# Vaccine Supply Chain Management through Blockchain Technology

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# 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<br>• Introduce a secure blockchain for enhanced vaccine safety and traceability in circulation. | • Uses cloud for efficient off-chain storage<br>• 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.<br>• Enhance EHR system interoperability for secure data exchange. | • Secure, consistent health records controlled by patients.<br>• 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.<br>• Handling counterfeit drugs in developing country pharmaceuticals. | • Secure Drug Supply Chain Record System<br>• 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<br>• Ensure Secure and Fair Distribution System | • Focus on trust and forecasting<br>• 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

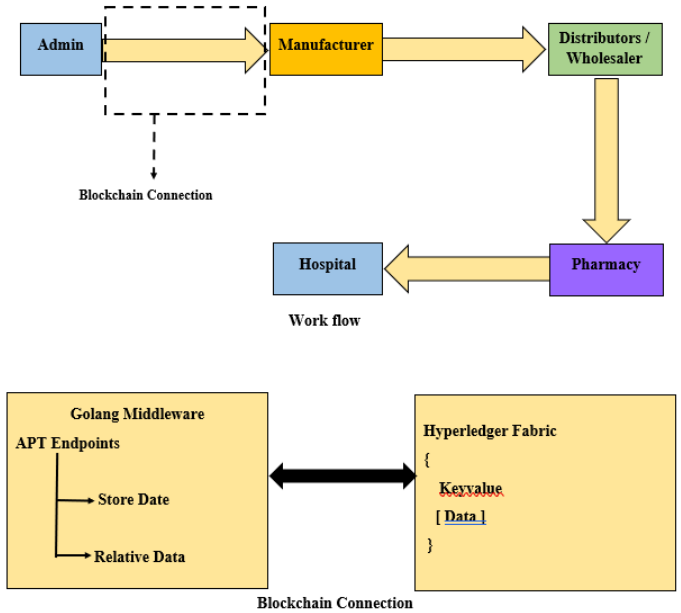


Figure 1: Work Flow

# Proposed System - Working Framework

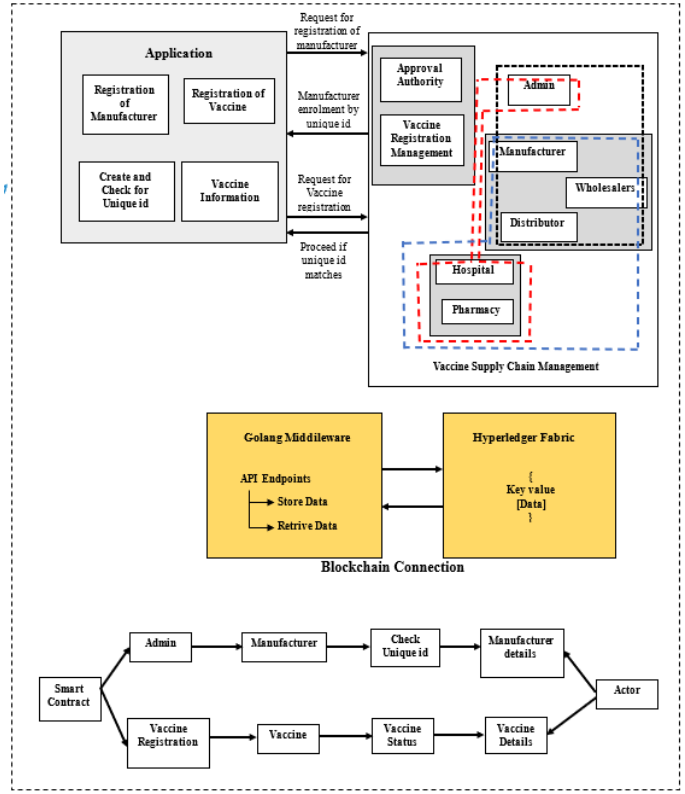


Figure 2: System Architecture

# 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

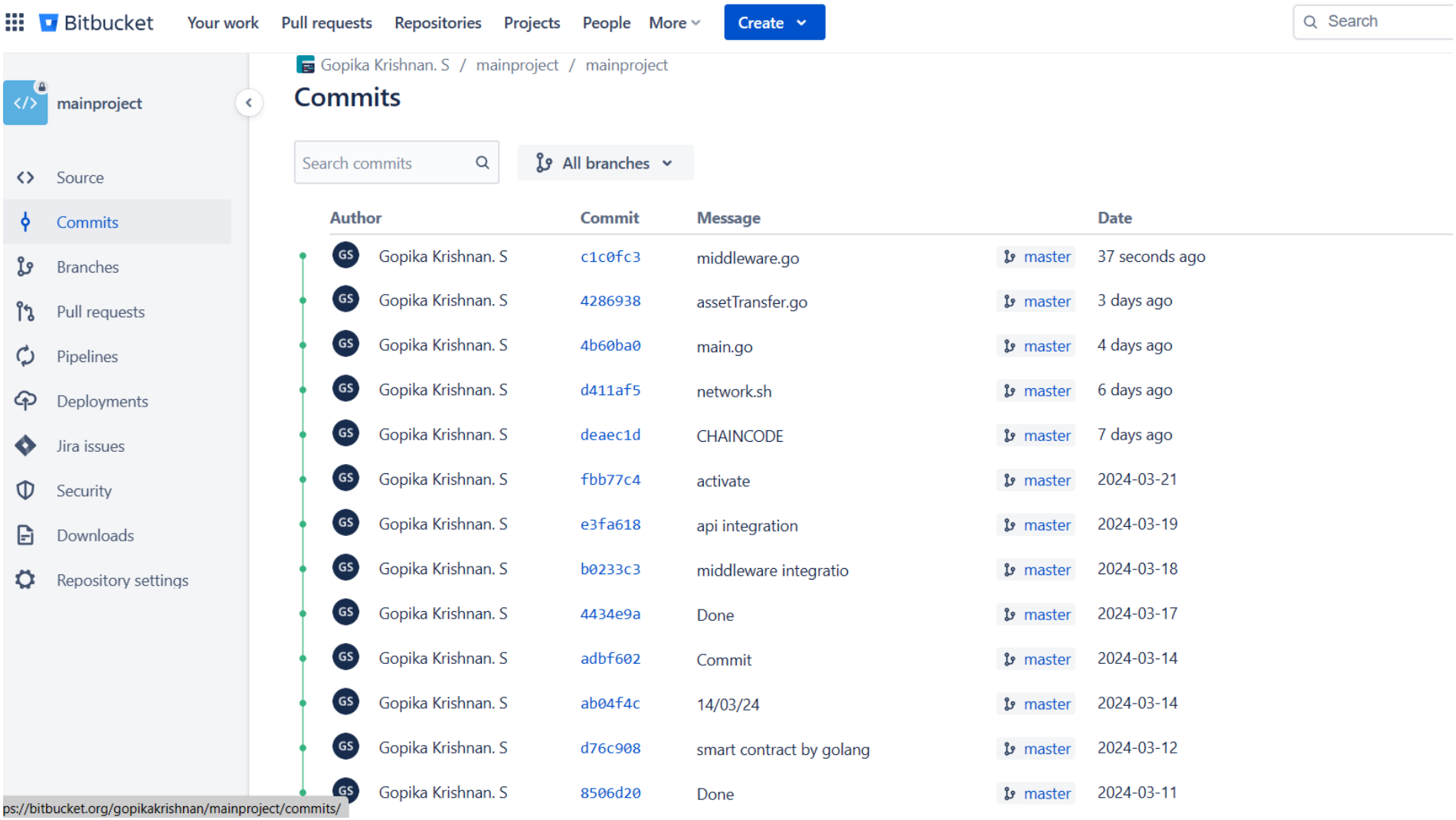


Figure 3: Git History

# Thank you!