy regulations and preserves patient confidentiality. The decentralized nature of blockchain ensures that patient data cannot be altered or accessed without consent, mitigating privacy risks associated with centralized databases where unauthorized access is a critical concern[10].

To ensure data consistency across healthcare providers in scenarios of network instability, researchers proposed an architecture called HealthyBlock. This system focuses on creating a resilient blockchain network for electronic medical records (EMRs) that can operate even in cases of connectivity failures. HealthyBlock enables multiple clinical providers to collaborate and share data seamlessly while retaining full data integrity in unstable network environments[4]. This framework also prioritizes ease of use, privacy protection, and security, ensuring that records remain secure and accessible even if some network nodes are temporarily unavailable. By maintaining EMR data integrity during outages, HealthyBlock offers a solution for regions with unreliable connectivity, where data loss or corruption due to network failure could otherwise compromise patient safety and care continuity.

In sum, these various blockchain-driven approaches demonstrate the potential of decentralized technologies in modernizing medical data management. Blockchain offers solutions ranging from encryption-based secure data storage to automated data sharing and privacy protection[10]. By incorporating mechanisms like smart contracts, IPFS for decentralized storage, and attribute-based encryption, these studies provide viable frameworks for patient-centric data control, efficient data sharing, and reliable privacy protection. Blockchain-based solutions, therefore, represent a significant shift towards improving data security, privacy, and interoperability in healthcare systems, enabling a more transparent and robust health information management structure that aligns with both patient and institutional needs.

III. EXISTING SYSTEM

The existing systems for pharmaceutical supply chain management face challenges related to counterfeit drugs, data integrity, and security. Some blockchain-based approaches have been proposed to tackle these issues. Blockchain technology, primarily known for cryptocurrency applications, has proven to be an excellent solution for ensuring traceability in supply chains, including pharmaceuticals.One such approach involves using blockchain to secure patient medical records, with applications in supply chains that involve pharmaceuticals. Madine et al. (2020) highlight how blockchain can give patients control over their medical records, and this model can be extended to the pharmaceutical supply chain to ensure the authenticity and security of drug data [1].Similarly, Sun et al. (2020) propose a blockchain-based storage and access scheme for electronic medical records, which could be adapted to manage pharmaceutical data securely [2].

Blockchain-based solutions, such as those proposed by Harshini et al. (2019), have been used to manage health records efficiently, and a similar methodology can be applied to pharmaceutical supply chains for effective tracking and verification of drug authenticity [3]. Additionally, Liu et al. (2019) focus on blockchain-based medical data sharing, which can be adapted to the pharmaceutical sector for ensuring the integrity of transaction data between suppliers, manufacturers, and distributors [4].

A key challenge in the existing systems is resilience to network failures, as discussed by Gutiérrez et al. (2020), who present a blockchain-based architecture for electronic medical records resilient to connectivity issues. This approach can be leveraged in environments with intermittent network access, a common situation in remote areas for pharmaceutical distribution [5]. Moreover, Wang et al. (2019) propose a blockchain-based personal health record sharing system with verifiable data integrity, which can be used to ensure that pharmaceutical data remains untampered throughout the supply chain [6]. In emergencies, the inability to quickly access accurate medical records can have serious consequences for patient outcomes. Furthermore, centralized systems are not scalable, as they become increasingly inefficient and expensive to maintain as the volume of medical data grows.

The importance of optimizing blockchain systems for medical information sharing is emphasized by Du et al. (2020), who highlight how optimized blockchain networks can improve efficiency in sharing sensitive information across various entities. This is highly relevant to the pharmaceutical sector, where sharing drug information securely across parties is essential [7]. Tith et al. (2020) also discuss how blockchain can improve patient record management in terms

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of privacy, scalability, and availability—key features for managing the vast amount of data in pharmaceutical supply chains [8]. This would add convenience while improving the overall security of the system. The absence of such features in the current setup demonstrates its lack of innovation in adopting modern technologies that can enhance the patient experience.

In the context of self-sovereign identity and patient privacy, Houtan et al. (2020) explore how blockchain can be used to give patients more control over their data. This concept can be applied to pharmaceutical supply chains to ensure product authenticity and traceability at every level [9]. Sharma and Balamurugan (2020) focus on preserving the privacy of health records using blockchain, a privacy-preserving method that can also be extended to pharmaceutical data, safeguarding sensitive transaction information throughout the supply chain [10]. In contrast, our proposed system moves away from Ethereum and introduces a localized blockchain that addresses these concerns. By building a blockchain tailored to specific healthcare needs, we can eliminate the inefficiencies associated with public blockchains, offering a more scalable and cost-effective solution for managing medical records.

This detailed comparison of the existing system highlights several areas where improvements are necessary, particularly in enhancing data security, privacy, scalability, and interoperability. As healthcare becomes increasingly digitized, these challenges must be addressed to ensure that medical records are managed in a way that benefits both patients and healthcare providers. The proposed system, with its focus on localized blockchain and QR code integration, presents a more robust and patient-centric approach to addressing these issues[5].

IV. PROPOSED SYSTEM

Blockchain technology originally provided the foundation for peer-to-peer digital currencies, most notably through the Bitcoin platform. However, the potential applications of blockchain extend far beyond cryptocurrencies, and it can offer an excellent solution for tracing drugs throughout the pharmaceutical supply chain. Understanding how the blockchain network operates reveals its ability to address the problem of drug counterfeiting, a critical concern in the pharmaceutical industry [4], [5].

Blockchain is fundamentally an immutable, distributed database that is shared by a group of nodes over a peer-to-peer (P2P) network. Every activity or transaction within this network is recorded and validated, forming a block. Each block is associated with a timestamp, a unique hash value, and the hash of the previous block, creating a chain of blocks. This design ensures that the ledger is tamper-proof and immutable, providing a secure and transparent way to record data [6], [7].

The blocks are appended to the blockchain network only after verification by a consensus algorithm, such as Proof-of-Work, or a custom consensus method. This verification process guarantees the accountability and integrity of the data recorded on the blockchain. The sequential arrangement of transactions within the blocks makes blockchain technology particularly suitable for solving traceability challenges within the pharmaceutical supply chain, ensuring that every step in the movement of goods is recorded securely and transparently [8], [9].

The system begins with the manufacturer, who creates a unique QR code containing essential information such as the manufacturer's name, the manufacturing date, expiry date, and a transaction number. The transaction number is crucial as it helps identify the specific batch of medicine within the blockchain system. As the product moves through the supply chain, the distributor scans the QR code to verify the product's validity. When the shipment leaves the distributor's storage, the distributor's signature is added to the blockchain record, confirming their involvement in the process. At each subsequent stage—wholesalers, retailers, and pharmacies—these entities will similarly record their transactions by scanning the QR code and adding their signature details. This process ensures that every transaction is securely logged, creating a fully traceable chain of custody for the drug [10].

V. SYSTEM ARCHITECTURE

The e-transaction system is designed with several modules to ensure secure and efficient processing. The Admin module oversees and manages system operations, while the Make Transaction module allows users to initiate transactions seamlessly. Block Generation and Blockchain Validation ensures the integrity of each transaction by generating blocks and validating them within the blockchain. The Consensus Algorithm Validation and Blockchain Recovery module supports system reliability by validating consensus and recovering the blockchain in case of

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disruptions. Finally, Results Generation provides feedback on transaction status and system outcomes. The system is engineered for practical deployment on traditional hardware configurations, allowing secure transactions without additional devices or third-party validation. Transactions are processed in a distributed, peer-to-peer network across multiple servers to maintain quality of service. The middleware architecture utilizes threading for load balancing, optimizing the system for real-time processing and addressing service quality and time limitations, making it a viable solution for complex e-transaction applications.

In this blockchain-based medicine supply chain on a localized device, components interact to secure and authenticate products without reliance on cloud infrastructure. Here's a concise overview:

User Interface & Application Layer: Stakeholders (e.g., manufacturers, distributors) use the User Interface for actions like product registration and QR scanning. This data flows to the Application Layer, where business logic verifies and updates the product's status by checking against blockchain records. Real-time feedback is then provided to users.

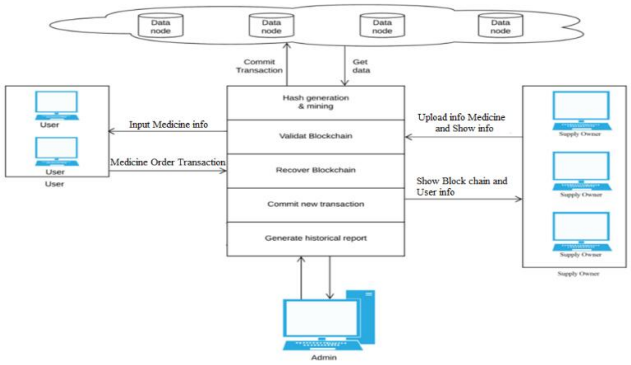
Application & Blockchain Layers: The Application Layer sends transactions to the Blockchain Layer, which maintains an immutable, peer-to-peer record of each verified transaction across nodes. This ensures each entry is tamper-proof. Confirmation updates the front end, showing current product status.

QR Code Verification: Products are assigned unique QR codes for authenticity checks. Each QR scan verifies product details against blockchain records. Valid products proceed in the chain, while counterfeit items are flagged to prevent distribution.

Application & Database Layer: The Database Layer (using MySQL) stores essential, non-transactional data, like user credentials and product details, accessed securely through JDBC. The Application Layer retrieves this data to ensure efficient, lightweight operations.

Blockchain & Security Layer: Data security is enhanced with digital signatures and encryption in the Security Layer. The Blockchain Layer relies on cryptographic verification to protect data from tampering, securing each transaction.

Local Network Infrastructure: Operating within a LAN, the system achieves high reliability and efficiency, with all peer-to-peer communication and QR-based authentication happening locally, making the system resilient to network vulnerabilities.



VI. FUTURE SCOPE

Future blockchain applications in supply chains aim to boost efficiency, security, and adaptability. Key goals include improving scalability with faster consensus mechanisms like Proof of Stake and Layer-2 solutions. Integrating blockchain with IoT for real-time tracking can enhance product traceability, especially in sectors like medicine, food, and luxury goods.

Cross-chain interoperability will allow data sharing across different blockchain platforms, while adaptable smart contracts can meet evolving regulations. AI and machine learning integration can enhance demand forecasting, fraud detection, and supply chain management. Standardizing data formats will improve communication and reduce errors.

Blockchain's decentralized structure ensures disaster recovery, and research should focus on intuitive user interfaces and clear legal frameworks to support widespread adoption and ensure compliance.

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VII. CONCLUSION

The pharmaceutical industry lacks a reliable traceability system, allowing counterfeit drugs to spread. This paper proposes a blockchain solution to improve transparency and secure tracking by assigning unique IDs and QR codes to products for easy verification. Consumer feedback integrated into the system enhances quality control and fosters continuous improvement.

Blockchain also reduces manual record-keeping, minimizes errors, and improves compliance, supporting regulatory oversight with secure, auditable data. In conclusion, blockchain adoption strengthens transparency, builds consumer trust, and protects public health, offering a transformative solution for supply chain security in the pharmaceutical industry.

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