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UNIVERSITY OF LIBERAL ARTS
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DRUG GUARD: A BLOCKCHAIN BASED SUPPLY CHAIN MANAGEMENT (SCM) TO PREVENT COUNTERFEIT DRUGS

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PREVENT COUNTERFEIT DRUGS

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A report submitted
in partial fulfillment of the requirements
for the degree of
Bachelor of Science in Computer Science and Engineering

UNIVERSITY OF LIBERAL ARTS BANGLADESH

Dhaka, Bangladesh

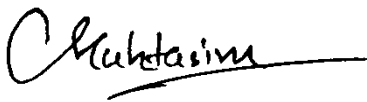
June 6th, 2021

AGREEMENT FORM

We take great pleasure in submitting our project report on “*DRUG GUARD: A BLOCKCHAIN BASED SUPPLY CHAIN MANAGEMENT (SCM) TO PREVENT COUNTERFEIT DRUGS*” is our own research without except as cited in the reference. This report is prepared as a prerequisite of the Capstone Project (CSE 499) which is a two-semester long course. This course includes multidisciplinary groups of understudies who construct and test custom outlined framework, components or engineering processes. The report and project is obtained in experiments carried out by us after and during development and have not been acknowledged for any degree and is not concurrently submitted in candidature of any other degree.

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CERTIFICATE OF APPROVAL

The project report entitled “*DRUG GUARD: A BLOCKCHAIN BASED SUPPLY CHAIN MANAGEMENT (SCM) TO PREVENT COUNTERFEIT DRUGS*” is submitted to the Department of Computer Science and Engineering at University of Liberal Arts Bangladesh (ULAB) in partial fulfillment of the requirements for the degree of Bachelor of Science.

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DEDICATION

We declare that this entire project and report titled “*DRUG GUARD: A BLOCKCHAIN BASED SUPPLY CHAIN MANAGEMENT (SCM) TO PREVENT COUNTERFEIT DRUGS*” is solely the result of our own work and the experimental work is almost entirely our own work, the collaborative contributions have been indicated clearly and acknowledged. Due references have been given on all supporting literary works and assets. This report and product is a result of our own research and have not been submitted for any other degree or proficient capability.

ACKNOWLEDGEMENT

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Special thanks and appreciation to our dearest supervisor Dr. Mohammad Shahriar Rahman, for persevering with us as our advisor throughout the time with a lot of patience. With his guidance and support, we have completed this project and report. He always believed in us and gave us hopes which helped us a lot to stay motivated and overcome various difficulties we faced during this project. His inspiration for the capstone project and advice helped us to assess our research and make our project more efficient.

And finally, we would like to express our deepest gratitude all of the faculty members of our university who have always encouraged us to do something new and taught us numerous lessons that we know today only because of them.

ABSTRACT

The production and distribution of fake or counterfeit drugs is a critical and progressively basic issue in Bangladesh. Also, it causes a serious threat of pharmaceutical drugs. There are many reasons for drug counterfeiting, but one major reason is the imperfect supply chain. It is difficult to track over the drugs from manufacturing to distribution and the major requirement of the drug supply chain is the assurance of drug quality, together with efficacy and safety. Here we proposed a blockchain based network of drug supply chain management (SCM) from manufacturer to pharmacist where we provide tracking over drugs as well as visibility and the safety of sensitive drug information. The existing drug supply chain of Bangladesh manufacturers don't know what happened with their drugs or which pharmacy is taking their drugs. But our proposed model ensures traceability so that manufacturers will be able to know which pharmacy is taking their drugs through the distributed network provided by blockchain. Our platform will provide a secure network where all participants can see all the transactions between other participants. All transactions between participants or users are recorded in the blockchain and other participants or users will be able to view the transactions history of participants. All blockchain transactions are also recorded in the database where we stored encrypted information of transactions and provide more security of our databases. Also encrypted QR (DAR number) will ensure that illegitimate participants will not be able to make a copy of the information given by the manufacturer and will not be able to produce fake drugs by providing the same information. So, it will provide security of information about drugs as well as it will provide an encrypted QR code system so that illegitimate participants cannot know about the information of drugs.

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LIST OF ABBREVIATIONS

- DAR = Daily Activity Rhythm
- SCM = Supply Chain Management
- MSC = Medical Supply Chain
- RFID = Radio Frequency Identification
- DSC = Drug Supply Chain
- MR = Medical Representative
- MPO = Medical Promotional Officer
- MSO = Medicine Supply Officer
- MD = Managing Director
- RSM = Regional Sales Officer
- USD = United States Dollar
- IoT = Internet of Things
- PIL = Patient Information Leaflet
- S_k = Secret Key
- Pharmacist = Chemist
- Spurious / False labeled / Falsified / Counterfeit = SFFC
- API = Active Pharmaceutical Ingredient
- Pharmacy = Chemist Shop

CHAPTER 1

INTRODUCTION

The counterfeiting of drugs has grown as a serious issue as the wellbeing of the people who expend such drugs may be at risk. Fake drugs are those which may contain no API at all, deficiently sum of the correct API, inadequate APIs, sole or in mixes, API within the right amount but with counterfeit or fake packing, labeling and patient information leaflet (PIL). The spurious/false labeled/falsified/counterfeit (SFFC) is the comparable terms utilized by diverse administrative specialists to demonstrate destitute quality of drugs which can cause treatment disappointment or passing too.

Counterfeit drugs can be introduced into the market through various channels, where the local depot in-charge and pharmacists are prominent. A chemist or owner of a pharmacy can purchase fake drugs at cheaper rates from unauthorized parties or frauds and can make a bountiful sum. Essentially, a nearby depot in-charge or territorial wholesaler channel can be a source of fake drugs, advertently or incidentally.

The fake drug market is flourishing at the cost of the patient's life, and the state machinery or government is incapable of preventing this immoral business of counterfeit drugs. The profit-making is enormous in comparison to investment in the business of fake drugs, which is a potent source of motivation to the phony medicine mafias, and the lack of solid and proficient watchfulness framework advance energizes this wrongful trade. The showcase value of fake drug is additionally expanding due to the awkwardness in supply and demand.

In the current SCM system pharmacists have no access to such systems through which they can check if the purchased drugs are genuine or not. In this way, organizations across the country are required to record the drug-related data right from its fabricating through wholesalers or depot in-charges and retailers to the persistent. Such a ledger will help to track the authenticity of the drug and will keep an overall inventory check on the produced drugs until the life cycle of the drug is ended. One essential concern whereas actualizing such a broad framework emerges out of the

belief. A centralized server or system cannot be trusted to manage such transactions of drugs via SCM. The issue with such a centralized framework is that it offers a single point of disappointment, which is undesirable when actualizing such a large-scale information-intensive organization. The arrangement lies in realizing the over necessities of a decentralized framework utilizing adequate cryptographic measures to guarantee the security and unchanging nature of the restorative information records. Luckily, blockchain innovation exists to offer a decentralized stage and secure the record kept up on different computer hubs or nodes.

In this composition, a dependable pharmaceutical verification framework based on blockchain innovation is proposed. Different partners within the medicine or drug supply chain can confirm the realness or authenticity of the drugs they get by utilizing the proposed framework.

1.1 Problem Statement

Supply chain management (SCM) of the pharmaceutical industry doesn't provide visibility [01]. Existing drug supply chain provides a centralized network where users cannot know about all transactions happening with other participants. The existing drugs supply chain in Bangladesh is outdated and manufacturers cannot keep track of their drugs. Once the drugs reach the end of the chain and are displayed at pharmacies their genuineness is no longer guaranteed. Also, it is difficult for any pharmacist to know the origin of drugs as well. Existing drug supply chain doesn't provide the security of sensitive data about drugs and there is a lack of confidentiality as well as integrity. Fraudulent activities and unauthorized manipulation become difficult to carry out [02]. Counterfeiting of various drugs causes serious threat to public health or who consumes drugs and also it causes revenue loss to the legitimate manufacturing companies [03]. Also drug information can be duplicated easily by the existing supply chain because raw data are given on drug boxes.

1.2 Aims of Project

- Eliminating the existing centralized database for transactions in SCM.
- Increasing the trust level between participants by eliminating the need of trust to the distributors or MRs / MPOs.

- Add traceability over the drugs of legitimate manufacturers.
- Provide a real time tracking system or status update for drugs.
- Provide encrypted QR code (aes-256-ctr algorithm) for the security of sensitive information of the pharmaceuticals.
- Provide a tamper proof data storage for drug information through blockchain.

1.3 Motivations of Project

Using a drug from any pharmacy without having the required quality of drugs can cause side effects, possibly even death [03]. Also, it is difficult to measure the economic loss due to counterfeit drugs [04]. The Bangladesh Pharmaceutical market is expected to reach a size of USD 5.11 billion by 2023 and the global pharmaceutical market is expected to reach USD 1,556 billion by 2023 [05]. This is a huge market price and an estimated Tk. 600 crore of counterfeit or fake drugs are traded in the Tk. 18,000 crore drugs market in Bangladesh each year [thedailystar.net]. Over the last five years, the licenses of several pharmaceutical companies were cancelled and in 2019, a total of 370 cases of fake drugs were filed [thefinancialexpress.com.bd]. The value of fake or counterfeit and contraband drugs flooding the market is almost between US \$100 million and \$150 million [pharmabiz]. Also, the existing system is not secure and is prone to various attacks such as ransomware, replay etc. To overcome these attacks and to ensure drug safety we proposed a blockchain based system and an encrypted QR code which can be decrypted by an authorized body of the drug supply chain (DSC).

CHAPTER 2

EXISTING SYSTEMS AND LITERATURE REVIEW

In the previous chapter we discussed the problems, aims and motivations of our project and in this chapter, we discussed the performance vector with other systems that already exist in Bangladesh, scenario of current supply chain in Bangladesh and similar study about drug supply chain.

2.1 Performance Vector

To evaluate any project and to compare it with the existing systems that are out there a performance vector is a must. We measured the performance of our project with the given features of the existing system. The descriptions of the features of existing features are given below:

- **Registration and Login:** The purpose of this process is to authenticate a user when he or she will try to register to our system as a depot in-charge or pharmacist or chemist. Then registered participants will be able to login to the system by giving the same information he or she set at the time of registration.
- **Security:** This is the major concern as we are also dealing with the information about drugs and we tried to ensure that the information is given by an authentic manufacturer.
- **View Available Drugs:** This feature provides depot in-charge and pharmacist to see the manufactured drug list or to explore the drug list updated by manufacturer. This feature is also provided by all existing systems given below.
- **Order Drugs:** By this feature depot in-charge and pharmacist are able to order drugs from manufacturer and depot in-charge respectively which is also provided by existing systems.

- **Real Time Order Status Update:** This feature is controlled by the drug sender and receiver will be able to view the location of the drug. By this feature receiver is able to know the order status of drugs which is controlled by the drug sender.
- **Real Time Location Update:** After receiving drugs from sender, receiver updates the status that he or she received the drugs sent by manufacturer or depot in-charge and the location of drug is updated. All participants are able to view the current location of drugs.
- **Blockchain:** This is an important feature of the system we deal with because it provides tamper less data storage. By this feature we provide a decentralized network of transactions where each participant is able to see all transactions between all participants.
- **Encrypted QR Code:** This feature provides the security of DAR numbers which are tagged on the boxes of drugs. By this feature illegitimate persons cannot create any fake drugs using the same DAR number.
- **Scope of Delivery:** This feature means the scope of order delivery. This system can be applied locally.

Table 2.1: Existing System Analysis

	Company Name			
	SK+F (Eskayef)		Renata	Radiant
Features	MReporting (Android)	ACCPAC (Web)	Online Order Sent	Provided by Messenger
Registration and Login	Yes	Yes	Yes	Yes
Security	Yes	Yes	Yes	Yes

View Available Drugs	Yes	Yes	Yes	Yes
Order Drugs	Yes	Yes	Yes	Yes
Blockchain	No	No	No	No
Real Time Order Status Update	No	No	No	No
Real Time Location Update	No	No	No	No
Encrypted QR Code	No	No	No	No
Scope of Delivery	Local	Local	Local	Local

2.2 Scenario of Current Supply Chain in Bangladesh

After talking with the executives of pharmaceuticals we got to know the supply chain in Bangladesh. Therefore, the following scenario shows how drug transaction happened between participants in the supply chain of Bangladesh:

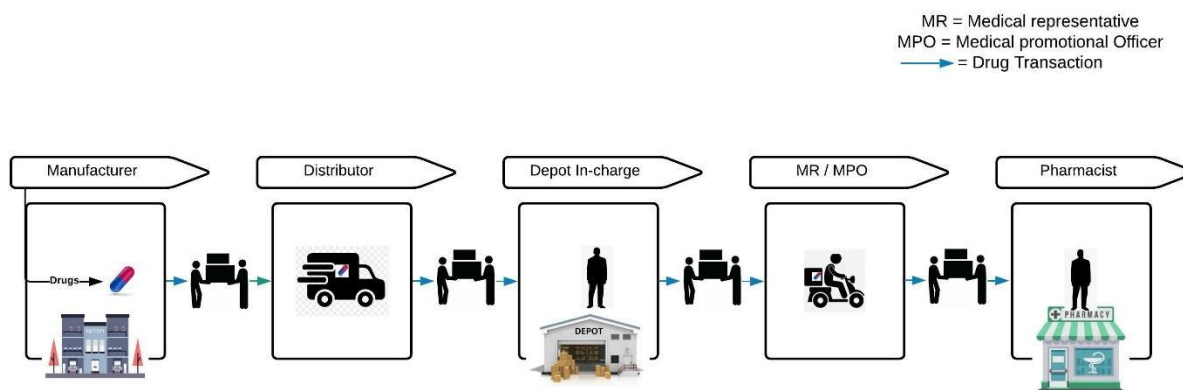


Figure 2.1: Current Supply Chain in Bangladesh

- **Manufacturer:** The person who produces drugs from raw materials by using various tools, equipment and processes and then delivers those drugs to depot in-charge by distributor.
- **Distributor:** Who takes drugs from manufacturer and delivers those drugs to depot where a depot in-charge takes the manufactured drugs.
- **Depot In-charge:** The person who takes orders from MR or MPO and places orders to the manufacturer according to the orders of MRs or MPOs.
- **MR or MPO:** The person who visits doctors and takes orders from pharmacies or chemist shops where pharmacist gives order according to the need of drugs.
- **Pharmacist:** The person who places an order to MR or MPO by the need of drugs by seeing the prescriptions of doctors.

2.3 Similar System Study

There are different procedures which have already been utilized for tracing fake drugs in MSC. The Author in [01], proposed a permissioned or private blockchain framework to store transactions and only trusted parties are allowed to join the network. Also, participants have key pairs which are used to assign each participant a specific activity and they proposed a user-friendly mobile app for doctors. Similarly, the Global Governance of the Blockchain (Gcoin Blockchain) double spending mechanism is proposed to alleviate the counterfeit-drug problem [04]. They proposed a QR code-based identification of drugs and digital signatures for verification. Also, blocks are generated every 15 seconds and it could handle 1.51 million transactions in one day. Also, in [06] a RFID is used for each shipment of products and parties can check where or not the products have passed a legitimate supply chain. The Author of [07] proposed model assures an electronic pedigree (2D barcode verification) for every produced single unit medicine and helps to trace all distribution chains from the manufacturer to the patient. Also, the author of [03], proposed a model where illegitimate participants cannot get access because of public key and an encrypted QR code

technique is introduced which will be accessed only by authorized bodies. None of these literatures introduce member revocation, but in [08] where the author proposed a member revocation without changing the key pairs of unrevoked members. In [09], they talked about serialization. Serialization is a unique anti-forged method. A unique identification number is effectively obvious on a pack and can effectively be verified by the customer’s phone, internet links to the database.

2.4 Study and Gap Analysis with Recently Published Paper

Here we described the differences between what we have done so far and what in the recently published e-paper on Blockchain Use in Pharma Supply Chain [thefinalcialexpress.com.bd].

Table 2.2: Gap Analysis

Current State			
· Login · Registration · Profile · Dash board (for Manufacturer, Depot In charge, Pharmacy) · Order tracking system or Participant to participant tracking system · Update chain status · Real time order update · Real time location update · Member revocation system · Transaction info shared in blockchain · CRUD operation · Invoice sharing · QR code with details like product ID and batch number · AES-256 encryption	Desired State		
		Gap	
	· Blockchain in conjunction with mobile technology · RFID · Blockchain in conjunction with mobile technology · QR code with details like drug name, location, timestamp, ingredients, usage of the drug and side effects. · Some of the drug details are stored in the blockchain are shared with the logistics providers to prepare for transit. · Cold chain management system.	· Cold chain management system. · QR code with much more details · RFID · Logistic provider	

Way outs to address the gap:

- First of all, the gap or difference between our project and the recently published e-paper on blockchain use in Pharma Supply Chain is, they have talked about the cold chain management systems. We know that the cold chain alludes to overseeing the temperature

of perishable items in order to preserve quality and security from the point of root through the distribution chain to the ultimate buyer. But we don't need to use this system in our project because the temperature issue is needed only for some specific kind of drugs. So, we are not using this in our project because this is not a mandatory feature.

- Secondly in our project, we have used encrypted QR code with the batch number and DAR no but they have talked about QR code with some more details like, drug name, location, timestamp, ingredients, usage of the drug and side effects of the drug. If we also generate QR code with more info then we have to generate QR code for every single file of the drug which seems very difficult to do.
- Thirdly in the paper they have talked about blockchain with RFID. RFID is a strategy of information collection where it includes automatically distinguishing objects through the low-power radio waves. Information is sent and gotten with a framework consisting of RFID labels, a radio wire, an RFID reader, and a handset. But we are not going to use this method because we are using encrypted QR code instead of that.
- The fourth gap which is identifiable that they have said about using logistic providers in blockchain for better tracking and transparency. In case we execute this in our project, at that point it will be more proficient through the real-time get to shipping information or exchange information and shipping reports, counting IoT information and sensor extending from temperature control to container weight. Through the utilization of Smart Contracts, computerized collaboration is encouraged among the different parties included in universal exchange.

CHAPTER 3

METHODOLOGY

In the previous chapter we discussed the existing frameworks in Bangladesh, about the current supply chain and the similar work journals and papers. In this chapter we discussed the methodology we followed to develop this project.

3.1 Software Process Model

A software process is a group of associated activities that lead to the making of the software. These exercises may include the development of the software from scratch or rebuilding an existing framework. For this process model we are choosing “Agile Model”. This model breaks tasks of the project into small increment builds and these parts are provided in iterations which gives flexibility, easy to manage and use. We choose this model because of its all advantages and mainly because it allows us to regularly adapt to changing requirements even late changes in requirements are welcomed, which is suitable for our project. We utilize it since of its celerity, where usage or advancement work is allocated into some packets.

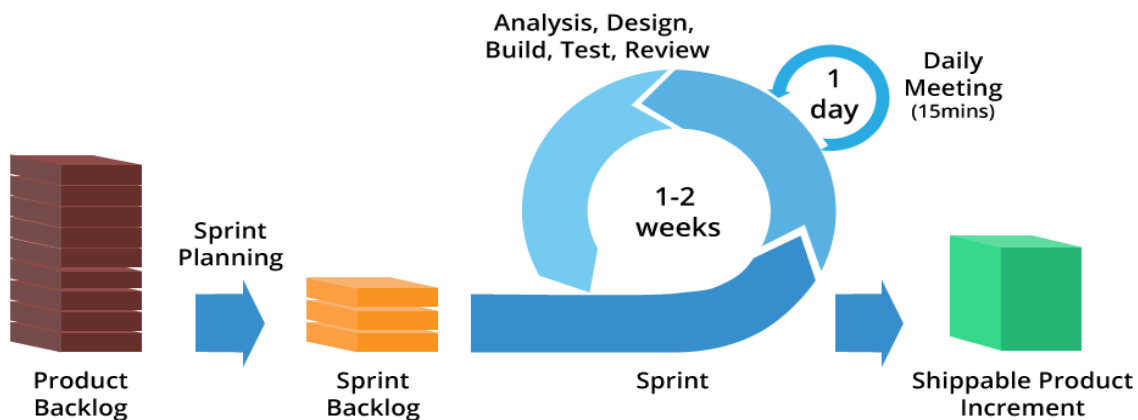


Figure 3.1: Agile Process Model

In this scrum development process how, we worked in each event are given below:

- i. **Sprint Planning:** This is the primary stage. Before starting an iteration, we conduct an online meeting where we decide about the plan for the upcoming sprint. Also we wrote next week's plans in our weekly journal.
- ii. **Daily Scrum:** In this event we talked with each other where we discussed what we have done individually and what we will do next and what is blocking our project. Also we divide our work between each other.
- iii. **Sprint review and retrospective:** In this event, we conduct meetings with our supervisor about our progress and the problems we faced each week. After discussion with our supervisor, he suggested to us what to do.

There are some phases in the agile iteration process and how we are working on these steps are given below:

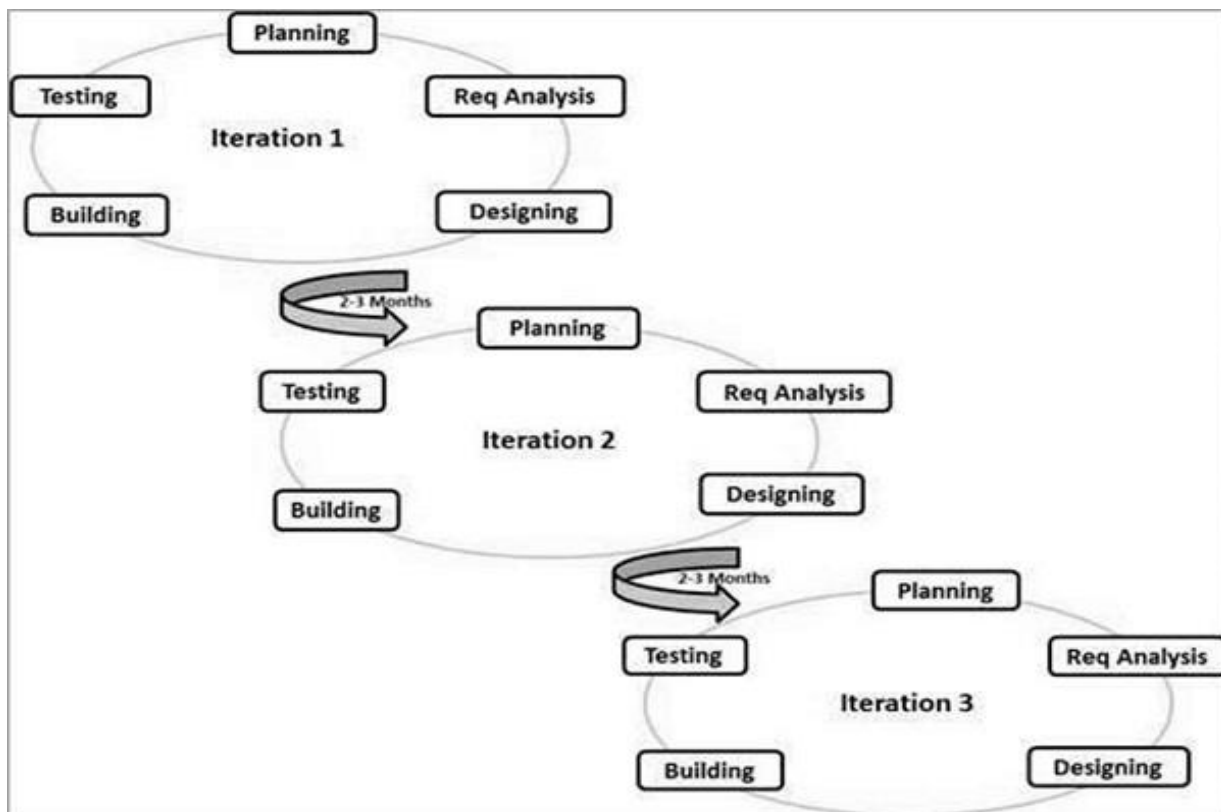


Figure 3.2: Agile Model Iteration Process Flow

- i. **Planning:** Usually the primary stage of the beginning of any project. This is the most crucial or important part of our project or product. In this phase we planned to develop a drug supply chain so that by using our system pharmacists can get drugs from authentic manufacturers.
- ii. **Requirement Analysis:** In this stage our team guarantees that the product necessities offer assistance to the end-user of the framework. We went to a company named SK+F (Eskayef Pharmaceuticals) where we talked with a lead executive of that company and gathered information about the supply chain they follow and identified the problems of the supply chain and read journals to solve the problem.
- iii. **Designing:** In this phase where we defined the overall system architecture. We design system architecture such as activity diagrams for all participants, whole process activity diagrams, use case diagram, data flow diagram.
- iv. **Software Development:** Software advancement turns our project's requirements or necessities and models into working code. It's the most punctual phase in which we begun to see something that takes after the ultimate product which we are attending in the actual. We developed a website and android application with every possible feature at this phase.
- v. **Software Testing:** In this software testing period, we put the code through its paces. We check for:
 - Code quality
 - That code meets the expressed prerequisites
 - Unit testing
 - Evidence of secure improvement principles
 - We checked how our service will work with many order requests at a time

The output of software testing can provide a superior arrangement that meets all cases and client or client needs.

3.2 Full Specification

This section describes the specifications of our project.

- We have three participants in this network. They are manufacturer, depot in-charge and pharmacist where we have created web apps for manufacturer and depot in-charge and mobile app for pharmacist. All participants must be registered with this network. Manufacturer is registered with this network by the system that means he has an account given by the system.
- All participants must be logged in to operate with the system. First of all, if anyone can get access to the system he has to fill-up a registration form. This request goes to the manufacturer. After checking the information manufacturer will create an account for him (account information will be saved into the database) and give him the password. Then that user can login and do orders according to his role.
- When any drug will be manufactured in the company, the manufacturer will add the drug information into database and depot in-charge and pharmacist can view the manufactured drug information.
- Also the manufacturer will add some secret things about the drugs into another database which is connected with the previous database where the manufacturer adds the public information about drugs. Manufacturer will generate encrypted QR code (using secret key) where DAR number is encrypted and he will attach the tags on drug boxes. All information about encrypted QR code will also be stored in the database.
- Pharmacists can place orders to depot in-charge using his mobile app. Here specific pharmacists are allowed to place orders to specific depot in-charge. After getting all orders from pharmacists of an area depot in-charge places orders to the manufacturer for drugs. Order databases are connected with the user (where all information of users are saved) database to get access easily with the user information who ordered drugs. Both transactions are recorded in blockchain and block data are also saved into a

database where we merge off-chain and on-chain data. All data is encrypted in database.

- Manufacturer controls the order statuses of depot in-charge and depot in-charge can view this as a real time update. Then the manufacturer will share the invoice with the depot in-charge through email. When the manufacturer completed an order status this transaction is recorded in the blockchain and also saved in the database as encrypted data. Here we also merged the off-chain and on-chain data.
- Depot in-charge confirmation is also saved in the blockchain and block data is saved into the database. This database is also encrypted.
- Depot in-charge controls the order status of pharmacist by following the same process of manufacturer.
- Pharmacists scan the QR code and get encrypted information. Then he can see the decrypted data from his mobile app.
- Blockchain provides a transparent network between participants for each transaction record. It provides a decentralized network between participants.

3.3 Software Tools

To develop any project lots of tools are required. There were lots of tools required for implementing this project. This section shows the list of software tools we used to develop our project:

3.3.1 Web Application Tools

Frontend:

- i. EJS → It is a straightforward template engine and language that lets any coder to generate HTML markup with plain JavaScript.

- ii. SASS → A preprocessor scripting dialect that's deciphered into Cascading Style Sheets (CSS).
- iii. JavaScript → A programming language that permits programmers or users to make web pages dynamic and implementing complex features.
- iv. Tailwind CSS → A utility-first CSS system for quickly building custom client interfacing.

Backend:

- i. Node JS → A stage built on Chrome's JavaScript runtime for effectively building quick and flexible network applications and it is a backend language.
- ii. Express JS → Express is an adaptable Node JS web application framework that gives a solid set of features for web applications and android applications.
- iii. Mongo DB → It is a cross platform and source oriented and report oriented database program. It is a report database with the versatility and adaptability that clients need with the questioning and ordering that we require.
- iv. Laravel Mix → A software tool for compiling and optimizing resources in a Laravel app.

3.3.2 Android Application Tools

- i. Design: XML → XML is a markup language much like HTML utilized to depict information. In Android we utilize xml for designing our formats or layouts since xml is a lightweight tool and it doesn't make any layout heavyweight.
- ii. Java → A language we used for android application.

3.3.3 Blockchain Server Tools

- i. Language: Solidity → An object-oriented, high-level language for actualizing smart contracts. Smart contracts are programs which regulate the behavior of accounts inside the ethereum state (solidity).

- ii. Platform: Ethereum → It is a software platform that is primarily used to support the world's second-largest crypto-currency by market capitalization after bitcoin (coindesk.com).
- iii. Package: Web3.js
- iv. Go Ethereum (geth) → We used it to run the server. It is an execution of an ethereum node within the Go programming language.

3.3.4 API Tools

- i. Sendinblue (SMTP) → It is used to send a transactional email with dummy HTML content.
- ii. Node JS
- iii. Yarn
- iv. Web3 → To do interaction with blockchain.

3.4.5 Development Tools

- i. IDE: Visual Studio Code (web app)
- ii. IDE: Android Studio (android app)
- iii. Postman and Insomnia (API development tool)

CHAPTER 4

PROPOSED SYSTEM

In the previous chapter we discussed the software process we followed to develop our project, full specifications of our project, software tools we used to develop our project and, in this chapter, we described our proposed system by showing some diagrams:

4.1 Project Architecture

The following diagram shows the SCM participants and how drugs are going to any pharmacist (chemist shop):

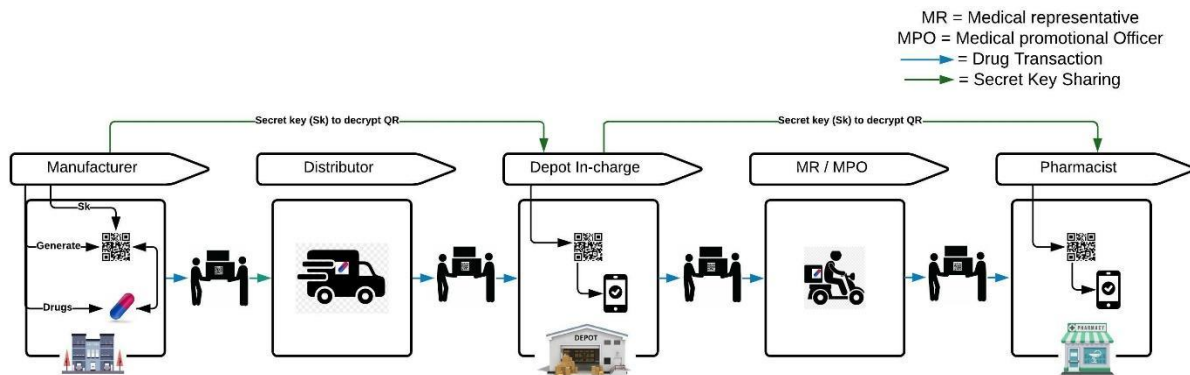


Figure 4.1: Proposed Project Architecture

Manufacturer will generate an encrypted QR code ($S_k(QR)$) when any drug will be manufactured. This secret key will be changed on each production of drugs. Distributor will give the drugs to depot in-charge and depot in-charge can see the order status update controlled by the manufacturer before he receives the drugs. After getting the drugs in hand, the depot in-charge will update the chain status. When a depot in-charge received drugs without any payment this is called primary sale according to MSC. All the transactions will be recorded in blockchain and blockchain data are saved into databases where we save encrypted data. After that, the depot in-charge will send those drugs to the pharmacy or chemist shop and the same process will be followed like the

manufacturer and depot in-charge. When a pharmacist or chemist gets ordered drugs and pays money this is called secondary sale.

4.2 Use Case Diagram

This section shows the use case diagram. The level 1 use case diagram of our project is given below:

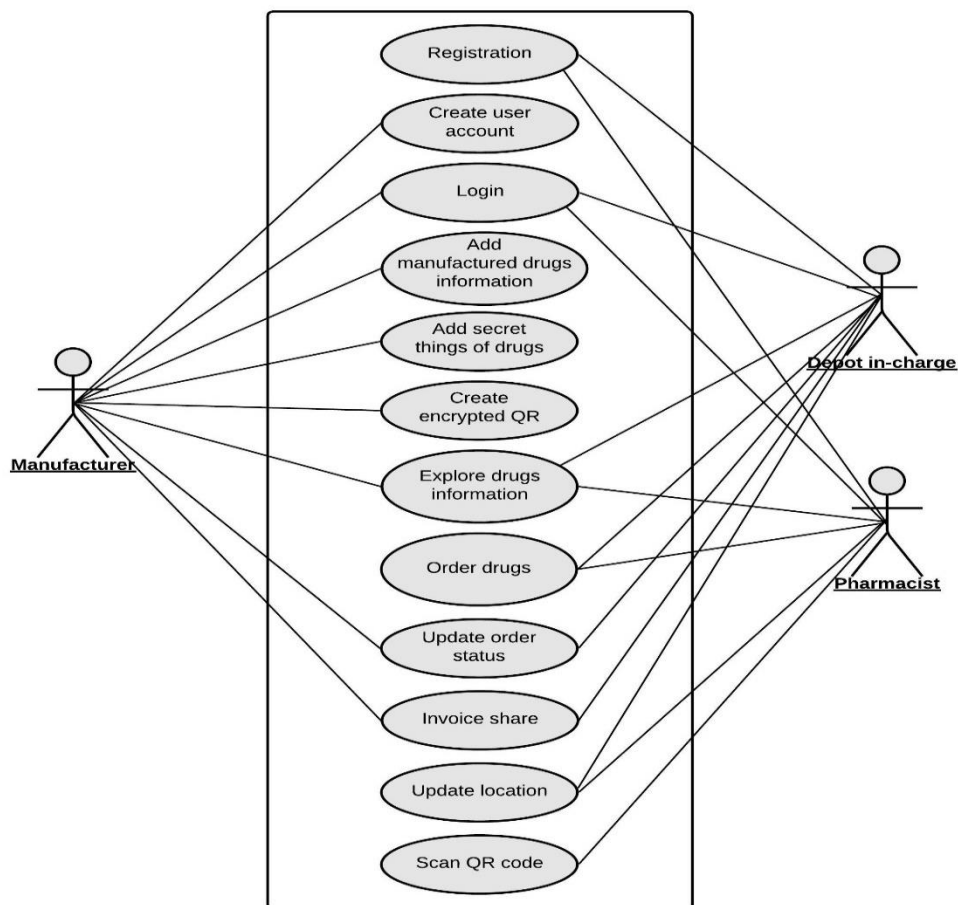


Figure 4.2: Use Case Diagram

This figure 4.2, shows the core functionalities of our system. In Drug guard, we have three types of users; Manufacturer, Depot in charge and Pharmacist. Two participants (depot in-charge and pharmacist) can do registration and all participants can login and explore the drugs information. But other functionalities work separately for each of them. Adding manufactured drugs information, adding secret things to drugs, creating encrypted QR code; these functionalities are

only for the manufacturer. Then updating order status and invoice sharing are both for the Manufacturer and Depot in charge. Ordering drugs and updating location are for Depot in charge and Pharmacist. And lastly, Pharmacists can scan the QR code and check the products authenticity.

4.3 Activity Diagrams

Activity diagrams show the actions and activities of the users or participants in the network. Here we are describing the activity diagrams, which are essentially a flowchart that shows activities performed by a system.

4.3.1 Activity Diagram for Pharmacist (Chemist)

This section shows the activities of pharmacists. It shows which operations can be done when a user is logged in as a pharmacist. The diagram of those activities is given below:

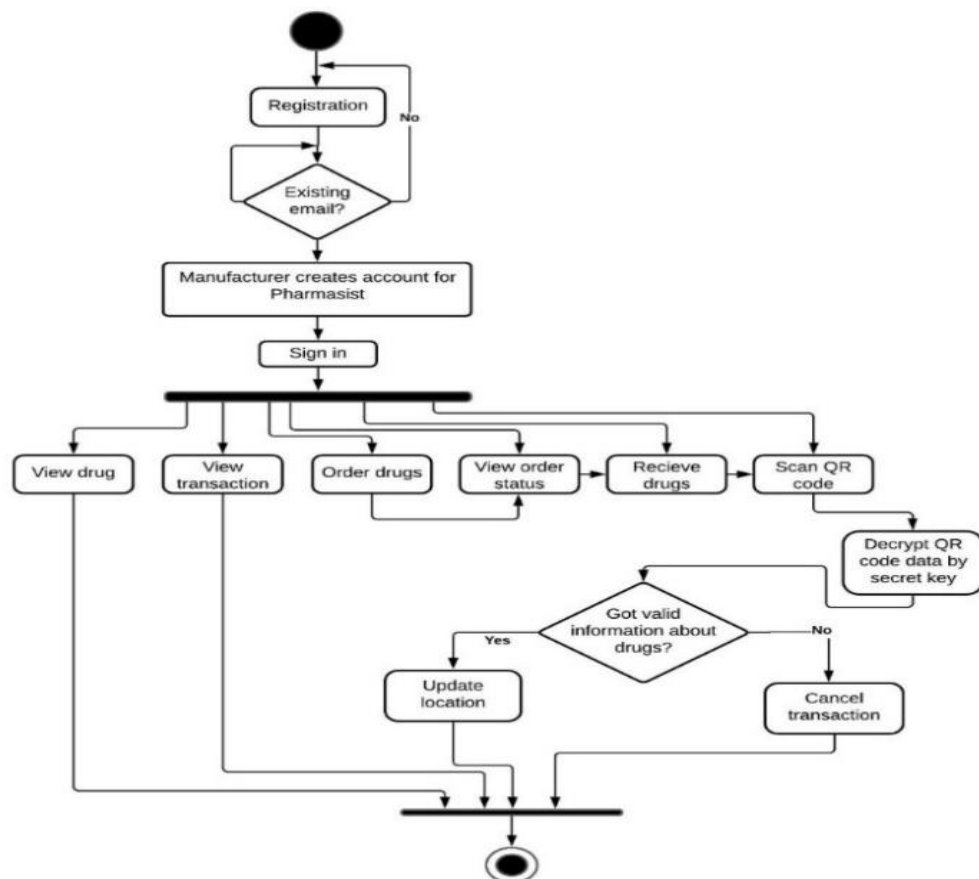


Figure 4.3: Activity Diagram of Pharmacist (Chemist)

4.3.2 Activity Diagram for Depot In-charge

This section shows activities of depot in-charge. The diagram of those activities is given below:

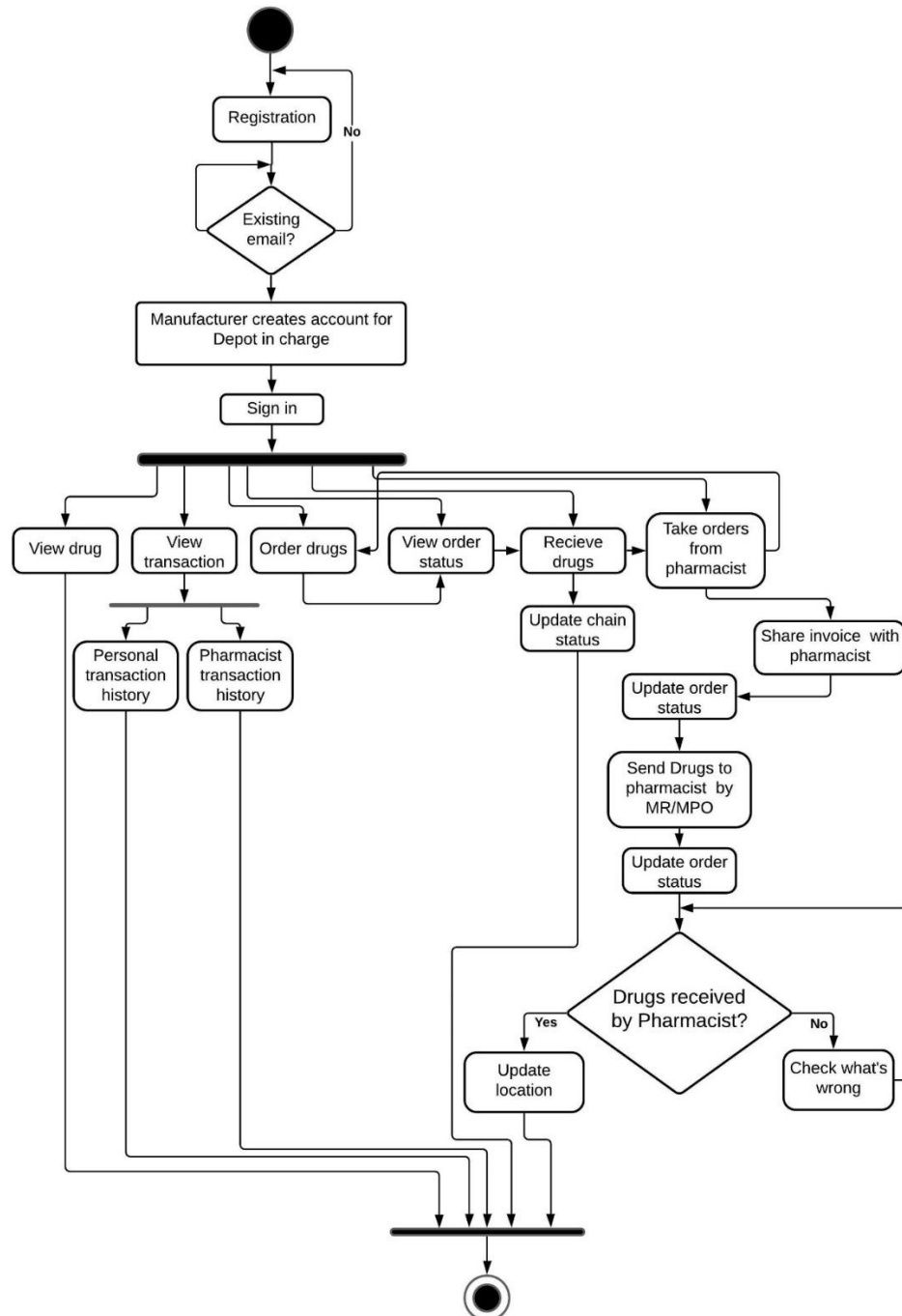


Figure 4.4: Activity Diagram of Depot In-charge

4.3.3 Activity Diagram for Manufacturer

This section shows activities of the manufacturer. The diagram of those activities is given below:

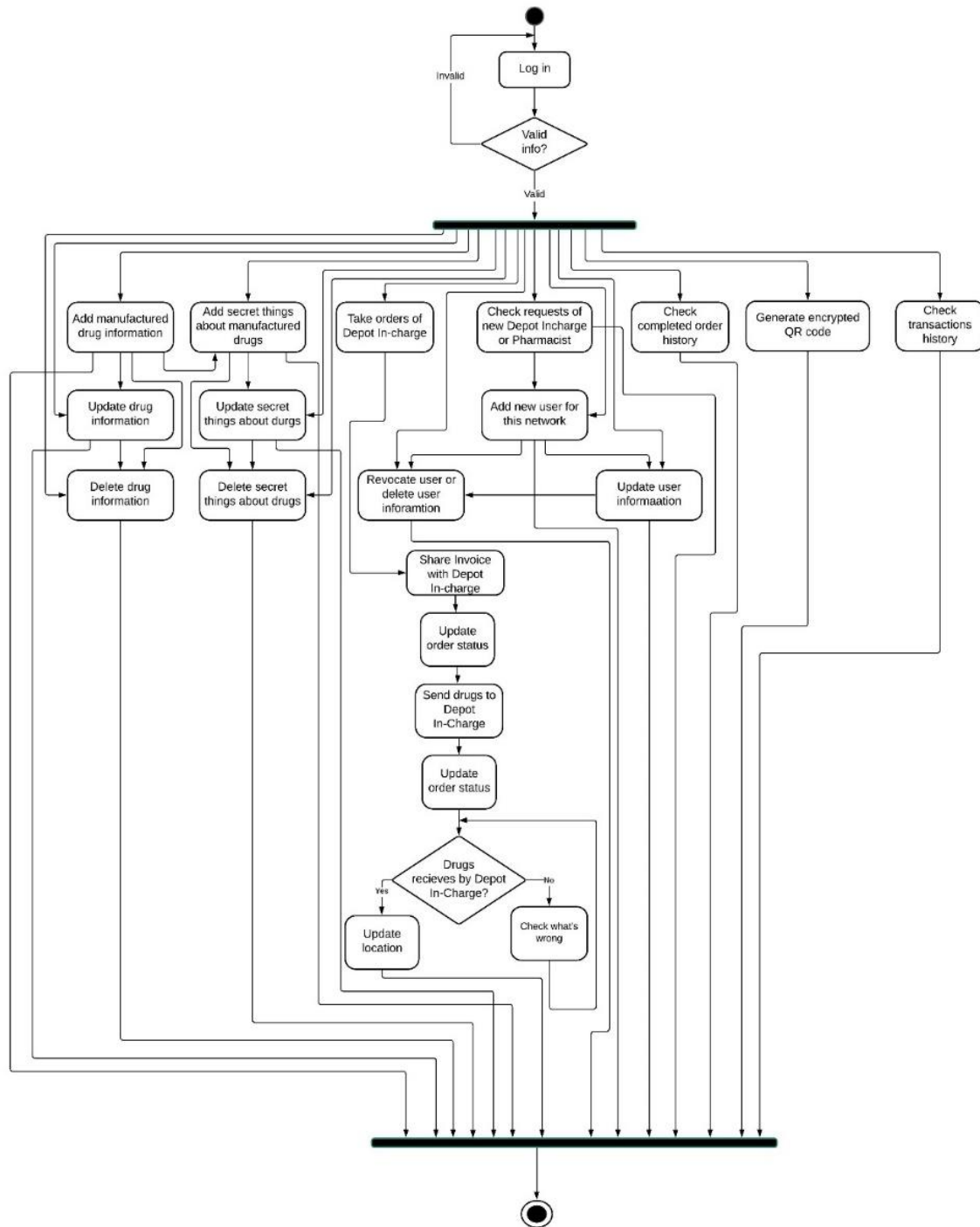


Figure 4.5: Activity Diagram of Manufacturer

4.3.4 Project Activity Diagram

This section shows the whole process of our project. The diagram of all processes is given below:

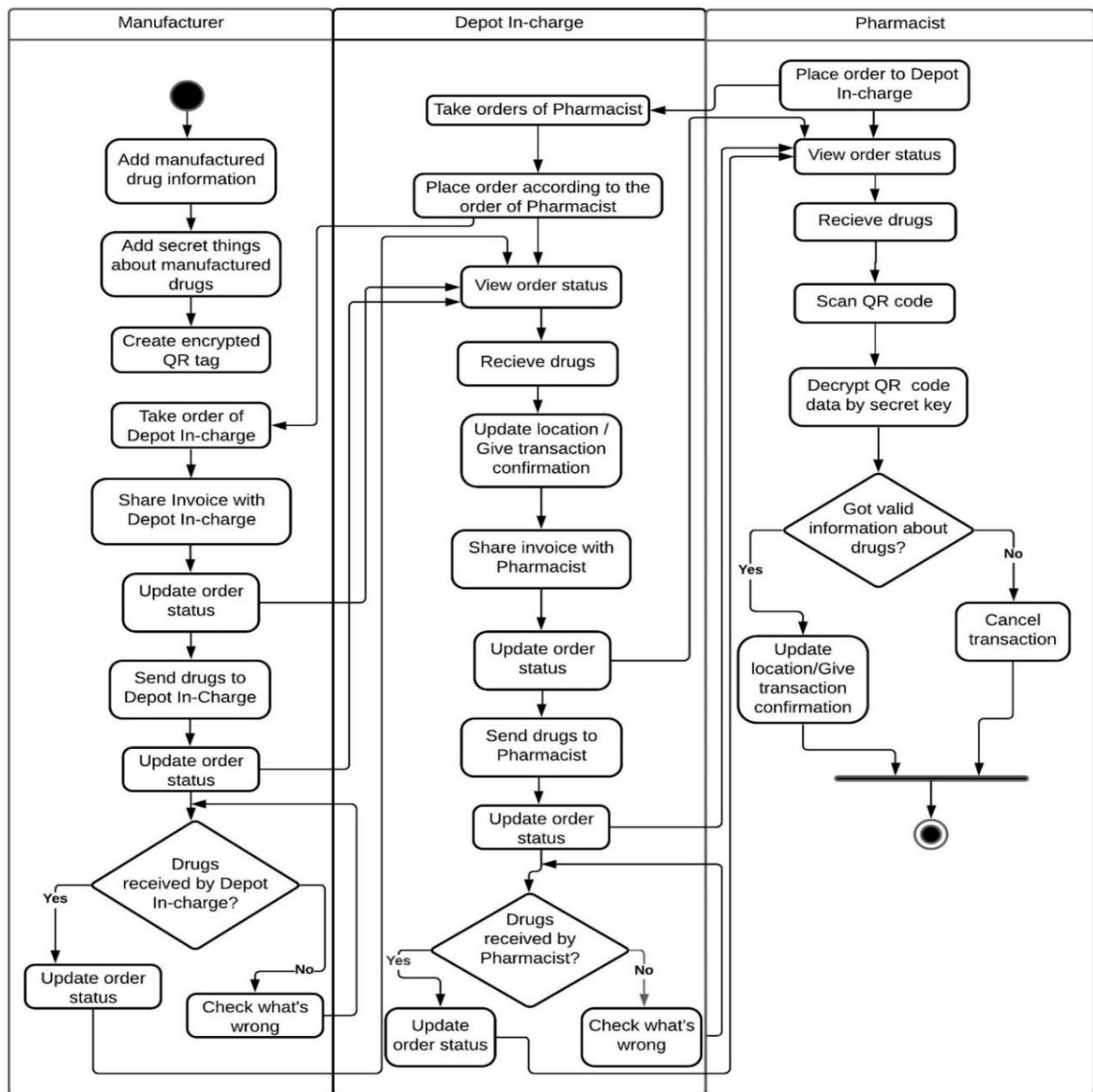


Figure 4.6: Project Activity Diagram

These figures show the participant's interaction with the framework according to their role. It also shows which user will do which operation. In these three diagrams we showed how the processes of users are related to each other. These diagrams show how each process acts logically according

to the user's input. This activity diagram also shows where validation is needed and where not. Many checking processes are situated in the system. For example, if the drugs received by the user or not, drugs have valid information or not. This gives an idea of where the security concerns of this system are. The diagram also shows that, to access one activity to the next, users must complete their previous activity. So, some activities are not independent. For example, in 4.6 the Pharmacist cannot view order status unless he orders drugs to depot in-charge and depot in-charge cannot change any order status unless the drug comes from Manufacturer.

4.4 Data Flow Diagram

This section shows the data flow diagram or the overview of our project. The context level diagram of our project is given below:

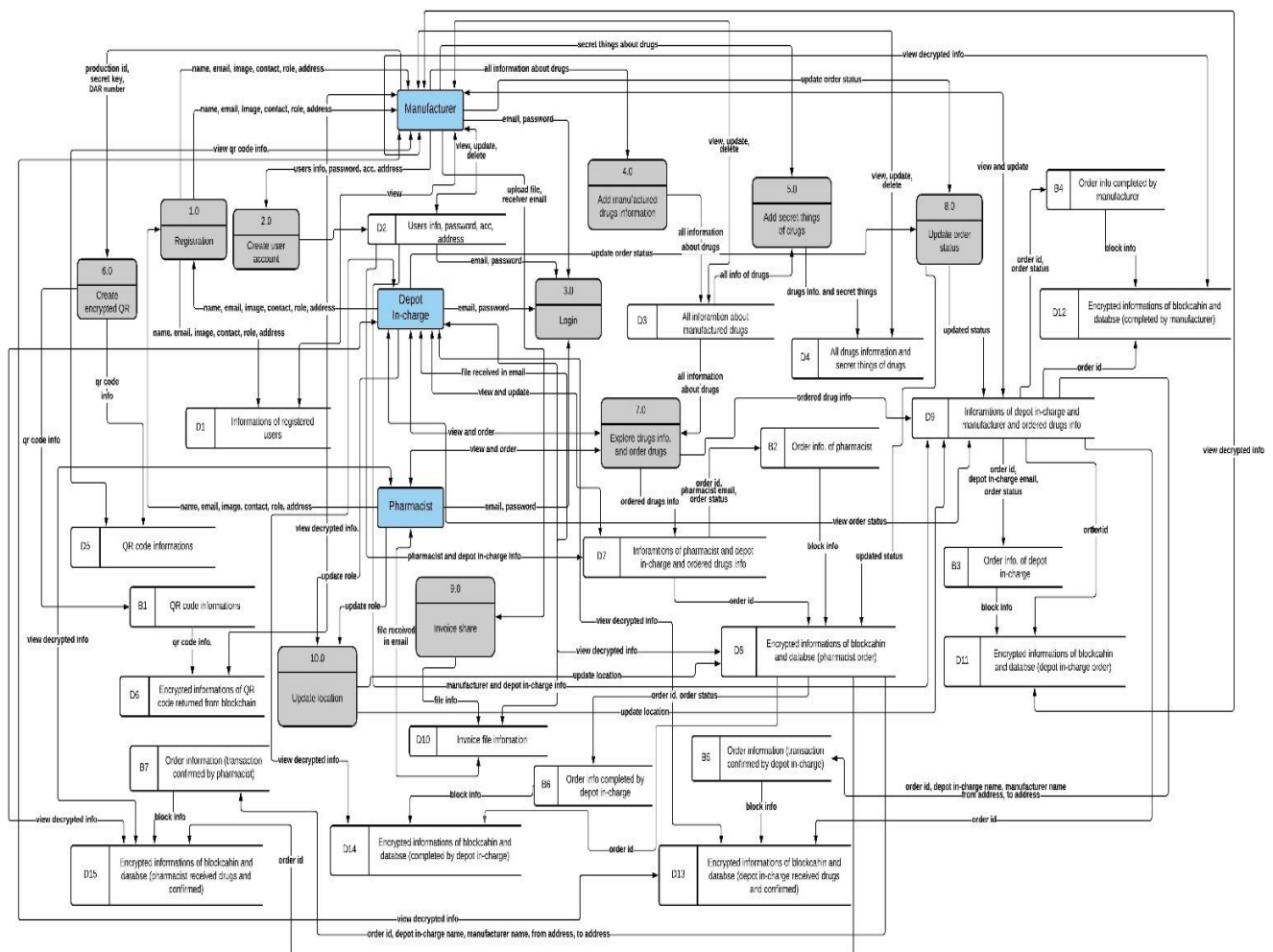


Figure 4.7: Data Flow Diagram

A data flow diagram (DFD) is a visual representation of the data stream flow through a framework or system. DFDs offer assistance in superior understanding of the method or framework operation to find potential problems, move forward effectiveness and create superior forms. In this diagram we have shown that eleven processes and sixteen data stores or databases are connected with the three users of the system. How the system functionally works, those have been discussed in the previous section. So here is given some description about the processes:

- i. Registration: This is the first process of our system. Users must have to be registered by giving some information like: image, name, email, contact number, address and role of the user (Depot in charge or Pharmacist). This registration form data is used as a request for creating a new account for users.
- ii. Create user account: According to the data given by any person who wants to be a part of the system as a depot in-charge or pharmacist, the manufacturer will create an account for that person with a password, address (blockchain account address) etc. By this process an account has been created for users.
- iii. Login: In this process the user gives two information: email and password. Then the system checks the info with the account creation information by manufacturer. If the user credential is valid then the system generates a session corresponding to the user.
- iv. Add manufactured drugs information: Manufacturers can add drug information into the database according to the list of drugs manufactured in the company. This information is shown to the home page of depot in-charge and pharmacist. By exploring the list of drugs they can order from their apps.
- v. Add secret things of drugs: According to the previous database some secret information, like: DAR number, production ID, batch number, production amount are stored in a database. These things are confidential for any company. These things are added by manufacturer only and only manufacturers have the access to view these data. This database is connected with the previous database where manufacturers added public drug information.

- vi. Create encrypted QR code: Manufacturer create an encrypted QR code where DAR number exists and this QR code is tagged on the drug boxes. For encryption we used the aes-256-ctr algorithm.
- vii. Explore drugs info and order drugs: This process is about to view the availability of needed drugs. Manufacturer, Depot in charge and Pharmacist all three users have access to view the drug information and depot in-charge and pharmacist can order drugs according to their need.
- viii. Update order status: When any user orders the drug they can view the order status, in this process Manufacturer and Depot in charge can update the order status. Such as, the order status is confirmed or delivered or completed. This is controlled by the sender of drugs (manufacturer or depot in-charge).
- ix. Invoice share: In this process, when the Manufacturer receives an order from Depot in charge, he shares an invoice file to Depot in charge through an email. This email works as an OTP; like, if the manufacturer sets the time two hours, then the Depot in charge has to download the file from the email within that time. After that time, the download link will expire and depot in-charge will not be able to download the invoice.
- x. Update location: This process is for the pharmacist and depot in charge. They can update the location. When a Pharmacist receives drugs from depot in charge, then pharmacist can update the location of DSC and when depot in-charge receives the drugs from manufacturer and confirms that he received the drugs the DSC is updated as location is updated.
- xi. Scan QR code: This process or feature is only for the Pharmacist. He can scan the QR code which is given in drug packaging, by using our mobile app and then he gets the authentic and valid information (DAR) about the drug.

CHAPTER 5

IMPLEMENTATION AND ANALYSIS

In the previous chapter we discussed the architecture, activity diagrams of our project. In this chapter we discussed the implementation of our project.

5.1 Implementation

Blockchain has two main types – Public blockchain and Permissioned (or private) blockchain (researchget.net). In a permissioned blockchain not everyone can write into the blockchain, as it were those members who have got permission or who have access, can write information on the blockchain. Within the setting of pharmaceutical – the superior alternative is to utilize a permissioned blockchain. In this proposed system, we are using the Ethereum based Blockchain network. So, this system is based on Ethereum architecture and emulated using 10 windows 64-bit PCs connected in a way to form a decentralized system, open-source blockchain with smart contract functionality. Originally, Ethereum is a public permission less blockchain-based platform implementing a Proof-of-Work (PoW) based consensus protocol. The system is based on a private blockchain network and we have used Proof-of-Work (PoW) based protocol. Here we have used it as a private platform (configurable feature) and requires a lot of computational power. All blocks are then sealed by approved signers. We have used geth which is a tool used to run a full Ethereum node on the framework. An Ethereum node is a framework that takes after the agreement of the Ethereum network. Solidity is a programming language we used to write smart contracts to interact with the network. We have written smart contracts in the Solidity object-oriented language for running Dapps (decentralized apps). Ethereum also introduces the Ethereum Virtual Machine (EVM) that enables any node to run any program regardless of the programming language.

When a company produces a new drug, the manufacturer adds the description (information) of that drug in the drug storage database and secret things of production in another database connected with this database. Then manufacturers generate encrypted QR codes and tag them on drug boxes.

For a particular number of pharmacists there will be a selected depot in-charge for each area. When a pharmacist orders drugs to the depot in-charge, the order information is stored in a database where some fields are by default, like: role (depot in-charge), dar (not selected) etc. Also this database has two fields that are sender and receiver. These fields are connected with the user database to get all the information of the user and this transaction is saved in blockchain with three information: unique order id, email address of pharmacist and order status. When a pharmacist places an order, the role field is “Depot In-charge” by default and the order status is “order placed” by default. Then the block data has been encrypted and saved in another database and this database is connected with the specific order information of the order database.

Then in the same way, when depot in-charge order drugs to the manufacturer, the transaction is saved in blockchain with three information: unique order id, email of depot in-charge and order status. As we discussed before here the role is manufacturer by default and other default things are the same, like: status (order placed), dar (not selected). The returned json from blockchain is saved into the databases as an encrypted data and this specific database collection is connected with the specific order database collection of depot in-charge. Then the manufacturer checks the drug storage and updates the amounts of storage by giving the ordered amount of depot in-charge (the production amount reduces). Then he checks how many secret keys will be needed for this order or transaction and selects the dar field as single or multiple dar for this order. Then he shares the invoice with the depot in-charge.

Then Manufacturer confirms the order of depot in-charge as a part of order status update and when he completed the order status a transaction is saved in blockchain like previous way where we passed order status (completed) and order id into block and this information's are then encrypted and saved into another database connected with that order database collection. After that when the depot in-charge receives the ordered drugs from the manufacturer and checks the authentication of drugs, he gives a confirmation that he has received the drug and blockchain transaction happens and the default role is changed to depot in-charge in the database. This transaction is saved in Blockchain with five information: order id, buyer name (depot in-charge name), seller name (manufacturer name), from address (blockchain account address of depot manufacturer) and to

address (blockchain account address of depot in-charge). Then the returned json has been encrypted again and saved into another database connected with that specific order database collection (off-chain and on-chain data are merged here).

Then in the same way depot in-charge controls the order status of pharmacists after receiving the drugs sent by the manufacturer and completed order status has a blockchain transaction again. Then returned json has been encrypted and saved into a database connected with the specific order database collection of the pharmacist. After the pharmacist receives the drugs from the depot in-charge he confirms he scans the QR code tagged on the drug boxes and sees the decrypted information (dar). Then he confirmed that he received the drugs and a transaction happened in Blockchain where five information is stored in block: order id (pharmacist order id), buyer name (pharmacist name), seller name (depot in-charge name), from address (blockchain account address of depot in-charge) and to address (blockchain account address of pharmacist).

We developed a cross-platform system. Here included some screenshots of our web apps (manufacturer and depot in-charge have web apps) and android app (pharmacist have android app):

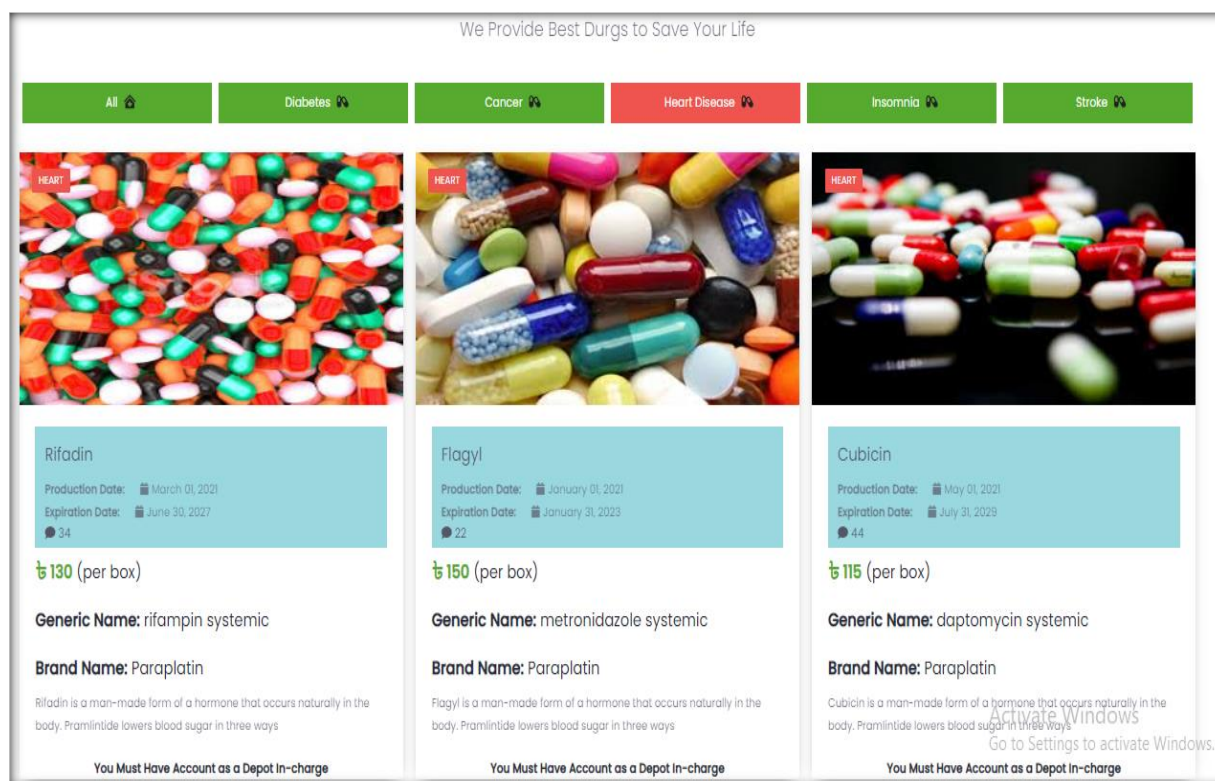


Figure 5.1: Home Page (Web App of Depot In-charge)

The registration page features a green header with the 'Drug Guard' logo and navigation links for Home, Register, Login, and a language dropdown set to 'Light'. The main content area contains a registration form with the following fields: Image (with a 'Choose File' button and 'No file chosen' text), Name (text input), Email (text input), Contact Number (text input), Role (radio buttons for 'Depot In-charge' and 'Pharmacist'), and Address (text input). A green 'Register' button is positioned below the form, followed by a link 'Already have account?'. The footer includes the copyright notice '©Secure Drug Supply Chain. All rights reserved by @Muhtasim.'.

Figure 5.2: Registration Page (Web App of Depot In-charge)

The login page has a green header with the 'Drug Guard' logo and navigation links for Home, Register, Login, and a language dropdown set to 'Light'. The main content area contains a login form with the following fields: Email (text input with the value 'muhtasim.fahim.98@gmail.c') and Private Key (text input with masked characters). A green 'Log In' button is located below the form, followed by a link 'Don't have account?'. The footer includes the copyright notice '©Secure Drug Supply Chain. All rights reserved by @Muhtasim.' and a Windows watermark 'Activate Windows'.

Figure 5.3: Login Page (Web App of Depot In-charge)



Figure 5.4: Empty Cart Page of Depot In-charge

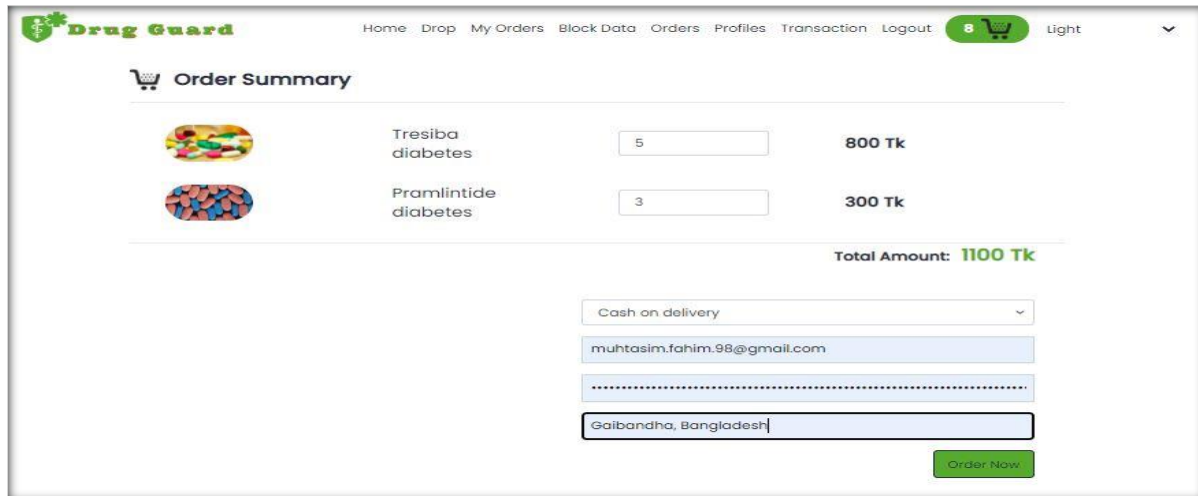


Figure 5.5: Cart Page of Depot In-charge

In Figure 5.1 we can see the homepage or guest page of our web app. Figure 5.2 and 5.3 are the registration and login page and after login depot in-charge gets an empty cart page (figure: 5.4) and after adding drugs to cart the cart page is shown at figure 5.5.

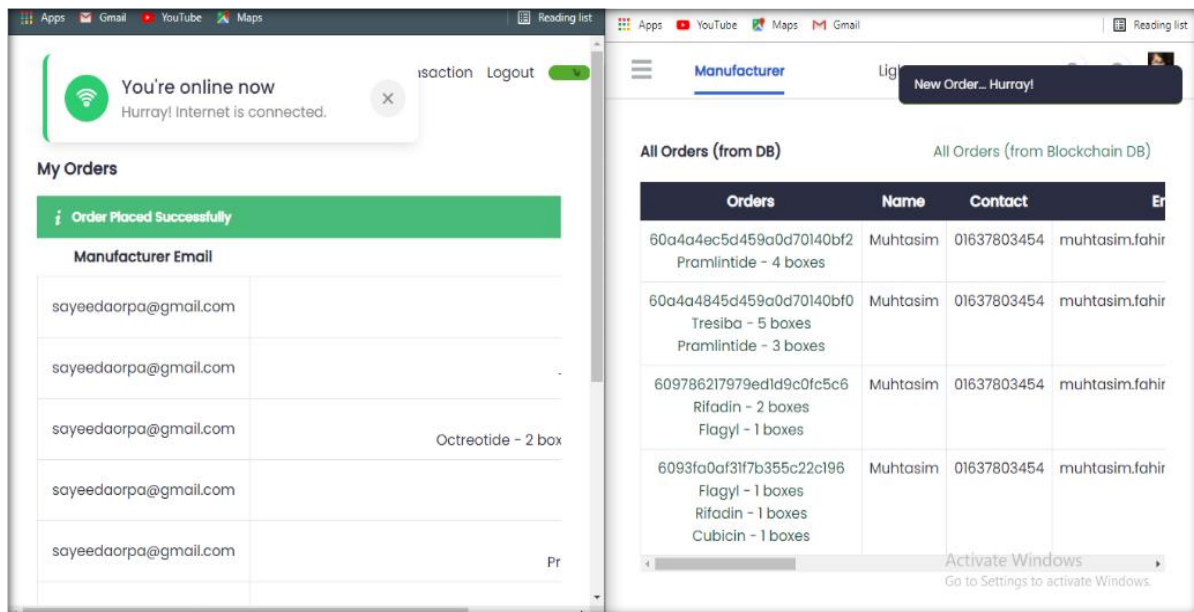


Figure 5.6: Real Time Order

Orders	Name	Contact	Email	Address	Status
609786217979ed1d9c0fc5c6 Rifadin - 2 boxes Flagyl - 1 boxes	Muhtasim	01637803454	muhtasim.fahim.98@gmail.com	Gaibandha, Bangladesh	Placed
6093fa0af31f7b355c22c196 Flagyl - 1 boxes Rifadin - 1 boxes Cubicin - 1 boxes	Muhtasim	01637803454	muhtasim.fahim.98@gmail.com	Gaibandha, Bangladesh	Placed

Address	Status	DAR	Production ID	Placed Date	Placed Time	Payment Status	Select Pr. ID
Gaibandha, Bangladesh	Placed	Not Selected	None	May 9th 2021	12:50 PM	Not paid	
Gaibandha, Bangladesh	Placed	Not Selected	None	May 6th 2021	08:15 PM	Not paid	

Figure 5.7: Placed Order Table of Depot In-charge (Web App of Manufacturer)

In these two pictures (Figure: 5.7) we showed the placed order table of depot in-charge in the manufacturer app where in-completed orders take place (those orders whose status is still incomplete).

Block Hash	Order ID	Order Status
0x45821c383daaa8842db9d0626b21522a4ad76518dced872b6b0f070fcd598a2	608f0c10db95df2070c3090b	order_placed
0x460816555bc3403a726ceca8d4c98d36fae127316dfa42477ab9cd216113d9f	608f9611d0c1e232d8d11a78	order_placed
0xca08ecd4b50ea62d84355ef518cfc89914727d5c1f0d48512988c11cf4cbb307	608f99a78a2424330814e8d5	order_placed
0x26781aa3fb244531dd51cfe7399d6a67f093a3325c6151023f2c091c55d5184b	609049555bf1aa3078e037fd	order_placed

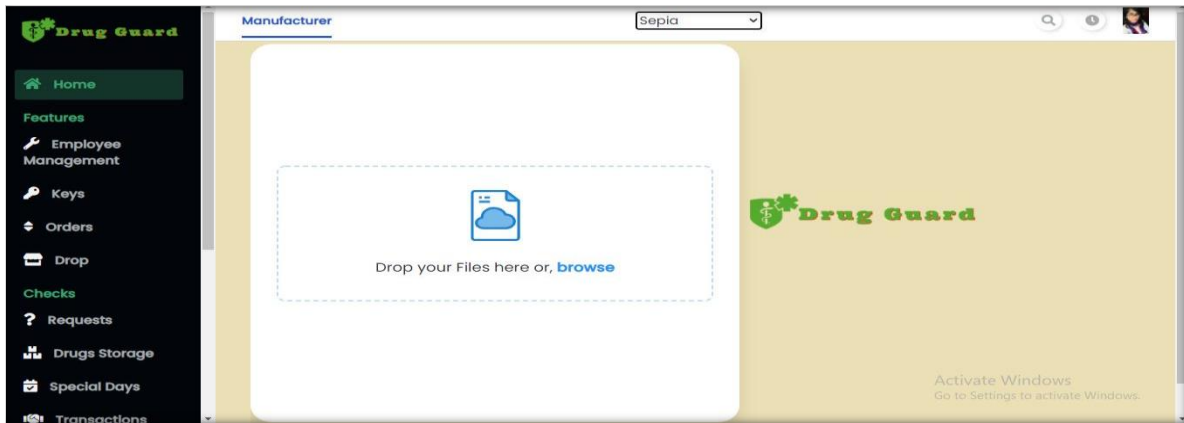


Figure 5.10: Invoice File Sharing Page (Web App of Manufacturer)

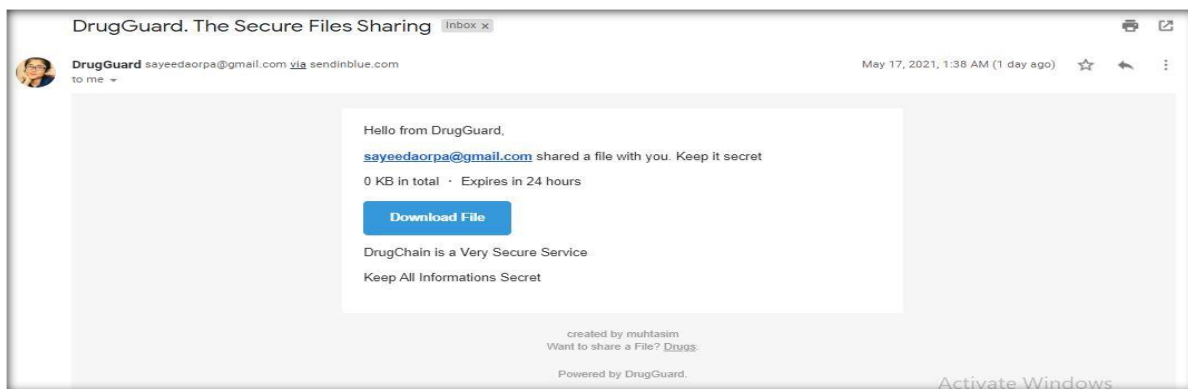


Figure 5.11: Email Template

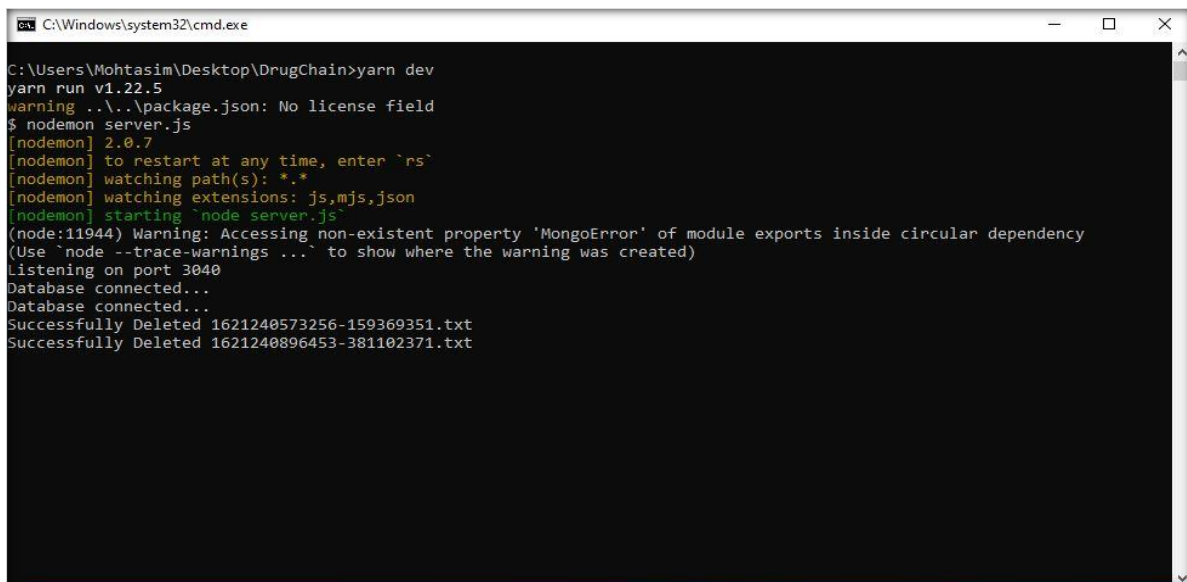


Figure 5.12: Invoice File Delete Message

Figure 5.10, 5.11 and 5.12 we showed the invoice file sharing page on the manufacturer web app, email template we have created for our product email and the message when the invoice file is deleted from the database.

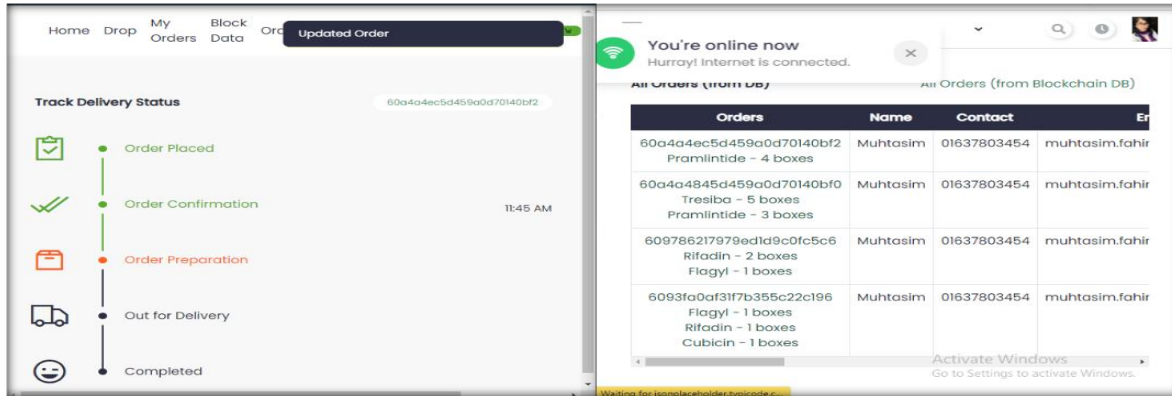


Figure 5.13: Real Time Order Tracking between Manufacturer and Depot In-charge

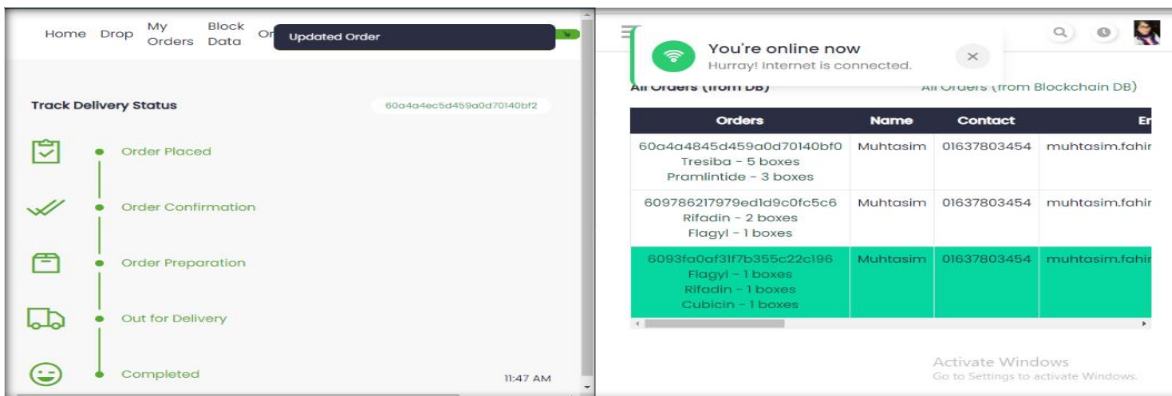


Figure 5.14: Completed Order Confirmation by Manufacturer

This two Figure (5.13 and 5.14) shows the order status which is controlled by the manufacturer and real time tracking which can be viewed by depot in-charge and when the manufacturer completes any order status this order information goes from this order table and real time tracking.

```
C:\Windows\system32\cmd.exe
{
  _id: 60a4a67b5d459a0d70140bf4,
  orderID: 60a4a4ec5d459a0d70140bf2,
  blockHash: 'dbc4123651e223fd7d583189f1520d5c8d0037ab710fbcc383cbf6d235485c477ad8995ab1b6c64e4295d584af0c31d8b
a15e0d312ea34e7f82dff0181d57997490',
  blockNumber: 'dd8d1638',
  contractAddress: null,
  cumulativeGasUsed: '090e11365e',
  from: 'dbc410265ae026af7e0f63dba5530e5dd0b6aa32002e8996868eb6b725c8a9577a089cff91b3b62e025',
  gasUsed: 'd90e11365e',
  logsBloom: 'dbc4133158e521af285d3788a4065f548e023ea27306ed986b6e6c6c705d82c124a58a9dff4a6830e12c595a49f29649d8
e5575c317b0f4f7d83daf2191b5e9f7595df1bbeeb66f22a2af29c7fe6d028bb385afce9f7e9753c88b1c0dc0004e4c2f09d753d8257034
2dda0e9a020010c5de0683aacc840b1a94124968277eca4b50e97cae482b31484b39f101a2cca2dab236bb9a1910dd6eb94c33136e8c92aa
3da79c4f3e0424f8798c63dbccff57d44b60991ff87b7d81d86fba738678b89cf510f9f829c9903be1be2ee24a30beb7f05a2de2a40fecdb4
8f7608bf9840044f4e4514bf4954337f03225c2677d942b176057afb136ed5bbbed0cc54eda99666b16acfec52b452f3c0df675ec9c3a8745
2cb96a5e78d71234d73528c12dbcc8b6bc4104a4f7670d3e246902aa63571428a04d738bc86897567698b52a1e80d99a738dbfcc7ce7f629
21464c1f293549b5f4d9883469a295874141a57d9c11d4b17a652b24e80f95f2786014091c1a0fe342ec20402924d37bb37e51a2e9d0d789
6cdf354179a511375a40dc07f72e9798f611b089ee09114317d88da2325391986ed23cb1daf9350303fc290db26fbd87a32be8b3d554461
e6d71fa7b9207c680d80ef7a99afe3610b8dcd1cd260359ec139c362330d8edfde1dfb01209ddc310c4266edfa1be8a88548de97e2cdc16d
1984e556f11db90d5582fee202b1084490',
  status: '9fce5664',
  to: 'dbc4133858e5206af7e5a30d9a25450608e0338f47a55e5ca3e66be682155d79524a18dceff4d3a30e924',
  transactionHash: 'dbc445305cec29fb7d0835dda202095cdd546bf72154e4986d6fbf6e225a8bc923adccbf94f6d38e0250b5c4ea6
921889b1040a932af8197c8adff5114e56c92493', transactionIndex: 'db',
  type: 'dbc413',
  orderSet: '88d34e7104b065fa7c',
  createdAt: 2021-05-19T05:47:39.142Z,
  updatedAt: 2021-05-19T05:47:39.142Z,
  __v: 0
}
```

Figure 5.15: Encrypted Block Data and Completed Order Database Data

```
C:\Windows\system32\cmd.exe
cee" elapsed=696.411ms
INFO [05-19|11:51:41.724] block reached canonical chain      number=6189 hash="448201_1f7b18"
INFO [05-19|11:51:42.000] Commit new mining work      number=6197 sealhash="8adb74_c11bad" uncles=0 txs=0 g
ns=0 fees=0 elapsed=276.254ms
INFO [05-19|11:51:42.007] mined potential block      number=6196 hash="e9226e_bebcee"
INFO [05-19|11:51:42.039] Commit new mining work      number=6197 sealhash="4256e1_46a856" uncles=0 txs=1 g
ns=24944 fees=2.4944e-05 elapsed=315.594ms
INFO [05-19|11:51:41.767] Submitted transaction      hash=0x78bca797473ef3ecdcb14b1af0af493f243c71917e028
c8f9e35ca00261149c from=0x372570f8dC1eA9c9d1c4513677218Dc53b6ACB19 nonce=215 recipient=0x090070f77A6B9b016f9C88e8B4A8eD0
47c078088 value=1000000000000000000
INFO [05-19|11:51:42.306] Successfully sealed new block number=6197 sealhash="4256e1_46a856" hash="3caeccc_75c
103" elapsed=270.313ms
INFO [05-19|11:51:42.313] block reached canonical chain      number=6190 hash="ff701c_f90c3e"
INFO [05-19|11:51:44.013] Commit new mining work      number=6198 sealhash="ec28a2_8d3013" uncles=0 txs=0 g
ns=0 fees=0 elapsed=1.700s
INFO [05-19|11:51:44.014] mined potential block      number=6197 hash="3caeccc_75c103"
INFO [05-19|11:51:45.124] Successfully sealed new block number=6198 sealhash="ec28a2_8d3013" hash="7f2d1e_528
1a9" elapsed=2.811s
INFO [05-19|11:51:45.124] block reached canonical chain      number=6191 hash="e269cd_532300"
INFO [05-19|11:51:45.146] Commit new mining work      number=6199 sealhash="df49fa_01714d" uncles=0 txs=0 g
ns=0 fees=0 elapsed=21.943ms
INFO [05-19|11:51:45.156] mined potential block      number=6198 hash="7f2d1e_5281a9"
INFO [05-19|11:51:47.683] Successfully sealed new block number=6199 sealhash="df49fa_01714d" hash="bee4d8_20b
f58" elapsed=2.558s
INFO [05-19|11:51:47.685] block reached canonical chain      number=6192 hash="c38891_6d33f4"
INFO [05-19|11:51:47.703] Commit new mining work      number=6200 sealhash="900488_2778a9" uncles=0 txs=0 g
ns=0 fees=0 elapsed=19.906ms
INFO [05-19|11:51:47.707] mined potential block      number=6199 hash="bee4d8_20bf58"
INFO [05-19|11:51:48.062] Successfully sealed new block number=6200 sealhash="900488_2778a9" hash="711c2b_e3c
ca6" elapsed=377.749ms
```

Figure 5.16: Submitted Transaction

Block Hash	Order ID	Order Status	DAR
0x1d24e2c56f744039a59ee2f23a44dace8d38fc7cb349d626f5234fa267d22ac7	608f0c10db95df2070c3090b	completed	Single DAR
0xad477b1d1aa8382e4f92c238a2bbe1957a1e545630b4255f1d3742aaf951c163	608f9611d0c1e232d8d11a78	completed	Single DAR
0x48741aca010bf1cf8239f69b09fd7871925cbec5d5d72f017d48eadf03b5ad54	608f99a78a2424330814e8d5	completed	Single DAR
0x0102c5f446bfe94d7e13edb32532d3c7dc8eabd7034f74a7c4ff29306e0236f	609049555bf1aa3078e03f7d	completed	Single DAR

Figure 5.17: Decrypted Block Data Table of Depot In-charge Completed Order (Web App of Manufacturer)

Figure 5.15 shows the encrypted block data and completed order database merge data. These data are saved in a database when the manufacturer completes the any order status of depot in-charge. Figure 5.17 shows the decrypted (encrypted data off Figure: 5.15 has been decrypted) data of that database which is saved when the manufacturer completes the order status.

```

{
  _id: '60a4a7705d459a0d70140bf5',
  orderID: '60a4a4ec5d459a0d70140bf2',
  depotID: {
    _id: '605a2b5cf72ab32ec8c3aee9',
    name: 'Muhtasim',
    image: 'image.jpeg',
    email: 'muhtasim.fahim.98@gmail.com',
    phone: '01637803454',
    role: 'Depot In-charge',
    address: 'Gaibandha, Bangladesh',
    private_key: '$2b$10$0t56Tlvh6VFPk841Cn4zhuCN54BVy2yU8CXFFBdzCdft1x55KWE56',
    public_key: 'MFwwDQYJKoZIhvcNAQEBBQADSwAwSAJBAlHObqo/1eEzKBTdAMGCCWk814KWH1uq wG0/hTyrFddYho5Ak1E4o61axRRUX22Nmz81z83rpPW1j89Tq1IH1vHsCAwEAAQ==',
    accountAddress: '0x000070f77a6b9b016f9c8be8b4a0ed047c07b088',
    createdAt: '2021-03-23T12:54:36.719Z',
    updatedAt: '2021-03-23T12:54:36.719Z',
    __v: 0
  },
  blockHash: 'dbc4106209b072fc7e5a31dea50457508a566af77201be9a6e6ae86f708881c826f18cfff9493b36e32c5b5e4bf4c51ddeb0525f392aa44a2e8189a61e1e0d9e7596',
  blockNumber: 'dd8d1a36',
  contractAddress: null,
  cumulativeGasUsed: 'd9881a355c',
  from: 'dbc4106209b072fc7e5a31dea50457508a566af77201be9a6e6ae86f708881c826f18cfff9493b36e32c5b5e4bf4c51ddeb0525f392aa44a2e8189a61e1e0d9e7596',
  gasUsed: 'd9881a355c',
  logsBloom: 'dbc413305e2eaf7e5a30d9a25456068e0338f47a55e5ca3e66be682155d79524a18dceff4d3a30e924',
  status: '9fce5664',
  to: 'dbc413305e2eaf7e5a30d9a25456068e0338f47a55e5ca3e66be682155d79524a18dceff4d3a30e924',
  transactionHash: 'dbc414390ab670a8215a338fa7530957d5b16af12107e9ca6a3fbaec770cd4c52da6dc9fbb493b37e025585d1cf294418bed01556478f51c2c83daf01f1a5f9b7cc6',
  transactionIndex: 'db',
  type: 'dbc413',
  transaction: 'successful',
  createdAt: '2021-03-19T05:51:44.130Z',
  updatedAt: '2021-03-19T05:51:44.130Z',
  __v: 0
}

```

Figure 5.18: Encrypted Block Data and Confirmed Transaction Data

Block Hash	Order ID	Order Status	DAR
0xd20ad7b126dbe2df7ebc451bec056a45a8de410af6ba9cc70e7d45edb2373cf1	608f0c10db95df2070c3090b	completed	Single DAR
0x3d16a39c056011a2f7d10ea9b50e9db462c0309c43bcb350f4758de3b7f92f60	608f9611d0c1e232d8d11a78	completed	Single DAR
0x7fca5dd8070ded3632c3d9fbd6e7c7cf5712630c4b2a5247eea33b9fd7976ccf	608f99a78a2424330814e8d5	completed	Single DAR
0xlead4340f2ba4ffe3fc83e055c7702206ffed1c60f3c95b92719721032360e4	609049555bflaa3078e03f7d	completed	Single DAR

DAR	Production ID	Order Role	Block Number	Gas Used	To	Depot In-Charge ID
Single DAR	1	Depot In-charge	4568	24944	0x090070f77a6b9b016f9c8be8b4a8ed047c07b088	605a2b5cf72ab32ec8c3aee9
Single DAR	1	Depot In-charge	4783	24944	0x090070f77a6b9b016f9c8be8b4a8ed047c07b088	605a2b5cf72ab32ec8c3aee9
Single DAR	1	Depot In-charge	4961	24944	0x090070f77a6b9b016f9c8be8b4a8ed047c07b088	605a2b5cf72ab32ec8c3aee9
Single DAR	1	Depot In-charge	5049	24944	0x090070f77a6b9b016f9c8be8b4a8ed047c07b088	605a2b5cf72ab32ec8c3aee9

Figure 5.19: Decrypted Block Data Table of Depot In-charge Transaction Confirmation
(Web App of Manufacturer)

Figure 5.18 shows that when depot in-charge confirmed that he received ordered drugs from manufacturer and those data has been encrypted and saved into database including order database data. Figure 5.19 shows that the transaction confirmation table where we showed the decrypted data (encrypted data off Figure: 5.17 has been decrypted) of the previous transaction which is happened when depot in-charge confirms that he received the drugs.

 Home Drop My Orders Block Data Orders Profiles Transaction Logout  Light	
Your Transactions Show Pharmacist Transactions	
Transaction Hash	Block Hash
0x3f02cece6bd46a323c740269e327b7b309bbcf646667381bda0249eb9e380f2	0x68ae00b2f01912c1902c530a81daf047c140eb2dadbf36aa02fd6eb3e9ab
0xc90a0837913f64521b63f693fb86007a9a0e7dfe25966f09c3b64e673438d62	0xc279c888b94c5c86b29abdac5273428f0bcdcf45098598b7251baa39687
0x7b59c05d8c470a94f25e50a76078b8624d20e038153f2213a77da52ebb9c77c8	0x642c1824ed3820066f8d2d8a8ddb6643818d047e7622b1a6830de91908fe

 Home Drop My Orders Block Data Orders Profiles Transaction Logout  Light							
Your Transactions Show Pharmacist Transactions							
Order ID	Order Status	DAR	Order Role	Block Number	Gas Used	From	Type
609b77da9fb2091d18aad0f6	completed	Single DAR	Depot In-charge	5780	24944	0x372570fbdclea9c9d1c4513677218dc53b6acb19	successful
609402598d02c936dc8e8567	completed	Single DAR	Depot In-charge	5553	24944	0x372570fbdclea9c9d1c4513677218dc53b6acb19	successful
6092e79a5e41e12604ceb913	completed	Single DAR	Depot In-charge	5397	24944	0x372570fbdclea9c9d1c4513677218dc53b6acb19	successful

Figure 5.20: Decrypted Block Data Table of Depot In-charge Transaction Confirmation (Web App of Depot In-charge)

Figure 5.20 shows the transaction confirmation table in depot in-charge app where we showed the decrypted data (encrypted data off Figure: 5.17 has been decrypted) of the transaction which happened when depot in-charge confirms that he received the drugs.

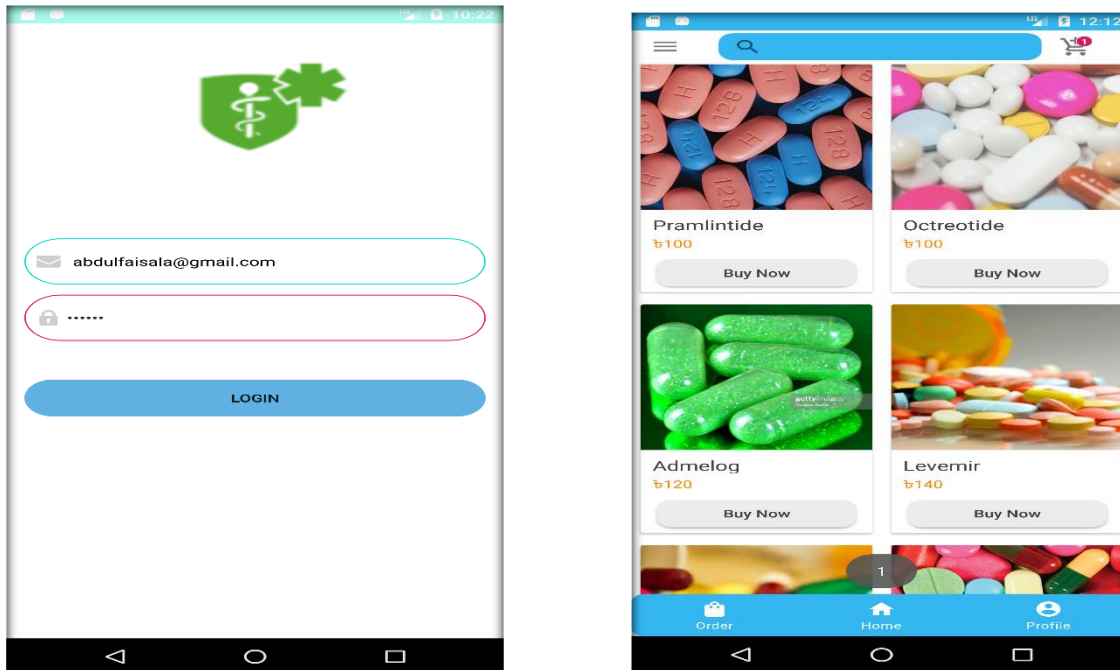


Figure 5.21: Login Page and Home Page (Android App of Pharmacist)

In figure 5.21 we showed the login page and home page of the pharmacist in the android app. The home page drug items are the same for depot in-charge and pharmacist and for guests too. Both can see the same drug list manufactured by the company.

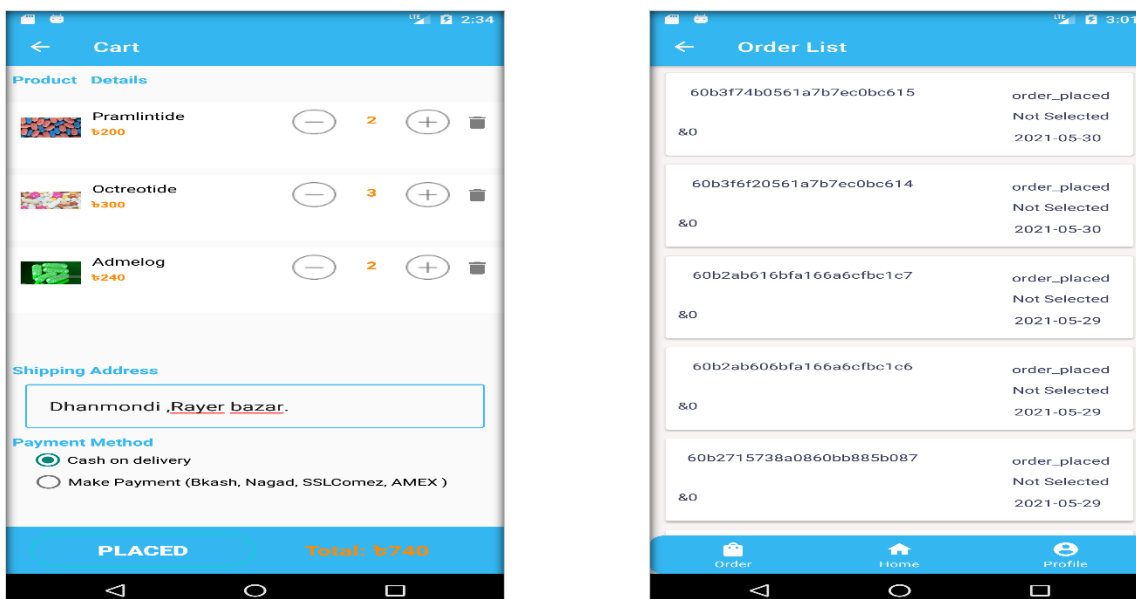


Figure 5.22: Cart and Order List Page (Android App of Pharmacist)

Figure 5.22 shows the cart page and order list page of the pharmacist. By using our mobile app pharmacists can order drugs to depot in-charge. It is a real time order from mobile app (pharmacist) to web app (depot in-charge). The order processes are the same as before we discussed for figure 5.7, 5.8 and 5.9. Then depot in-charge shares the invoice with the pharmacist as we showed before in figure 5.10, 5.11 and 5.12. After that depot in-charge will change the order status like manufacturer (we described it in figure 5.13, 5.14 and 5.15).

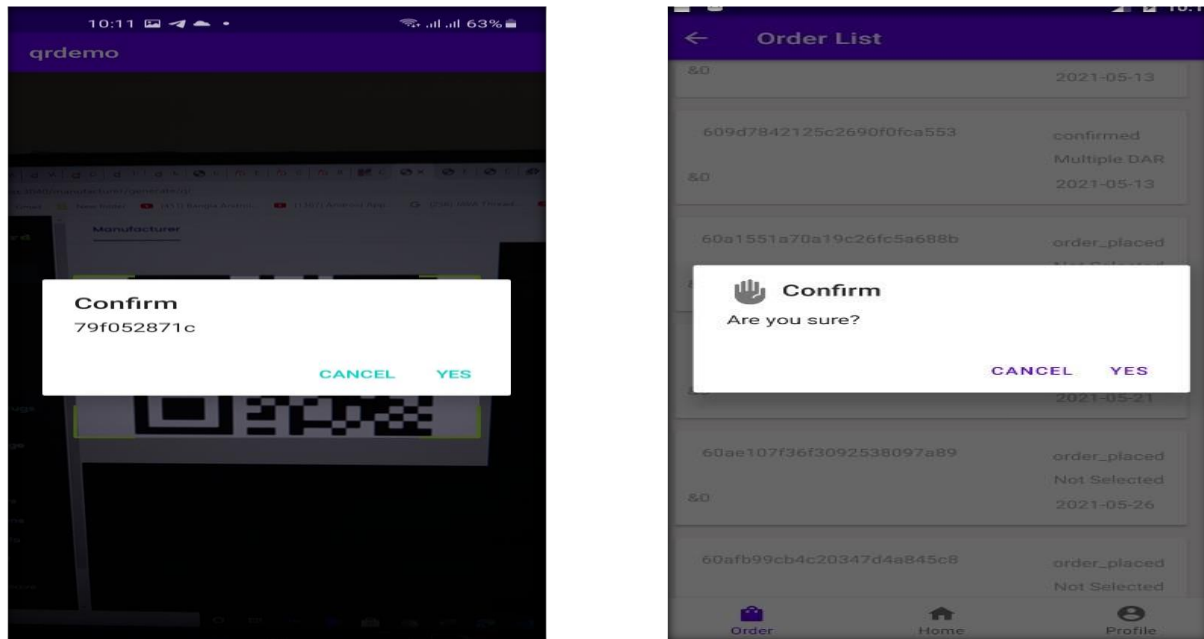


Figure 5.23: QR Code Scanner and Transaction Confirmation Alert (Android App of Pharmacist)

In figure 5.23 we showed the encrypted QR code scanner in android app (pharmacist) and transaction confirmation alert box of pharmacist. As we discussed before in figure 5.18 a blockchain transaction happens when the pharmacist ensures that he received the drugs sent by depot in-charge by clicking the button “yes” in figure 5.23(2) and the role has been changed to pharmacist. This data has been encrypted then and merged with the specific order database table of the pharmacist and saved into another database.

 Home Drop My Orders Block Data Orders Profiles Transaction Logout  Light				
Orders (from Blockchain DB)			Completed Order(from Blockchain DB)	
Block Hash	Order ID	Order Status	Block Number	Gas Used
0x89a967f4bcef8a843296288a8782ded802ec98377e5a050d1dbab2c01f842e81	60915764b256452ed8a442cf	order_placed	5098	22984
0x3d4bb1670838ea6ebe5440b8dclff9a3c98a5e676ff9342e3e92622ef97a7c1d	609157cdb256452ed8a442d2	order_placed	5174	22984
0xa40ae88f2ae86dcff95b6922c8a6df156e4c4fe976f883627d155c6879419ea6	60915922b256452ed8a442d5	order_placed	5270	22984

 Home Drop My Orders Block Data Orders Profiles Transaction Logout  Light			
Orders (from Blockchain DB)			Completed Order(from Blockchain DB)
Pharmacist ID	Pharmacist Email	Transaction Hash	Transaction Status
60879a2bc00cb31b50430edc	abdulfaisala@gmail.com	0x5cdab4afd73ef2ed08a51d42483184498b0cd5a5318c0d5da8115698f2447da0	true
60879a2bc00cb31b50430edc	abdulfaisala@gmail.com	0x61877149126ef6c3c2cb28e5783ec092bb193cd0304215fe7c37daae1b141c76	true
60879a2bc00cb31b50430edc	abdulfaisala@gmail.com	0xb83d4fe9eacd2c755504a81b0ba4fbd6d50fa66bfd175e3b18088e6df16d0020	true

Figure 5.24: Decrypted Block Data Table of Pharmacist's Placed Order (Web App of Depot In-charge)

 Home Drop My Orders Block Data Orders Profiles Transaction Logout  Light	
Pharmacist Transactions	Show My Transactions
Transaction Hash	Block Hash
0x7393f9c3983d57ae61790900312ba0827a1cca176c5877877d25882bb41b1b4a	0xa587c7d81d4e07777e9216b571ac88922c630097268c0aa9cbd526c9b00150
0x155c06dc0a4f29c3317640da4e3d2599415d3efb86081f582471592cbb2fad1	0x596504373ccca3517c7491e13afd083ce7371f9cfdc06054986438c111eb1723
0xa950f40d87f9c1fe879798297763dc8277da3fb4773679697d9f2aaf6740fc99	0x2830104d84ddebaf8ed2224f6515451858dc37dafb564295243653a815dbb7e

 Home Drop My Orders Block Data Orders Profiles Transaction Logout  Light							
Pharmacist Transactions							Show My Transactions
Order ID	Order Status	DAR	Order Role	Block Number	Gas Used	To	Ph
60a1598638456316444a2705	completed	Single DAR	Pharmacist	5850	24860	0xd0120064047564b484a0c1d558dbf4b6385e714f	60879a2b
60a15d2f1ac9cde34d7fda0	completed	Single DAR	Pharmacist	5939	24860	0xd0120064047564b484a0c1d558dbf4b6385e714f	60879a2b
60a15e7c1ac9cde34d7fda4	completed	Single DAR	Pharmacist	6020	24860	0xd0120064047564b484a0c1d558dbf4b6385e714f	60879a2b



[Home](#)
[Drop](#)
[My Orders](#)
[Block Data](#)
[Orders](#)
[Profiles](#)
[Transaction](#)
[Logout](#)


Light

Pharmacist Transactions

Show My Transactions

Order ID	Order Role	Block Number	Gas Used	To	Pharmacist ID	Type	Time	Date
gleAR	Pharmacist	5850	24860	0xd0120064047564b484a0c1d558dbf4b6385e714f	60879a2bc00cb31b50430edc	successful	11:43 PM	May 16th 2021
gleAR	Pharmacist	5939	24860	0xd0120064047564b484a0c1d558dbf4b6385e714f		successful	11:59 PM	May 16th 2021
gleAR	Pharmacist	6020	24860	0xd0120064047564b484a0c1d558dbf4b6385e714f		successful	12:05 AM	May 17th 2021

Figure 5.25: Decrypted Block Data Table of Pharmacist's Transaction Confirmation (Web App of Depot In-charge)

Figure 5.24 and 5.25 shows the data returned from blockchain and saved into the database after doing encryption using aes-256-ctr algorithm. Figure 5.24 is the placed order table of pharmacists as we showed before for depot in-charge in figure 5.8 and figure 5.25 shows the transaction confirmation of pharmacist as we showed before for depot in-charge in figure 5.19 and 5.20.

Collection Name *	Documents	Avg. Document Size	Total Document Size	Num. Indexes	Total Index Size	Properties
completes	10	1.8 KB	17.8 KB	1	26.0 KB	
contracts	1	1019.0 B	1019.0 B	1	26.0 KB	
drugs	28	402.0 B	10.2 KB	1	26.0 KB	
files	0	-	0.0 B	1	12.0 KB	
orders	26	1.4 KB	50.4 KB	1	26.0 KB	
ordertrids	34	1.9 KB	62.4 KB	1	26.0 KB	
phocompletes	8	1.8 KB	14.3 KB	1	26.0 KB	
phrorders	10	429.7 B	4.3 KB	1	26.0 KB	
phrordertrids	10	1.9 KB	18.7 KB	1	26.0 KB	
phrtransactions	6	1.8 KB	9.0 KB	1	26.0 KB	
qrccodes	2	143.6 B	287.0 B	2	72.0 KB	
qrccodetransactions	2	1.6 KB	3.2 KB	1	26.0 KB	
requests	2	262.0 B	767.0 B	2	108.0 KB	
sessions	2	219.0 B	438.0 B	2	72.0 KB	
storages	26	206.0 B	5.3 KB	1	26.0 KB	
transactions	10	1.8 KB	17.9 KB	1	26.0 KB	
users	8	461.8 B	3.6 KB	3	108.0 KB	

Figure 5.26: Database of Our Product

Figure 5.26 shows the database of our product. We have seventeen (17) database collections where we stored all the information of users, orders, blockchain transactions (encrypted) etc.

5.2 Analysis

5.2.1 Security analysis

Blockchain produces a structure of information with characteristic security qualities. It's based on standards of cryptography, decentralization and agreement, which guarantees belief in transactions between parties. In most blockchains or distributed ledger technologies (DLT), the information is organized into blocks and each block contains a transaction hashes. Here in our system, transaction information of every point of the supply chain is stored in the blockchain. Each new block connects with the previous block before it gets mined and also connects with the next block after mining. It provides a tamper proof network. All transactions inside the blocks are approved and concurred upon by a component or mechanism, guaranteeing that each transaction is genuine.

Blockchain technology empowers decentralization through the interest of individuals across a distributed network. There is no chance of failure in blocks and any user or fraud cannot change the record of transactions. We have set up a secured and trusted network, where only the trusted parties are permitted to join the network. By registration policy, the trusted people will get access to the network. On the backend there is a permissioned blockchain to store all the specified transactions and once the data entered to it – can never be changed. Besides this, we have built a web APP named “Drug Guard” and a user-friendly mobile APP to make transactions to the blockchain. By using this web app and android app, the participants will be able to buy authentic drugs by checking whether the transaction is valid or not. Our system can ensure that the drugs will be safe from the fraud attack and it is not possible to have any counterfeit drug in the supply chain as every transaction is stored in blockchain which is not possible to change.

We stored encrypted data into the database where blocks information and order database information are merged. If any malicious user gets the database he or she cannot do anything with the data as he or she cannot get the real or decrypted data. For encryption of database aes-256-ctr algorithm has been used.

Also we provide encrypted QR code for DAR number. So it is quite difficult for any illegitimate person to make a duplicate QR code and sell their counterfeit drugs.

5.2.2 Cost Analysis

In this section, we showed a rough budget to develop this project. Here we discussed the total development cost of our project. The development time of Drug Guard is almost 14 weeks that means 3.2 months. The cost analysis of our project is given below:

Table 5.1: Cost Analysis

Type of Cost	Description	Amount	Percentage
Hardware Cost	1 Router: Tk. 1,800/=	Tk.	36.37%
	2 Computers: Computer 1: Tk. 70,000/=	1,41,800/=	
	Computer 2: Tk. 70,000/=		
Software Cost	Domain: Tk. 1,500/= (1 Year)	Tk. 8,100/=	2.08%
	VPS hosting: Per month: Tk. 1,600/=		
	Development period: 3.2 months		
	Total: Tk. 5,600/=		
	Ethereum: Tk. 1000/=		
Developer Cost	Junior developer (2): Per month: Tk. 30,000/=	Tk.	53.86%
	Development period: 3.2 months	2,10,000/=	
Maintenance Cost	Monthly maintenance: Tk. 4,000/=	Tk.	5.13%
	Total: 16,000/=	20,000/=	
	Monthly internet bill: Tk. 1000/=		
	Total Tk.: 4,000/=		
Additional and Marketing Cost	Damage repair: Tk. 8,000/=	Tk.	2.56%
	Marketing: Tk. 2,000/=	10,000/=	
		Total: Tk. 3,89,900/=	Total: 100%

This table describes the whole cost of our project that is required to complete this project. There are almost 4 core costs during the development of this project, which are hardware cost, software cost, developer cost, maintenance cost, and additional and marketing costs.

During the development of the project, we didn't need that much hardware; we only required a Router that provides the internet and 2 computers for 2 developers to develop the system.

2 Computer Cost: $70,000 * 2 = 1,40,000$ Taka.

1 router cost: 1,800

Total Hardware Cost is $1,40,000 + 1,800 = 1,41,800$ Taka.

During the development stage, we had 3.2 months. And the total software cost is 8,100 Taka

The big chunk of the cost goes to the developer's salary. This is the maximum cost during development. There are a total of 2 developers and the total development period is 14 weeks which is equivalent to 3.2 months.

Total Developer salary (3.2 months): $30,000 * 3.2 * 2 = 2,10,000$ Taka

Monthly maintenance cost is 4000 Taka and monthly internet cost is 1000 Taka

Total Maintenance Cost: $16,000 + 4,000 = 20,000$ Taka

There are some other costs which include damage repair, marketing etc. Cost is: 10,000 Taka.

So, the total cost of developing this project is:

$$= 1,41,800 + 8,100 + 2,10,000 + 20,000 + 10,000 = 3,89,900 \text{ Taka}$$

5.2.3 Risk Analysis

This section describes the challenges and risks of our product. We described the risks that can be faced in future. These dangers or risks can be isolated into two parts. Those are technical risks and business risks.

- Technical risks: Block size could be a risk. Blockchain ecosystem has block size limitations (amount of data stored). Ethereum has integrated “side” storage capabilities but we are recommending to minimize the amount of data stored or to

store only sensitive data. Also block gas limits can be a risk if it exceeds block data. Risks like “hard forks”, where blockchain changes the rules for the future but permits members on either the modern or new rules or the old ones. We will work with NIST SP 800-171 requirements) so that participants need to agree with rules if any update happens.

- Business risks: All the participants must be trusted. If any participants leak out the sensitive information stored in blocks it will be harmful or if any user tries to duplicate QR code and use the decryption option provided by our mobile app then it will be dangerous for the whole system. To solve these risks we designed a member revocation system which will be controlled by the manufacturer to revoke participants who violate rules.

5.2.4 Performance Analysis

In this section we discussed about the performance of our product. This section describes the performance evaluation that means the graph showing relationship between time versus number of requests or users.

We set up an environment to evaluate our protocol by writing programs using Solidity 0.8.3 with a computer Intel(R) Core(TM) i5, CPU 2.50 GHz, 4.00 GB of RAM, HP SSD S700 Pro 128 GB, Windows 10, 64-bit OS. We used VS Code (v: 1.56.2), geth (v: 1.10.1-stable) to run blockchain server (port: 8000) and web3 (v: 1.3.5), node (v: 14.11.0) to run our local server on port 3040 and yarn (v: 1.22.5) and mongo-dB compass (v: 4.4.1-stable) database. Some other important dependencies are crypto (v: 1.0.1), qrcode (v: 1.4.4), connect-mongo (v: 4.4.0), ethereumjs-tx (v: 2.1.2), express (v: 4.17.1), express-ejs-layouts (v: 0.0.2), nodemailer (v: 6.5.0) etc. and development dependencies are laravel-mix (v: 6.0.13), nodemon (v: 2.0.7), sass (v: 1.32.8) etc.

Table 5.2: Transaction Cost for Placed Order

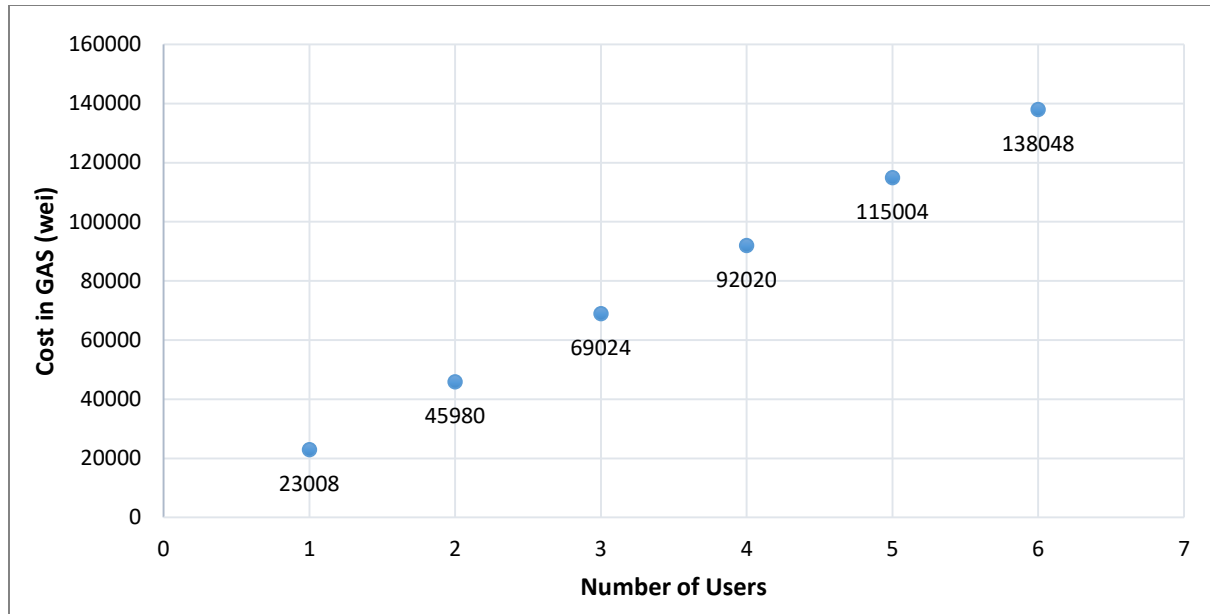


Table 5.2 shows the transaction cost in GAS (wei) for depot in-charge orders. Here we tested our server using 6 depot in-charge at a time. For placing order we passed three strings (order ID, depot in-charge email, and order status) in block and these are the results in total GAS (wei). First user cost in GAS is 23008 wei and for second user cost in gas is 22972 wei and total is 45980 wei and goes on [1 ether = 10^{18} wei (smallest denomination of ether)].

When manufacturer or depot in-charge completes any order status transaction cost is fixed, that is 22276 wei. Here we passed two strings (order ID, order status) in the block. The order ID is the same ID which was created when users placed their order and for each order, order ID is unique.

Table 5.3: Transaction Cost for Transaction Confirmation

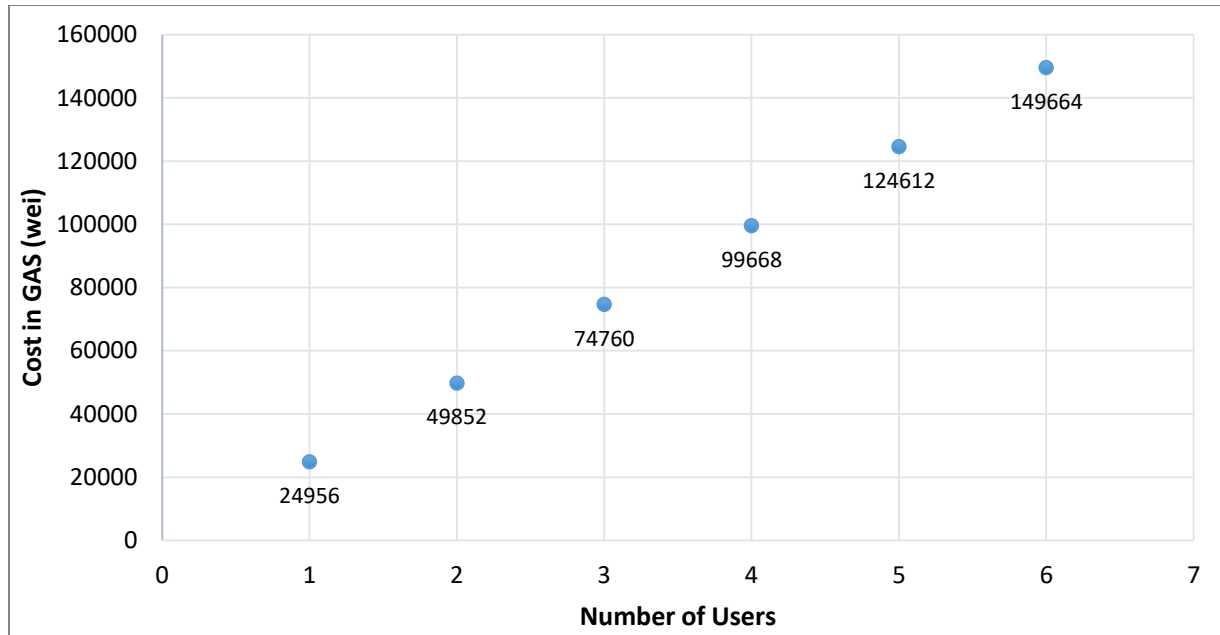


Table 5.3 shows the transaction confirmation table which is done by depot in-charge when he received ordered drugs and gave confirmation. We also tested it using 6 users (depot in-charge). Where the cost of first transaction is 24956 wei and cost of second and third transactions in wei are 24896 and 24908 and goes on. Total is 149664 GAS (wei).

CHAPTER 6

CONCLUSION

In the previous chapter we discussed the implementation and analysis of our product and in this chapter, we discussed the timeline we have taken to build this project and social, legal, ethical and environmental issues.

6.1 Summary

Drug Guard is a final product of our final year capstone project and we find it beneficiary to pharmaceuticals. It provides a secure network for DSC. From our observation it has a very appreciable market demand considering the decentralized network which works as a Proof-of-Work and other systems have not so far considered such features in a dedicated system in Bangladesh. This project is focused on making an online platform which is based on blockchain smart contract, where the product will be under tracing and delivery system. By the decentralized network product authenticity is insured. This supply chain will build the trust between parties because only trusted parties can join the network and only trusted parties can interact with the system. Also encrypted QR code reduces the chance of duplicate information and selling fake drugs. This DSC guarantees the drug safety as well as the traceability of drugs. By this system pharmacists will be able to see the origin of drugs and manufacturers will know which pharmacy is using their drugs. This system provides a transparent network between participants. We hope to make this product a very considerably appreciable product for the pharmaceutical industry.

6.2 Project Timeline

To develop the system, we have maintained a well generated timeline and worked according to that. The total duration of our project was approximately 7 months 1 week. There are four main tasks – proposal submission, literature review and proposed methodology, development and

implementation, final report writing. After each week there is a task to do which is an online meeting with Supervisor. As we are doing this project following the Agile Scrum SDLC process there are multiple iterations in the design & implementation stage. Throughout the entire journey, we always tried to full-fill all the requirements and actions that we needed to do to develop the system. The timeline of our project is representing by the Gantt chart is given below:

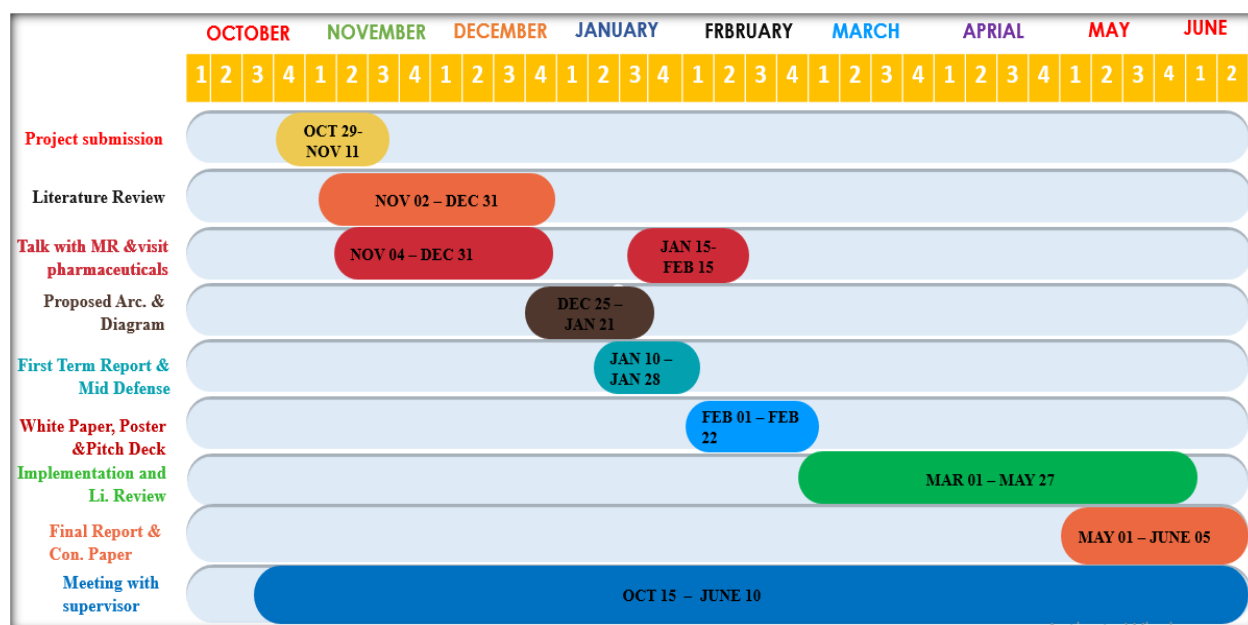


Figure 6.1: Drug Guard Project Timeline

6.3 Social, Legal, Ethical and Environmental Issues

It is a large-scale project for pharmaceutical industries. By this project we tried to solve the drug counterfeiting in DSC where now in Bangladesh it is a huge problem to solve. This product is for the pharmaceutical industries supply chain. We tried to create a transparent SCM so that fake drugs cannot take place and we solved the problems of existing SCM in Bangladesh. So, it will have a great impact on our society. In the existing system, it is easy to produce fake drugs by using the name tag (QR code tag or DAR number) of authentic pharmaceuticals and using any drug without having the required quality can cause side effects as well as death. But our system will solve this problem. As for the environmental perspective, our system will play an important role. It is

troublesome to measure the financial misfortune due to counterfeit or fake drugs. It will save a huge amount of money if fraudulent activities cannot take place. Also, blockchain will ensure the transparency of transactions for future statistics.

6.4 Future Plans

This section describes the features we want to add to our project next.

- Add DGDA to the network who is the governance body of the drug supply chain. DGDA will provide licenses to pharmaceuticals and pharmacies (chemist shops). Companies have to agree with the profiles where requirements (defined by DGDA of Bangladesh, WHO requirements and NIST SP 800-171 requirements) will exist to get license.
- Auto distance giving and dropping: It will be a feature by which system will decide which depot in-charge will get drugs first. By this feature remote distance will be served first and nearest distance will be served last.
- Expiration signal: This feature will help the manufacturer decide which drugs should be sold first from the drug storage. If any drug expiration date get nearest software will give a signal or notification to the manufacturer to sell the drugs as soon as possible.
- Make end-end-encryption QR code so that any malicious person cannot read the decrypted QR code (IP packet) when the server sends it to the pharmacist. We will ensure this feature in future so that malicious users cannot do any harm to our network.

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Thank You