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Anti Drug Counterfeit Using Blockchain Technology

C G Nivetheni, S Saagarika and Dr.A. Kannammal

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Nivetheni C.G.[1], Saagarika S.[2], A. Kannammal[3]
[1,2]*M. Sc Decision and Computing Sciences,*
[3]*Department of Computing (Decision and Computing Sciences),*
[1,2,3]*Coimbatore Institute of Technology, Coimbatore, Tamil Nadu.*
[1]nivethenisekar5@gmail.com
[2]saagarikas042000@gmail.com
[3]kannammal@cit.edu.in

1. Abstract

According to a WHO report, about 10.5% of prescription drugs in low/middle income countries are counterfeit, and such drugs can pose a serious threat to public health, sometimes leading to death. Keeping this threat in mind, this paper proposes a blockchain-based model to track the movement of drugs from the industry to the patient and reduce the likelihood of drug counterfeiting. Reasons for using blockchain technology include the immutable nature and ease of tracking organizations in the supply chain. Through this proposed model, manufacturers can upload the relevant details of the drug, after which hospitals and pharmacies can approve drugs according to their requirements. To implement this model, the Ethereum Blockchain is used because it is more proofed than existing protocols. The implementation of the proposed blockchain-based model shows that the model can successfully detect counterfeit drugs of any kind. It will be useful for users affected by fake medicine. In addition, we can track the movement of a drug from the factory to the patient who uses the drug.

Keywords: Blockchain, counterfeit, drug, Ethereum, Supplychain

2. Introduction:

Pharmaceutical companies track their suppliers, verify the quality and authenticity of their supply chain, and ensure high-level quality control. Still, it is difficult to guarantee full protection against criminal activity – at least it has been so far.

Today, blockchain technology can offer full protection against counterfeit drugs entering the supply chain. Its advantage lies in the inherent functionality that allows data to no longer be stored centrally. Instead, this data can be stored in a distributed network of nodes in a decentralized database. Each record is individually encrypted. Any changes must be verified by all nodes in the system, so blockchain solutions are virtually impossible to hack as the data cannot be manipulated afterwards.

Blockchain technology therefore makes it much easier to detect fraud and identify weak links. Thanks to this, companies can gain full transparency of their supply chain. The technology also opens up the possibility for each customer to verify the authenticity of the purchased medicines — for example, by scanning the QR code on the packaging through the app. Every buyer can easily find out whether their product is real or fake. Blockchain technology thus increases not only the protection of the trademark, but also the safety of products and patients.

In addition to combining distributed ledger technology with QR codes, blockchain solutions are also compatible with other technologies. To achieve even better protection against counterfeit drugs, it can be combined with RFID or GPS technologies that are based on contactless data transmission. Thanks to such combinations and integration into existing systems, blockchain can be adapted to the individual requirements of each company and brings many advantages.

Ensuring the authenticity of products at the highest level is possible only with the help of blockchain technology. It also serves as an effective deterrent to counterfeiters, as it is relatively easy to detect exactly where counterfeits may have entered the supply chain. Blockchain is rightly gaining the attention of companies during this crisis. After being downplayed and associated only with cryptocurrencies for a long time, it is now recognized as providing the necessary transparency and security that can help save lives.

3. Problem Identification

Counterfeit drugs imperil patients around the globe, and their penetration across the globe is increasing over time. In addition to inserting counterfeit drugs in the legitimate drug supply, the rogue Internet pharmacies and the consumers who purchase while traveling abroad, allow counterfeit drugs to endanger patients. Pharmacists across the globe need to understand the nature and severity of the issue and must directly counter it through personal actions to secure a legitimate drug supply. It can be done by using verified distributors, examining the shipment packaging, product packaging, the bottles they are stored in, and the label for evidence to determine if it is counterfeit or has been tampered with. They can also indirectly counter through patient education and by working with other key stakeholders in the healthcare system. Given the risks to patients, pharmacists play an important role in limiting the use of
counterfeit medicines by patients.

4. Literature Survey

I. Sudeep Tanwar et al. (2019) “Automating COVID19 vaccine forward supply chain”:Elsevier, proposes a blockchain-based decentralized solution for COVID-19 medical equipment by automating forward supply chain processes. A fully trustworthy, transparent, traceable, and secure information exchange during waste management is

provided among all the stakeholders. Integration of interplanetary file systems (IPFS) with the Ethereum blockchain is proposed. By using IPFS, secure decentralized storage to securely store, fetch and share the data related to the COVID-19 forward supply chain is well defined. However, vaccination data and its supply chain is missing in this work.

II. Alshahrani et al. (2022) "Assessment of Blockchain Technology Application in the Improvement of Pharmaceutical Industry": IEEE, discusses the assessment of blockchain applications to improve the pharmaceutical industry. The authors used quantitative analysis methods to collect data. They found that the main hindrances to blockchain application in the pharmaceutical industry in Saudi Arabia were healthcare professionals' perceptions, lack of cooperation, and economic inequality. The authors also identified factors that could facilitate blockchain applications, including system robustness, data safety, improved supply chain management, decentralization, interoperability, and government policies and laws. However, the paper did not discuss anything related to blockchain technology, issues, and challenges.

III. Alaa A. Abdalrazaq et al. (2021) "Tracking system for COVID-19": Elsevier, a very well-defined and a trusted tracking system for COVID-19. Their work proposes an improved data management system for clinical trials, reduced delay in regulatory approvals, and transparent, immutable, and secure communication between all stakeholders in the supply chain. The data relating to new cases, recovered cases, and deaths collected from many external trusted sources are stored on the Ethereum blockchain. However, in the medical supply chain traceability of only PPE kits and other medical supplies has been explained, the cost of transactions is high and no implementation of DApps.

IV. Antal et al. (2021) "COVID-19 vaccine supply management": IEEE, is an Ethereum based monitor and tracking system implemented on the ropsten network. It gives a detailed view of COVID-19 vaccine registration, storage, and delivery, and after that side effects self-report. All handling rules given by vaccine manufacturers are kept assured in a smart contract.

V. Uddin et al. (2021) "Blockchain for drug traceability": SAGE, discusses the architectures and challenges of using blockchain for drug traceability. They discussed issues related to product traceability in the pharmaceutical supply chain and highlighted solutions for the effective use of blockchain technology in tracking and tracing to mitigate counterfeit medications. Apart from the pharmaceutical supply chain, the authors did not discuss blockchain technology or the issues and challenges related to other domains of the technology's applications in the pharmaceutical industry.

VI. Bryatov, S et al. (2019) “Counterfeit Drug”: CEUR, helps to track drugs and to accurately determine the authenticity of the drug in Russia. Hyperledger Fabric has been used and for development purposes, Hyperledger composer is used. Authors define a supply chain with major stakeholders including manufacturers, wholesalers, and retailers. These are responsible for producing, transporting, and distributing the drugs in the pharmacies. The supply chain demonstrates the information regarding the identification of the drugs produced in the manufacturing plant and the movement patterns of those drugs in the supply chain to ensure the verification and authenticity of the drugs which are transported to the pharmacies. Only the relational model is thought out, no smart contracts have been created, no use of access lists, no tests have been carried out and no prototype model of the system is defined.

VII. Pashkov et al. (2019) “Counterfeit Drug, Logistics cost”: EDP Sciences, have presented a method of legally implementing Blockchain technology in pharmacies. This legal implementation provides a cover for tracking and also supplying drugs in the pharmacies. The delivery process is made transparent with less expenditure on logistics. The problem addressed in this paper is the counterfeiting of the drugs and minimization of the operational costs in the supply chain. This research is only limited to Europe.

VIII. Chiacchio et al. (2020) “A decentralized application for the traceability process in the pharma industry”: Elsevier, proposes a decentralized application based on blockchain and serialization technologies to support immutable traceability. The proposed framework is based on proof of authority and smart contracts, and a preliminary empirical study was undertaken to evaluate it.

IX. Shruti Srivastava et al. (2019) “Tracking drug distribution”: IJSTR, have introduced a cryptographically secured tracking solution having a decentralized and distributed track and trace system. They make use of radio frequency identification codes (RFID) and barcodes. It provides a detailed and well-explained tracking system from manufacturers to drug serialization process to drug distribution. But the author does not provide any practical implementation.

X. Makarov & Pisarenko, 2019 “Blockchain technology in the production and supply of pharmaceutical products”: Atlantis Press, this paper proposed a counterfeit prevention system that involved tracking drugs from the manufacturer until they reach the end- user. In this model, drug manufacturers control and record all transactions on the blockchain. Any attempted fraud is revealed by a comparison of the details of data previously stored on the blockchain with what is entered, where mismatches reveal fake medications. The proof of work (PoW) consensus algorithm was used by the authors as the drug manufacturers are the data Miners.

XI. Raj, R, Rai, N et al. (2019) “Counterfeit Drug”: IEEE, Proof of Ownership is used to establish the anti-counterfeiting in the supply chain of Pharmaceuticals. A transparent and traceable system using Blockchain is implemented. The logistic companies are provided with real-time monitoring of the drugs being transported. Only the parties with ownership have the option to hand over their authorities to some other stakeholders of the supply chain.

5. Gap Analysis

Instead of fixing the design of the existing system, the Gap Analysis here focuses on fixing the problem of developing a blockchain based system for counterfeiting the drugs. The Analysis focuses on identifying the technology or the design gaps of the existing system. The predictive gap analysis helps in understanding the supply chain of the drugs through a public blockchain and will showcase the users the entire flow from drug manufacturing to drug supply with utmost accuracy. From the literature review, all the existing research focuses only on the theoretical aspect of the implementation. There is no practical implementation shown. The existing systems are built on Hyperledger fabric, which is an open- source platform for building distributed ledger solutions. The proposed system focuses on Ethereum blockchain. By using Ethereum smart contracts, the common business involved in the supply chain is realized using blockchain technology, and the key information of supply chain production and circulation stored on the blockchain to ensure the information cannot be tampered. At the same time, based on smart contracts, the reputation of enterprises in the supply chain can be evaluated, which can provide reference for suppliers to select among enterprises.

6. What is a Supply Chain?

A supply chain can be defined as a network of individuals and companies involved in creating a product and delivering it to the consumer. Links in the chain start with raw material producers and end when the supplier delivers the finished product to the end user.

Supply chain management is a critical process because an optimized supply chain leads to lower costs and a more efficient production cycle. Companies are looking to improve their supply chains in order to reduce their costs and remain competitive.

The supply chain includes every step involved in delivering a finished product or service to a customer. The steps may include sourcing raw materials, moving them into production, and then transporting finished products to a distribution center or retail store where they can be delivered to consumers.

Entities involved in the supply chain include manufacturers, sellers, warehouses, shipping companies, distribution centers and retailers.

The supply chain begins to function when a business receives an order from a customer. Its core functions therefore include product development, marketing, operations, distribution networks, finance and customer service When supply chain management is effective, it can reduce a company's overall costs and increase its profitability. If one link breaks, it can affect the rest of the chain and be costly.

6.1. Blockchain

Blockchain is a distributed and decentralized public ledger of trust that makes it possible for organizations and people to engage in safe and secured ways. Apart from blockchain, there are other forms of distributed ledger technology (DLT) that are revolutionizing how we operate business, keep data, and share information. Looking at the design of Blockchain, it has the potential to revolutionize a variety of activities through increased security, and privacy-enhancing features.

The term “blockchain” is accumulating a lot of attention lately due to the growth of cryptography. What does it actually mean, though?

Nowadays all transactions take place digitally in our environment, therefore people become more and more dependent on technology. But these transactions frequently take a long time to complete and they are also vulnerable to cybercrime. This is because the current technologies require a mediator to conduct all the activities.

Blockchain rises here. This peer-to-peer (P2P) network is decentralized, controlled, and distributed. Every transaction that takes place is irreversible since it cannot be altered and it is recorded on the blockchain almost instantly.

This technology does not require any third party and enables safe two-party digital transactions. One of the advantages of blockchain is that it records all the events in an encrypted format thus providing a shield for people from online transactions.

Blockchain is different from conventional databases by the way it stores and manages data. Every information is stored in blocks. Each block has a specific amount of space for storage. When the block has been fully utilized, it is closed and linked to the previous block. This is how the chain of blocks are formed.

6.2. Blockchain in Supply Chain

Supply Chain Management has always been ranked up as the top use case that should be disrupted by blockchain technology. The main reasons for that are supply chains consisting of huge, distributed networks of participants that don't trust one another and where fraud is rife. There isn't an industry player that can really claim to know where their product is in the supply chain. It is very difficult to harmonize the data from all components of a supply chain, and the chances of finding someone providing false information are very low.

Blockchain has been transforming and revolutionizing the supply chain of major industries. Supply chains need to improve their efficiency in tracking, and put a hold on exploitative behaviors. The primary consumer products such as pharmaceuticals, luxury and electronic products, and so on are more susceptible to counterfeiting and fraud.

Issues like this can be easily taken care of, with the implementation of hybrid, public, and private blockchain in the supply chain. The influence of blockchain on supply chain management will be huge as they can drastically improve traceability, accountability, as well as transparency to the movement of goods and commodities.

6.3. Drug Supply Chain

The pharmaceutical supply chain is the means by which prescription drugs are manufactured and delivered to patients. However, the supply chain network is actually very complex and requires a number of steps to be taken to make medicines affordable and accessible to patients.

A wide range of stakeholders are also involved in the pharmaceutical supply chain, including manufacturers, wholesale distributors, and pharmacy benefit managers (PBMs).

In such a complex process, the stakes are high for pharmaceutical companies. Drugs that are distributed incorrectly affect both a company's reputation and customer satisfaction, as well as potential profits. An inefficient supply chain could also disrupt patient treatment processes and negatively impact public health, the Kaiser Family Foundation report found.

The pharmaceutical supply chain faces its own challenges, including supply chain visibility, drug counterfeiting, cold chain shipping, and prescription drug price increases that can significantly increase out-of-pocket costs for patients.

At the most basic level, there are five steps in the pharmaceutical supply chain to ensure that drug supplies are readily available for distribution to providers and patients. The five steps are:

a) Medicines come from manufacturing plants

b) They are converted to wholesale distributors

c) Stocked in retail, mail order and other types of pharmacies

d) Price is negotiable and processed through pharmacy benefit management company quality and utilization screens

e) They are dispensed by pharmacies; and finally delivered and received by patients

There are many variations on this basic pharmaceutical supply chain structure, the researchers note, in large part due to the constantly evolving players in the supply chain.

The key players in the pharmaceutical supply chain network enable it to run smoothly and efficiently. These players include manufacturers, wholesale distributors, pharmacies and PBMs.

A pharmaceutical manufacturer supplies a quantity of its products that ideally equals the consumer/patient demand for its products. These manufacturers then manage the actual distribution of the drugs from the facilities to drug wholesalers or directly to retail pharmacy chains, mail order and specialty pharmacies, hospital chains, and some health plans.

According to the researchers, pharmaceutical manufacturers in particular have the greatest influence on drug prices, as they assess expected demand, future competition and projected marketing costs when determining wholesale acquisition costs (WAC).

Next in the network are wholesale distributors who buy pharmaceutical products from manufacturers and distribute them to various customers, including pharmacies.Some wholesalers sell to a wide range of potential customers, while others specialize in selling specific products, such as organic products, or selling to specific types of customers.

PBMs are other key players in the supply chain. Although not a direct link in the physical supply chain of pharmaceutical products, PBMs have become an integral part of most consumer drug purchases.

PBMs work with third-party payers to manage consumer drug purchases by defining which drugs will be paid for and what amounts the pharmacy will receive. This player also determines how much the consumer must pay out of pocket when the prescription is filled, based on the rebates it negotiates with other participants in the supply chain.

Pharmacies are the last step before drugs reach the patient, and arguably the most important step, as they serve as the information link between PBMs, drug manufacturers, and wholesale distributors.

Pharmacies buy drugs from wholesalers or directly from manufacturers. After the products have been purchased, pharmacies must maintain an adequate supply of medicinal products and provide consumers with information on the safe and effective use of prescription drugs.

6.4. Problems in Drug Supply Chain

The problem of counterfeit medicines is growing every day and the offer of these counterfeit medicines comes from all over the world. Innovation is important for economic growth to be competitive in the global market, and intellectual property protection gives companies the opportunity to thrive on innovation. The pharmaceutical and biopharmaceutical industries are particularly important in terms of innovation in healthcare. In addition to taking away income from consumers and pharmaceutical companies, counterfeit drugs also pose health risks to patients, including death. Internet pharmacies, which are often the source of counterfeit drugs, often misrepresent themselves to increase consumer acceptance. Adding to the problems is the lack of medicines, which makes it easier for counterfeiters to access. A long and convoluted supply chain also facilitates counterfeiting. In addition, the wholesale market comprising many firms is a convenient target for counterfeit medicines. Trading counterfeits can be extremely profitable; detecting fakes is difficult and penalties are light.

7. Existing System

There is a significant gap between the strategic vision and operational realities of the sector. Firms are facing challenges on multiple fronts in their supply chains. They need to overcome these hurdles to unlock their full potential.

However, while the pharma sector’s growth trajectory looks promising on the surface, it is evident that there is a significant gap between the strategic vision and operational realities. The pharmaceutical companies are facing a unique set of challenges that are creating significant pressure on them to transform their supply chains.

Quality and regulatory issues continue to be a hot topic in the industry. Quality issues have widened and deepened over time and are increasing across the value chain. These issues range from problems occurring at the procurement level over quality of raw materials, to issues at manufacturing stage where plant shutdowns and inability to get authorized certifications have created unused capacity. Lack of quality control at the R&D stage has led to more failures of trial batches as a result it causes delays in product launches.

The pharmaceutical companies are extending their portfolio at a fast pace. This includes new product development, enhanced formulations, new dosage forms and changes in labeling and packaging to cater to new markets.

This fast-paced product proliferation has several indications for the supply chain, including more inventory, higher manufacturing and distribution costs, and a larger supplier base.

Coming to Supply chain fragmentation, sheer number of players at each stage with varying requirements, lack of proximity to the manufacturer, differing degrees of quality standards, and lack of clear categorization are clear challenges.

As a result, changes in production schedule are becoming more common because of poor service levels of the suppliers, further affecting the ability of the supply chain to make and deliver the goods on time.

About two thirds of the global pharma industry have outsourced and decentralized R&D. These companies use multiple third-party organizations at different stages of their supply chain development which creates a convolution of technology and data transfer, increasing costs to deal with discrepancies, lengthening the timelines for regulatory approval and reducing plant utilization.

In terms of storage, there is a significant gap in today's pharma infrastructure due to lack of a robust cold chain network to support the supply chain. Drugs have varying requirements for storage to ensure that throughout their shelf life the potency is maintained. Some moving specialty products and vaccines require continuous and precise monitoring at all stages of the value chain. However, companies are still unable to ensure how to store a product at the required conditions throughout its transition.

8. Blockchain in Drug Supply Chain

Blockchain technology has flourished in usefulness, innovation and diversity in recent years. It has evolved from a mere rival to the existing banking system to include other channels like healthcare and supply chain. This has also benefited one of the most critical industries in the healthcare domain, which is the pharmaceutical industry.

The pharmaceutical industry includes the production of crucial items for sustainable healthcare; it is a complex process with multiple moving parts, where most of the issues and gaps are. Let us look at the traceability of the drug supply chain.

Recent research conducted on the pharmaceutical business showed that they are facing lot of challenges like

- Transparency
- Time constraints
- Sustainability
- Counterfeit drugs
- Trust

An extensive examination of the survey reveals that blockchain is revolutionizing some of the most crucial components of the pharmaceutical supply chain: counterfeit pharmaceuticals, on top of prescription drugs, are under surveillance due to their increased risk of misuse.

9. How will Blockchain Help in Drug Tracing and Tracking?

A pharmaceutical company does not get any clear chit after its manufactured product goes out of the gate. There is a high risk that the cargo may be delayed, the drugs may be substituted with low-quality or fake drugs. The only solution for all these problems is Blockchain.

The solution is a unique encrypted code that is immutable, irreplaceable and unalterable. As the drug ID on each strip is unique, every drug can be tracked to see where it is in the process, is it still on its way, or any alteration has taken place?

Consumer is the main entity of the Pharma Supply chain, who also uses the same key to access information on the drug received from the pharmacy. This trading strategy is unique since it is unchangeable and is constantly available on the network. So a patient or customer can fully trace and monitor their prescribed drug from its manufacturing to endpoint. They can validate its legitimacy, that is sustainable, open, transparent and permanent. The pharma companies are trying to adopt this in order to change the face of the modern healthcare system.

In recent years, multinational pharma has implemented blockchain in their supply chain to authenticate and track the usage of the COVID-19 vaccination. This has boosted the feasibility of vaccination and also proved that the blockchain has provided robustness to the existing system. According to recent research, about 80 % of pharma businesses are keen to participate in the emerging blockchain technology that has hastened by the pandemic.

10. Functional Requirements

- The major functional requirements of the Anti-Drug Counterfeit system are as follows:
- The proposed system must be resilient. The customer must be able to see the full product life cycle.
- The system must provide data integrity, as the transactions that are once authenticated by the consensus mechanism are practically tamper-proof and cannot be modified. This establishes a high-level of data integrity, thereby making data secure, compliant and available for all the participants.
- The system must be traceable, keeping track of multiple transactions performed by a multitude of participants.
- The system must be able to reduce the losses occurring due to counterfeiting by enabling clear visualization of the drug's journey from manufacturer to patients with the digitized transactions.
- The system must have efficient recall management by allowing the identification of exact locations of medicines.

11. Proposed System

The proposed system consists of implementing Supply Chain Management using Ethereum Blockchain. Why to use Ethereum Blockchain? Ethereum is a decentralized blockchain with smart contract capabilities. Ethereum's blockchain allows apps to function without the risk of third-party interference, downtime, control or fraud through its smart contracts. The power of the Ethereum blockchain lies in its programmability. It is excellent for arbitrating transactional events in trade finance, supply networks, energy grids, government registries, and many other areas.

People can verify all the entities of the supply chain whether they are genuine and verified. The proposed system consists of many entities like suppliers, transporters, manufacturers, wholesalers, distributors, and customers/retailers and is connected through a decentralized network. Each of the above entities of the supply chain is a node on the public blockchain. Each of these nodes has its own Ethereum Account, which is used for representing its identity. The specific roles and functionalities of each are discussed below:

1. Owner
    - CREATE a new user to be added to the chain.
    - READ the information of any user.
    - UPDATE the roles of a user.

2. Transporter
    - Verify the package (Raw Material or Medicine).
    - Pick the package from an entity (based on transporter type).
    - Deliver the product to an entity.

3. Supplier
    - CREATE a Raw Material.
    - Transport it to the Manufacturer.

4. Manufacturer
    - Receive the Raw Material from the Supplier through the Transporter.
    - Verify the source of the product received.
    - CREATE a new Medicine using received raw materials.

5. Wholesaler
    - Receive the medicine from the manufacturer through the Transporter.
    - Verify the source of the medicine.
    - Transfer the ownership of the medicine.

6. Distributor
    - Receive the medicine from the Wholesaler through the Transporter.
    - Verify the source of the medicine.
    - Transfer the ownership of the medicine.

7. Customer

- Receive the medicine from the Distributor through the Transporter.
- Verify the source of the medicine.
- Can trace back the complete supply chain through QR Scanning.
- Get medical drug information.

11.1. Modules of proposed system

Module 1 - Authentication:

- The stakeholders of the supply chain register to the ethereum network by entering a valid Ethereum Address and password.
- Each entity inside the system must be an authorized user to perform transactions.
- The personal information used to verify a user's identity is stored on the block's hash such as username or password. This will help to achieve a self-sovereign identity.

Module 2 - Transaction:

- Each user has their own private key and a public key that everyone can see. Using them both creates a secure digital identity authenticating the user via digital signatures and to 'unlock' the transaction they want to perform.
- When a user registers to a system, a genesis block is created for the first time. After successful registration, when a user performs some operations, the transaction takes place and blocks are created and linked to that respective user chain.
- Transactions are sent from and received by user-created Ethereum accounts. A sender must sign transactions and spend Ether, Ethereum's native cryptocurrency, as a cost of processing transactions on the network.

Module 3 - Smart Contract:

- On a new stakeholder registration, the authenticity of the individual is verified and a block is created for that particular ID.
- When an information is updated, the authenticity of the individual who is making the changes are verified and another block is created for the same user ID which is linked to the previous block ID.
- On transaction of money and goods from one stakeholder to another, a contract is written to ensure the reachability of the service from both ends.

12. System Workflow

Stakeholders that can be involved in the distribution of drugs are as follows:

- Suppliers
- Manufacturers
- Logistic Service Providers
- Distributors
- Retailers
- Hospital/Pharmacy
- Patient

Step 1: The raw materials needed for drug manufacturing are supplied by Suppliers

The raw materials are sent to the drug manufacturers by the suppliers and the data is added to the QR code. The QR code contains essential information like the Chemical names, Date of Shipment, Delivery date, Supplier and Manufacturer information and so on.

Step 2: The drugs are manufactured by Manufacturers.

The drugs supplied by the suppliers are manufactured into medicines and the data is added to the QR code. The QR code contains essential information like Medicine name, Date of Shipment, Delivery date, Manufacturer, Logistics and Distributor information. All the information that is added by the manufacturer are stored on the ethereum blockchain, providing transparency on the supply chain to other stakeholders. A unique hash is generated once information is added to the blockchain, that can be used for tracking the transactions.

Step 3: The drugs are sent to hospitals/pharmacists by Distributors

Distributors can verify the origin of medicines with the help of Hash ID stored on the blockchain, after collecting them from the logistics service providers. All the information that is added by manufacturers such as the date and place of manufacturing can be traced back. If it goes through all the quality checks, distributors validate the authenticity of the received medicines and sign the digital transaction, and that transaction is added to the Ethereum network. This further triggers the smart contracts to send the drugs from distributors to the hospitals/pharmacists.

Step 4: Pharmacists receive the drugs from Distributors and verify its origin.

Pharmacists verify the origin of the drugs by tracing back, using the hash ID saved on the network. Suppose any illicit distributor tries to sell counterfeit drugs with a fake ID to pharmacists or patients, it can be detected and the transaction is considered invalid because of the fake information added about the drug. Also, without a valid private key, unauthorized individuals cannot perform any transactions in the drug supply chain ecosystem. Therefore, anomalies are found immediately within the transactions by the pharmacists. Once the received medicines are approved by the pharmacist , the transaction between him and the distributor is added to the network, ensuring the legal deal.

Step 5: Patients buy the drugs and origin is traced back through QR scanning.

Patients need to ensure that they are buying safe medicine. One can scan the QR code attached to the drug's packaging via their mobile app in order to know its source and quality standards. The hash ID that is linked to the QR code would fetch all the history of information from the blockchain network for patient's access. Patients can give feedback or ratings for the drugs they purchase, linked to the drug's ID stored on the blockchain network. The ratings that are added by the buyer can help other individuals to decide whether the specific drug is effective or not.

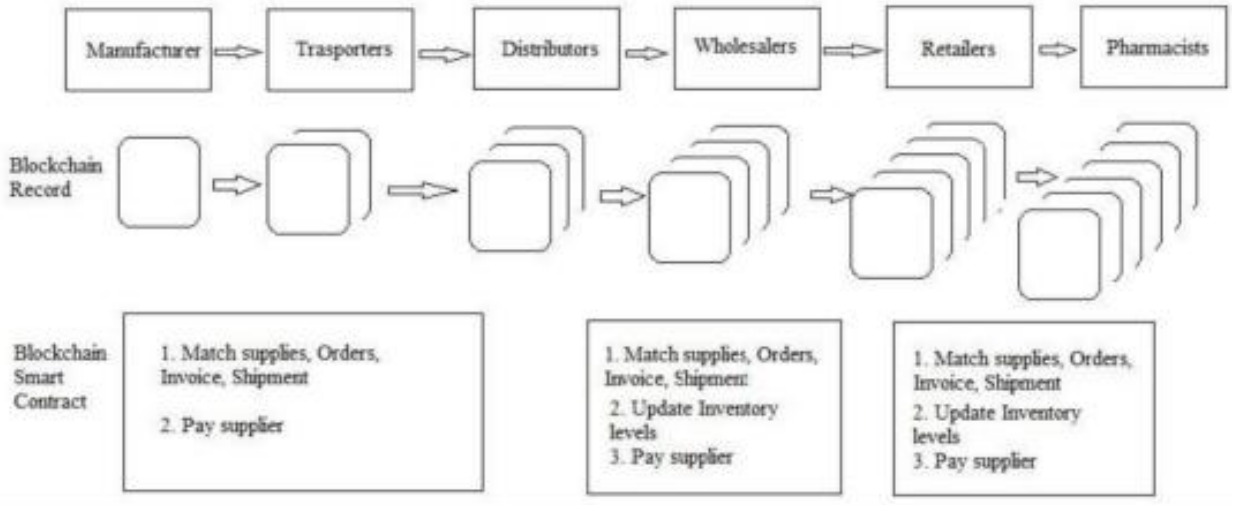

Fig.12.1. Module Diagram of Drug Supply Chain

13. Model Testing

13.1. Unit Testing:

Unit testing is defined as testing individual pieces of code prepared by developers using useful and valid data. In this process, combinations of one or more programming modules, along with associated control data, usage, and operational procedures, are tested to evaluate their usefulness. It usually has one or more inputs and usually one output. The Drug Counterfeit system has been tested in several test cases to improve its accuracy and is able to efficiently process all incoming data.

13.2. Integration Testing:

Integration testing is used to combine different parts of modules and check that they work as a group. The purpose of this level testing is intended to detect errors between integrated units. Test drivers and test snippets are used to aid in integration testing. The complete flow was tested by integrating with all modules of the network.

13.3. Block Chain Testing

API Testing: API testing ensures that the interaction between applications in the blockchain ecosystem is as expected.

Block testing: All blocks in the network are tested individually to ensure proper cooperation.

Functional testing: In functional testing, the work of various functional parts of the block-chain was evaluated (e.g. Contracts).

Performance testing: Details such as network latency based on block size, network size, expected transaction size, and how long a query takes to return output using a specialized validation protocol.

Security Testing: In this it is ensured that the application is vulnerable to attack and systems can and are able to protect data dealing with malicious attacks etc.

Integration Testing: In integration testing it is ensured that all application components are properly integrated and perform actions accordingly

Smart contract testing: Smart contract testing is being used for performing detailed functional testing of business logic and processes involved in the block chain process.

Website Testing: Through website functionality testing, several testing parameters like user interface, API, database testing, security testing, client and server testing and basic website functionality are verified.

Usability Testing: The functionality of every feature on the site is tested

Interface Testing: Three areas will be tested here – application, web and database server

a) Application: It is tested whether the requests are correctly sent to the database and client-side output is displayed correctly. Any errors that occur are caught by the application and displayed only to the administrator, not to the end user.
b) Web Server: The testing of a web server handles all application requests without any denial of service.
c) Database server: It is ensured whether the queries sent to the database return the expected results.
d) Compatibility Testing: Compatibility tests ensure that the web application displays correctly on different devices. This includes Browser compatibility test, i.e. The same website in different browsers will be displayed differently if it is not browser compact. It tests if the web application displays correctly across browsers. Java Script and AJAX compatibility are also checked.

14. Architectural Design

Architectural design is the process of defining a collection of structure of data, hardware and software components and their interfaces to establish the framework for the development of a computer-based system. It focuses on the decomposition of a system into different components and their interactions to satisfy functionality and performance requirements as well as non- functional requirements of the system. An architectural pattern is a general, reusable solution to a commonly occurring problem in software architecture within a given context.

The architectural pattern for the Drug Supply Chain Management separates an application into three main logical components: the model, the view, and the controller. Each of these components are built to handle specific development aspects of an application. MVC is one of the most frequently used industry- standard web development frameworks to create scalable and extensible projects. The below figure is the architectural diagram:

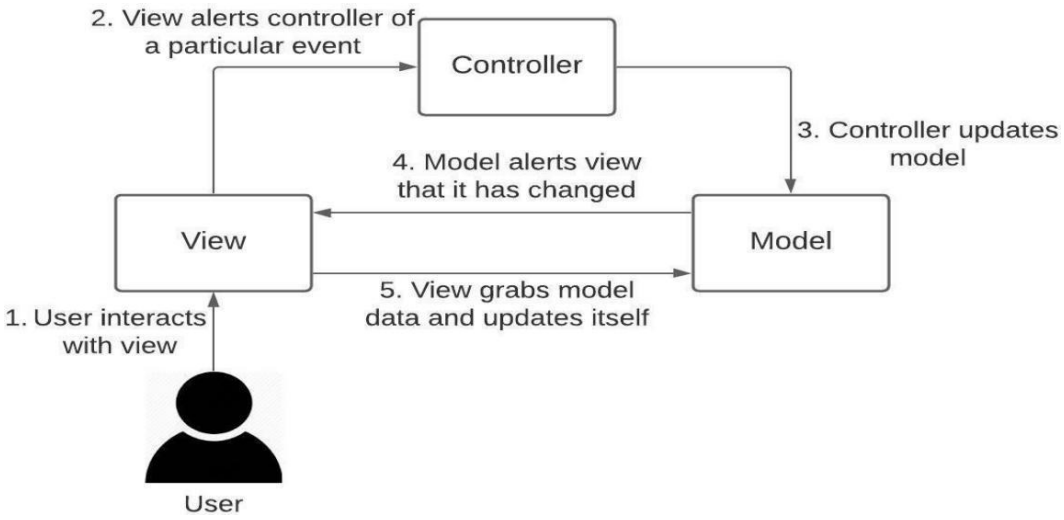

Fig.14.1. Architectural design for Drug Supply Chain Management

Each screen has this architecture where the UI (front-end) is connected to the back-end via controller where all the functionalities are done there. This architecture is similar to MVC framework where UI is the view, adapters are the controllers and model is the business object. Figure 2 is a representation of the architecture used for this application. This application works in the Model View Controller pattern, where from the landing page of the system it takes the input from the user and first it accesses the controller and then it is redirected to the model of the system. Where it gets access to the modules behind and starts executing its tasks and reports individually. Then it gets the page view and displays it in the browser.

15. User Interface Design

User interface design or UI design generally refers to the visual layout of the elements that a user might interact with in a website, or technological product. This could be the control buttons of a radio, or the visual layout of a web-page. User interface designs must not only be attractive to potential users, but must also be functional and created with users in mind.

15.1. Registration Page

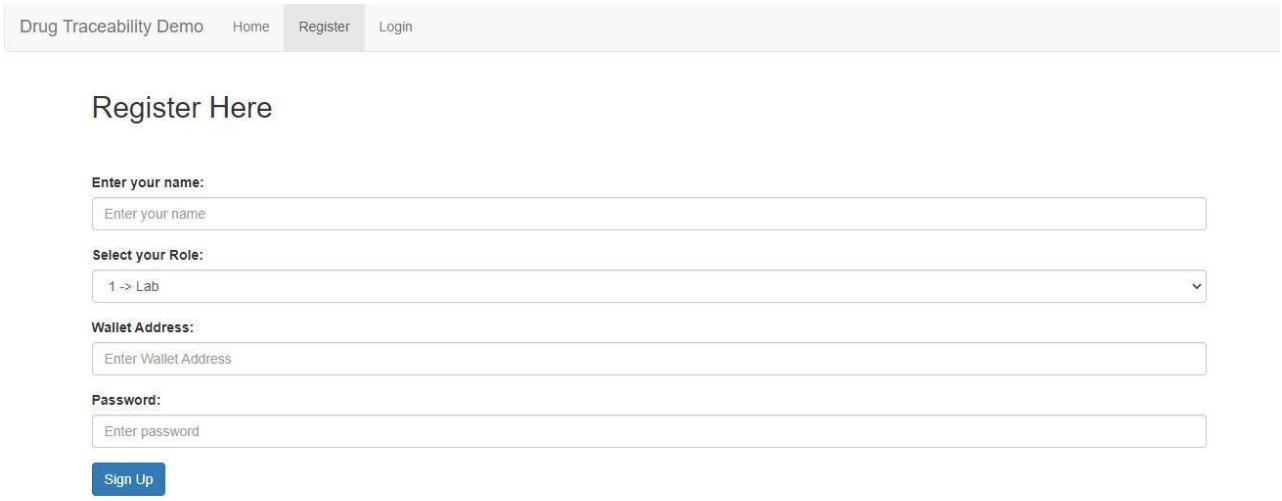

Fig.15.1. The UI Design of the Registration

15.2. Login Page

Fig.15.2. The UI Design of the Login Form

15.3. Laboratory Dashboard

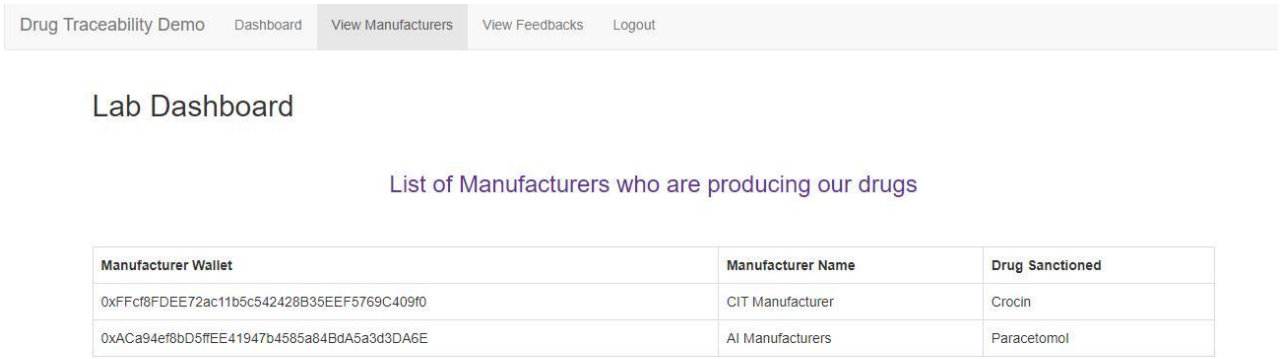

Fig.15.3. The UI Design of the Laboratory Dashboard

15.4. Manufacturer Dashboard

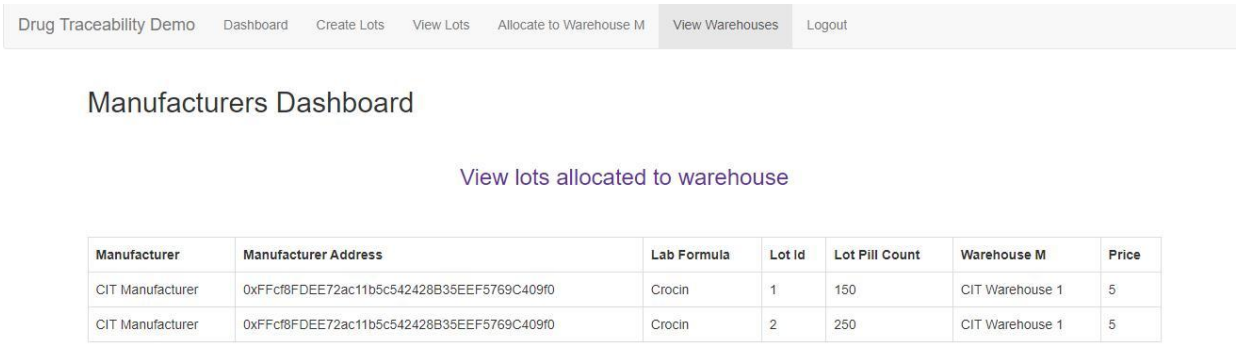

Fig.15.4. The UI Design of the Manufacturers Dashboard

15.5. Warehouse Dashboard

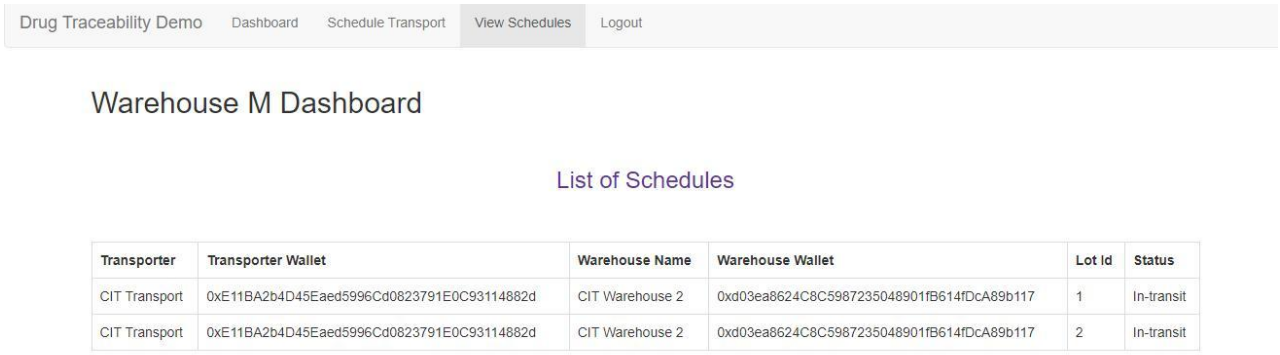

Fig.15.5. The UI Design of the Warehouse Dashboard

15.6. Transportation Dashboard

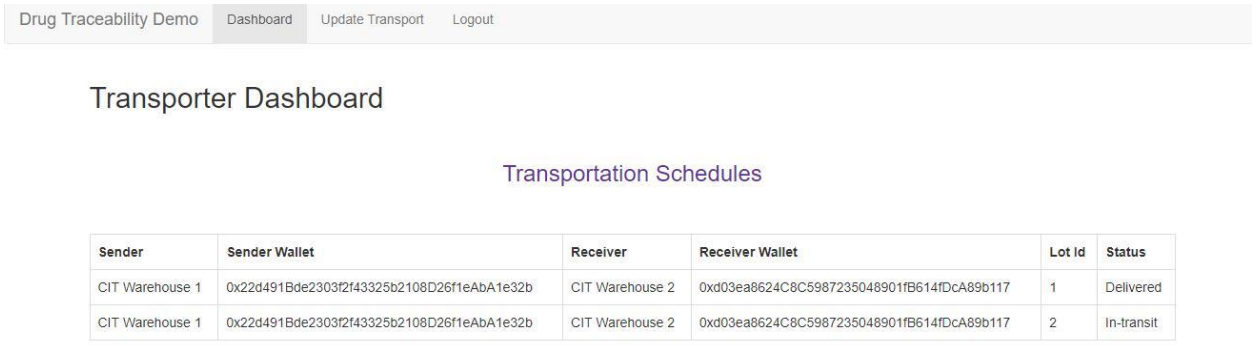

Fig.15.6. The UI Design of the Transportation Dashboard

15.7. Warehouse-2 Dashboard

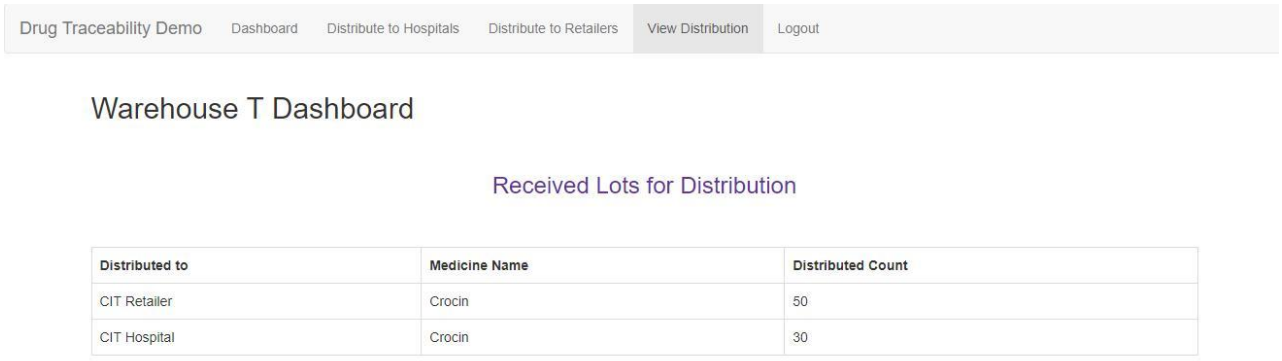

Fig.15.7. The UI Design of the Warehouse-2 Dashboard

15.8. Hospital/Retailer Dashboard

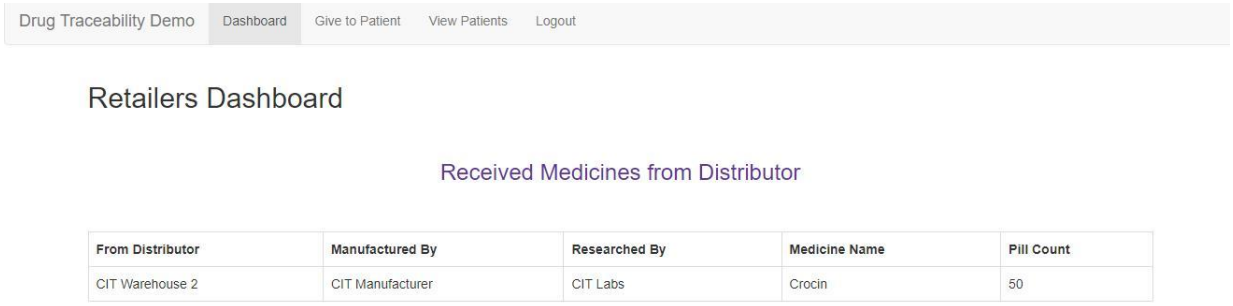

Fig.15.8. The UI Design of the Retailer Dashboard

15.9. Patient Dashboard

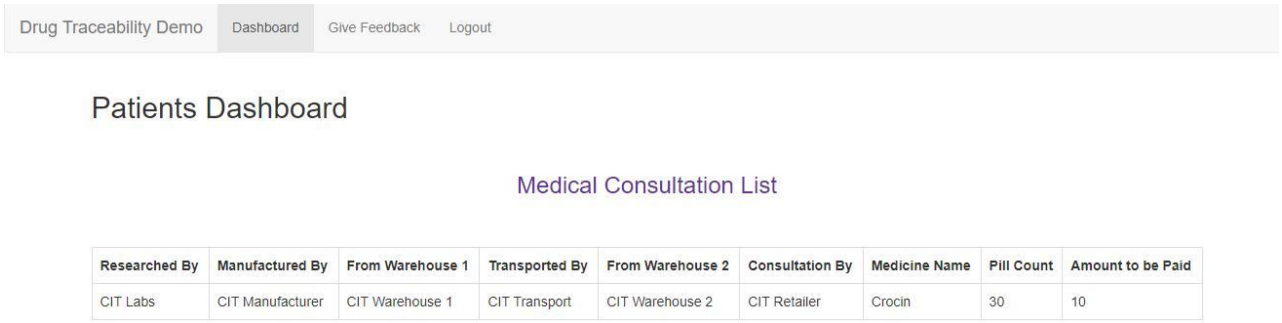

Fig.15.9. The UI Design of the Patient Dashboard

15.10. Ethers Transaction

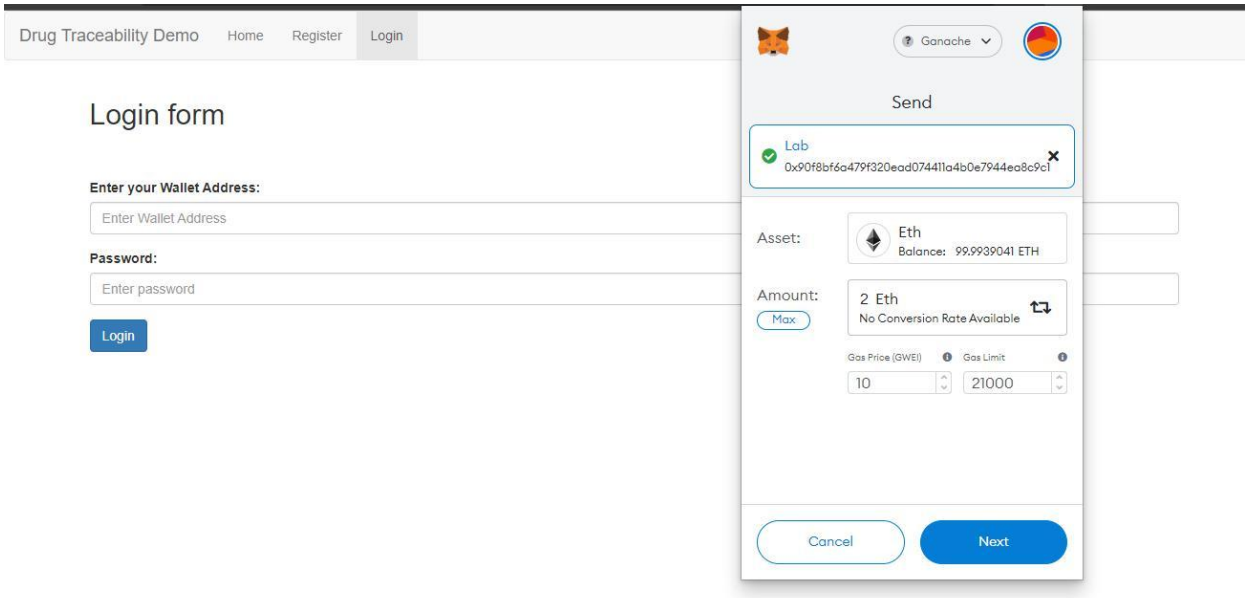

Fig.15.10. The UI Design of the Ether Transaction Initiation

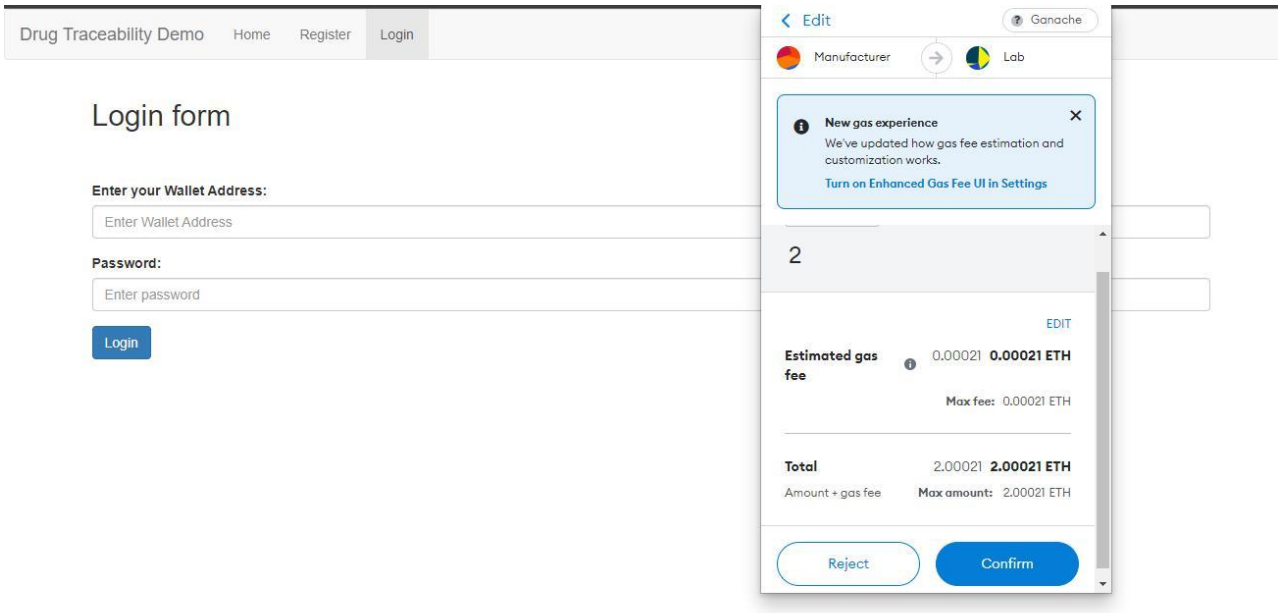

Fig.15.11. The UI Design of the Ether Transaction confirmation

16. Activity Diagram

Activity Diagrams are used to illustrate the flow of control in a system and refer to the steps involved in the execution of a use case. Sequential processing and concurrent processing of activities is designed using activity diagrams. It captures the dynamic behavior of the system.

16.1. User Registration:

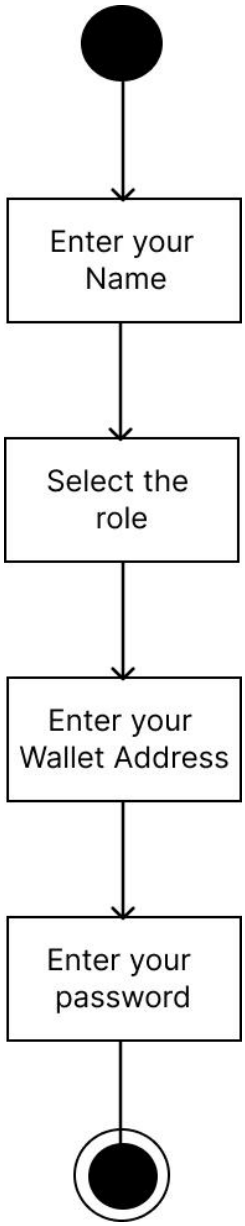

Fig.16.1. Activity Diagram of the User Registration

16.2. User Login

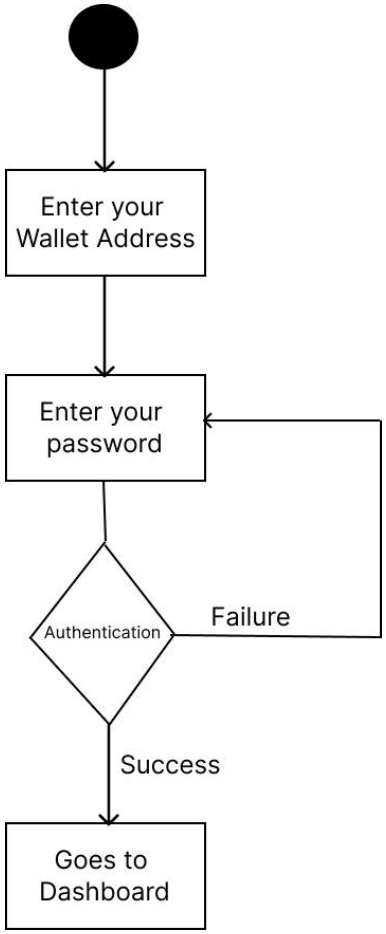

Fig.16.2. Activity Diagram of the user login

16.3. Laboratory Role

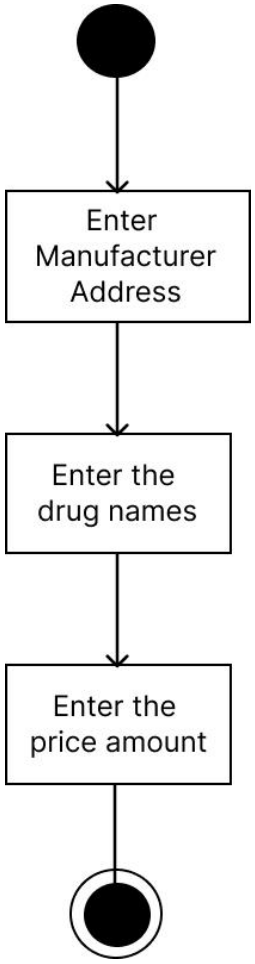

Fig.16.3. Activity Diagram of the Laboratory Role

16.4. Manufacturer Role

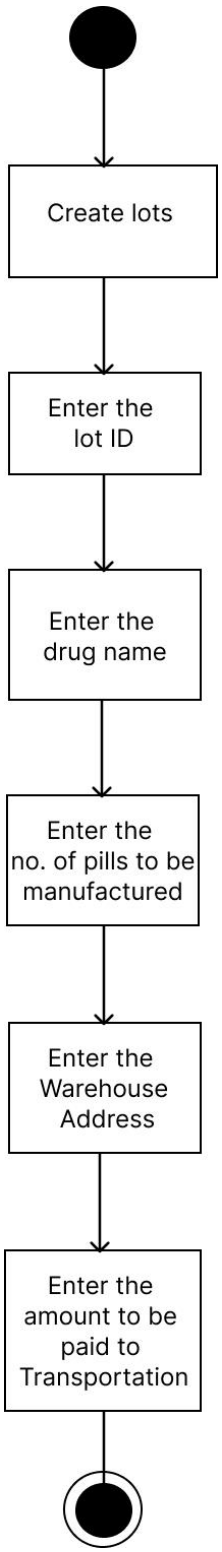

Fig.16.4. Activity Diagram of the Manufacturer Role

16.5. Warehouse Role

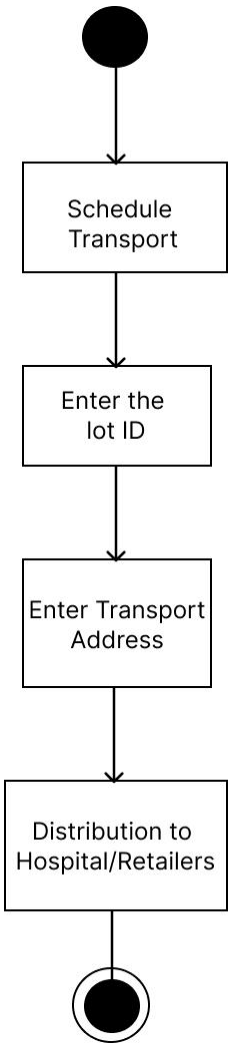

Fig.16.5. Activity Diagram of the Warehouse Role

16.6. Hospital/Retailers Role:

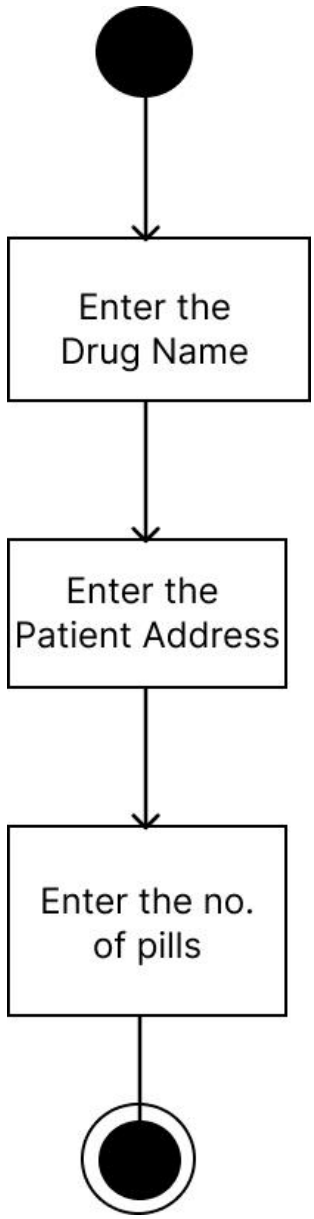

Fig.16.6. The Activity Diagram of the Retailer Role

17. Deployment

Docker is a software platform that allows one to build, test, and deploy any applications quickly. Docker consists of standardized units called containers through which one can run any software without actually installing the codes and packages separately. The container itself includes all the libraries, system tools, code, and runtime. One needs to simply build the container and run then to launch the application. The Anti-counterfeit Drug Supply Chain using Blockchain Technology web app has been deployed through docker. The container consists of a Docker file which includes all the necessary dependencies and code for the app.

A Docker file is nothing but a text file which contains a series of commands or instructions. Through this Docker file, a Docker image has been created which can be pulled and run in various systems.

Docker-compose tool has been used to deploy and manage multiple containers at the same time. A docker-compose.yml file has been created which contains instructions on how to run the container. The following were instructed in this file:

1) From where to take the Dockerfile to build a particular image
2) The ports that are to be exposed
3) How to link containers
4) Which ports to bind to the host machine

Docker Compose reads that file and executes commands. It is used instead of all optional parameters when building and running a single docker container

18. Test Case and Test Reports

Test cases are built around the requirements and specifications i.e., what the system is supposed to do. Test cases are generally driven from the external descriptions of the framework and design parameters. Fig 20 contains the list of test cases and their respective test reports.

Each test case contains item criteria such as:

- PASS - All expected results are achieved and/or all unexpected events are resolved.
- PASS WITH EXCEPTIONS - Unexpected events require alternative procedures that have been implemented and those events are called Exceptions.
- FAIL - Testing process response does not confirm the expected results.

The system is tested with datasets in each level of the supply chain process.

Test Case ID	Test Scenario	Test Steps	Test Data	Result
T1	Unit Testing	Testing each individual module	Corresponding input to each module	Successful processing of each module
T2	Integration Testing	Combining all the modules together	Results from the previous modules	Got the expected final result
T3	Ether Transfer Testing	Increase the amount of ether sent to each user	Ethers in each account	Performance must be improved. A certain amount of lag is found while transferring huge ethers
T4	Network	Connect and Disconnect network	Ongoing process of application	Application tries to reconnect by itself and updates the same to the user
T5	Validation	Inserting unauthorized or tampered data/block inside	Data/block from other modules	Shows error if the hash does not match with the existing ones

Table.18.1. Test Cases and Test Reports

19. Conclusion

Security is a major concern for almost everyone from a normal person to the CEO of a large company. Although automated solutions for the problem have existed for a long time, there is no software that encompasses it all at once. More than just providing security to their premises, providing security to their personal data is very crucial. Data protection is a fundamental right. Data Security and Privacy are two foundational elements of building trust between the company and the user.

Here, at Drug counterfeit system no compromise has been made on data security. People can use the power of block-chain based authentication to get critical updates across critical junctions in their organization and ensure whether the operations of the organization is running smoothly in the system.

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