# BLOCKCHAIN-BASED COVID VACCINATION REGISTRATION AND MONITORING

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Computer Science and Engineering

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# APPROVAL

This Project titled "**BLOCKCHAIN-BASED COVID VACCINATION REGISTRATION AND MONITORING**", submitted by Shirajus Salekin Nabil ID:171-15-9263, Md. Sabbir Alam Pran ID:171-15-9267 and Ali Abrar Al Haque ID:171-15-8632 to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 3rd June 2021.

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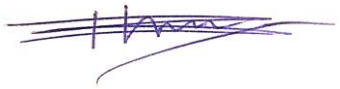

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# DECLARATION

We hereby declare that, this project has been done by us under the supervision of **Mr. Narayan Ranjan Chakraborty, Assistant Professor Department of CSE** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

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# ABSTRACT

The earth is sick now for an invisible enemy, the covid 19. The world hasn't seen this amount of death in past centuries. Top-notch upgradation in technology and the advancement in the research area creates the hope of life by inventing vaccines. As only three vaccines got approved, there are issues related to the demand. The question arises how first and how effectively those vaccines can be distributed at a mass level. And obviously how the authenticity and security will be ensured related to vaccination. Counterfeit vaccine passport or covid test passport already being a viral topic in Bangladesh recently. Here's come the power and effectiveness of blockchain technology in terms of mitigating the authenticity issues. This piece of research contributes in covid test report generation and vaccination passport generation along with a unique feature of prioritization. Well, we know it's impossible to fill all the needs of vaccines cause the production is limited. And a country like Bangladesh with a huge population is so tough to ensure quality distribution. This research can mitigate these issues. We all know that it's very urgent to vaccinate the area where the positive test ratio is greater than the other area. According to this concept, a prioritization-based system with trustworthiness and authenticity has been introduced by using blockchain. This research approach to mitigate the counterfeit test and vaccination passport and a prioritization-based safe vaccination system that ensure effective inoculation based on blockchain.

# TABLE OF CONTENTS

 

# LIST OF FIGURES

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

This deadly virus has first discovered in Wuhan City China in the latter part of November 2019. From then till now around 192 Countries have been affected, 151,542,965 People have been infected, 3,183,274 Died in the whole world [John Hopkins University]. It breaks all the past records of viral infection. Bangladesh first got the first affected case on 7th march 2020 [IEDCR] And till now 7,60,584 have been affected and 11,510 have been died [1]. Safety measured like wearing a mask, keep hands clean with an appropriate sanitizer, maintain social distance and lockdown are still the most effective way to face the challenges with this deadly virus. It's important to test as much as possible so that the infected person can be separated from others and impose lockdown to the surrounding area strictly. The test certificate is a key to prove oneself whether he is infected or not. By these measures the offices, air travel, sports, etc. places where mass attendance need undeniable is doing their job. So, an authentic test certificate has no alternative. The recent scam of counterfeit test certificate production in Bangladesh became a viral topic. The authenticity and trustworthiness became questioned. Hopefully there are some vaccines which are approved by WHO now. Even a Bangladeshi vaccine named BongoVax from Glob Biotech has passed animal trial and now working with human trial [2]. Which is really a great news for Bangladesh. So, in the future vaccination certificates or passports will be a great measure for travel or participation in any public program. So, authentic vaccination certificate is also a prime concern. A blockchain-based test and vaccination certificate is a great way to prevent these issues as blockchain cannot be tampered with. Blockchain comes with the concept of Trustworthy ness, Immutability, and Authenticity. All these three terms can ensure a quality covid test and vaccination passport.

Bangladesh government already started the inoculation process with the approved one AstraZeneca. But the fact is a centralized system was always questioned as there's exist a central authority that can alter any data. Any vaccine can be inoculated to the person who is not at the top according to the preceding by nepotism or power. So here needs a system where inoculation will be done by predetermined preceding where any serial break can be

traced. In this research, a prioritization-based inoculation system has been developed using blockchain. Prioritization has set accordingly to the positive and negative tested numbers ratio. Where the positive ratio is high that place will be at higher risk as the infection rate is higher there. The negative tested people should be vaccinated first to stop the spreading. Using this concept, we've developed an algorithm to ensure the proper inoculation. As the system developed in blockchain, it's become impossible to deny preceding orders by inoculating any favorite one.

### 1.2 Motivation

Covid 19 is threatening to the whole world now. It's high time to show humanity. Researchers are trying to contribute as much as they can to fight against this virus. Doing something for mankind against this virus itself a great motivation.

Bangladesh is a country with a very high population rate. This virus is a great threat to the people of Bangladesh as it spread in densely populated areas very faster. The only way to prevent this is vaccination. But due to the stock limitation of vaccines, it's necessary to ensure prioritization-based vaccination with proper authenticity. There's exist a system but that has a central authority to regulate the system. So, authenticity and transparency become questioned.

The test passport and vaccination passport both will be an asset to join in regular life in the upcoming days. But the fake passport generation scam broke the trust. It's necessary to bring that trust again.

There are lots of approaches from researchers in this field but for Bangladesh and in the aspects of prioritization no researches have done yet.

### 1.3 Rationale of the Study

Covid health passport, Digital Health Passport, Digital Contract Tracing, and many more works have done using blockchain in the last two years. Covid 19 is a very alarming issue now. So. it forces researchers to contribute and innovate something that can help in the fight against this virus. Our target is to ensure authenticity and trustworthiness among the whole community about test passports and vaccination passports. In addition, there's a prioritization-based vaccination system that assures the proper use of the limited number

of vaccines. Our work is partially similar to some researches. But for Bangladesh this the very first research ad also the prioritization feature is more unique. No such work exists that has this unique prioritization feature. Due to the use of blockchain, the whole system becomes more transparent and secure to operate.

### 1.4 Objective

As we've mentioned earlier that it's a war between invisible and visible. So, an effective contribution to this war can also be a goal of every researcher.

The covid test and vaccination certificate generation and prioritization-based vaccination system building is the main objective along with these some of the objectives are printed as below:

- ensuring trustworthy test and vaccination certificate generation
- bringing transparency in the whole vaccination system.
- Prioritization-based vaccination system, where preceding maintained strictly.
- Immutable process of vaccination
- Bringing acceptability of both covid test and vaccination certificate.

### 1.5 Research Question

We are hopeful that the following questions can be answered by our research work.

- How this system mitigates the risk of fake covid tests and vaccination certificates?
- How this system brings transparency to the vaccination system?
- How to ensure quality vaccination using priority which will be maintained strictly?
- If any anomaly occurs in the test certificate Generation and vaccination process can the system trace where it occurred?

### 1.6 Expected Output

A system that can auto priorities the area where vaccination is a crying need. Our system has a user-Friendly interface. Where all the entities can operate their activities in more easy way. The user will be able to request for test and the issuer entity will issue the result. After getting the result, if he or she tested positive then that individual has to meet the preceding orders of the prioritized location to become vaccinated. He will get both test and vaccination certificates in a QR form which can be verified later for attending any public program. Here's all this information related to test data, vaccination data, the user's personal data, hospital information, test issuers information, and the prioritization information that will store in the blockchain instead of storing in a central database. Where this information becomes immutable as blockchain offers this great feature.

So, the authentic test and vaccination certificate generation and prioritization-based vaccination along with the Immutability feature which ensures trustworthiness will be the outcome of this research.

### 1.7 Research Management and Finance

As the project has been implemented and hosted locally, it took no cost at all to build.

# CHAPTER 2
# BACKGROUND

## 2.1 Introduction

It's important to become united to win the war against an invisible enemy Covid19. Lots of research work have been done and lots are one the way on this topic. AI, IOT and Blockchain based mesmerizing works took place. In measuring the outbreak, statistical analysis, predicting and also in vaccine development AI did amazingly well [3]. IOT based devices like smart thermometer, IOT button, Medicare tool proves the ability to help in fighting with covid [4]. IOT based wearable devices can track patient's health conditions and provide information which helps to track patient's condition remotely [5].

Blockchain becoming a very emerging technology for its decentralization feature. People now want decentralization as there exists no such central authority that can regulate the system in his choice. Blockchain is applicable where trust and transparency become a key fact. Though it comes to limelight after the invention of peer-to-peer transaction system bitcoin but its usability is various sectors proves its diversity. In medical sector patient's prescription is a very sophisticated information. Blockchain ensures authenticity and transparency in health data [6][7]. Its also being used in track and management of educational system [8]. Also in food quality, safety assurance during supply blockchain has been used [9]. Currently most awaited challenge is education during this pandemic. Distance learning platform becoming popular and blockchain took place here also [10]. Information movement is one of the vital features of supply chain management. To ensure proper transparency blockchain is the best platform [11]. In e-commerce sector unbiasedness needs to be ensured which can be achieved easily using blockchain [12].

However, the most successful application of blockchain is bitcoin. In 2008 Satoshi Nakamoto first introduced bitcoin [13]. Still, no one knows whether Satoshi Nakamoto is an individual or a group of people. It's a public blockchain that brought a revolutionary change in cryptocurrency. Here the consensus algorithm is proof of work. Where the miners can be anyone with great computational power. Each block contains the transaction amount, hash of the previous block, and hash of it. While a transaction occurs in the network then a bunch of transactions becomes a block. That block is waiting for the

approval of all the nodes of the network. The acceptance depends on the mining. Miners mine a 32-bit number with a predetermined condition. Which is known as Nonce. By competing with each other the first miner who becomes successful got the chance of adding the block. And for his tremendous computational effort, he gets some incentives. The following figure gives a visualization of the proof of work technique.

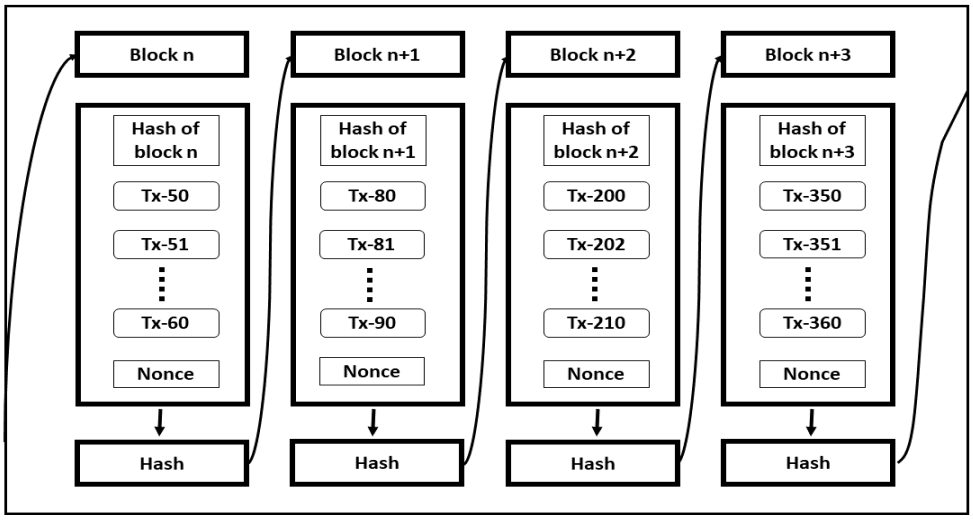


Figure 2.1.1: Proof of Work

In our system, we've chosen Ethereum public blockchain. Which also follows the proof of work consensus. Ethereum is a great place where any application of blockchain can be done. We've chosen Ethereum because of its public feature and huge resource.

## 2.2 Related Work

In test certificate generation and vaccination passport generation there exist the question of trust. So blockchain can play an emerging role to mitigate these issues. Lots of researches took place during last year.

Using timestamp, the validity of vaccines, vaccine Production record information tracking system has been introduced where a double-layered blockchain ensures tamperproof ness [14].

QR code-based test report generation based on blockchain where a prototype app has presented to operate the whole system [15].

Artificial intelligence also did some great improvisation with blockchain. A safe vaccine supply system where the supply process has been traced. Using a hybrid machine learning algorithm, a suggestion-making capability build for people about which vaccine should an individual take according to that individual's Condition [16].

Biometric data inclusion along with blockchain makes systems security insane. A system built with retina scan system which used to ensure the proper identity of a user. DLT based blockchain took place there [17].

DHP (Digital Health Passport) and DCT (Digital Contract Tracing) this two-term can attract researchers highly. Where DHP used in official places, traveling, and the places where the test is mandatory to access [18].

Immunity testing certification along with biometric data where the biometric data and system implemented in blockchain ensure immutability. By taking a user's contact number and geolocation along with timestamp DCT implemented [19].

Self-testing system using AI where location also traced for ensuring contract tracing has implemented where all these data have been gathered in blockchain to enrich security and trustworthiness [20].

All these works are partially related to our work but there doesn't exist any system for Bangladeshi people. Also, prioritization-based vaccination has not been implemented yet.

### 2.3 Comparative Analysis and Summary

The technology revolution has made our life easier and smoother. Blockchain is a great example of that. The decentralization concept is growing more interesting among the whole world. Trustworthiness and transparency in the health sector can mitigate every barrier of indiscipline work. From the background of our research area, we have found some partial similarities. We've seen in the related work section that covid trust certificate and contract tracing got fame in the research area. Because the only blockchain can ensure an unbiased result that is more acceptable than the centralized one. Also, in vaccine production monitoring and immunity tracing exist some promising work. The thing is the certificate generation is partially similar to our work but for Bangladeshi people, this is the very first work that has a suitable web application. The sophisticated data hiding system from the

profile, 4-layer checking in accessing profile, Prioritization all these features are new in this sector. These features made our work unique and effective. Also, vaccination passport and test passport generation in QR form which is verifiable from the system made our work more significant.

### 2.4 Challenges

Cryptocurrency is a very sophisticated term. Bitcoin becoming very famous day by day. The price of bitcoins increasing like a rabbit run. It's not been approved in many countries as it is a very safe place for the smugglers to transact without identity. Even in Bangladesh, it's not been approved yet. Users need a crypto wallet to get the services. People have less idea about that. Ethereum also growing its value. Currently, it's so tough to implement an idea over this public blockchain as the price of Ethereum is increasing highly. Even last year it was a great place to implement an idea.

So, the possible challenges are:

- Cryptocurrency approval.
- Become habituate with the crypto wallet.
- Cost efficiency.

# CHAPTER 3
# RESEARCH METHODOLOGY

## 3.1 Research Subject and Instrumentation

This research aims to solve the most sophisticated issues in the covid vaccination process besides test and vaccination certification also a vital aspect of the research. covid has taken a lot from us. It’s time to show unity. Technology has paved the way for fighting Against this enemy. This research will help to build a disciplined way of vaccination as it’s not possible to vaccinate all the population in a month. So, the critical areas must be vaccinated first. Also, an authentic and trustworthy test and vaccination certificate will produce to make life easier in both current and after covid period.

We've used Ethereum public blockchain to demonstrate our idea. We've used remis ide to generate our algorithm. Using ganache, we've taken some dummy accounts. Using metamask wallet the holder, authority, vaccine providers, and Issuer’s account have been taken. Using web3 js the frontend backend has been connected.

## 3.2 System Design

This research has two parts. One is the test and vaccination certificate generation and the other one is the prioritization-based vaccination. The four main entities of our system are Authority, Issuer, Vaccine Provider, Holder.

Authority will have the Governance of the whole system. In our system, Bangladesh Government will be the authority. Authority will bear all the development costs of the system.

Figure 3.2.1 denotes the registration form of Authority.

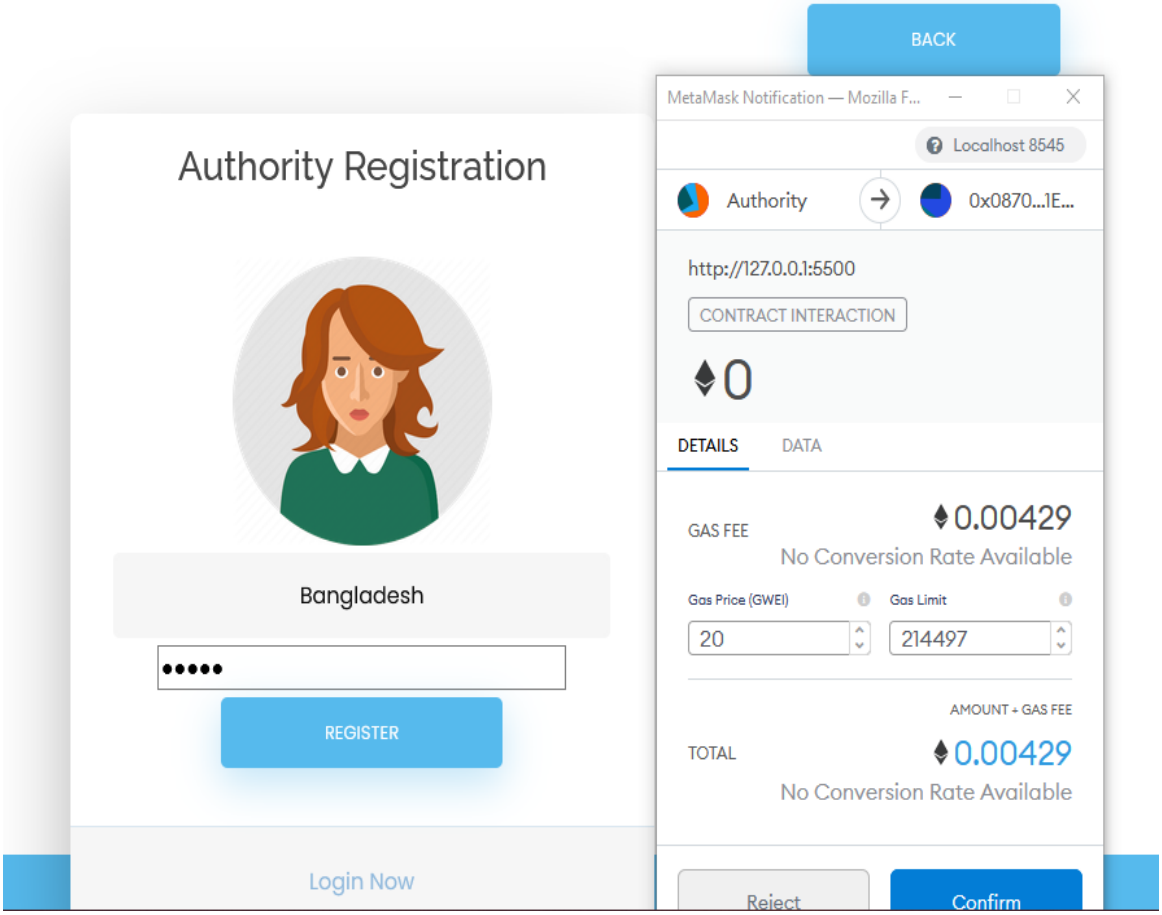


Figure 3.2.1: Authority's Registration

Figure 3.2.2 denoting the duties of authority to do. Authority can view its own profile, add or update vaccine storage, set priorities, and so on.


Figure 3.2.2: Authority's Governance

Figure 3.2.3 shows the criteria that have to fill up by the authority to update or add new vaccine information after stock confirmation.

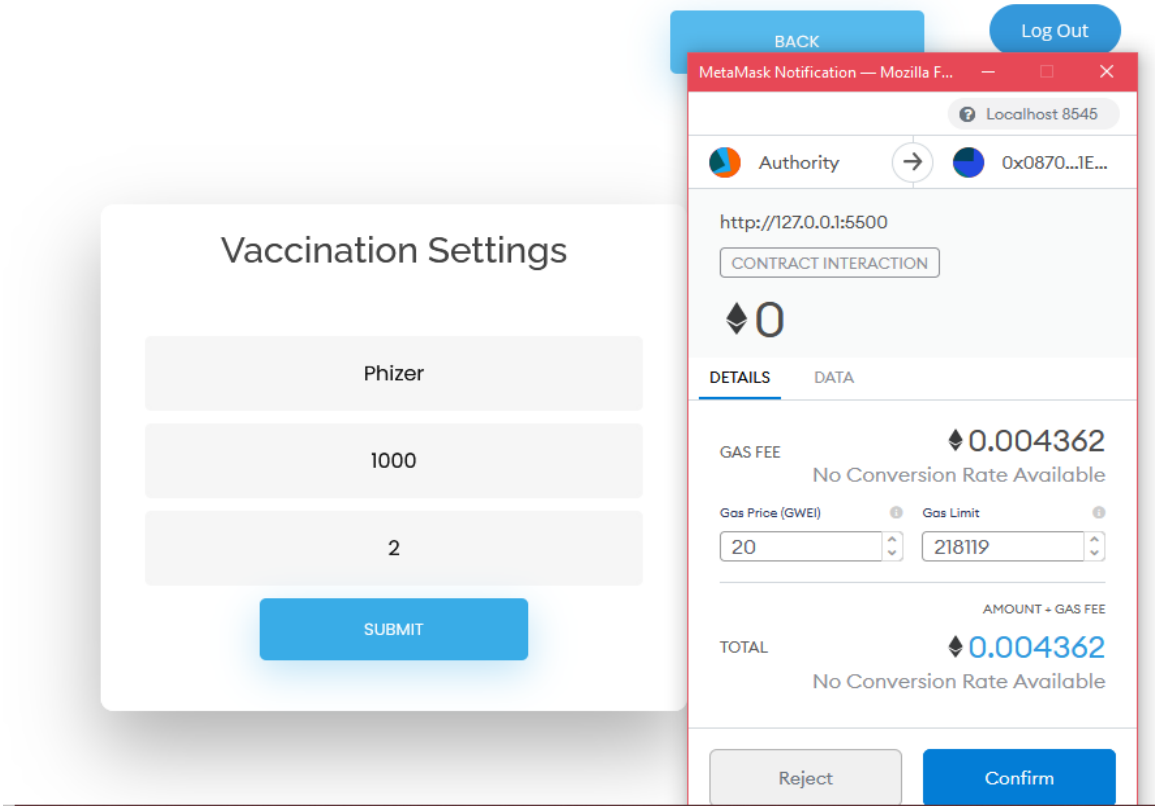


Figure 3.2.3: Add or Update Vaccine Storage

Issuer are the individual who will issue the test results of the patient. The issuer can register on the system by filling up necessary information like his name, profile photo, location, qualification, and password. The following figure 3.2.4 is the form of registration for the Issuers.

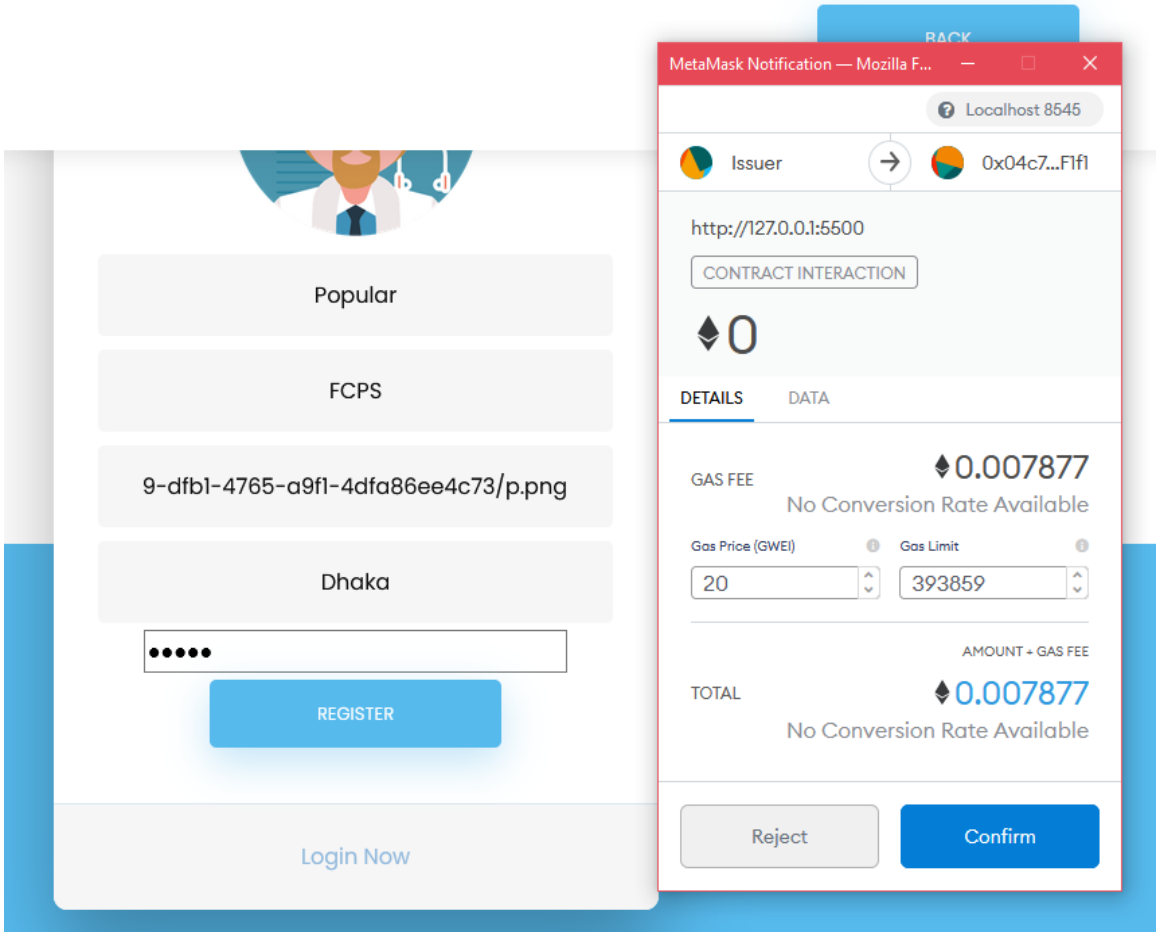


Figure 3.2.4: Issuer Registration

After issuing one's result, his information will be added to that result like issued by Mr. 'X'. Thus, his identity will be traceable. And he cannot escape by doing any malicious work. After adding issue result and issuers info along with the tested person info a QR code will be generated which will be used as a covid test passport.

The following two figure 3.2.5 and 3.2.6 reflects the way how issuer issue result and provide QR code as test certificate.

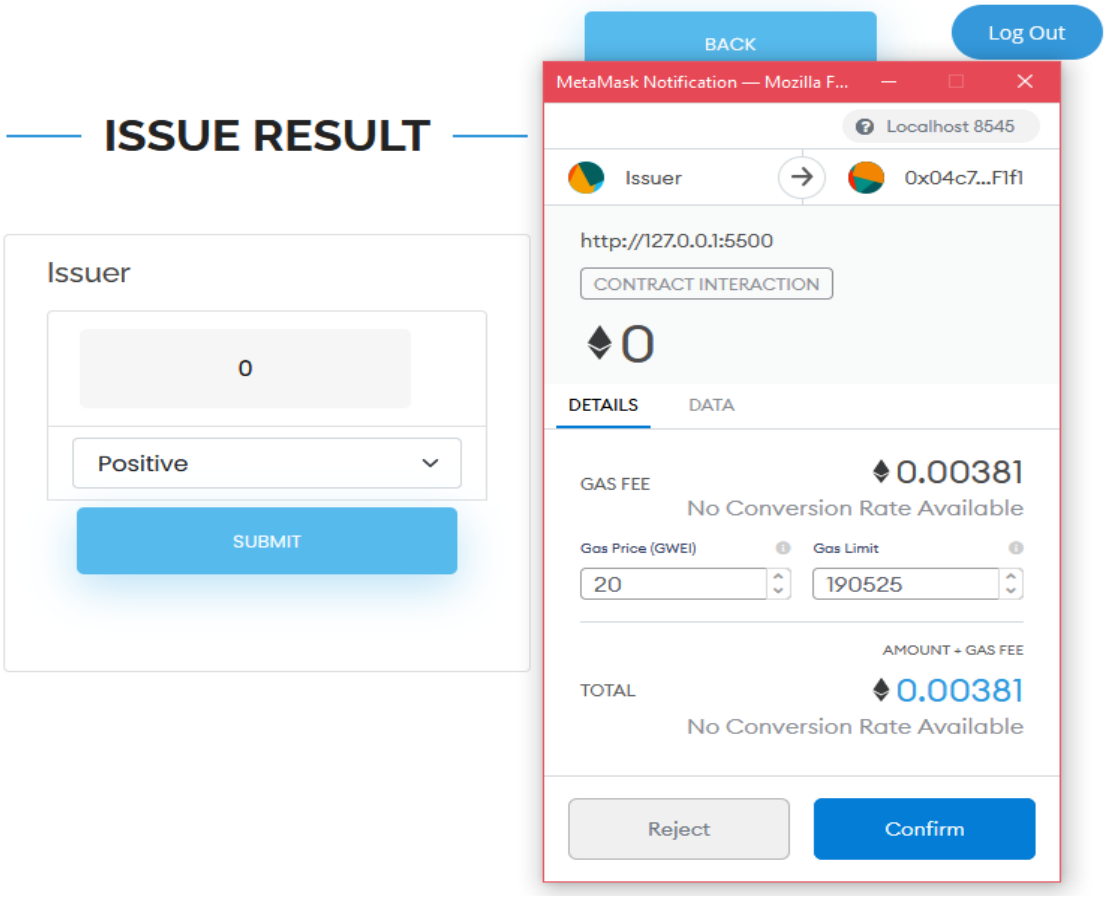


Figure 3.2.5: Issue Test Result

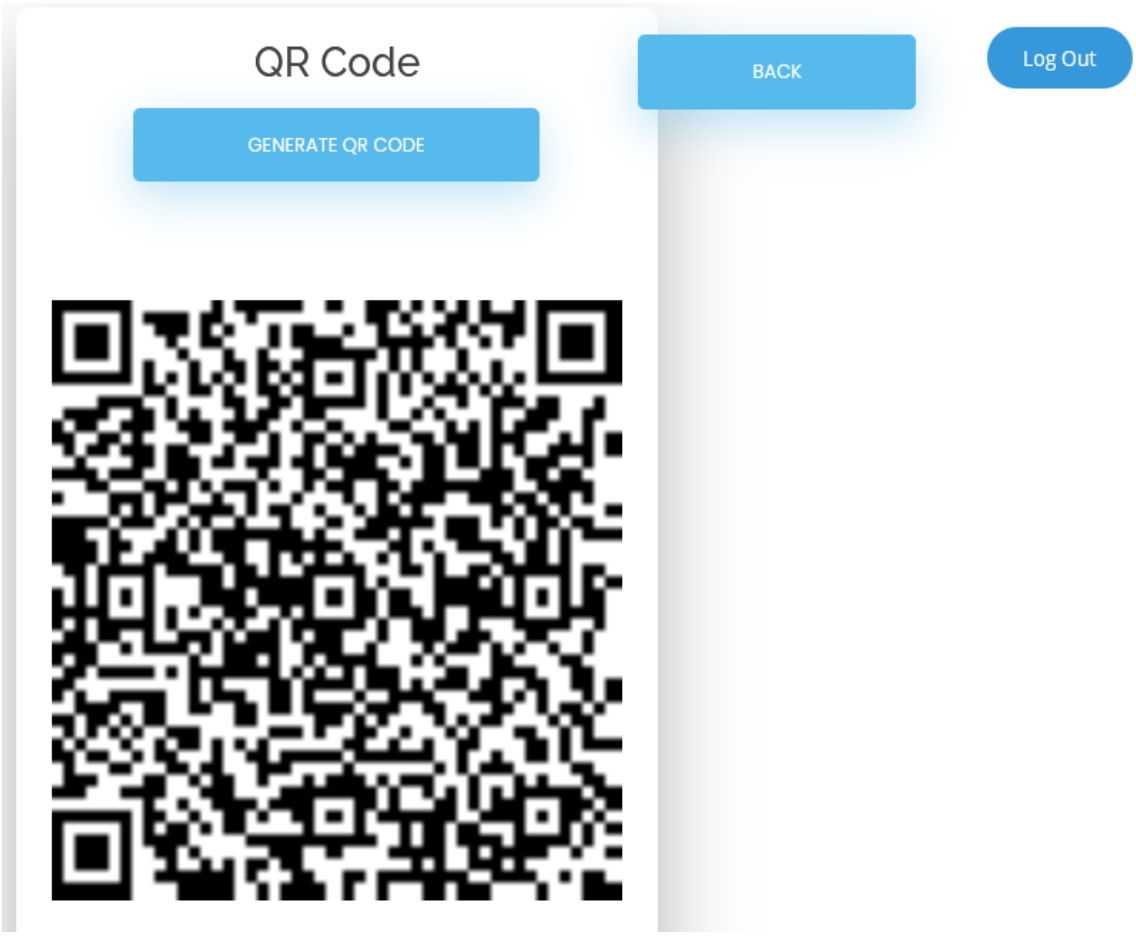


Figure 3.2.6: QR Code of Test Certificate

Vaccine providers are the registered hospitals where inoculation will be done. By giving their name, location, profile photo they can register.

Figure 3.2.7 is the registration form of the vaccine provider.

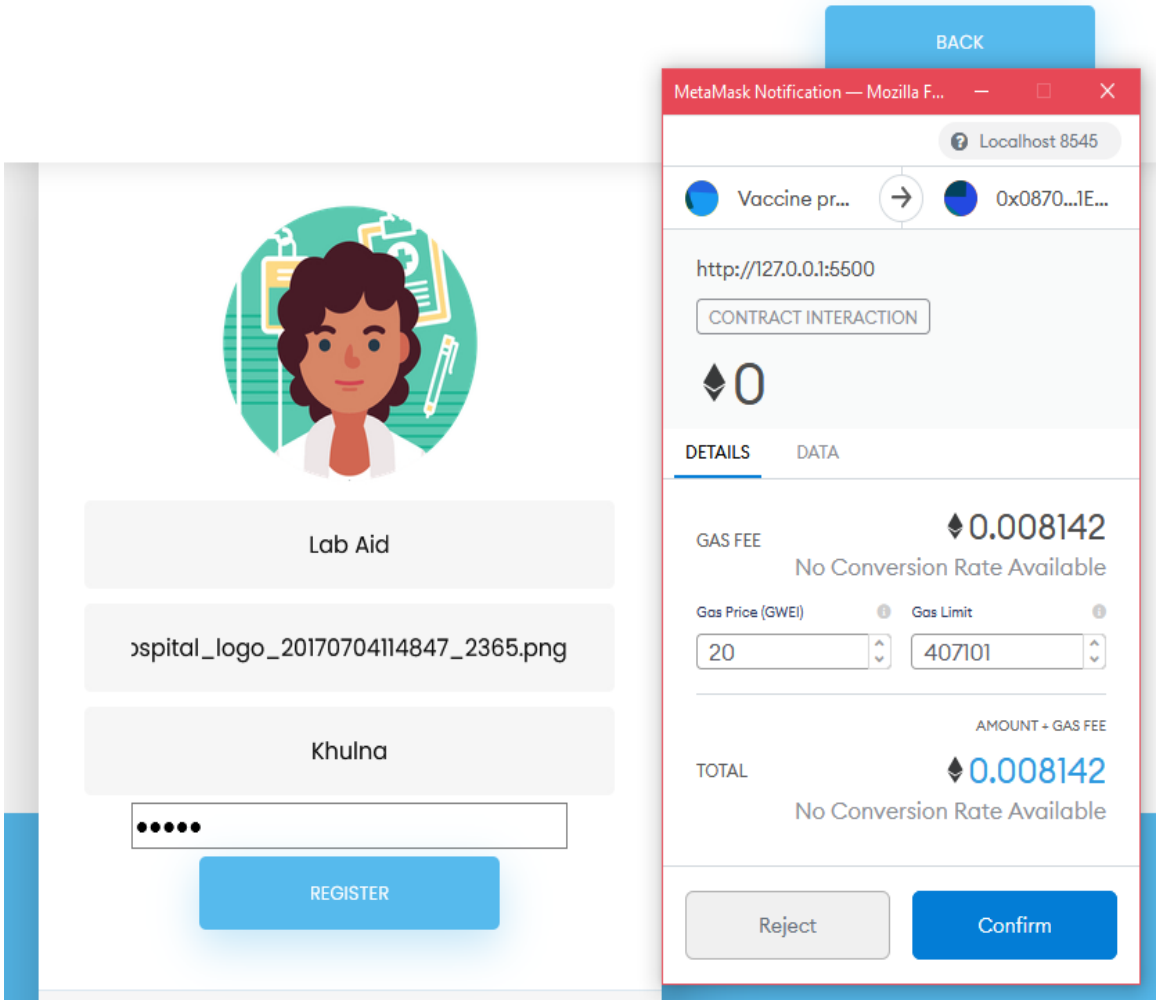


Figure 3.2.7: Vaccine Provider Registration

On the basis of the vaccine availability, they can inoculate. Here the inoculated vaccine info will be added after inoculation along with the vaccine providers and the inoculated person info a QR code will be generated. That can will be used as a vaccine passport.

The following two figures 3.2.8 and 3.2.9 show how the inoculation will be done and the QR code of the vaccination passport.

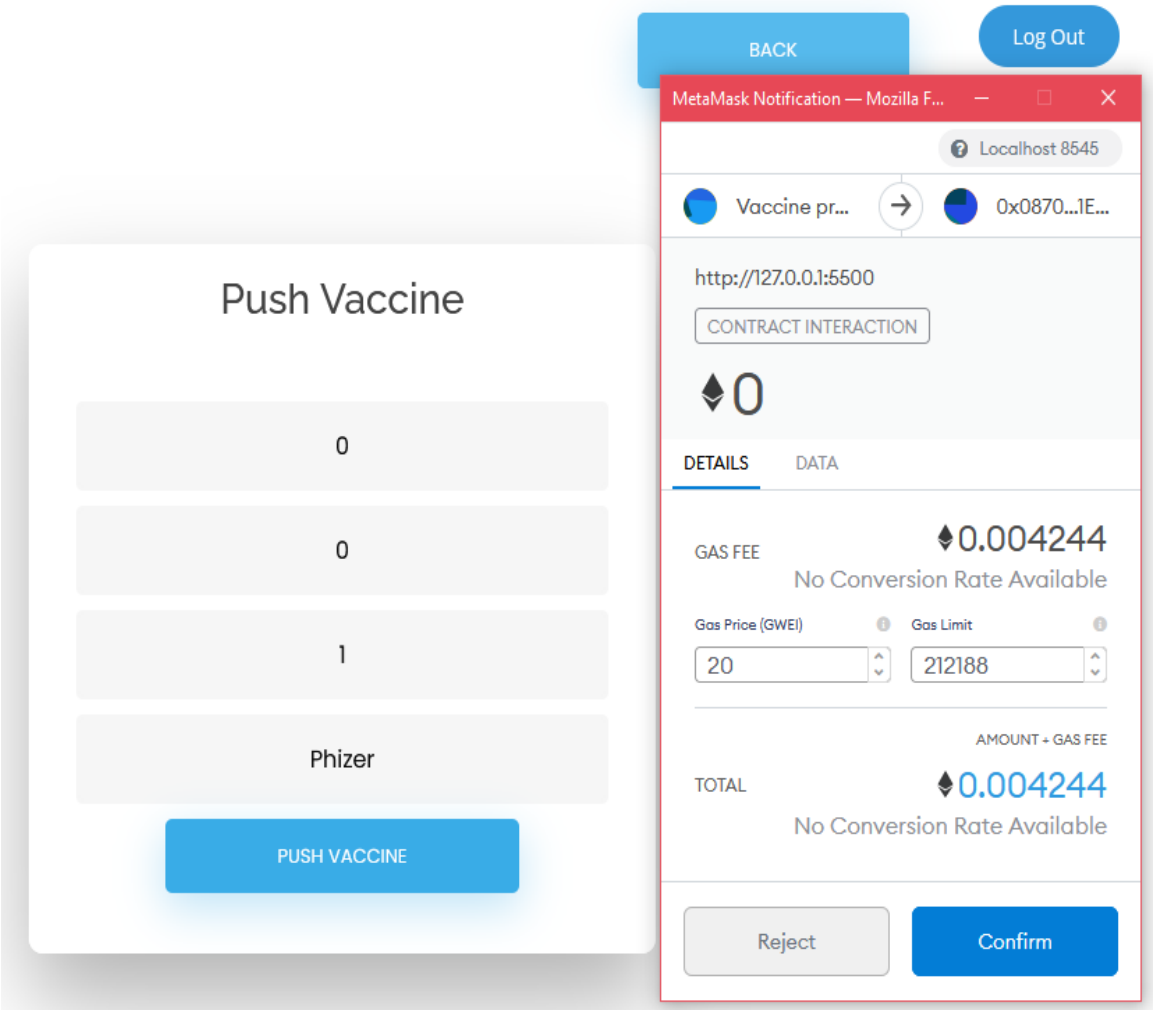


Figure 3.2.8: Inoculation

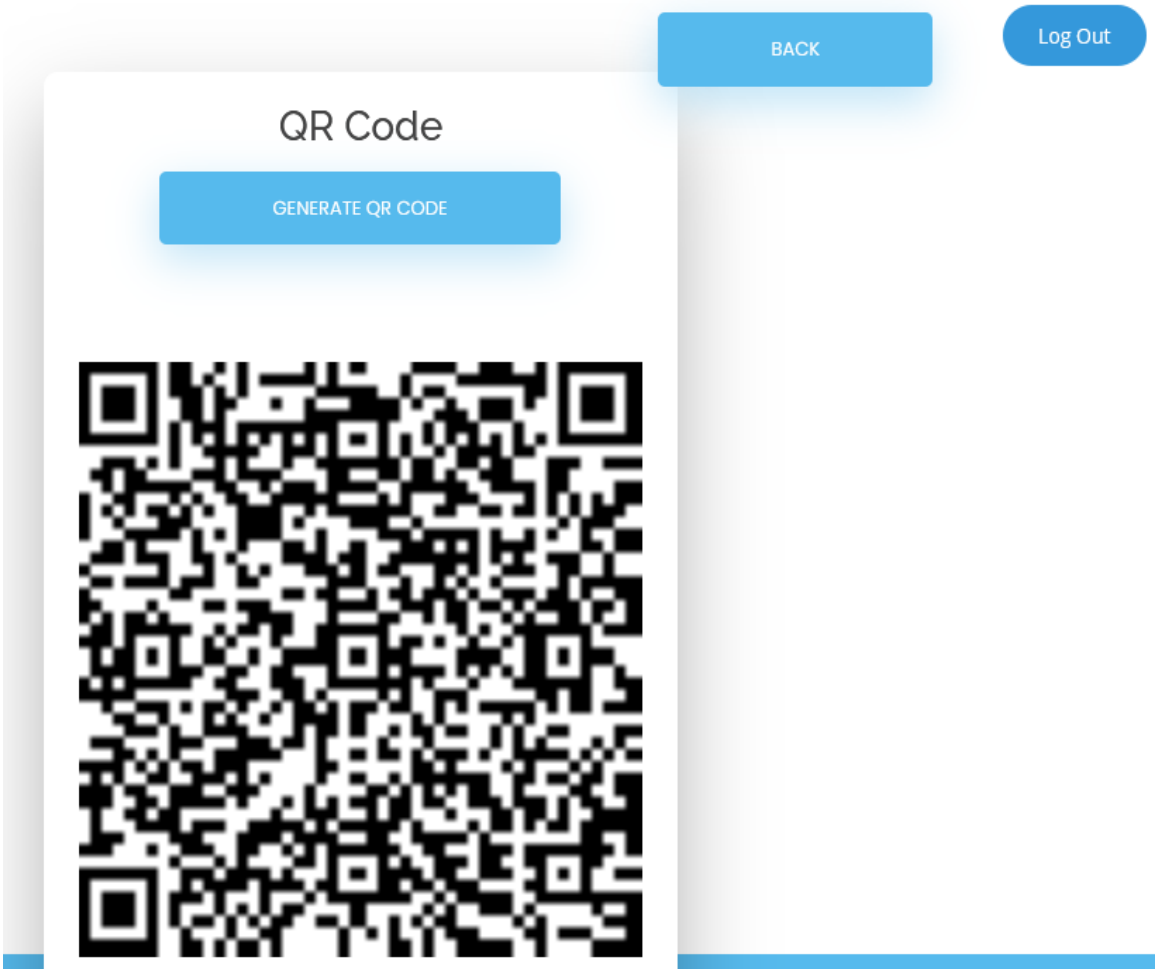


Figure 3.2.9: QR Code of Vaccination Certificate

The in general people who will be inoculated is the holder. By giving their name, profile photo, location, the age they can register themselves in the system. After that, they can apply for tests and vaccination from the system. Figure 3.2.10 denotes the registration form of holders.

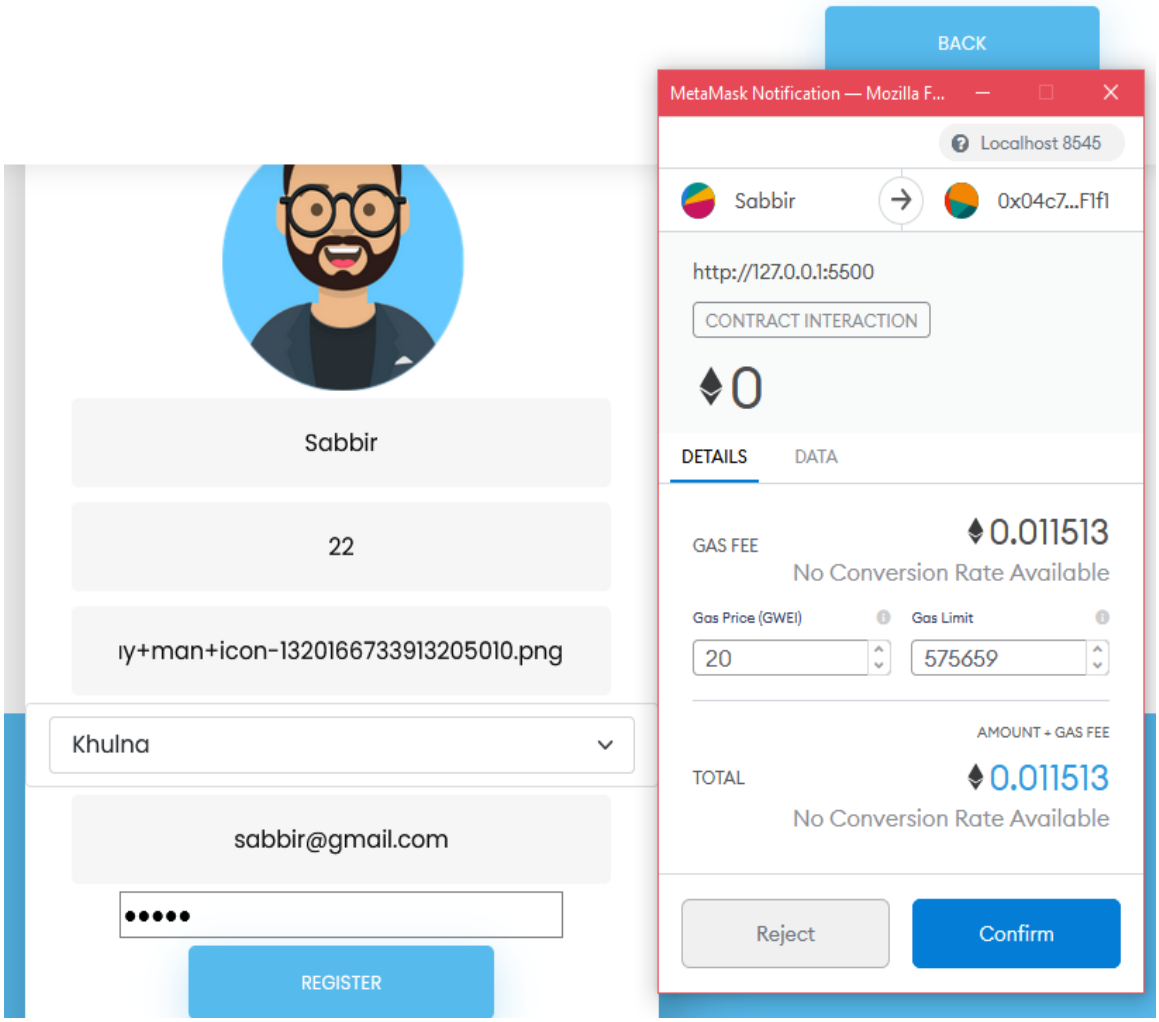


Figure 3.2.10: Holder registration

The QR code that will be generated after issuing the result will be used as a test passport and the last QR code that will be generated after being vaccinated will be used as a vaccination passport in the future. As these, all will sustain in blockchain so that no change of fake report generation. If a QR code generated that can be cross-checked from the system easily thus the fraudulent activities can be restricted.

The prioritization-based vaccine concept raises due to the limited manufacturing quantity of vaccines. We've analyzed the positive and negative tested ratios. As the location where the positive tested patient is greater according to the total test is at high risk. The negative people should be vaccinated as early as possible to curb the spreading.

### 3.3 Proposed Methodology/Applied Mechanism

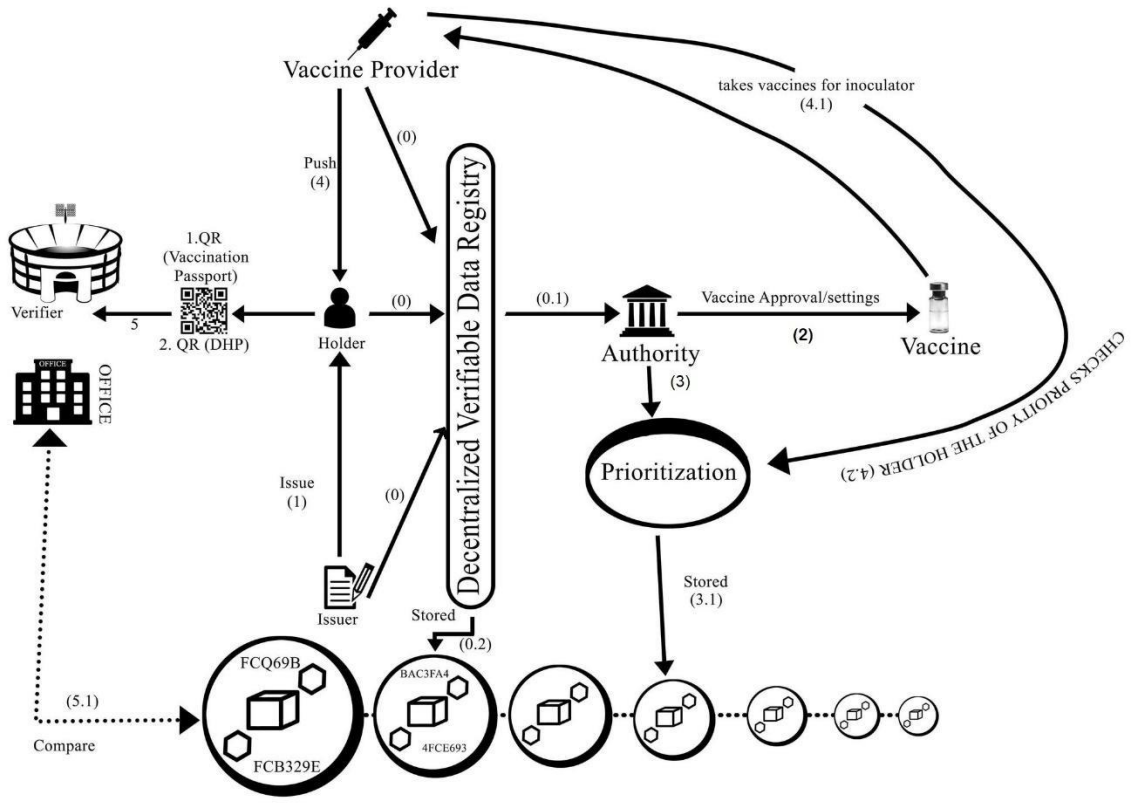


Figure 3.3.1: Methodology (workflow and use case)

The fig denotes the whole methodology of the project.

- the very first step (0) is the prerequisite step. In this step, all the issuers, holders, issuers will sign up as an entity by choosing their roles.
- the next step (0.1) is the identity verification process where the signed-up entities will be verified by analyzing their provided data. On basis of that, the authority can accept or reject that entity.
- Then comes the accessibility (0.2). The signed-up entities can operate the system after got acceptance by the government who is the authority.
- In this step (1) the general user will be able to register themselves by filling up necessary information like name, age, location, photo URL, and then they can apply for the test. After applying the assigned issuer will issue the result.
- Now the issuer will generate the QR code of the test certificate where the issuer's id will be included. (1.1)
- Well, the authority has the access to update vaccine storage by providing necessary information about the vaccine. (2)
- Here comes the most unique feature of prioritization (3) of our project. Prioritization is a Mandatory term as there is a limitation in vaccine production. Only three approved vaccine is available and the whole world is depending upon them. In a country like Bangladesh with a huge population, it's not possible to provide vaccines in a month. So, the limited vaccines should use effectively. We have measured the ratio of a tested positive and total test case of a specific location. A location with a high ratio is in danger as the ratio is higher. So, it's important to vaccinate the negative people so that the spreading becomes in control.
- Here the list (3.1) of the prioritized location will generate and store in the blockchain. So that none can change the preceding. This order has to be maintained appropriately otherwise vaccinated data cannot be imported into the system.
- -Now (4) the assigned vaccine providers can inoculate people according to the preceding.

- -To resume the vaccination process vaccine provider request (4.1) for vaccines to the authority.
- -In this step (4.2) the vaccine provider will ask the individual holder to provide their test certificate and by taking that he or she will check whether the individual is allowed to take the vaccine according to the preceding.
- In this section (4.3) the vaccine provider will provide the vaccination passport where the holder's vaccination information along with the provides id will be shown. By this, the authenticity of the vaccine certificate is being ensured and it can be used in the future with proper trust.
- The verifier (5) can be any organization or place where a vaccination passport or testing passport is required to get access. By providing those certificates in form of a QR code will ease the way of current and post covid period. As all these will happen on the blockchain so questions related to trustworthiness will be ensured by the transparency of the system.

Finally, the QR codes can be extracted and by providing that info to the system the validity of those QR codes can be ensured.

### 3.4 Implementation Requirements

Currently, this project runs as a dummy. It's not live yet. To make it live funds required as cryptocurrency cost is very high. To make the dummy project we've used ganache for taking dummy account which offers us 10 fake accounts which contain 100 ethers. These are for only development purposes. Meta mask wallet has used to store those accounts and make transactions. We've done our coding in remix Ethereum ide. A smooth simple web application has been developed using bootstrap and simple JavaScript. By using the web3 js library we've connected both our front end and back end interactive.

If we want to make it live then the whole system has to deploy in the Ethereum network. Web hosting required for the web application. Crypto wallet and ether will be needed to register on the network. These can be listed below.

- Web hosting
- Crypto wallet

- Ether
- An authority who will bear the initial deployment cost.

### 3.5 Implementation

We've implemented our system in Ethereum by using remix ide as we've mentioned earlier. We've generated three smart contracts those are vaccination, locationInfo, dhp. The following figure 3.5.1 denotes the UML diagram of all of those contracts and figure 3.5.2 is the ER (entity relationship) diagram of our whole system.

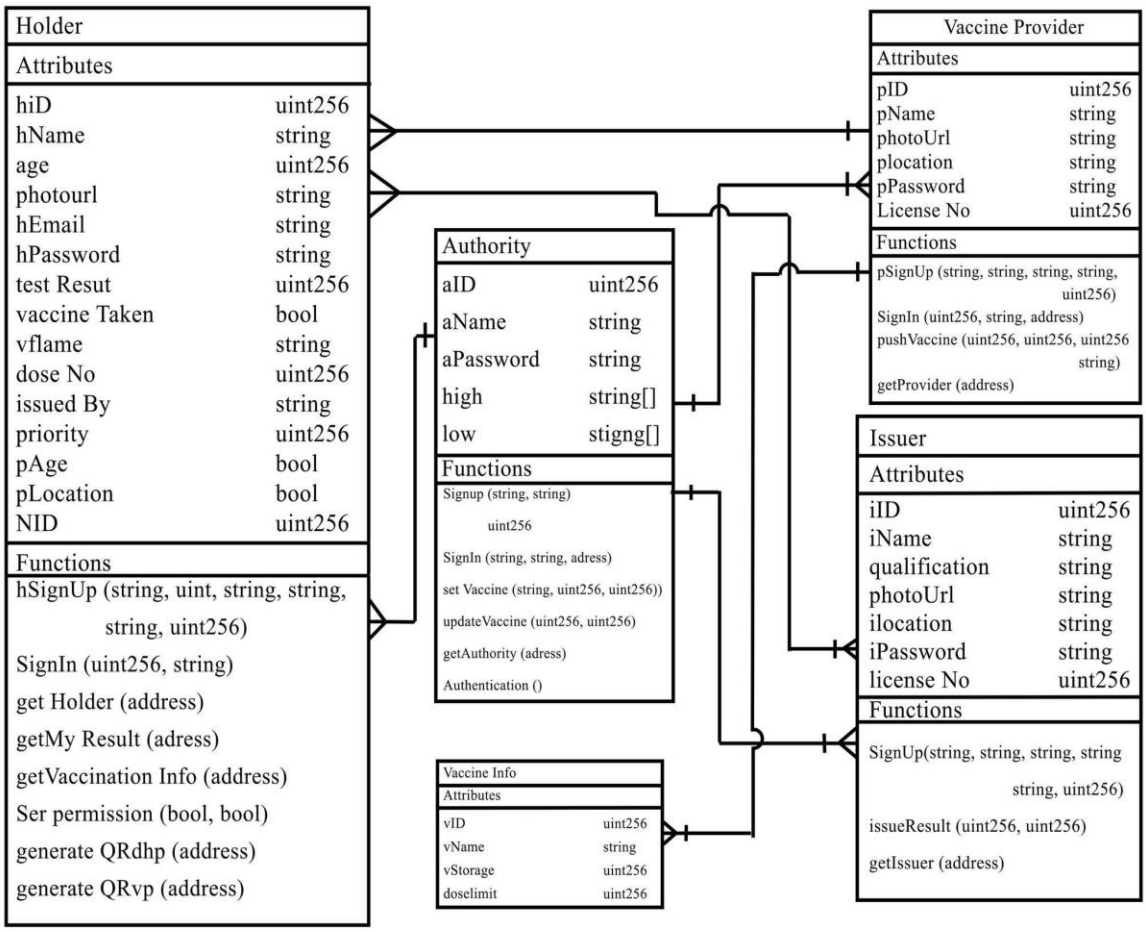


Figure 3.5.1: UML Diagram

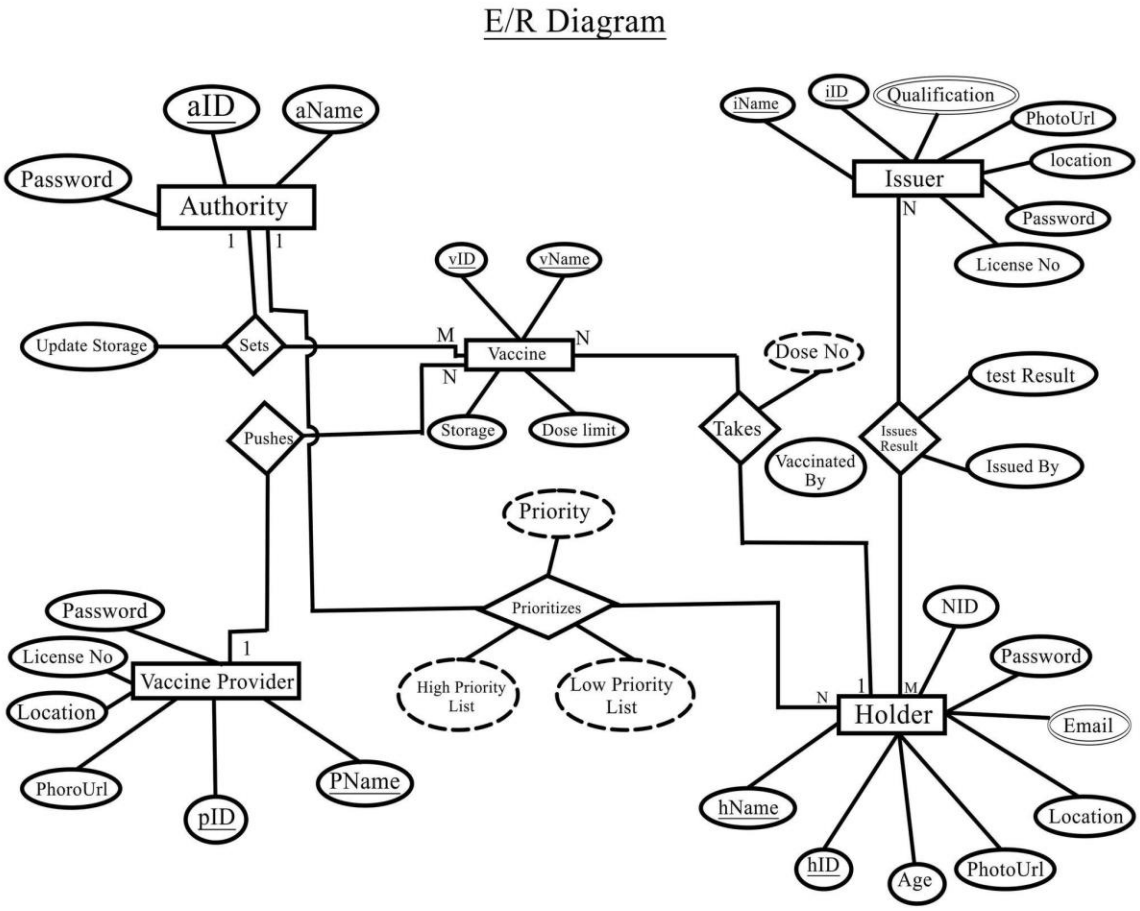


Figure 3.5.2: Entity Relationship Diagram

We've made the locationInfo smart contract purely independent. But both dhp and vaccination smart contract have been connected with each other and both of them are connected with the locationInfo smart contract. Duties of users and holders have been implemented in dhp smart contract. Using this contract, the test certificate will be generated. On the other hand, the vaccine, authority, and vaccine providers feature have implemented on vaccination smart contract. This contract will finally generate the QR code of the vaccination passport or certificate.

The locationInfo smart contract stores the location of individual users to make the ratio of total test and total positive cases and list the ratio in descending order. By which the vaccination will be done.

Now the Algorithms of some key features have been discussed as below:

- **SignUp function of all interface in DHP smart contract:** During signing up the individual have to choose his or her role. There are four roles that can be chosen those are holder, issuer, authority, and vaccine provider. We've created four checkers to check whether the individual's wallet is already existing as a role or not. If the checker allows then the account can proceed to register. After registration, the SignUp function will inform this event to all the relevant entities to change the date and time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified.

  The figure 3.5.3 and 3.5.4 is the algorithm that we used to develop sign up function.

**Algorithm 1:** dhp: Checker (In General) - query

```
Initialisation of address (holds the Ethereum Address of the function
 caller).;
i=0;
while i less than total length of the structure do
    if The caller has already registered then
        break ;
    end if
    i++;
end while
Return (i);
```

[N.B.- Checker function finds the ID which is given after the registration (If not registered it returns a greater value than its total length)]

Figure 3.5.3: Algorithm-Checker

**Algorithm 2:** dhp: SignUp (In General) - TX

Initialisation of Details (required details of the function caller to register).;

**Checker()**;

**if** *function caller has no registered account and has filled all the required fields* **then**

  Using the function caller's information, emit an event to alert listeners about the user addition.;

**else**

  Return the contract to its previous state by showing an error.;

**end if**

Figure 3.5.4: Algorithm-DHP SignUP

- **SignIn function of DHP smart Contract:** During sign-in by combining both wallet address and the id of the wallet owner, a new hash will be generated that makes the sign-in function more secure. After that, the owner also has to provide his password. The new hash will be compared with all the hashes that combined in the system according to the user's specification. There's a flag used to check the validation of the user. After doing all these the user can access his or her role menu. Figure 3.5.5 is the algorithm that we've used to develop Sign in function.

**Algorithm 3:** dhp: SignIn

```
Initialisation of SID, Password, Address. (Address holds the Ethereum
 Address of the function caller);
Flag = "None";
if new hash == existing Issuer hash then
    Flag = "issuer";
else if new hash == existing Holder hash then
    Flag = "holder";
else if new hash == existing Authority hash then
    Flag = "authority";
else if new hash == existing Vaccine Provider hash then
    Flag = "vaccine provider";
else
    Show an error or failed to Sign In.;
end if
```

Figure 3.5.5: Algorithm-DHP SignIn

- **IssueResult Function of DHP smart contract:** In our system only, the registered issuer is allowed to issue the result. To verify the issuer the caller's address will be checked with the account holder's address. If it satisfied then the issuer will issue the result by providing the holder's id and the test result. Then the function will send an event to entities that are involved with this function and change the info along with time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified.

  Figure 3.5.6 is the algorithm that we've used to illustrate the IssueResult function.

**Algorithm 4:** dhp: Issue Result - TX

Initialisation of caller ID, caller address, Test Result.;

**Issuer Checker()**;

Holder's test result = Positive/Negative;

Increase total test numbers by 1 for that area;

**if** *test result == Positive* **then**

  Increase total positive numbers by 1 for that area;

**end if**

Issued By = Issuer ID;

Figure 3.5.6: Algorithm-DHP IssueResult

- **UpdateVaccine function of Vaccination smart contract:** The upgradation or addition power of new or existing vaccine is in authority's hand. So, during operating that function it needs to ensure whether the wallet holder is an authority or not. To do so the function caller address will be checked. If it satisfied then by providing vaccine name, quantity, and doses authority can add a new vaccine. Then the function will send an event to entities that are involved with this function and change the info along with time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified. Figure 3.5.7 is the algorithm that we've used to illustrate Add or Update vaccine function.

**Algorithm 5:** vaccination: Add Vaccine - TX

Initialisation of caller ID, caller address, Vaccine Name, Storage, Dose Limit.;

**Authority Checker()**;

Using the function caller's information, emit an event to alert listeners about the vaccine addition;

**Algorithm 6:** vaccination: Add Update- TX

Initialisation of caller ID, caller address, Vaccine ID, Quantity Added.;

**Authority Checker()**;

Using the function caller's information, emit an event to alert listeners about the vaccine update.;

Figure 3.5.7: Algorithm-vaccination Add/update vaccine

- **Prioritization function of vaccination smart contract:** Now the most significant feature of our system is prioritization that can be done by the authority. So, it needs to ensure whether the wallet belongs to the registered Authority or not. To do so the function caller address will be checked. After satisfying the authority will be able to make a priority list of the holders who exist that time in the system. He will just click a single button else will be done in the backend. We've taken 8 divisions to Illustrate our work. So, there are 8*2 16 levels to prioritize the holder's priority. Then the function will send an event to entities that are involved with this function and change the info along with time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified. Figure 3.5.8 is the algorithm that we've used to illustrate the prioritization function.

**Algorithm 7:** vaccination: Prioritization - TX

```
Initialisation of caller address.;
Authority Checker();
j=8, k=0;
while j runs for 8 times do
    if Totaltest greater than 1 then
        while traversing the entire holder's length do
            if the holder has Positive result after testing Covid-19 and holder location
             == running location then
                Set the holder's name to the low priority list;
                Increase the number that belongs to the running (j) priority;
                Holder Priority = j;
            else if the holder has Negative result after testing Covid-19 and holder
             location == running location then
                Set the holder's name to the high priority list;
                Increase the number that belongs to the running (k) priority;
                Holder Priority = k;
            end if
            J++;
            K++;
        end while
    end if
end while
```

Figure 3.5.8: Algorithm-vaccination Prioritization

- **Authorization and approval of Issuer, Vaccine Provider, and Holder registration function of vaccination smart contract:** Issuer, holder, and vaccine provider will be allowed to the system after being approved by the authority. So only authority has that power to do this. To do so the function caller address will be checked. After being satisfied the authority will be allowed to authorize the requested entities. Then the function will send an event to entities that are involved with this function and change the info along with time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified. Figure 3.5.9 is the algorithm that we've used to illustrate the function.

**Algorithm 8:** vaccination: Review User Details (Issuer, Vaccine Provider and Holder) - query

**Input:** None. (A counter variable "m" is globally declared and initialized '0');

"M" refers to the index number of the structure;

**if** *the value of m (an ID) less than length of the struct* **then**

  Return (Details) [Details include - License Number for Vaccine Providers & Issuers, NID for Holders, etc];

**else**

  Show Error.;

**end if**

**Algorithm 9:** vaccination: Approval - TX

**Input:** Approval (Accept/Reject).;

**Authority Checker()**;

**if** *Approval == Accept* **then**

  The user enrolls the system successfully.;

**else if** *Approval == Reject* **then**

  The user is banned from the system.;

**end if**

m++;

Figure 3.5.9: Algorithm-vaccination Prioritization

- **PushVaccine function of Vaccination smart contract:** The inoculation power contains in the vaccine provider entity. So, its need to verify during inoculation that the vaccine provider is authentic. To do so the function caller address will be checked. After being satisfied the vaccine provider then allowed to vaccinate the individual accordingly to the priority list. Due to long intervals between two doses the lower priority people can be vaccinated just after high priority people are being completed their first dose. Then the function will send an event to entities that are involved with this function and change the info along with time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified. Figure 3.5.10 is the algorithm that we've used to illustrate the function.

**Algorithm 10:** vaccination: Inoculation/Push Vaccine - TX

```
Input: Authority ID, Vaccine ID, Holder ID, Vaccine Name;
Vaccine Provider Checker();
j=0, k=0;
while j less than 8 do
    if HighPriorityNo[j] != 0 then
        [HighPriorityNo[j] - The number of holders in j-th priority who haven't taken the
          first dose] break;
    end if
    j++;
end while
if j less than 8 then
    if Holder belongs to the running priority then
        Push Vaccine;
        Vaccine Storage -=1;
        Dose Number (Holder) +=1;
        HighPriorityNo[j] -=1;
    end if
end if

else if j greater equal 8 then
    while j less than 16 do
        if LowPriorityNo[k] != 0 then
            break;
        end if
        j++;
        k++;
    end while
    if  j less than 16 then
        if Holder belongs to the running priority then
            Push Vaccine;
            Vaccine Storage -=1;
            Dose Number (Holder) +=1;
            LowPriorityNo[j] -=1;
        end if
    end if
end if
```

```
else if j greater equal 16 then
    k=0;
    while k less than 8 do
        if HighPriorityComp[k] != 0 then
            break;
        end if
        K++;
    end while
    if k less than 8 then
        if Holder belongs to the running priority then
            Push Vaccine;
            Vaccine Storage -=1;
            Dose Number (Holder) +=1;
            HighPriorityComp[k] -=1;
            if Dose Number == Dose Limit then
                Eliminate the Holder's name from the vaccination list;
            end if
        end if
    end if
end if

else if k greater equal 8 then
    j=0;
    while k less than 16 do
        if LowPriorityComp[j] != 0 then
            break;
        end if
        j++;
        k++;
    end while
    if  k less than 16 then
        if Holder belongs to the running priority then
            Push Vaccine;
            Vaccine Storage -=1;
            Dose Number (Holder) +=1;
            LowPriorityComp[k] -=1;
            if Dose Number == Dose Limit then
                Eliminate the Holder's name from the vaccination;
            end if
        end if
    end if
end if
```

Figure 3.5.10: Algorithm-vaccination Push Vaccine

- **Profile Permission of DHP smart contract:** For keeping the holder's personal information (age, location) secure there's a feature of hiding the information. The holder can do this. But before this, it needs to check whether the requested wallet is a holder or not. To do so the function caller address will be checked. After successful checking, the holder is allowed to change the status to hide. Then the function will send an event to entities that are involved with this function and change the info along with time. The BC (Blockchain Client) and gateways can operate this event as a filtered event so that their records are properly modified. Figure 3.5.11 is the algorithm that we've used to illustrate the function.

**Algorithm 11:** dhp: Profile Permission - TX

**Input:** Permission Parameters.;
**Holders Checker()**;
Info 1 = Show/Hide;
Info 2 = Show/Hide;
.....;
Info 'n' = Show/Hide;

Figure 3.5.11: Algorithm-DHP profile permission

- **Health passport of DHP smart contract:** After completing the covid test the holder can generate a QR code as a health passport. But before doing this the wallet should be checked whether the wallet belongs to a specific holder or not. To do so the function caller address will be checked. If the requirement satisfied then the holder can generate his health passport which contains his name, age, photo, location, test result, and the name of the issuer. Figure 3.5.12 is the algorithm that we've used to illustrate the function.

**Algorithm 12:** dhp: Digital Health Passport (DHP) - query

**Input:** Address (holds the Ethereum Address of the function caller).;

**Holders Checker**();

**Return**(Holder's name, age, photo, location, test result, the name of the Issuer) [In a form of QR code abiding the holder's given permission];

Figure 3.5.12: Algorithm-DHP Digital Health Passport

- **Vaccination passport function of DHP smart contract:** After taking the vaccine the holder can generate a QR code as a vaccination passport. But before doing this the wallet should be checked whether the wallet belongs to a specific holder or not. To do so the function caller address will be checked. If the requirement satisfied then the holder can generate his vaccination passport which contains his name, vaccine taken, vaccine name, dose number, and priority.

  Figure 3.5.13 is the algorithm that we've used to illustrate the function.

**Algorithm 13:** dhp: Vaccination Passport (VP) - query

**Input:** Address (holds the Ethereum Address of the function caller). ;

**Holders Checker**();

**Return**(Holder's name, vaccine taken, vaccine name, dose number, priority) [In a form of QR code abiding the holder's given permission] ;

Figure 3.5.13: Algorithm-DHP Vaccination Passport

# CHAPTER 4
# EXPERIMENTAL RESULTS AND DISCUSSION

## 4.1 Experimental Setup

We've experimented with our system by taking 10 dummy accounts from the ganache. Ganache is a great tool which provides fake accounts with dummy ether for development purpose. Figure 4.1.1 shows the ganache interface with some dummy accounts.

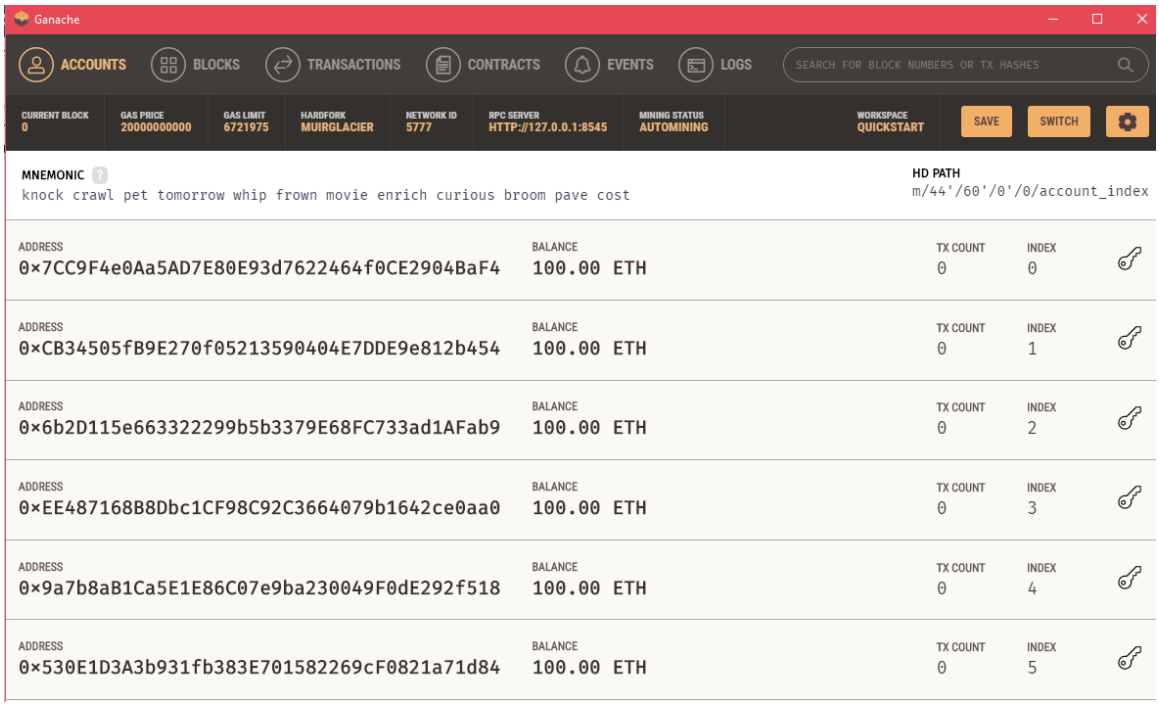


Figure 4.1.1: Ganache interface of dummy Ethereum account

We've taken an authority account an issuer and a holder's account. Then signed those up to the system according to their responsibility. Then we've taken more than 5 accounts and signed up those as holders. Then from the authorities' account, the whole contract has been deployed. The vaccine storage with vaccine quantity and name has been updated from the authority's account.

Now the holder's result has been issued one by one by the registered issuer. By setting the holder's id and the test result, the issuer updates the test result of each holder. The result

has published as a QR code which is the test passport. By verifying that QR code he proofs himself whether he or she is positive or not.

Now the authority will set priority by clicking a button. In the backend, the ratio according to the holder's location has generated. Now every entity has the access to see the priority list. By maintaining that list, the vaccine provider will then vaccinate the holders. After vaccination, a QR code has generated for each holder. Holders can view that from his id. And can use it to prove himself vaccinated.

For vaccines that need two doses to complete, there's an interval between the 1st dose and the second dose. For this reason, we've maintained the 1st dose according to the prioritization. Here's a question that arises that the vaccines need to complete both doses for marking an individual vaccinated. So, does the system need to fulfill both doses to count an individual as vaccinated? The answer is no. We've maintained the prioritized criteria for the first dose only. After getting the first dose using the preceding, the system will allow the next individual to vaccinate. But the person who got only 1st dose won't be out of the list. He or she will be counted as vaccinated and remove from the list after getting both doses. For taking the second dose, the same order will be maintained to complete the whole inoculation.

During verification, a holder can allow his age and location info to view by the verifier. If the holder doesn't want that he or she can hide the age and location from the QR code. Thus, privacy has been maintained.

This is how we've set up our experiment and got a fruitful result.

### 4.2 Experimental Results & Analysis

We've presented our idea through this work. Our system doing well in the development section. We've done several tests and got no technical errors. Well, this kind of system will help a lot for a country like Bangladesh where it's crying need to ensure a disciplined vaccination. To compete with this war every should think about mankind and be tolerant. Transparency and immutability made the system more acceptable. Moreover, the test certification and vaccination certifications importance has already been tested in a recent test report scam. So, to bring people's trust and the acceptance of both of the certificates our system will play a key role.

Nothing can be 100% perfect. There's some drawback also. The cost of Ethereum has increased at an alarming rate. Even last year it was within a tolerable limit. But the fact is we have implemented our system which proves that this concept can be introduced. By introducing a centralized server along with blockchain the cost can be minimized. We don't need to store whole data in blockchain rather than the most sophisticated one should store. Or private blockchain can also do the job. Cryptocurrency is not allowed in Bangladesh yet. So instead of using a public blockchain, a private blockchain will solve that problem. In our future work, we will introduce private blockchain or hybrid blockchain to mitigate these issues.

### 4.3 Discussion

Our proposed system meets all the research questions. It’s an effective way of vaccination. Though the cost is higher in terms of mankind cost should be negotiable. Proper inoculation can prevent covid from the world. We can again lead our lives like the past. But indiscipline vaccination will be a threat to the nation. Cause it cannot curb the spreading. A falsified test certificate also a threat because that individual with a false certificate is a threat to healthy people. So, from both of these perspectives, the system will be a bite at the cherry to overcome this pandemic.

# CHAPTER 5
# IMPACT ON SOCIETY, ENVIRONMENT AND SUSTAINABILITY

## 5.1 Impact on Society

In this chapter, we talk about what impact do our project has on our society and environment. We will also discuss the sustainability of our project.

Our goal is to provide Digital Health Passport to people to use this DHP in various sectors like joining workplaces again, traveling, and enjoying facilities from any institution. This passport is proof that the person has been vaccinated and at low risk for him/herself and others. It will greatly impact society as more people at work mean the society and country will develop economically and it will omit financial crisis as well from a person and from the society.

Moreover, as DHP will ensure that a person is shielded by vaccine so that person is less likely a risk for other people, so the person will enjoy the benefit of free-pass to travel anywhere in the world, which also means a vast number of Bangladeshi workers who work in other countries and send us remittance regularly can go back to their work and thus help us to make our foreign reserve richer.

However, the only downside of our research goes to those who can't get ahold of the Digital Health Passport. Initially, our resources aren't as big as possible to provide this service to every people. So, citizens who will be deprived of this benefit will most possibly be discriminated from those who have the DHP. So, the longer impact here can be named discrimination. In such a scenario, the people who have DHP will be highly beneficial, which will eventually encourage people who don't have DHP to get one immediately.

## 5.2 Impact on Environment

The vaccination program has been started in many countries. Unlike Bangladesh, we notice chaos in several places worldwide as they don't have sophisticated measures to ensure the

proper way of vaccine distribution and prioritization. But in our system, vaccine distribution and prioritization have been ensured in such a way so that no obstacles or disorientation would occur. We ensure who gets the vaccine based on priority by a higher ratio.

By ensuring health benefits and successful vaccine distribution, this stand can impact society vastly than anything else to achieve immunity.

More people with vaccine immunity mean less coronavirus in the environment. Thus, our DHP project will help reducing viruses from our environment and make it safer for people. With lesser bodies to spread over, vaccines will eventually get no carrier for fertilization. Thus, they will omit from our environment, and we can move around just like before without having any material to stick to our mouth for protection from the virus, which goes without saying a much-needed relief.

### 5.3 Ethical Aspects

We are using the Blockchain platform to implement the DHP project. The blockchain provides a distributed framework with greater anonymity, accountability, and authenticity. Our research aids in decentralizing the total testing and vaccine providing process, allowing it to be straightforward and private. Our research demonstrated and introduced real-time validation of tamper-proof findings and a straightforward and effective vaccination scheme, a prominent approach to establish ethical ground.

### 5.4 Sustainability Plan

Once a blockchain has been deployed, it can’t be deployed again. So before deploying a blockchain, we need to ensure that there will be no bugs in the system so that redeployment will not be needed. Otherwise, it will cause a problem later. This is a sustainability issue that our system has. Moreover, as we are dealing with cryptocurrency (Ethereum, in our case), the cryptocurrency market is highly unstable. The price can fluctuate to a higher rate at any time and without any explainable cause. This is also a sustainability issue.

On a positive note, our project will ensure a sustainable vaccination distribution program that will eventually benefit society in the long run. Having a DHP will achieve sustainability in returning to our daily life and keeping it that way.

# CHAPTER 6
# SUMMARY, CONCLUSION, RECOMMENDATION AND IMPLICATION FOR FUTURE RESEARCH

## 6.1 Summary of the Study

In this chapter, we talk about the future implications of our work, limitations, and recommendations.

We used the Blockchain platform to implement a Digital health passport, also known as DHP. As blockchain technology is a distributed network that ensures privacy and transparency, our system will eradicate all users' privacy concerns, and the system will be more authentic. Our work will ensure that the test report generation and vaccine passport generation will be tamperproof, and our vaccine program will be based on prioritization as it's not possible to cover all populations under vaccination at the same time due to limited resources.

So proper prioritization will ensure the fastest mitigation of the virus. There will be an authority, holder, the issuer in the testing system, and a vaccine provider in the vaccination program. Finally, a DHP will be generated. DHP will be a certification that says the person's infection status and vaccine immunization status. This system will ensure the effectiveness of the entire process with the help of the blockchain platform.

## 6.2 Conclusions

Our planet is still fighting the unseen virus named Covid-19. Viruses are difficult to combat or produce antibodies against it. We've seen in the past that developing a suitable vaccine for influenza, Ebola, and many others viruses took many years. However, thanks to rapid technological advancements, three vaccines have been approved within a year. Cause of manufacturing constraints, it is difficult to vaccinate all of the population at the same time. As a result, the probability of chaos grows.

In our system, we have implemented all those criteria that ensure authenticity and proper validity. Our Authentic testing certification comes up with impartial and genuine

certificates having no risk of being rejected. We've recently seen a slew of scams involving fake Covid test certificates. Blockchain eliminates the possibility of tampering and increases accountability.
We illustrated cost-effectiveness which demonstrates that our system can promptly provide all of these services. Prioritization is the most distinctive but crucial function that will ensure optimal vaccination.

As a result of modern science's gift, we should expect more licensed vaccines with improved efficacy. We'll be back to our regular routines soon. Since then, we must be mindful of and adhere to all safety precautions.

### 6.3 Recommendation

- The government should promote the program so that many people will be aware and use it.

- Proper guidelines and Q/A facts should be installed by the authority to understand how to use the entire system.

### 6.4 Implication for Further Study

- A mobile application can be made so that people can use it more freely.

- After testing, if a patient’s result comes positive, there can be a doctor’s portal where the potential patient can consult with a doctor and take proper medication.

# REFERENCES


[1] Covid19 Tracker Bd. Online: http://covid19tracker.gov.bd/ [access date: 01 May 2021]

[2] K. Nag, J. Chandra Baray, M. Rahman Khan, A. Mahmud, J. Islam,S. Myti, R. Ali, E. Haq Sarker, S. Kumar, M. Hossain Chowdhury, R. Roy, F. Islam, U. Barman, H. Khan, S. Chakraborty, A. Bad-sha, M. Hossain, S. Ahammad, M. Rahman Chowdhury, P. Ghosh,R. Islam Shimul, R. Ahmmed, E. Hussain Bhuiya, B. Kumar Biswas,M. Mohiuddin, N. Sultana, An mrna-based vaccine candidate against sars cov2 elicits stable immuno-response with single dose, Vaccinedoi:https://doi.org/10.1016/j.vaccine.2021.05.035. URL: https://www.sciencedirect.com/science/article/pii/S0264410X2100607136.

[3] P. P. Nguyen D.C., Dinh M., S. A., Blockchain and ai-based solutions to combat coronavirus (covid-19)-like epidemics: A survey. preprints202004 doi:10.20944/preprints:202004. 0325.v1.

[4] V. Chamola, V. Hassija, V. Gupta, M. Guizani, A comprehensive review ofthe covid-19 pandemic and the role of iot, drones, ai, blockchain, and 5g in managing its impact, IEEE Access 8 (2020) 90225–90265. doi:10.1109/ACCESS.2020.2992341.

[5] M. Rahman, N. Peeri, N. Shrestha, R. Zaki, U. Haque, S. Hamid, Defendingagainst the novel coronavirus (covid-19) outbreak: How can the internet ofthings (iot) help to save the world? Health Policy and Technology 9 (2). doi: 10.1016/j.hlpt.2020.04.005.

[6] H. H. Kung, Y.-F. Cheng, H.-A. Lee, C.-Y. Hsu, Personal health record in fhir format based on blockchain architecture (2020) 1776–1788.

[7] A. Ekblaw, A. Azaria, J. D. Halamka, A. Lippman, A case study for blockchain in healthcare: "medrec" prototype for electronic health recordsand medical research data 13 (2016) 13.

[8] L. M. S. Santiago, J. W. Abijaude, P. de Lima Sobreira, O. A. Wahab,K. E. Guemhioui, F. Greve, Blockchain applied to academic environmentsas a way to ensure educational process quality control, in: 2020 IEEEWorld Conference on Engineering Education (EDUNINE), 2020, pp. 1–5. doi:10.1109/EDUNINE48860.2020.9149491.

[9] M. H. Iftekhar, X. Cui, W. Afzal, Application of blockchain and internetof things to ensure tamper-proof data availability for food safety, Journalof Food Quality. doi:10.1155/2020/5385207. URL: https://doi.org/10.1155/2020/5385207.

[10] H. M., Blockchain-based secure framework for e-learning during covid-19, Indian Journal of Science and Technology 13 (2020) 1328–1341.doi:10.17485/IJST/v13i12.152.

[11] G. Balakrishna Reddy, K. Ratna Kumar, Quality improvement in organicfood supply chain using blockchain technology (2020) 887–896.

[12] G. Kumar, R. Saha, W. J. Buchanan, G. Geetha, R. Thomas, M. K. Rai, T.-H. Kim, M. Alazab, Decentralized accessibility of e-commerce products through blockchain technology, Sustainable Cities and Society 62 (2020)102361. doi: https://doi.org/10.1016/j.scs.2020.102361. URL: https://www.sciencedirect.com/science/article/pii/S2210670720305825.

[13] S. Nakamoto, A. Bitcoin, A peer-to-peer electronic cash system, Bitcoin. URL: https://bitcoin. org/bitcoin. pdf 4.
[14] S. Peng, X. Hu, J. Zhang, X. Xie, C. Long, Z. Tian, H. Jiang, An efficient double-layer blockchain method for vaccine production supervision, IEEE Transactions on NanoBioscience 19 (3) (2020) 579–587. doi:10.1109/TNB.2020.2999637.
[15] M. Eisenstadt, M. Ramachandran, N. Chowdhury, A. Third, J. Domingue, Covid-19 antibody test/vaccination certification: There's an app for that, IEEE Open Journal of Engineering in Medicine and Biology 1 (2020) 148–515155. doi:10.1109/OJEMB.2020.2999214.
[16] B. Yong, J. Shen, X. Liu, F. Li, H. Chen, Q. Zhou, An intelligent blockchain-based system for safe vaccine supply and supervision, International Journal of Information Management 52 (2020)102024. doi: https://doi.org/10.1016/j.ijinfomgt.2019.10.009.
URLhttps://www.sciencedirect.com/science/article/pii/S0268401219304505
[17] S. Chaudhari, M. Clear, H. Tewari, Framework for a dlt based covid-19passport, arXiv preprint arXiv:2008.01120.
[18] H. Xu, L. Zhang, O. Onireti, Y. Fang, W. J. Buchanan, M. A. Imran, Beeptrace: blockchain-enabled privacy-preserving contact tracing for covid-19 pandemic and beyond, IEEE Internet of Things Journal.
[19] A. Bansal, C. Garg, R. P. Padappayil, Optimizing the implementation of covid-19 "immunity certificates" using blockchain, Journal of medical systems 44 (9) (2020) 1–2.
[20] T. P. Mashamba-Thompson, E. D. Crayton, Blockchain and artificial intelligence technology for novel coronavirus disease-19 self-testing (2020).

# PLAGIARISM REPORT

Final Test

ORIGINALITY REPORT

| 6% | 5% | 2% | 5% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | Submitted to Daffodil International University<br>Student Paper | 3% |
| 2 | dspace.daffodilvarsity.edu.bd:8080<br>Internet Source | 2% |
| 3 | dspace.library.daffodilvarsity.edu.bd:8080<br>Internet Source | <1% |
| 4 | Submitted to TechKnowledge<br>Student Paper | <1% |
| 5 | Submitted to Rochester Institute of Technology<br>Student Paper | <1% |
| 6 | dokumen.pub<br>Internet Source | <1% |
| 7 | Submitted to Napier University<br>Student Paper | <1% |
| 8 | argon.ess.washington.edu<br>Internet Source | <1% |