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Protecting Vaccine Safety: An Improved, Blockchain-Based, Storage-Efficient Scheme

Gatla Roshini1, K.Divya Reddy2, Rehana Begum
Dr.P. Avinash4
Professor,Email: avinashjntuh@gmail.com

1, 2, 3, 4 Sridevi Women's Engineering College, V.N.PALLY , NEAR WIPRO GOPANANPALLY, HYDERABAD, Ranga Reddy, 500075 ; Email : admin@swec.ac.inWebsite, www.swec.ac.in ;

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.

Keywords: Protecting Vaccine Safety, Blockchain Technology, Storage-Efficient Scheme, Vaccine Storage, Data Integrity, Security, Immunization, Distributed Ledger, Decentralization, Healthcare, Pharmaceutical Supply Chain.

I INTRODUCTION

In recent years, vaccine safety incidents have attracted people's attention. The reported fraud and data tampering in the vaccine supply chain is causing worries. The vaccine supply chain has several potential risks. First, manufacturers could produce unqualified vaccines or even modify vaccine data. Second, unqualified intermediate suppliers could collude with vaccination institutions (VIs) to sell and use fake/unqualified vaccines. Third, vaccine transportation fails to comply with strict cold chain requirements.

Compared with other product supply chain management issues, vaccine supply chain management is more urgent and worrying. The current vaccine supervision system uses the traditional centralized information management system. Traditional information management systems face potential security problems, such as easy tampering and a single point of failure. Each entity in the vaccine circulation process also needs to have its own database to store the data, which causes data islands. Thus, it is not easy to form an effective closed loop of trust in the entire supply chain. Because the blockchain is able to build a global and distributive trust, using blockchain to solve the trust issue becomes a promising approach. Blockchain provides distributed data storage. The entire distributed network jointly maintains a globally unique chain. The data on the chain can only be added and modified through consensus mechanisms. The blockchain also maintains the system's consistency without relying on the central node. This feature makes the blockchain tamper proof. The decentralized architecture of the blockchain has also become a new form of distributed software system design.

II RELATED WORK

The state-of-the-art research in blockchain enabling vaccine safety includes. These works model the vaccine circulation process using different blockchain infrastructures (such as Ethereum, Hyperledger, FISCO BCOS, etc.) and different blockchain architectures (single chain, double chain, etc.) to integrate vaccine circulation data on the chain to protect the safety of the vaccine supply chain. Due to the blockchain infrastructure's performance limitation, these systems face large data expansion and system delay problems. The blockchain network requires each node to keep the same copy of the data. The amount of data in the vaccine supply chain is huge, which will eventually lead to excessive storage pressure on each node. Simultaneously, due to the throughput limitation of the blockchain infrastructure, transactions in a certain period of time cannot be uploaded to the chain in time, resulting in system delays.

Aiming at better performance, we have made a new research attempt. We design a blockchain-cloud-based vaccine traceability system to protect vaccine circulation safety. At a high level, we model the blockchain as a globally unique database. We use the blockchain to store the digital digest of vaccine circulation data and different entities' digital signatures in the vaccine circulation process. They serve as evidence for tracing vaccine safety incidents. We employ the cloud to provide vaccine data storage, circulation management, and vaccine tracing. The cloud serves to alleviate blockchain storage requirements and accelerates system processing.

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.

III SYSTEM ANALYSIS

i) Existing System

Zhang et al. proposed a blockchain-based method to control milk production quality. Milk production includes six steps: 1) harvesting; 2) transportation; 3) storage; 4) testing; 5) processing; and 6) packaging. Blockchain is mainly used to store the source information of milk raw materials. Based on these data, milk production, transportation, and sales processes are tracked throughout the milk supply chain. Once problems with milk raw materials are discovered, the problematic milk's sales channels can be traced back in time. Simultaneously, as a public distributed database, the blockchain increases the data transparency of the supply chain and makes the identification of responsibility easier.

Cao et al. proposed a blockchain-based steel supply chain traceability system. They combined blockchain, sensors, RFID, and GPS technologies to manage and track the production, distribution, consumption, and steel supervision. Each product has an RFID tag, which is the virtual identification of the product in the system.

Peng et al. proposed a two-layer blockchain architecture to protect the security of the vaccine supply chain. They focused on the safety of vaccine production. The first layer is the private data of vaccine manufacturers; the second layer is public data, including production record hashes and vaccine information. Through the two-tier architecture, manufacturers can submit production records in time and avoid exposing some sensitive information. At the same time, they also proposed a cutting mechanism for vaccine data.

Westerkamp et al. proposed a distributed supply chain management system based on blockchain smart contracts. In their proposed system, commodities are represented by tokens. The token can be transferred, split, merged, and authenticated.

Disadvantages

The security is very less since an existing system is NOT IN BLOCKCHAIN based vaccine supply.

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In an existing system, Sharding is not actually a traditional database technology that divides large databases into smaller, faster, and easier to- managge parts.

ii) Proposed System

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3) transportation; and 4) distrib ution. From the beginning of vaccine production, each vaccine is assigned a digital identity (i.e., vacccine 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.

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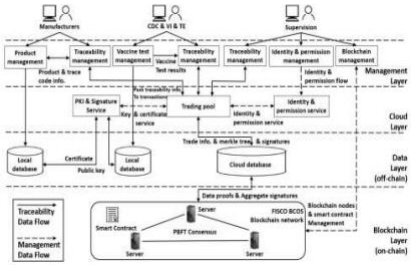
Technically, there exist two key challenges in the proposed scheme. The first challenge is how to ensure the reliability of vaccine circulation data. The second challenge is how to relieve the pressure of blockchain storage and communicattion.

Advantages

In the proposed system, design a blockchain-cloud-based vaaccine traceability system to protect vaccine circulation safety. At a high level, we model the blockchain as a globally unique database.

Blockchain only stores the data digest and involved entities' signnatures of the circulation data. The systeem structures and stores the vaccine circulaation data in the cloud into a Merkle tree. We store the root of the tree on the chain as evidence.

iii) System Architecture



Proposed Architecture

IV METHODOLOGY

i) Blockchain for Supply Chaain Management:

Description: Several projects and studies explore the use of blockchain to enhancee the transparency and traceability of the vaccine supply chain. This involves tracking the prodduction, storage, and distribution of vaccines to e nsure their safety and authenticity.

Example: "A Blockchain-Based Approach for Ensuring the Integrity of Me dical Data and Supply Chain Traceability" (Li et al., 2019).

ii) Vaccine Authenticaation and Anti-Counterfeiting:

Description: Blockchain can be utilized to create an immutable record of vacccine production and distribution, helping to prevennt counterfeit vaccines from entering the supply chaiin. Each vaccine batch can be associated with a unique identifier on the blockchain.

Example: "Blockchain for Anti-Counterfeit of Drugs" (Kshetri, 2018).

iii) Decentralized Vaccine Reegistries:

Description: Blockchain offerrs a decentralized and secure way to manage vaccinne registries, providing individuals and healthcare pro viders with easy access to vaccination records. This can contribute to the overall safety and monnitoring of vaccine administration.

Example: "A Decentralized System for Secure and Privacy-Preserving Vacciine Credentialing" (Narayanan et al., 2021).

iv) Smart Contracts for Veriffication:

Description: Smart contracts on the blockchain can automate verification processes, ensuring that only authorized and verified entities can handle vaccines, reducing the risk of mishandling or tampering.

Example: "A Blockchain-Based Smart Contract System for Healthcare Management" (Zhang et al., 2018).

v) Data Privacy and Consent Management:

Description: Blockchain can be used to establish a secure and consent-based system for managing patient data related to vaccines. Patients have control over who can access their vaccination history while ensuring data integrity.

Example: "Blockchain and Consent Management for Personal Health Records" (Mettler, 2016).

vi) Collaborative Research Platforms:

Description: Blockchain facilitates secure and collaborative platforms for vaccine-related research and development. Multiple stakeholders can contribute to research efforts while maintaining data integrity and security.

Example: "A Blockchain Framework for Data Sharing with Fine-Grained Access Control in Decentralized Storage Systems" (Liang et al., 2019).

V 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.

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