DISTRIBUTED HEALTH CARE FRAMEWORK FOR PATIENT HEALTH RECORD MANAGEMENT AND PHARMACEUTICAL DIAGNOSIS

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Dissertation submitted in partial fulfillment of the requirements for the BSc (Hons) in Information Technology Specializing in Software Engineering

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Declaration

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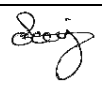
Wickramarathna W.G.M.S.	IT19004778	

The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

…….. Date :……

Signature of the supervisor:

(Mr. Jeewaka Perera)

…….. Date :……

Signature of the supervisor:

(Ms. Laneesha Ruggahakotuwa)

Abstract

Electronic Health Record (EHR) systems are growing day by day, but the main challenges in these systems are preventing unauthorized access and sharing with only authorized professionals; EHR systems should have backup servers, thus protecting patient details. Our goal is to overcome these issues and build a decentralized system as a solution. We use blockchain directly without relying on centralized technologies. The reason was choosing blockchain as our technology is the blockchain already has overcome the issues are mentioned above [1]. The blockchain uses a distributed ledger, and every participant has the exact same ledger, so blockchain has greater transparency. Using "smart contracts." we can even automate transactions. By storing individual patient medication history, doctors can prevent unnecessary time consumption for examining the patient from the beginning. There are a couple of pros storing data on the blockchain, such as cannot delete or alter data as well as can reduce the cost of backup data. According to our research plan, we are planning to store and share data using blockchain, and doctors are the people who can perform activities with blockchain. Always the last prescription will be shared with the relevant patient.

***Keyword**: Blockchain, Machine Learning, Digital Healthcare,* coronavirus (COVID-19) *Natural Language Processing, Image Processing, Optical Character Recognition*

Acknowledgements

Mr. Jeewaka Perera (Sri Lanka Institute of Information Technology, Sri Lanka) and Ms. Laneesha Ruggahakotuwa (Sri Lanka Institute of Information Technology, Sri Lanka) thank them for their constant supervision, encouragement, and support.

Dedication

The author wishes to dedicate this information to the scientific community, which is working persistently to find answers to improve healthcare results.

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List of Abbreviations

Abbreviation	Description
EHR	Electronic Health Record
GDP	Gross domestic product

1. Introduction

1.1 Background Study

Heath is a preliminary need for human beings. Health care services are improving day by day worldwide. Every country spends a lot of money to give good health care facilities to their citizens.

According to Sri Lankan traditional health care services, the patient should keep a record book for storing past medication details, and if that book is misplaced, the patient's medication history will be lost forever. Furthermore, the patient has the right to seek treatment from a variety of doctors, which has resulted in a situation in which each episode of an illness or disease process is managed by a variety of specialists with varying levels of experience, which frequently causes problems. In such cases, every doctor should examine the patient from the beginning because there are no registered patient records in any healthcare institution in Sri Lanka. As a result, there is a communication gap between multiple caregivers, resulting in inadequate coordination of care.

The world is changing day by day with technology. The health care industry also is changing with new technology. No matter where the technology is, nature can change people's lives in one second. In those situations, people cannot perform their habitual actions. The latest example is the Covid-19 pandemic. During the Covid-19 pandemic, people faced different types of challenges in the healthcare industry. During those days most countries had to implement lockdowns and ask people to maintain their social distance.

The conventional healthcare system cannot adequately and sustainably treat people in these circumstances. To give a better experience in health care, we are proposing a solution called Oxygen. Oxygen is not only for health care experts but also for patients who can use this. The Oxygen has 4 major components as bellow.

- Blockchain-based distributed healthcare framework for securely storing and accessing patient data

- A Deep Learning and Natural Language Processing based medical document scanner to prevent the errors that are due to manually entering data
- An Image Processing based drug identification module for remote pharmaceutical diagnosis
- A Natural Language Processing and Machine Learning based virtual chatbot in healthcare assistance

1.2 Literature Survey

The authors of the study "Application of Blockchain to Maintaining Patient Records in Electronic Health Records for Enhanced Privacy, Scalability, and Availability" [1] focused on employing chain code logic to improve performance. And their findings revealed that doctors may use their system to access patient data, and patients can view their previous health information via the system. For auditing purposes, the study team kept the access log immutable and transferred data via a proxy re-encryption mechanism.

According to a study published in 2019 by Yongbin Zhang, Meng Cui, Lijuan Zheng, Rui Zhang2,3, Lili Meng, Dong Gao, and Yu Zhang titled "Research on electronic medical record access control based on blockchain" [2], it is found that lack of interoperability and sharing in are some common issues in handling medical data. This group of researchers employed methods like access control technology and information entropy technology to improve data privacy. The blockchain's security is dependent on the private key, and if the private key is lost, the storage's security is also compromised. However, those concerns were not addressed in this study.

In the year 2021, Hassan Mansur Hussien, Sharifah Md Yasin, Nur Izura Udzir, Mohd Izuan Hafez Ninggal, and Sadeq Salman employed bibliometric analysis of dataset distribution to perform a research study on "Blockchain technology in the healthcare industry: Trends and possibilities" [3]. According to the research

findings it is found that patients' data is truly held by patients, and blockchain can permit the health record to be time stamped. To put this another way, once data is placed in the distributed ledger, it cannot be tampered with by anyone. The research study emphasizes the need of focusing on the standardization of cross-border healthcare data.

According to the study "Blockchain Technology in Healthcare: A Comprehensive Review and Directions for Future Research" conducted by a research team from Lakehead University in Canada [4], Blockchain can transfer traditional industry with properties such as decentralization and persistency. Furthermore, the research indicates that an innovative strategy should be used to reduce the mining delays that occur when the number of transactions grows. The study highlights that Blockchain will be a vital tool for legitimate drug delivery to patients, billing, and payment administration in healthcare and to securely store patients' data preserving patients' privacy.

Previous research works have been focused on the interoperability of the data exchange between business entities and the research on "Blockchain Technology for Healthcare: Facilitating the Transition 3 to Patient-Driven Interoperability" is such [5]. The study focuses on how the transition takes through five mechanisms including data liquidity, data aggregation, digital access rules, patient identity and data immutability. The study demonstrates that blockchain technology may be used as a platform for digital exchange and that healthcare data can be stored in many systems, necessitating several interactions between institutions.

According to a 2019 research paper titled "Health Record Management using Blockchain Technology", the cost of data breaches in the healthcare industry is projected to be over $380 per record, with the 2016 Breach Barometer report revealing that 27,314,647 patient records were compromised [6]. This study emphasizes the necessity of the security of healthcare records. This article emphasizes the significance of patient-centric distributed healthcare solutions for securely storing patient data, as well as the value of using Blockchain to address these concerns. It also demonstrates that Blockchain not only provides

decentralization, but also data confidentiality, real-time access, and data authentication and authorization.

According to the findings by Randhir Kumar and Rakesh Tripathi [7], maintaining privacy and openness are major problems when using central storage to hold patient data. Distributed on-chain and off-chain storage methods were proposed in this study. They did this with the use of a consortium blockchain and interplanetary file systems. They've solely placed content-addressable patient records within the blockchain to preserve scalability. Furthermore, the suggested solution is independent of third-party infrastructure.

Blockchain technology can be a superior option in biomedical research and teaching, as well as in keeping electronic medical health records, according to the study paper "Blockchain Technology in Healthcare: A Systematic Review" [8]. They also indicate that while various blockchain prototypes have been produced to date, not enough research has been done to solve the difficulties that blockchain technology offers, such as security and privacy. Latency and interoperability are two issues that need to be addressed, and more studies should be done in these areas.

1.3 Research Gap

Most of the research papers and products focus on storing their patient records. They are not sharing patient details among various hospitals. For example, there is a couple of patient records keeping systems in Kalubowila and the military hospital in Sri Lanka. Still, there is no way to access those data from another hospital. Private hospitals keep their patient details, such as Asiri hospital [9], but when patients change their hospital, there is no external connection between hospitals to share patient information.

There are two types of hospitals in a country: government and private hospitals. Under government hospitals, there are a lot of hospitals. Private hospitals may have some branches. According to this, civilians have many options. Instead of managing this many hospitals, doctors cannot give efficient service to their patients. Doctors need to understand and examine the patient from the beginning. Our proposed solution is to maintain individual patient records and share those among health care professionals.

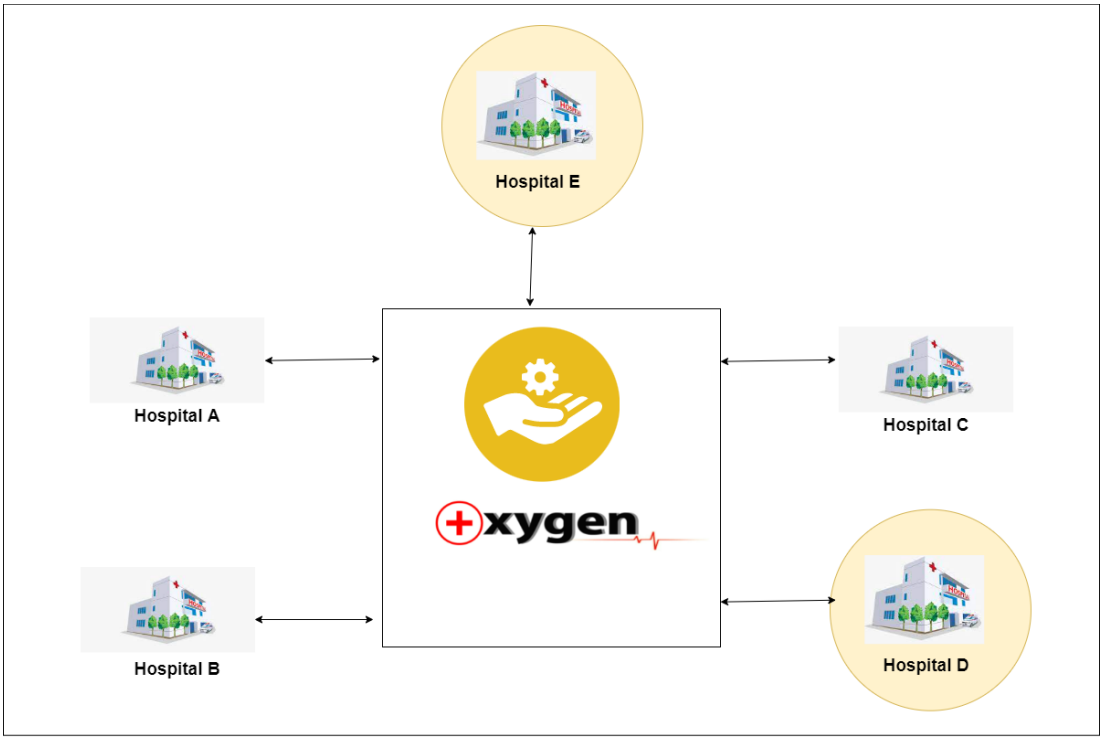


Figure 1.3.1: Integration between Oxygen and other EHRs (Electronic Health Record)

According to the above diagram hospital, “D” and hospitals “E” have their own patient details management system but they are not sharing them with external hospitals. When a patient is requesting to share their details, doctors can share those details with our solution. Once they shared those data any doctor of the hospital can access those details. It means our proposed solution allows them to integrate their private systems.

If we assume hospital “A”, hospital “B”, and hospital “C” do not have a system for storing their patient details but our proposed solution allows them to store their data in our system.

1.4 Research Problem

According to the Ministry of Health, Sri Lanka has 1103 government hospitals [9]. Sri Lanka currently has a population of 21,556,478 people [9]. People have many options to take their medications. They can use either government hospital service or private hospital service. Instead of using these two services, they can also use the Ayurvedic hospital service. When doctors examine a patient, they ask about previous medications or refer patient medical history books such as clinic books.

Some institutions employ EHR systems instead of keeping data in a book or asking patients for details. Storing/ accessing, and sharing patients' details are critical; thus, patient history is crucial to caring for a patient well. Without knowing the patients' history, doctors cannot make correct decisions.

We have done a simple survey using 210 participants.

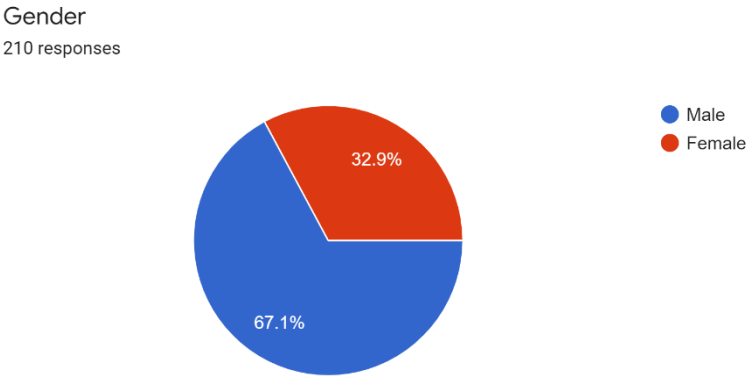


Figure 2.4.1: *Participants' gender*

According to the above figure, most of the participants were male. As a percentage, it was 67.1%.

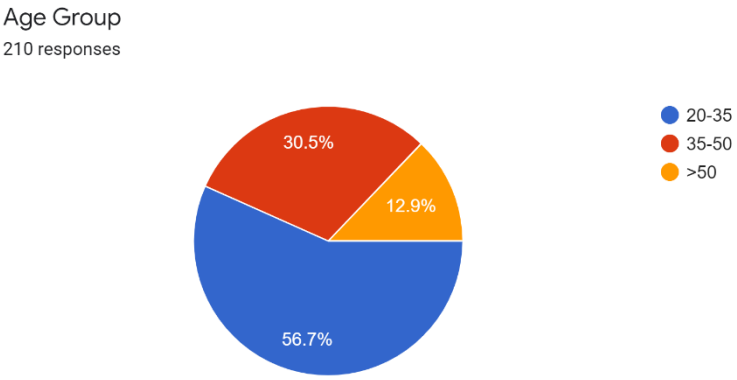


Figure 3.4.2: *participants age group*

Most of the participants were aged between 20-35. It was 56.7%.

We could see most of the participants had some health care issues during this pandemic. We could see, the governments are still taking some actions to provide a better health care service to their civilians. Also, some of the responsible parties are trying to automate some parts of health care services. By looking at the figure below, most of the participants have a medical logbook

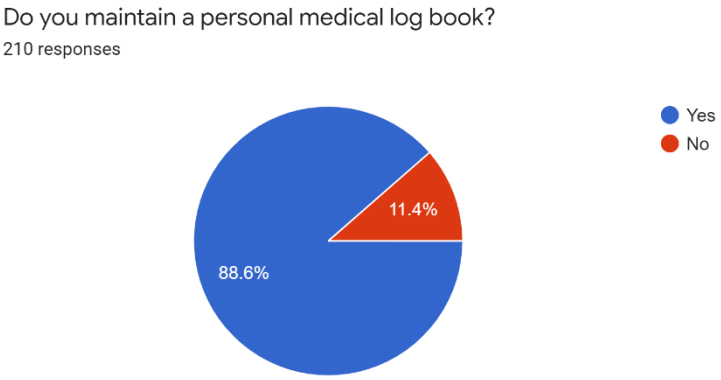


Figure 4.4.3: *Survey results regarding participant's medical logbooks*

There are a bunch of problems that can occur. Such as,

- The logbook can be misplaced.
- The logbook can be damaged.

Traditional health care services cannot give a proper answer for the above-mentioned issues. In such situations, the only option is to replace the medical book. Not only that there are a couple of hospitals that have EHR systems, but they are not sharing those patient details with other hospitals. According to the Sri Lankan, health care service patients have multiple options to choose from. This problem cannot solve only by storing their information but also need to be shared with authorized professionals.

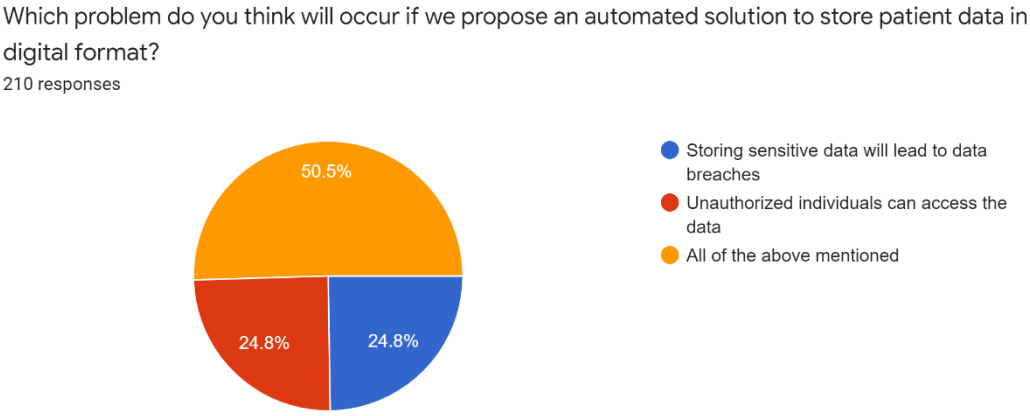


Figure 5.4.4: *Participant's personal opinions*

Storing / sharing and accessing patient information is most critical thus patients' lives depend on their medications. According to the above diagram, people are worrying to share their information with EHRs thus the malicious attacks. Data privacy is a key factor of the EHR system.

1.5 **Research Objectives**

1.5.1 Main Objective

As an EHR system main objective is to address the primary issues in the health care industry. Apart from that this component stores/access and share patient details among the health care professionals such as doctors while protecting data privacy.

1.5.2 Specific Objectives

The following specific objectives address the different areas of the main objective.

1. Storing patient information while protecting data privacy.

   There are many issues in storing patient information in medical logbooks and storing information in a centralized server. Those drawbacks will be omitted in this component.

2. Prevent unauthorized access to the system data.

   Access control mechanisms will be used here to control unauthorized access to the system.

3. Use smart contacts to automate the execution

   Smart contracts will be used for executing the predesigned procedures.

4. Prevent unauthorized apply changes to the system data

   There will be several user levels with several privileges. Such as doctors will be able to add a new record, edit and view but nurses/pharmacies' staff will only be able to view the record.

5. Accessible from anywhere

   This is not focusing on a specific institution. Any authorized organization can use this service from anywhere. Methodology

1.6 **Project Overview**

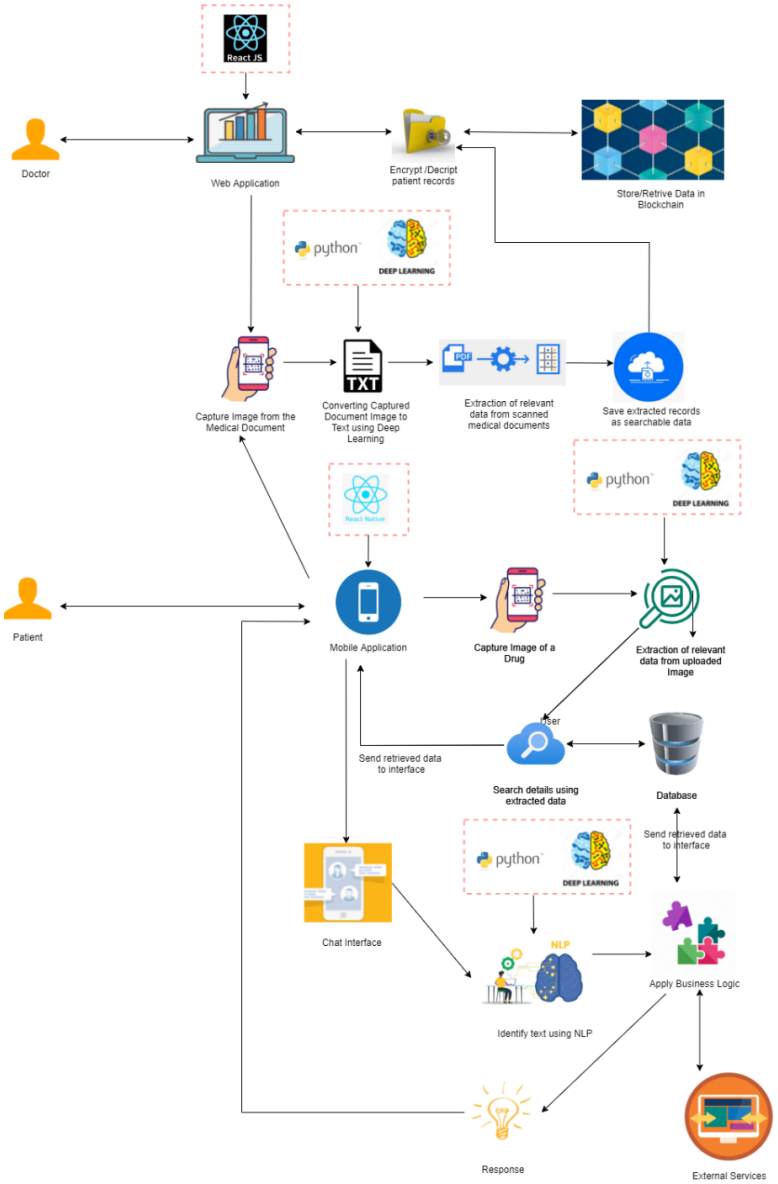


Figure 6.6.1: *Project Overview Diagram*

According to figure 1.6.1, Oxygen contains with four main components. Those are,

1. Blockchain Component
2. Medical Document Scanner
3. Drug Identifier
4. Virtual Medical Chat Bot

Each component is responsible for doing specific task. When considering Blockchain component, it is responsible for storing, sharing and accessing patient's data, The

Medical Document Scanner can scan and extract clinical laboratory reports. The Drug Identifier component can recognize drugs by using just an image. The Virtual Chat Bot is responsible for guide the patients according to the latest prescription.

1.7 System Overview Diagram

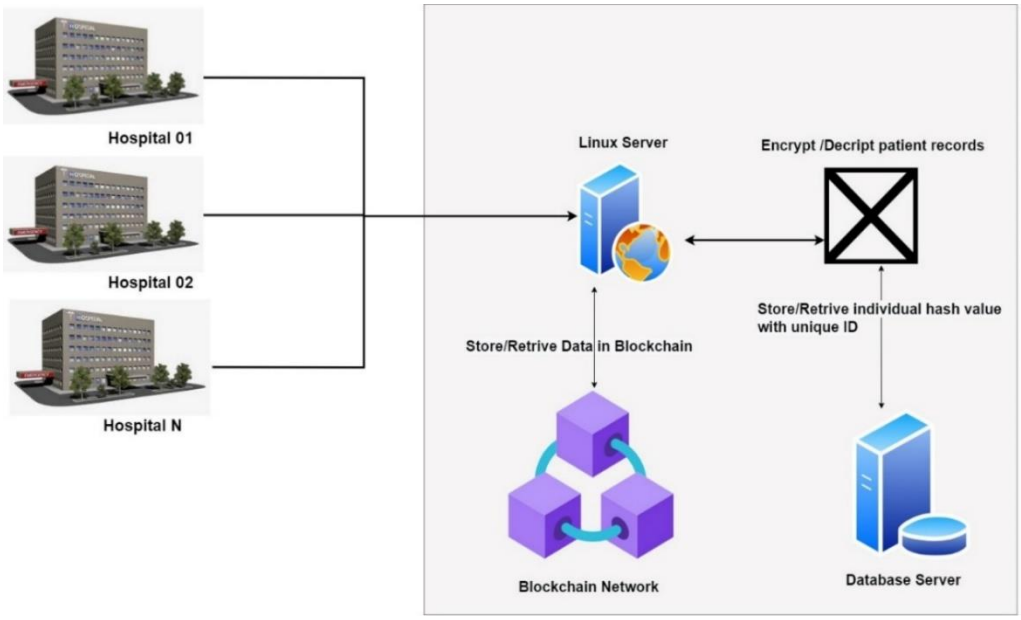


Figure 7.7.1: *System Overview Diagram*

1.8 System Overview

Figure This component is responsible for storing/accessing and sharing patient information among health care professionals. Only authorized doctors can perform the storing task in this system. Patient records will be encrypted before storing the patient record. The Hash function will be used for encrypting the record. Once encrypted record will be pushed to the blockchain and it will be stored in a centralized database server with a unique key. Only the hash value and the unique key is stored in the centralized server.

When accessing the individual patient record, initially the record will be searched from the centralized server. The record is searched from the blockchain only when the record is existing. Only authorized doctors can alter the records. After altering the record, it will be again updated the database server before pushing the record into the blockchain network. Different authorized stakeholders can use the system from any

place where the system operates. The smart contract will help to get the latest prescription of the individual patient and will be shared with them.

1.9 Project Requirements

1.9.1 Functional Requirements

1. Store patient details in an accurate way

   Encrypted data will be stored in the blockchain and centralized database with a unique key

2. Access patient details

   Authorized stakeholders can access the system from different areas.

3. Share patient details through the system

   Any authorized stakeholder can share patient details through the system

4. Modify patient details

   According to the access privileges, only doctors will be able to alter patient records.

1.9.2 Non-Functional Requirements

1. Security and Transparency

   Since using blockchain data secure and transparent than centralized systems.

2. Scalability

   The nature of blockchain is decentralized therefore scalability is easy than centralized applications.

3. Availability

   The system will be available 24/7 with minimum downtime for only authorized users.

4. Usability

   Different users will be able to perform different tasks under user privileges.

5. Performance

   The system will respond to the user fast and efficiently.

1.10 Word Suggestion Model

This component will not directly impact the blockchain component, but this model can help doctors to eliminate their typing mistakes. This model has been integrated with adding a new prescription component. The doctor is also a human so there can occur human error when typing details on the given input field. The main purpose of having this kind of model, this model can be predicted medical domain words by using the last word.

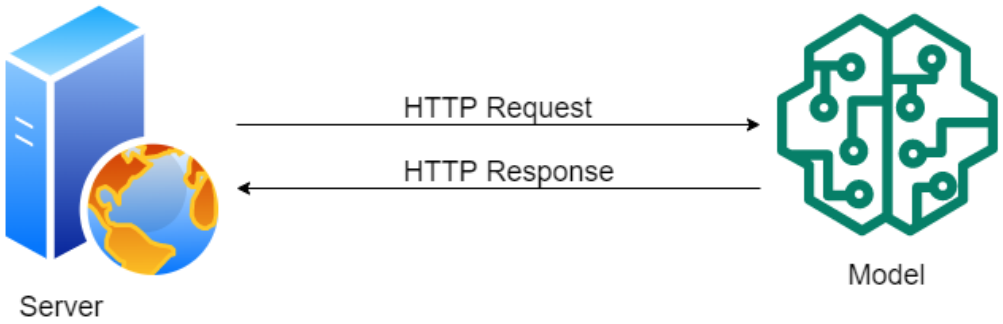


Figure 1.10.1: Oxygen Server and Model

The model and the server are not tightly coupled components. The server can work without the model. Both components communicate via HTTP protocol. I used the LSTM model because it is a special Recurrent Neural Network.

2. Business Potential

2.1 Targeted Audience

This study is mostly focused on the healthcare industry. Physicians, healthcare workers, and patients are the primary audience.

2.2 Benefits from the system

1. Rather than having specific EHR consumers can store / access and share patient details.
2. Any EHR system can integrate the system easily and share patient details through the system accurately.
3. Medical document scanner will extract text from the reports and annotate special values.
4. Patients can identify the drugs using user friendly application.
5. 24/7 virtual chat bot for guide the patient according to the latest prescription.

2.3 Implementation

2.3.1 Project Set Up

2.3.1.1 Prerequisite

This component is running on the Ethereum Goerli test network. Two main smart contracts are deployed on that network. Infura.io is the middle layer of this component. Considering these things some sort of prerequisites must have for running this component. Those are,

- Node JS
- React JS
- Account on Infura.io
- Python

Apart from that for the understanding purpose need to have some knowledge of the below things,

- Solidity
- Web3JS
- Blockchain networks

2.3.1.2 Configurations

There are several configurations should be needed to run this component. When we are deploying a system, we should provide configuration. The purpose of using hard-coded values we can provide those necessary values via config files or using environment variable files.

- ETHEREUM_NETWORK -> This should be the network that smart contracts will be deployed.
- INFURA_API_KEY -> This can get from that created Infura.io account
- PRIVATE_KEY -> Private key also should be there.
- NETWORK_ENDPOINT -> This is the Uri that will be given from Infura.io
- SMART_CONTRACT_DEPOYED_ADDRESS -> When we are deploying smart contracts, they will provide us an address. Without having this address system will not allow to perform any task. Not only system but also the network.

2.3.2 Web UIs

2.3.2.1 Login Interface

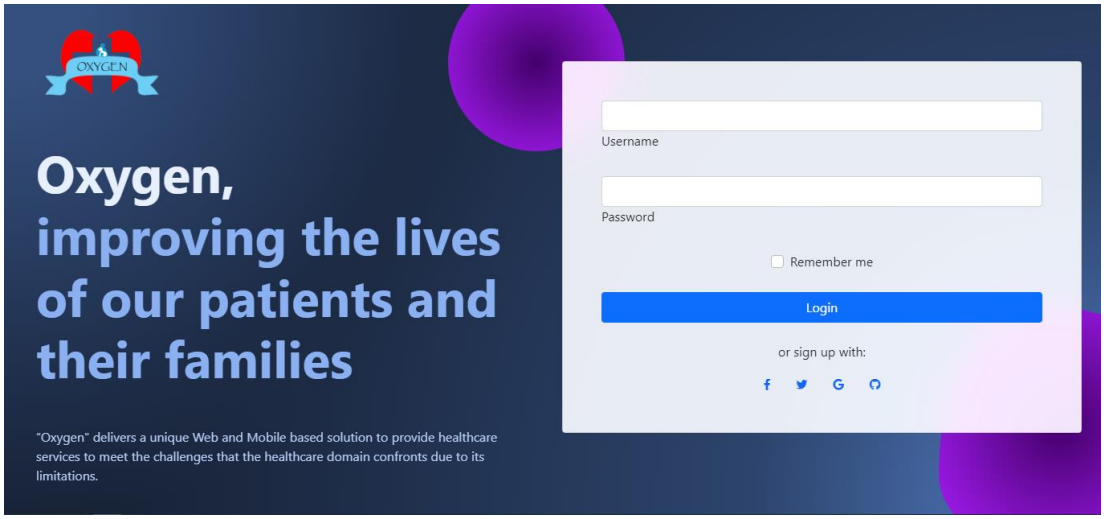


Figure 2.3.2.1.1: Login Interface

This is the place, where all users are allowed to log in to the system. Once the user adds their username and password, the backend server is responsible for validating those details with all users in the blockchain. Since that user can be validated the server will create a JWT token according to the user details and will pass it to the front end.

2.3.2.2 Navigation Panel

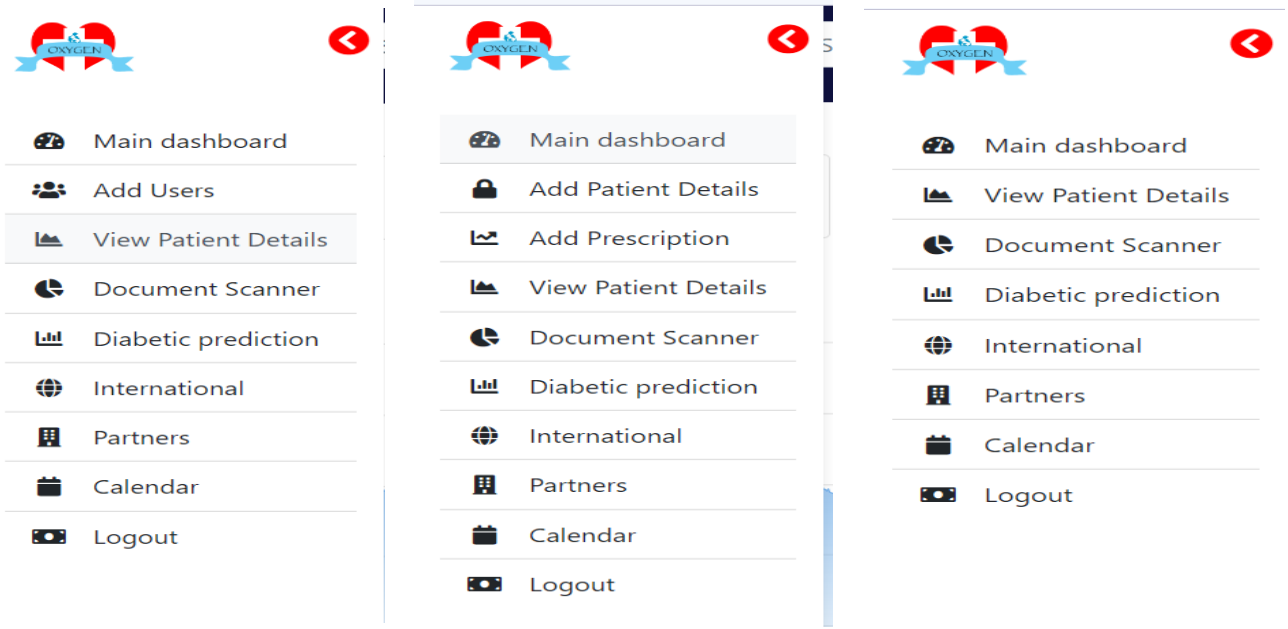


Figure 2.3.2.2.1: Navigation Panels

According to the above figure 2.3.2.2.1, Options for Navigation will be displayed according to the user. The JWT token holds the role of the user. The front-end server decrypts the JWT token and will allow the user to perform their tasks according to the role.

2.3.2.3 Dashboard

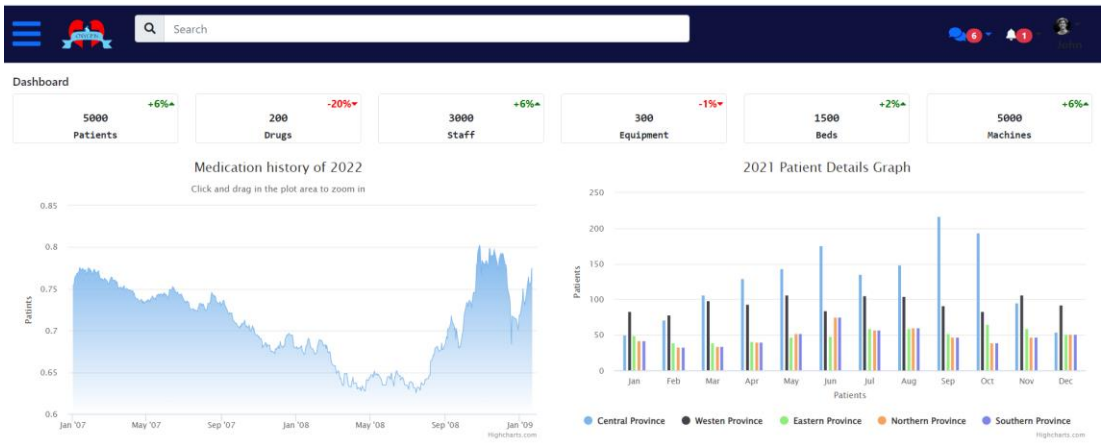


Figure 2.3.2.3.1: Dashboard

This interface shows some sort of information in graphical way.

2.3.2.4 View Patient Details

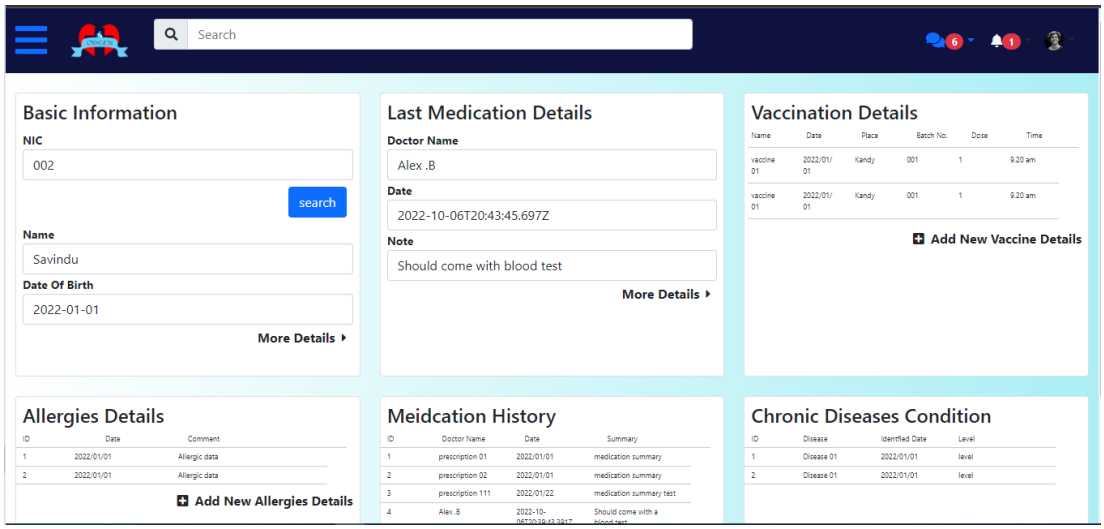


Figure 2.3.2.4.1: View Patient Details Main Page

This page will help the medical staff to examine patients' medication history. To retrieve the patient's history, need to provide the patient's NIC.

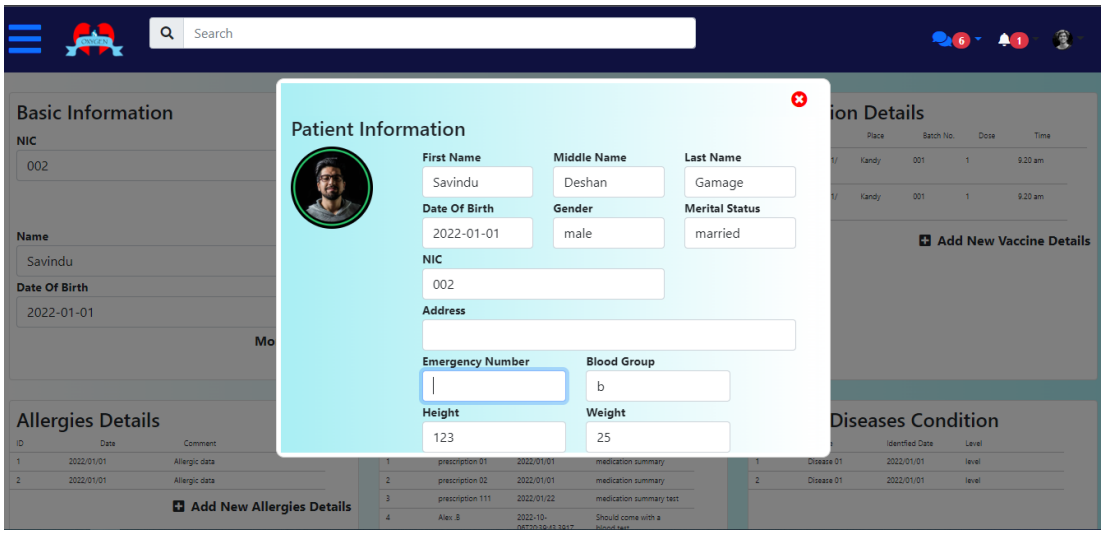


Figure 2.3.2.4.2: Patient Information Model

By opening this model, the staff member can get more details about the patient.

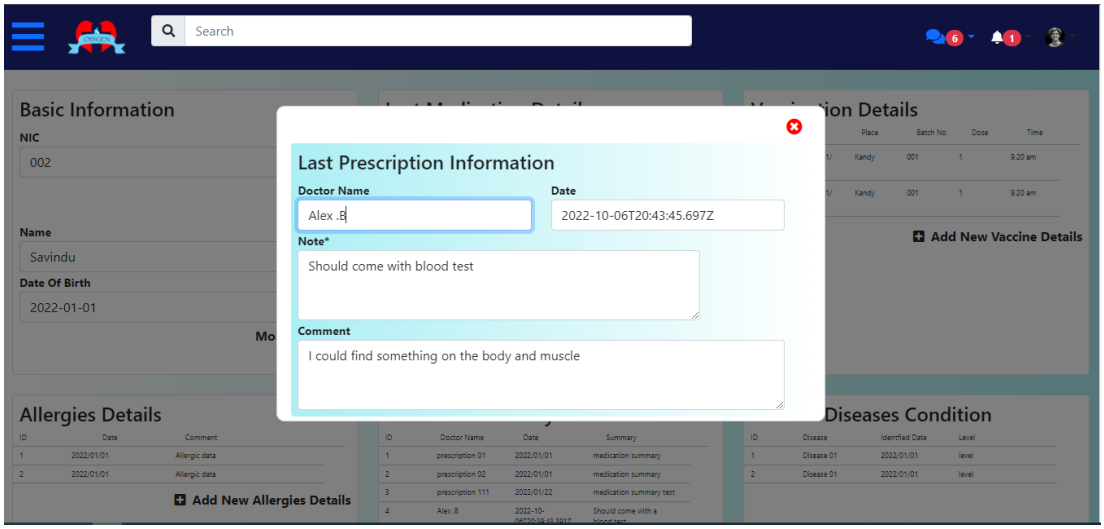


Figure 2.3.2.4.2: Patient Information Model

2.3.2.5 Add Patient Details

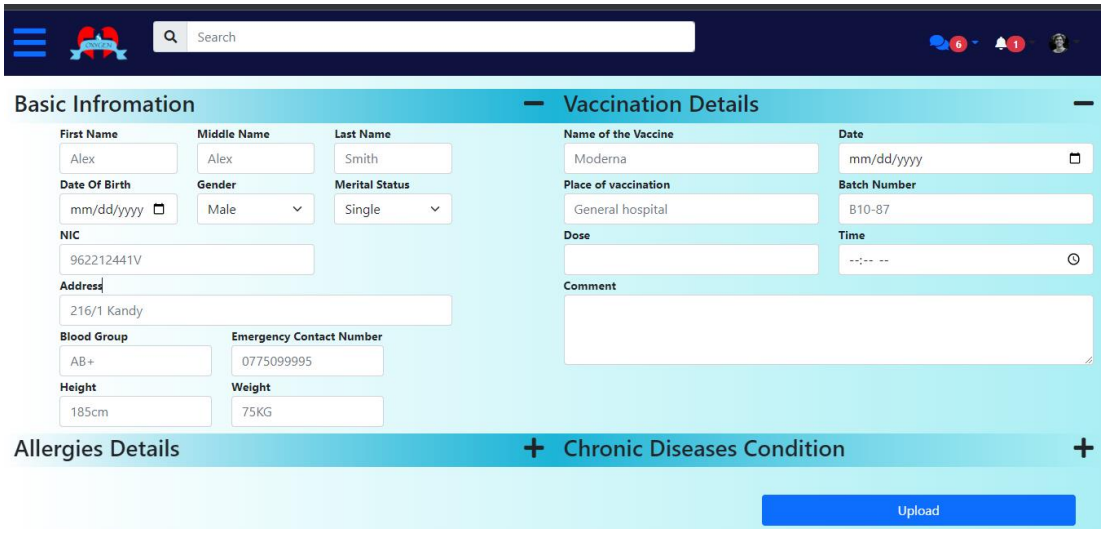


Figure 2.3.2.5.1: Add New Patient Details

This interface will help the user to register a patient. Once the user hit the upload button all data will be saved on the blockchain. Before adding to the blockchain all data will be encrypted.

2.3.2.6 Add New User

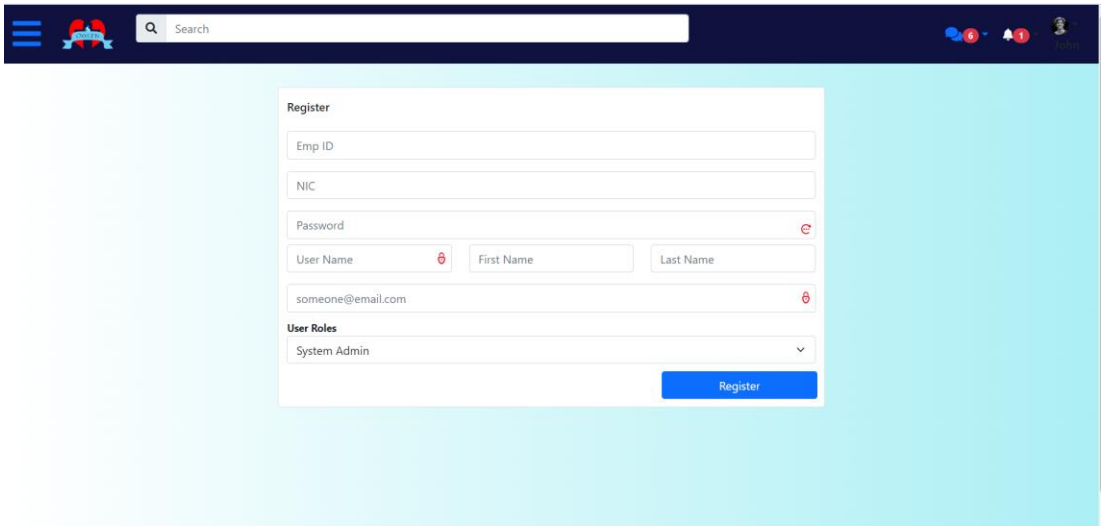


Figure 2.3.2.6.1: Add New Patient Details

Using this interface only the system admin can register a new user. In Oxygen does not provide any interface to sign up. According to the user permissions, the system admin the role that can perform only this task.

2.3.2.7 Add New Prescription

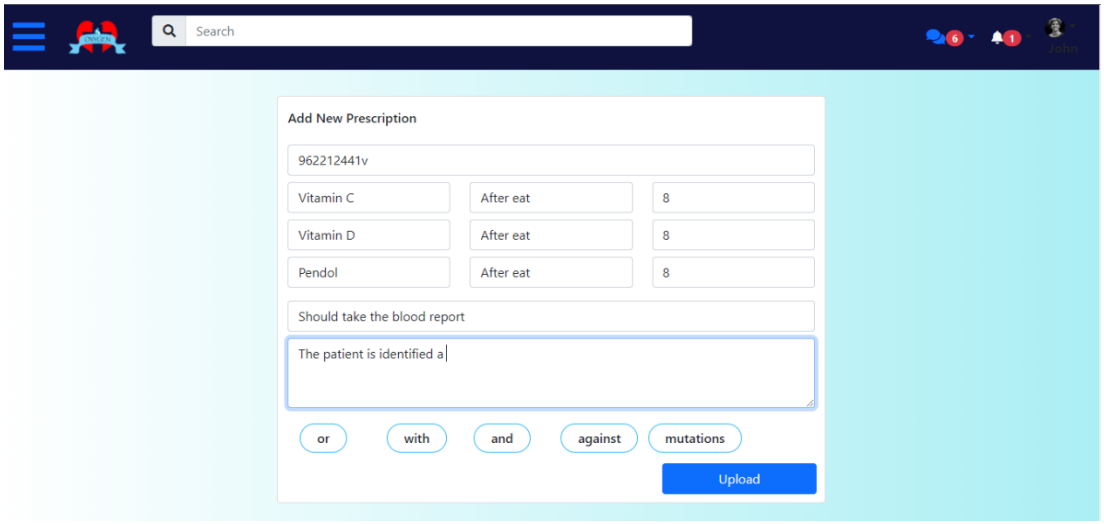


Figure 2.3.2.7.1: Add New Prescription

This Interface will help the doctor to add new prescriptions. One a doctor hits the upload button the data block will be stored according to the patient id. Apart from that, this component integrates with the word suggestion model. Once the doctor hits the space bar front end server will send the last word that the doctor entered. According to the last word the model predicts some word related to the healthcare domain and send them back to the front-end server. The front-end server will show all words as above.

2.4 Work Breakdown Structure and Gantt Chart

2.4.1 Work Breakdown Structure

The Figure 2.4.1.1 shows the Work Breakdown Structure of the Blockchain-based sub-component.

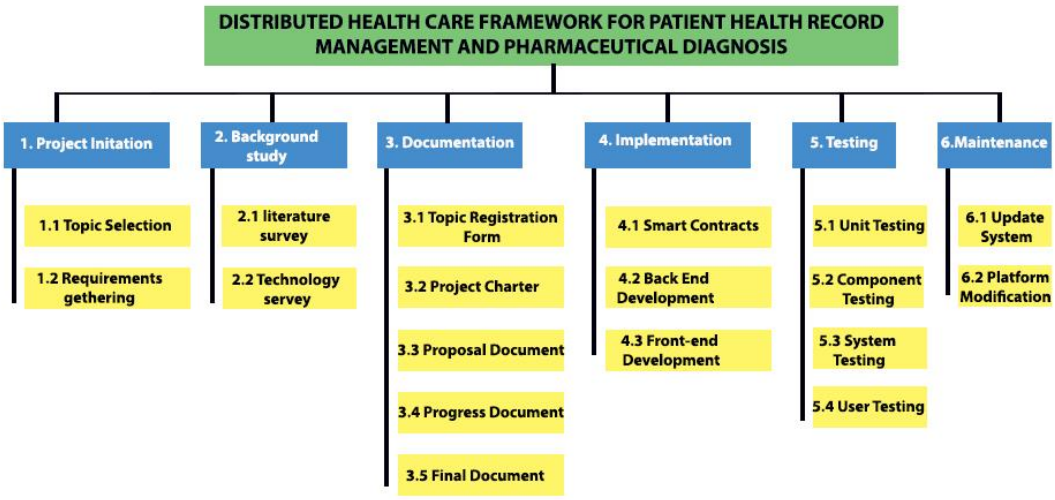
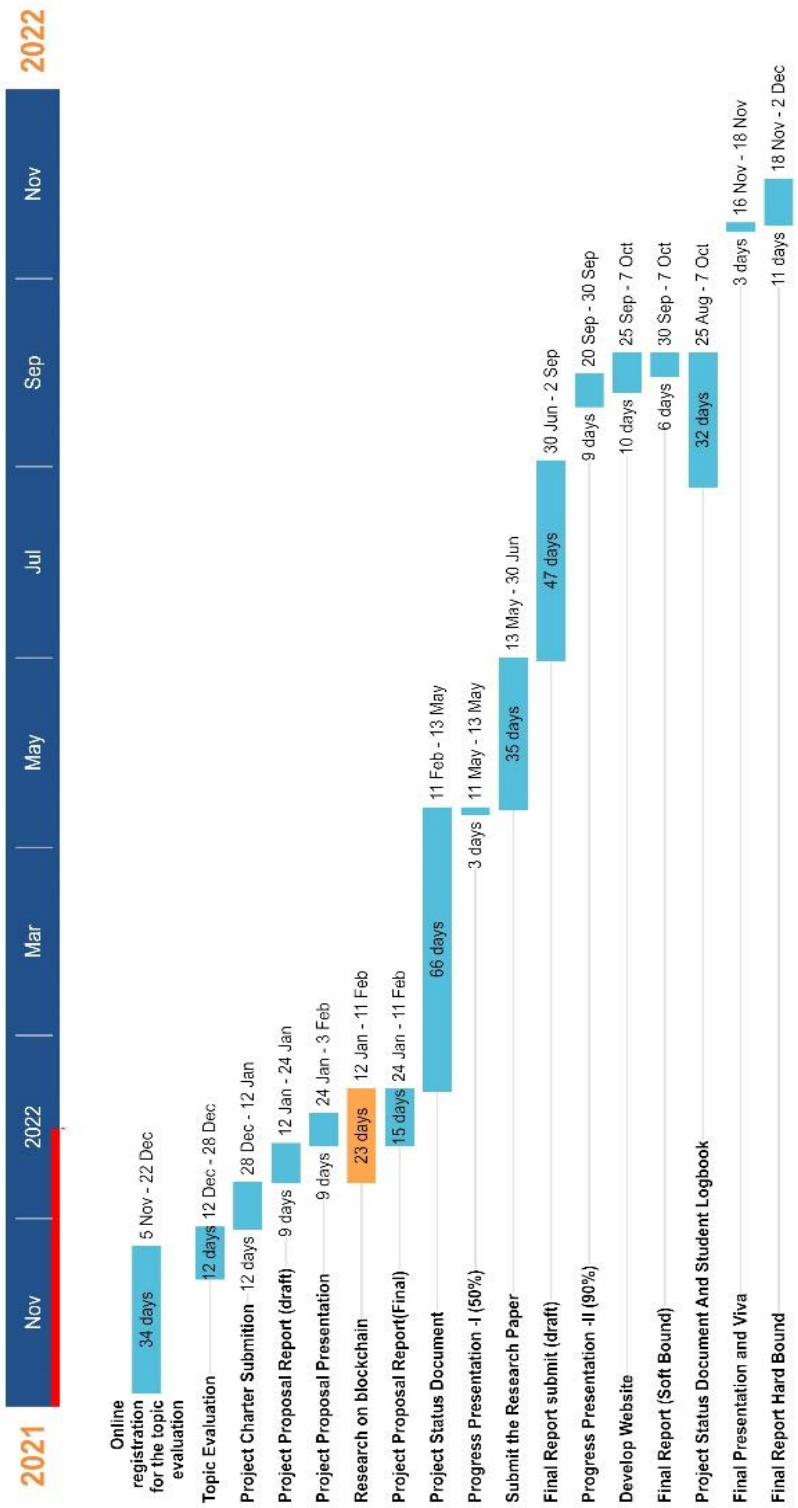


Figure 2.4.1.1: Work Breakdown Structure

2.4.2Gantt Chart

The following Figure 2.4.2.1 shows the Gantt Chart of the project.



2.4.3 Project Management

For delivering the project on time project management is crucial. We used GITLAB as our project management tool.

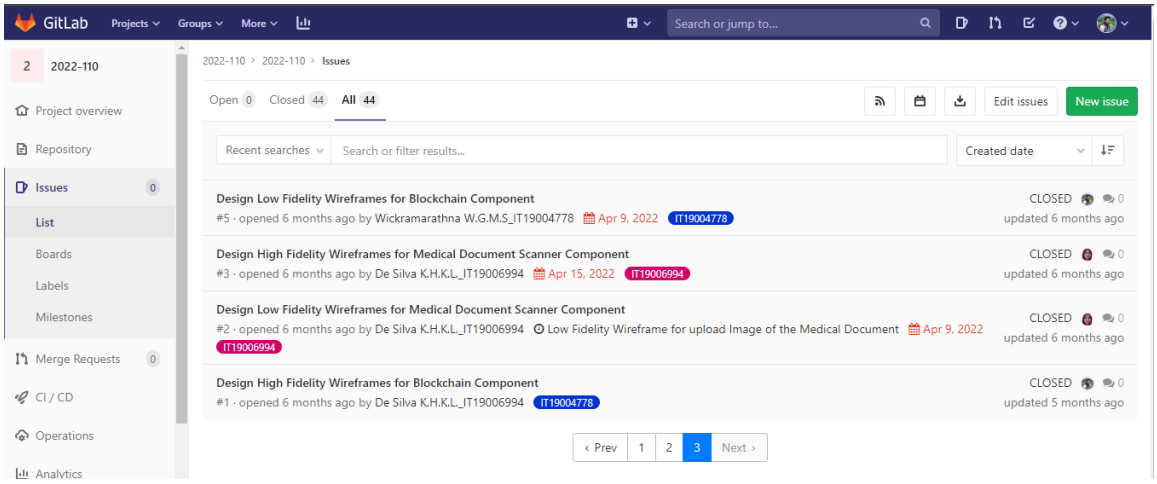


Figure 2.4.3.1: Issue List

According to above figure 2.4.3.1, We had 44 issues in our project. Not Only that sometimes we used Microsoft Planner to manage our tasks.

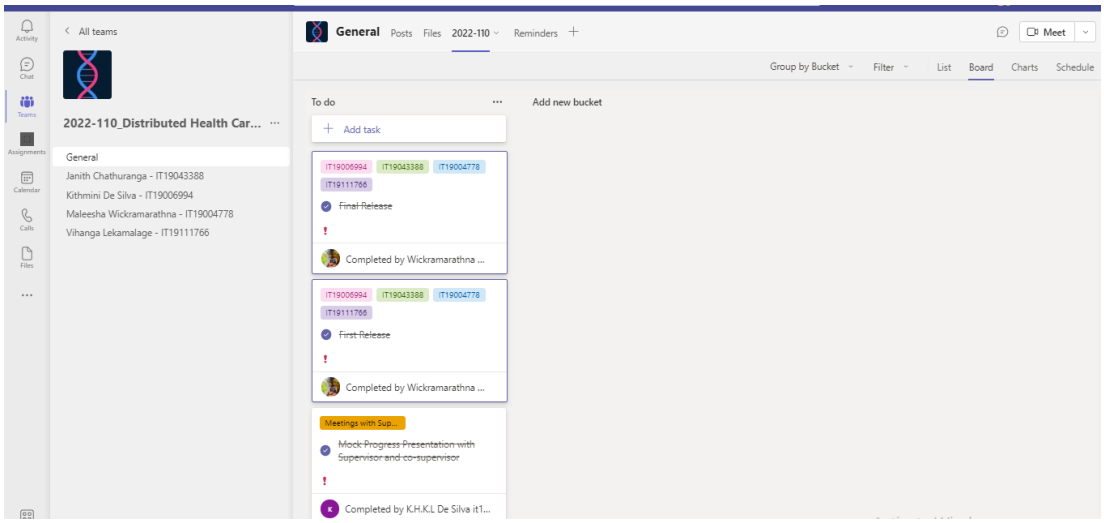


Figure 2.4.3.2: Issues in the Board

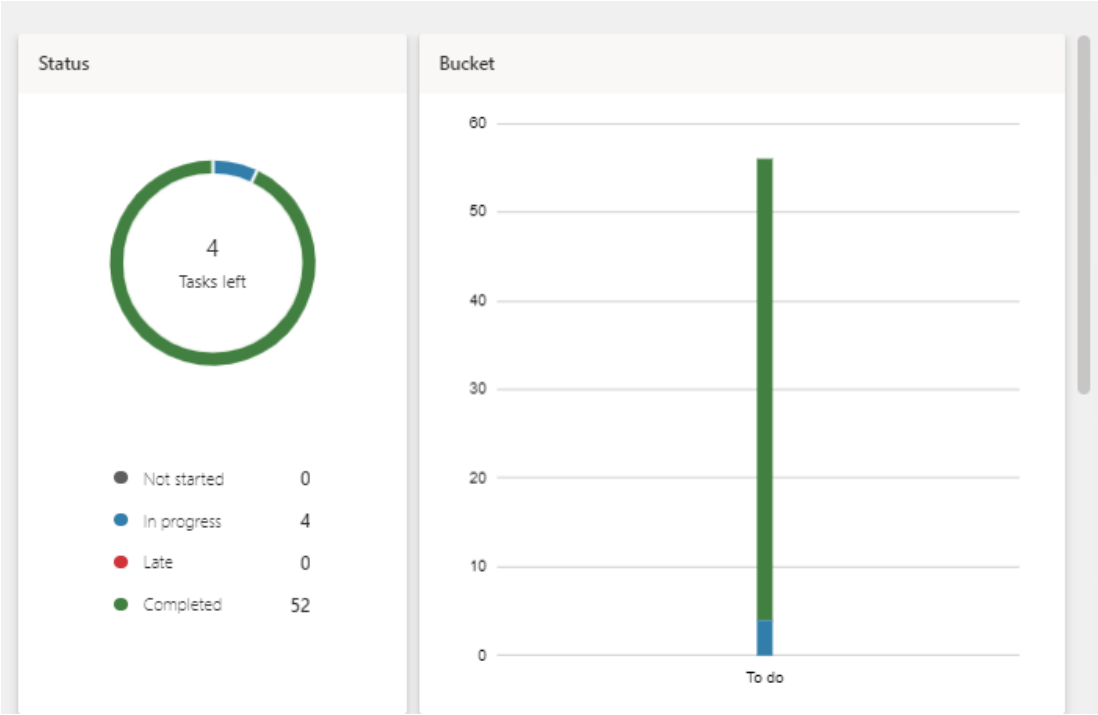


Figure 2.4.3.3: Overall Status in Microsoft planner

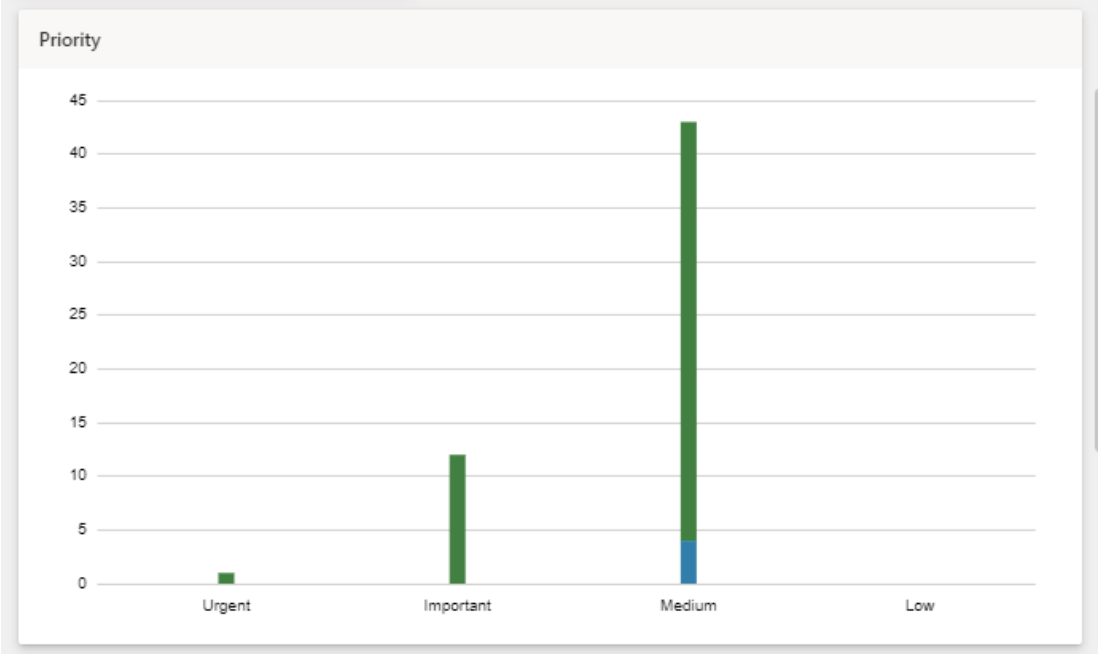


Figure 2.4.3.4: According to the Priority

Figure 2.4.3.4: Overall Status of all members

2.4.4 Version Controlling

Version control tools help developers to eliminate some issues during development phrase and after that. Sometimes computers or their operating systems can be crashed. In such situations, developed code can be destroyed. Using version control tool, we can overcome such issues. Not only that but also, we can manage a lot of versions of current system. We used GitLab as our version control tool.

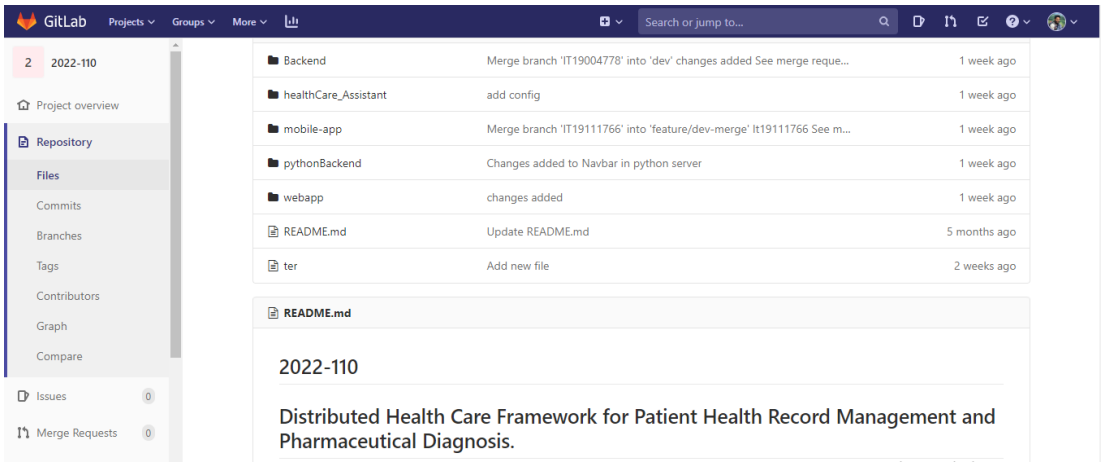


Figure 2.4.4.1: First Page of GitLab

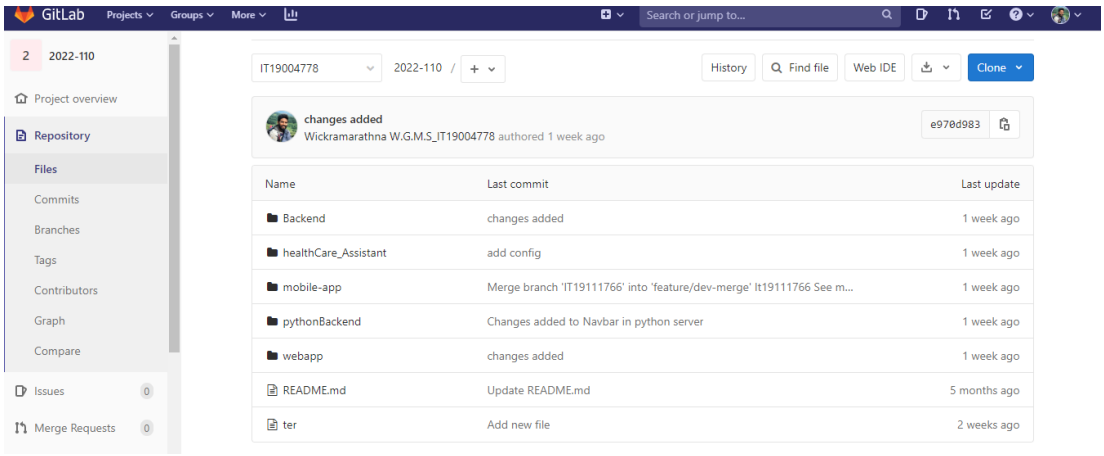


Figure 2.4.4.2: Branch of the Blockchain Component

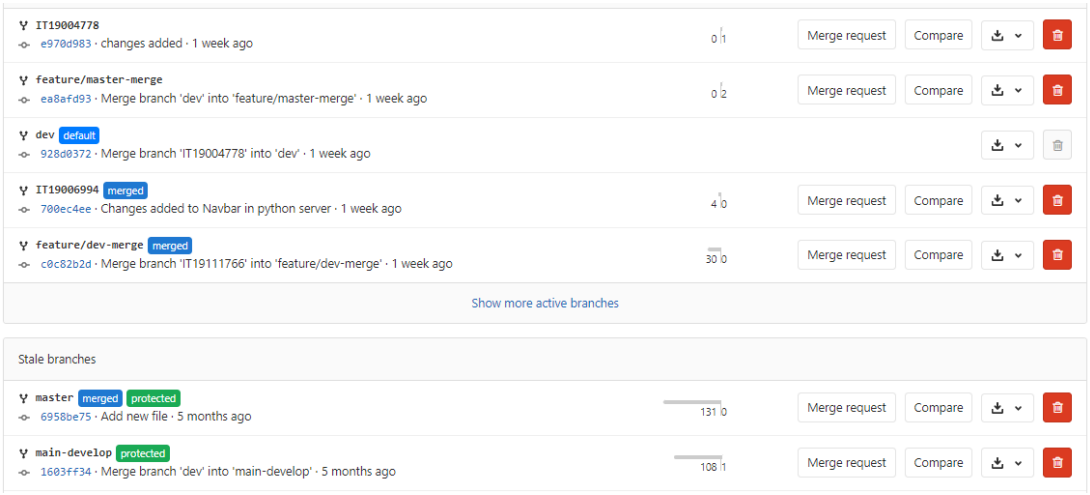


Figure 2.4.4.3: All Branches the we maintained

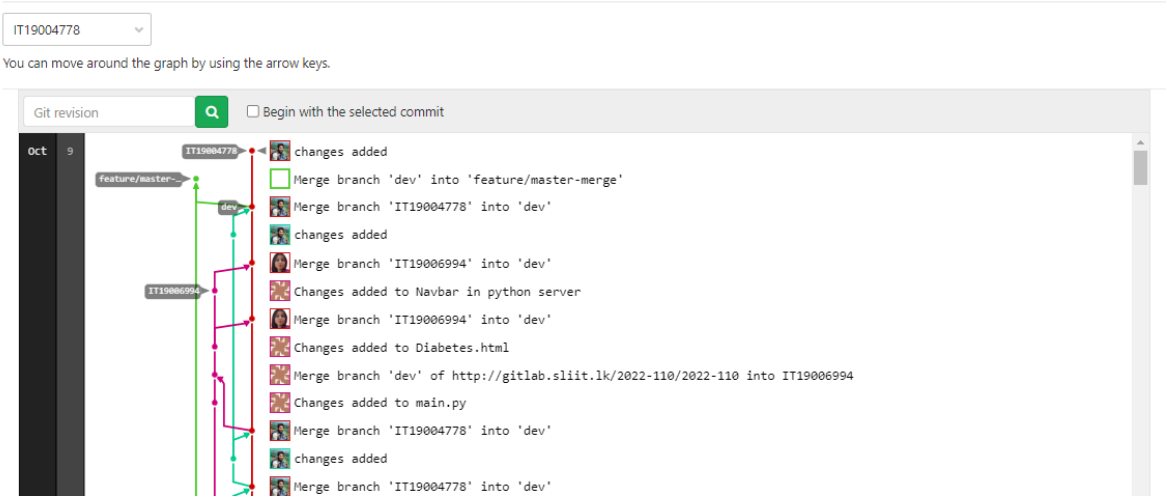


Figure 2.4.4.4: Overall view of the graph

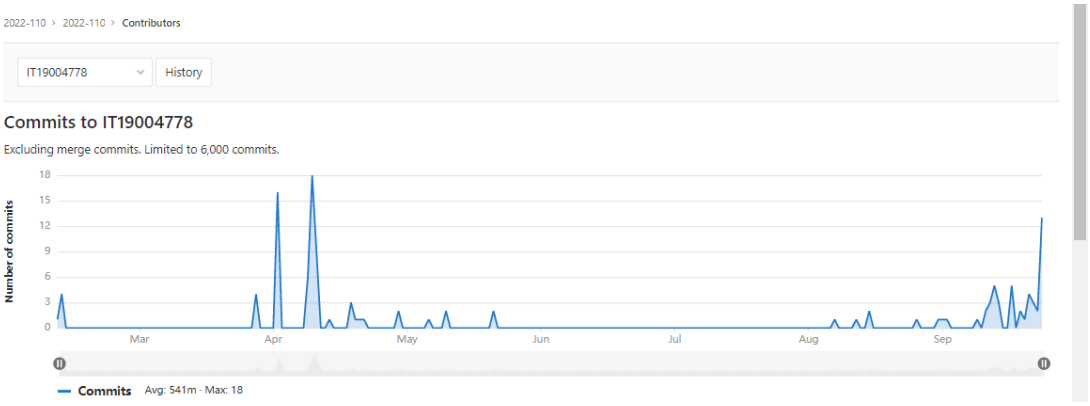


Figure 2.4.4.3: Contribution

3. Results and Discussion

3.1 Results

3.1.1 Outputs

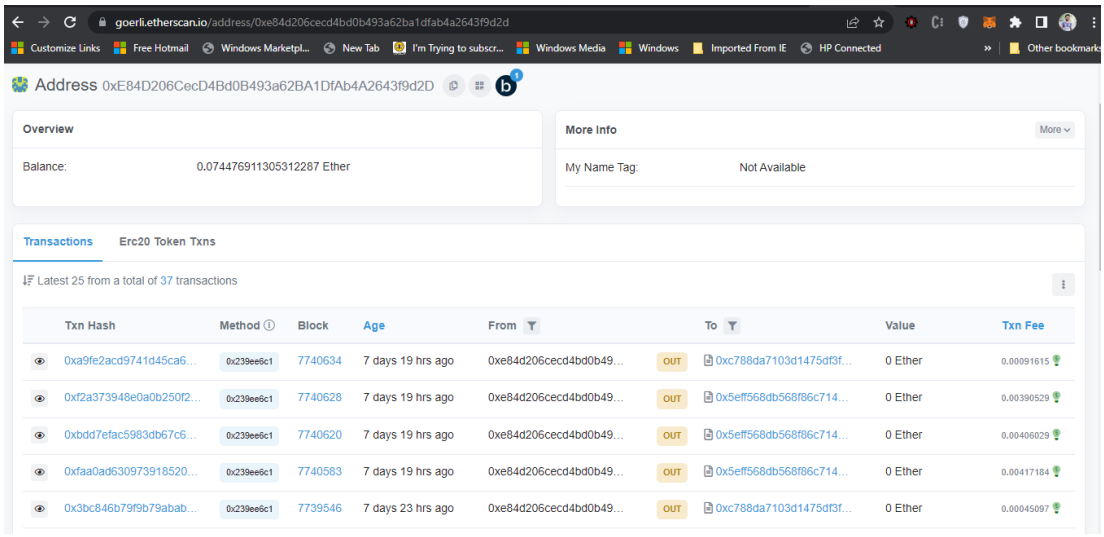


Figure 3.1.1.1: Transaction in Test Network

Figure 3.1.1.1 is showing the last few transactions that performed by the Oxygen.

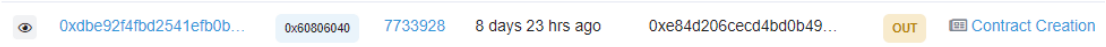


Figure 3.1.1.2: Contact Creation

Figure 3.1.1.2 shows the transaction of smart contract creation.

3.2 Discussion

Blockchain is one of the newest technologies in the current world. It already has overcome a lot of general problems. It could change the world from web2 to web3. There are a lot of advantages to blockchain. Such as,

- Immutability
- Transparency
- Efficiency
- Traceability
- Security

In Oxygen, we tried to indicate using blockchain in the healthcare industry, we can avoid problems that are facing not only doctors but also patients. Instead of having multiple systems for every hospital, the government can introduce one decentralized health care system like Oxygen. By having this kind of decentralized solution,

- No need to waste money for installs different systems from every hospital
- After hosting the server on the cloud can be accessed from anywhere.
- No need to worry about the specification of the computers.
- Since it uses blockchain no need to worry about storage.
- High Security
- Instead of handling a lot of files, this will provide attractive and easy interfaces.
- No need to waste time.

Everything has two sides, In the blockchain also has pros and cons. When we are considering cons in the blockchain technology.

- Time consumption is high for development.
- High energy consumption
- Still not mature

3.3 Problem Occur During the implementations

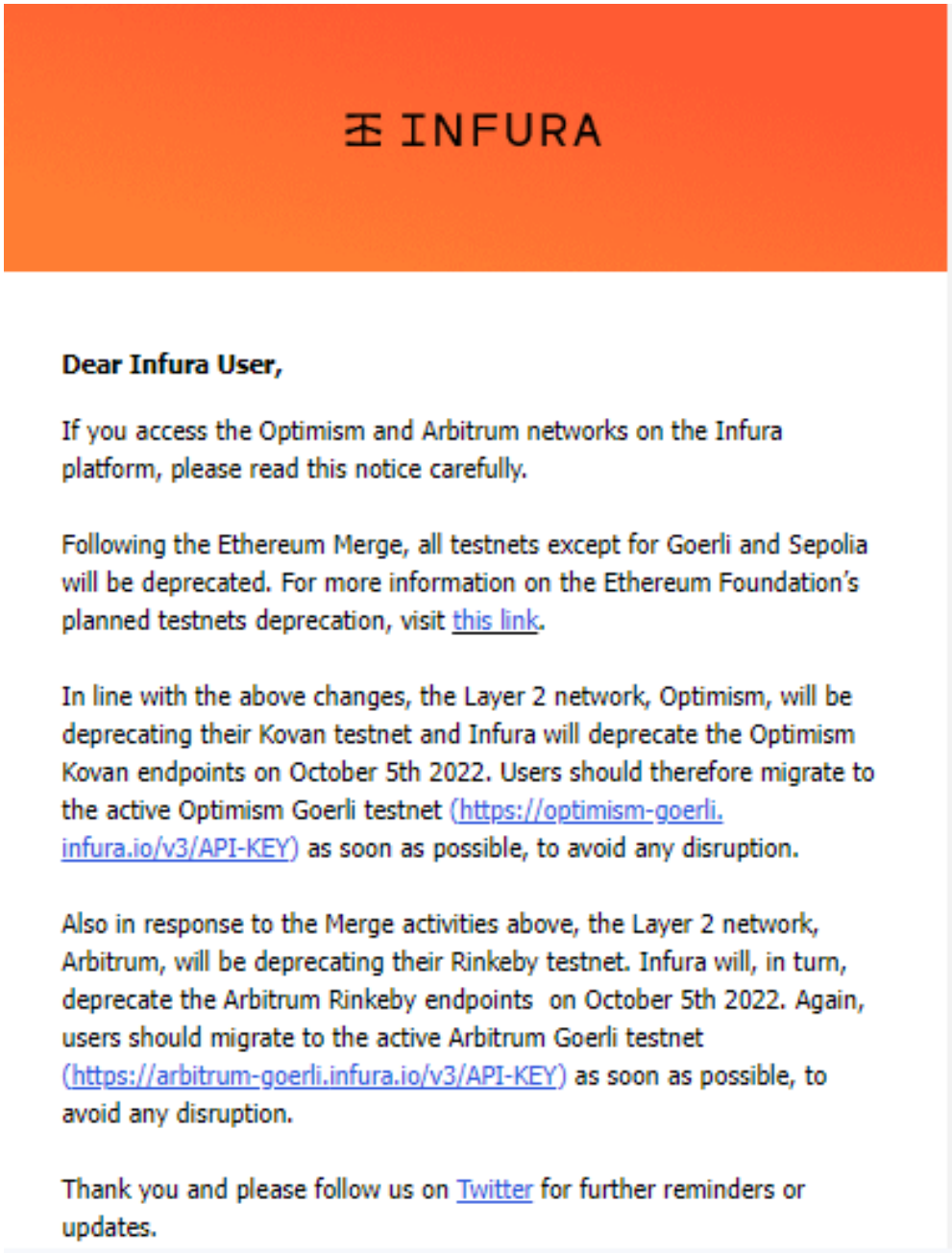


Figure 3.3.1: Infura Email

During the implementation phrase I got this main from Infura.io. I used Infura.io to integrate the Oxygen back-end server with Ethereum Rinkeby test network. They were asking to change the network. So, I made changes again not only to deploy the contract but also to the code.

3.4 **Future Works**

In the future, we are planning to integrate this solution with the insurance industry. By using Oxygen, both clients and companies will be able to get much more efficient service from both sides.

Apart from that, we will try to reduce the gas cost further.

4. Conclusion

The COVID19 epidemic has exposed the flaws in conventional healthcare and highlighted the significance of healthcare automation. Although electronic health records are growing increasingly popular, securely accessing patient data distributed across several EHRS remains a challenge. Blockchain technology has progressed over time, and its distributed nature will aid in the resolving of data privacy concerns. We intend to introduce a distributed healthcare framework in the proposed solution that may deliver healthcare services to both doctors and patients. Patient data will be maintained on the blockchain, and the proposed solution would use medical document scanners to reduce the amount of data that must be manually entered into the blockchain.

A virtual conversational chatbot will deliver healthcare services as part of the proposed solution. The medical chatbot can receive the most up-to-date prescription information from the Blockchain and send reminders to patients to take their medications on time. Not only that, but the chatbot can recognize pharmaceuticals based on their image and offer details such as dosage and adverse effects.

The solution is offered to reduce healthcare limitations and to assist in the resolving of difficulties that arise during the COVID19 pandemic.

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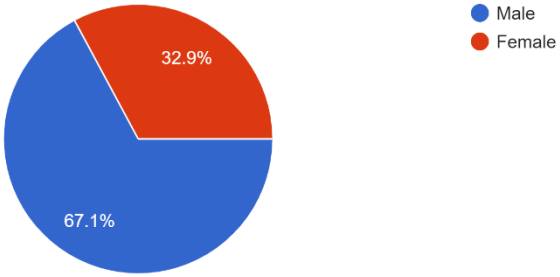
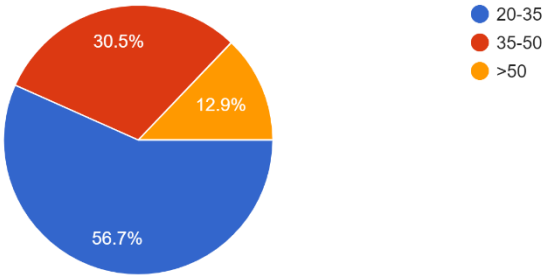
Appendices

Appendix A –Research Survey

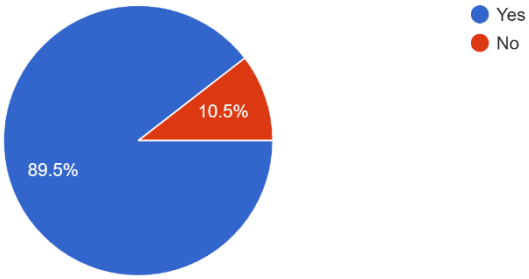
Gender
210 responses



Age Group
210 responses

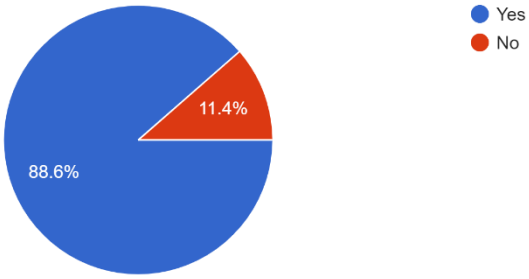


Do you believe that healthcare automation is critical in the occurrence of a pandemic?
210 responses



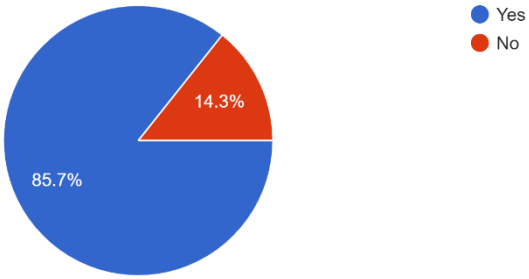
Do you maintain a personal medical log book?

210 responses



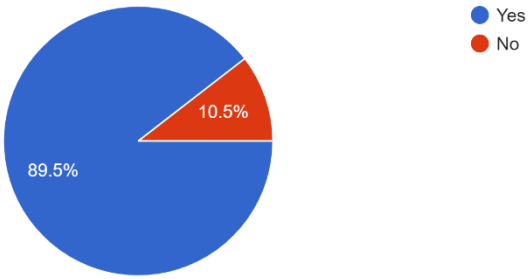
If Yes, Have you ever misplaced your medication history logbook?

210 responses



Do you like to keep track of your medication history in an electronic format?

210 responses



Which problem do you think will occur if we propose an automated solution to store patient data in digital format?

210 responses