National University of Computer & Emerging Sciences (FAST-NUCES)

Patient-Centric Healthcare using Blockchain

Making healthcare systems secure, accessible and interoperable

Project Supervisor
Dr. Jawwad Shamsi

Project Co- Supervisor
Miss Anam Qureshi

Project Team

Muhammad Saad 16K-3604
Muhammad Soman 16K-3639
Syed M. Taseen 16K-3616

Submitted in the partial fulfilment of the requirements for the degree of Bachelor of Science

Submitted on: June 7, 2020

Department of Computer Science

National University of Computer & Emerging Sciences (FAST-NU)

Main Campus, Karachi

7 June 2020

Project Supervisor	**Dr. Jawwad Shamsi**
Project Co Supervisor	**Ms. Anam Qureshi**
Project Team	**k163604, k163616, k163639**
Submission Date	**7 June 2020**

Supervisor

Dr. Jawwad Shamsi _____

Head of Department

Dr. Muhammad Atif Tahir _____

Department of Computer Science

National University of Computer & Emerging Sciences (FAST-NU)

Main Campus, Karachi

ACKNOWLEDGEMENT

The authors are immensely grateful to Allah Almighty without whose decree this research based product would not have been possible.

We would like to appreciate these people for helping us in our studies in one way or another and making Patient-Centric Healthcare using Blockchain a possibility:

Dr. Jawwad Shamsi, supervisor and adviser, who assisted in broadening our scope and helping us focus on the practical feasibility of the product. From research to a deployable product, Dr. Jawwad helped us in achieving the fruitful end to this research.

Ms. Anam Qureshi, co-supervisor, who assisted in every detail of the project starting from the fundamentals of Blockchain. Ms. Anam helped us dive into the world of distributed ledgers, how Blockchain evolved over the years and the possibilities that this technology brings to the world.

Apart from that, we would like to thank each and everyone of the individuals whose slightest to substantial contribution made a significant progress in the project. That includes the jury, the lab support IT staff, the faculty members and other teachers who helped in our formal and informal education.

Document Information

Category	Information
Customer	Project Jury
Project Title	Patient-Centric Healthcare using Blockchain
Document Version	1.0
Author(s)	Muhammad Saad, Muhammad Taseen, Muhammad Soman
Approver(s)	
Issue Date	7 June 2020

Definition of Terms, Acronyms, and Abbreviations

Term	Definition
BFT	Byzantine Fault Tolerance Algorithm
PII	Personally Identifiable Information
Healthcare Provider	Healthcare organizations including hospitals, clinics, laboratories, research centers, universities

ABSTRACT

The objective of this project is to develop a Patient-Centric Healthcare System using Blockchain smart contracts that allow patients to securely share their data across a Blockchain network The application helps in achieving the interoperability among various health institutes promoting research and analytics of the patient data. The technologies used for this application Go Ethereum Private Blockchain network setup, AWS ECS Container Services, smart contracts using Solidity, RPC, MetaMask wallet, PoW/PoA Consensus, Remix IDE, Node Js, Truffle Suits, Ganache ,React Js and Web3

The Patient-Centric Healthcare system is a dApp that provides tamper-proof decentralization of access privileges to the Electronic Health Records (EHR), Electronic Medical Records (EMR) and Personal Health Records (PHR) using cutting-edge Blockchain technology. Patients, with a web interface, will have a fully private control over the data that is shared among healthcare organizations using digital signatures and public key cryptography. Similarly, Providers have their own interface facilitating in accessing and managing their patients data.

Table of Contents

1. Introduction

1.1 Need For Product

Privacy is recognized as a basic human right by the United Nations in the Universal Declaration of Human Rights (UDHR) at the 1948 United Nations General Assembly. The aim of Patient-Centric Healthcare systems using Blockchain technology is to ensure patient agency with respect to the patient's personal health information. Consistent with GDPR standards, using Blockchain technology, we have developed a system (with Easy-to-Use Interface) in compliance with international standards of personal privacy. Once the data is accessible through our platform, health analytics can be performed on the data to predict patterns of certain diseases and infections prevalent in a particular area. Furthermore, interoperability among various Healthcare Organizations for better quality and availability of data is a concern that has been made possible using this project.

1.2 Associated CS Problems

Patient-Centric Healthcare using Blockchain has associated problems of privacy and security as medical data is critical. Most of these problems are related to data availability, information security, cryptography & digital signatures, consensus, BFT and 51% attack. As data is multiplied across a distributed network of various nodes, failure of any of the node(s) must not collapse the system and the system should run with consensus among other nodes. Another concern is the privacy of patients' PII, following Privacy Act, as a huge amount of personal health data is stored on the blockchain network for exchange among different Healthcare Organizations.

1.3 Benefits To Users

This system allows medical health records to be shared among various healthcare organizations providing interoperability of useful patient records while maintaining complete patient agency. Patient nodes get control and access over their personal data generated through medical encounters, prescriptions or lab reports. Provider nodes get access to the patients' medical history allowing them to better diagnose the disease, opening gates to further research opportunities.

1.4 Gap Analysis with Existing Solutions

The idea of storing patient's health information on a Blockchain network, preferably Hyperledger Fabric and Ethereum, has been implemented in various projects throughout the globe with certain amendments. Including Healthchain [1], MedRec [2], MedicalChain [3], Ancile [4], Bowhead [5]; there are approximately 20 systems that we found are similar to our concept of private health information exchange. The researchers are contributing to provide a solution for a patient-centric healthcare system to boost robustness, privacy, interoperability and quality of the data. In our project, we are building a private Ethereum blockchain for the purpose with textual medical encounters, prescriptions and lab reports. Our aim is to allow integration of epidemics analytics on the data available through patient's consent to contribute further in the area.

2. Requirements Analysis

2.1 Functional Requirements (Features)

Following is the summary of features that are part of the Patient-Centric Healthcare system using Blockchain Technology. This gives an idea of the scope of our project.

- Ethereum (Blockchain 2.0) network as a distributed ledger of access permissions
    - Digital signatures through Public Key Cryptography
    - Validation and Verification
    - Consensus
    - Smart Contracts
- Provider (Healthcare Organization) node(s) as Web Interface
    - Authentication (Login)
    - Add Medical Encounter for a Patient
    - Add Prescription for a Patient
    - Add Lab Report for a Patient
    - View Medical Encounter for accessible Patients

- View Prescriptions for accessible Patients
- View Medical Encounters for accessible Patients
- Request Permission to read or update Patient's Medical History

- Patient node(s) as Web Interface
  - Authentication (Login)
  - View personal Medical Encounter(s)
  - View personal Prescriptions(s)
  - View personal Lab Report(s)
  - View Healthcare Providers having access to personal Medical Data
  - Update Permissions to personal Medical Data
  - Accept/Reject Permission Request(s) to read or update personal Medical Data

2.2 Non Functional Requirements

The first requirement is the privacy of patients while they maintain control over their data. With this comes the security of stored data that must be confidential and available while integrity is maintained.

The project is dependent on the speed of mining blocks in the Ethereum Blockchain. The project is only feasible if all the nodes have enough system specifications to store and run the Blockchain.

Each node must be connected to the Blockchain network and should be able to make transactions at optimum speed.

The project is reliable following modern cryptographic algorithms (Encryption and HMAC) including digital signatures.

The users and providers have a specific identity number that identifies their account. The account is accessed via a string password that is mapped to the Ethereum account of the user. The system is secure with the assumption that the password of every individual entity is kept secure. In the future, we can integrate OTP for SMS or email verification mechanisms as well.

As data will be generated from multiple organizations, data must be accessible and consistent at all times. The integrity of the data must not be compromised.

2.3 Features

We have Implemented a user friendly application user interface using ReactJs technology. It provides an interactive and responsive UI with adequate performance. The navigation from one page to another is explicitly shown.

The project included the following features with respect to patients and providers (Healthcare institutions).

- **Login:** Login page for patient and provider
- **Signup:** Signup page for patient and provider

Pages Related To Patients

- **View Record:** This page shows patient his/her available respective data
- **View Permission Request:** The patients can view the requests of all the providers who wish to get access to their medical data.
- **Give Permission:** The patients can give respective providers permission to access their health records.However, there are two types of permission granted to providers i.e. read the data only or write and read the data.
- **Change Permission:**
- **Revoke Permission:** The patient can take away the rights to access their medical data from any provider at any time.

Pages Respective To Provider:

- **Add Record:** Provider can add medical encounter details of the respective patient.
- **View Permissioned Data:** Provider can view the permissioned data of the patients.
- **Add Encounter:** The healthcare facility can add information to patient's encounter data as per their initial diagnosis.

- **Add Prescription:** If there is a need for a prescription to be added to encounter data of patients then the healthcare facility can add it .
- **Add Lab Report:** The lab report will be added to respective patients' encounter data if only the healthcare institutions advised it.

2.4 Use Case Diagram

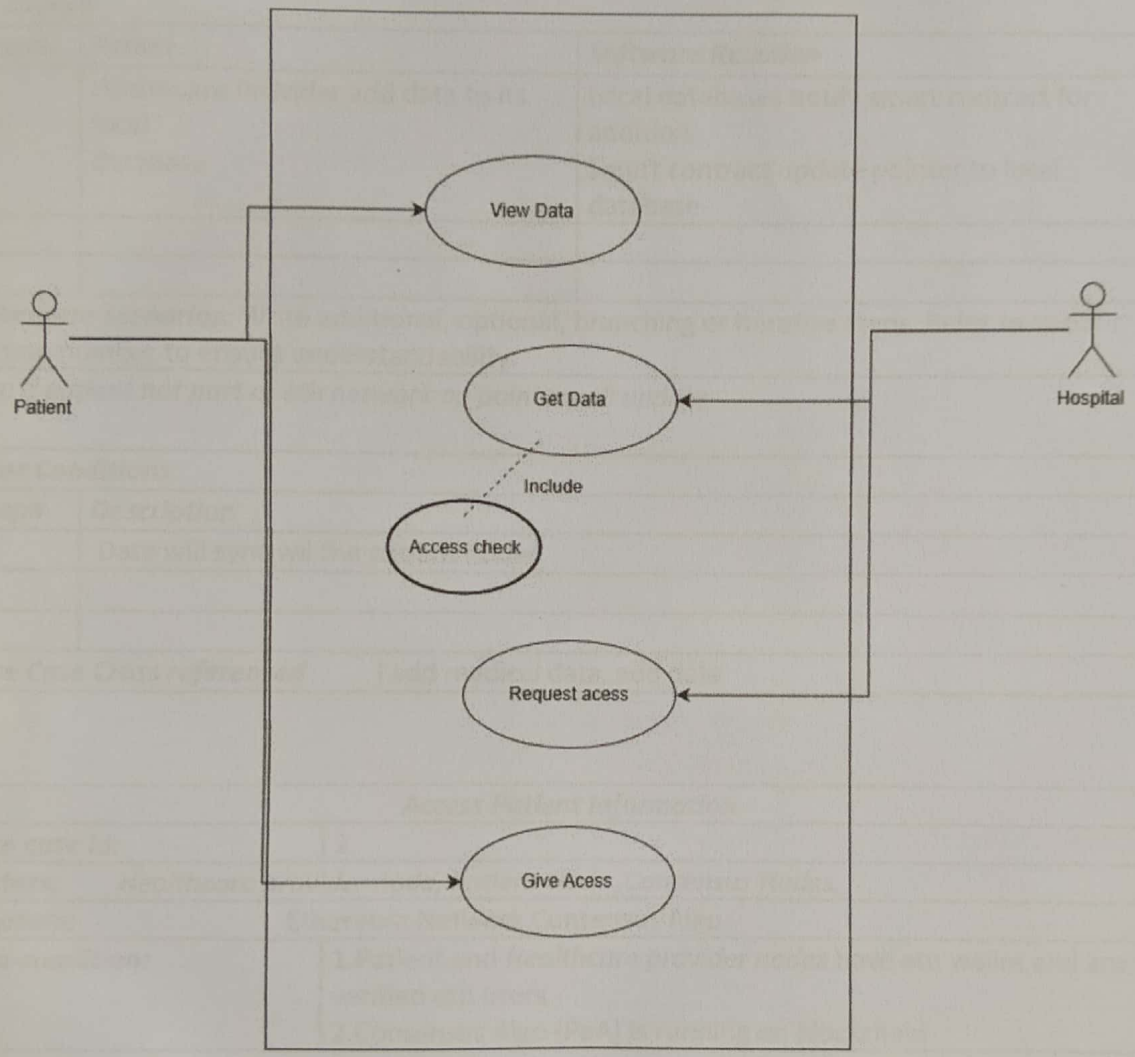

Figure 2.4: Use Case Diagram for Patient Centric Healthcare using Blockchain

2.4 Use Case Description

Add Patient Data		
Use case Id:	1	
Actors:	*Patient Node,Healthcare provider node*	
Feature:	Ethereum Network ,Smart contract,local databases	
Pre-condition:	1.Patient and *Healthcare provider nodes* have eth wallet and are verified eth users 2.Pointer to local databases store in smart contract	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	Healthcare Provider add data to its local database	Local databases notify smart contract for addition Smart contract update pointer to local database
2.		
Alternate Scenarios: Write additional, optional, branching or iterative steps. Refer to specific action number to ensure understandability.		
1a: *if patient not part of eth network no pointer will update*		
Post Conditions		
Step#	**Description**	
1	Data will sync wil the patient nodes	
Use Case Cross referenced	add medical data, add data	

Access Patient Information		
Use case Id:	2	
Actors:	*Healthcare provider node, Patient Node ,Consensus Nodes,*	
Feature:	Ethereum Network,Consensus Algo	
Pre-condition:	1.Patient and *Healthcare provider nodes* have eth wallet and are verified eth users 2.Consensus Algo (PoA) is running on blockchain	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	*Healthcare provider node* ask patient to access its information	Contract will check if patient has given access to requested *Healthcare provider* if not Notify the patient
2.	*Patient Node view notify and decide to give information*	*Contract will run the patient action* *Consensus Algo will verify the the transaction* *Transaction block added to Eth Network chain*

		Ledger update in all the Nodes
Alternate Scenarios: Write additional, optional, branching or iterative steps. Refer to specific action number to ensure understandability.		
1a: If patient has already given access return the patient data to *Healthcare provider* ***2a:If patient decided not to give information*** *Healthcare provider node* ***will not get data***		
Post Conditions		
Step#	***Description***	
1.	Contract gather all data from all patient *Healthcare provider nodes* show it to requested *Healthcare provider node*	
2.	*Healthcare provider* ***can add data***	
Use Case Cross referenced	Get Data,Request Access ,Give Access	

Patient View Data		
Use case Id:	3	
Actors: *Patient Node ,Healthcare provider node*		
Feature: *Ethereum Network,Smart Contract and Local databases*		
Pre-condition:	Patient node has eth wallet, smart contract has pointer to databases	
Scenarios		
Step#	***Action***	***Software Reaction***
1.	Patient Node request access to View his information	Smart Contract Verify the User that is requesting Smart Contract Gather all the patient data form the pointer to local databases Return Data to Patient Node
2.		
Alternate Scenarios: Write additional, optional, branching or iterative steps. Refer to specific action number to ensure understandability.		
1a:If User requesting is not verified return access denied		
Post Conditions		
Step#	***Description***	
1	Patient Node will get the data	
2	***View the data in form of table to the user***	

Use Case Cross referenced	View Data

3. Design Details

3.1 System Architecture

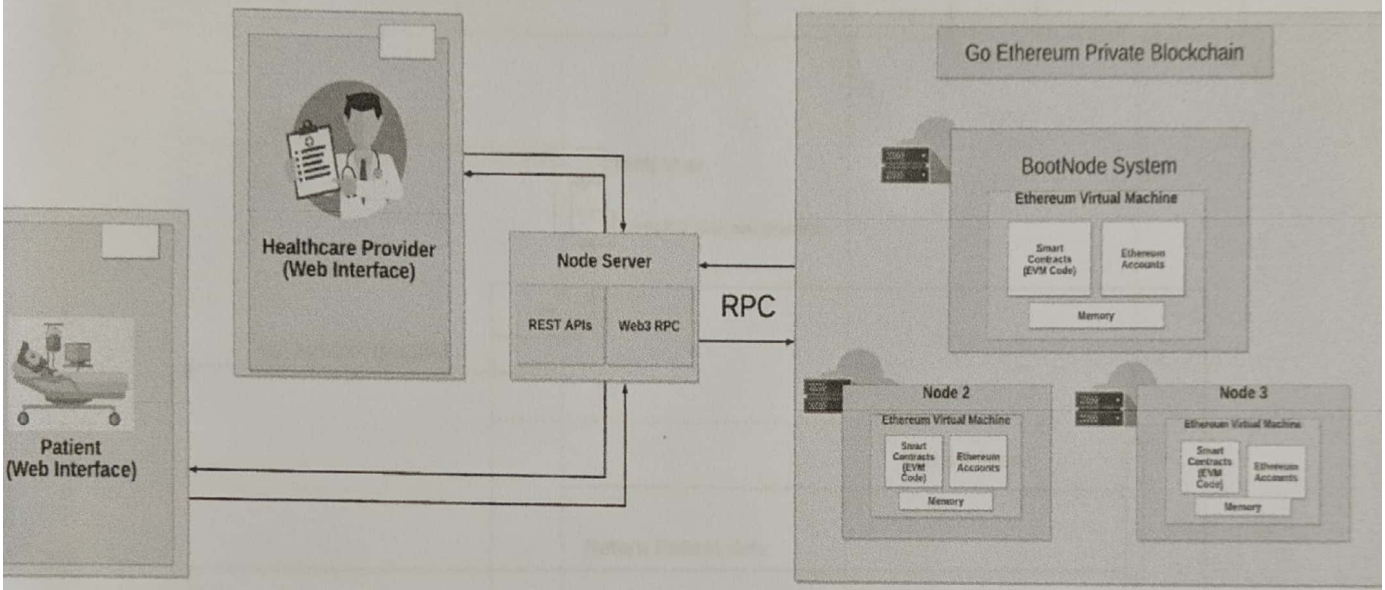

Figure 3.1: System Architecture for Patient Centric Healthcare using Blockchain

3.2 Process Model

3.2.1 Sequence Diagrams

3.2.1.1 Retrieving Patient Data

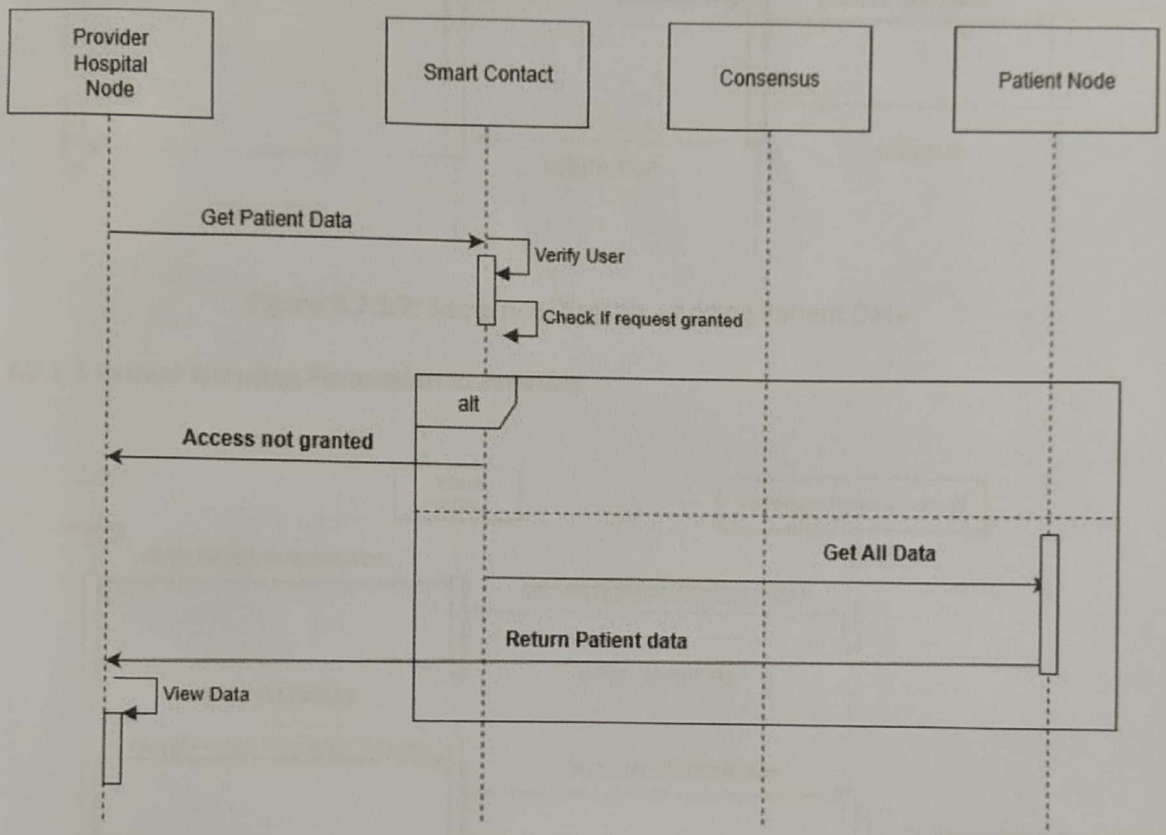

Figure 3.2.1.1: Sequence Diagram - Retrieving Patient Data

3.2.1.2 Adding Patient Data

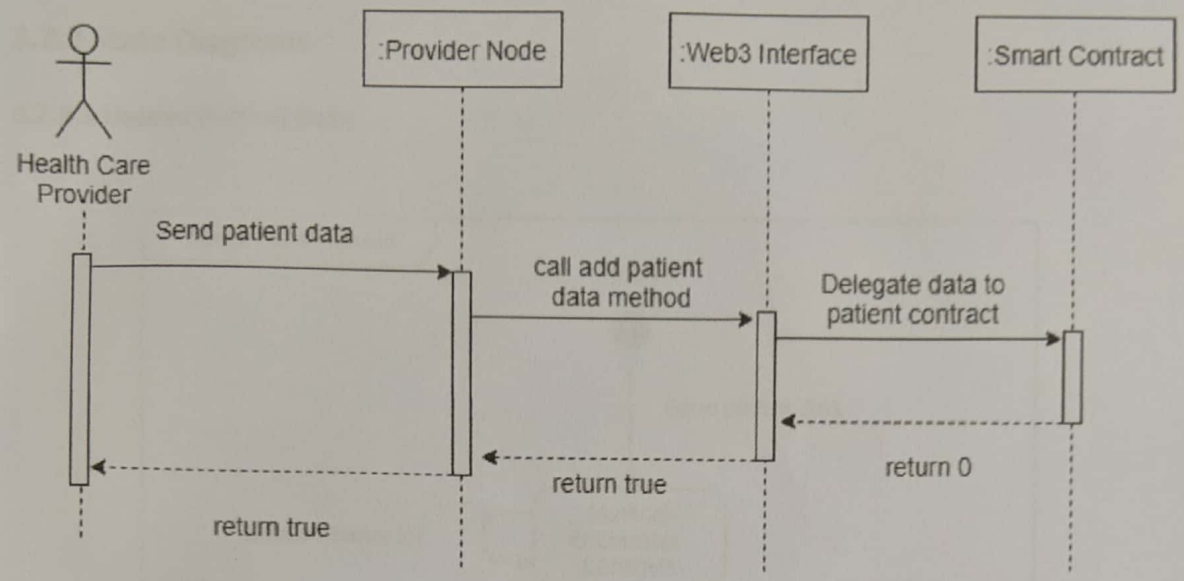

Figure 3.2.1.2: Sequence Diagram - Adding Patient Data

3.2.1.3 Patient Granting Permission to Provider

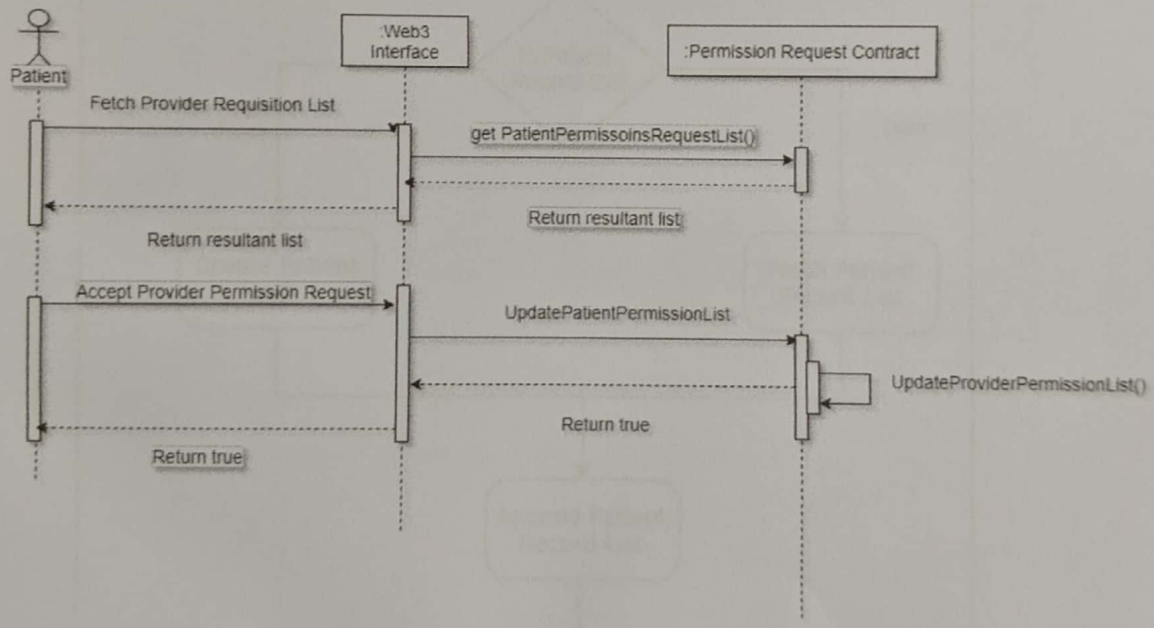

Figure 3.2.1.3: Sequence Diagram - Patient Granting Permission to Provider

3.2.2 State Diagrams

3.2.2.1 Upload Patient Data

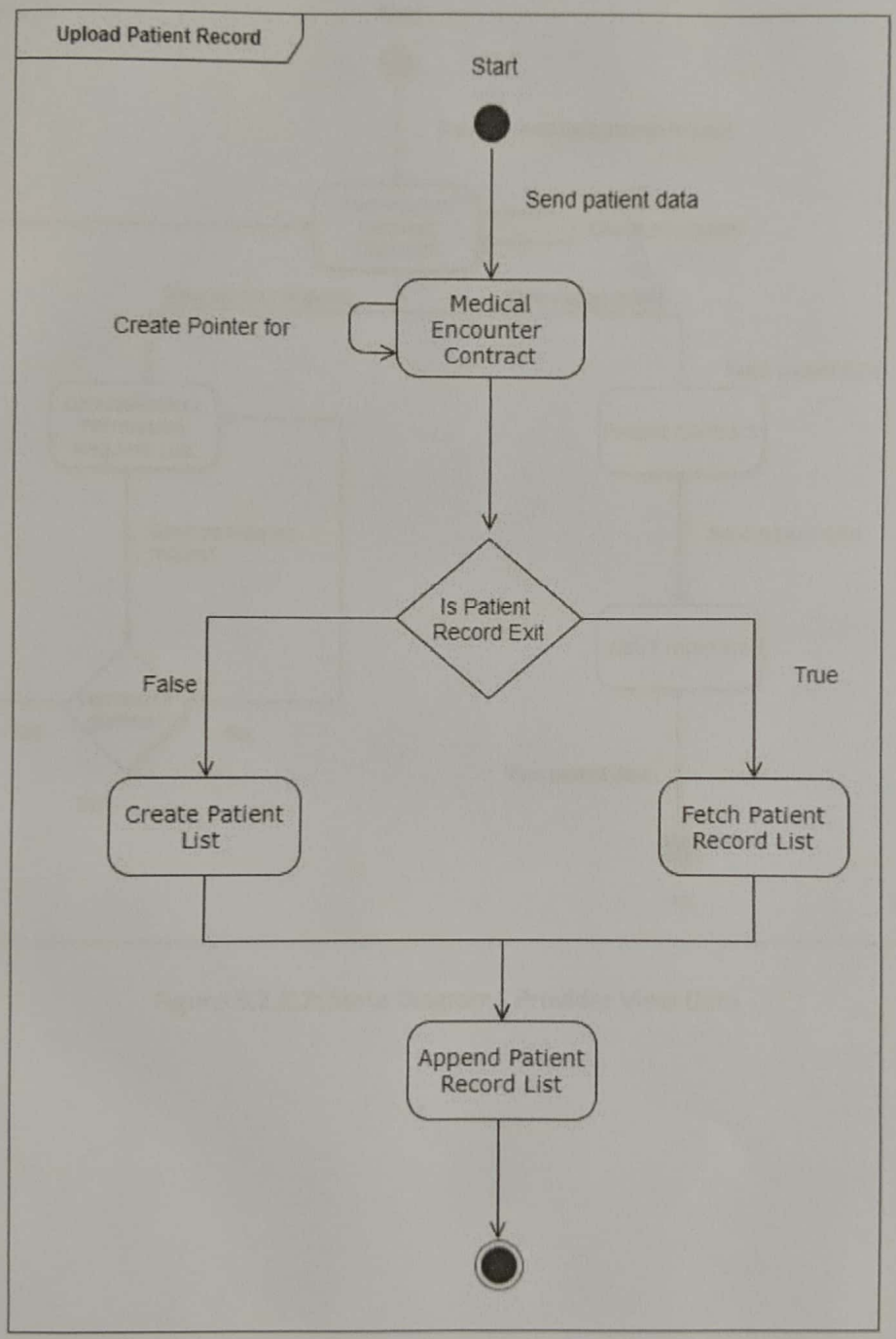

Figure 3.2.2.1: State Diagram - Upload Patient Data

3.2.2.2 Provider View Data

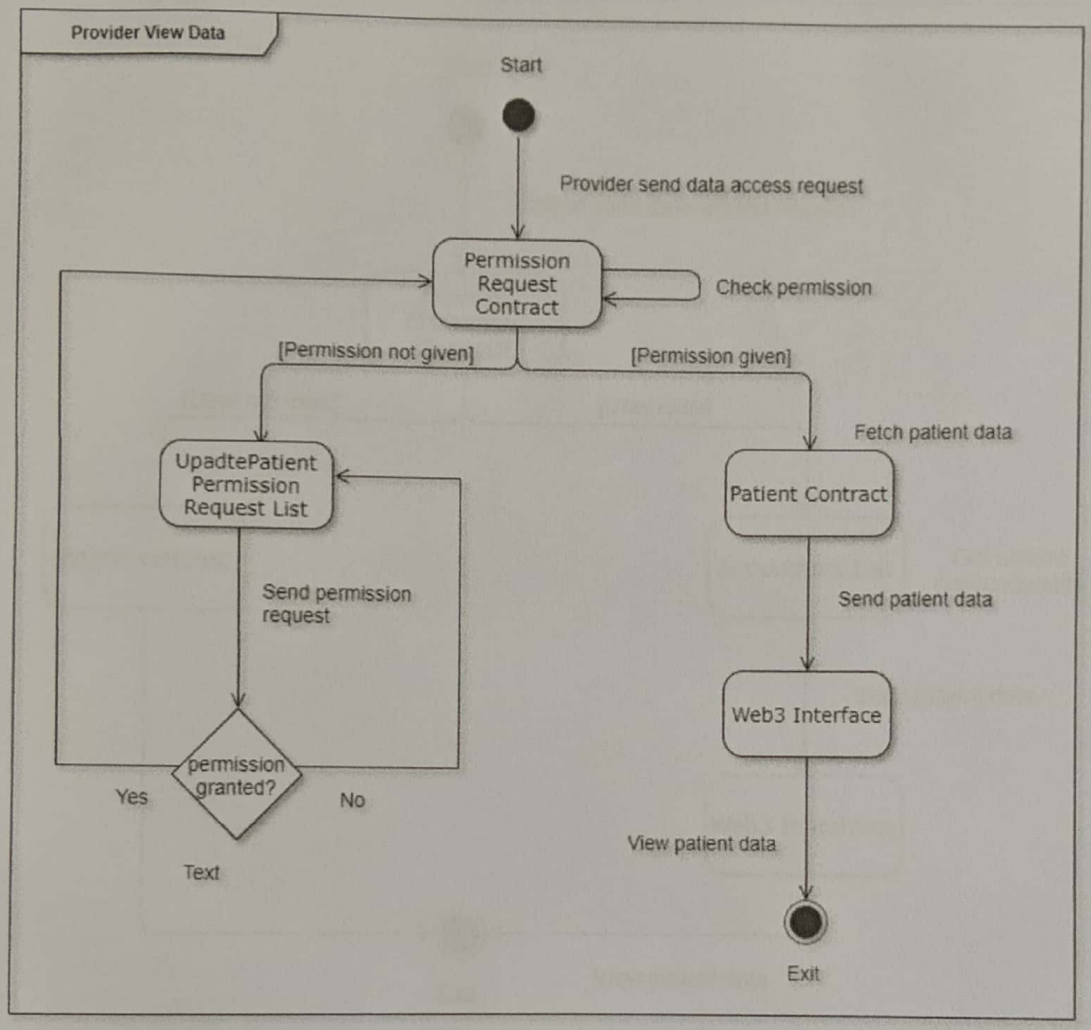

Figure 3.2.2.2: State Diagram - Provider View Data

3.2.2.3 Patient View Data

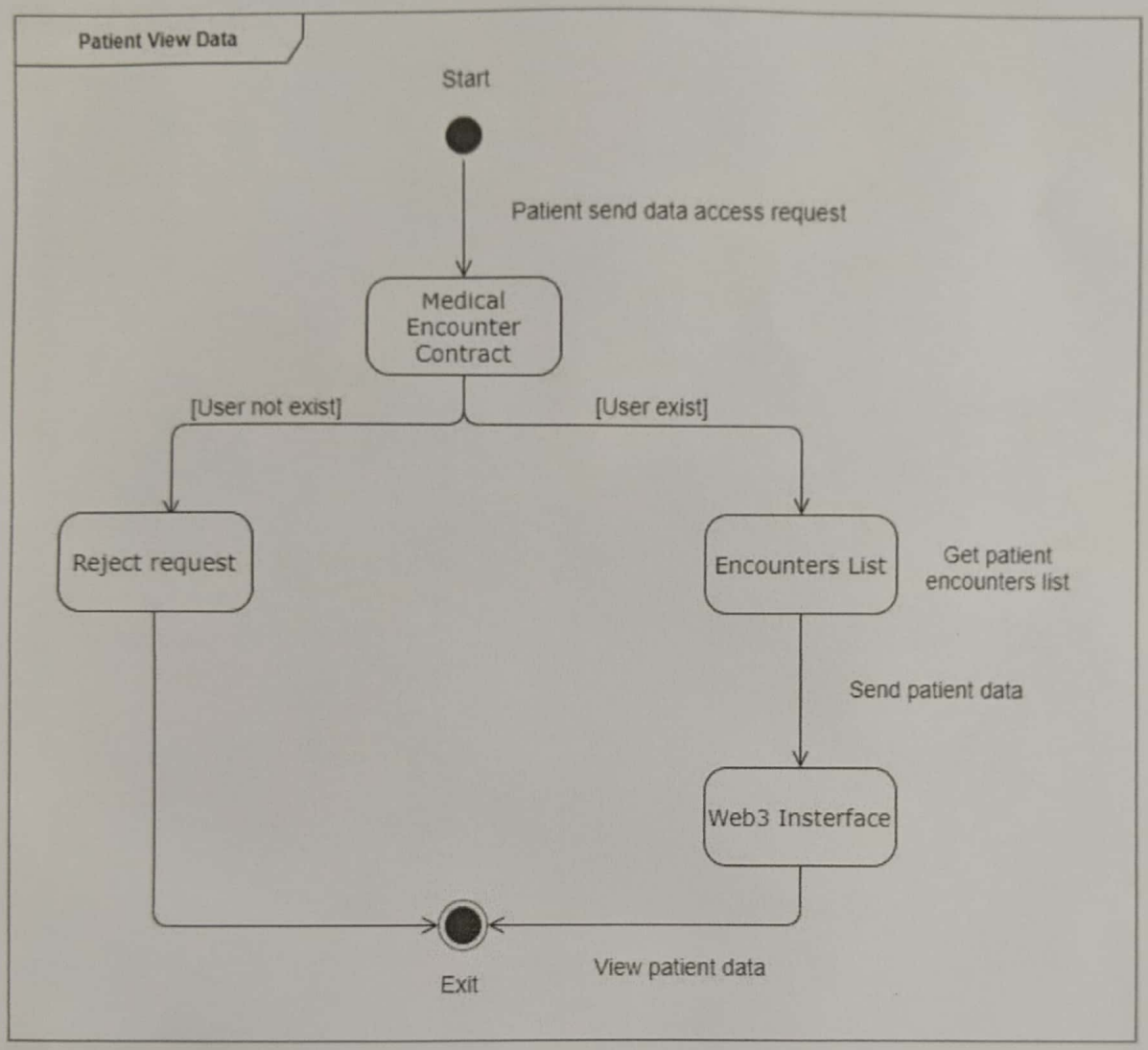

Figure 3.2.2.3: State Diagram - Patient View Data

3.3 Data Model

3.3.1 ER Diagram

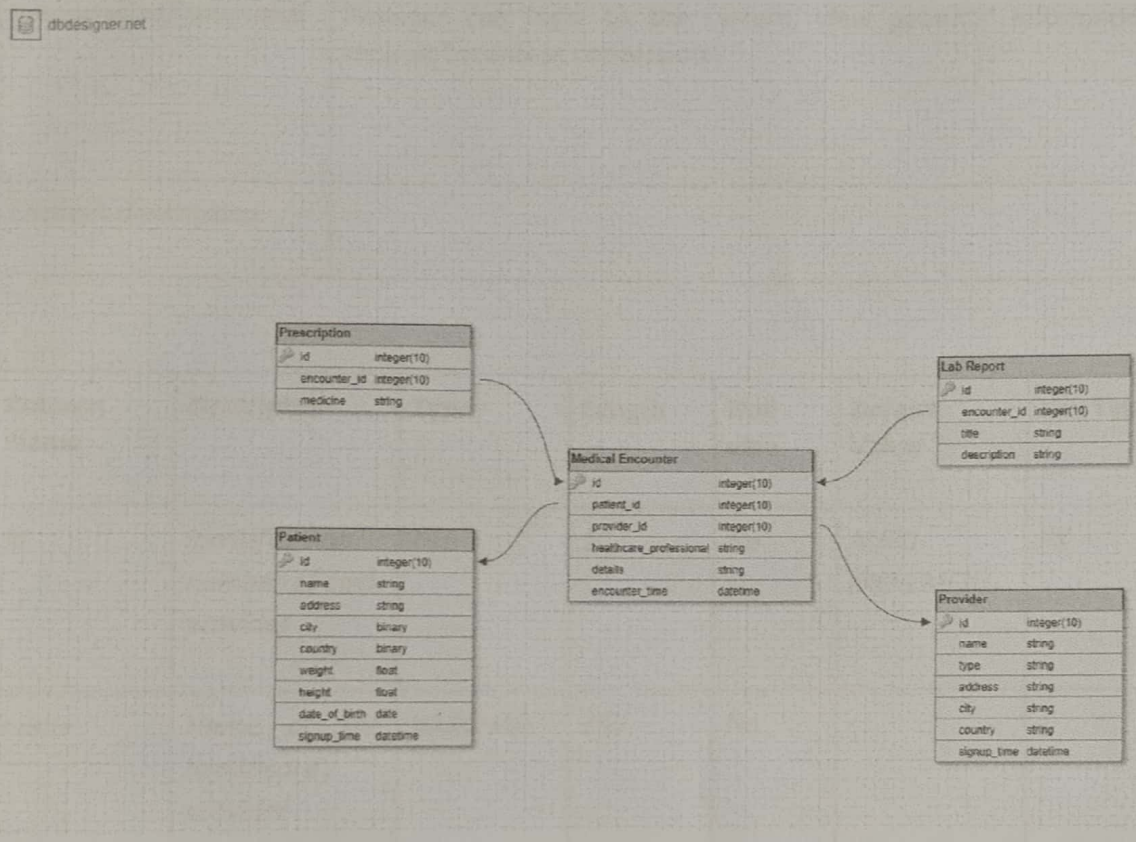

Figure 3.3.1: ER Diagram for the system

3.3.2 Data Dictionary

Provider	
Name	Provider

Alias	Healthcare Provider
Where-used/how-used	Provider can login to the system, view patients' information, request for access permissions
Content description	-

Column Name	Description	Type	Length	Null able	Default Value	Key Type
id	*Identification number of each provider*	*INT*	*10*	*No*	*AUTO INCREMENT*	*PK*
name	*Name of the healthcare provider*	*VARCHAR*	*255*	*No*	-	-
type	*Hospital, clinic, laboratory, research institute*	*VARCHAR*	*50*	*No*	-	-
address	*Address*	*VARCHAR*	*50*	*No*	-	-
city	*City*	*VARCHAR*	*50*	*No*	-	-
country	*Country*	*VARCHAR*	*50*	*No*	-	-

signup_time	*Time of the registration of the provider*	*DATETIME*	-	*No*	*CURRENT TIMESTAMP*	-

Patient	
Name	Patient
Alias	Personal Info. of a Patient
Where-used/how-used	Patient can login to the system, view their medical history and grant access permission of their personal data to different entities
Content description	-

Column Name	**Description**	**Type**	**Length**	**Null able**	**Default Value**	**Key Type**
id	*Identification number of each patient, can be a CNIC*	*INT*	*10*	*No*	*AUTO INCREMENT*	*PK*

name	*Name of the patient*	*VARCHAR*	*255*	*No*	-	-
address	*Address*	*VARCHAR*	*50*	*No*	-	-
city	*City*	*VARCHAR*	*50*	*No*	-	-
country	*Country*	*VARCHAR*	*50*	*No*	-	-
Date of birth	*Born date*	*DATETIME*	-	*No*	-	-
age	*age*	*INT*	*2*	*No*	-	-
Weight (body mass)	*weight*	*DOUBLE*	-	*Yes*	-	-
Height	*Height*	*DOUBLE*	-	*Yes*	-	-
signup_time	*Time of the registration of the provider*	*DATETIME*	-	*No*	*CURRENT TIMESTAMP*	-

Medical Encounter	
Name	Medical Encounter

Alias	Patient – Provider Meeting
Where-used/how-used	Whenever a patient goes to a healthcare institute, their data is generated.
Content description	-

Column Name	Description	Type	Length	Null able	Default Value	Key Type
id	*Encounter id*	*INT*	*10*	*No*	*AUTO INCREMENT*	*PK*
Patient_id	*[Description of the column]*	*[Type of column]*	*[Length of column]*	*No*		*FK*
Provider id				*No*		*FK*
Healthcare Professional	*Name and info of healthcare professional*	*SMALL TEXT*	-	*Yes*	-	-
Encounter Description	*Description*	*MEDIUM TEXT*	-	*Yes*	-	-

Encounter time		*DATETIME*	-	*No*	*CURRENT TIMESTAMP*	-

Prescription	
Name	Prescription
Alias	Medicine
Where-used/how-used	Whenever there's a medical encounter, patient is provided with a prescription of medicines
Content description	-

Column Name	**Description**	**Type**	**Length**	**Null able**	**Default Value**	**Key Type**
id	*Prescription id*	*INT*	*10*	*No*	*AUTO INCREMENT*	*PK*
Medicine	*The prescribed medication description*	*MEDIUM TEXT*	-	*Yes*	-	-

Medical encounter id	*Medical encounter id*	*INT*	*10*	*No*		*PK*

Lab Report						
Name	Lab Report					
Alias	Lab Provision, Report, Laboratory Encounter					
Where-used/how-used	Certain results of medical tests of individuals will be recorded as text.					
Content description	-					
Column Name	**Description**	**Type**	**Length**	**Nullable**	**Default Value**	**Key Type**
id	*report id*	*INT*	*10*	*No*	*AUTO INCREMENT*	*PK*

Lab report title	*Title of the lab report for example Blood Report*	*MEDIUM TEXT*	-	*No*	-	-
Lab report description	*Description*	*MEDIUM TEXT*	-	*Yes*	-	-
Lab report location	*Local path location of lab report in .PDF format*	*MEDIUM TEXT*	-	*No*	-	-
Medical encounter id	*Medical encounter id*	*INT*	*10*	*No*		*FK*

4. Implementation Details

4.1 Choice of Development Tools

Following is the list of development tools used in Patient-Centric Healthcare:

- Ethereum - Base model
- Go-Ethereum Private Blockchain - Ethereum implementation in go lang
- Ganache - Testing Framework
- Solidity - Full-fledged programming language for Smart Contracts
- Remix IDE - Executing Solidity contracts with compilation and deployment
- Truffle Suites - Contracts compilation and migration to deployment
- Meta Mask - Wallet for supporting Ethereum accounts

- PoW Consensus - Allowing validation through mining by individual nodes
- NodeJS - Server for hosting application
- ExpressJS - RESTful APIs
- Web3.JS - Remote Procedural Calls between contracts and application logic
- React Native / HTML5 / CSS3 - Frontend for patient and provider node(s)
- EC2 - Amazon Web Services instance for live deployment

4.2 Design Trade-Offs

The system of Patient-Centric Healthcare using Blockchain consists of a three tier system design architecture. For a secure, available and privacy oriented structure of our system, we have chosen Ethereum blockchain. Blockchain will provide a distributed network for secure storage of patient's critical medical data. With this distributed data, we can develop a system beyond a single point of failure. Ethereum helps us add a business layer to the secure storage of Private Blockchain (Consortium Blockchain). Another alternative is Hyperledger Fabric that related products have been built on. We have chosen Ethereum as better support is available for Ethereum in the community.

For the private blockchain setup of Ethereum, we used Ganache which did not provide a great detail of features. Hence, we used Go-Ethereum which provided us with a console to have more control of the system. We define our custom genesis.json file and deploy our contracts using Truffle. Remix IDE had been used to develop and test the contracts but the deployment was local so we had to shift to Truffle.

To integrate our Blockchain contracts with the users' frontend app, we have used NodeJS that comes up with Web3.JS library. Web3 provides RPC (Remote Procedure Calls) that allows us to interact with the smart contracts built using Solidity (JavaScript based language for Ethereum smart contracts). We have our frontend built on ReactJS which is one of the latest technologies for building dynamic web applications.

5. Testing

5.1 SYSTEM TESTING

5.1.1 ITEMS TO BE TESTED / NOT TESTED

Item to Test	Test Description	Test Date	Responsibility
User Registration	Patient and Provider register on blockchain network	6/6/2020	Taseen
Provider Permission request	Provider ask permission to patient to access data	6/6/2020	Saad
Patient Give Permission	Patient give access control to provider to view data	6/6/2020	Soman
Provider add record	If provider have access he/she can add record	6/6/2020	Soman
Patient/Provider View record	patient can view his own record Provider if has access can view patient record	6/6/2020	Saad

5.1.2 TEST APPROACH(S)

Test is based on a user testing system through frontend and using the system and testing the use cases.

5.1.3 TEST PASS / FAIL CRITERIA

If the result of the test matches the expected outcome of the given use case if passed otherwise it fails.

5.1.4 TEST DELIVERABLES

Result of the test will be system running smoothly and data is being saved on blockchain

5.1.5 TEST CASES

TEST CASE ID: 01

DESCRIPTION :Patient Addition

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
1.	Enter (FullName,Address,City,Country,Cnic,Password)	detail are entered	detail entered	pass
2.	Submit & Api called	call success full	call successful	pass
3.	Web3 to Smart tContract Update	Addition in smart contract	Addition in smart contract	pass

TEST CASE ID: 02

DESCRIPTION:Provider Addition

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
1.	Enter (FullName,Address,City,Country,Cnic,Password)	detail are entered	detail entered	pass
2.	Submit & Api called	call success full	call successful	pass
3.	Web3 to Smart Contract Update	Addition in smart contract	Addition in smart contract	pass

TEST CASE ID: 03

DESCRIPTION: Provider Permission request

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
4.	Provider Search for the wanted User	User Found	User found	pass
5.	Provider click on ask for read only or read and write request	click successful	click successful	pass
6.	Request Submitted on blockchain network	Submit on blockchain	Submit on blockchain	pass

TEST CASE ID: 04

DESCRIPTION: Patient Give Permission

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
7.	Patient Search for the provider	Provider found	provider found	pass
8.	Patient click on either to give read access or read/write access	click successful	click successful	pass
9.	Permission response Submitted on blockchain network	Submit on blockchain	Submit on blockchain	pass

TEST CASE ID: 05

DESCRIPTION: Provider add record

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
10.	Select the patient	Patient selected	Patient selected	pass
11.	check access is given	access is given	access is given	pass
12.	Add encounter detail	detail are entered	detail are entered	pass
13.	Add prescription	detail are entered	detail are entered	pass
14.	Add Lab reports	detail are entered	detail are entered	pass
15.	Submit data into blockchain	Data Saved	Data Saved	pass

TEST CASE ID: 06

DESCRIPTION: Patient/Provider View record

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
16.	Select Patent Or My records	Selected	Selected	pass
17.	Select Patient encounters form the list to view it data	Encounter found and selected	Encounter found and selected	pass
18.	Data is viewed of its encounter prescription and report	Data viewed	data viewed	pass

5.2 VALIDATION TESTING

5.2.1 ITEMS TO BE TESTED / NOT TESTED

Item to Test	Test Description	Test Date	Responsibility
Regsitration	User either patient or provider signup to the system	6/62020	Taseen
Permission access controls	Patient can give read only or read and write control to the provide on its data	6/62020	Saad

Patient Data Insertion	Provider can insert the patient records if have access	6/62020	Soman
Patient Data View	Patient acn view its own data Provide if have access can view it data	6/62020	Taseen

5.2.2 TEST APPROACH(S)

Functionality that we implemented if follow the above test cases then system is validated the it is right

5.2.3 TEST DELIVERABLES

System functionalities validate the above mentioned requirements

5.2.4 TEST CASES

TEST CASE ID:1				
DESCRIPTION: Patient and Provider registration				
No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
1.	WebApp front page show login and sign up	Login sign up views	login sign up view	pass
2.	User can either sign as patient or provider by entering details	detail are entered	details are entered	pass
3.	Submit details on to blockchain network	data submitted	data submitted	pass

TEST CASE ID:2				
DESCRIPTION:Permission access control				
No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL

1.	Provider select the user	user found from list and selected	user found from list and selected	pass
2.	Provide request for access control	ask Read only access or read/write	ask Read only access or read/write	pass
3.	Patient Give access control	give Read only access or read/write	give Read only access or read/write	pass

TEST CASE ID:3
DESCRIPTION:Patient Data insertion

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
1.	Provide check if have access	Access is given	access is given	pass
2.	Provider add information	Information added encounter, prescription and report	information added encounter, prescription and report	Pass
3.	provider submit information to block chain	info submitted	info submitted	pass

TEST CASE ID:4

DESCRIPTION:Patient data view

No.	STEPS	EXPECTED RESULTS	ACTUAL RESULTS	PASS/ FAIL
1.	Check if access have given	access have given	access have given	pass
2.	select from the encounter to view	encounter selected	encounter selected	pass
3.	data viewed	prescription and lab report shown	prescription and lab report show	pass

6. Outputs of the Product

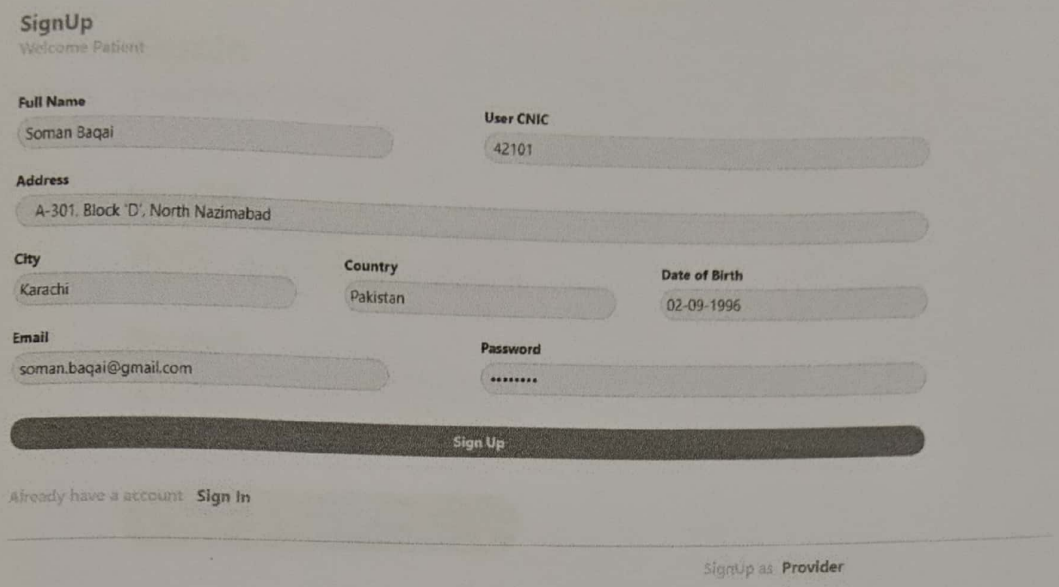

Figure 6.1: Signup for Patient

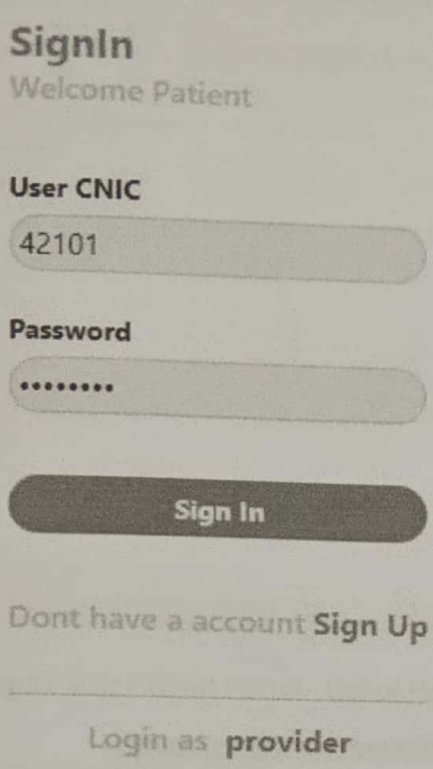

Figure 6.2: Sign in for Patient

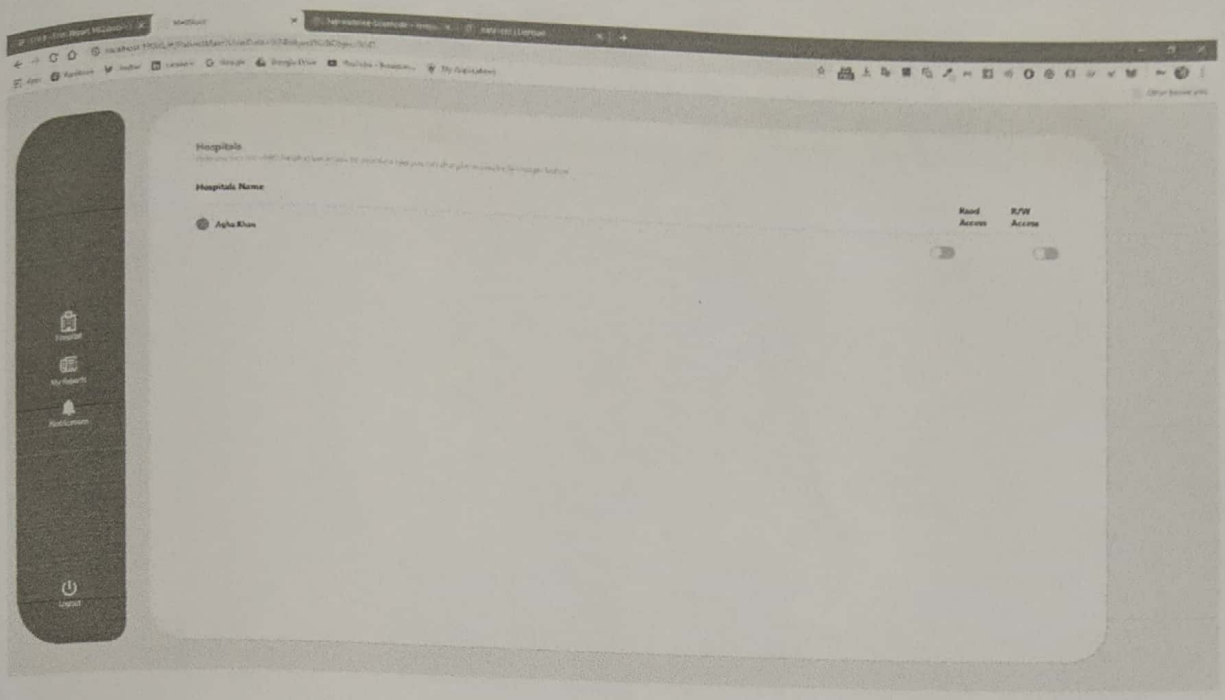

Figure 6.3: Patient Portal - List of Hospitals to grant permission to

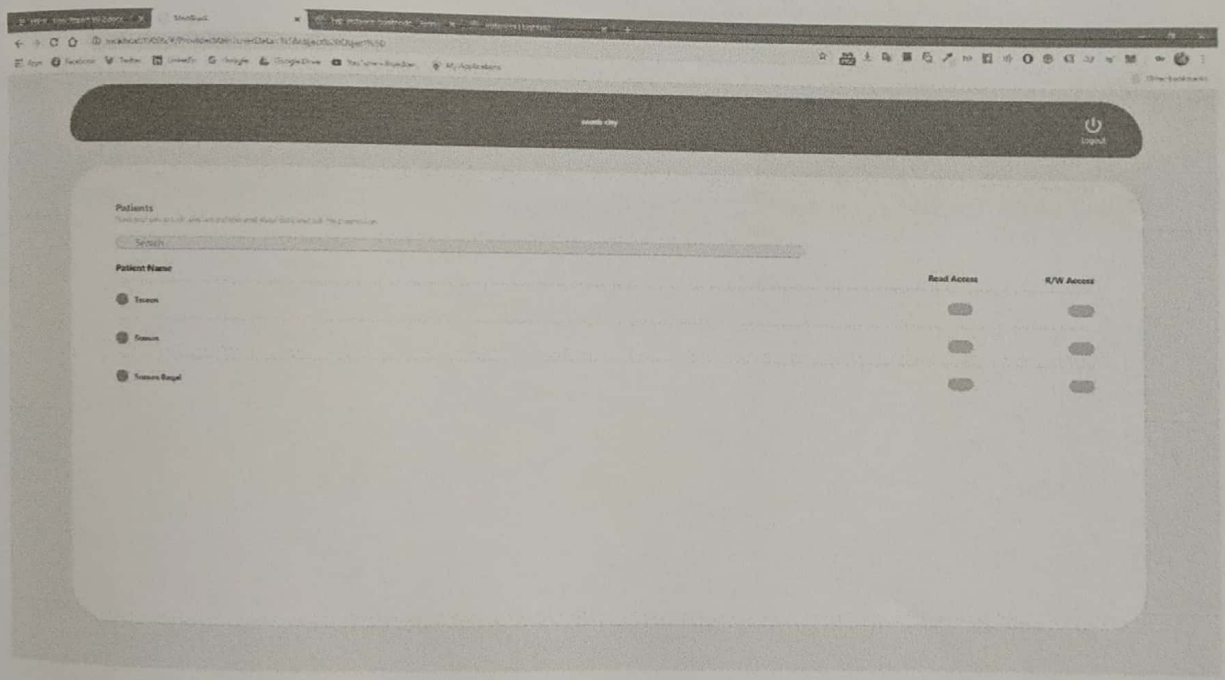

Figure 6.4: List of Patients to request permission from

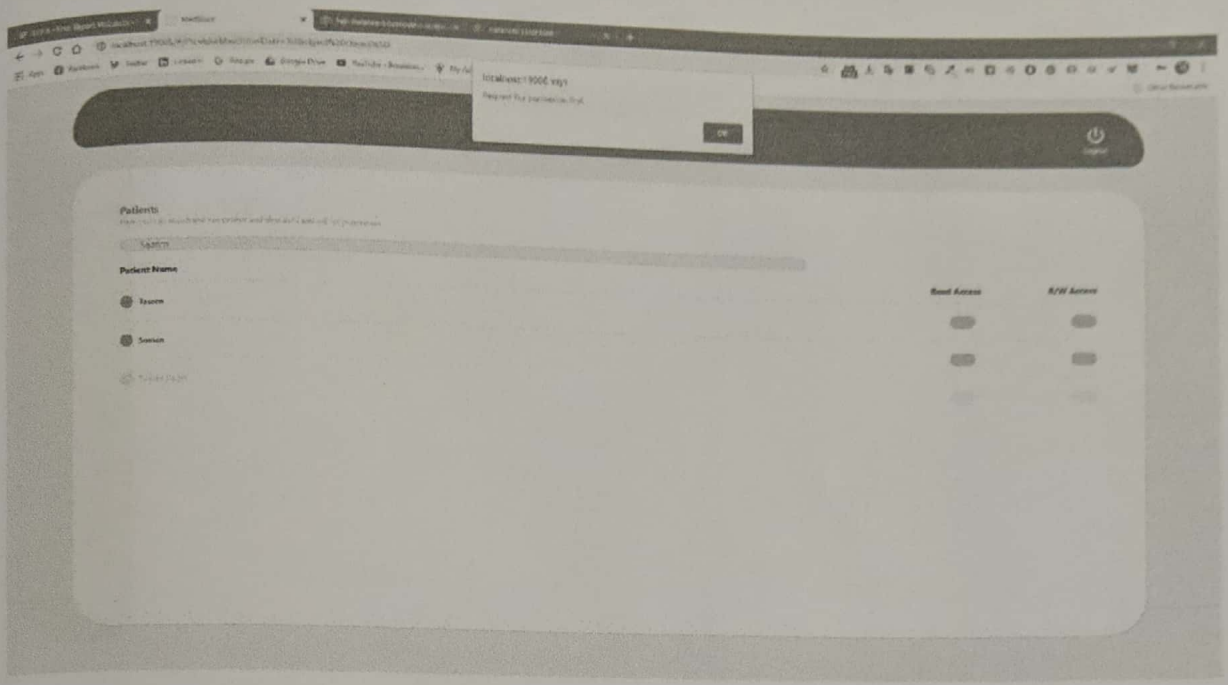

Figure 6.5: Read Acces Permission requested from patient

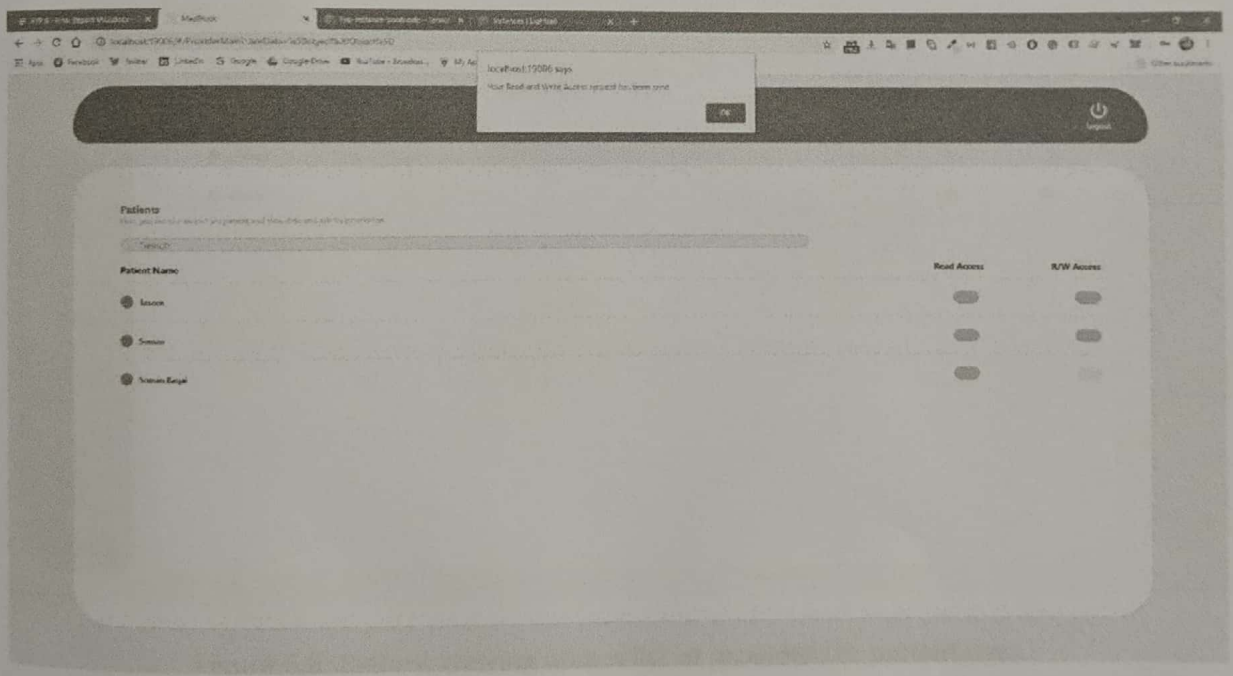

Figure 6.6: Read and Write Access requested from patient

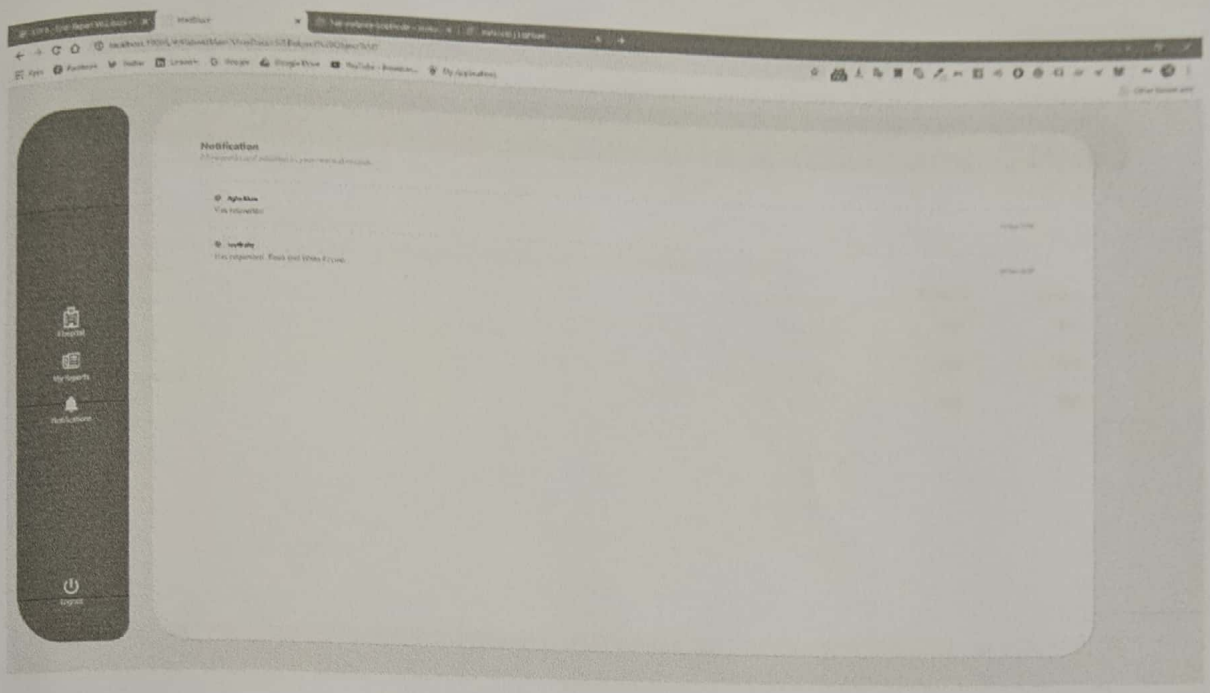

Figure 6.7: Patient getting permission request notifcation

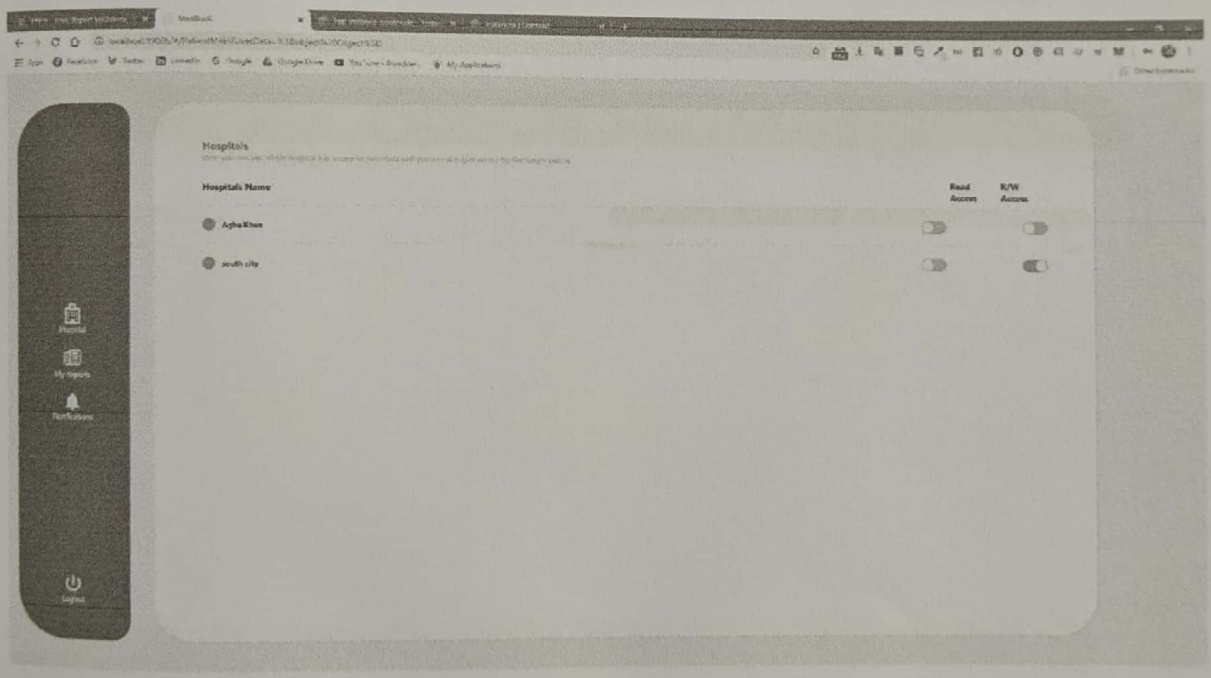

Figure 6.8: Patient viewing access list of providers to patient data

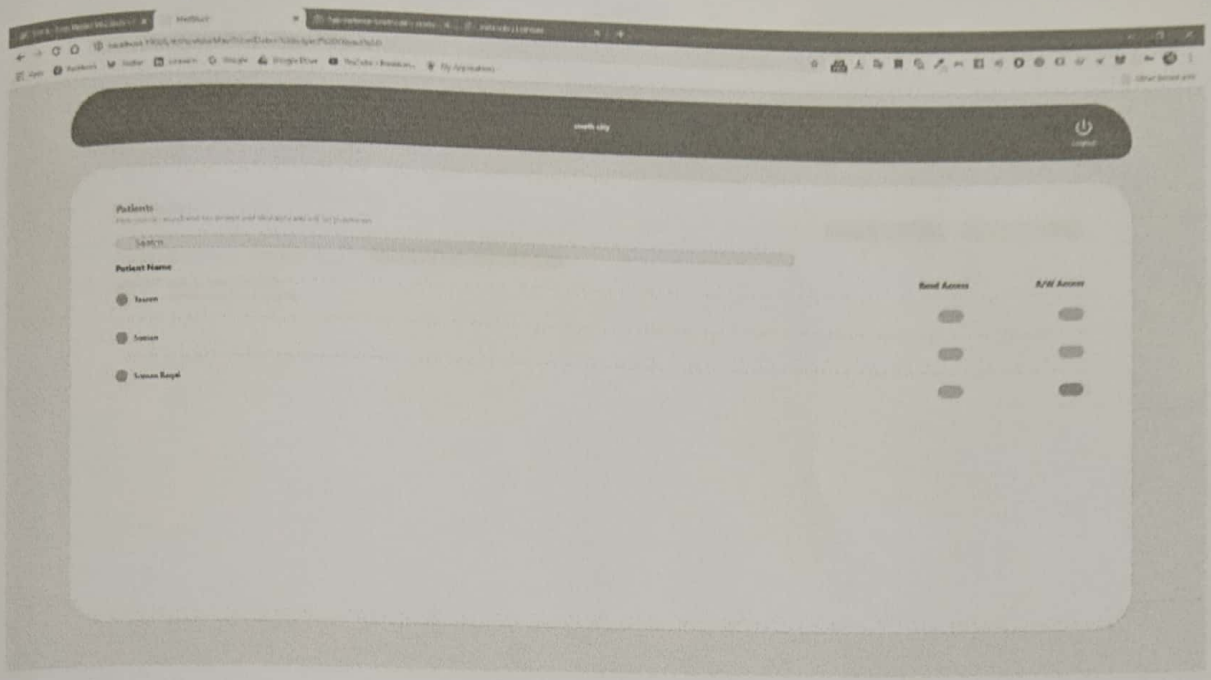

Figure 6.9: Provider with R/W Access to patient in list of patient permissions

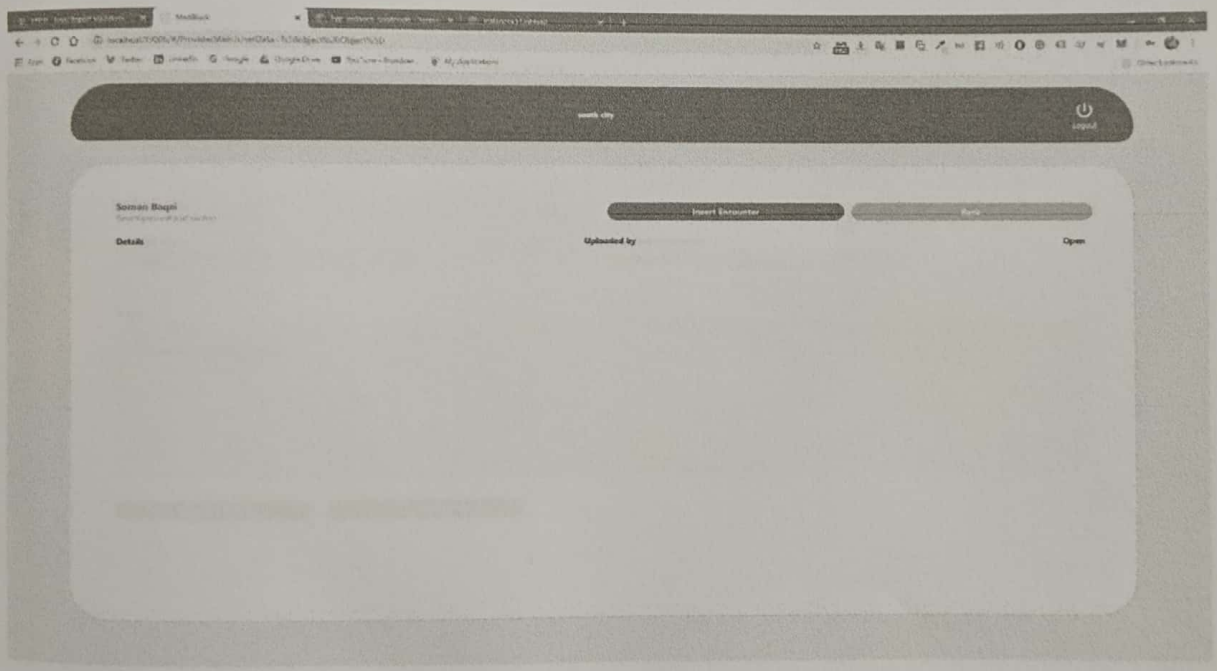

Figure 6.10: Provider inserting medical encounter data for specific patient

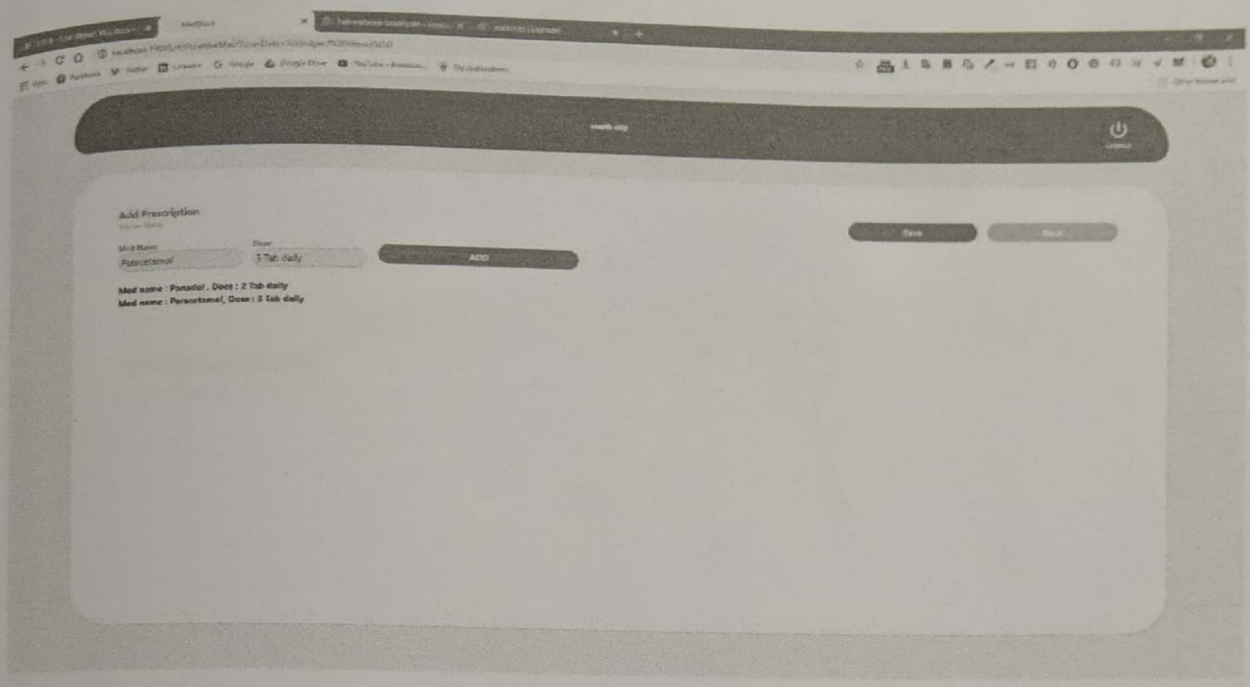

Figure 6.11: Provider adding Prescription data for patient

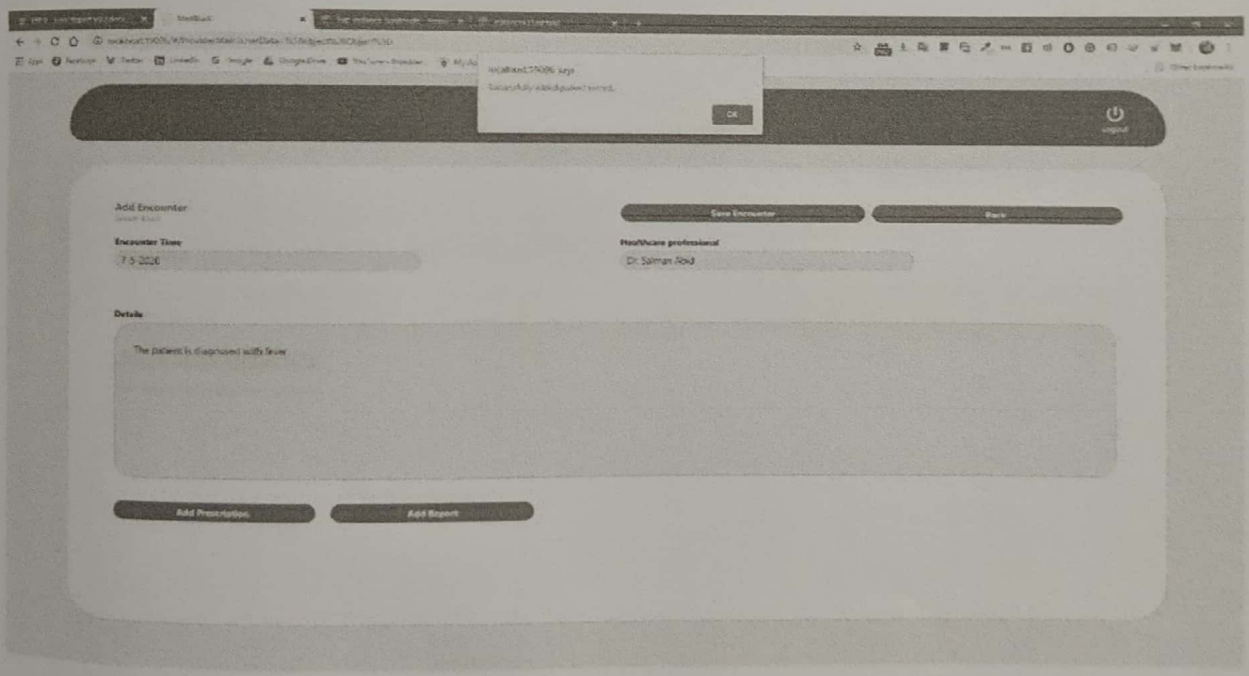

Figure 6.12 Provider adding medical data for patient

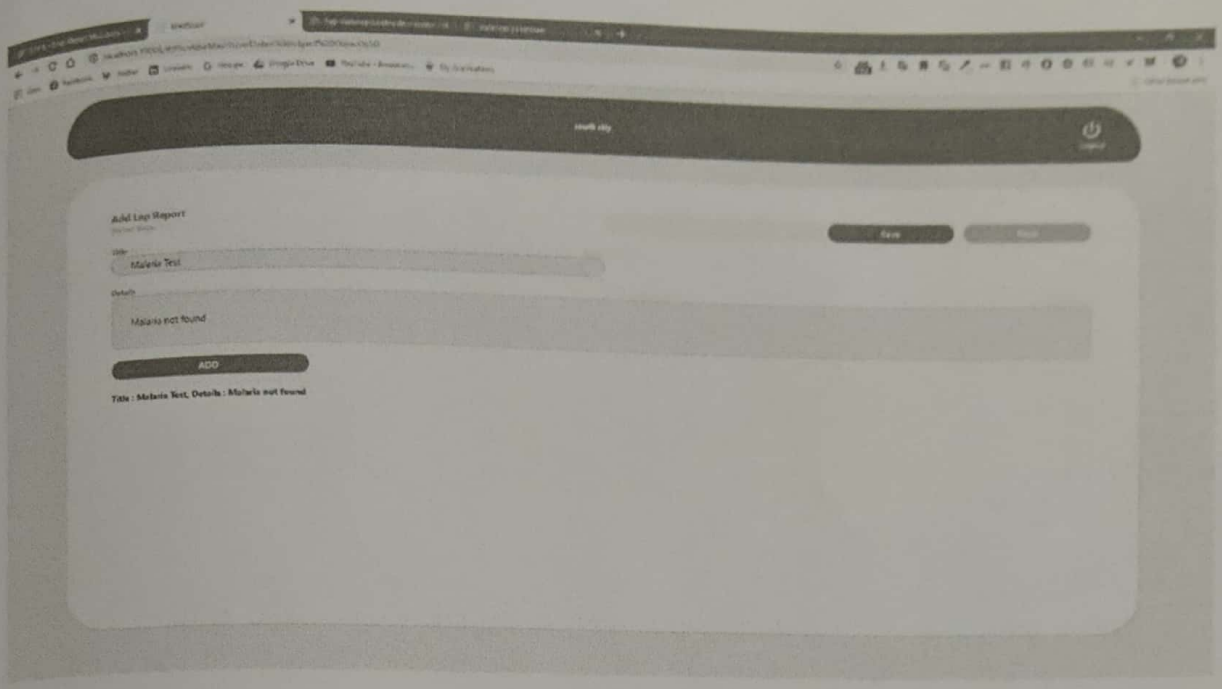

Figure 6.13: Provider adding Lap Report data for a patient

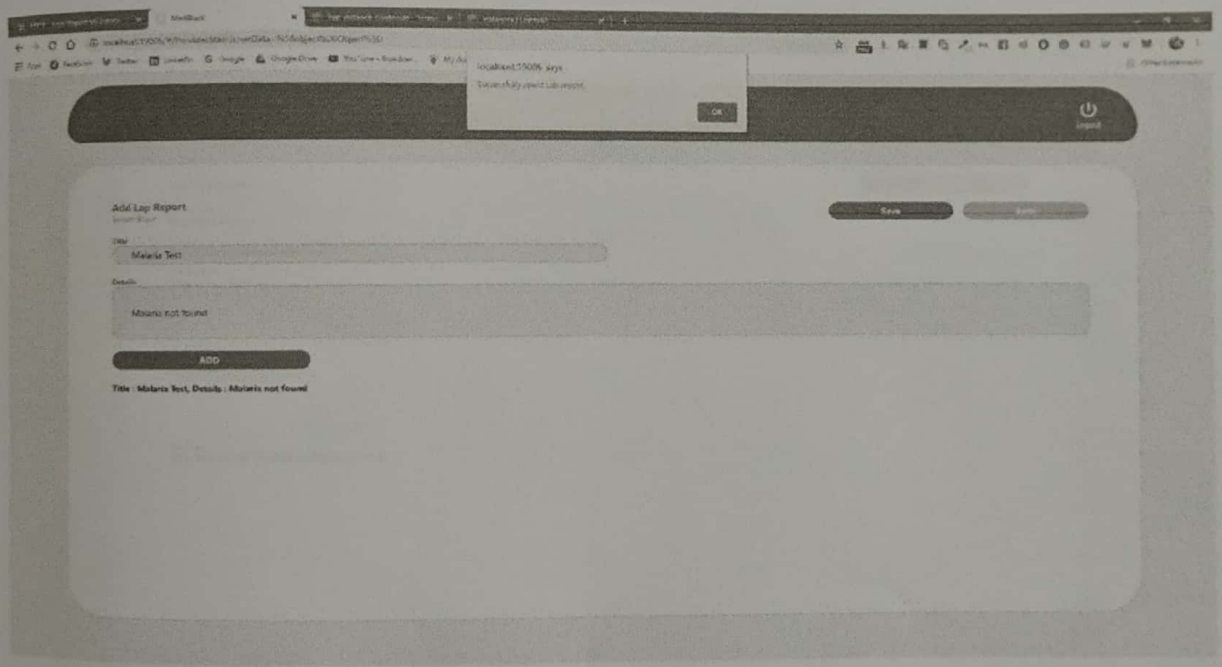

Figure 6.14: Lab Report data for patient has been recorded

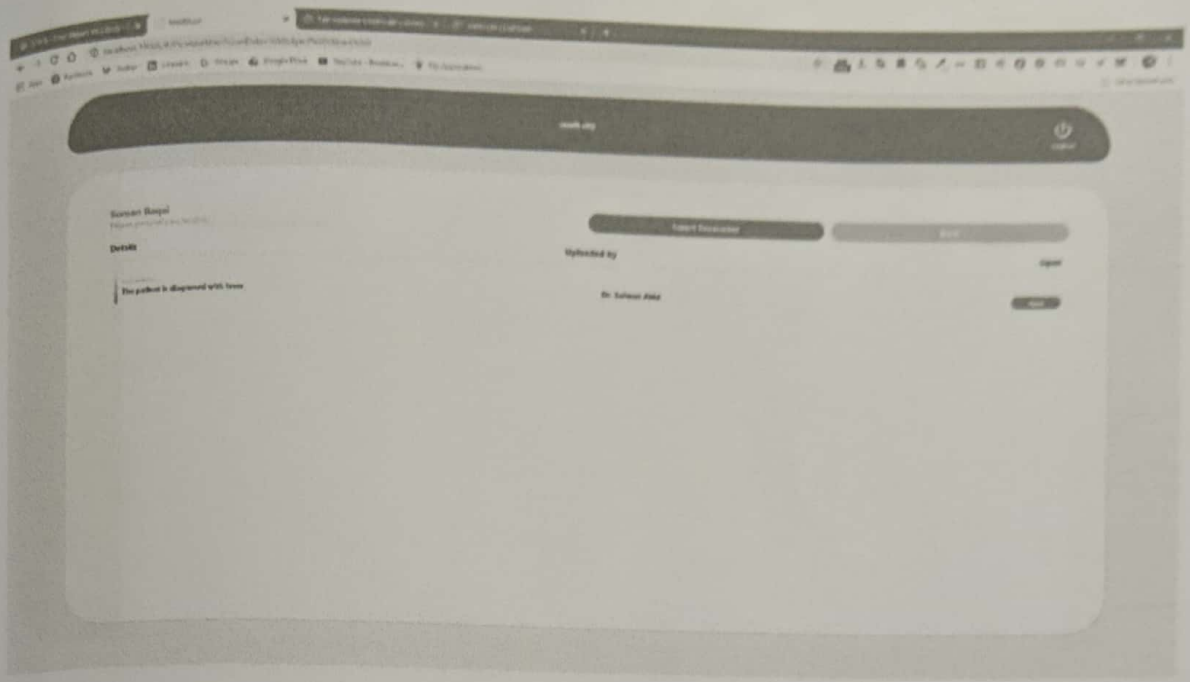

Figure 6.15: Medical Encounter data has been added for a patient

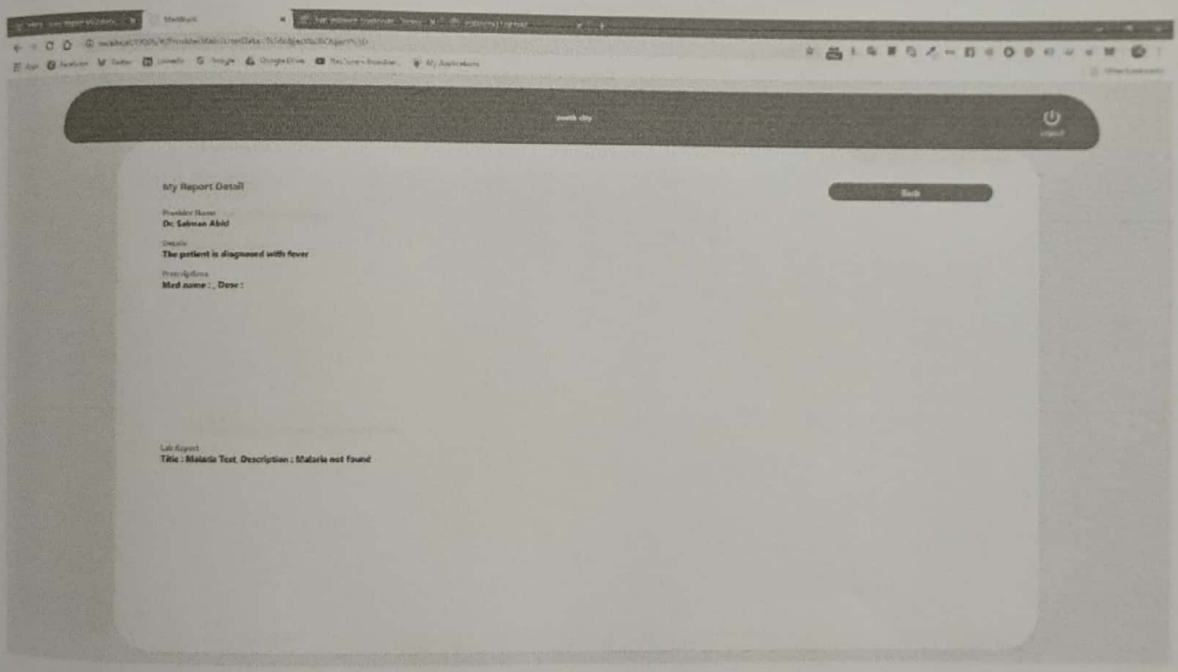

Figure 6.16: Patient viewing medical encounter data in patient portal

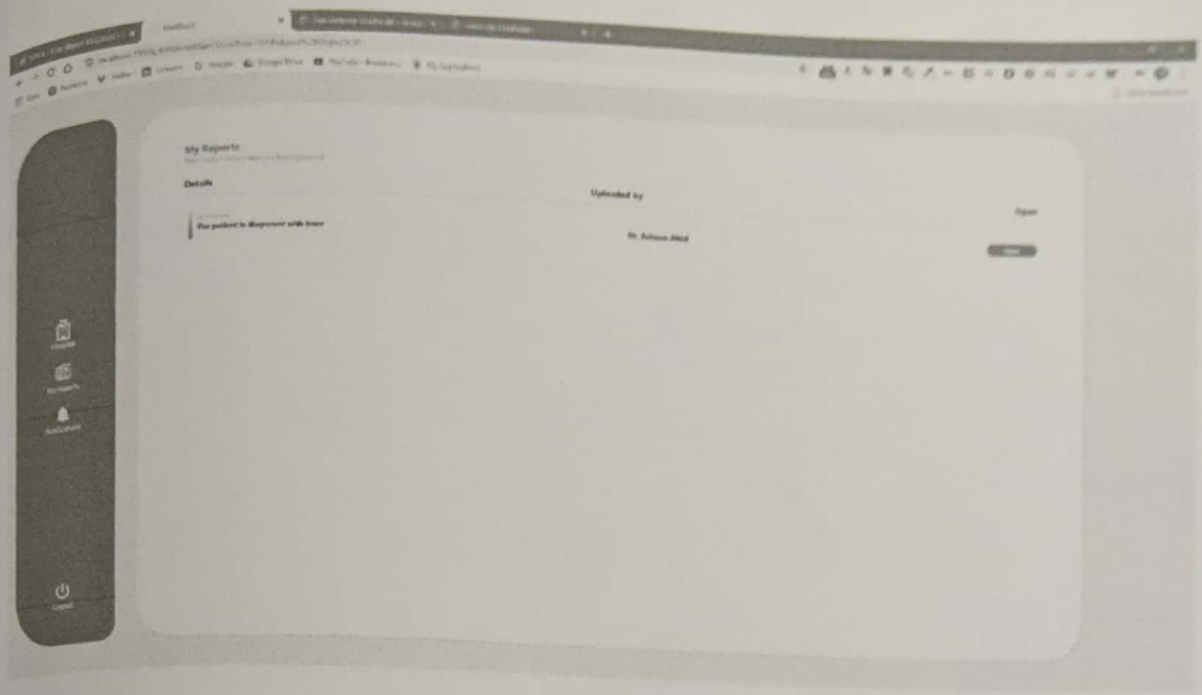

Figure 6.17: Patient viewing list of reports having patient data from different providers

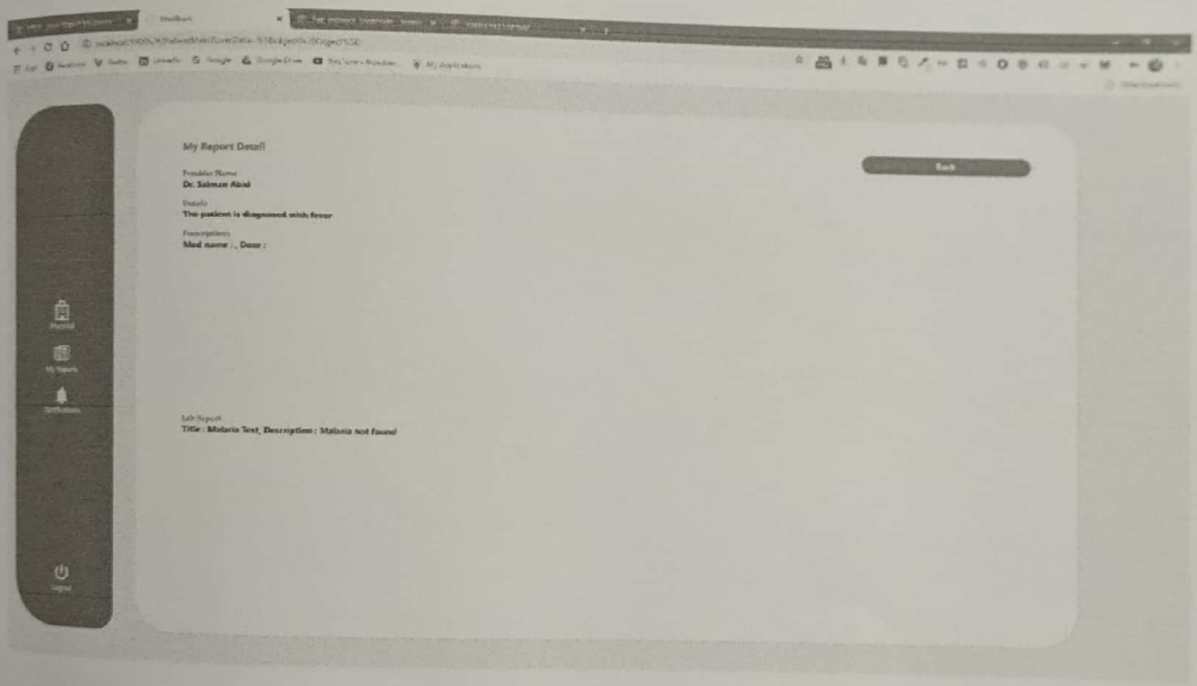

Figure 6.18: Recorded data in a medical report for a patient

});

8. Limitations of the System

Limitations of the system are based on the limitations of provisions of Blockchain especially Blockchain 2.0 i.e. Ethereum. 51% attack is a possibility if more than half of the nodes are recording invalid data, the whole system will be compromised or corrupted. CAP theorem is applicable as well.

Ethereum can only process 15-20 transactions per second which is a limit of the underlying technology that this system has to be consistent with. Hence, this system will require further work to make it scalable.

This system cannot be easily integrated with the already established hospital management systems as this system has its own frontend that connects with RESTful APIs. For integration with other systems, a lot of time and effort will be put in to parse the data according to the requirements of Patient-Centric Healthcare using Blockchain.

Bootnode of the Blockchain system is responsible for creating and managing other nodes. If the bootnode goes down, the system can face a downtime. In order to allow failover, multiple bootnodes must be put in place which is out of scope of this project.

Once the data has been fetched from the Blockchain or when the data is being sent to the Blockchain, it depends on the system to provide confidentiality, integrity and availability which is out of the scope of this project. Certain encryption techniques can be used to keep the data safe while it is out of the Blockchain.

9. Future Work

Once the system has become fully compliant with HIPAA and/or GDPR standards, the system can be used globally to process medical transactions. For this, apart from Blockchain, the data between the client and the server end has to be made secure as well. It must also be easily integratable with the existing healthcare solutions.

Actual future of Patient-Centric Healthcare using Blockchain lies in the analytical perspective of medical health records. Once the data is compliant, research organizations can use medical data that has been consented from respective patients to gain insights on patient health records. Once the medical history of patients has been recorded, doctors can make better diagnostic decisions for the patients. Similarly, certain health insights can be extracted based on geography, ethnicity, gender or age.

10. Conclusion

Patient-Centric Healthcare using Blockchain is a breakthrough solution that brings Computer Science and Medical Sciences together for greater purposes. It bridges the gap between the patient agency and scientific research. Data has to be compliant but data also has to be used for research purposes for the advancement in the field. This system forms the basis and opens gates for further research in the medical sciences using data science.

11. References

1. Ahram, T.; Sargolzaei, A.; Sargolzaei, S.; Daniels, J.; Amaba, B. Blockchain Technology Innovations.In Proceedings of the 2017 IEEE Technology & Engineering Management Conference (TEMSCON),Santa Clara, CA, USA, 8–10 June 2017; pp. 137–141.
2. Azaria, A.; Ekblaw, A.; Vieira, T.; Lippman, A. MedRec: Using Blockchain for Medical Data Access and Permission Management. In Proceedings of the 2016 2nd International Conference on Open and Big Data (OBD), Vienna, Austria, 22–24 August 2016; pp. 25–30.
3. Gordon,W.J.;Catalini,C.BlockchainTechnologyforHealthcare: Facilitating the Transition to Patient-Driven Interoperability. Comput. Struct. Biotechnol. J. 2018, 16, 224–230
4. Dagher, G.G.; Mohler, J.; Milojkovic, M.; Marella, P.B.; Marella, B. Ancile: Privacy-Preserving Framework for Access Control and Interoperability of Electronic Health Records Using Blockchain Technology. Sustain. Cities Soc. 2018, 39, 283–297.
5. Dr. Rhea Mehta,Dr. Francisco Diaz-Mitoma,Saúl Bueno.(June 10th, 2017),The Future of Digital Health:Bowhead Health.
6. Zyskind, G., Nathan, O. and Pentland, A. (2015) Decentralizing Privacy: Using Blockchain to Protect Personal Data. IEEE Security and Privacy Workshops, San Jose, 180-184.
7. Juneja, A., Marefat, M., 2018. Leveraging blockchain for retraining deep learning architecture in patient-specific arrhythmia classification. In: 2018 IEEE EMBS International Conference on Biomedical and Health Informatics, BHI 2018, vol. 2018-January, pp. 393–397.
8. P. Mamoshina, et al. Converging blockchain and next-generation artificial intelligence technologies to decentralize and accelerate biomedical research and healthcare Oncotarget, 9 (5) (2018), pp. 5665-5690
9. T.T. Kuo, H.E. Kim, L. Ohno-Machado Blockchain distributed ledger technologies for biomedical and health care applications J. Am. Med. Inform. Assoc., 24 (6) (2017), pp. 1211-1220
10. V. Patel A framework for secure and decentralized sharing of medical imaging data via blockchain consensus Health Inf. J. (2018)
11. Kaur, H.; Alam, M.A.; Jameel, R.; Kumar Mourya, A.; Chang, V.; Alam, M.A.; Jameel, R.; Mourya, A.K.; Chang, V. A Proposed Solution and Future Direction for Blockchain-Based Heterogeneous Medicare Data in Cloud Environment. J. Med. Syst. 2018, 42, 156.