Vaccine Supply Chain Management through Blockchain Technology

Gopika Krishnan S
Roll No: 25
Reg.No: KTE22MCA-2025

Guided By
Dr. Sangeetha Jose
Department of Computer Applications
Rajiv Gandhi Institute of Technology, Kottayam

April 8, 2024

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, security and traceability.

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

- To implement a decentralized system with ensured integrity, optimized traceability, and counterfeiting mitigation using blockchain technology.

Literature Review

Table 1: Literature Review

Sl No.	Title	Author	Objective	Features
1	Protecting Vaccine Safety: An Improved, Blockchain-Based, Storage-Efficient Scheme (2022) [2]	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) [3]	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 Continued

Table 2: Literature Review

Sl No.	Title	Author	Objective	Features
3	A Novel Medical Blockchain Model for Drug Supply Chain Integrity Management in a Smart Hospital (2019) [4]	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) [5]	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 - Work Flow

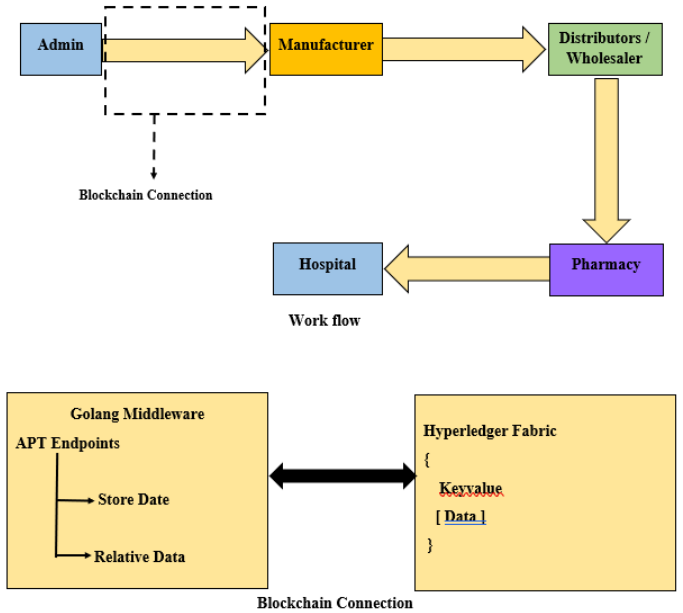

Figure 1: Work Flow

Proposed System - Working Framework

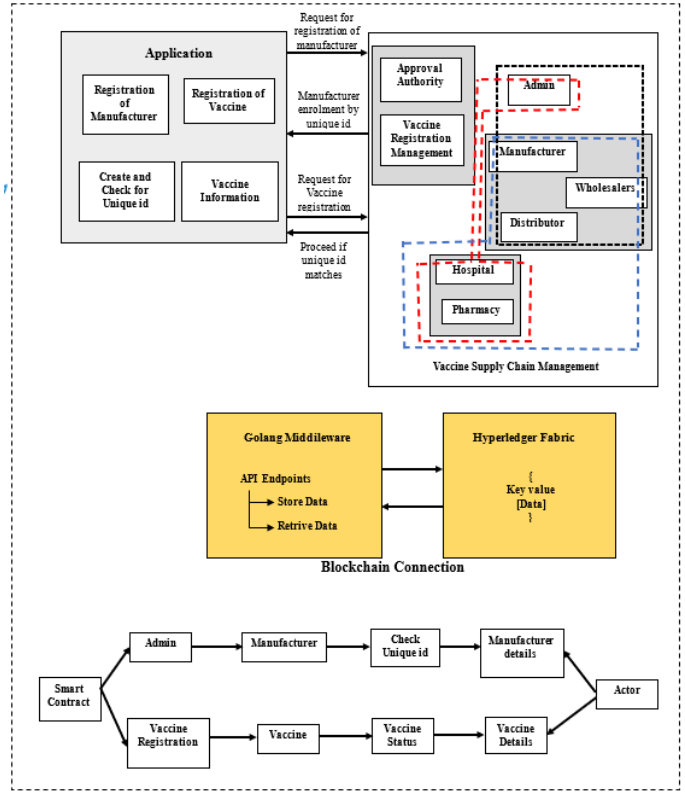

Figure 2: System Architecture

Proposed System - Algorithm

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, where ”f” represents the maximum number of faulty nodes.
- 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

Important 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	
address	CharField	
licence_no	CharField	
status	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

- In comparison to the existing system, the proposed system achieves the following goals:
  - Immutability ensured through the utilization of the SHA3-256 hashing algorithm.
  - Data Integrity maintained via the PBFT consensus algorithm.
  - Transparency facilitated by a shared ledger.
  - Traceability enhanced by unique identifiers.
  - Security is reinforced through cryptographic features, such as public key encryption.

Performance Analysis

Table 5: Performance Analysis

Feature	**Mechanism**	**Benefits Achieved**
Immutability	SHA-256 Hashing Algorithm	Data Remains Unalterable
Data Integrity	PBFT Consensus Algorithm	Ensures Data Consistency
Transparency	Shared Ledger	Enables Real-time Visibility
Traceability	Unique Identifiers	Facilitates Precise Tracking
Security	Cryptographic Features	Prevents Unauthorized Access
Decentralization	Distributed Ledger	Enhances System Resilience
Efficiency	Smart Contracts	Automates Processes & Reduces Errors

Performance Analysis

- The performance of the Hyperledger Fabric platform is evaluated in terms of throughput, latency, and scalability.
- The evaluation utilizes the Hyperledger Caliper tool, which represents multiple clients capable of injecting workloads into the blockchain network.
- It depends on hardware configuration, blockchain network design, and smart contract complexity/operations.

Conclusion & Future Scope

- Targeting a revolution in vaccine distribution within the pharmaceutical industry through blockchain technology.
- Promises to enhance trust, security, and efficiency in vaccine distribution.
- Future scope involves real-world deployment, integration with cold chain processes, and enhancement based on user feedback.

Implementation Status and Plan

Table 6: Implementation Status and Plan

Task	**Status**	**Remarks**
Research and Analysis	Completed	
Database Design	Completed	
API Design	Completed	
Smart Contract Implementation	Completed	
Middleware Implementation	Completed	
Hyperledger Implementation	Completed	
Integration of Frontend with APIs	Completed	

Reference

[1] Muhammad Rehman et al. “A cyber secure medical management system by using blockchain”. In: *IEEE Transactions on Computational Social Systems* (2022).

[2] Laizhong Cui et al. “Protecting vaccine safety: An improved, blockchain-based, storage-efficient scheme”. In: *IEEE Transactions on Cybernetics* (2022).

[3] Tomilayo Fatokun, Avishek Nag, and Sachin Sharma. “Towards a blockchain assisted patient owned system for electronic health records”. In: *Electronics* 10.5 (2021), p. 580.

[4] Faisal Jamil et al. “A novel medical blockchain model for drug supply chain integrity management in a smart hospital”. In: *Electronics* 8.5 (2019), p. 505.

[5] AR Nair, R Gupta, and S Tanwar. *FAIR: A Blockchain-based Vaccine Distribution Scheme for Pandemics. In 2021 IEEE Globecom Workshops (GC Wkshps)(pp. 1–6)*. 2021.

Git History

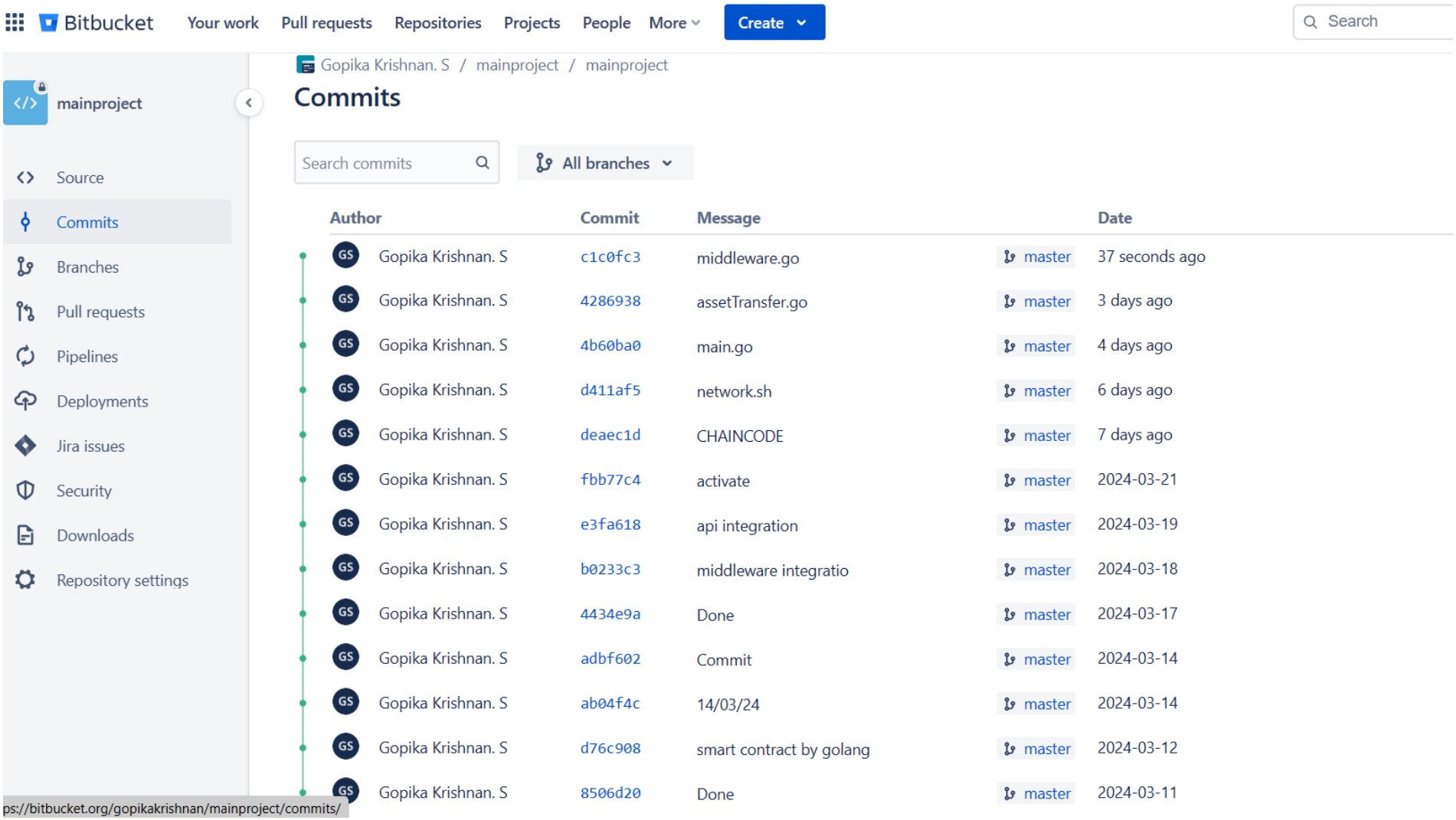

Figure 3: Git History

Thank you!