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, 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

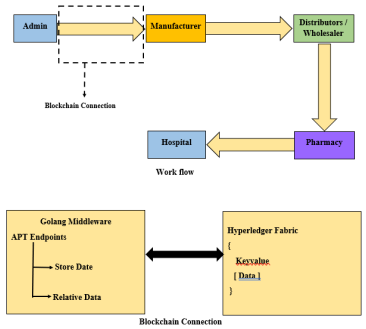

Figure 1: Work Flow

Proposed System - Working Framework

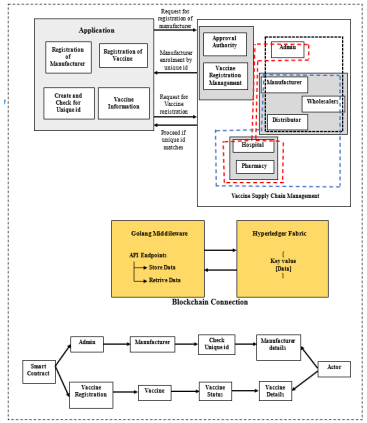

Figure 2: System Architecture

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	SHA3-256 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

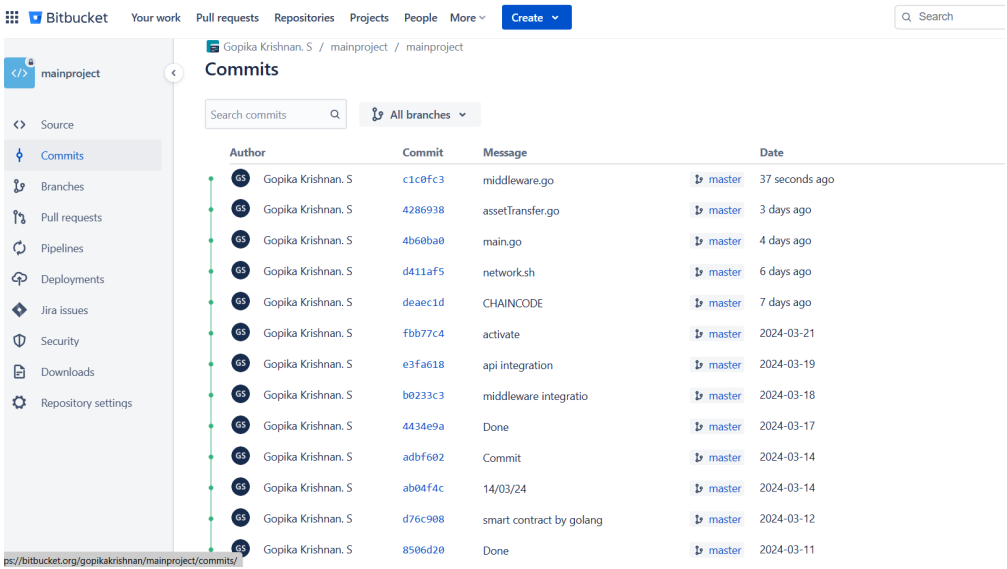

Figure 3: Git History

Thank you!