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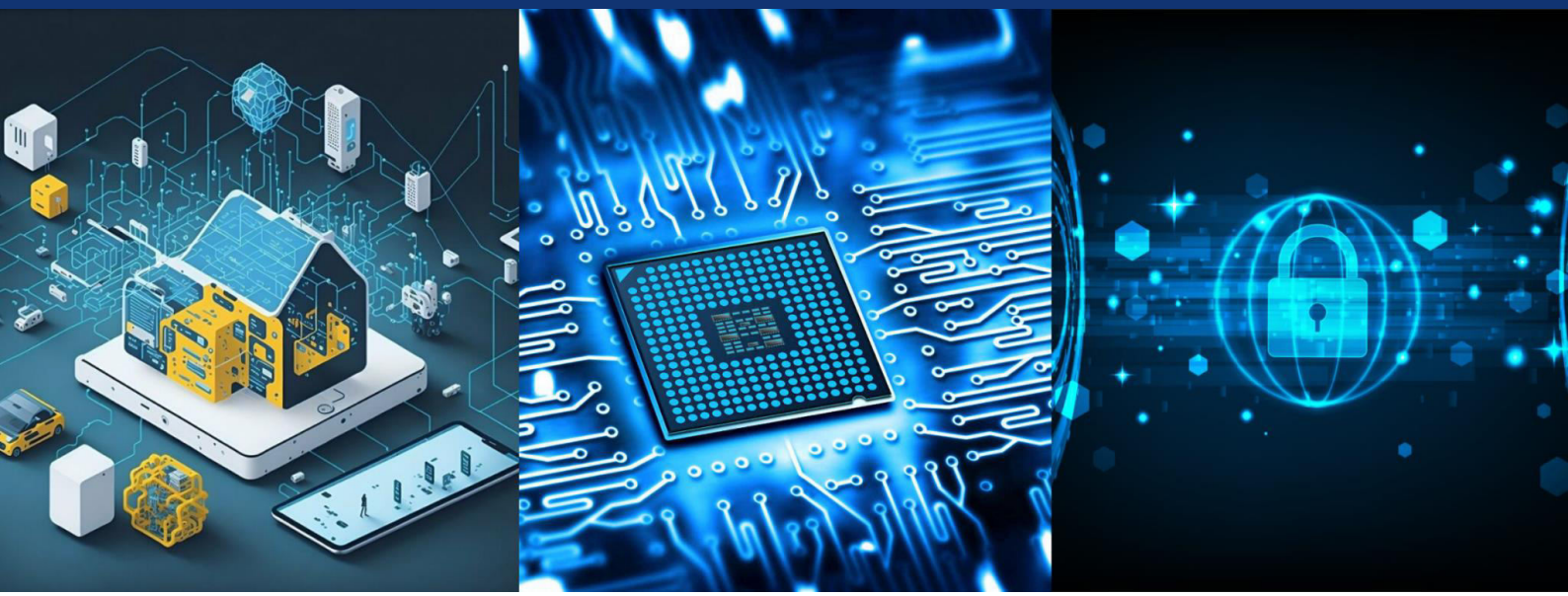

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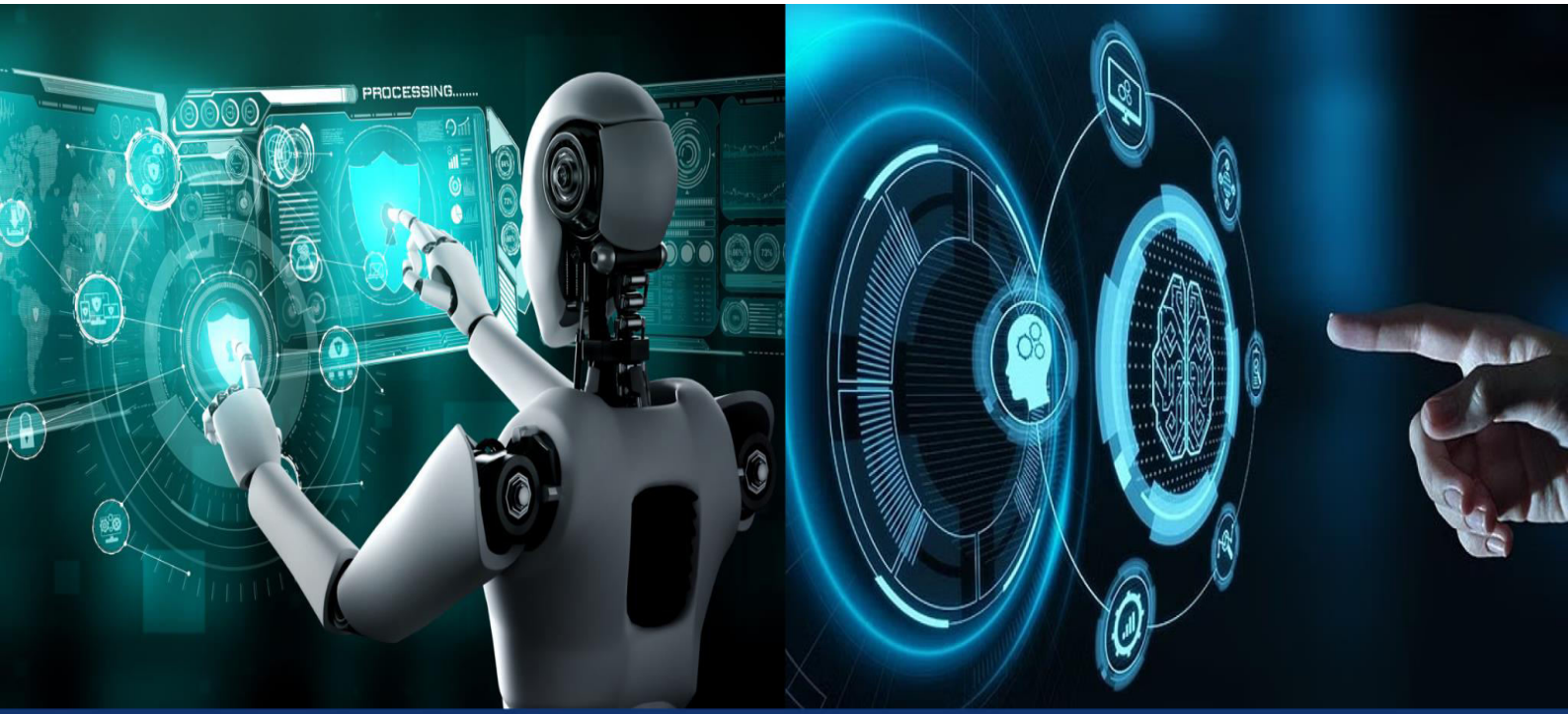

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Pharma Chain: Drug Supply Chain Security with Blockchain

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ABSTRACT: Pharma Chain merges the power of AI and blockchain to create a transparent and secure drug supply chain. The drugs will be tracked from manufacturing to the patients, preventing counterfeiting, ensuring authenticity of the products, and patient safety. Decreased drug counterfeiting, increased patient safety, improved efficiency and transparency of the pharmaceutical supply chain, and cost savings associated with counterfeit drugs and supply chain inefficiencies. Other than security, benefits of Pharma Chain include operational efficiency, cost savings, and improved collaboration among the stakeholders. Case studies and simulations are used to demonstrate the actual applications of Pharma Chain in different pharmaceutical supply chain settings. To build a private/permissioned blockchain network for secure data management and transaction tracking using Ethereum. For developing a user-friendly interface for interacting with the Pharma Chain platform using React/node.js.

KEYWORDS: Blockchain, Supply Chain, Counterfeit, Traceability, Supplier, Manufacturer, Distributor, Retailer.

I. INTRODUCTION

Pharmaceutical supply chain management plays a pivotal role in ensuring the delivery of safe, high-quality medicines to patients worldwide. However, this complex and globalized process is fraught with challenges, including counterfeiting, inefficiencies, and a lack of transparency. Counterfeit drugs, a significant threat to public health, account for billions of dollars in losses annually and pose life-threatening risks to patients. Traditional supply chain systems, reliant on centralized databases, are often vulnerable to data tampering, inefficiencies, and miscommunication among stakeholders.

Blockchain technology, with its decentralized, immutable, and transparent ledger, presents an innovative solution to these challenges. By securely recording every transaction and movement of a pharmaceutical product, blockchain ensures end-to-end traceability and accountability. When integrated with QR codes, this technology becomes even more powerful. QR codes serve as unique identifiers for each product, allowing stakeholders, including manufacturers, distributors, retailers, and consumers, to access real-time information about a product's origin, authenticity, and journey through the supply chain.

This integration enables efficient product recalls, combats counterfeit drugs, and enhances regulatory compliance by providing a tamper-proof, auditable record of the supply chain. Consumers, with a simple scan of a QR code, can verify a product's authenticity, fostering trust and confidence in the pharmaceutical industry.
This paper invokes literature survey regarding the blockchain technology, Methodologies and algorithms, execution flow how the product got delivered from manufacturing stage to end user that is patients,Analysis and results how the blockchain provides security to the data and transparency to to each stage of product transferring and letting us to know whether the product got reached to respective dealer,conclusion of the project.At last, the references are attached to know from where we take the details and data to evaluate the technology features.

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II. LITERATURE SURVEY

Anand, A. et al., The integration of blockchain technology into supply chains, as explored in various studies, highlights its potential to enhance traceability, transparency, and efficiency. Applications in dairy and other sectors emphasize its capacity to mitigate fraud, streamline operations, and build consumer trust. Challenges such as cost, awareness, and regulatory frameworks remain barriers to its adoption.[1]

Shuvam Shingh et al., The implementation of blockchain technology in the dairy supply chain enhances transparency, traceability, and trust among stakeholders. By enabling real-time data sharing and monitoring, blockchain ensures better consumer trust, compliance, and operational efficiency. It offers solutions to issues like adulteration and mismanagement, ensuring sustainable practices and higher accountability across the dairy industry[2]

Wasim Akram et al., Blockchain transforms pharmaceutical supply chains by ensuring product authenticity, enhancing traceability, and mitigating counterfeit risks. Its secure and immutable nature supports compliance, efficient cold-chain logistics, and transparent collaboration among stakeholders. This technology is pivotal in improving drug safety and trust, addressing global health challenges effectively.[3]

Hamma Adama et al., This study investigates how blockchain technology could help reduce counterfeit drugs in Nigeria's pharmaceutical supply chain. The researchers found that there is a high prevalence of counterfeit drugs and a significant lack of awareness about blockchain among stakeholders, which makes it difficult to adopt this technology. They concluded that before blockchain can be effectively implemented, the Nigerian government needs to improve the supply chain's structure and regulatory systems.[4]

Ganesan Subramanian et al., The current pharmaceutical supply chain lacks complete transparency, making it easier for counterfeit and substandard medicines to enter the market. To address this issue, the authors propose a mobile application that allows consumers to verify medicines by scanning a QR code on the product, creating a clear flow of information among doctors, manufacturers, resellers, and patients. This application uses a hybrid blockchain system to ensure secure tracking of medicines, while also integrating Internet of Things (IoT) technology to monitor storage conditions, like temperature, to maintain product quality.[5]

The below table (Table 1) depicts the literature survey conducted by reviewing existing research papers to understand the current State of knowledge in Blockchain Technology. The papers was published in reputated journals and conferences. The literature survey revealed the transparency while others explored scalability and security. The review of existing literature provided a solid foundation for the current study, which aims to provide the transparency to each stage of product manufacturing.

Table 1. Survey on relevant papers

Author Name	Publication & Year	Objective	Key Contributions	Limitations and Open issues	Reference
Anand K. Bapatlal et al.	Wiley - 2022	Develop a blockchain-based supply chain to combat counterfeit drugs.Enable realtime drug tracking using loT and blockchain. Improve data accuracy and reduce errors through automation.Ensure accountability with a tamper-proof ledger.	Introduces PharmaChain, integrating blockchain, loT, and Oracles.Employs Proof-of-Authority (PoA) for scalability.Implements Role-Based Access Control (RBAC) for secure access.Leverages hybrid smart contracts for real-time data integration.	Interoperability with existing systems.Privacy concerns with sensitive data on blockchain.Real-world scalability and energy efficiency testing.Dependency on third-party devices increases risks..	6

Sarmistha Sarna Gomasta et al.,	Heliyon - 2023	Create a blockchain-based PharmaChain to combat drug counterfeiting. Use Hyperledger Fabric for secure, scalable data management.Employ smart contracts for automating and verifying supply chain MansacOn	Develops a tamper-proof, secure blockchain solution for pharmaceutical traceability.Implements elliptic curve cryptography (ECC) and SHA-256 for data security. Uses smart contracts for seamless transactions and automated traceability. Introduces a three-tier governance framework for compliance and efficiency.	High setup costs for blockchain and loT infrastructure. Centrali zed Certificate Authority (CA) reduces decentralization.Limit ed focus on drug quality verification.Potential scalability issues for large networks.	7
Ganesan Subramanian et al.,	IEEE - 2020	Develop a hybrid blockchain-based solution to tackle counterfeit medicines. Ensure secure, transparent drug tracking with NEM blockchain and loT integration.	Combines blockchain and loT to enhance pharmaceutical supply chain transparency. Uses NEM blockchain features like namespace, mosaic, and QR codes for tracking. Integrates loT for real-time monitoring of drug storage conditions.	High costs for blockchain and IoT implementation. Limited focus on drug quality validation. Scalability challenges for global deployment. Requires technical knowledge for widespread adoption.	8
Kevin A. Clauson et al.,	Blockchain in Healthcare Today - 2018	To analyze the opportunities and challenges of blockchain adoption in healthcare supply chains, focusing on pharmaceuticals, medical devices, the Internet of Healthy Things (IoHT), and public health sectors, while aligning blockchain capabilities with regulatory frameworks.	Blockchain Applications: Identified use cases such as combating counterfeit medicines, securing medical devices, optimizing IoHT functionality, and improving public health supply chain resilience.	Early-Stage Deployment: Most blockchain initiatives remain in proof-of-concept or pilot phases, lacking real-world scalability. Regulatory Challenges: Compliance with healthcare privacy laws (e.g., HIPAA, GDPR) and alignment with existing policies require further exploration.	9
Ahmad Musamih et al.,	IEEE - 2021	To design a blockchain-based framework (PharmaChain) using Hyperledger Fabric to enhance traceability, prevent counterfeit drugs, and ensure data security, transparency, and compliance in the pharmaceutical supply chain, particularly addressing challenges in Bangladesh.	Hyperledger Fabric Framework: Proposed a decentralized architecture with on-chain (immutable ledger) and off-chain (identity repositories) storage mechanisms for scalability and reduced network traffic. Smart Contracts: Developed multiple smart contracts (e.g., registration, shipment, negotiation).	Scalability Constraints: While off-chain storage reduces network traffic, handling large-scale transactions across fragmented supply chains (e.g., small vendors) remains challenging. Privacy Concerns: Lack of case-specific ledgers with k-anonymity for data mining while preserving privacy.	10

Munyao Sharon Mwende et al.,	Uonbi - 2022	To design and implement a blockchain-based system (using Hyperledger Fabric) to enhance drug traceability, combat counterfeit drugs in the pharmaceutical supply chain, and enable end-consumer verification of drug provenance, with a focus on Kenya.	Hyperledger Fabric Framework: Developed a consortium blockchain network integrating stakeholders (manufacturers, wholesalers, retailers) to track drug movement. QR Code Integration: Enabled end-consumers to verify drug authenticity via QR codes linked to immutable blockchain records.	Does not apply to drugs sold without packaging or unique identifiers (e.g., loose tablets). Unable to trace counterfeit drugs distributed outside authorized channels. Real-World Applicability: Tested in a controlled environment; real-world scalability and stakeholder adoption challenges remain unaddressed. Data Privacy Regulatory Gaps	11
Kailash Chandra Bandhu et al.	Springer - 2023	The objective of this paper is to address the lack of transparency and tracking in traditional supply chains by proposing a blockchain-based solution for a healthcare supply chain track-and-trace mechanism.	The proposed system uses Ethereum blockchain-based smart contracts and data immutability to track goods' histories. The system's algorithms and methods are tested against a variety of inputs, and the results are presented as an average gas cost for specific functionality.	There is a challenge in getting all stakeholders to agree to the system, as they may fear losing their competitive edge in the market.	12

III. METHODOLOGY

Existing System:
Traditional pharmaceutical supply chains rely centrally on DBMS, which manage and track information in an efficient manner. These databases record every manufacturing, shipment, and selling record for drugs. Enterprise resource planning systems, relational databases, and cloud-based solutions are offered by various companies to store data and manage the supply chain. Though traceability and some degree of automation are provided through these systems, inherent vulnerabilities remain, such as data tampering, unauthorized access, and the lack of real-time visibility by stakeholders. The mechanisms among different database systems also poses an issue, leading to a limit on seamless sharing of data among manufacturers, distributors, and regulators.

Proposed System

We suggest that the current limitation of existing database systems within the pharmaceutical supply chain be mitigated through the implementation of a hybrid blockchain model. Such an approach takes the strengths of public blockchains and integrates them with those of private blockchains. Here, the key data concerning all drug movement shall be kept transparently on a public ledger to establish an immutable and verifiable history open to all. A private blockchain would enable secure and confidential business transactions between authorized entities, ensuring privacy while maintaining integrity. We aim to automate regulatory compliance, enforce contractual obligations, and streamline supply chain coordination through the integration of smart contracts. This framework empowers all participants in the drug distribution chain to independently verify the authenticity of each product, thus reducing reliance on centralized intermediaries.

This research presents a blockchain-based methodology to enhance security and prevent counterfeit medicine within the supply chain. By integrating decentralized technologies, we ensure authenticity at each transportation level, from manufacturing to end users.

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3.1 Connectivity of Ganache to MetaMask

To enable blockchain transactions and smart contract execution, we establish connectivity between Ganache and MetaMask. This setup allows users to interact with the system securely. The detailed process can be followed through the link provided [13].

3.2 Connectivity of Server

The backend server is responsible for handling requests and storing relevant metadata related to transactions and user authentication. The configuration and connection details are to done as per our requirement and here is a sample connectivity [14].

3.3 Interface for Tracking

The user interface (UI) provides a seamless experience for tracking and securing medicine from production to final delivery. The interface incorporates the following key steps:

IV. FLOW CHART EXPLAINING THE COMPLETE PROCESS

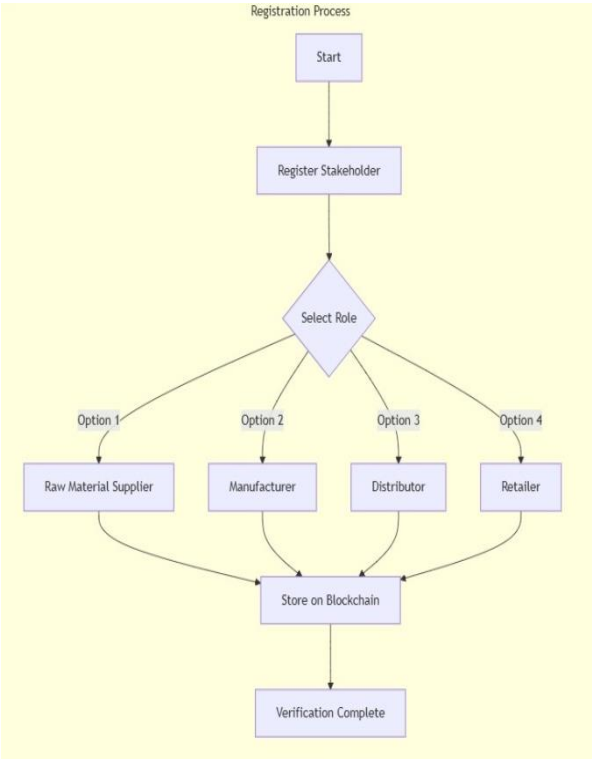

Fig-1. Registration Process

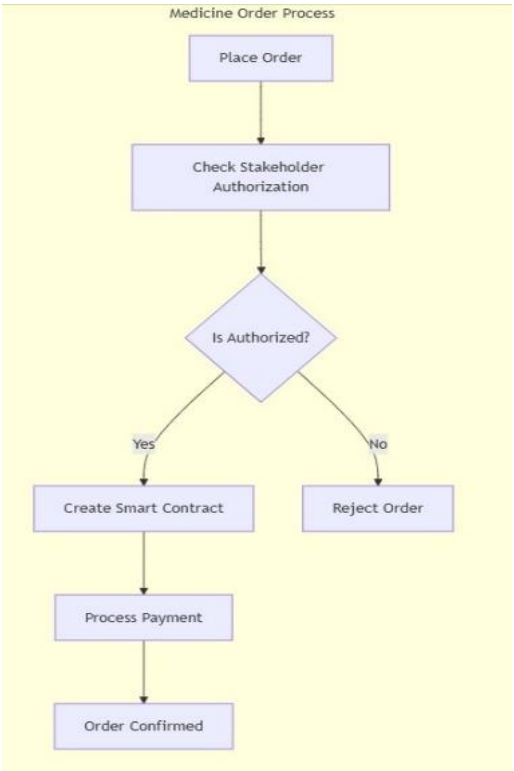

Fig-2. Medicine Ordering

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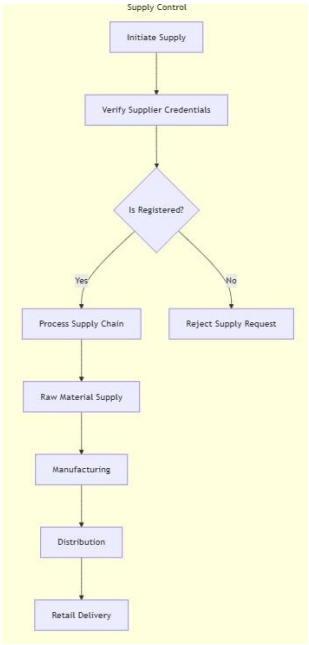

Fig-3. Supply Control

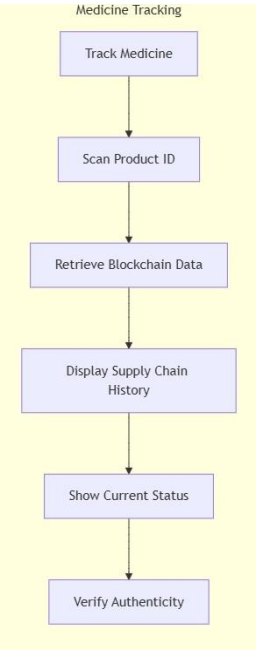

Fig-4. Tracking of Medicine

3.3.1 Registration

Registration is the fundamental step to ensure security using private keys from MetaMask. Every participant in the supply chain must register under one of the following roles:

- Supplier: Provides raw materials.

- Manufacturer Produces the medicine.

- Distributor: Ensures logistics and distribution.

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- Retailer: Sells the medicine to end users.

3.3.2 Ordering Medicine

Users can order medicines through the system by following these steps:

1. Search Medicine: Locate required medicine through the search functionality.

2. Select Medicine: Choose the required medicine from available options.

3. Choose Quantity: Specify the required quantity.

4. Add Medicine Details: Provide additional details such as purpose and description.

3.3.3 Supply Chain Control

A permissionless blockchain is used to maintain supply chain transparency. Every step requires connectivity to a MetaMask account for transaction verification. The supply chain is managed through the following steps:

1. Supply Raw Material: Assign a medicine ID, supply it via MetaMask, and confirm.

2. Manufacturer Processing: Perform Step 1 at the manufacturer level.

3. Distributor Processing: Perform Step 1 at the distributor level.

4. Retailer Processing: Perform Step 1 at the retailer level.

5. Mark as Sold: Finalize the process by marking the product as sold.

3.3.4 Medicine Tracking

Users can track medicine at every stage of the supply chain. Tracking is facilitated through:

- Transaction history at each stage.
- QR code verification for authenticity and traceability.

This methodology ensures transparency, security, and counterfeit prevention within the pharmaceutical supply chain.

V. RESULTS

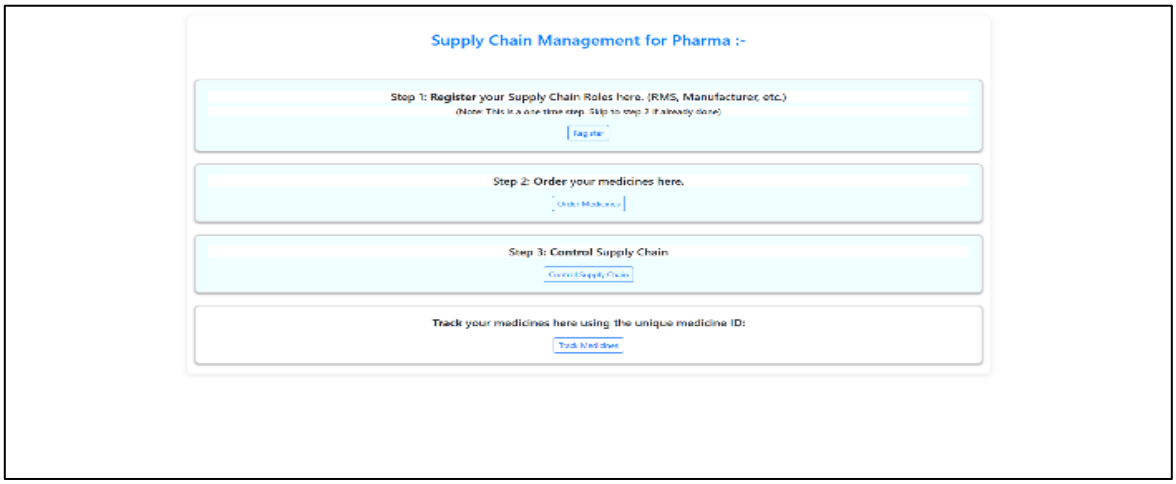

Fig 1: Home Page

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This Picture depicts the interface what we supposed to perform operations on Pharma supply chain. At each stage we need to register the intermediate stages of registration from manufacture of a certain product to end stage called tracing of product like whether in which process the medicine got traced.

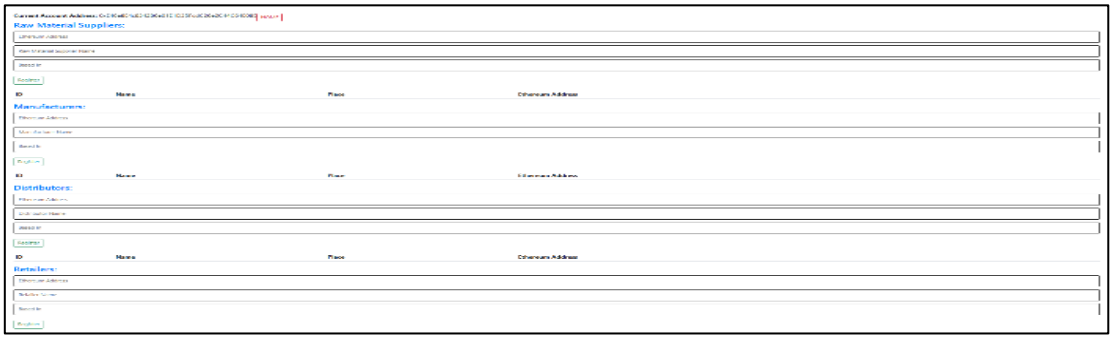

Fig 2: Registration Page

The Registration page includes manufacturing the product and at a certain place where the product needs to reach the end users. Here, we need to supply the Name of medicine and place where we need to deliver the medicine and we have to provide the Ethereum address.

Fig 3: Add Medicines Page

In this Page we can order the medicine by adding the features like medicine name and the usage of medicine and contribute the symptoms at which situation we use the respective medicine for a cause.

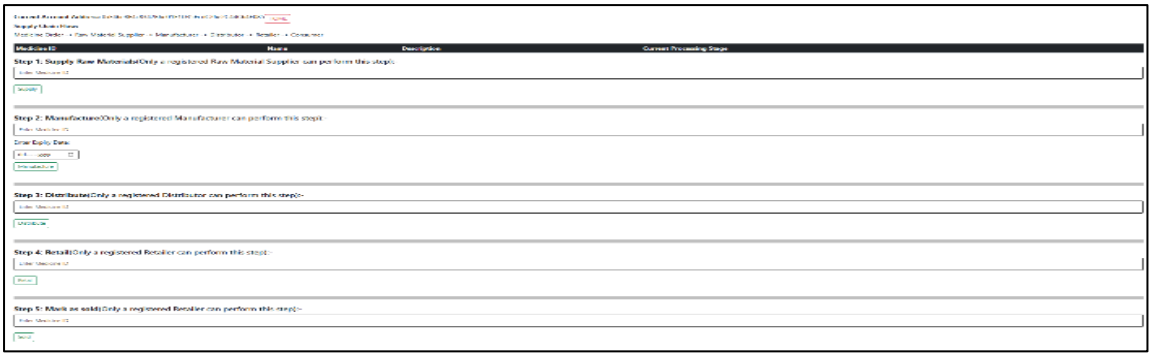

Fig 4: Supply Management Page

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This image hand over the details such as by contribute the medicine id and the stage of producers where we need to bestow the medicine and mark it as supply then the certain medicine got supplied to stage of generating medicine.

Fig 5: Tracking Page

This visual depicts the each stage of tracking a respective medicine in many ways through QR and by textual too. It bestows the clear visualization of tracing the medicine.

VI. CONCLUSION

The Pharma Chain project offers a whole fresh and creative way to use blockchain technology to protect the pharmaceutical supply network. From manufacturers to end users, the system improves openness, traceability, and security by including a hybrid blockchain model with automated agreements called smart contracts and QR code validation. This distributed system not only enhances regulatory compliance but also helps to build trust among stakeholders by so reducing the dangers of fake medications. Furthermore optimizing operational efficiency and lowering costs and inefficiencies related with conventional supply chain management is the application of AI-driven analytics and automation.

By guaranteeing drug authenticity, safety, and quality, Pharma Chain shows the useful application of blockchain in actual pharmaceutical environments. The technology solves important problems including data corruption, absence of real-time monitoring, and supply chain inefficiencies by offering a safe, unchangeable record of transactions. Future developments like more industry-wide adoption and AI-based predictive analytics could help Pharma Chain to further more effectively transform pharmaceutical shipping and guarantee worldwide drug safety.

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