Decentralized Medical Record System (DMRS)

Graduation Project, Part-I (SWE 496)
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ABSTRACT

The aim of this project is to develop a Decentralized Medical Record System where every patient has a medical record shared among all related stakeholders of the healthcare network. Medical records are shared using the Blockchain technology. This system would improve the overall services for patients, and guarantee that medical records are perpetually free of any alterations, which provides privacy services to ensure role-based access. This system will be implemented as a web application, and another web application is going to be developed for the patients, which will provide the ability to timely and efficiently access their medical records.

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1. Introduction

Healthcare medical records has a long history of being inefficient, expensive and vulnerable. Currently, each hospital has its own copy of a patient's medical record. Every time a patient visits a hospital, the hospital updates the patient's medical record. As years pass, the patient ends up having dozens of separate medical records stored in every hospital he has visited. This system of storing records has been around since the 13'th century, and people have been trying to digitize a system through traditional approaches. It is expensive in terms of the amount of time and effort required to manage medical records and perform internal and external audits across different medical facilities. It is also vulnerable to fraud, malicious modification, or a cyber-attack. Mistakes are difficult to render should they get into the records. This is the current situation before Blockchain.

Blockchain applies 4 important principles: Consensus (determining who within the network gets to validate or approve a transaction), Provenance (a complete record of the patient history through his life), Immutability (impossible to tamper with the blocks once they are written), and Finality (once a piece of information is committed into the blockchain, we have got one system of records across the network which can effectively assure that disputes are very easy to resolve should they occur).

The Decentralized Medical Record System will be implemented using the Blockchain technology. Allowing the medical records to be shared among all registered medical facilities preventing any attempt to mutate the data. A web application is used so that patients can view their records, and medical facilities can only store to and retrieve from existing records.

the project attempts to establish a thing that we all are trying to do in the future and also trying to do now since it is an impratant thing that every single one of us should do and apply in their life

2. Domain Analysis

There are a few electronic medical record systems that in a way serve the patient and medical facilities, but they are either centralized (do not connect facilities in a shared network), or have the possibility of altering the data. In addition, the Ministry of Health authority does not have access, and pharmacy systems are isolated and work independently.

Table 1 lists some of these systems and provide a brief comparison between them and our project:

Table 1 DMRS in comparison to other systems in the domain

3. Risk/Constraints

This section demonstrates the possible risks that could face this work whether it's from a project or business perspective. As well as showing how much those risks could potentially affect the team's progress, and providing solutions for reducing the outcomes of those risks.

Table 2 Risks

No	*Risk*	*Type*	*Severity*	*Priority*	*Risk management strategy*
1	General conflict with exams and other projects	Project	High	Medium	Organize work, avoid delaying
2	Lack of resources of Blockchain technology	Project	High	High	Research in scientific references, attending training courses, consulting domain experts.
3	Acceptance of blockchain technology for stakeholders	Business	Medium	Medium	Raise awareness of blockchain importance, create courses and introductory lectures about this new technology
4	Not enough team background knowledge	Project	High	Medium	Research and reading
5	Amount of time required to prepare multiple hospital websites to be developed for creating the project demo.	Project	Medium	low	cooperate between the work team and distribute work tasks among them
6*	Impossible to remove invalid information once it's submitted	Business	High	High	Ask for confirmation before submitting the information

* Any type of data entered in the blockchain is a transaction. Transactions are not atomic, but linked to each other. Every transaction can be tracked back to when it was mined. All transactions on the blockchain are stored on each node that is part of the network, so even if a transaction could be deleted from a specific node, it would require the same transaction to be deleted from at least 51% of all the nodes in the network at the same time. Each block contains the hash of the previous block, so no block can be deleted.

4. Project Plan

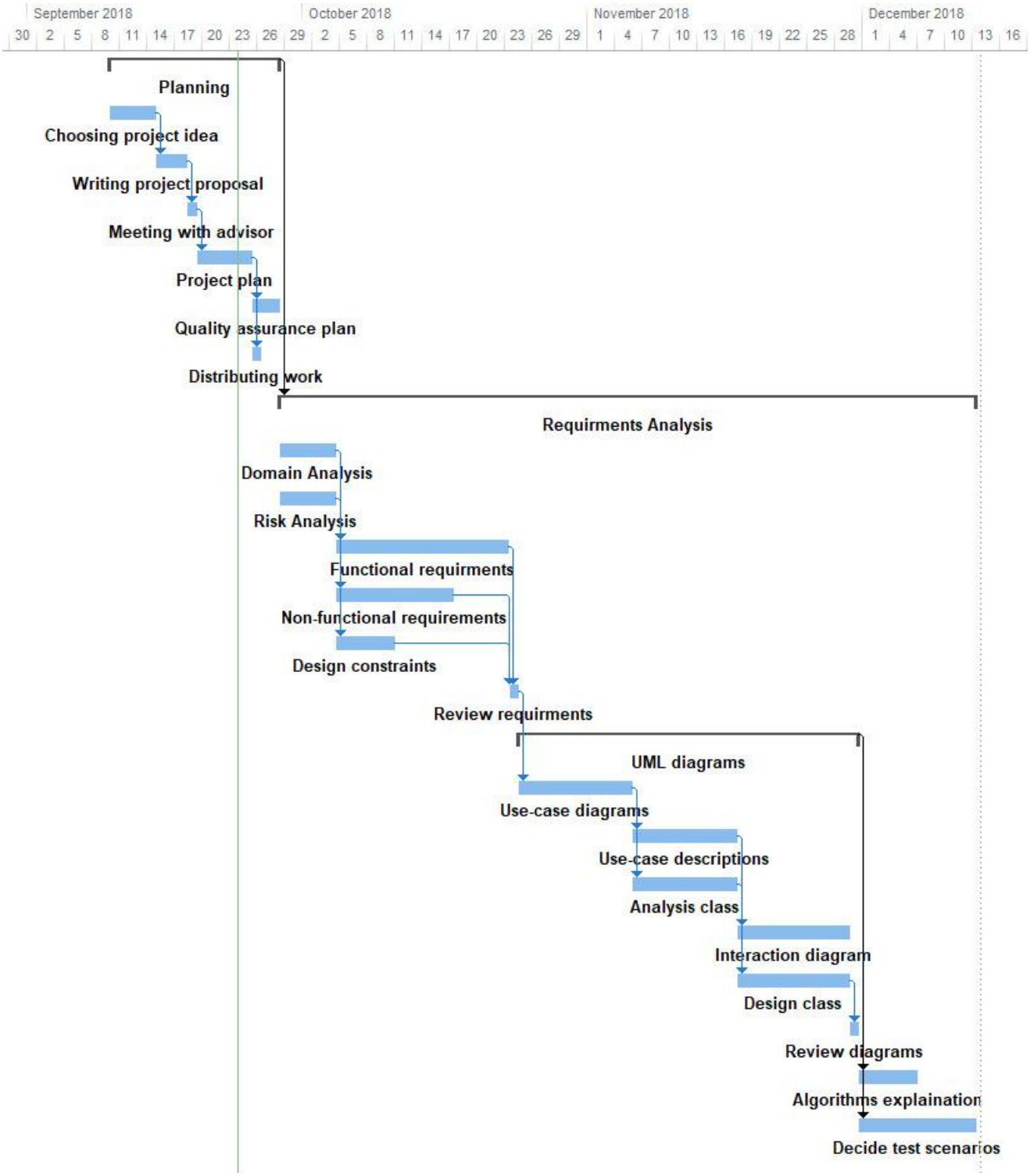


Figure 1 Project Plan

Table 3 Project Plan Table

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Planning**	**16 days?**	**Mon 9/10/18**	**Fri 9/28/18**	
2		Choosing project idea	1 wk	Mon 9/10/18	Fri 9/14/18	
3		Writing project proposal	2 days	Sat 9/15/18	Tue 9/18/18	2
4		Meeting with advisor	1 day?	Tue 9/18/18	Wed 9/19/18	3
5		Project plan	1 wk	Wed 9/19/18	Tue 9/25/18	4
6		Quality assurance plan	3 days	Tue 9/25/18	Fri 9/28/18	5
7		Distributing work	1 day?	Tue 9/25/18	Wed 9/26/18	5
8		**Requirments Analysis**	**62 days?**	**Fri 9/28/18**	**Thu 12/13/18**	**1**
9		Domain Analysis	1 wk	Fri 9/28/18	Thu 10/4/18	
10		Risk Analysis	1 wk	Fri 9/28/18	Thu 10/4/18	
11		Functional requirments	3 wks	Thu 10/4/18	Tue 10/23/18	10,9
12		Non-functional requirements	2 wks	Thu 10/4/18	Wed 10/17/18	10,9
13		Design constraints	1 wk	Thu 10/4/18	Wed 10/10/18	10,9
14		Review requirments	1 day?	Tue 10/23/18	Wed 10/24/18	11,12,13
15		**UML diagrams**	**31 days?**	**Wed 10/24/18**	**Fri 11/30/18**	
16		Use-case diagrams	2 wks	Wed 10/24/18	Mon 11/5/18	14
17		Use-case descriptions	2 wks	Tue 11/6/18	Sat 11/17/18	16
18		Analysis class	2 wks	Tue 11/6/18	Sat 11/17/18	16
19		Interaction diagram	2 wks	Sat 11/17/18	Thu 11/29/18	17,18
20		Design class	2 wks	Sat 11/17/18	Thu 11/29/18	18
21		Review diagrams	1 day?	Thu 11/29/18	Fri 11/30/18	20
22		Algorithms explaination	1 wk	Fri 11/30/18	Thu 12/6/18	15
23		Decide test scenarios	10 days	Fri 11/30/18	Thu 12/13/18	15

5. Quality Assurance Plan

5.1 Inspections

At every Tuesday a meeting is arranged for the purpose of reviewing the work accomplished by each team member in the past week, and assign new responsibilities to each member.

5.2 Formal Reviews

A meeting with the supervisor is conducted every two weeks for document review of the work by the group. Problems are categorized into three levels based on their effect and work that should be put into them:

1. High level problems: The ones that require extensive work and are necessary to fix.
2. Medium level problems: Related to design fixes, or restructuring.
3. Low level problems: Normally small fixes like misspelled words, or small design fixes.

End of Deliverable 1

6. Requirements

6.1 Functional Requirements

6.1.1 Hospital Related Requirements

1. Hospital shall be able to check if a patient has a medical record by patient's national ID.
2. Hospital shall be able to create a patient record containing his name, date of birth, emergency contacts, mobile number, national number, and gender.
3. Hospital shall be able to access medical record using patient's national ID.
4. Hospital shall be able to add data to a patient record:
   4.1. Hospital shall be able to add diagnosis details to a patient record.
   4.2. Hospital shall be able to add surgery information to a patient record.
   4.3. Hospital shall be able to add radiology scans to a patient record.
   4.4. Hospital shall be able to add laboratory test results to a patient record.
   4.5. Hospital shall be able to add drug prescription to a patient record.
   4.6. Hospital shall be able to add blood transfer information to a patient record.
5. Hospital shall be able to view a patient's medical record.
6. Hospital shall be able to create a corrective transaction and link it to the original transaction.

6.1.2 Ministry of Health Related Requirements

1. Ministry of Health shall be able to add a new hospital to the network.
2. Ministry of Health shall be able to mark a transaction as a medical error.
3. Ministry of Health shall be able to retrieve data for any medical record:
   3.1. Ministry of Health shall be able to retrieve all past diagnosis details from a patient record.
   3.2. Ministry of Health shall be able to retrieve all past surgery history from a patient record.
   3.3. Ministry of Health shall be able to retrieve all past radiology scans from a patient record.
   3.4. Ministry of Health shall be able to retrieve all past laboratory results from a patient record.
   3.5. Ministry of Health shall be able to retrieve all past drug prescriptions from a patient record.
   3.6. Ministry of Health shall be able to retrieve all history of blood transfers from a patient record.

6.1.3 Patient Related Requirements

1. Patient shall be able to log in to his medical record using his national identification number.
2. Patient shall be able to view his medical record:
   2.1. Patient shall be able to retrieve all past diagnosis details from a patient record.
   2.2. Patient shall be able to retrieve all past surgery history from a patient record.
   2.3. Patient shall be able to retrieve all past radiology scans from a patient record.
   2.4. Patient shall be able to retrieve all past laboratory results from a patient record.
   2.5. Patient shall be able to retrieve all past drug prescriptions from a patient record.
   2.6. Patient shall be able to retrieve all history of blood transfers from a patient record.

6.1.4 Pharmacy Related Requirements

1. Pharmacy shall be able to view all old drug prescriptions of any patient.
2. Pharmacy shall be able to track which medicines were dispensed.
3. Pharmacy shall be able to mark a specific drug from the drug prescription as dispensed.

6.2 Non-Functional Requirements

6.2.1 Usability

- The app will have a help and training menu – when accessed will play a 3 minutes video that will train the user about how to use the app.

6.2.2 Availability

- System shall be available 99.9999% of the time. There will be a node acting as a backup to the blockchain incase all other nodes shut down, thereby, insuring availability.

6.2.3 Performance

- Response time: Average response time shall be less than two seconds.
- Capacity: System shall be able to process at least 2000 transactions per second (based on the capacity of the Ethereum blockchain).

6.2.4 Supportability

- System shall support English languages with the ability of adding Arabic support in the future.

6.2.5 Maintainability

- As long as there is a maintenance period, the system will be switched to a backup environment.

7. System Use Cases

7.1 Use Case Diagrams

Figure 2 Hospital Use Case Diagram

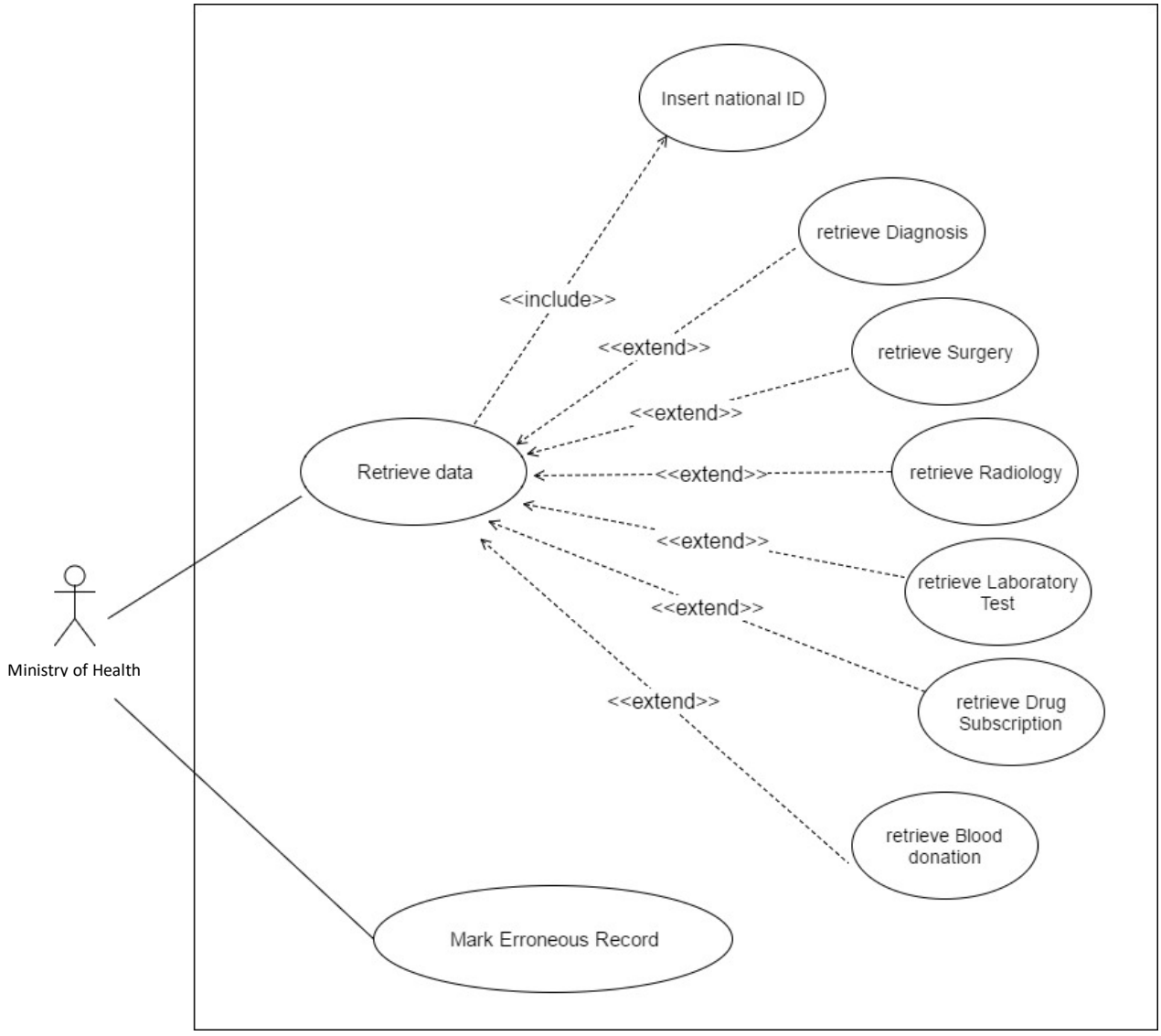


Figure 3 Ministry of Health Use Case Diagram

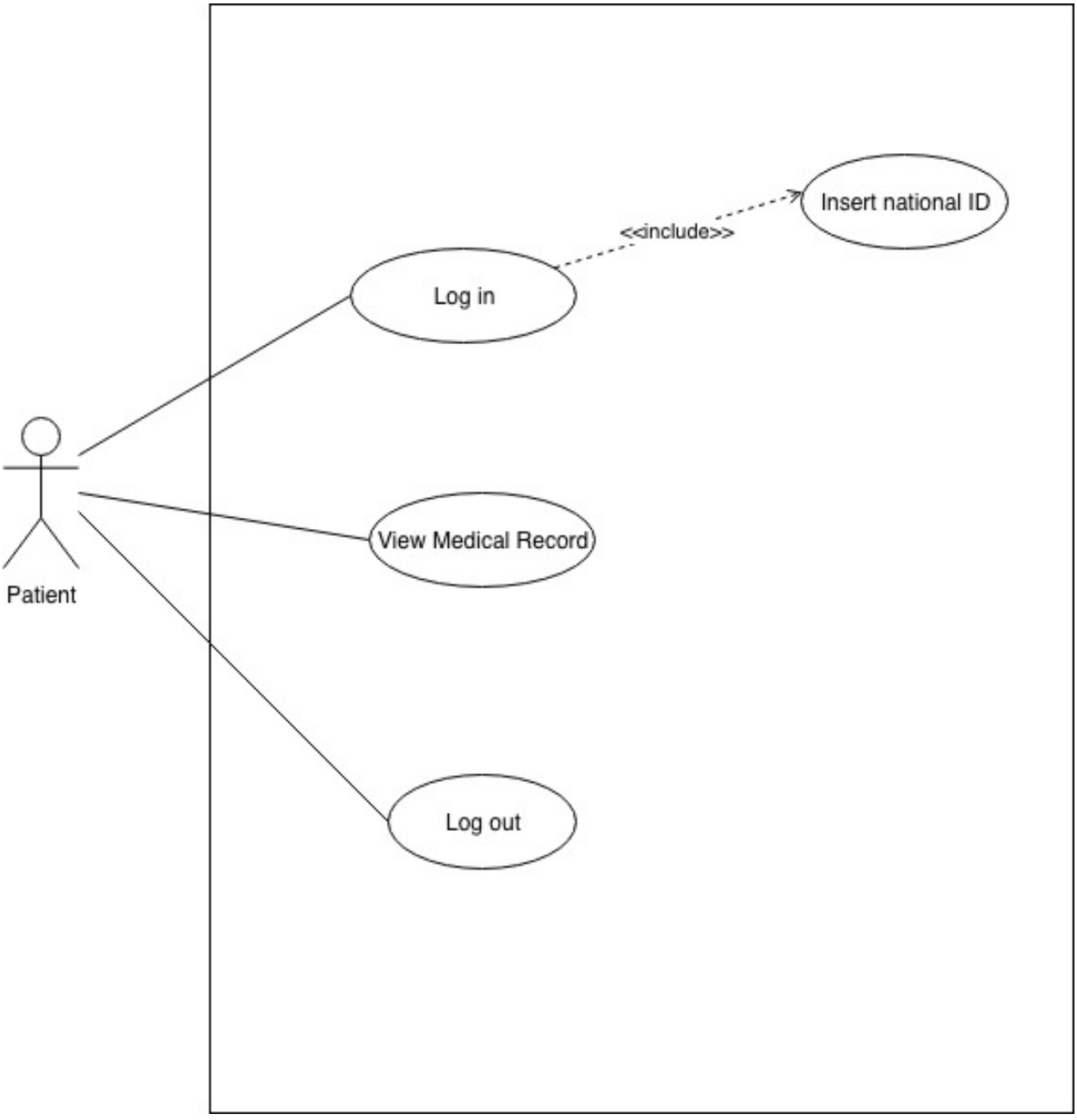


Figure 4 Patient Use Case Diagram

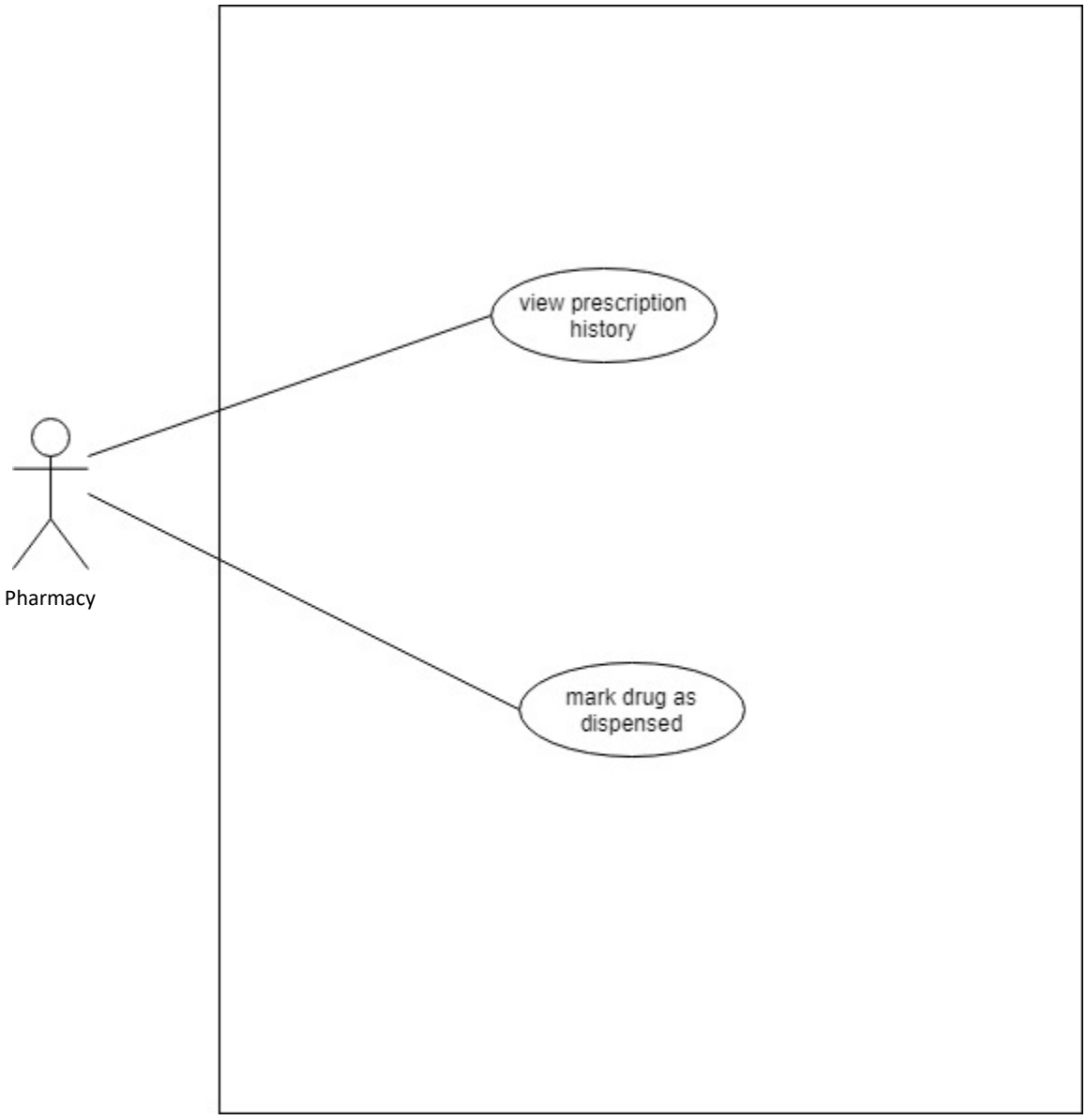


Figure 5 Pharmacy Use Case Diagram

7.2 Use Case Descriptions

7.2.1 Retrieve data from medical record use case

System	Decentralized Medical Record System		
Use Case ID:	1		
Use Case Name:	Retrieve medical record		
Created By:	Abdulrahman Alkilani	Last Updated By:	
Date Created:	17/10/2018	Date Last Updated:	

Actor:	Ministry of Health
Description:	When the Ministry of Health wants to see any medical record for a patient, it can log in to the system by patient's ID.
Preconditions:	The Ministry of Health has access to network and has patient national ID.
Postconditions:	All medical record data for the patient is displayed to Ministry of Health

Steps:

Ministry of Health	System
1. Ministry of Health log in to the system by patient national ID. 2. Click "View Medical Record" button.	1.1 System checks if the national ID has medical record. 2.1 System displays the data on the screen.

Alternative and exceptional flows:

1. In step 1.1 if the patient national ID is not correct, the system will not display any data.

Relationships:	Include: 1. Insert national ID. Extend: 1. Retrieve Diagnosis. 2. Retrieve Surgery. 3. Retrieve Radiology. 4. Retrieve Laboratory Test. 5. Retrieve Drug Subscription. 6. Retrieve Blood donation.

7.2.2 Create patient medical record use case

System	Decentralized Medical Record System		
Use Case ID:	2		
Use Case Name:	Create patient medical record		
Created By:	Wadhah Essam	Last Updated By:	
Date Created:	17/10/2018	Date Last Updated:	

Actor:	Hospital
Description:	When a patient enters a hospital that applies the system for his first time, the hospital should be able to create account for him based on his national ID.
Preconditions:	The patient must have no existing medical record.
Postconditions:	A new medical record will be created based on the patient's national ID by the system and the address of it will be returned to the hospital.

Steps:

Hospital	System
1. Hospital creates a medical record for patient. 2. Hospital provides the patients required data to create a new medical record like name, date of birth, gender and national ID. 3. Hospital receives the address of the medical record and starts interacting with it.	2.1 System receives data and check if the patient has a medical record associated with him. 2.2 System creates medical record for the patient with the provided data. 2.3 System returns the address of the patient medical record to the hospital.

Alternative and exceptional flows:

1. In step 2.1 if the patient already has medical record, the system will not create a new one and it will return the address of the already created medical record to the hospital.
2. In step 2.2 if the data that was provided has some invalid values, it will not create a new record and instead it will delegate the error to the hospital to deal with it.

Relationships:	Include: 1. Insert national ID. 2. Insert patient information. Extend: None

System	Decentralized Medical Record System		
Use Case ID:	3		
Use Case Name:	View medical record		
Created By:	Abdulaziz Alobaili	Last Updated By:	
Date Created:	17/10/2018	Date Last Updated:	

Actor:	Patient
Description:	When a Patient log in to the web application, Patient can see the full medical record.
Preconditions:	The patient is logged in. and connected to the network.
Postconditions:	If the basic flow is successful, the medical record is displayed.

Steps:

Hospital	System
1. Patient click the “View Medical Record” button.	1.1 System loads all data related to Patient’s national identification number. 1.2 System displays the data on the screen.

Alternative and exceptional flows:

1.3 Connection is interrupted so System displays error message.

Relationships:	Include: None. Extend: None.

System	Decentralized Medical Record System		
Use Case ID:	4		
Use Case Name:	Mark drug as dispensed		
Created By:	Mohamed Majd Aldeen Alsadat	Last Updated By:	
Date Created:	17/10/2018	Date Last Updated:	

Actor:	Pharmacy
Description:	A pharmacist can see the last subscription for patient in his medical record that the patient did not have yet to give the drugs based on it and determine a drug taken by the patient and the drugs he did not take.
Preconditions:	Pharmacy systems must be linked to the system network. A pharmacist must enter the patient's ID so that he can see the patient's last subscription in his medical record
Postconditions:	If the basic flow is successful, patient's last subscription is displayed, and a pharmacist can determine drugs taken by a patient.

Steps:

Ministry of Health	System
A pharmacist logs in to the system by patient national ID. Click " view subscription " button. .	1.1 System checks if the national ID has medical record. 1.2 System checks if a patient has any subscription in his medical record not got it yet 2.1 System displays the data on the screen

Alternative and exceptional flows:

In step 1.2 If the patient has taken all the subscription in his medical record , it will not show the pharmacist anything on the system.

Relationships:	Include: None. Extend: None

System	Decentralized Medical Record System		
Use Case ID:	5		
Use Case Name:	Mark wrong data		
Created By:	Abdulrahman Alkilani	Last Updated By:	
Date Created:	10/11/2018	Date Last Updated:	

Actor:	Ministry of Health
Description:	When the patient has wrong data in his medical record and the patient wants to correct that data, only the Ministry of Health has the authority to mark this data as wrong.
Preconditions:	The Ministry of Health has access to network and has patient national ID.
Postconditions:	The patient's wrong medical data has been corrected.

Steps:

Ministry of Health	System
1. Ministry of Health log in to the system by patient national ID. 2. Click "View Medical Record" button. 3. Search for wrong data of the patient. 4. Mark that data as wrong by new transaction.	1.1. System checks if the national ID has medical record. 2.2. System displays the data on the screen. 4.1. System saves new transaction in patient record

Alternative and exceptional flows:

In step 1.1, if the patient national ID is not correct the system will not display any data.

Relationships:	Include: 1. Insert national ID. Extend: 1. Retrieve Diagnosis. 2. Retrieve Surgery. 3. Retrieve Radiology. 4. Retrieve Laboratory Test. 5. Retrieve Drug Subscription 6. Retrieve Blood Donation

System	Decentralized Medical Record System		
Use Case ID:	6		
Use Case Name:	Add surgery		
Created By:	Wadhah Essam	Last Updated By:	
Date Created:	10/11/2018	Date Last Updated:	

Actor:	Hospital
Description:	Hospitals can add surgeries information to the patient's medical record.
Preconditions:	Hospital has accessed the patient’s medical record.
Postconditions:	New Surgery is added to the patient’s medical error.

Steps:

Ministry of Health	System
1. Hospital representor submits information of the patient surgery. 2. Hospital shows a confirmation message on the screen.	1.1. System receives information and submits a new transaction to the blockchain which includes the surgery information. 1.2 System sends back to the hospital a confirmation of adding the surgery information.

Alternative and exceptional flows:

In step 1.2, if the process does not go as expected, and the surgery information was not added, the system sends back an error with the details to the hospital.

Relationships:	Include: None. Extend: None

System	Decentralized Medical Record System		
Use Case ID:	7		
Use Case Name:	View prescription history		
Created By:	Mohamed Majd Aldeen Alsadat	Last Updated By:	
Date Created:	10/11/2018	Date Last Updated:	

Actor:	Pharmacy
Description:	The pharmacist can access the patient's medical record by patient national ID and view the patient's last subscription only
Preconditions:	• Pharmacy systems must be linked to the system network. • A pharmacist must enter the patient's ID so that he can see the patient's last subscription in his medical record.
Postconditions:	If the basic flow is successful, patient's last subscription is displayed

Steps:

Ministry of Health	System
1. A pharmacist logs in to the system by a patients national ID. 2. Click “View subscription” button.	1.1. System checks if a medical record is associated with the national ID. 1.2. System checks if a patient has any subscriptions in his medical record which are not given yet. 2.1 System displays the data on the screen.

Alternative and exceptional flows:

In step 1.2, if the patient has taken all the subscriptions in his medical record, it will not show the pharmacist anything on the system.

Relationships:	Include: None. Extend: None

System	Decentralized Medical Record System		
Use Case ID:	8		
Use Case Name:	View last drug subscription for a patient		
Created By:	Abdulaziz Alobaili	Last Updated By:	
Date Created:	10/11/2018	Date Last Updated:	

Actor:	Ministry of Health
Description:	Ministry of Health can create a new account for a hospital and connects it to the system.
Preconditions:	Hospital has its account address
Postconditions:	The hospital is successfully added to the system.

Steps:

Ministry of Health	System
1. Ministry of Health adds the hospital address to the network.	1.1. System checks if the address is not already added to the network. 1.2. System adds the hospital as a new node to the network. 1.3. System displays a message that the account is added successfully.

Alternative and exceptional flows:

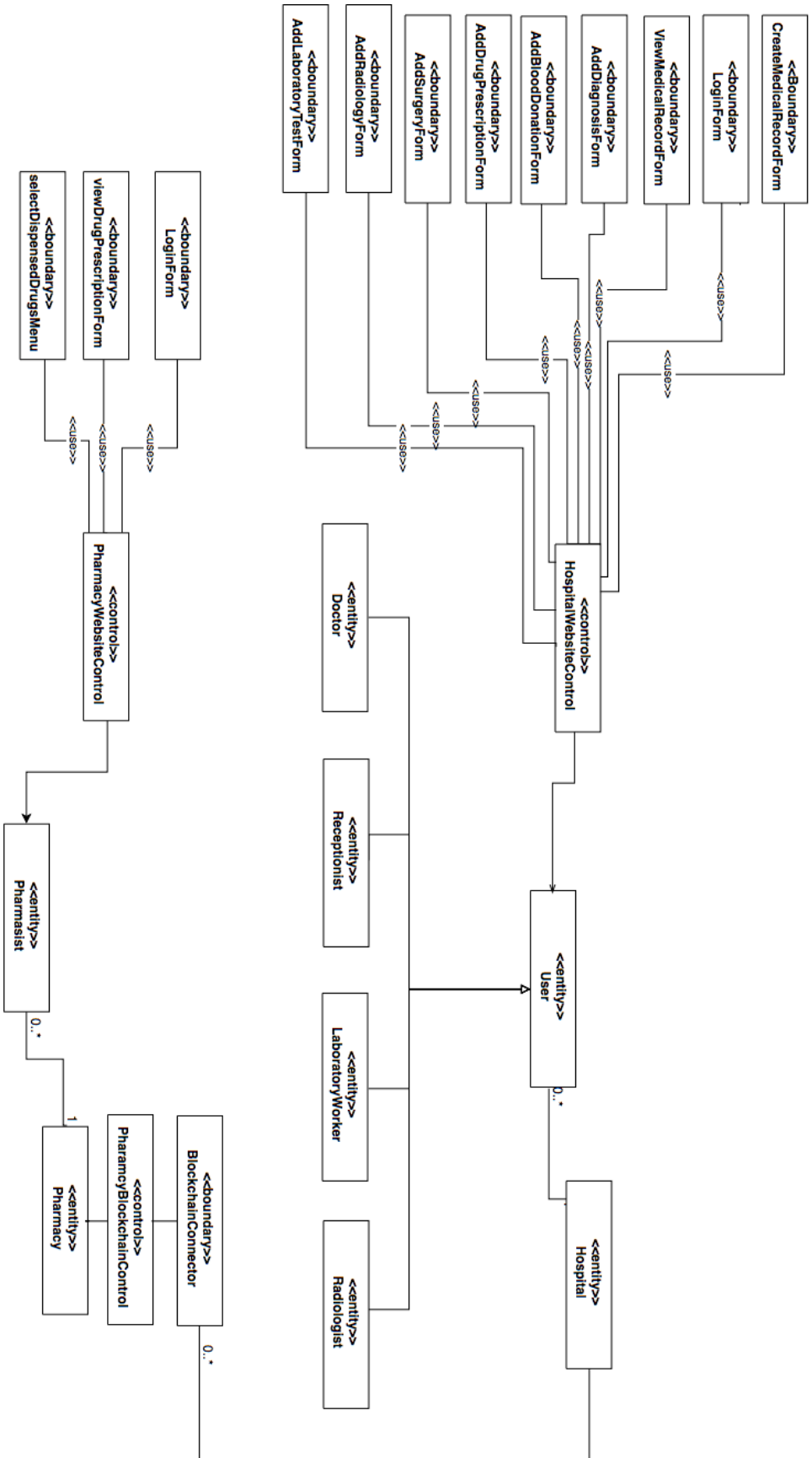
In step 1.1. If the hospital account is already added, an error message is displayed.

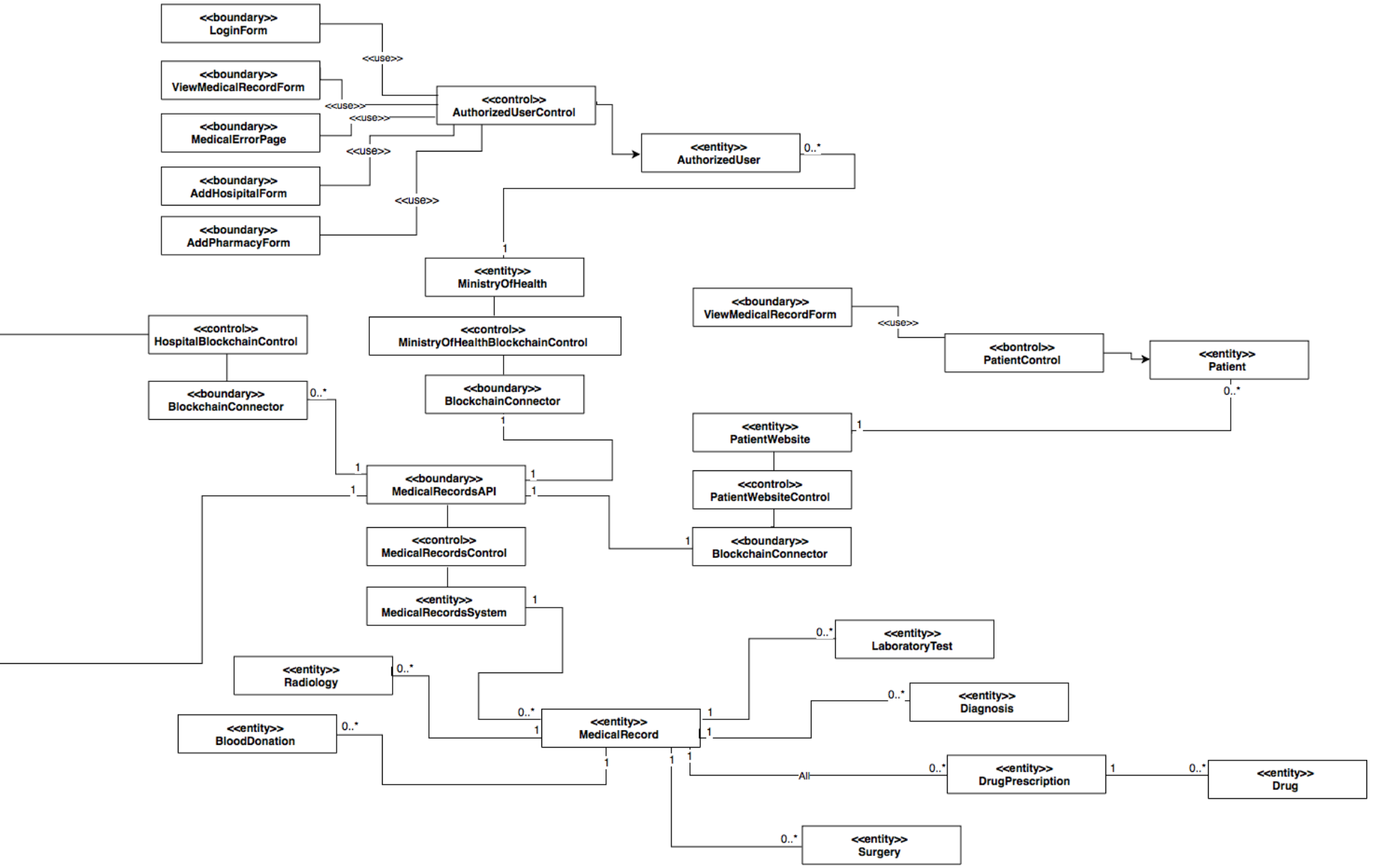
Relationships:	Include: None. Extend: None

End of Deliverable 2

8. Analysis Class

Half of the analysis class is covered in this page and the other half in the next page. For better view of the figure, visit this link:
https://drive.google.com/file/d/11asBf5ViKPbIVNde74T4_y7_y-Z7yBqW/view?usp=sharing

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9. Interaction Diagram

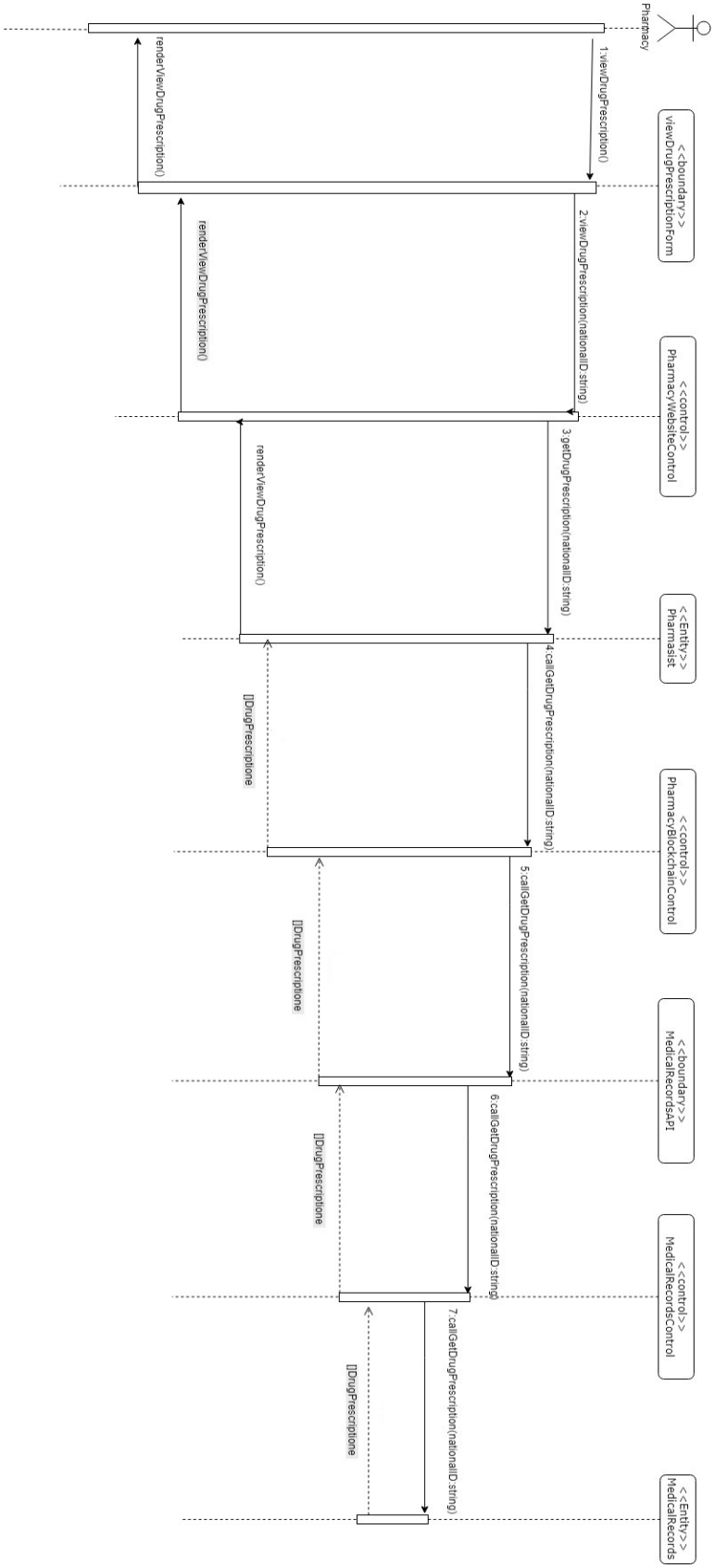

Figure 6 Pharmacy interaction diagram

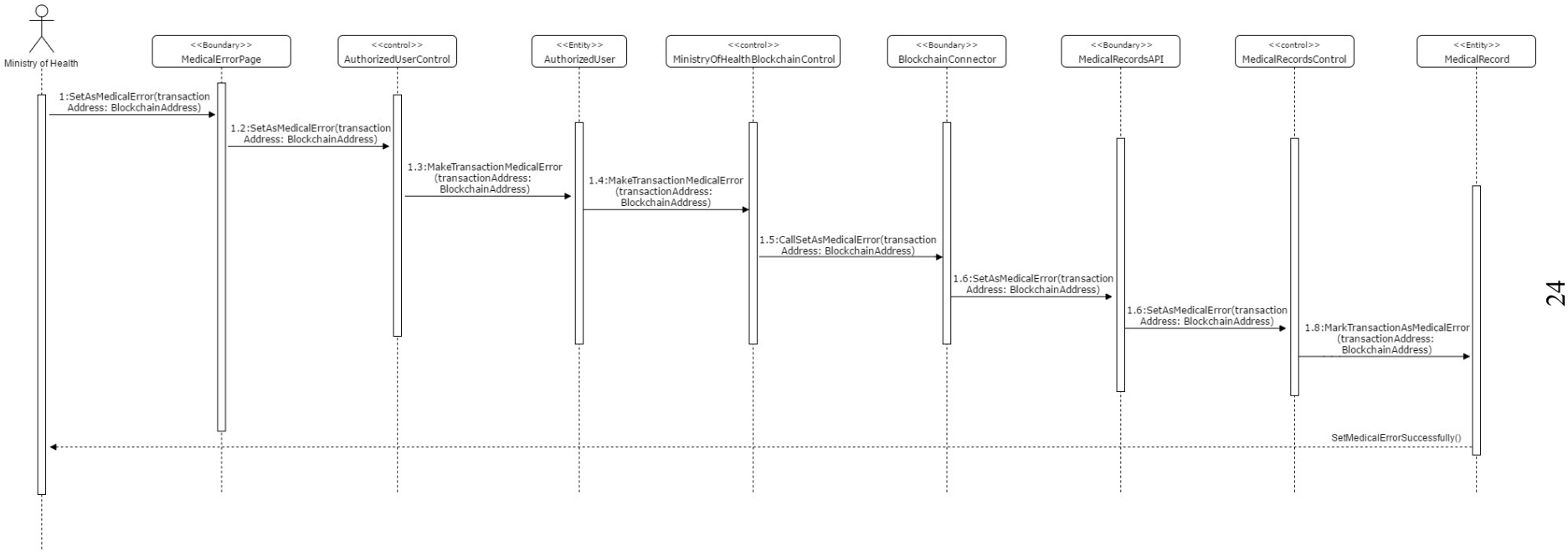

Figure 7 markMedicalError interaction diagram

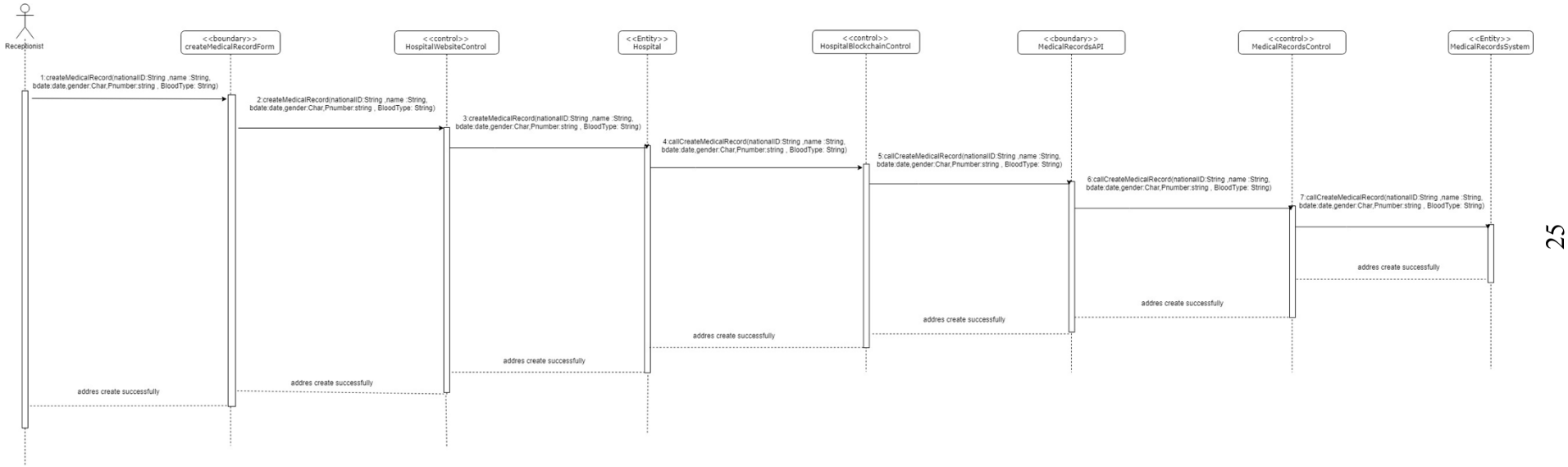

Figure 8 creatPatient interaction diagram

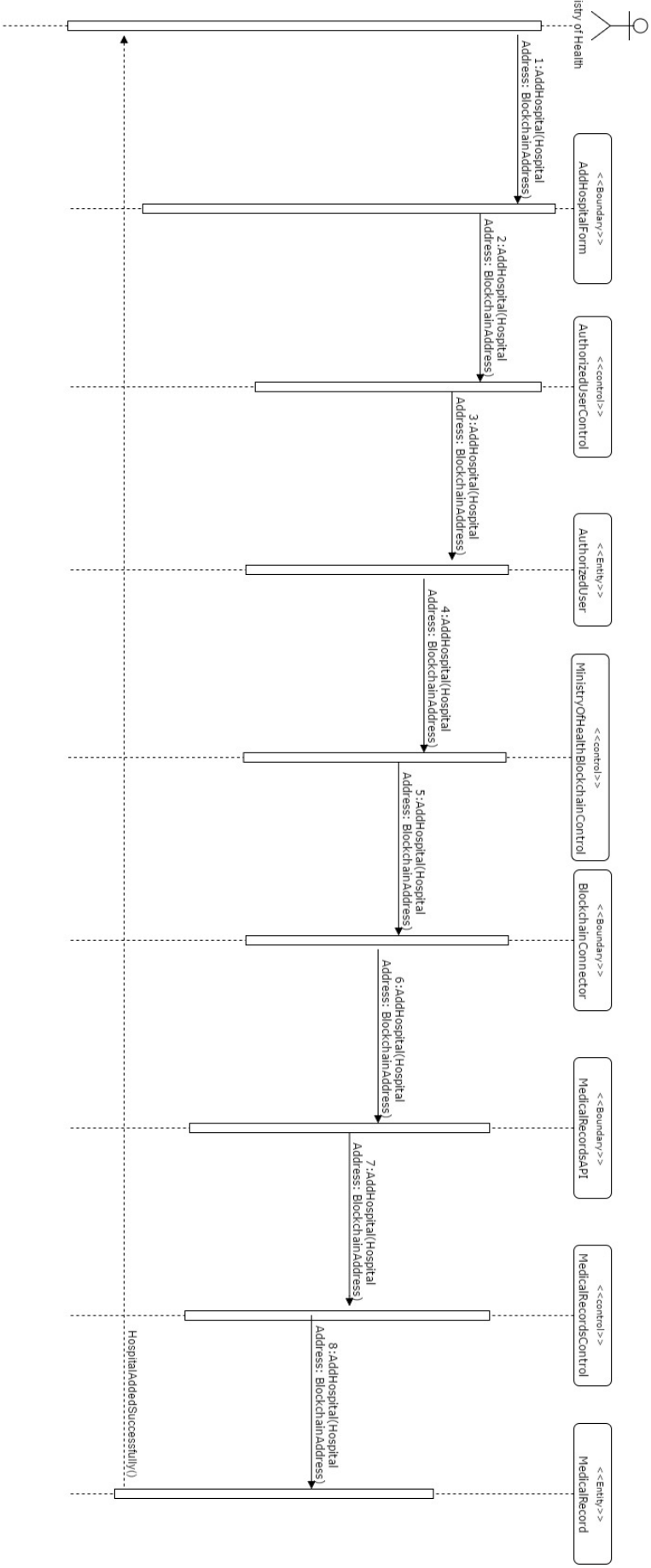

Figure 9 addHospital interaction diagram

10. Design Class

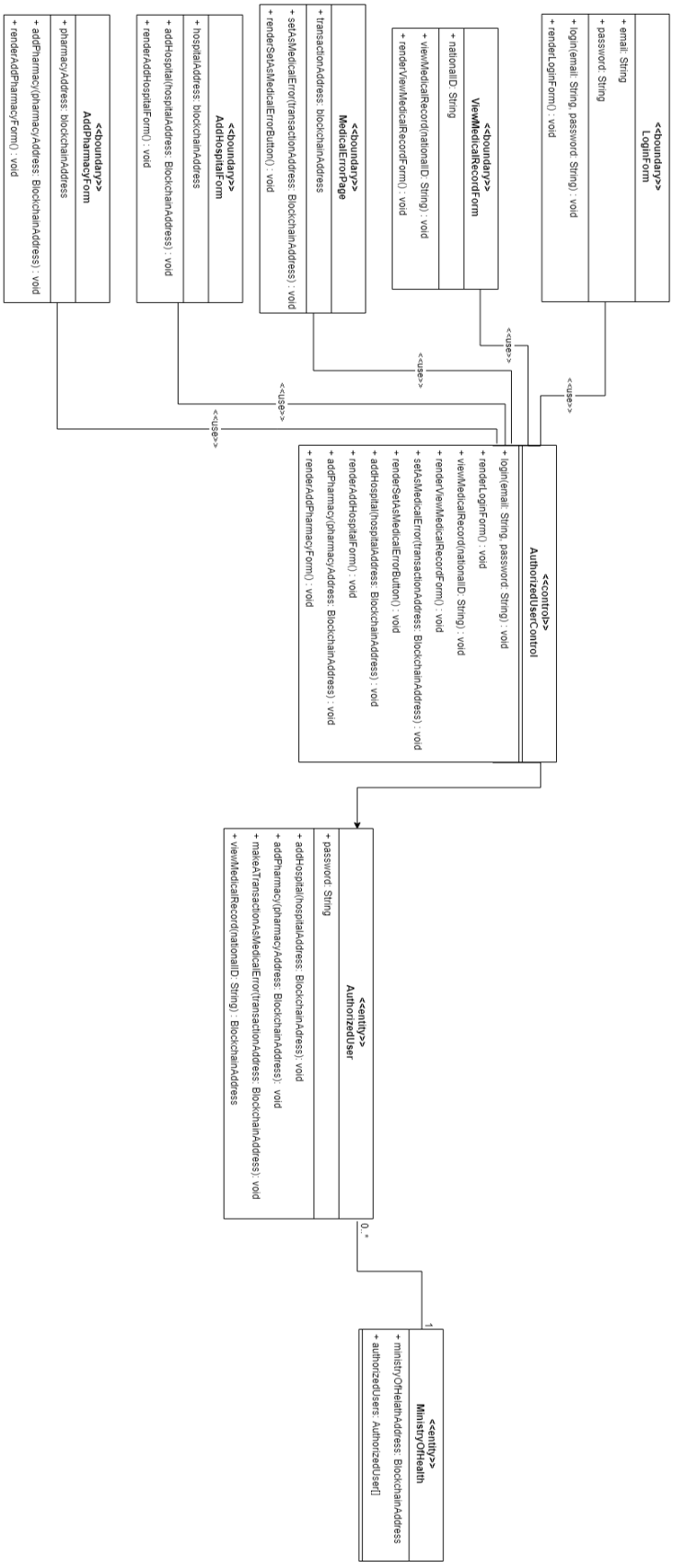

Figure 10 Ministry of Health design class

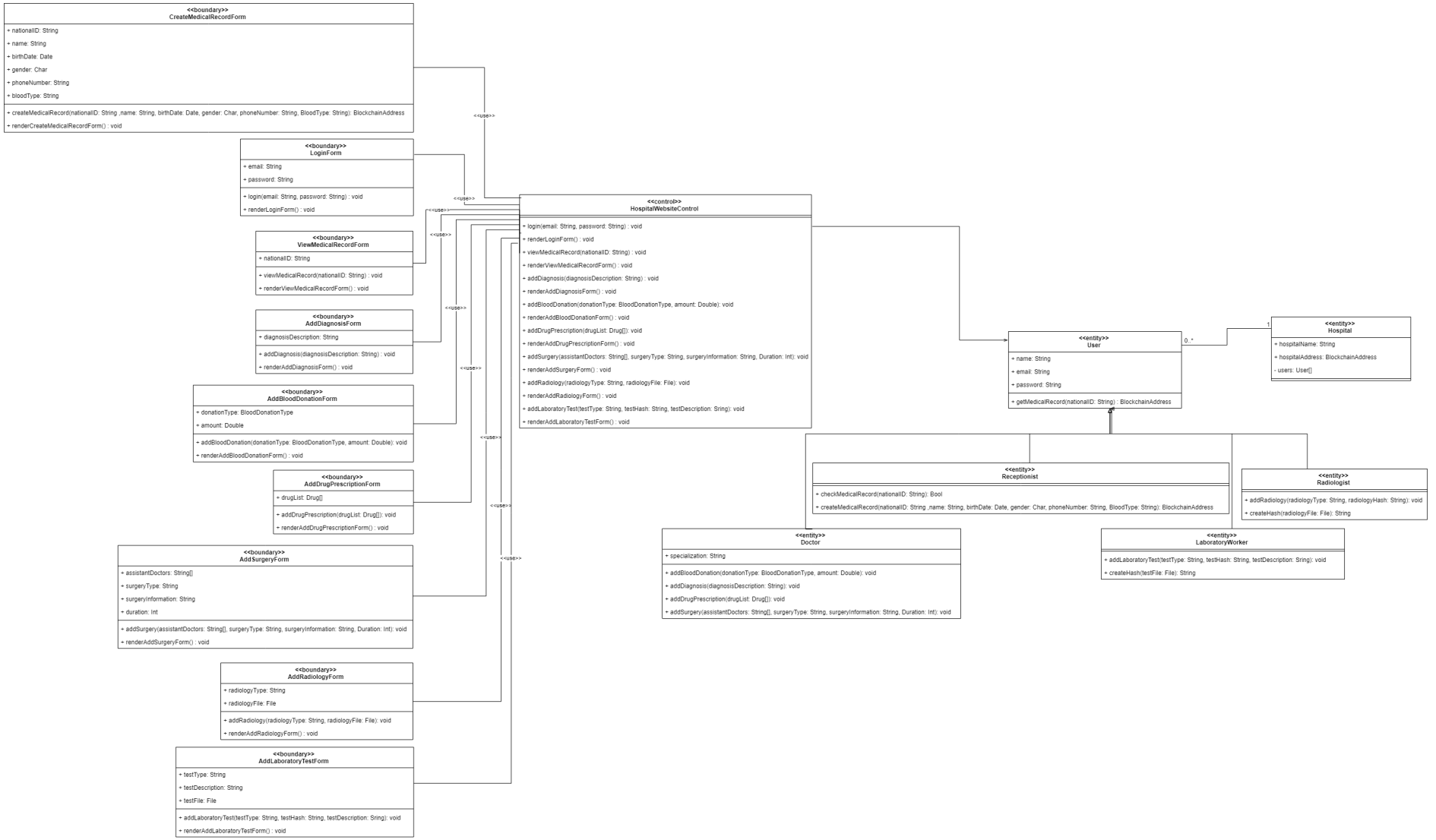

Figure 11 Hospital design class

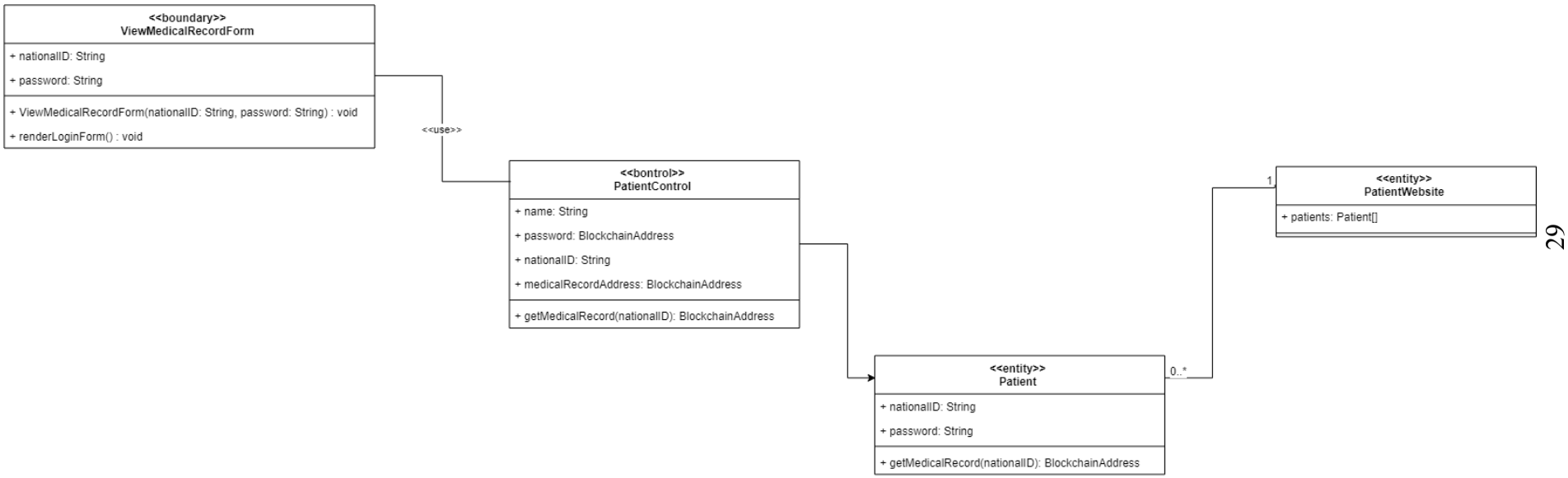

Figure 12 Patient Website design class

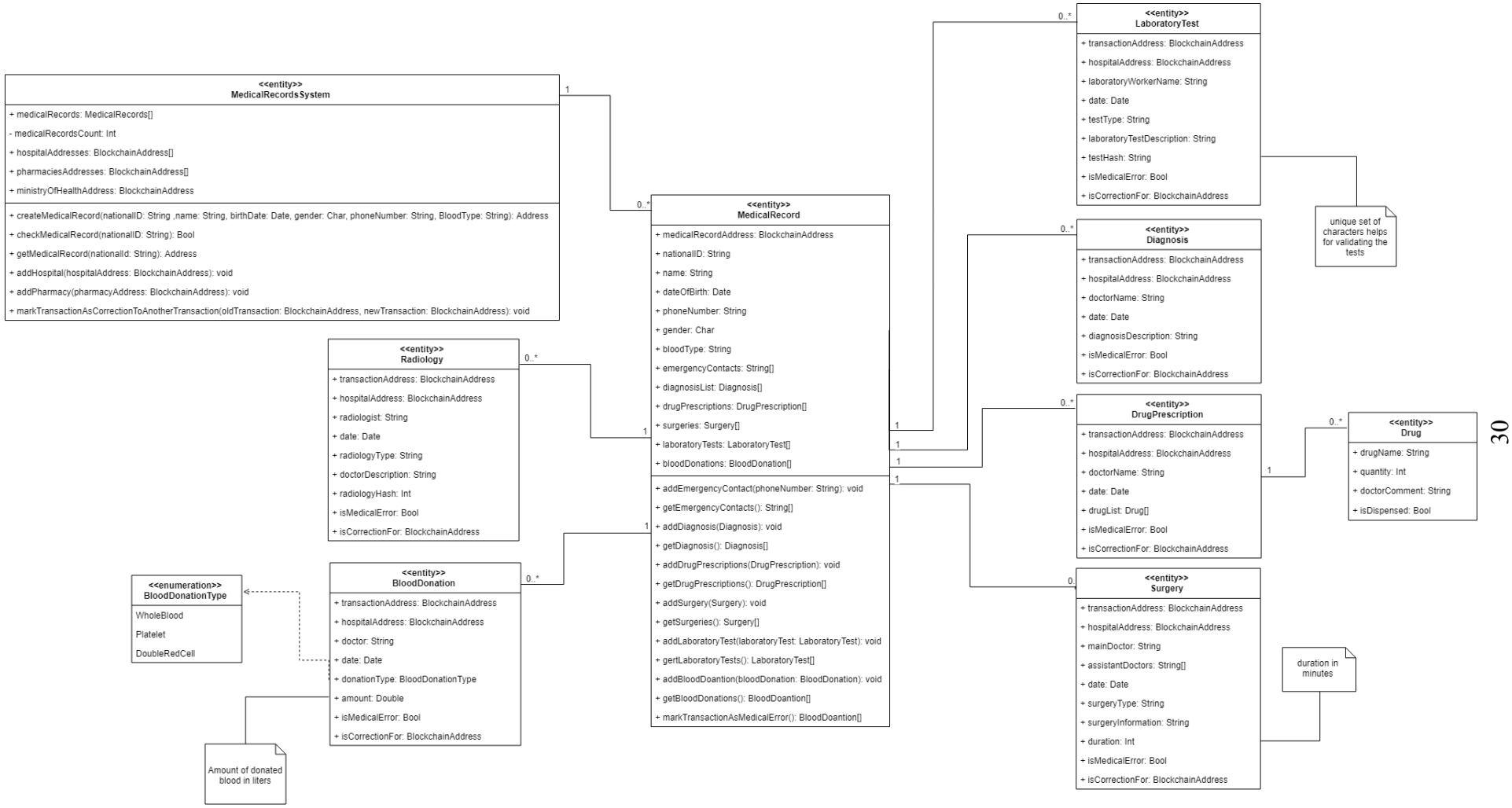

Figure 13 Blockchain design class

11. System Architecture

Since it is a decentralized, peer-to-peer system. It consists of a number of nodes, each of which has a local copy of the blockchain. The nodes belong to different hospitals. The nodes communicate to each other in order to gain agreement on the contents of the blockchain, and do not require a central authority to validate the transactions. One of the nodes will represent the web app to which the users will connect to to view their medical records. See the figure.

As in figure, a blockchain consists of a chain of blocks, each block contains the following:

- Proof of work nonce: The random value in a block that was used get the proof of work satisfied.
- Data block: which contains the list of transactions (data added to the patient medical record).
- Hash: a hexadecimal number unique to the block.
- Previous: the hexadecimal number referencing the previous block.

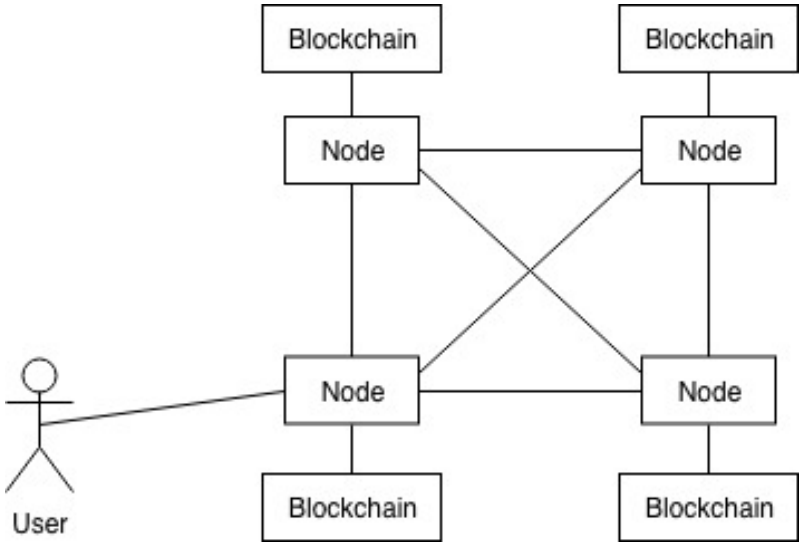

Figure 14 Ethereum network architecture

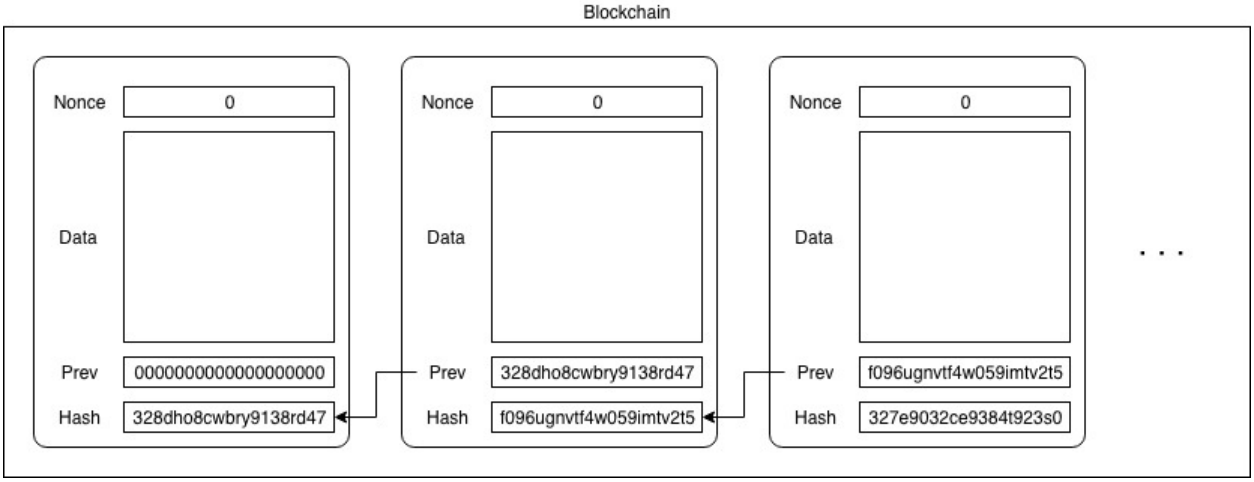

Figure 15 Blockchain architecture

12. User Interface Mockup

Below is the UI mockup of the View Medical Record web application which will be used by patients.

Figure 17 Sign in screen mockup

Figure 16 SMS verification screen mockup

Figure 18 Medical record screen mockup

End of Deliverable 3

13. Algorithms

- The system uses the sha256 for hashing for generating the hash for each block. [6]
- The system uses the Ethash as a Proof of Work algorithm for Ethereum. 5]
- The system uses secp256k1 which is an Elliptic Curve Digital Signature Algorithm used for generating public and private keys. 7]
- The system uses an algorithm for generating Universally Unique Identifiers based on the RFC4122 UUIDs.[8]

14. Proposed Deployment

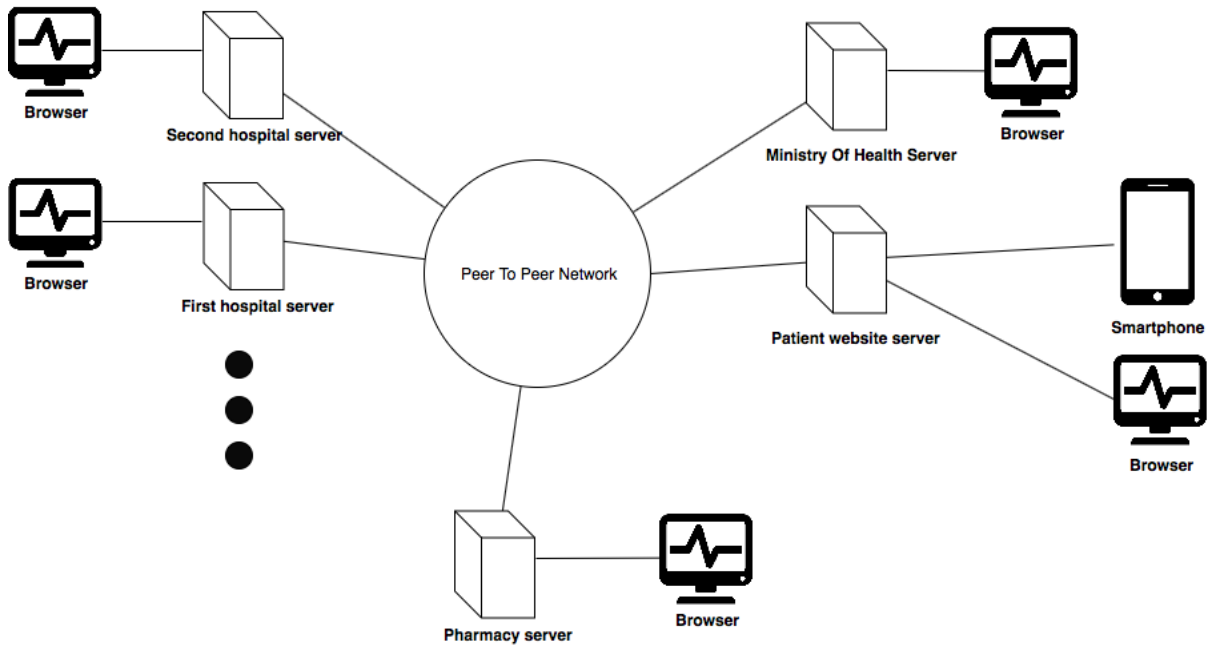

Figure 19 System deployment diagram

15. Test Scenario

Table 4 Test Scenario

Test Case ID	Test Scenario	Expected Results
1	Hospital tries to change the contents of a previous block	Error message is displayed
2	Patient logs in to the system by wrong patient national ID	Error message is displayed
3	Pharmacist marks a single drug as dispensed	Successful message is displayed
4	Hospital retrieves data for any medical record	The queried data is displayed
5	Hospital marks a transaction as a medical error	Error message is displayed
6	Ministry of Health adds a new hospital	Successful message is displayed

15.1 Test case 1: Hospital tries to change the contents of the previous block

15.1.1 Process:

When the hospital tries to change the contents of a previous block, the hashed of that block and all the following blocks change automatically, which leads to the whole system rejecting the hospital's version of the blockchain.

15.1.2 Result:

An error message is displayed.

15.2 Test case 2: Patient logs in to the system by wrong patient national ID

15.2.1 Process:

The system verifies if the national ID is already linked with a medical record. In this case the national ID is not.

15.2.2 Result:

An error message is displayed.

15.3 Test case 3: Pharmacist marks a single drug from the Drug Prescriptions as given.

15.3.1 Process:

If the drug is not already dispensed by the Pharmacist to the Patient, the Pharmacist can choose to mark the drug as dispensed.

15.3.2 Result:

Successful message is displayed.

15.4 Test case 4: Hospital retrieves data for any medical record.

15.4.1 Process:

Provided the patient's national ID, the Hospital can query the blockchain with the data stored in the medical record.

15.4.2 Result:

The queried data is displayed.

15.5 Test case 5: Hospital marks a transaction as a medical error.

15.5.1 Process:

Only the Ministry of Health has the privilege of marking a transaction as a medical error. When the Hospital tries to perform this action, the system rejects the request.

15.5.2 Result:

Error message is displayed.

15.6 Test case 6: Ministry of Health adds a new hospital.

15.6.1 Process:

Only the Ministry of Health has the privilege of adding a new Hospital to the network, when it performs this action, a message is displayed showing that the action was performed successfully.

15.6.2 Result:

Successful message is displayed.

16. Project Status

The project is progressing as expected and each deliverable was submitted on time. Our weekly meetings with the advisor insured that we are on the right track. Before submitting each deliverable, we have conducted a review through the entire project and make sure everything is consistent. We distributed the required objectives for each deliverable among the group members and organize weekly meetings every Tuesday to make sure the whole work meets the same level of quality.

17. Conclusion

Medical information, in its current state, can be tampered with, misused, stolen or even lost because of the intermediaries getting access to it, and also due to heavy reliance on paper-based documents. We decided in our project to use the blockchain technology, which is considered to be one of the most secure technologies.

Medical records should be stored on a blockchain, which is shared between patients, healthcare providers, and the government represented by the Ministry of Health. In this case, the Ministry of Health acts as the regulator. Any change in any medical record will appear to all parties interested in this medical record including the date, time and all details regarding this change. By implementing the project in this way, we achieve our main goal of the project, which is to protect patients' medical records.

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End of Deliverable 4