



APPLYING FEDERATED LEARNING WITH SMART CONTRACTS IN HEALTHCARE

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AbSTRACT

This FYP project aims to address the problem of the lack of medical data sharing in healthcare, which is a major obstacle in integrating artificial intelligence (AI) technology. The reason behind the data-sharing hurdle is that medical data is highly confidential, and hospitals are reluctant to share it due to privacy concerns. As a result, machine learning (ML) models cannot be trained, and progress in this field is stalled. To overcome this issue, this project proposes an alternative approach, which involves model sharing and federated learning. The proposed system consists of two entities, the Super user and hospitals. The Super user requests hospitals to participate in federated learning, and registered hospitals are granted access to global model files through IPFS hashes. These hashes are stored on the block chain via smart contracts. The technologies used in this project include Solidity for smart contract development, React.js for the frontend, and IPFS Piñata for hosting ML model files. This solution provides a viable and secure way to enable AI integration in healthcare while maintaining patient privacy.

Table of Contents

<i>List of Figure</i>	6
<i>List of Tables</i>	7
<i>Introduction</i>	8
<i>Project Scope</i>	8
<i>Project Objective</i>	8
<i>Requirements Analysis</i>	10
Functional Requirements	10
Functional Hierarchy.....	10
Use Cases	11
Form Submission	11
Hospital/Super user Use Case	14
Non-functional Requirements.....	15
Performance Requirements	15
Safety Requirements.....	15
Security Requirements	15
User Documentation	15
<i>Design Details</i>	16
Design Strategy.....	16
ER Model	16
ER Diagram.....	16
Data Dictionary	16
Application Design	17
Class Diagram	17
Sequence Diagram	17
State Diagram.....	21
Data Flow Diagram.....	24
<i>Implementation Details</i>	25
System Architecture.....	25
System Component Design.....	26
Software Architecture	26
Development Tools Used	27
<i>Testing and Evaluation</i>	27
Environmental Needs.....	27

Validation Testing..... 28
 Testing Approach(s).....28
 Test Pass/Fail Criteria28
 Test Cases29

List of Figure

Figure 1 Use Case Diagram 1	11
Figure 2 Use Case Diagram 2	13
Figure 6 Register Sequence Diagram 1	17
Figure 7 Login Sequence Diagram 2	18
Figure 8 Upload Model Sequence Diagram 3	19
Figure 9 Update Model Sequence Diagram 4	19
Figure 10 Delete Model Sequence Diagram 5	20
Figure 15 Login State Diagram 1	21
Figure 15 Training State Diagram 2	21
Figure 15 System State Diagram 3	21
Figure 15 Registration State Diagram 4	21
Figure 18 System Architecture	25
Figure 20 Layered Software Architecture	26

List of Tables

Table 1 Register User	11
Table 2 Login	13
Table 3 Test case 1	29
Table 4 Test case 2	29
Table 5 Test Case 3	29
Table 6 Test Case 4	30
Table 7 Test Case 5	30
Table 8 Test Case 6	31
Table 9 Test Case 7	31
Table 10 Test Case 8	32
Table 11 Test Case 9	32
Table 12 Test Case 10	33

Introduction

Block chain is also used in the healthcare management system for effective maintenance of electronic health and medical records. The technology ensures security, privacy, and immutability. This work proposes a framework by integrating the block chain and Federated Deep Learning in order to provide a tailored recommendation system. Electronic medical records contain personal and confidential information that traditional storage methods must protect against cyberattacks and third-party authentication. To overcome this challenge, a method of distributed storage was proposed in this work. The focus of this work is also on making treatment recommendations to patients by comparing their medical records with historical data. This work is motivated by the limitations of existing work. The current study supports his EHR preservation, but the recommendation system is neither discussed nor incorporated, making it difficult to create a treatment recommendation system. Federated learning may therefore lead to more accurate treatment recommendations

Project Scope

Primarily, the scope of our final year project is limited. We will be limiting our scope to the medical sectors where a patient data will be recorded on our system and by means of recording, we will be using that data only to train our machine learning model. We will be using the concept of federated Learning Through Federated learning; multiple organizations or institutions work together to solve a machine-learning problem under the coordination of a central server or service provide. Thus, a deep-learning model is maintained and improved upon within a central server. The model is trained by distributing itself to hospitals which allows these sites to keep their data localized. Data from each collaborator is never exchanged or transferred during training. Instead of bringing the data to the central server, as in conventional deep learning, the central server maintains a global shared model, which is disseminated to all institutions. Each entity subsequently maintains a separate model based on its own patients' data. Thereafter, each center provides feedback to the server based on its individually trained model—either by its weight or the error gradient of the model. The central server aggregates the feedback from all participants, and based on predefined criteria, updates the global model. The predefined criteria allow the model to evaluate the quality of the feedback and therefore to only incorporate that which is value-adding. The feedback from centers with adverse or strange results can thus be ignored. This process forms one round of federated learning, and it is iterated until the global model is trained.

Not in Scope

We will be only targeting one/two disease for the recommendation and it will be running on local environment not globally deployed. It will be on private block chain and only people who are connected will have the feasibility to connect to it

Project Objectives

Our system implementation addresses the three major issues:

1. slow access to medical data

2. system interoperability

patient agency

Recent advances in deep learning have shown many successful stories in smart healthcare applications with data-driven insight into improving clinical institutions' quality of care. Excellent deep learning models are heavily data-driven. The more data trained, the more robust and more generalizable the performance of the deep learning model. However, pooling the medical data into centralized storage to train a robust deep learning model faces privacy, ownership, and strict regulation challenges. **Federated learning** resolves the previous challenges with a shared global deep learning model using a central aggregator server. At the same time, patient data remain with the local party, maintaining data anonymity and security.

This method provides decentralized machine learning model training with-out transmitting medical data through a coordinated central aggregate server. Medical institutions, working as client nodes, train their deep learning models locally and then periodically forward them to the aggregate server. The central server coordinates and aggregates the local models from each node to create a global model, then distributes the global model to all the other nodes. It is worth noting that the training data are kept private to each node and never transmitted during the training process. Only the model's weight and parameters are transmitted, ensuring that medical data remain confidential. For these reasons, FL mitigates many security concerns because it retains sensitive and private data while enabling multiple medical institutions to work together. FL holds an excellent promise in healthcare applications to improve medical services for both institutions and patients—for instance, predict autism spectrum disorder, mortality and intensive care unit (ICU) stay-time prediction.

1 Functional Requirements

1.1 Functional Hierarchy

The super Admin and providers have a specific identity number that identifies their account. The account is accessed via a special account address of web3 provider such as meta mask and for another way of authentication we will use firebase to authenticate the data

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.

Features

We have Implemented a user-friendly application user interface using React Js 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 super admin and providers (Healthcare institutions).

Login: Login page for super Admin and provider

Signup: Signup page for provider

functionalities related to provider

View Form: Doctor can view patient available respective data

Fill form: Receptionist will submit the form of the patient

Request a particular doctor: Receptionist can request a particular doctor

Take part in training: provider will have a functionality to train its model

functionalities related to super Admin

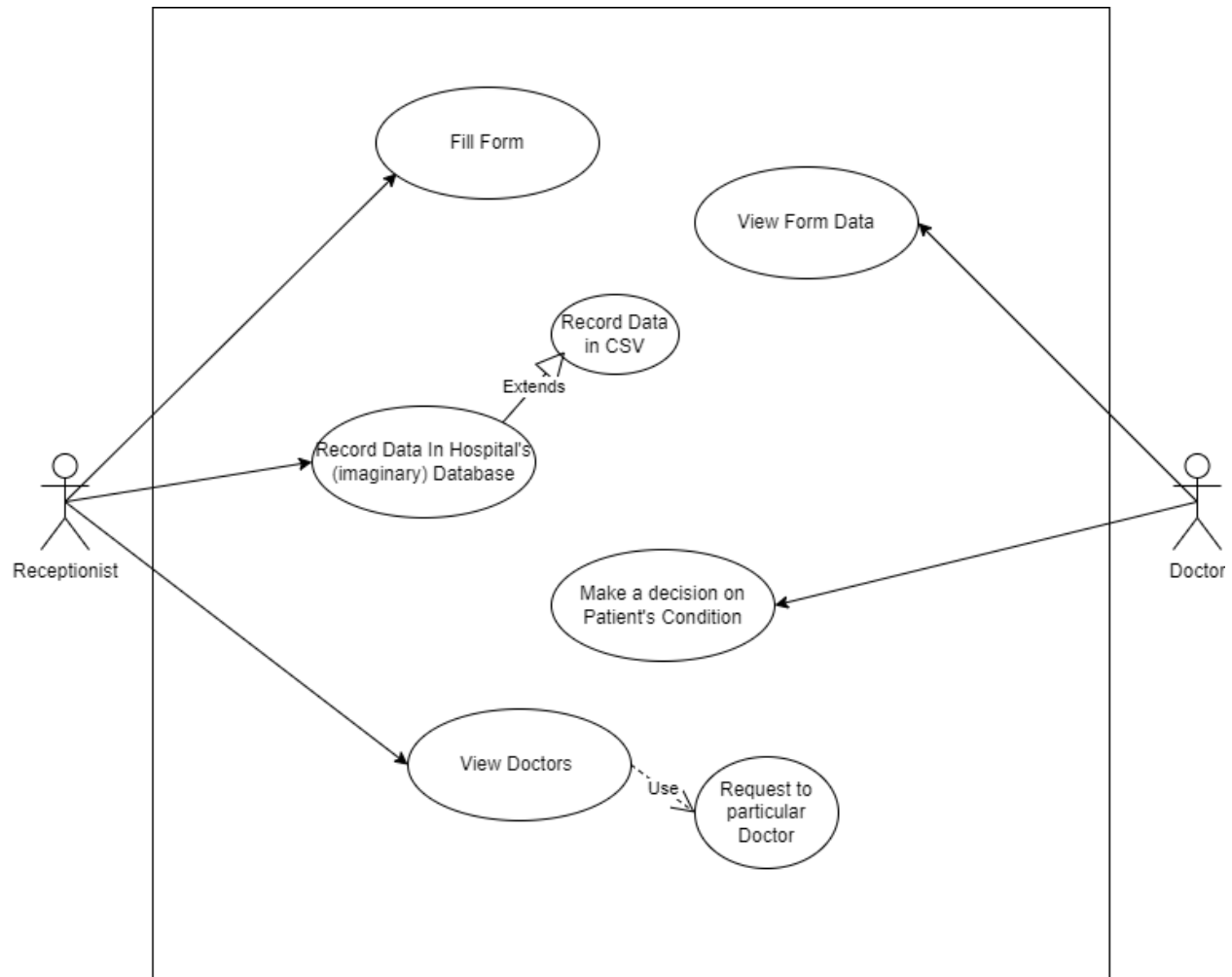
Retrieve model: super Admin can retrieve hospital model and make it interact with the global model

Aggregation of model: super admin will aggregate the model based on the weights of the different models

1.2 Use Cases

1.2.1 Form Submission

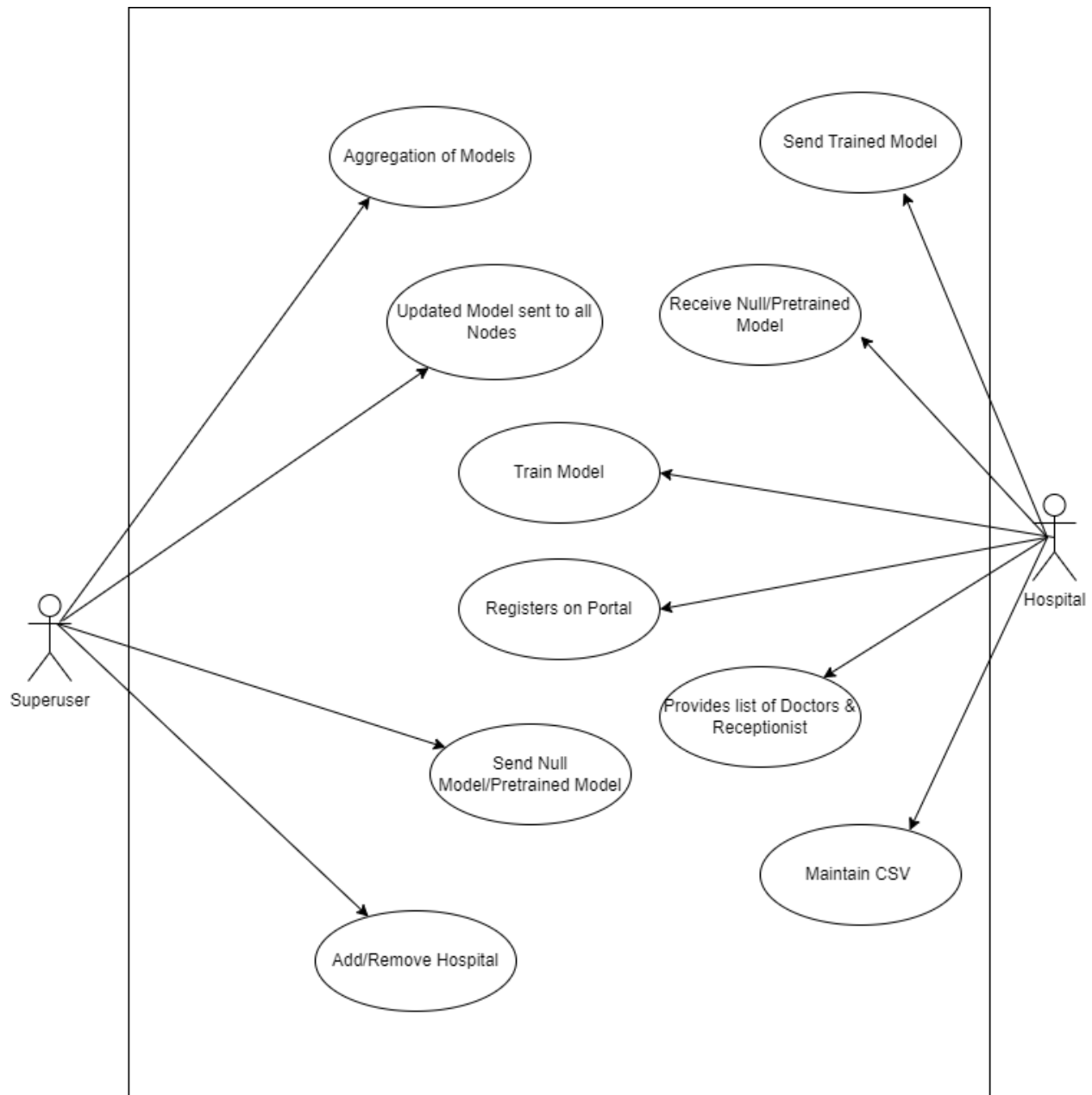
[Use Case Diagram]



Form Submission		
Use case Id:	1	
Actors:	Receptionist, Doctor	
Feature:	Submission of form	
Pre-condition:	Receptionist must be logged in and have a list of doctors Doctor should be authenticated and have a verified account given by the provider	
Scenarios		
Step#	Action	Software Reaction
1.	Fill the form of the patient	Fill input fields provided on the user interface and submit it

2.	Doctor will make a decision on the given form data and patient condition	A form view option will be visible to the doctor and he can view the patient data on the form and will make a decision accordingly for the treatment
Alternate Scenarios:		
None		
Post Conditions		
Step#	Description	
1	A final decision for the patient treatment will be taken and if the patient agrees to take part in training aggregate weights will be updated on the global server	
Use Case Cross referenced		None

1.2.2 Hospital/Super user Use Case



[Use Case Description]

Model training	
Use case Id:	2
Actors:	Super User,Hospital
Feature:	Training of Model
Pre-condition:	SuperUser must be logged in and have access to global server model and have weights passed to it by the hospital
Scenarios	

Step#	Action	Software Reaction
1.	Hospital will register itself on the portal	Hospital will get access to take part in training of model and interacting with our system
2.	Superuser can add or remove provider from the system	Hospitals with the penalty charges or the hospital which are sucessfully registered will act accordingly
Alternate Scenarios:		
None		
Post Conditions		
Step#	Description	
1	Trained model on the recent data will be passed to the hospital and all the nodes will be updated	
Use Case Cross referenced		1

2 Non-Functional Requirements

2.1 Performance Requirement

The System shall be based on web and has to be run from a web server. The system shall take initial load time depending on internet connection strength which also depends on the media from which the product is run. The performance shall depend upon hardware components of the client/customer

2.2 Safety Requirement

The software is completely environmentally friendly and does not cause any safety violations. The web page will have a flexible font that can be zoomed so as to not over constrain the eyes.

2.3 Security Requirement

Data Transfer

- The system shall use secure sockets in all transactions that include any confidential customer information.
- The system shall automatically log out all customers after a period of inactivity.
- The system shall confirm all transactions with the customer's web browser.
- The system shall not leave any cookies on the customer's computer containing the user's password.
- The system shall not leave any cookies on the customer's computer containing any of the user's confidential information.

Data Storage

- The customer's web browser shall never display a customer's password. It shall always be echoed with special characters representing typed characters.
- The customer's web browser shall never display a customer's credit card number after retrieving from the database. It shall always be shown with just the last 4 digits of the credit card number.
- The system's back-end servers shall never display a customer's password. The customer's password may be reset but never shown.
- The system's back-end servers shall only be accessible to authenticated administrators.
- The system's back-end databases shall be encrypted.

2.4 User Documentation

The software is accompanied by the following materials for further help:

- Software Requirement Document
- Software Design Specification Document

3 Design Strategy

3.1 Future System Extension or Enhancement

The system will be built using the latest edition of framework and incase a new update occurs in technology we must be ready. Stay updated by tracking orders with customized alerts and resolve issues proactively. Track real-time, Optimize routes and schedules and resource allocation in one centralized view.

3.2 User Interface Paradigm

The user interface is very reliable and understandable to the user, the interface designed in such a way that mostly any expertise of people can easily learn and understand that what happens if I click this option, interface is very effective and efficient to increase the usability of users.

3.3 Data Management

Main Data which are models will be stored on the IPFS and the relevant hashes of the model will be stored on smart contracts. Hospital will upload the model on web3 interface then store the model on the IPFS which will be use to apply federated leaning through aggregating of all these models.

Form typically collects the following data:

Patient Name

Fever

Blood Pressure

Heart Rate

Platelets

Blood Group

Weight

Age

ETC

4 Design Strategy

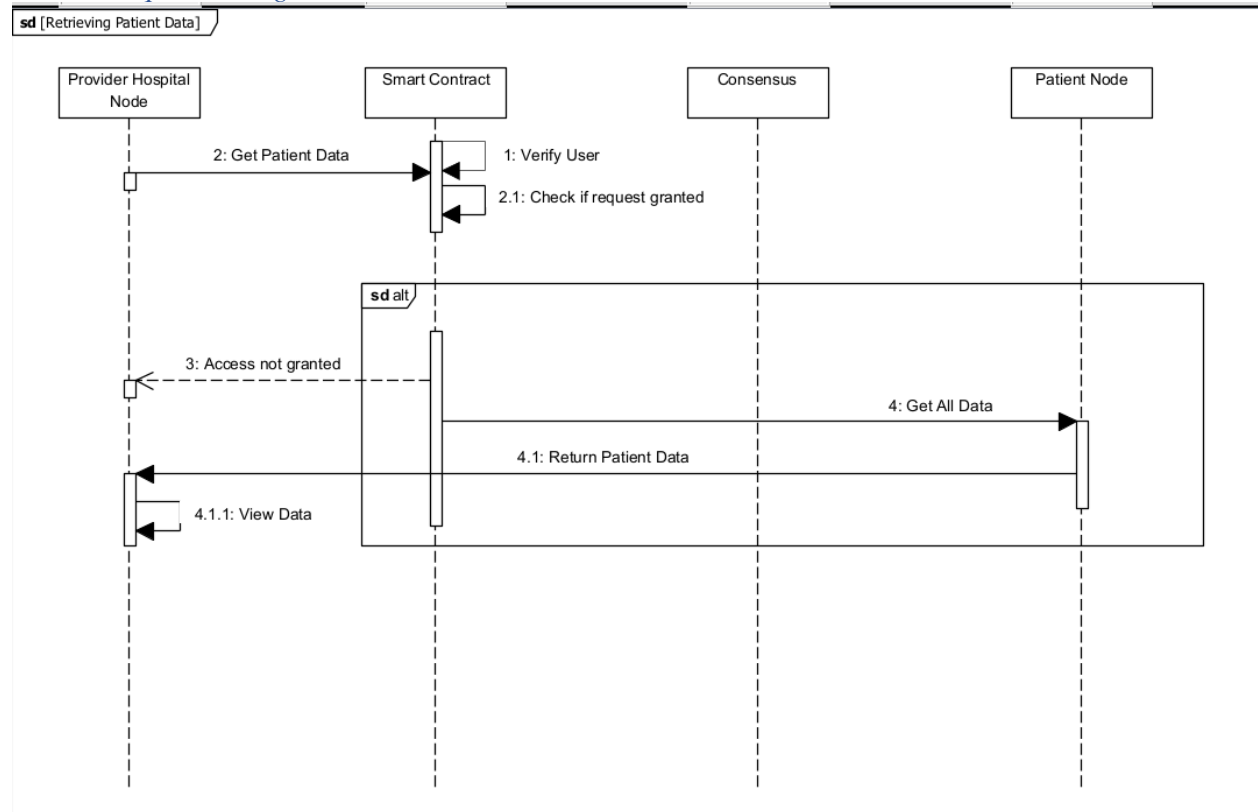
4.1 Database Design

Not applicable (Database is being used to store data temporarily for authorization and registration purpose only, there are no other relations)

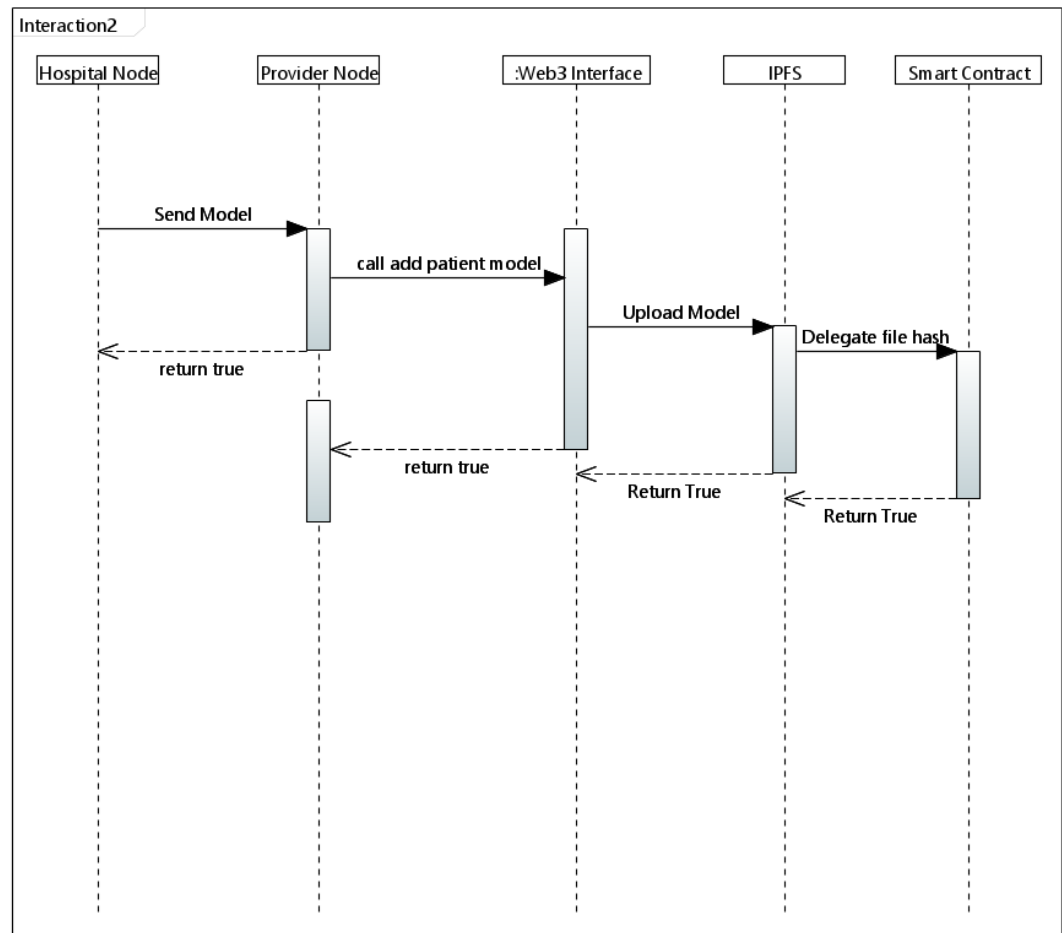
4.2 Application Design

4.2.1 Sequence Diagram

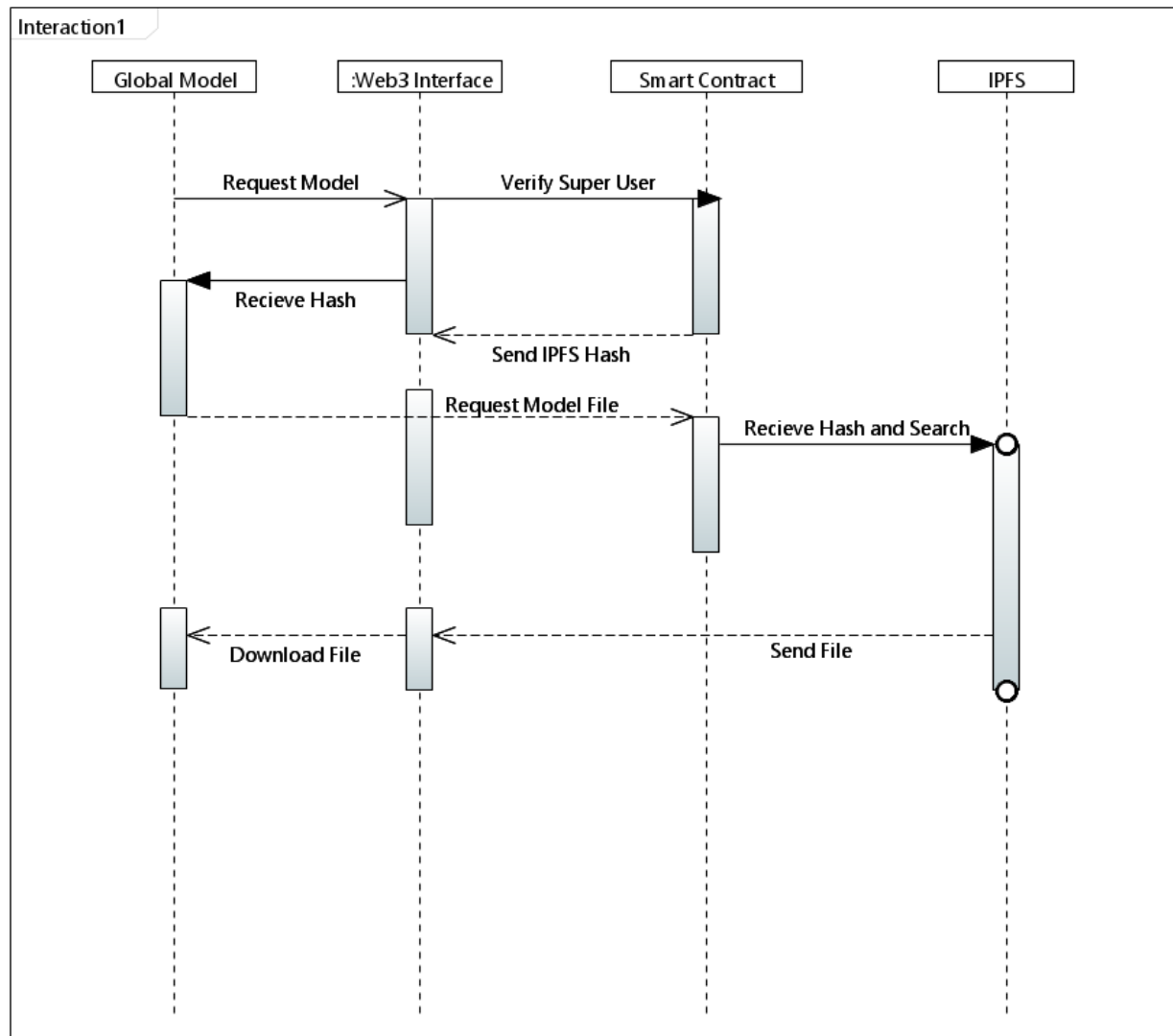
5.2.1.1 <Sequence Diagram 1>



5.2.1.2<Sequence Diagram 2>

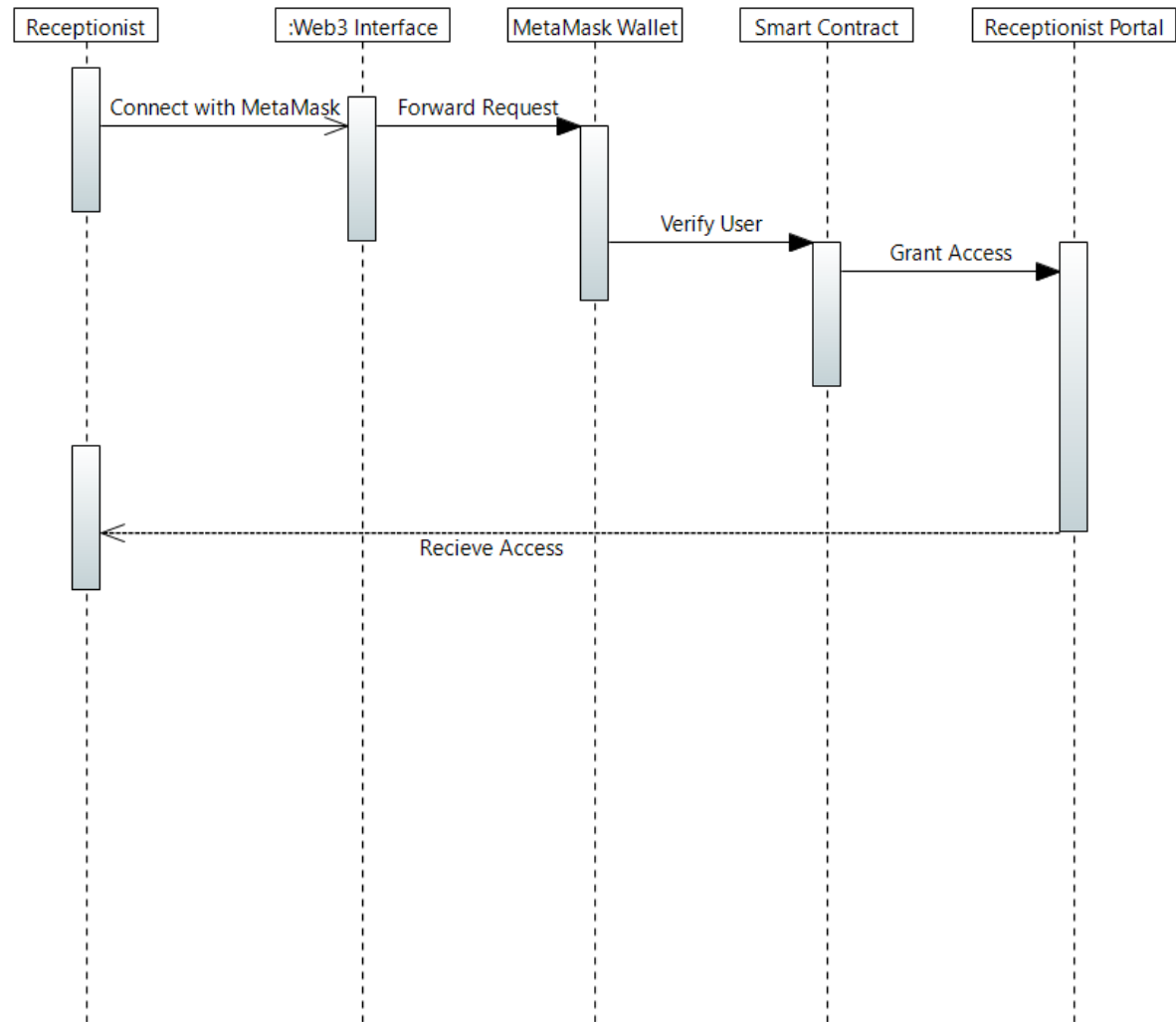


5.2.1.3 <Sequence Diagram 3>

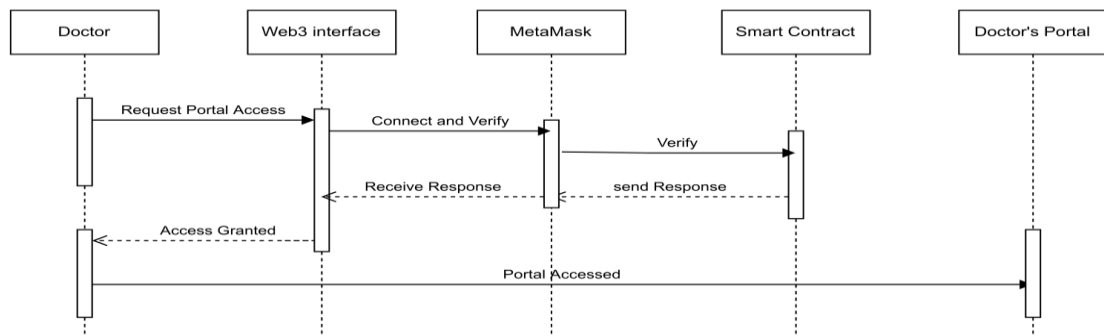


5.2.1.4<Sequence Diagram 4>

Interaction1

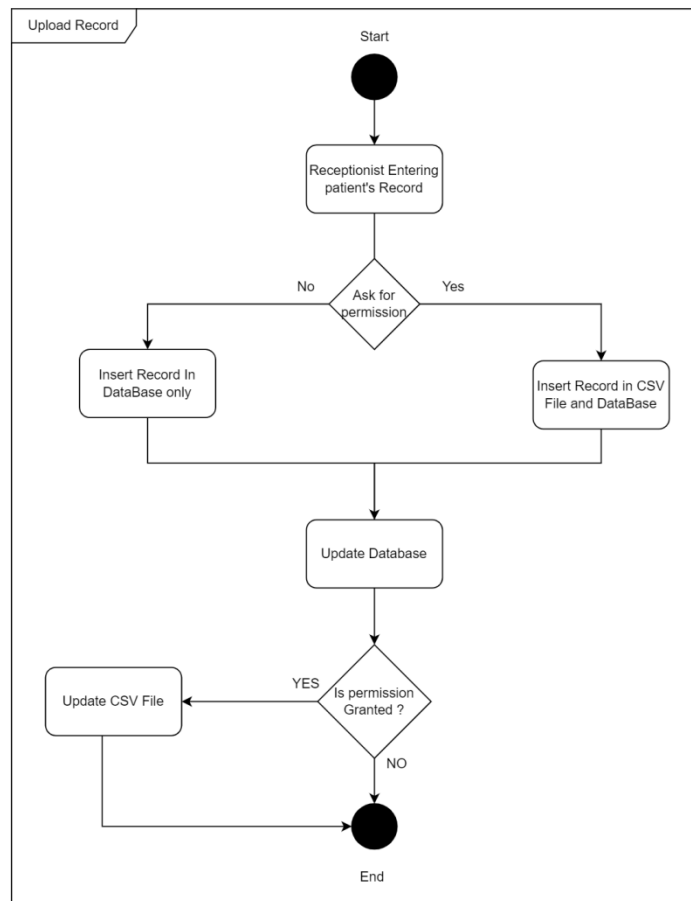


5.2.1.5 <Sequence Diagram 5>

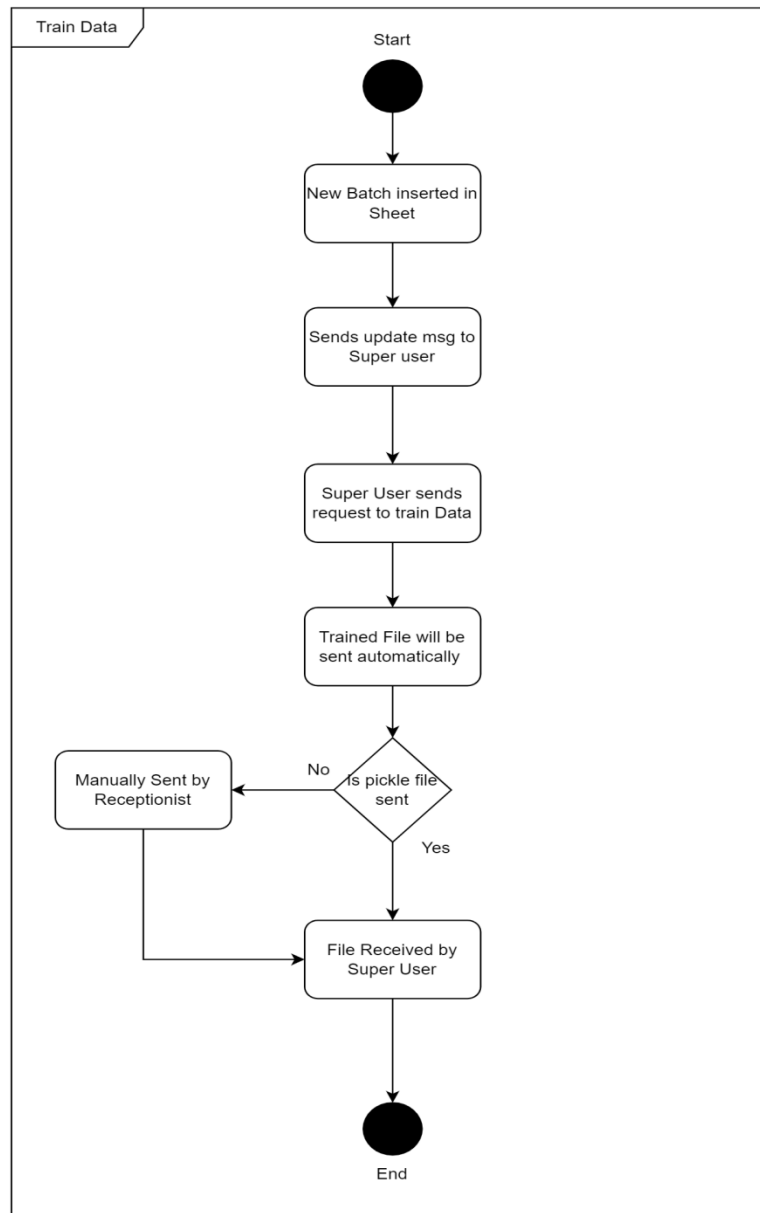


4.2.2 State Diagram

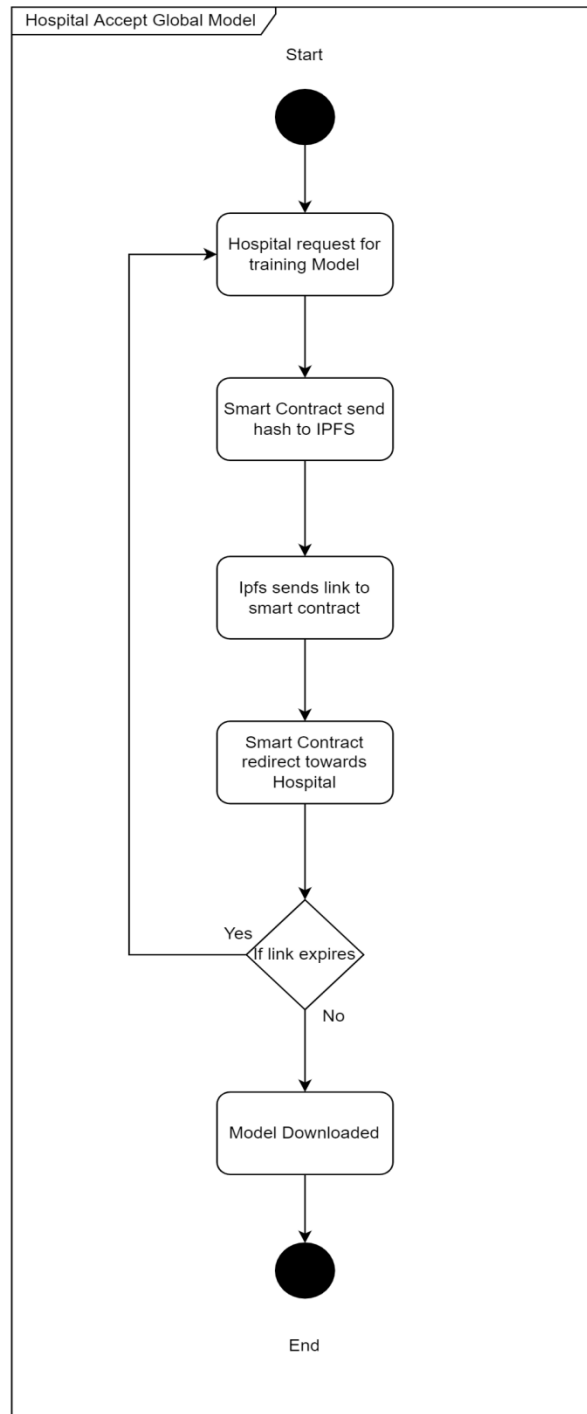
5.2.2.1<State Diagram 1>



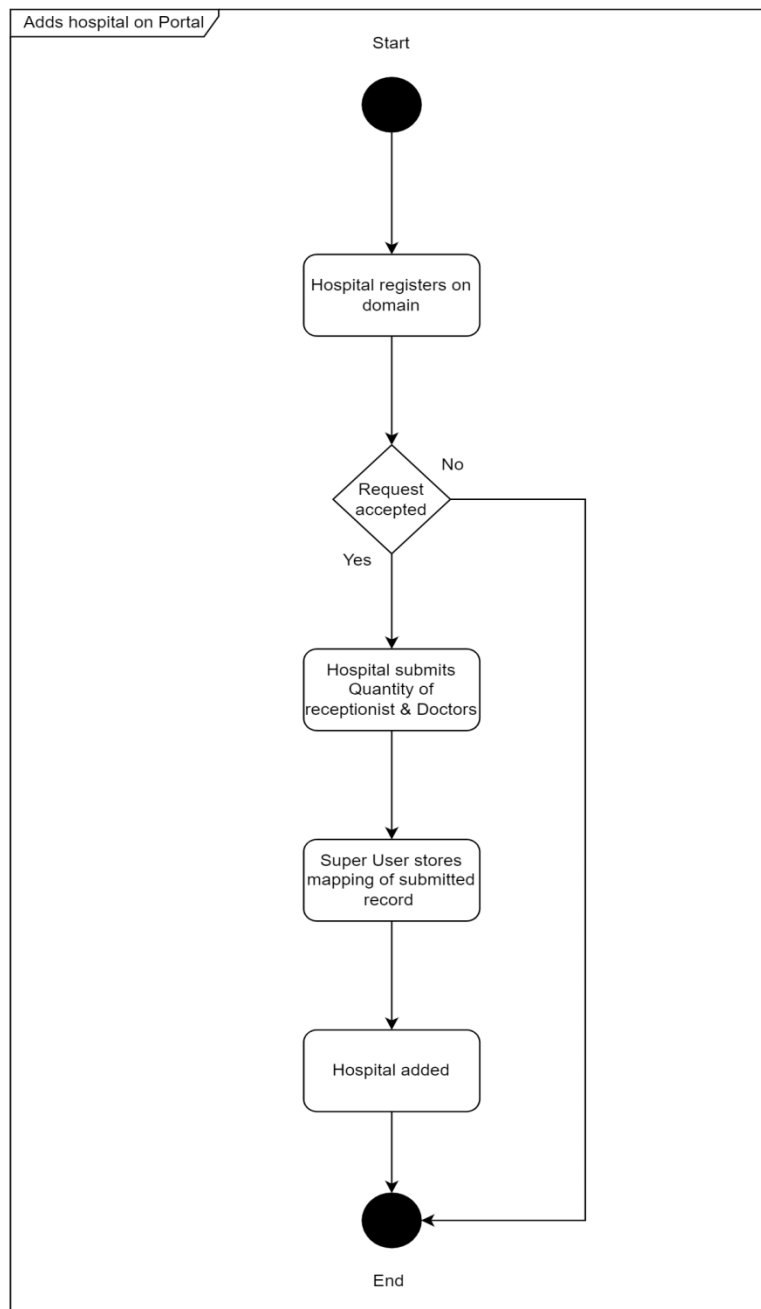
5.2.2.2<State Diagram 2>



5.2.2.3<State Diagram 3>



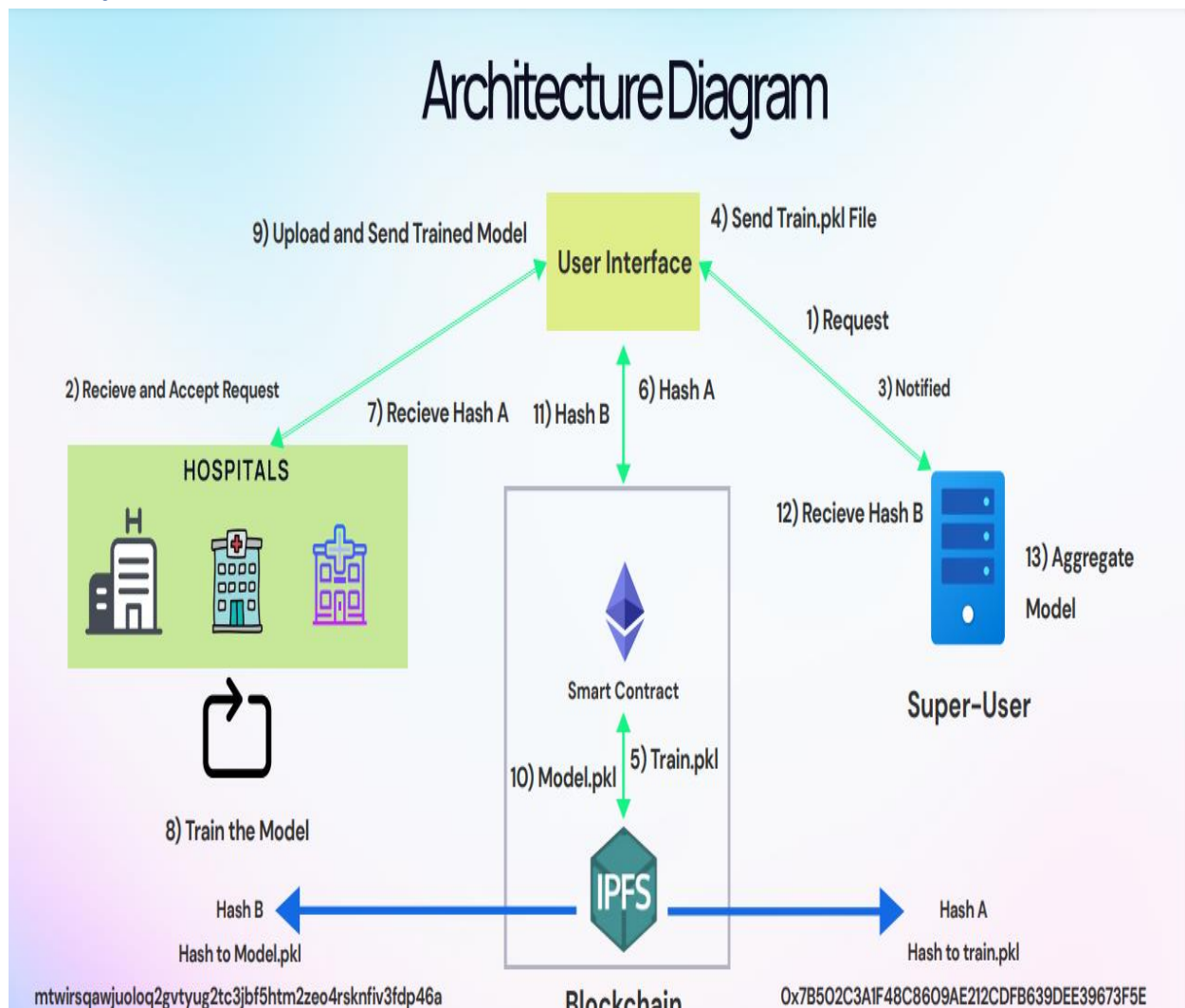
5.2.2.4<State Diagram 4>



5 System Architecture

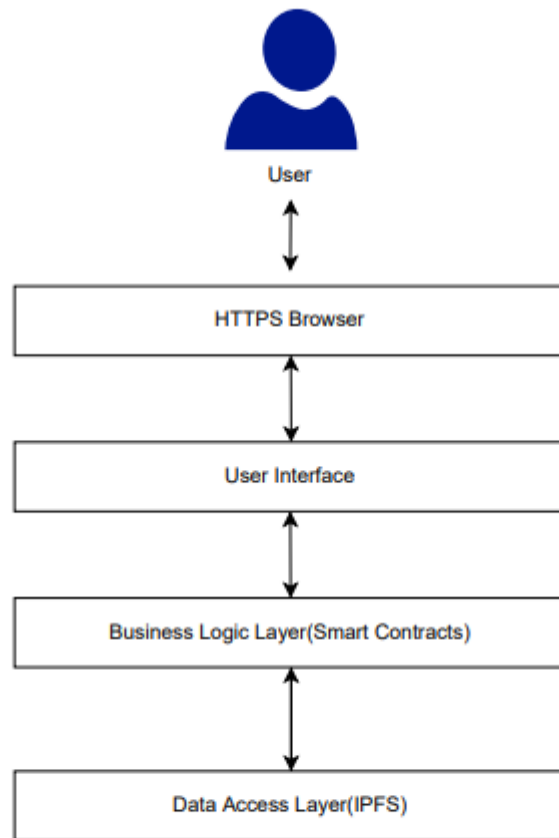
Hospital can request the model from the Global server then download the model. After downloading the model, they will be training it on their own data. After the training is completed, the model will be sent back to the global server this process will be repeated by all the hospitals on the network who are taking part in this training after all the models are received by the global server it will then aggregate all these models through ensemble learning and a new model with combined intelligence of all the aggregated model will be formed This new model will be delegated back to all the hospital.

5.1 System Level Architecture



High Level System Architecture

5.2 Software Architecture



Layered Software Architecture

Development Tools Used

The development tools and software technologies used are as follows:

- React JS
- Node JS
- Express JS
- Git version controlling
- Pycharm
- Visual Studio Code
- Postman
- Thunder Client
- Solidity
- Remix
- Etherjs
- Web3
- Hardhat
- MetaMask
- Ganache

Testing and Evaluation

The purpose of this document is to provide a comprehensive outline of the validation and testing procedures necessary for ensuring the effectiveness and proper functionality of our project. The primary objective of this endeavor is to ascertain whether the project satisfies its requirements. In order to achieve this goal, three distinct types of testing will be conducted: unit testing, performance testing, and system testing. Through these rigorous testing procedures, the entire system will be thoroughly scrutinized to guarantee its efficient operation and robust performance. It is hoped that the results of these tests will provide valuable insights that will enable us to improve and optimize the project, thus enhancing its overall efficacy and value.

Environmental Needs

Following are the hardware assumptions for using the system

- **13** core processor or above
- **4 GB** RAM or above
- **256 GB** SSD space
- Keyboard and Mouse
- Internet Browser (any)
- English language supported only

Validation Testing

Testing Approach(s)

- **Unit Testing:** The main objective is to test individual components of a system are tested in isolation to ensure that they are working properly. This helps to identify and fix any defects or bugs in the system's components before they are integrated.
- **Integration Testing:** Testing all integrated modules to verify that the combined functionality after integration is in a workable state. The objective of this testing is to ensure that all the integrated modules are working properly and are producing the desired output.
- **System Testing:** The entire system is tested as per the requirements. Overall requirement specifications and all the combined parts of a system are tested.
- **Usability Testing:** The objective of this testing is to ensure that the system is easy to use, user-friendly, and meets the user's expectations. It involves testing the system's navigation, interface, functionality, and user experience to identify any usability issues and to provide recommendations for improvement.
- **Performance Testing:** The objective of this testing is to ensure the system works under heavy traffic that includes large size video length processing.

Test Pass/Fail Criteria

If the application failed to generate results, provide errors or crashes then it is a failure else it is Pass.

Test Cases

Test Case: 01				
Description: Test login functionality				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	User route to the login page	Display the page	Page displayed	Pass
2	User enters their credentials	Check for empty fields	Verify empty fields	Pass
3	User clicks on login button	Validate user login credentials	Validated credentials	Pass
4	User is redirected to respective page	Display the respective page	Displaying the respective user page	Pass

Table 19 Test case 1

Test Case: 02				
Description: Test register user functionality				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	Admin route to the register user page	Display the page	Page displayed	Pass
2	Admin enters the user credentials	Check for empty fields	Verify empty fields	Pass
3	Admin clicks on register button	Check credentials and register user in the database	Validated credentials and a new entry is added in the database	Pass

Table 20 Test case 2

Test Case: 03				
Description: Test Upload Model				
No.	Steps	Expected Result	Actual Result	Pass/Fail

1	User route to the upload Model page	Display the page	Page displayed	Pass
2	User enters the Model name & JSON and pickle files	Check for empty fields	Verify empty fields	Pass
3	User clicks on submit button	Upload Model Files on IPFS & hash In the smart contract	Upload Model Files on IPFS & hash In the smart contract	Pass

Table 21 Test Case 3

Test Case: 04				
Description: Test update Model				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	User route to the update Model page	Display the page	Page displayed	Pass
2	User enters the Model name & JSON and pickle files	Check for empty fields	Verify emptyfields	Pass
3	User clicks on update button	Update Model Files on IPFS & hash In the smart contract	Update Model Files on IPFS & hash In the smart contract	Pass
4	User selected model will be uploaded	New Version of Model Uploaded	New Version of Model Uploaded	Pass

Table 22 Test Case 4

Test Case: 05				
Description: Test extract query functionality				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	User route to the start person identification page	Display the page	Page displayed	Pass
2	User select the incident folder	Display all the incident folders	Display the incident folders	Pass
3	User clicks on next button	Redirect to extract query page	Display the page	Pass
4	User select the video from the dropdown	Display the selected video	Video is displayed	Pass

5	User clicks on the extract button	Display the current video frame and frame extractor	The current video frame and frame extractor is displayed	Pass
6	User capture the query and clicks on capture button	Display the capture image on the UI and upload the image on the server	Image is displayed and uploaded on the server	Pass

Table 23 Test Case 5

Test Case: 06				
Description: Test start person identification functionality				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	User clicks on the start person re-identification button	Display the page and start the process	Page displayed and process is executed	Pass
2	Copy all the videos of the selected incident on the flask server	Files are copied	Files are copied	Pass
3	Copy the query image on the flask server	Copy the query image	Query image is copied	Pass
4	Execute the AI model process	Process is executed	Process is executing	Pass
5	Display the log results via socket	Display the messages	Messages are displayed	Pass

Table 24 Test Case 6

Test Case: 07				
Description: Test multiprocessing frame extraction functionality				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	User clicks on the start person re-identification button	Display the page and start the process	Page displayed and process is executed	Pass
2	Execute the AI model process	Process is executed	Process is executing	Pass
3	The multi-processing base frame extraction is executed	Execute frame extraction on spawned processes	The processes are spawned on which frame extraction is execute. Reduced	Pass

			time duration.	
4	Display the log results via socket	Display the messages	Messages are displayed	Pass

Table 25 Test Case 7

Test Case: 08				
Description: Test multithreaded inferencing bounding box functionality				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	Execute the Person Detection process	Process is executed	Process is executing	Pass
2	The multithreading inferencing bounding box and cropping is executed	Execute inferencing bounding box and cropping on spawned threads	The threads are spawned on which frame extraction is execute. Reduced time duration.	Pass
3	Display the log results via socket	Display the messages	Messages are displayed	Pass

Table 26 Test Case 8

Test Case: 09				
Description: Test the resulted video				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	Execute the person re-identification process	Process is executed	Process is executing and result is displayed on UI	Pass
2	User clicks on the video	Display the video with the marked points in the video where query person is found. Heatmap Graph must be present	Videos are displayed in which person is found and the marked points are available in the video timestamp. Heatmap graph is displayed	Pass

Table 27 Test Case 9

Test Case: 10				
Description: Test the generate report feature				
No.	Steps	Expected Result	Actual Result	Pass/Fail
1	User clicks on the generate report button	Generate the report of the current executed person re-identification process	Report is being generated	Pass

Table 28 Test Case 10