PHARMACHAIN: BLOCKCHAIN-BASED PHARMACEUTICAL SUPPLY CHAIN TRACKING AND COUNTERFEIT PRODUCT DETECTION

CENG 3550, DECENTRALIZED SYSTEMS AND APPLICATIONS

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Abstract

According to World Health Organization data, 10% of medicines worldwide are counterfeit or substandard. The lack of transparency in traditional supply chains allows counterfeit products to infiltrate the system, posing severe risks to public health. This study proposes "PharmaChain," a blockchain-based system designed to track pharmaceutical products from the manufacturer to the patient. By utilizing smart contracts and IoT integration, PharmaChain ensures an immutable, transparent, and traceable record system. The proposed model aims to reduce counterfeit drug incidents by 90% while maintaining operational efficiency and complying with regulations such as EU FMD and FDA DSCSA.

1 Introduction

The pharmaceutical industry faces a critical challenge regarding the integrity of its supply chain. In multi-party systems involving manufacturers, distributors, warehouses, and pharmacies, the level of trust is inherently low. Centralized systems, which are currently the standard, pose risks of data manipulation and single points of failure. The primary motivation of this project is to prevent counterfeit drugs from entering the market through a decentralized approach.

The requirement is clear: a prevention mechanism that relies on an immutable record system. PharmaChain addresses this by assigning a unique product ID to each medicine and tracking its ownership and condition (via IoT sensors) across the entire lifecycle.

In the next section, the fundamentals of the blockchain technology used will be given. Then the related works will be discussed in Section 3. In Section 4, details of the PharmaChain system proposal are given. The proof of concept implementation of the system is given in Section 5. Results are projected in Section 6. Conclusion and future works will be given in the last section.

2 Fundamentals

2.1 Blockchain Technology and Quorum

Blockchain creates a decentralized ledger where transactions are recorded across multiple nodes. For PharmaChain, a private blockchain network is essential to ensure data privacy among competitors (e.g., different distributors) while maintaining a shared source of truth. We utilize Quorum, an enterprise-focused Ethereum variant, which allows for high throughput and privacy controls suitable for supply chain applications.

2.2 Smart Contracts

Smart contracts are self-executing contracts with the terms of the agreement directly written into code. In our system, product ownership transfers and location updates are automatically verified through smart contracts, eliminating the need for a central authority to validate transactions.

3 RELATED WORKS

Traditional supply chain tracking relies heavily on centralized databases managed by individual stakeholders. While effective for internal logistics, these systems create "data silos" that prevent end-to-end visibility.

- **Centralized Systems:** Vulnerable to hacking and data manipulation. If a server is compromised, the entire history can be altered.
- **Existing Blockchain Solutions:** Some proposals exist in the literature for general supply chains, but PharmaChain focuses specifically on the pharmaceutical requirements, including cold-chain monitoring (temperature control) via IoT, which is critical for sensitive drugs like vaccines.

This study focuses on integrating IoT sensor data directly into the blockchain to ensure not just the authenticity of the product, but also its quality preservation during transport.

4 SYSTEM PROPOSAL

The proposed solution, PharmaChain, is a blockchain-based system that tracks pharmaceutical products from manufacturer to patient. The system architecture is visualized below.

4.1 System Architecture

The system consists of the following key stakeholders:

1. **Manufacturer:** Registers the product with a unique ID.
2. **Distributor & Warehouse:** Transport and store the product. IoT sensors record temperature and location data during this phase.
3. **Pharmacy:** Verifies the product's entire history before selling it.
4. **Patient:** Can scan the product to verify its authenticity.

Figure 1: PharmaChain System Architecture: End-to-End Flow from Manufacturer to Patient

4.2 Unique Value Proposition

PharmaChain offers several unique advantages:

- **Immutable Records:** Retroactive changes are impossible.
- **Trustless Verification:** Verification is performed without a central authority.
- **Regulatory Compliance:** Designed to comply with KVKK, GDPR, and FDA DSCSA.
- **Data Minimization:** Sensitive patient data is stored off-chain in encrypted form to ensure privacy.

5 IMPLEMENTATION

The prototype system is designed to run on a Quorum testnet. The implementation involves technical components such as Smart Contracts, Web Interfaces, and IoT Simulations.

5.1 Smart Contract (Solidity)

The core logic is written in Solidity. Below is a snippet of the contract used to register and transfer products:

```
struct Drug {
    uint256 id;
    string name;
    address currentOwner;
    int256 temperature;
    string location;
}

function transferDrug(uint256 _id, address _newOwner) public {
    Drug storage drug = drugs[_id];
    require(msg.sender == drug.currentOwner, "Unauthorized");
    drug.currentOwner = _newOwner;
    // History update logic...
}
```

5.2 Web Interface Development

A user-friendly web interface has been developed to allow stakeholders (Pharmacists, Distributors) to interact with the blockchain without needing technical knowledge. The dashboard provides real-time tracking and verification status.

5.3 IoT Integration Simulation

Critical data such as temperature and location are recorded in real-time. In our MVP, we simulate IoT sensors pushing data to the blockchain. This ensures that if a drug is exposed to high temperatures, the incident is permanently recorded on the ledger.

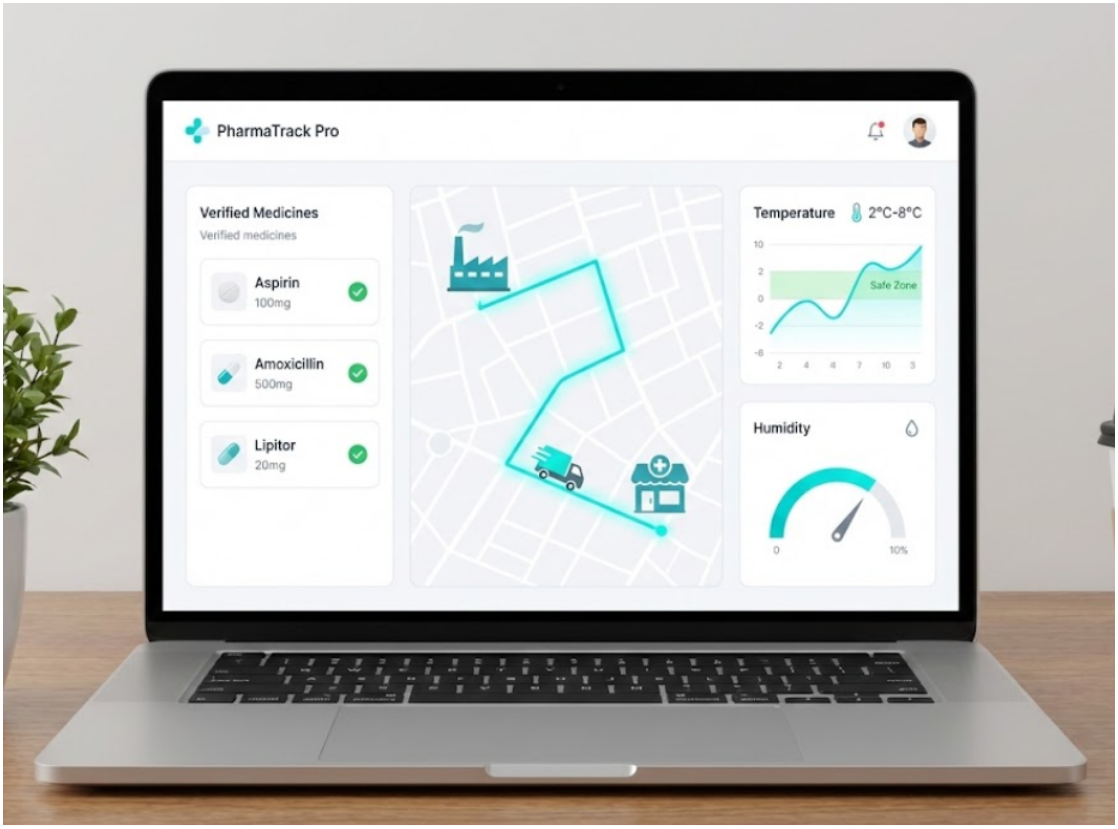

Figure 2: PharmaChain Web Interface: Tracking Dashboard for Pharmacists and Distributors

Figure 3: IoT Integration: Real-time Temperature Monitoring Simulation on Drug Vials

5.4 Team Roles

- **Doğukan Taha Tıraş:** Smart contract development (Solidity), Quorum network setup, and backend testing.
- **Seyfullah Korkmaz:** System architecture design, Web interface development (Frontend), and IoT sensor integration simulation.

6 RESULTS and DISCUSSION

6.1 Projected Impact

The primary hypothesis of this study is that the system can reduce counterfeit drug incidents by 90% while maintaining operational efficiency.

- **Healthcare Safety:** Patient safety is significantly enhanced.
- **Economic Impact:** Billions of dollars in annual losses due to counterfeit drugs can be prevented.
- **Trust:** Increasing confidence among patients and healthcare professionals.

6.2 Timeline and Work Packages

The project follows a strict 11-week timeline (Nov 4, 2025 - Jan 12, 2026). The initial phase focused on Requirements Analysis (Weeks 1-2), followed by Blockchain Setup (Weeks 3-4). Currently, the Smart Contract and Web Interface development phases are in progress.

7 CONCLUSION

PharmaChain presents a robust solution to the global problem of counterfeit pharmaceuticals. By leveraging blockchain for immutability and IoT for condition monitoring, it establishes a model for decentralized supply chain management. Future work will focus on deploying the system on a larger scale testnet with 100+ nodes to test scalability and integrating real physical IoT devices instead of simulations.

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