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Original Article

Developing Intelligent and Immutable Vaccine Supply and Operations Platform Using Blockchain Technology

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Abstract

In recent years, vaccine safety incidents have occurred frequently. To protect vaccine safety, researchers have proposed to use blockchain to secure the vaccine circulation process. Technically, blockchain has some limitations in solving vaccine and other supply chain problems, such as large on-chain storage consumption and low throughput. To better alleviate these restrictions, we propose an improved, blockchain based, storage-efficient vaccine safety protection scheme in this work. Specifically, we first model the vaccine circulation process. We then design a system to protect vaccine circulation using blockchain, cloud, and cryptographic mechanisms. The proposed system leverages the cloud to implement the vaccine circulation model.Correspondingly, it uses the blockchain to store circulating data certificates and signatures.We evaluated the proposed conceptual model using a consortium blockchain. The experimental results show that the proposed system is efficient. Three core cryptographic algorithms to secure the immutable vaccine supply and location platform. SHA-256 is used to generate tamper-proof hashes for all vaccine records, ensuring data integrity on the blockchain. AES encrypts sensitive vaccine information to maintain confidentiality during storage and transmission. CP-ABE enables fine-grained, attribute-based access control so that only authorized users can decrypt and view protected data. Together, these algorithms ensure a secure, trustworthy, and decentralized vaccine management solution developed using Java and blockchain technology.

Introduction

The project titled "Developing an Intelligent and Immutable Vaccine Supply and Operation Platform Using Blockchain Technology" focuses on addressing critical challenges in vaccine safety, transparency, and traceability across the supply chain. In recent years, issues such as counterfeit vaccines, improper storage conditions, and lack of real-time monitoring have highlighted the need for a secure and reliable system. To overcome these challenges, this project leverages blockchain technology to create a decentralized and tamper-proof platform that ensures the integrity and authenticity of vaccine data throughout its lifecycle.

The proposed system integrates blockchain with cloud computing to achieve both efficiency and scalability. While the cloud handles large-scale data storage and processing, the blockchain maintains immutable records of transactions, including vaccine production, distribution, and delivery. Cryptographic techniques such as SHA-256 are used to generate secure hashes for data integrity, AES ensures confidentiality of sensitive information, and CP-ABE provides fine-grained access control, allowing only authorized stakeholders to access specific data.

Developed using Java, the platform is designed to be robust, scalable, and user-friendly, enabling seamless interaction among manufacturers, distributors, healthcare providers, and regulatory authorities. By ensuring transparency, security, and trust, this system enhances vaccine management and helps prevent fraud, ultimately contributing to improved public health outcomes.

Background

Vaccines play a very important role in protecting people from dangerous diseases. However, the vaccine supply chain is very complex because vaccines must be produced, stored, transported, and delivered safely to hospitals and health centers. During this process, many problems can occur such as data manipulation, lack of transparency, fake vaccines, improper storage conditions, and delays in delivery.

Traditional vaccine management systems mostly use centralized databases, which makes them vulnerable to data tampering, cyberattacks, and lack of trust among stakeholders. It is often difficult to track the complete journey of vaccines from the manufacturer to the final vaccination center. This lack of transparency can lead to inefficiencies and risks to public health.

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Problem Statement

The vaccine supply chain involves several stages such as manufacturing, storage, transportation, and distribution to healthcare centers. Managing these operations using traditional centralized systems often leads to issues like lack of transparency, data manipulation, and difficulty in tracking vaccine movement. It is often challenging to monitor the complete journey of vaccines, which can result in delays, improper storage conditions, and inefficiencies in distribution.

Another major problem is the risk of fake, expired, or unauthorized vaccines entering the supply chain due to poor tracking and verification systems. Since the data stored in traditional systems can be modified, it becomes difficult to maintain trust among stakeholders such as manufacturers, distributors, healthcare providers, and government authorities.

Literature Survey

The global distribution of vaccines presents critical challenges related to transparency, traceability, and trust among various stakeholders. Traditional centralized vaccine supply systems often suffer from inefficiencies, lack of real-time monitoring, and risks of counterfeit vaccines entering the distribution chain. To overcome these challenges, recent research has emphasized the integration of blockchain technology into vaccine supply and operations management. Blockchain provides immutability, decentralization, and traceability, making it an ideal solution for maintaining a secure and tamper-proof record of vaccine production, distribution, and delivery.

Several studies highlight the importance of blockchain in enhancing the efficiency and security of the vaccine supply chain. Antal et al. (2021) proposed a blockchain-based platform for COVID- 19 vaccine distribution using Ethereum smart contracts. Their work demonstrated how blockchain ensures transparency and accountability among manufacturers, distributors, and healthcare institutions. Similarly, Musamih et al. (2021) developed a blockchain-enabled system to manage vaccine delivery and maintain immutable records of vaccine batches. The authors emphasized how combining blockchain with the Internet of Things (IoT) sensors enables continuous temperature monitoring, ensuring that vaccines remain within required cold-chain conditions throughout transportation and storage.

Another significant contribution comes from Yadav et al. (2023), who discussed blockchain's potential in securing vaccine supply chains in developing countries like India. The study found that blockchain, when integrated with IoT devices, helps in real-time tracking, eliminates counterfeit products, and ensures efficient data sharing across all levels of the supply network. Furthermore, Gao et al. (2023) proposed integrating Artificial Intelligence (AI) with blockchain to create an intelligent decision-support system for vaccine allocation. Their model used AI algorithms to forecast vaccine demand and optimize distribution routes, while blockchain maintained an immutable record of every decision and transaction, ensuring accountability and transparency.

Proposed system

The proposed scheme covers the four vaccine circulation processes, that is: 1) production; 2) sales; 3) transportation; and 4) distribution. From the beginning of vaccine production, each vaccine is assigned a digital identity (i.e., vaccine trace code) to uniquely identify a vaccine. Vaccine trace code represents the endorsement of regulatory agencies and manufacturers. It is essential to vaccine safety throughout the vaccine circulation process.

The involved entities will query the blockchain at each circulation step to verify the correctness of the vaccine data before entering the next circulation step. Once a vaccine incident happens, the system supervisor (i.e., the national authority) will query the blockchain to track the vaccine's source and then conduct timely prevention and accountability.

Technically, there exist two key challenges in the proposed scheme. The first challenge is how to ensure the reliability of vaccine circulation data. The second challenge is how to relieve the pressure of blockchain storage and communication.

Modules Used

Supervision: In this module, the Admin has to login by using valid user name and password. After login successful he can do some operations such as Login, View All CDC, View All Manufacturers, Add Category, View All Categories, View All Vaccines, View All Purchase Details, View All CDC Account Details, View All Vaccines By Block chain, View All Vaccine Rank Results.

CDC: In this module, there are n numbers of users are present. User should register with group option before doing some operations. After registration successful he has to wait for admin to authorize him and after admin authorized him. He can login by using authorized user name and password. Login successful he will do some operations like Search Documents, View Files, Request Secret Key, Download. Register and Login, View Profile, Create/Manage Account, Search Products, View All Purchases.

Manufacturers: In this module, there are n numbers of users are present. Manufacturer user should register with group option before doing some operations. After registration successful he has to wait for admin to authorize him and after admin authorized him. He can login by using authorized user name and password. Login successful he will do some operations like Register and Login, View Profile, Add Vaccines, View Uploaded Vaccines, View All Purchased Vaccines and Total Bill, View All Purchased Requests.

Technologies Used Programming Languages

Programming Language: Java

Blockchain Technology: Consortium Blockchain (e.g., Hyperledger)

Cloud Platform: Cloud Storage for off-chain data management Database: SQL / NoSQL Database

Cryptographic Algorithms:

- SHA-256 (for data integrity)
- AES (for data encryption)
- CP-ABE (for access control)

Backend Framework: Java-based frameworks (Spring Boot, etc.)

Frontend Technologies: HTML, CSS, JavaScript

API Communication: RESTful APIs

Security Mechanisms: Digital Signatures, Encryption Techniques

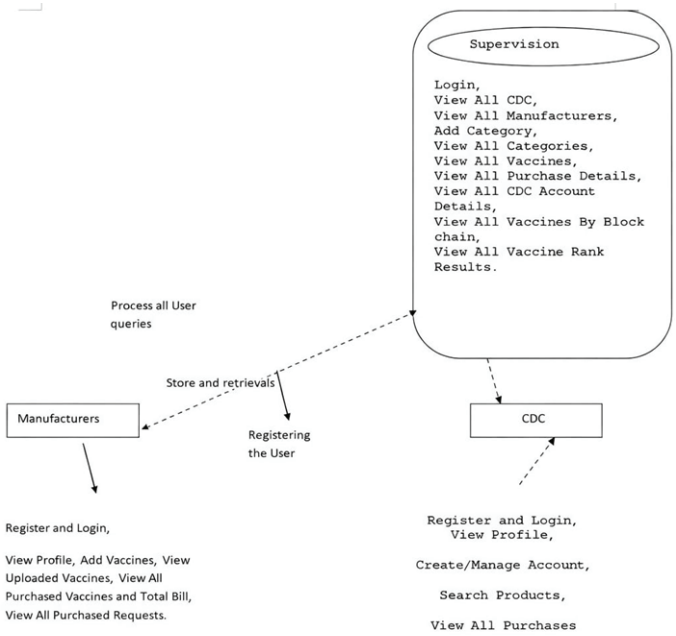
Advantages of proposed system

- **Enhanced Data Security:** Uses cryptographic algorithms like SHA-256 and AES to protect data from tampering and unauthorized access.
- **Data Integrity and Immutability**: Blockchain ensures

that once vaccine data is recorded, it cannot be altered, preventing fraud and manipulation.

- **Improved Transparency:** All stakeholders (manufacturers, distributors, healthcare providers) can track vaccine movement in real time.
- **Efficient Access Control:** CP-ABE enables fine-grained access, allowing only authorized users to view sensitive data.
- **Reduced Storage Overhead:** Integration with cloud storage reduces the burden on blockchain, making the system more scalable.
- **High Traceability:** Enables end-to-end tracking of vaccines from production to delivery, ensuring authenticity.
- **Decentralization:** Eliminates reliance on a single authority, increasing trust and reliability.
- **Faster and Secure Transactions:** Consortium blockchain improves performance compared to public blockchain systems.
- **Prevention of Counterfeit Vaccines:** Tamper-proof records help identify and eliminate fake vaccines.
- **Scalability and Flexibility:** The system can handle large-scale vaccine data efficiently using cloud and blockchain integration.
- **Improved Public Trust:** Ensures safe vaccine distribution, increasing confidence among users and authorities

System Architecture



Results

The results of the proposed project demonstrate that the intelligent and immutable vaccine supply and operation platform effectively improves security, transparency, and efficiency in vaccine management. By utilizing blockchain technology, the system ensures that all vaccine-related data is stored in a tamper-proof and immutable manner, significantly reducing the risk of data manipulation and counterfeit vaccines. The integration of cloud storage minimizes on-chain data load, resulting in better performance and scalability. Cryptographic mechanisms such as SHA-256 ensure data integrity, AES protects sensitive information, and CP-ABE enables secure and controlled data access. Experimental evaluation using a consortium blockchain shows that the system achieves efficient transaction processing, reduced storage overhead, and reliable tracking of vaccines across the supply chain. Overall, the results confirm that the proposed system provides a secure, scalable, and trustworthy solution for vaccine distribution and management.

Conclusion

Ensuring vaccine safety is critical. To improve the safety of vaccine circulation, we proposed an improved block chain based system to make the vaccine circulation process traceable and verifiable. The improved system alleviates the storage pressure of the block chain. We also implemented and verified the proposed scheme. The experimental results showed promising performance and potentiality. We also discussed the limitation of the proposed scheme and possible further improvement. We hope that the proposed scheme provides new insights for ensuring vaccine safety. In the future, one important work is to fine-tune the proposed system to achieve better performance by incorporating different entities' interests. Another important work is to conduct incentive mechanism research that could encourage the stakeholders along the vaccine supply chain to migrate existing systems to a block chain-based one.

Future scope

Integration with Internet of Things (IoT): Future versions of the system can integrate IoT-based temperature and location sensors to automatically track and record vaccine shipment conditions in real time on the blockchain.

Artificial Intelligence (AI) for Predictive Analytics: AI algorithms can be implemented to predict vaccine demand, optimize distribution routes, and identify potential supply shortages before they occur.

Mobile Application Development: A mobile version of the platform can be developed for field staff and healthcare workers to update and verify vaccine information instantly using smartphones.

Multi-Blockchain Interoperability: The system can be enhanced to support interoperability between multiple blockchain networks, allowing different health organizations to share vaccine data securely.

References

1. S. Jarrett et al., "The role of manufacturers in the implementation of global traceability standards in the supply chain to combat vaccine counterfeiting and enhance safety monitoring," Vaccine, vol. 38, no. 52, pp. 8318–8325, 2020.
2. B. M. G. Rosa, S. Anastasova, and G. Z. Yang, "NFC-powered implantable device for on- body parameters monitoring with secure data exchange link to a medical blockchain type of network," IEEE Trans.Cybern., early access, Jul. 1, 2021, doi: 10.1109/TCYB.2021.3088711.
3. W. Zheng, K. Wang, and F.-Y. Wang, "Gan-based key secretsharing scheme in blockchain," IEEE Trans. Cybern., vol. 51, no. 1, pp. 393–404, Jan. 2021.
4. C. Tang, C. Li, X. Yu, Z. Zheng, and Z. Chen, "Cooperative mining in blockchain networks with zero-determinant strategies," IEEE Trans. Cybern., vol. 50, no. 10, pp. 4544–4549, Oct. 2020.

5. Y. Li, H. Li, X. Ding, and G. Zhao, "Leader–follower consensus of multiagent systems with time delays over finite fields," IEEE Trans. Cybern., vol. 49, no. 8, pp. 3203–3208, Aug. 2019.
6. B. Tian, H. Lu, Z. Zuo, and W. Yang, "Fixed-time leader–follower outputfeedback c onsensus for second-order multiagent systems," IEEE Trans.Cybern., vol. 49, no. 4, pp. 1545– 1550, Apr. 2019.
7. B. Yong, J. Shen, X. Liu, F. Li, H. Chen, and Q. Zhou, "An intelligent blockchain-based system for safe vaccine supply and supervision," Int.J. Inf. Manage., vol. 52, Jun. 2020, Art. no. 102024
8. G. Falco, C. Li, P. Fedorov, C. Caldera, R. Arora, and K. Jackson,"NeuroMesh: IoT security enabled by a blockchain powered botnet vaccine," in Proc. Int. Conf. Omni-Layer Intell. Syst., 2019, pp. 1–6.
9. S. Peng et al., "An efficient double-layer blockchain method for vaccine production supervision," IEEE Trans. NanoBiosci., vol. 19, no. 3, pp. 579–587, Jul. 2020.
10. L. Cui et al., "Improving vaccine safety using blockchain," ACM Trans.Internet Technol., vol. 21, no. 2, pp. 1–24, 2021.
11. Y. Cao, F. Jia, and G. Manogaran, "Efficient traceability systems of steel products using blockchain-based Industrial Internet of Things," IEEE Trans. Ind. Informat., vol. 16, no. 9, pp. 6004–6012, Sep. 2020.