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Blockchain Technology Based Traceable and Safe Pharmaceutical Supply Chain Framework: An Effective Method for Searchable Pharma Chains

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Abstract:

The paper explores the potential applications of emerging technologies to develop a blockchain-constructed pharmaceuticals supply chain traceability organization. In essence, a blockchain-based medication tracking system is vital for both government regulation and corporate operations. A reliable drug traceability system would make it simple for patients and those working in the drug supply chain to determine where the drug disappeared or has been. The drug traceability system is designed according to a number of concepts. First and foremost, the blockchain system for drug traceability must to accurately represent the supply chain's actual drug transaction logic, particularly with regard to drug-related data. Second, privacy and authenticity should be guaranteed by the drug traceability system. We propose Hyperledger Fabric, a potential blockchain-based decentralized architecture, to fulfill important medication traceability requirements, such as privacy, trust, openness, security, authorization and authentication, and scalability. We suggest, talk about, and contrast two possible drug traceability architectures: centralized and decentralized. We enumerate and discuss some open research questions related to medication tracking using blockchain technology. The pharmaceutical business can benefit from the suggested blockchain architectures.

Keywords: Block-chain Technology, Drug Traceability System, Supply Chain Technology, Pharmaceutical Industry, Hyperledger Fabric.

Introduction

1.1. Overview

In essence, a blockchain-enabled drug tracking system is vital for both government regulation and corporate operations. Patients and pharma supply chain participants can benefit from a trustworthy drug tracing system. Generally speaking, a traceability system for drugs should be able to track or monitor the movement of drug transactions across different supply chain partners. A ledger-enabled drug traceability platform is a completely scenario-oriented blockchain framework for regulating drugs and traceability. As time passes, it ultimately achieves reliable blockchain storage, rebuilds the entire service architecture, and guarantees the privacy and validity of traceability data. Additionally, algorithms that mirror the real-world operations of the pharmaceutical supply chain have been introduced.

The drug traceability system is designed according to a number of concepts. First and foremost, the blockchain system for drug traceability must to accurately represent the supply chain's actual drug transaction logic, particularly with regard to drug-related data. Second, privacy and authenticity should be guaranteed by the drug traceability system. Thirdly, in order to guarantee storage scalability over time, the blockchain system's data storage should not be endlessly expanding.

1.2. Motivation

A key topic in the context of sustainable development is the medication traceability system. The flow of drug transactions via various stakeholders in the drug supply chain is typically too complicated for a drug provider to monitor or trace. Blockchain technology makes it easy to track down the location of drugs.

Generally speaking, the practical needs of various scenarios (such as package and unpackaged), how to safeguard commercial data privacy when using public smart contracts, and how to minimize system storage are not taken into consideration at the proof of concept smart contract level. These issues are all otherwise covered in a blockchain-based drug traceability system. It will improve traceability and medication regulation. Over time, it accomplishes stable blockchain storage, rebuilds the entire service architecture, and guarantees the privacy and validity of traceability data.

1.3. Problem Definition and Objective

Drug counterfeiting has been a global problem for about 20 years, and current data indicates that counterfeit drugs will continue to infiltrate genuine pharmaceutical supply chains (PSCs). Therefore, recognizing the problems PSCs encounter is crucial to tackling the problem of counterfeit drugs, which would necessitate the use of technology in different PSC (Pharmacy Service Centre) phases to increase visibility. The goal is to put in place a drug tracking system for counterfeit medications in the pharmaceutical sector that is enabled by blockchain technology.

1.4. Research Scope and Limitations

The development of a blockchain-enabled drug tracking system for pharmaceutical industry counterfeits is the focus of our research. Drug traceability systems ought to be able to track or monitor the movement of drug transactions across different supply chain actors. Over time, it accomplishes stable blockchain storage, guarantees the privacy and validity of traceability data, and rebuilds the entire service architecture. Below, we go over some of these possible drawbacks of blockchain technology in healthcare supply chains.

- **Scalability:** Blockchain technology's inability to scale due to the fixed size of each data storage block is one of its primary drawbacks. Because of the 1 MB block size, only a small number of transactions may be kept on a single block.
- **Immaturity:** Since blockchain technology is still relatively new, people are not yet ready to invest in it and have little faith in it. However, a number of blockchain applications are succeeding in various industries, but more people must trust it before it can be fully utilized.

- **Energy Consuming:** The fact that it requires a lot of effort to validate any transaction makes it problematic. According to the survey, 0.3 percent of global electricity will have been used for blockchain-based transaction verification by 2018.
- **Time-Overwhelming:** To add the next block to the chain, miners must continually compute nonce values, which takes time and needs to be accelerated for industrial use.
- **Legal Formalities:** Some countries do not support the use of blockchain technology in the commercial sector and have banned its applications, including crypto currency, due to environmental concerns.
- **Storage:** Blockchain databases are stored on each network node, which creates a storage issue because more storage will be required as transaction volume rises.
- **Regulations:** Blockchain is problematic for certain financial institutions. Other technological elements will be required for blockchain to be widely adopted.

1.5. Different Research Methodologies of Problem Solving

1. Define the requirements: Clearly define the requirements and objectives of the drug traceability system using Hyperledger Fabric. Identify the entities and processes involved in the system, such as drug manufacturers, distributors, pharmacies, and regulatory bodies.
2. Design the network: Design the Hyperledger Fabric network architecture based on the requirements. Define the number of organizations, peers, and orders needed. Determine the network topology, consensus mechanism, and data privacy requirements (e.g., private channels, access control).
3. Create smart contracts: Develop smart contracts (also known as chain code) using a programming language supported by Hyperledger Fabric, such as Go, JavaScript, or Java. Define the necessary functions and data structures to facilitate drug traceability, including drug information, ownership transfers, and transaction history.
4. Implement the network: Set up the Hyperledger Fabric network infrastructure. Deploy the necessary nodes, including peers, orders, and certificate authorities (CAs). Establish the necessary channels and configure network permissions and access control policies.
5. Develop user interfaces: Create and create user interfaces for the various parties involved, including pharmacies, distributors, and manufacturers. Develop mobile or web-based apps that communicate with the Hyperledger Fabric network and let people monitor and confirm the legitimacy of medications.
6. Integrate external systems: If required, integrate the drug traceability system with external systems, such as existing supply chain organization systems or regulatory databases. Implement APIs or other integration mechanisms to enable data exchange and interoperability.
7. Test and validate: Conduct comprehensive testing to confirm the functionality, safety, and performance of the drug traceability system. Test the smart contracts, network communication, and user interfaces. Validate the system against different use cases and scenarios.
8. Deploy and monitor: Deploy the drug traceability system to a production environment, ensuring high availability and scalability. Monitor the network performance, transaction throughput, and resource utilization. Implement monitoring tools and mechanisms to detect and address any issues or anomalies.
9. Training and documentation: Educate stakeholders on the proper usage of the drug tracking system. To help users comprehend the features, procedures, and interfaces of the system, provide documentation such as user manuals and technical guides.
10. Continuous improvement: Iteratively improve the system, collect user input, and assess its performance on a regular basis. Updates, bug fixes, and improvements should be incorporated in accordance with user expectations and changing legal requirements.

2. Related Works

2.1. Literature Survey based on Blockchain Methodology

The new technology known as blockchain is quickly spreading throughout a variety of sectors, including finance, energy, government, and healthcare. A distributed ledger, or blockchain, is a decentralized peer-to-peer network system that keeps track of every transaction [1]. The fundamental behavior unit of blockchain is the transaction, which is commonly understood to represent the transfer of a digital asset that may have real-world significance. The replicated state machine's current configurations are based on previously agreed transactions. New transactions can be copied and eventually given to the blockchain system by executing the relevant set of replicated state machines, which frequently involves executing a consensus process and externally confirming the transactions [2]. The concept of a smart contract (if then) is part of blockchain. The terms of the buyer-seller contract are directly encoded into computer code in a smart contract, which is a self-executing agreement. The code and agreements are dispersed throughout a network of decentralized blockchains. The code controls how transactions are carried out, and they are tractable and irrevocable. According to the previously described blockchain criteria, a drug traceability system stores crucial data and information on the blockchain [3].

2.2. Challenges in the Supply chain

The pharmaceutical industry's main goal is to find, create, manufacture, and sell medications. However, there are some broad talks about how counterfeits affect the pharmaceutical sector. Based on PSI data, the regions with the highest rates of pharmaceutical counterfeiting in 2009 were Asia and Latin America, next to Europe, North America, Eurasia, the Near East, and Africa [4].

A medication can be classified as counterfeit if it has none of the recommended active ingredients, the correct active elements in the incorrect dosage, or the incorrect active ingredients altogether. The many stakeholders in the pharmaceutical supply chain—suppliers, manufacturers, distributors, retailers, pharmacies, and patients—make it very challenging to trace and confirm the origin of drugs. Distributing products usually requires intricate packing, unloading, and repackaging processes. As is well known, the supply chain is a network of individuals, processes, information, and resources that converts raw materials and components into finished goods and services and distributes them to clients. It includes suppliers, intermediaries, third-party service providers, and customers. Furthermore, it includes all aspects of logistics, marketing, sales, product design, finance, and information technology in addition to production operations [5].

2.3. Possible Solutions

It is a drug supply chain and blockchain integration system for drug control and traceability. It puts into practice the package, repackage, and unpackaged processes, which are crucial for the actual transaction logic and full traceability [6]. Together with a distributed digital ledger, the decentralized Blockchain technology securely, openly, and quickly records and transfers data. A blockchain-powered medication supply chain will rely on a reliable network optimized by blockchain [7]. Some architectures are based on two blockchain platforms, Hyperledger Fabric and Hyperledger Beau, because they provide a higher level of trust, decentralization, openness, security, confidentiality, data accuracy, deployment, modularity, and scalability than other blockchain platforms like Ethereum, Quorum, Big Chain, etc. In private permissioned blockchain-based systems enabled by these designs, pharmaceutical stakeholders and their end users may be registered, controlled, and regulated by a governing authority or a group of authorities/stakeholders [8].

The Ethereum blockchain platform was Musamih Ahmad's suggested remedy. Since Ethereum is permission-less public blockchain, anybody can use it. The Remix IDE is used to compile and test the Solidity-written smart contract. The remix is a web-based development environment that enables the user to write and run smart contract code as well as debug and test the Solidity code environment. The complete code is now openly accessible. Peer-to-peer networks and solutions have certain drawbacks, such as the Sybil and Eclipse attacks. A node in the network actively operates numerous identities at the same time in a Sybil assault, while in an Eclipse attack, an artificial environment is created around nodes [9].

This study suggests a brand-new, cutting-edge blockchain-enabled medical ledger system that uses chain codes, or smart contracts, to take use of the Hyperledger Fabric blockchain platform. Safe and efficient execution of medication supply chain transactions is made possible by the proposed medical ledger system in a fabric-enabled private permissioned distributed network comprising different pharmaceutical stakeholders. By doing away with the need for middlemen, a centralized authority, and transaction records, our proposed traceability approach increases safety and efficacy while maintaining high truthfulness, reliability, and privacy, which reduces the likelihood of tampering with recorded data on the medical ledger [10].

Researchers describe the PSC's product traceability issues in this paper and speculate that blockchain technology could provide a provenance, track, and trace solution that successfully lowers the incidence of fake medications. We propose Hyperledger Fabric and Beau, two potential blockchain-based decentralized architectures, to fulfill important medication traceability requirements, such as privacy, trust, openness, safety, authorizations and authentication, and scalability [11].

This paper provides a comprehensive examination of the various technical implementation aspects of blockchain-enabled SC traceability systems. The authors categorized the selected literature using a number of criteria, such as (a) the various areas of currently available blockchain-enabled SC traceability systems and the relevant methodologies employed; (b) the technical implementation details and the stage of development of these systems' implementations; and (c) the sustainability viewpoint (the economy, the environment, and socially conscious) that permeates these implementations [12].

In this study, an integrated five-layer Blockchain and Internet of Things-based smart tracking and tracing (BIoT3, to put it simply) infrastructure is proposed to provide a decentralized traceability solution in the drug supply chain. Implementing the five-layer blockchain platform architecture provides a practical roadmap for the pharmaceutical industry to achieve blockchain development, design, application, and evaluation. Additionally, three key enabling elements are introduced: smart contract-enabled medication services, on-chain and off-chain mechanisms, and IoT-based drug identity management [13].

In this study, we introduce PHTrack, a decentralized blockchain-based infrastructure that tracks drug supply chains using Hyperledger Saw tooth. Hyperledger saw tooth addresses scalability issues by offering a robust framework to manage extensive drug supply chain procedures in a modular fashion for all involved stakeholders [14].

This paper proposes a blockchain-based pharmaceutical supply chain architecture that is secure, efficient, and traceable. The proposed method is built on smart contracts and tracks how all entities supply and record relevant events. As a result, everyone concerned may remain informed about the most recent developments and ensure a safe supply of pharmaceuticals free from counterfeiting and supply record forgeries. Additionally, to provide effective traceability, we use multiple chunk replications of the records and parallel search, which efficiently searches the blockchain network's stored records [15].

3. Proposed Research Methodology

As seen in Figure 1, this section presents and talks about a blockchain-based architecture that meets significant requirements for medicine traceability. A blockchain-enabled drug traceability platform is one type of system that monitors and verifies the movement of pharmaceutical drugs along the supply chain. This can guarantee that patients receive safe and efficient treatment while also assisting in the decrease of counterfeit drugs. Depending on the particular implementation, a blockchain-enabled medication traceability system's architecture can change. But generally speaking, such a system will include the following elements:

- **A blockchain platform:** This technology serves as the foundation for the traceability system. It provides a safe, immutable, decentralized ledger for monitoring and verifying the movement of drugs across the supply chain.
- **Drug traceability records:** These records are stored on the blockchain and are required to track the movement of pharmaceuticals along the supply chain. These documents might contain details on the drugs' manufacturer, batch number, expiration date, and destination.
- **Contributors in the supply chain:** These are the different parties, including pharmacies, wholesalers, and distributors, which are engaged in the transportation of medications from the producer to the patient. To record and validate drug traceability records, each of these participants will require access to the blockchain platform.

Here the rules and logic that control the flow of medications through the supply chain may be encoded using chain code, sometimes referred to as smart contracts, in this blockchain-enabled drug traceability system architecture. The business rules and limitations that apply to transactions on the blockchain are defined by chain code, a program that runs on top of the blockchain platform. Chain code could be used in a drug traceability system to specify guidelines such who can update drug traceability records, what data must be entered into them, and how the records should be checked and validated. Chain coding can be used to create a transparent, responsible, and unbreakable method for tracking the movement of pharmaceuticals across the supply chain.

The SHA-256 cryptography hash function can be used by chain code to generate secure and distinct identification for drug traceability data. The SHA-256 function is a widely used cryptographic algorithm that takes an input of any length and produces a fixed-length output (called a "hash") that is unique to that input. This enables supply chain manufacturers to give each drug tracking record a distinct, tamper-evident identification that can be used to confirm the integrity and authenticity of the record.

The SHA-256 function can be used in chain code software for purposes other than creating unique IDs for drug traceability data. For example, it might be used to create secure electronic signatures for blockchain transactions, verify the integrity of data stored on the blockchain, or facilitate secure interaction between supply chain participants.

Once a drug is manufactured, it must be labeled with the manufacturer's unique ID, the drug's name, composition, and other information, as demonstrated in architecture. The medications will now be transferred from the manufacturer to the distributor. Patients can now receive the medications, or they can be purchased from pharmacies. The consumer may be able to learn every detail about a drug, from its source to the final user, just by scanning a QR code on the packaging. In such a system, each drug traceability record could be associated with a unique QR code that encodes the record's hash value. When a consumer scans the QR code on the drug packet, the system could use the encoded hash value to retrieve the corresponding drug traceability record from the blockchain and display the relevant information to the consumer. This could include details such as the manufacturer, batch number, expiration date, and destination of the drug, as well as any other relevant information that is recorded in the traceability record.

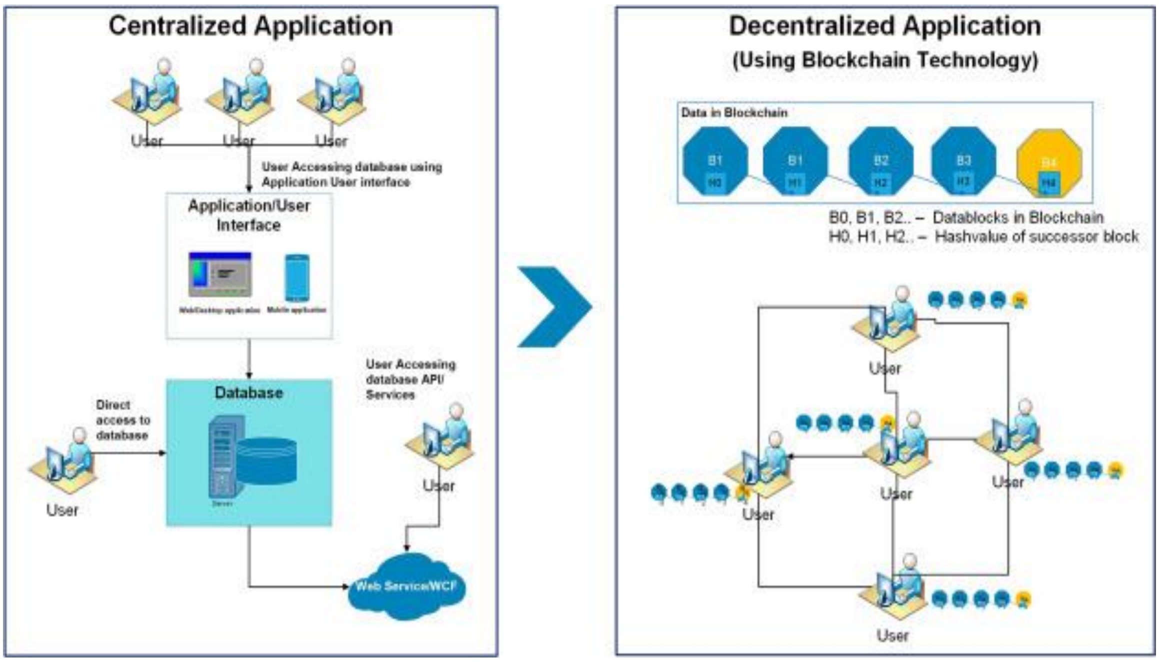

Figure 1: The purposed research architecture [5].

The consumer would require a device that can scan QR codes and access the blockchain platform in order for this to function. This could be a smartphone with a QR code scanning app and a blockchain wallet, or some other type of device that is equipped with the necessary capabilities. The consumer would also need to be connected to the internet in order to access the blockchain platform and retrieve the drug traceability records.

All things considered, this approach may give consumers greater control and openness regarding the pharmaceutical manufacturing process since they can easily verify the authenticity and provenance of the drugs they are taking. Additionally, it could guarantee that patients obtain safe and efficient treatment and aid in the decrease of counterfeit drugs.

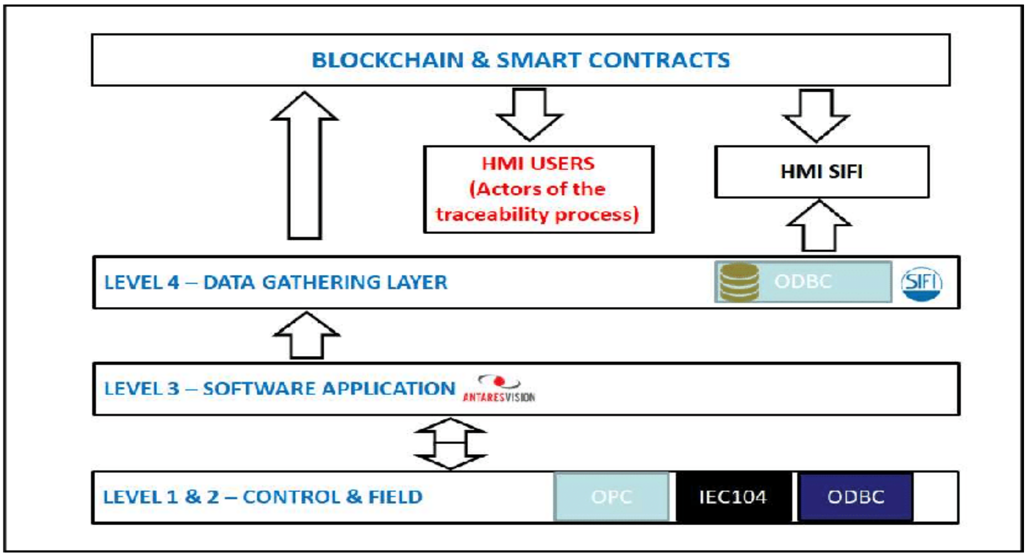

Figure 2: Internal system architecture of blockchain-enabled drug traceability system [6]

3.1. MATHEMATICAL MODEL

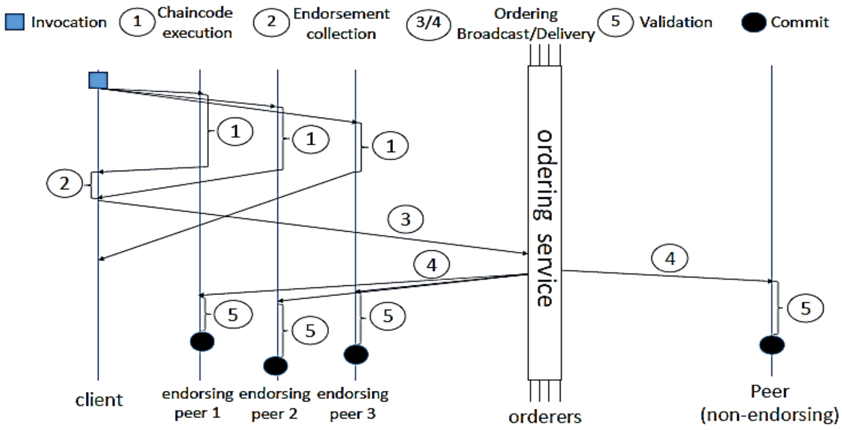

Figure 3: The scientific model of chain code [10].

- A transaction is submitted to the network. The transaction is first processed by the chain code on the endorsing peers. The endorsing peers then sign the transaction, which indicates that they have verified the transaction and agree with the changes that it makes to the ledger data. As seen in Figure 3, the ordering service receives the signed transaction after which it orders the financial transactions and broadcast them to every peer in the network. The peers then execute the chain code and update their local copy of the ledger data.

4. Implementation Details

- **Super Admin:** This module is responsible for creating and managing the network. They can add and remove participants, and they can create and modify channels.
- **Pharmaceutical:** Drug manufacture is the responsibility of this module. They are able to track the movement of their drugs along the supply chain and create and distribute medical tokens. Along with creating and managing drug carts, customers can also add and update drug information.
- **Distributor:** This module is responsible for distributing drugs. They can receive drug tokens from pharmaceutical, and they can deliver them to customers. They can also view all drugs and carts, and they can give status to pharmaceutical if cart is received.
- **Customer:** This module is responsible for purchasing and using drugs. They can confirm a drug's provenance and legitimacy by scanning its QR code.

The following are the interactions between the modules:

The network is created and participants are added by the super admin. Pharmaceutical firms create, disseminate, and track the movement of their drugs along the supply chain using drug tokens. Pharmaceutical companies give medicine tokens to distributors, who then deliver them to customers. To confirm the legitimacy and provenance of a medicine, a customer scans its QR code.

4.1. Algorithm Details

4.1.1. Kafka ordering service consensus algorithm is used in a Hyperledger Fabric

A pharmaceutical business records the batch quantity, manufacturing date, and date of expiration when it produces a new batch of medication. The purchasing service, which uses the Kafka consensus method, receives the transaction before it gets uploaded to the blockchain. After receiving the transaction, the Kafka ordering service publishes it to every network node. After receiving the transaction, each node verifies it in accordance with the guidelines specified in the smart contract. The ordering service receives an acknowledgement from the majority of nodes after the transaction has been verified. The ordering service adds the transaction to the blockchain after a predetermined number of nodes have acknowledged it. The ordering service announces the new block to every network node and adds the transaction to the blockchains subsequent block. After receiving the new block, every node verifies the transactions contained within. The ordering service receives an acknowledgement from the majority of nodes after they have verified the new block. Once a certain number of nodes have recognized the new block, the ordering service adds it to the blockchain. The process is repeated each time a new block or transaction is added to the blockchain. The drug traceability system may guarantee that transactions are verified by the majority of network nodes prior to being added to the blockchain by utilizing the Kafka ordering service consensus method as shown in Figure 4. This adds another degree of protection and keeps transactions from being uploaded to the blockchain that are fraudulent or incorrect.

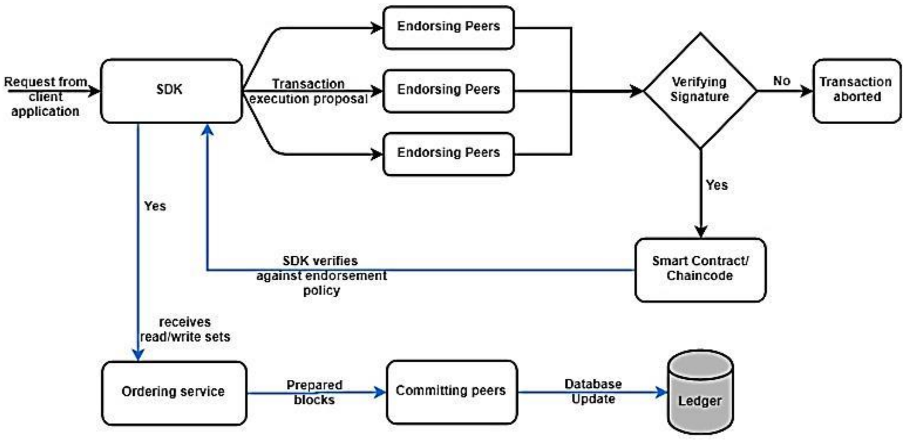

Figure 4: Consensus Algorithm Used in Hyperledger Fabric [12]

4.1.2. Secured Hash Algorithm-256

A drug tracking system enabled by the Hyperledger Fabric blockchain uses the SHA-256 hash mechanism. In a transaction, a pharmaceutical company manufactures a new batch of medicine and logs the consignment number, manufacture date, and expiration date. The SHA-256 hash function is used to hash the transaction before it is posted to the blockchain. The transaction data is represented by the hash value, which is a fixed-length string of characters. After that, a new block with the hash value is added to the network.

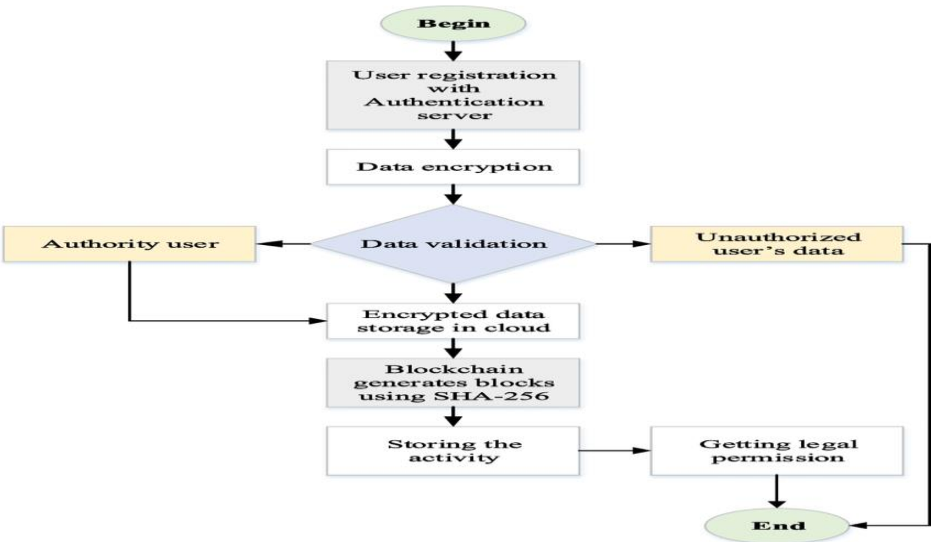

Figure 5: Flow diagram of SHA-256 hash function in blockchain [16]

Using their preferred consensus mechanism, the network's nodes assess the transactions in each new block and decide which order to add them to the blockchain (e.g., Kafka ordering service). Once a consensus has been reached, the hash value is calculated and added to the next block, and the new block is added to the blockchain. Any changes made to the transaction data, like manipulating the expiration date, would result in a new hash value. This makes it nearly impossible to change the transaction data without anyone noticing. The drug traceability system can guarantee this by hashing transactions using the SHA-256 hash function prior to their inclusion in the blockchain as shown in Figure 5.

4.1.3. Consensus Algorithm PBFT

A distributed networking system feature called Byzantine Fault Tolerance allows us to recover networks in the event that some nodes are unable to provide accurate information. The primary goal of Byzantine Fault Tolerance is to offer protection against system failure. Reducing the problematic node is another goal. In spite of malevolent nodes running within the system, PBFT attempts to offer a workable Byzantine state machine replication as shown in Figure 6. In a distributed system with PBFT capability, one node is the primary (also called the leader node), and the remaining nodes are called secondary (also called the backup nodes). Notably, every eligible node in the system has the ability to move from secondary to primary status, typically in the case of a primary node failure. The goal is for all reliable nodes to help reach a consensus regarding the present state of the system by applying the majority rule.

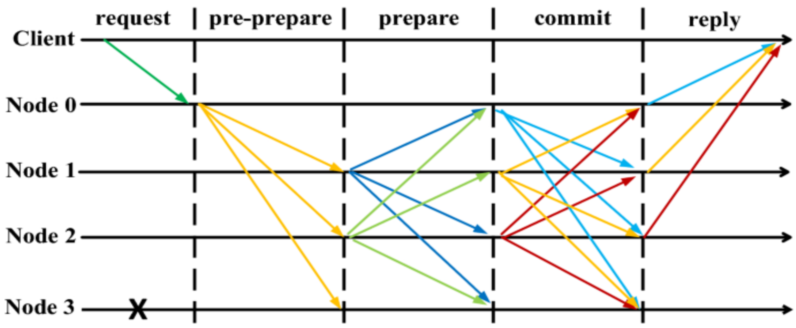

Figure 6: Practical Byzantine Fault Tolerance [13].

5. Results and Discussions

Implementing a drug traceability system using blockchain can provide several outcomes, including:

- **Improved supply chain transparency:** Blockchain technology can offer an unchangeable record of each drug transaction and movement along the supply chain. This can increase traceability and transparency and facilitate the detection and resolution of problems like product recalls or fake medications. Enhanced productivity and cost savings: Blockchain can automate a number of manual drug traceability procedures, including tracking and recordkeeping. This can save time and money, increase efficiency, and decrease errors.
- **Enhanced security:** Blockchain technologies distributed and decentralized architecture may improve supply chain security for pharmaceuticals. By using cryptography to secure transactions and data, blockchain can help prevent data manipulation and hacking, protecting the confidentiality of the supply chain for pharmaceuticals.
- **Better regulatory compliance:** Blockchain technology has the potential to simplify regulatory compliance, including FDA and DEA standards. Blockchain can assist guarantee that medications are appropriately tracked and accounted for by offering an unchangeable and transparent record of drug movements and transactions. This can make regulatory compliance easier.

- **Improved patient safety:** Blockchain can lessen the possibility that patients would receive tainted or fake medications by enhancing supply chain traceability and transparency. This can improve patient safety and lessen the chance of disease or harm.

Overall, implementing a drug traceability system using blockchain can provide several benefits that can help improve supply chain transparency, efficiency, and security, while also enhancing regulatory compliance and patient safety.

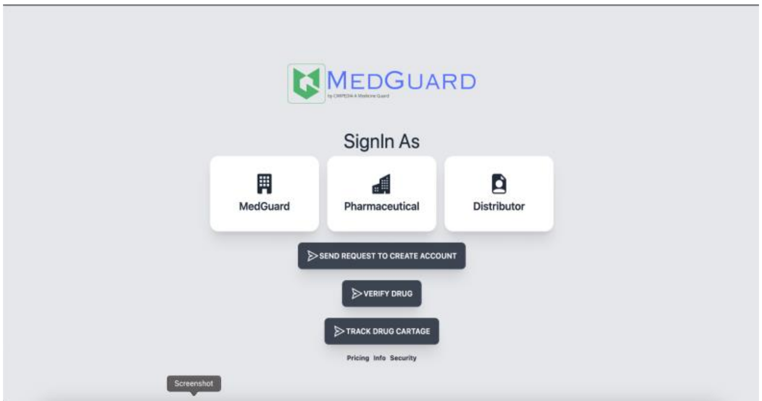

Figure 7: Sign in page

The sign in page is the main page which consists of the three options to sign in as shown in Figure 7. MedGuard admin, pharmaceutical, distributor. Along with the request to create account for the new user.

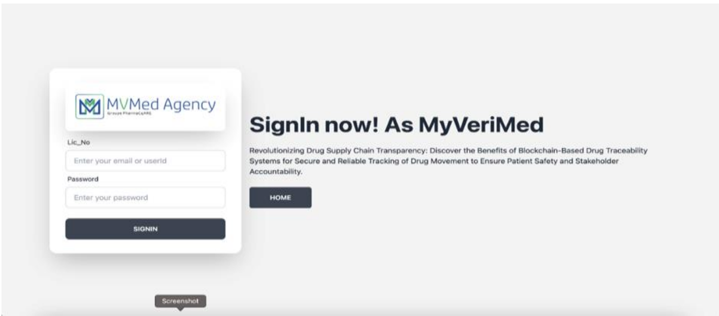

Figure 8: MyVeriMed sign in page

The sign in page for the MyVeriMed to check the drug details, to login the license number which is used for the registration is required with password to login successfully and see the details as shown in Figure 8.

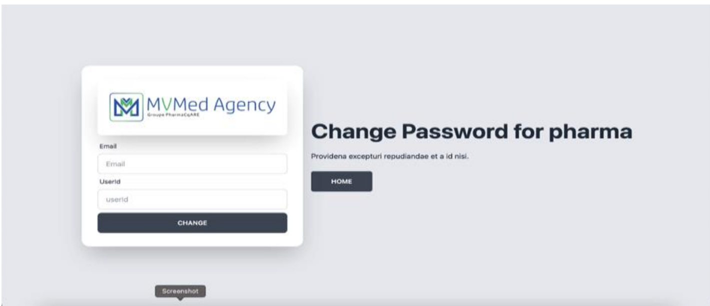

Figure 9: The password changes page

To change the password of the pharma there should be registered Email id and user-id to make change as shown in Figure 9.

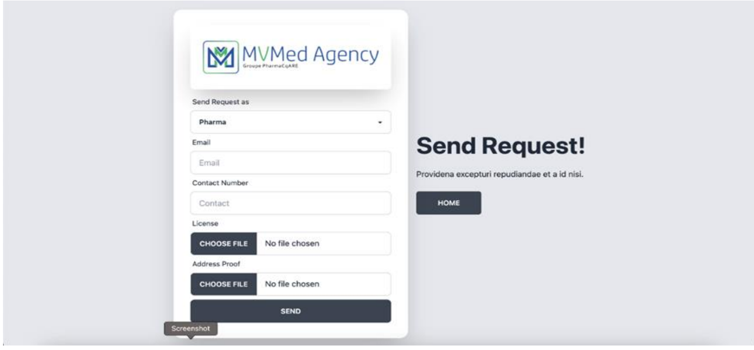

Figure 10: Request to create account.

To create new account or user to the system various details along with file should be provided then request to create an account is sent as shown in Figure 10.

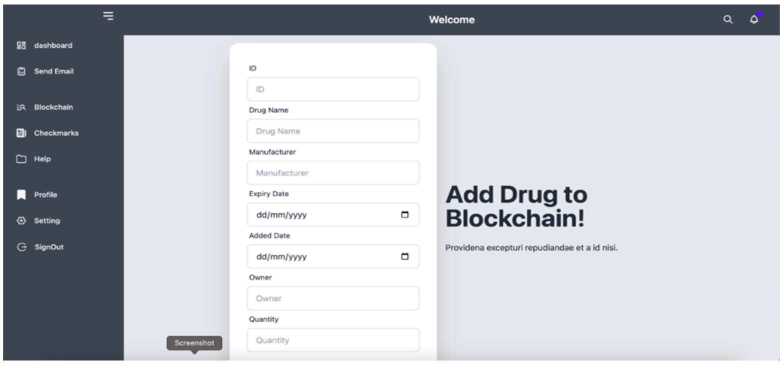

Figure 11: Add drug to blockchain

To add the drug to the blockchain Id, drug name along with manufacturer and dates etc. are required which will be further stored in the blockchain and accessible by admin as well as the pharmaceutical to track the drug as shown in Figure 11.

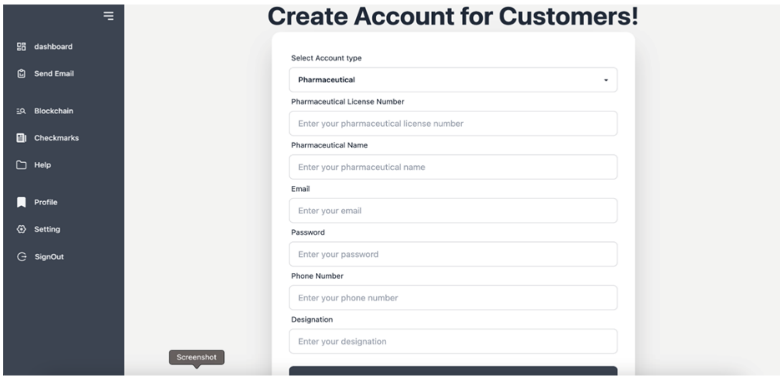

Figure 12: The create account for customers.

To create account for the customers there is need to provide the various details and afterwards customer will be able to see the drug details as shown in Figure 12.

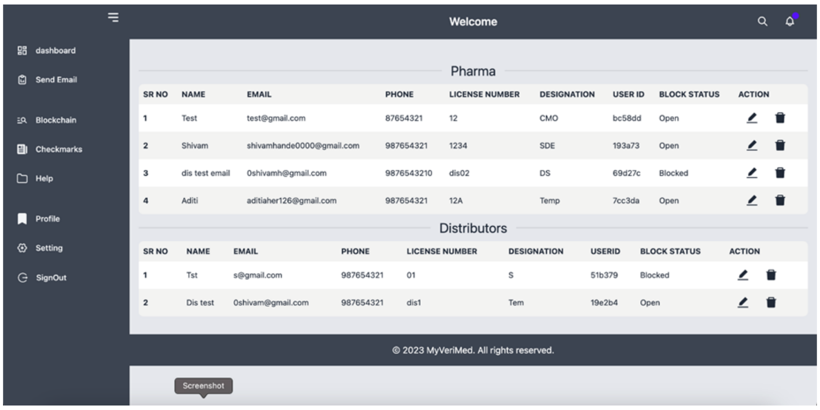

Figure 13: The database or dashboard for the pharma and distributor

After creating the pharma and distributor accounts data is stored along with the other details and it is accessible only to admin as shown in Figure 13.

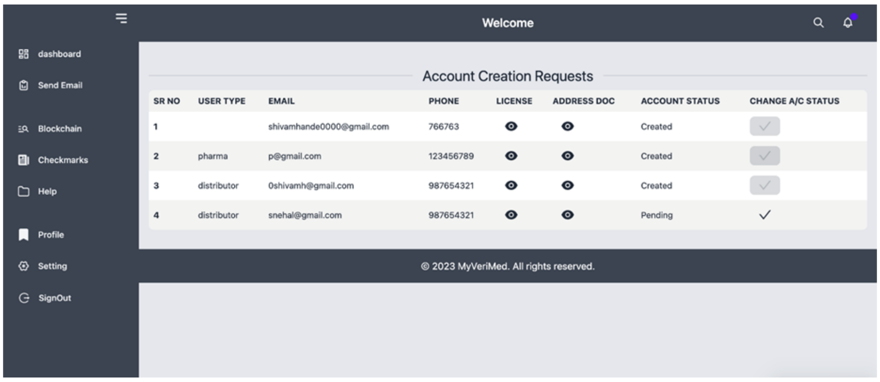

Figure 14: The account creation request

Account creation request for various user types and their data with the account status of it as shown in Figure 14.

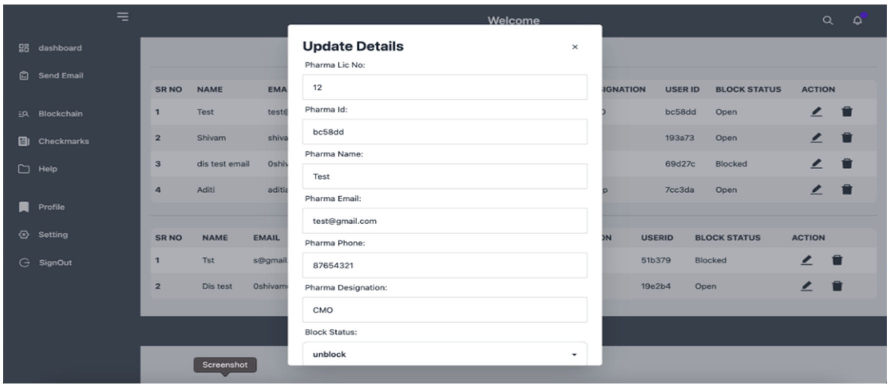

Figure 15: The update details for pharma

You can change the details of pharma details along with other details by providing the correct information entered while account creation and along with it along can check the block or unblock status of it and all this information is accessible and visible to the administrator as shown in Figure 15.

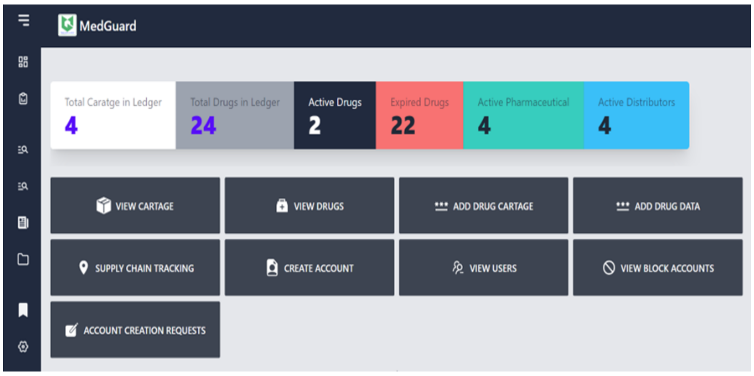

Figure 16: The dashboard for MedGuard

This is the generalized dashboard gets after logging in into the MedGuard as shown in Figure 16. This gives more information about, total cartage in ledger, total drugs in ledger, active drugs, expired drugs, active pharmaceutical, active distributors.

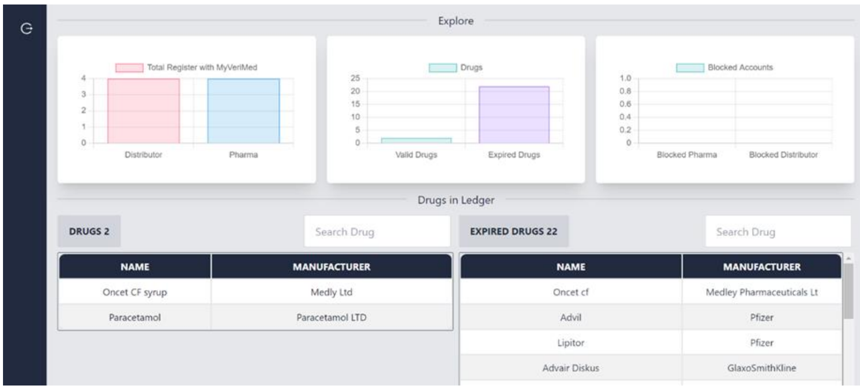

Figure 17: The graphically representation of distributor's vs. pharma and valid drug vs. expired drugs

Those bar graphs contains general information of the number of registrations of distributor's vs. pharma and distribution of numbers, also the bar graph of the valid drug vs. expired drugs and blocked accounts as shown in Figure 17.

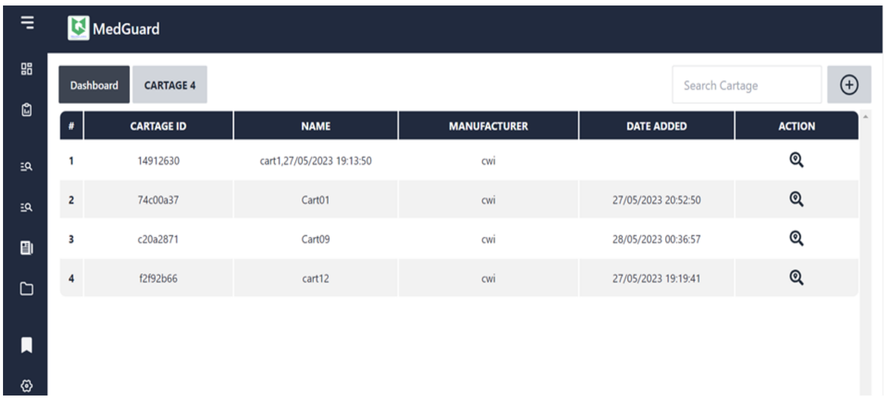

Figure 18: The view drug cartage

Dashboard of view drug cartage consists of the cartage id along with the name, manufacture id date added and action of the cartage as shown in Figure 18.

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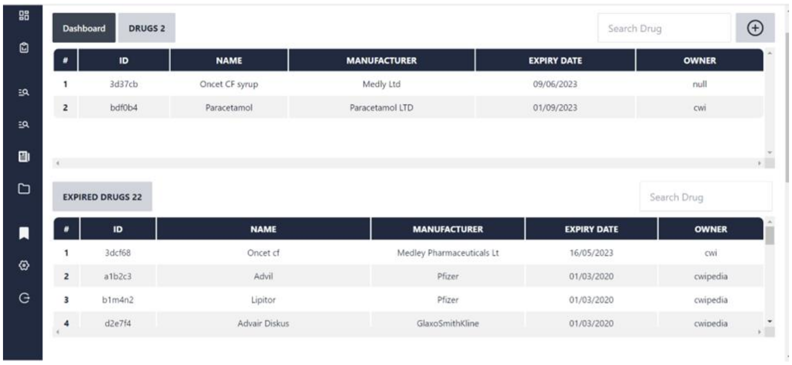

Figure 19: The view drugs

View drugs dashboard consist of the two components unexpired and expired drugs along with its more details like id, name, manufacturer, expiry date and owner as shown in Figure 19.

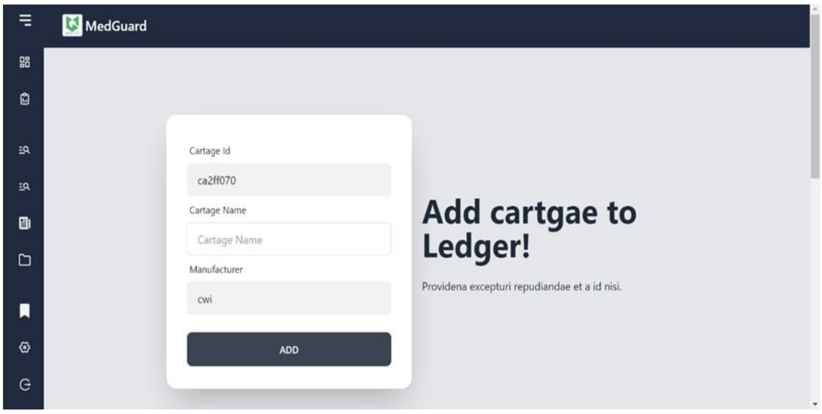

Figure 20: The add drug cartage

Add drug cartage consist of all procedure of adding the whole drug cartage to the system and to add there is need to provide cartage id, cartage name and the manufacturer as shown in Figure 20.

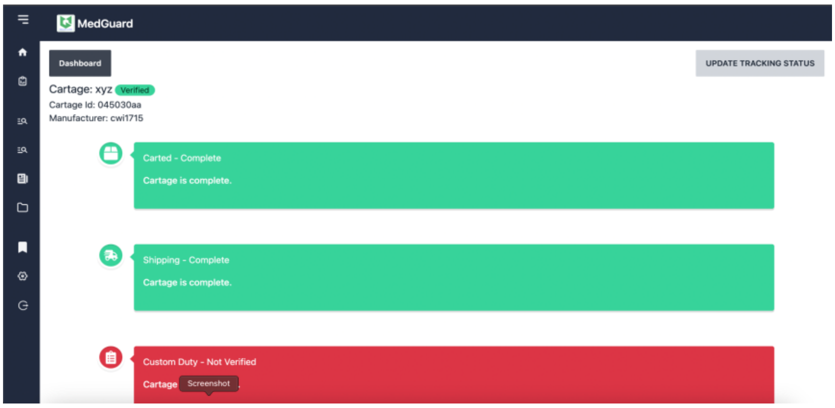

Figure 21: The supply chain tracking

Supply chain tracking is used to track the cartage which is in the market this consist of the cartage id, name of cartage along with manufacturer, date added and action which is to track.

6. Conclusion and Future Work

Throughout this study, we discuss how blockchain technology could help trace pharmaceuticals throughout the supply chain to prevent counterfeiting. Here, we proposed blockchain designs based on Hyperledger. Some of the key characteristics and needs that these systems can provide include safety, confidentiality, accessibility, transparency, and scalability. Additionally, they provide a decentralized, trustworthy, permissioned, and shared platform for storage and communication amongst different pharmaceutical supply chain participants. We contrast the two platforms and enumerate some practical challenges that hinder the widespread adoption of blockchain technology for effective drug tracking. As part of our work plan, we intend to create smart contracts, implement the system's general components, and create user interface DApps for the suggested designs.

Blockchain technology is expected to be used in drug traceability systems more frequently in the future as more pharmaceutical businesses and government organizations become aware of its potential advantages. In subsequent research, we will enhance the blockchain system's trust mechanism even more and add machine learning and artificial intelligence to the system's current capabilities. We also intend to work on drug strip traceability in the future.

7. Applications

- **Pharmaceutical Industry:** Pharmaceutical firms can use our technology to track and trace medications from production to distribution, improving supply chain visibility and guaranteeing regulatory compliance.
- **Drug Authentication:** Customers and medical professionals can access blockchain data to confirm the legitimacy of medications, lowering the possibility of fake goods and enhancing patient safety.
- **Government Oversight:** Regulatory agencies can use your system to keep an eye on and control the pharmaceutical supply chain, guaranteeing adherence to safety regulations, stopping the illegal drug trade, and lowering the possibility of inferior or out-of-date medications reaching the market.
- **Healthcare Institutions:** In order to improve patient safety and lower the possibility of medication errors, hospitals and other healthcare providers can utilize your system to confirm the integrity and authenticity of the medications they purchase.
- **Research and Development:** The system can be used by pharmaceutical research organizations to monitor the supply chain for study materials, guaranteeing data integrity and transparency all the way through the development process.
- **International Trade:** Through offering a safe and open platform for confirming the legitimacy and caliber of imported medications, our system can lower barriers and boost confidence, thereby facilitating the cross-border drug trade.

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