Vaccine Supply Chain Management through Blockchain Technology

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Contents

Introduction

- The pharmaceutical industry faces vaccine supply chain concerns.
- Challenges involve transparency issues and fraud in vaccine records.
- To address these issues, develop a decentralized vaccine supply chain data management system using blockchain.
- Blockchain's decentralized, immutable nature enhances transparency, traceability, and security.

Current State of Art

- Centralized and Unclear
- Manual Tracking
- Vulnerable to Tampering
- Counterfeit Risks

Motivation

- Enhanced Transparency
- Improved Traceability
- Data Integrity Assurance
- Decentralized Trust
- Security Against Counterfeiting

Objectives

- Decentralize the System
- Guarantee Data Integrity
- Optimize Traceability
- Mitigate Counterfeiting

Literature Review

Table 1: Literature Review

Sl No.	Title	Author	Objective	Features
1	Protecting Vaccine Safety: An Improved, Blockchain-Based, Storage-Efficient Scheme (2022)	L. Cui et al	• Tackle vaccine circulation reliability challenges. • Introduce a secure blockchain for enhanced vaccine safety and traceability in circulation.	• Uses cloud for efficient off-chain storage. • Utilizes consortium blockchain for secure recording of vaccine circulation data.
2	Towards a Blockchain Assisted Patient Owned System for Electronic Health Records (2021)	T. Fatokun et al	• Introduce a patient-centric EHR system using blockchain. • Enhance EHR system interoperability for secure data exchange.	• Secure, consistent health records controlled by patients. • Patient-Centric EHR Web Portal

Literature Review

Table 2: Literature Review (Continued)

Sl No.	Title	Author	Objective	Features
3	A Novel Medical Blockchain Model for Drug Supply Chain Integrity Management in a Smart Hospital (2019)	F. Jamil et al	• Creating a secure drug supply chain with Hyperledger Fabric blockchain. • Handling counterfeit drugs in developing country pharmaceuticals.	• Secure Drug Supply Chain Record System. • Access Control and Permissions.
4	FAIR: A Blockchain-based Vaccine Distribution Scheme for Pandemics (2021)	A. R. Nair et al	• Address healthcare supply chain challenges. • Ensure Secure and Fair Distribution System.	• Focus on trust and forecasting. • Distinct working layers.

Proposed Methodology

- **API Design**
  - Registering new vaccines
  - Tracking vaccine batches
  - Verifying vaccine authenticity
  - Retrieving vaccine information
- **Data Models**
  - Define data structures for vaccine batches, including attributes like batch number, manufacturer, production date, etc.
  - Define structures for transactions and blocks in the Hyperledger blockchain.
- **Middleware Development**
  - Implement a middleware layer in Golang to expose API endpoints.
  - Utilize libraries like Gorilla Mux for routing and handling HTTP requests.

Proposed Methodology

- **Hyperledger Integration**
  - Integrate Golang middleware with Hyperledger Fabric.
  - Implement smart contracts for managing vaccine transactions and authenticity verification.
- **Authentication and Authorization**
  - Implement authentication mechanisms (e.g., JWT tokens) to secure API endpoints.
  - Define roles and permissions for accessing different functionalities.
- **Testing**
  - Develop unit tests for API endpoints and middleware functions.
  - Conduct integration tests to ensure interoperability with Hyperledger.

Proposed System

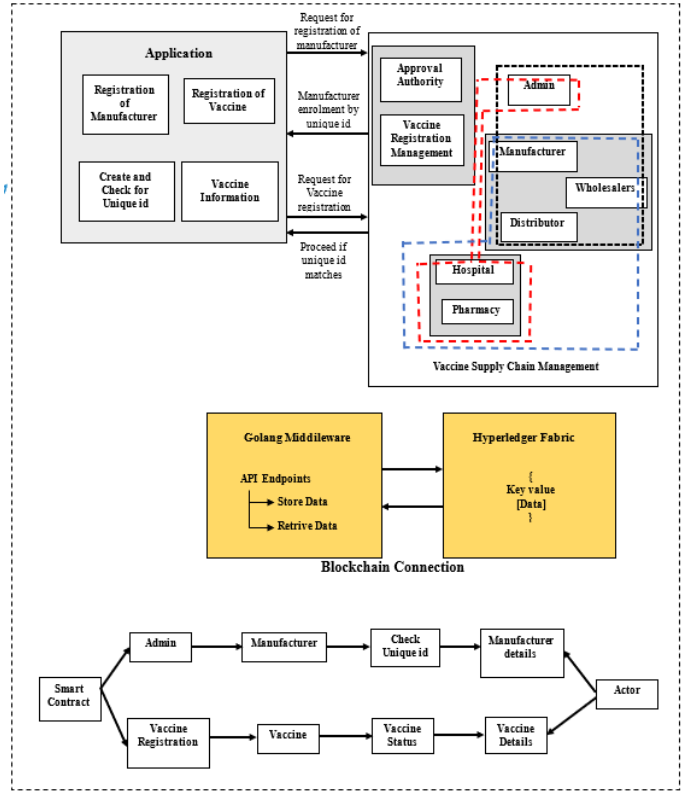

Figure 1: System Architecture

Proposed System

Algorithm: PBFT (Practical Byzantine Fault Tolerance)

- Replicas maintain state machines and logs.
- Client sends request to network.
- Primary replica assigns sequence number and sends pre-prepare.
- Replicas broadcast prepare messages and wait for 2f+1 prepares.
- Replicas execute operation upon receiving commit messages.
- Checkpointing and view change handle faults; tolerates up to f Byzantine faults with low latency and high throughput.

Proposed System-Database Schema

Tables

Table 3: User login table

Field Name	Datatype	Constraints
log_id	AutoField	PRIMARY KEY
username	CharField	
password	CharField	
role	CharField	

Table 4: Manufacturer table

Field Name	Datatype	Constraints
manufacturer_id	AutoField	PRIMARY KEY
company_name	CharField	
vaccine_approval_status	CharField	
unique_account	CharField	
access_to_smartcontracts	CharField	

Materials and Methods - Environmental Setup

- Docker
  - Docker containerizes applications and dependencies, ensuring consistent environments.
  - It facilitates both development and deployment processes.
- Hyperledger Fabric
  - Establish a permissioned blockchain network.
  - This network offers customizable access controls for stakeholders.
- IDE
  - Use Visual Studio Code for efficient code writing and debugging.
- SDK
  - Utilize Hyperledger Fabric SDKs for blockchain network interaction.

Materials and Methods - Tools

- CPU: Intel Core i5 or higher
- RAM: 8 GB or higher
- Hard disk: 512 GB or higher
- Blockchain Development Framework: Hyperledger Fabric
- Smart Contract Development: Golang (Go)
- Database: MySQL
- IDE: Visual Studio Code
- Containerization Platform: Docker

Result

- Utilized blockchain's immutability to guarantee the integrity of vaccine-related data.
- Reduced reliance on centralized authorities, ensuring greater accountability and trust.
- Developed robust tracking mechanisms from production to distribution.
- Employed cryptographic techniques to create secure unforgeable records.

Performance Analysis

- ★ Immutability
  - The SHA-256 cryptographic hashing algorithm ensures immutability.
  - It generates a unique hash value for each block.
- ★ Data Integrity
  - The PBFT consensus algorithm ensures the integrity of the blockchain network.
  - It broadcasts transactions, validates order, and achieves consensus.
- ★ Transparency
  - Blockchain's transparent nature enables stakeholders to access the data.
  - Also verify the information, ensuring transparency in the process.

Performance Analysis

- ★ Traceability
  - Each vaccine batch is assigned a unique identifier recorded on the blockchain.
  - This facilitates precise tracking of its journey from production to distribution and administration.
- ★ Security
  - Blockchain's cryptographic features ensure secure data transmission and prevent unauthorized access.
- ★ Efficiency
  - Blockchain enables real-time tracking of vaccine status and location.
  - This optimizes supply chain logistics, leading to increased efficiency.

Conclusion & Future Scope

Conclusion

- Targets revolutionizing vaccine distribution via blockchain in pharmaceuticals.
- Promises to enhance trust, security, and efficiency in vaccine distribution.

Future Scope

- Real-World Deployment
- Cold Chain Process Integration
- Performance Metrics Refinement

Implementation Status and Plan

Table 5: Implementation Status and Plan

Task	**Status**	**Remarks**
Research and Analysis	Completed	
API design	Completed	
Golang and Solidity setup	Completed	
Middleware Implementation	Completed	
Hyperledger Integration	In Progress	
Authentication Setup	Yet to start	Planning to complete by April 10th 2024

Reference

1 M. Rehman, I. T. Javed, K. N. Qureshi, T. Margaria, and G. Jeon, ”A Cyber Secure Medical Management System by Using Blockchain,” IEEE Transactions on Computational Social Systems, vol. 10, no. 4, pp. 2123-2136, Aug. 2023.

2 L. Cui, Z. Xiao, F. Chen, H. Dai, and J. Li, “Protecting vaccine safety: An improved, blockchain-based, storage-efficient scheme,” IEEE Trans. Cybern., early access, Apr. 13, 2022, doi: 10.1109/TCYB.2022.3163743.

3 F. Jamil, L. Hang, K. Kim, and D. Kim, “A novel medical blockchain model for drug supply chain integrity management in a smart hospital,” Electronics, vol. 8, p. 505, Apr. 2019.

4 T. Fatokun, A. Nag, and S. Sharma, “Towards a blockchain assisted patient owned system for electronic health records,” Electronics, vol. 10, no. 5, p. 580, Mar. 2021.

Git History

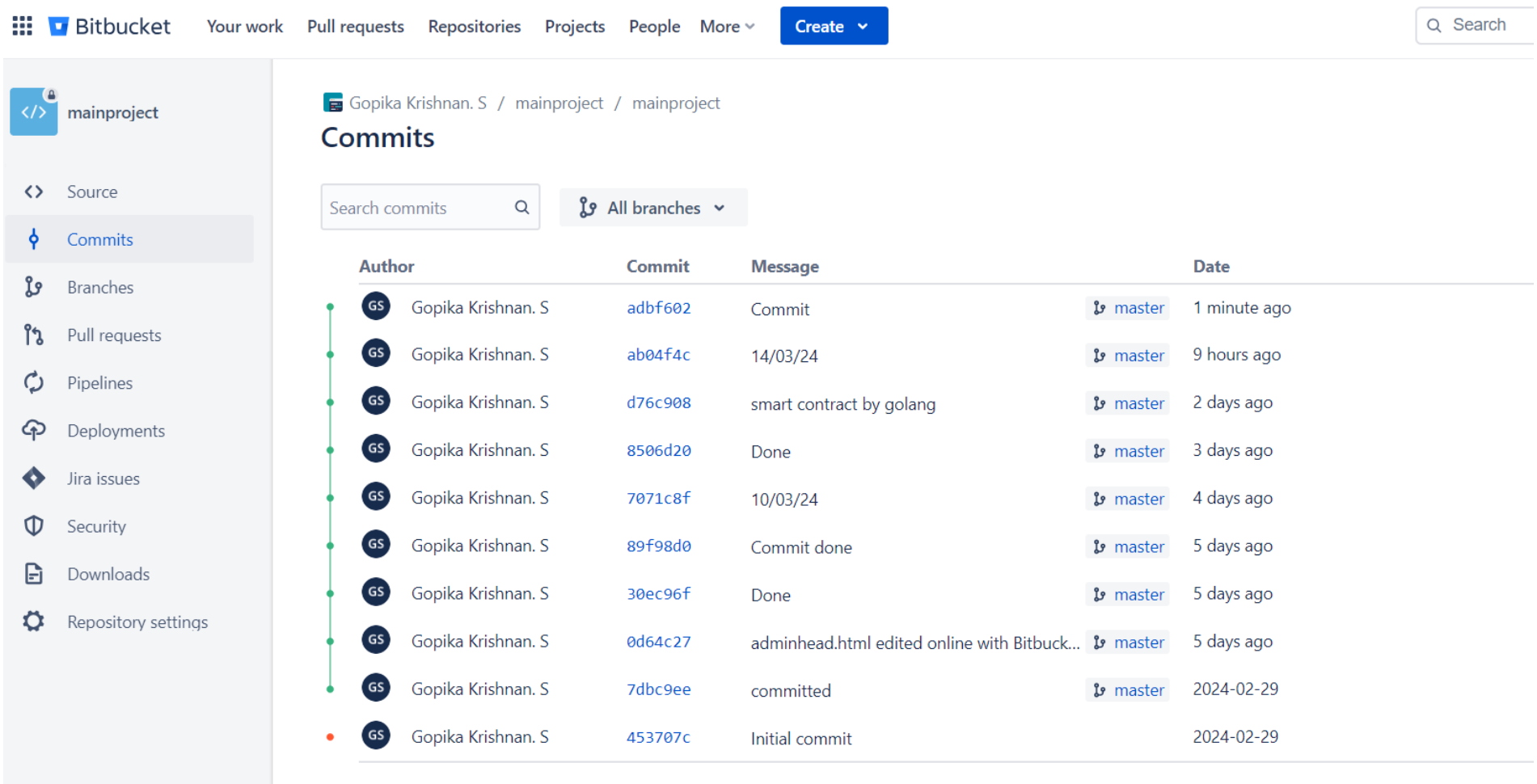

Figure 2: Git History

Thank you!