VACCINATION VERIFICATION APP USING BLOCK CHAIN

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CERTIFICATE

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Abstract

Covid-19 (SARS-CoV-2) has altered nearly every element of our way of life. Governments around the world have applied lockdown to slow down broadcasts. In the interim, researchers diligently searched for the vaccine. Thankfully, we have discovered the vaccination, and many of them at that. Managing the testing and vaccination of the entire population is a monumental task. Multiple organizations from the public and business sectors collaborate to ensure adequate testing and vaccination.

However, delays and data silo issues are always present in multi-organizational projects. Therefore, it is essential to streamline this procedure to increase efficiency and save more lives. It has been demonstrated that technology, especially blockchain, substantially impacts the healthcare industry. Blockchain offers a decentralized system with enhanced privacy, transparency, and authenticity. In this project, we describe a blockchain-based system that smoothly connects testing and immunization systems, enabling the system's transparency.

Acknowledgements

In the name of the All-Powerful Allah, the Most Gracious and Merciful. Allah be praised for the virtues and His approval of this accomplishment. I would also like to show my gratitude and admiration to my esteemed supervisor, ”Dr. Ibrahim Tariq,” who gave direction and support at many and challenging stages of the project and supervised me in a well-defined and acceptable manner. In addition, I would like to recognise my parents’ support during the duration of this project.

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""A vaccination cannot be effective if it is not distributed correctly and customers do not have belief in it."
- Jason Kelley

Abbreviations

AI: Artificial Intelligence
DCT: Digital Contract Tracing
DFD: Data Flow Diagram
DHP: Digital Health Passport
EVM: Ethereum Virtual Machine
EHRs: Electronic Health Records
GUI: Graphical User Interface
UI: User Interface
POW: Proof Of Work

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VACCINATION VERIFICATION APP USING BLOCK CHAIN

1 Chapter 1

Introduction

1.1 Introduction

Introduced in the fintech industry, Bitcoin was the first electronic payment system to truly exploit the power of blockchain technology. Since then, blockchain technology has been infiltrating various fields of Information Technology (IT). Blockchain's wave of disruption is beginning to shape the way information/value is exchanged in the financial sector, supply chain, healthcare system, and reputation system; to name a few.[Singhal, Dhameja and Panda, "The potential benefits of the blockchain are more than just economic-they extend into political, humanitarian, social, and scientific domains-and the technological capacity of the blockchain is already being harnessed by specific groups to address real-world problems. Blockchain in principle is becoming an archetype of conducting business in a decentralized manner with more efficiency. Besides, it brings forward governance and, affirmation of all the activities from the involved entities within the blockchain, laying the foundation for a higher order of collaboration. Many emerging new technologies are subject to the hype, and blockchain is no different. Gartner hype cycle[Gartner, 2019] helps to understand the emerging technologies via a hype cycle entitled "Gartner Hype Cycle" where they state that each technology goes through innovation trigger to start with, where early proof-of-concept are published and no usable products exist. The early publicity gained during 'innovation trigger' phase is followed by 'peak of inflated expectation' phase where the number of success stories produced along with some failures. Then the technology goes through 'trough a disillusionment' phase where investors continue to invest only if products improve to a satisfactory level. After that, the concept of how technology can benefit the enterprise start to become clear and newer generation of products start to appear from providers. In this phase, which is also known as 'slope of enlightenment' phase, more enterprise start to fund the project. Finally, the technology reaches 'plateau of productivity' where mainstream adoption takes place.

People are vaccinated with the expectation that it will prevent future cases of influenza and other diseases. The purpose of vaccines is to immunize individuals. However, if it is not stored at the correct temperature and administered within the allotted time frame, it can have adverse effects on the health of those who took it to prevent illness. Therefore, the required temperature and time controls must be maintained at all nodes of the vaccine's end-to-end supply chain. It is also essential to ensure that the product changes hands as few times as possible along the supply chain. Blockchain has a significant impact on the healthcare industry. Implementing a blockchain-based medical record system has helped patients maintain their records more securely. A distributed ledger-like blockchain facilitates the confidentiality and security of these data. Al-ready Blockchain has demonstrated its efficacy in various health-related research. Privacy, flexibility, and authenticity of personal health data were maintained when blockchain was used to store them. Implementing a risk alerting system and a location- and Bluetooth-based contact tracking system to assure tamper-free services was facilitated by applying blockchain technology in many facets of covid-19 pandemic management. In addition, the Chinese University of Hong Kong has suggested a concept that describes the construction of a blockchain-based vaccine passport that includes health records. Additionally, blockchain technology can ensure the safety, security, transparency, and traceability of covid vaccine distribution. In addition to tracking vaccine manufacturing and information, blockchain has been utilized for this purpose. Using a timestamp, the information about businesses and vaccines is rendered tamper-proof, and the vaccine's validity period is determined. A data reduction system has been implemented.

This thesis examines the COVID-19 emergency deployment. In this use case, it was also determined that the distribution of required vaccines would be geographically dispersed across the globe. This also results in strained authority oversight capacities and fragmented supply chains. To maintain public confidence, reduce vaccine reluctance, and achieve rapid herd immunity, it is essential to have adequate visibility over the supply chain to reduce the risk of falsified, counterfeited, and substandard products.

Figure 1 Shows the vaccine verification through block chain.

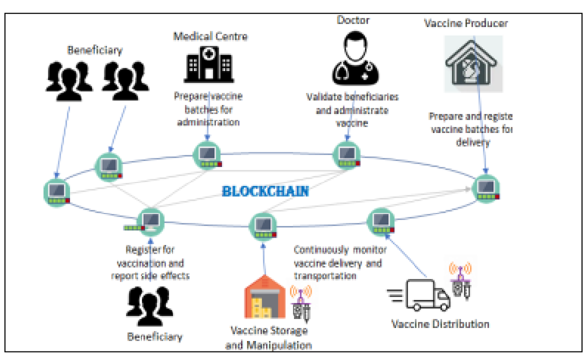


Figure 1: Vaccination Verification App Using Block Chain

1.2 Objectives

Developing a web-based app that will Scan vaccine shipment serial numbers and record them on a distributed ledger, items can be validated at any step along the supply chain. To comprehend how block chain technology handles the problems of data storage, retrieval processes, and information sharing, it is necessary to comprehend the process by which it does so.. To achieve the above-mentioned objectives, we will focus on the following provisions:

- To introduce block chain to vaccination verification systems.
- To make the vaccination verification easy and seamless.
- To secure the vaccination process and end any human corruption.
- Distributed ledger for record-keeping, making the process more transparent and trusted.

1.3 Scope

Scope of this project is basically to be able to contribute to future research by providing a method that will assist software developers in putting into practice this concept for a Block-chain based vaccine verification application. Because this project is applying block-chain technology to the field of medicine, it will make new opportunities available in Pakistan. In this day and age of evidence manipulation and fraud, we hope to see an application that will serve as a deterrent to such activities and assist in tracking and validating current figures of covid patients. This will enable future steps to be planned and carried out to prevent more covid patients from developing the condition.

1.4 Problem Description

Any country's ability to control the pandemic hinges on the ability to verify the vaccines they are using. To assess the security of indoor and outdoor gatherings and provide real-time statistics on vaccinated populations, it is necessary to have a reliable, secure, and accurate verification system. Many vaccine verification systems exist worldwide, but developing a secure and accurate, reliable, and trustworthy system continues to be a challenge. Data storage and retrieval protocols are partly to blame. Information sharing is a significant challenge when considering the importance of vaccine verification systems being accepted across domestic and international borders. Five prerequisites must be met for a system to function correctly.

- A computerized immunization information system, i.e., an online record of vaccinations received by individuals, should be used to ensure accuracy.
- Adequate safeguards and assurances must protect everyone's personal information.
- In unforeseen circumstances, it should be possible to use other forms of identification.
- The system should only be used to verify vaccination records and not add information about previous tests and results to avoid clustering data, such as the ability to use paper vaccination records with additional personal verification, such as a photo ID.
- Moreover, it has to be available immediately.

Information technology implementation and adoption in the healthcare industry has historically proven to be a challenge. In the US, the US Centers for Medicare and Medicaid Services spent 37 billion dollars just in incentive payments for healthcare IT from 2011 to May 2017, however, with little to none of the desired impact. Current electronic health record (EHR) systems account for massive expenses, while being used only as an electronic storage of documents rather than an all-encompassing system used for data analysis, optimization, health care quality improvement, etc. While traditional systems leave the power and responsibility of managing data and the supplementary IT infrastructure completely in the hands of centralized healthcare institutions and administration, trends indicate a rise in patient empowerment, i.e. a tendency for patients to collect and share data with the healthcare system on their own. Furthermore, the healthcare industry, particularly in the US, has been growing faster than other industries, however, due to the increasing number of healthcare workers and IT systems development, the industry's productivity as a whole has seen minimal changes. Sahni et al. emphasize that implementing high-quality IT systems in healthcare and assuring their acceptance and adoption by all stakeholders is a key challenge for the industry. In addition, they highlight the need for effective data gathering and analytics mechanisms, which can result in higher quality, more effective treatments. Systems and data interoperability are also among the challenges the current healthcare system is facing that contribute to the inability to use data effectively for research and improved treatment. In the EU, the European Commission set similar goals in 2016, such as granting patients access to their health data and enabling providers to exchange data securely through an eHealth Digital Service Infrastructure, operating across borders in the European Union. The program also aims at introducing digital tools for person-centered healthcare and for data pooling for the development

of personalized medicine and overall medical research. Despite the ambitious goal setting, not much successful development and system implementation has been observed in the recent years.
Blockchain has the potential to enhance the information systems management in a multitude of industries as evident from use cases being implemented in the financial sector, supply chain, real estate, etc. A large number of startups as well as corporates are pursuing a range of use case implementations and the interest in the technology overall keeps on increasing

1.5 Problem Solution

We have created a Blockchain-based app for vaccine verification. The current system's shortcomings can be solved with blockchain, a distributed ledger technology. It facilitates the integration of numerous systems and enables all parties to participate freely in the plans. The system will be maintained by all parties and will be automatically updated if any illegal conduct is discovered to prevent it. It gives all parties concerned a clear view of the data and aids in establishing confidence. In addition, data corruption is prohibited because no one has access to the information. Using traditional audits and re-testing, it is possible to determine if an individual purposefully submits inaccurate data. The blockchain's immutability makes it simple to identify and punish the bad actor.

1.6 Tools and Technology

Below is a list of the tools and technologies that will be used in the making of this project.

- EVM
- Solidity Compiler
- Remix
- Java Script
- CSS
- Meta-mask Wallet

2 Chapter 2

Literature Review

2.1 Introduction

The literature study is done to get comfortable and distinguish the new strategies utilised in vaccination verification app, how they are used, and at what stages.The literature review contains the work of some scientists like Yong et al, Dr. Srinath S., i Chen and Arui Shi who have worked on block chain technology.

The challenges and limitations gathered from the literature review provided us with the motivation to work on this idea. This motivation significantly increased the reasons why new and improved systems should be built.

2.2 Block Chain

Even though the underlying blockchain technology was conceptualized and published in Nakamoto's white paper in 2008, a widely accepted definition was not part of this paper and has not been developed until today. Jeffries in her article "'Blockchain' is meaningless" , collects impressions from various fields and use cases, such as governments, finance, law, etc., and concludes that "establishing a clear definition will help clear up some (of these) misunderstandings". Walch notes that the vagueness of the vocabulary used regarding the technology can be due to several factors such as "word taint", the phenomenon of some terms acquiring undesirable meanings; technology variation - the continuous development of all underlying technology that blockchain relies on; and "cross-field communication", the fact that terms are utilized across multiple fields and industries with varying degrees of technological expertise. The International Standards Organization is currently working on the standard ISO/TC 307 which aims at defining and standardizing various aspects of blockchain and distributed ledger technology such as terminology, security, privacy and interactions through smart contracts. A definition of blockchain devised by Seebacher and Schu¨ritz, also to be adopted in this paper, states the following:
A blockchain is a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks, holding timestamped transactions that are secured by public-key cryptography and verified by the network community.
Information can be stored on the blockchain and it can be distributed across all nodes on the network, thus, forming a decentralized network. All participating nodes agree on a set of rules before joining the blockchain network and operate accordingly. Depending on the specifics of the rules, the type, aim and functionality of the network is determined. One of the basic characteristics

of a blockchain network is its immutability, i.e. all records made are permanent and can be changed only at a very high cost. Several types of blockchain networks exist. They are generally characterized based on the consensus and governance models employed, namely, decentralized (public, not permissioned), hybrid (consortium, permissioned), centralized (private/ governed by a single organization, permissioned).
Blockchain's provision of transparency is said to be based on the peer-to-peer nature of the network it is built on, thus enabling shared and public interactions among the participants. Due to the fact that all transactions are publicly viewable and broadcasted to the entire network, all actors.
on the system are able to acquire timely and thorough information. Furthermore, due to the fact that a central authority who could singlehandedly influence transactions, allow them, discard them or alter them, is replaced with a trust model based on network-wide consensus, transparency and trust are essential characteristics of blockchain.The technology also facilitates data integrity due to the reliance on public-key encryption and hashing that together enable high security levels and govern the direct interaction with data stored on the system. The third important characteristic of blockchain contributing to asserting trust is its so-called immutability. Theoretically, once a transaction is approved by the network participants, added to a block, and the block is then added to the blockchain, it cannot be modified. This transformation is processed through the use of consensus mechanisms, such as proof-of-work and proof-of-stake, that allow the participants to demonstrate their trustworthiness. While the immutability claim is commonly cited, it must be noted that a "sufficient amount of computing power" can be used to alter a blockchain (for example, in the case of the Ethereum Decentralized Autonomous Organization fork in 2016 thus, Conte de Leon et al. describe the immutability property of blockchain as "emergent", that is to imply that it is not fully demonstrated, yet is desired. Additionally, it is a challenge to claim with certainty that such characteristics hold true in reality. Some research (e.g. [53]) has been done on analyzing the performance and security of blockchains, specifically the proof-of-work algorithm, while others such as Cucurull and Puiggali made a proposal that "enhances the security of the immutable logs" and provides further integrity and non-repudiation by "publishing log identity proofs on the blockchain".

In the context of blockchain, trust and decentralization are interconnected as transparency, data integrity, and immutability are all necessary elements for the creation of a decentralized network. Decentralization, on the other hand, including the aspects of privacy, reliability, and versatility, are necessary to assure the participants' participation. To elaborate, privacy in a blockchain-based system is built-in through the use of public and private keys which authenticate users without the need for revelation of real identities. While transactions can be traced back to a specific key, thus, making the network pseudonymous, privacy is still enabled. Blockchain's reliability is another aspect which is labeled as "emergent" due to certain risks that while unlikely and computationally difficult, still exist. The reliability claim is based on two factors: firstly, the information and transactions being shared and stored in a distributed manner across the network, and secondly, on the automated nature of the system. However, Conte de Leon et al. argue that if the blockchain has been tampered with, for example through an adversary taking over 51 or more percent of the computational power in the network, such an attack can be left unnoticed, thus compromising the reliability of future transactions. If a single party controls at least 51

2.3 Proof Of Work

The Proof of Work (PoW) consensus mechanism is the most widely used consensus algorithm among existing blockchains [53]. The underlying idea is that the selection of the random node, that forms the next block in the chain, is proportionately based on the resources available to that node. In the case of proof of work the resource in question is computing power. Based on the notion that at least 51 percent of the network must be controlled by a single entity for a Sybil attack to be launched, thus, nullifying the blockchain's integrity, the assumption is that it is close to impossible for an adversary to reach such a high level of control over the computing power available in a blockchain network. The operation of the PoW algorithm will be elaborated on based on the proof of work system used in Bitcoin. The Bitcoin network obtains proof of work using hash-based puzzles. In order to propose a new block, a node needs to find a random value (nonce) that concatenated with the hash of the block falls in a certain target value bracket. This target space is a very small subset of the overall output space. Assuming that hash functions are cryptographically secure, trying all possible combinations is the only way to find a solution to such a problem. Therefore, it is likely that the node which will find the solution to the problem is the one that has most computing power available. Hash puzzles have three important properties. The first one is the computational difficulty, which increases over time, every 2016 blocks, to adapt to the increasing availability of computing power in the network. The second property, resulting from this adjustment, is the variability of the cost for a block. Considering the increasing difficulty and the continuous growth of the network, the effort to mine a block increases over time, thus, either increasing the demand for more computing power, i.e. hardware, or diminishing a node's chances to find a block. The third essential property is the ease to verify the solution to the puzzle published by a node. On average it takes a node 1020 tries to find a nonce that fulfills the condition that the hash falls below the target and that nonce must be published as part of the block. Once that is done, any other node can verify that the hash of the block's contents is below the target value. This asserts the decentralization characteristic of blockchain as no central authority is needed to verify the network operation.

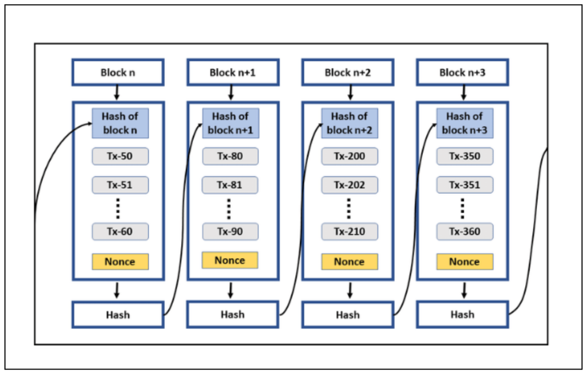


Figure 2: Proof Of Work

2.4 Block Chain In Health Care

One of the biggest, frequently occurring, and most damaging security incidents is health-related data breaches[Dickson, 2018]. "Healthcare is the only industry in which internal actors are the biggest threat to an organization,". Healthcare industry is heavily fragmented. This results in inefficiency in the system and is also major hurdle as of now. Healthcare providers usually do not have the access to all the vital data of the patients that can be crucial during the process of diagnosis and treatment, which in turn, can comprise the health of the patient. Aforementioned issue is also one of the reasons why researchers struggle to find the data desired, as a consequence slowing down the research in the field of healthcare.

One of the biggest impact blockchain can have in the healthcare industry is data management. Different approaches and tools are being used by health care organisations and health care personnel to exchange the patient's health information. People move from one place to another due to multiple reasons, therefore they usually seek health care services from different providers in different regions. Health-related information can be fragmented and outdated which can lead to a poor connection between provider and patient's medical information for data exchange. Given that HIE between organisations is possible, patients rely on HIEs to improve the speed of treatment process, enhance care coordination, and increase the quality of care. Patient's trust in HIE is core, as security and privacy issue can occur during information sharing process, depending on the type of information system being used. Blockchain can facilitate business transactions (i.e. information-sharing) in electronic context via a distributed ledger spreading in various locations rather than through a central authority. It can also provide data ownership to the patient, where they decide which data is to be shared to which organisation.

The principal perk of using blockchain in the healthcare industry is that it provides a platform for storing health-related data by maintaining privacy and immutability. Slow-moving manual processes have posed significant difficulties for healthcare companies, significantly complicating data-driven processes and procedures. Blockchain technology can improve such systems' efficiency resulting in more successful corporate operations, according to the PwC Health Research Institute. In addition to inventory management systems for pharmaceuticals, blockchain is also utilized in systems for identifying transaction history. Additionally, blockchain technology enables people to share their private medical information with physicians. With increased privacy and security, blockchain technology's powerful security system assists businesses in monitoring compliance information and reporting deviations from the established rules. Therefore, there is strong evidence that blockchain has substantial applications in healthcare data administration and can be utilized to manage vaccination information.
The majority of peer-reviewed articles, included in the systematic literature review, focused on the need for implementation of robust Electronic Health Records (EHRs) systems as well as their design. In particular, 22 out of the 42 papers exclusively discuss the design and evaluation of a specific new EHRs application. Additionally, each of the 14 articles, presenting an overview of the state of blockchain in healthcare, extensively examines the implications of EHRs. While practitioners also emphasize the importance of handling data management related challenges, other pressing problems are to be addressed in the field too. Areas such as pharmaceutical supply chain, interoperability, insurance claims processing, and credentials management have been mentioned in literature; however, they remain almost completely unexplored in regard to Proof-of-Concept-level implementations (at least by those presented in the investigated set of literature). Furthermore, considering the wide divide between nonacademic and academic publications, which surfaced from a comparison between the initial research conducted in preparation for this thesis and the detailed systematic literature review, it is evident that academic literature and overall research lags behind implementation trends. The same observation was made by several of the interview respondents. Therefore, the first identified research gap highlights the lack of research directed at exploring the implications, including PoCs and business models, blockchain has for solving issues in healthcare other than data management and specifically EHRs. Furthermore, to this moment academic literature related to healthcare has not sufficiently addressed the integration of blockchain with other technologies such as quantum computing, artificial intelligence, machine learning, etc. Another significant

misalignment between literature and practice became apparent when analyzing the challenges and hurdles blockchain is facing in the healthcare industry. The majority of literature refers to these rather as risks and limitations and attempts to identify mitigation strategies to address them. However, according to practitioners from all backgrounds, tackling issues such as the infancy of blockchain technology as well as the interoperability challenge between blockchain solutions are pain points that need to be dealt with independent of any specific implementation or even industry. In addition, the practical perspective places a much greater emphasis on the importance of education, thorough communication and the lack of understanding of the core value proposition of blockchain among the general public. Similarly to the technological challenges, this fundamental gap must be minimized before any widespread adoption becomes possible. The second prominent area where lack of research is evident is user adoption in general and specifically, the identification of suitable communication and education channels which could drive adoption forward. Thirdly, literature and practice also come to an agreement regarding the influence of missing regulations, thus, highlighting another major research gap. Academic literature so far only identifies the mismatch between existing regulations and blockchain implementations, however, does not propose strategies on how to resolve the challenge. In light of existent frameworks such as HIPAA, GDPR, etc. and the forthcoming blockchain development in a multitude of industries, including finance, supply chain, healthcare, research alongside regulatory bodies is failing to shed light on the future of the regulatory landscape. Overall, researchers should consider diversifying the range of challenges they focus on in order to reflect the real-world growth and rate of change blockchain is facing. The discussion of multiple applications, aiming at solving the same problem (EHR management) is limiting the expansion of knowledge and ultimately leads to the halt of research interest and further development.

Blockchain technology has a promising future in health care applications that will increase the status quo's efficiency and transparency; however, it is still in its infancy and requires careful, incremental steps to understand the inherent safety and scalability risks associated with its application. Mettler concludes that blockchain technology has a promising future in healthcare and will disrupt service delivery by expediting digital transformation.

According to Kuo et al., the primary advantage of utilizing blockchain in healthcare and biomedical applications is the decentralized management of data, enabling healthcare stakeholders such as hospitals and government regulatory bodies to collaborate and share data without a central intermediary. In addition, immutability, robustness, and security are the primary advantages of blockchain use in healthcare, leading to enhanced data integrity and greater efficiency.

2.5 Existing Solutions

The existing design includes a central database that collects data on the attributes of food products after they reach the distributor and then the merchant. However, information regarding upstream items is stored in database silos. We recommend the use of GPS, sensors, etc. in the upstream supply chain to have more precise data and to use that data in the blockchain network for transparency across different nodes of the network with immutable entries that prohibit any nefarious activity.
Several works on covid certifications, covid testings, and the blockchain-based "Digital Health Passport" (DHP) have been completed. These terms are the same, although they have been given different names. These are described further below. A prototype app has been created where will generate user testing results, and will achieve transperancy due to the application's blockchain-based development. In addition, benchmarking results are displayed there. Using a Qr code-based verification mechanism, users' information is concealed. The Bangladesh Government's ICT division launched a centralized app called "SUROKKHA." Currently, the Bangladeshi government is administering the vaccination process. The DHP is a health passport based on a secure distributed network blockchain. DHP can be utilized for travel, work, and other purposes and helps a nation's economy recover. It demonstrates that the individual is unaffected by covid-19 or already has immunity. DHP is a proactive measure that aids in preventing the transmission of the virus. Digital ContractTracing (DCT) has also been the subject of research, and it has both benefits and limits. A blockchain-based covid-19 vaccination passport provides the vaccination status of a person whose identity has been verified using retina scanning. Grayscale eye images have been generated using Masesk's Algorithm. A person's immunization status is updated by collecting his or her biometric data and vaccination information. The biometric data's encrypted version has been kept on the blockchain platform. Both biometric data and blockchain technology offer increased security and scalability.A blockchain-based certification for immunity testing has also been proposed, with user data registered on a blockchain network governed by the government [18]. Hospitals also serve as testing facilities. The collection of biometric data from the user has enhanced security. Additionally, contact tracing has been implemented by collecting the user's phone number, geolocation, and timestamp . In addition, an app has been built to store user testing information on the blockchain network, which provides reliability and artificial intelligence for tracking patient location details and self-testing.

Vaccines, as a product that can have deadly effects on a patient if they are substandard or outdated, must be closely regulated. As evidenced by the current COVID-19 outbreak, vaccination is essential for maintaining public health, and it eventually affects the economic and social components of society. Vaccine supply chains continue to be beset by issues that undermine the trust of regulatory organizations and vaccine manufacturers, resulting in vaccine reluctance.

By ensuring immutability, scalability, and universal access to information, it is essential to establish confidence amongst different stages of the vaccine supply chain. According to several studies, blockchain can provide this chance with proper investment and research. This study tries to investigate this solution.

2.6 Proposed Model

The proposed system will be a web application and will be user-friendly.here are total 4 roles: Owner, Manufacturer, Administrator and User.
Administrator is the account of medical worker who will inject the vaccine. User will be the person who gets injected . There is option now to view list of all vaccines added. This is needed to keep track of all entries since we cannot retrieve the original data from mapping.Vaccine data will now show all details of vaccine searched for. Administrator can add record of delivered vaccines under administrator tab .System works as: owner adds a manufacturer who can add vaccine . Owner also adds the administrator who will deliver vaccine to user.Lastly, users can view their vaccination history under 'records' tab Through this service, life will become easier than before as the work done will be less time consuming.

3 Chapter 3

Requirement Specification

3.1 Functional Requirements

Following are the functional requirements of our system:

- Manufacturer and Administrator must add their wallet addresses.
- User must provide accurate data of vaccination.
- Data must be saved on the Blockchain under valid indexing.
- Smart Contract must handle the Logic layer of the application.

3.2 Non-Functional Requirements

- Reliable
  Our system is reliable in terms of performance and authenticity.
- Availability
  Our system will be available to the user in every platform for them to use.
- Effectiveness
  The algorithms, tools and techniques used for creating this system is effective and efficient as they produce accurate and fast results.
- Usability
  Our system is user-friendly and easy to navigate. There is no complex things and hidden options. Everything is clear and right in front of the user. User can easily do things that they want.
- Integrity
  Data backups will be done frequently so that there is no data loss in unforeseen situations.
- Security
  Our system is very secure and safe in every possible manner. User's personal information and their records will be confidential and will not be

exposed except to them.

- Cost-Effectiveness
  Our system will be free of cost and will be available to the user online.

3.3 Use Case Diagrams

3.3.1 Application Use Case

Figure 3 shows the use case diagram of our application. The figure mentions the possible roles along with their functionalities.

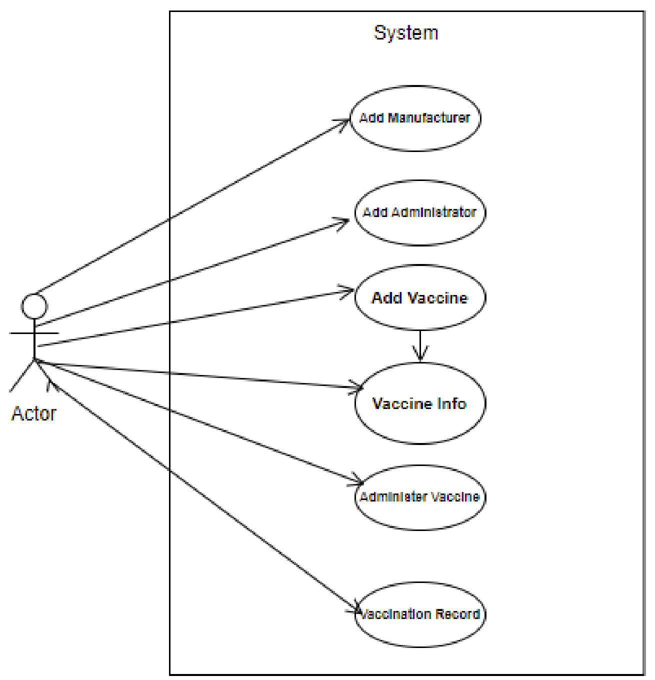
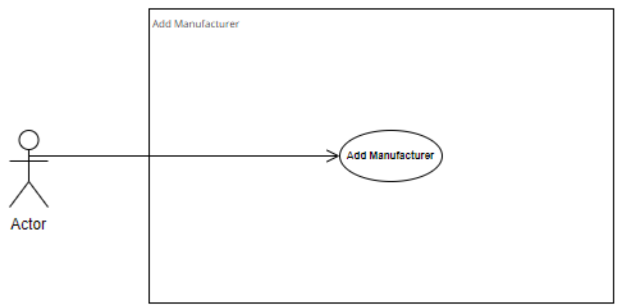
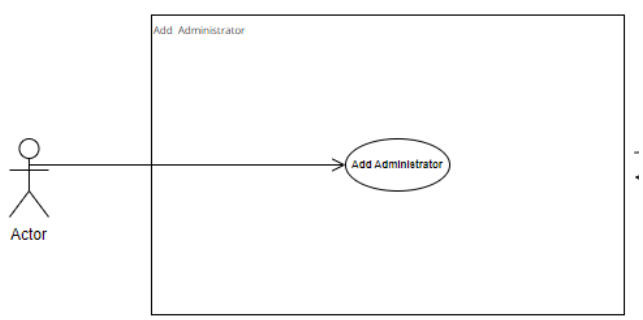


Figure 3: System - Use case diagram



(a) Add Manufacturer

Figure 4: Add Manufacturer Use case diagram



(a) Add Administrator

Figure 5: Add Administrator Use case diagram

3.3.2 Description Table - Add Manufacturer

Use Case ID	UC-01
Use Case Name	Add Manufacturer
Description	Process will add manufacturer wallet address
Primary Actor	End User
Secondary Actor	Manufacturer
Pre-Conditions	The Manufacturer wallet is connected
Post-Conditions	The Manufacturer address is ready to submit
Flow of Events	**Detail of the action**
Actor Action	User will connect the wallet
System Action	System will add the address
Alternative Flow	None

Table 1: Description table for Add Manufacturer

Table 1 describes the use case of add manufacturer. It includes all steps and constraints to be followed during the admin add manufacturer.

3.3.3 Description Table - Add Administrator

Use Case ID	UC-02
Use Case Name	Add Administrator
Description	Process will add Administrator wallet address
Primary Actor	End User
Secondary Actor	Administrator
Pre-Conditions	Administrator wallet is connected
Post-Conditions	The Administrator address is ready to submit
Flow of Events	**Detail of the action**
Actor Action	User will connect the wallet
System Action	System will add the address
Alternative Flow	None

Table 2: Description table for Add Administrator

Table 2 describes the use case of add administrator. It includes all steps and constraints to be followed during the user add manufacturer.

3.3.4 Description Table - Vaccine Info

Use Case ID	UC-03
Use Case Name	Vaccine Info
Description	Adding Vaccine Info process will start
Primary Actor	End User
Secondary Actor	None
Pre-Conditions	Vaccine data should be accurate
Post-Conditions	The vaccine data is submitted for further processing
Flow of Events	**Detail of the action**
Actor Action	Press submit button to start the process
System Action	System will start adding vaccine info
Alternative Flow	None

Table 3: Description table for vaccine info use case

Table 3 describes the use case of vaccine information. It includes all steps and constraints to be followed during the user add vaccine data.

3.3.5 Description Table - Display Record

Use Case ID	UC-04
Use Case Name	Display Record
Description	Record of the vaccine will be displayed
Primary Actor	Both
Secondary Actor	None
Pre-Conditions	Vaccine data must be stored
Post-Conditions	Record will be displayed
Flow of Events	**Detail of the action**
Actor Action	The user will click the button generate your vaccination record
System Action	The system will display the vaccination record
Alternative Flow	None

Table 4: Description table for display record

Table 4 describes the use case of display records. It includes all steps and constraints to be followed during the system display the records of vaccination.

4 Chapter 4

Design

4.1 System Architecture

Our proposed system follows the 3-tier architecture that is presentation layer, logic layer and the database. This architecture is very reliable and efficient. All the three layers work together in such a way that if any thing is wrong with on layer, then other layers are not interrupted, and they continue to do their work.

4.2 Presentation Layer

Presentation layer is the front-end of the project with which the user interacts directly.It is designed keeping in mind the comfort and ease of the user. Front-end is simple and easy to navigate. It is very appealing to the eyes and is user friendly. It is designed in Java Script language.

4.3 Logic Layer

Logic layer is the back-end of the project or the middle layer in 3-tier architecture. In this layer, all the operations and functions are performed. Like this, in our proposed system, all the algorithms are implemented in this layer. Implementation of the back-end is done with using blockchain technology and is done in Java Script language

4.4 Database

This is the third and last layer of the 3-tier architecture which is database of our proposed system which contains all the information regarding the user's bio data and product specifications. We have used SQLite as our database. It is very secure and helps protect the data of users and product.

4.5 Design Constraints

Following are the design constraints of our system:

- User must have an web device.
- An internet connection is required.
- Administrator Manufacturer must have their own meta mask wallet account.
- User must put accurate and authentic information of the vaccine.

.

4.6 High Level Design

The High-Level Design (HLD) diagram will explain how the system will develop.

4.6.1 Architecture Diagram

A visual depiction that depicts the actual physical implementation of a software system's components is called an architecture diagram. It displays the relationships, constraints, and boundaries between each piece as well as the overall structure of our project.

Figure 6 shows the system architecture. It is a graphical representation that depicts the physical implementation of our application.

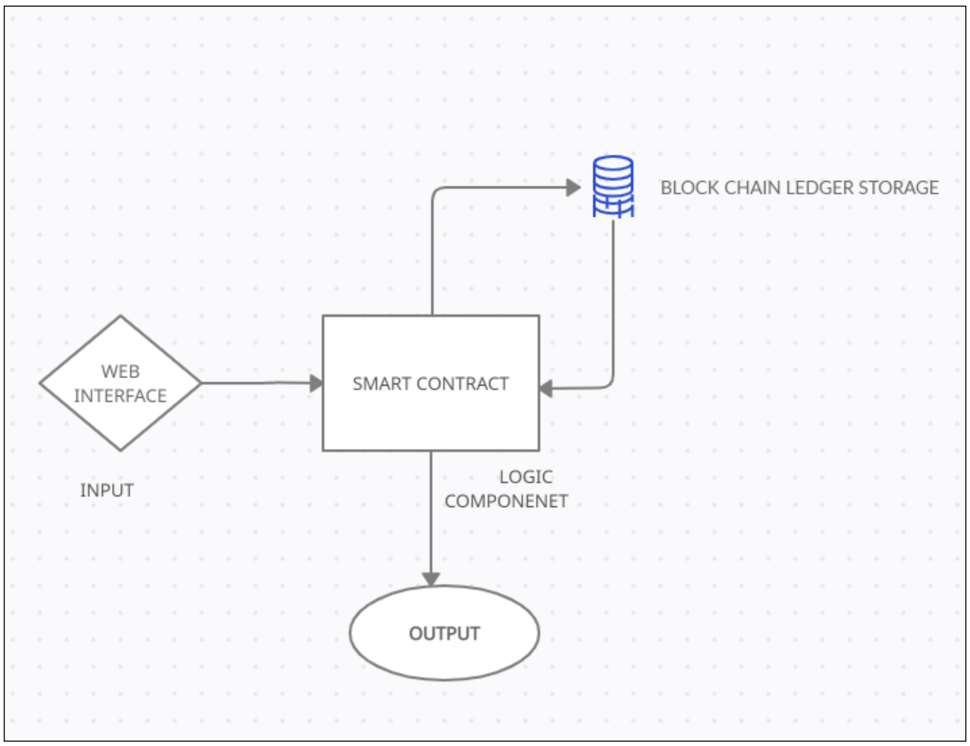


Figure 6: System Architecture

4.6.2 Activity Diagram

The activity diagram shows the software processes as a progression of actions. In this activity diagram the steps for Input data have been defined. These actions are carried out by the user, while it also describe business processes and use cases that rely under the flow of this activity.

Figure 7 shows the activity diagram, when the user initiates the process of adding vaccine information.

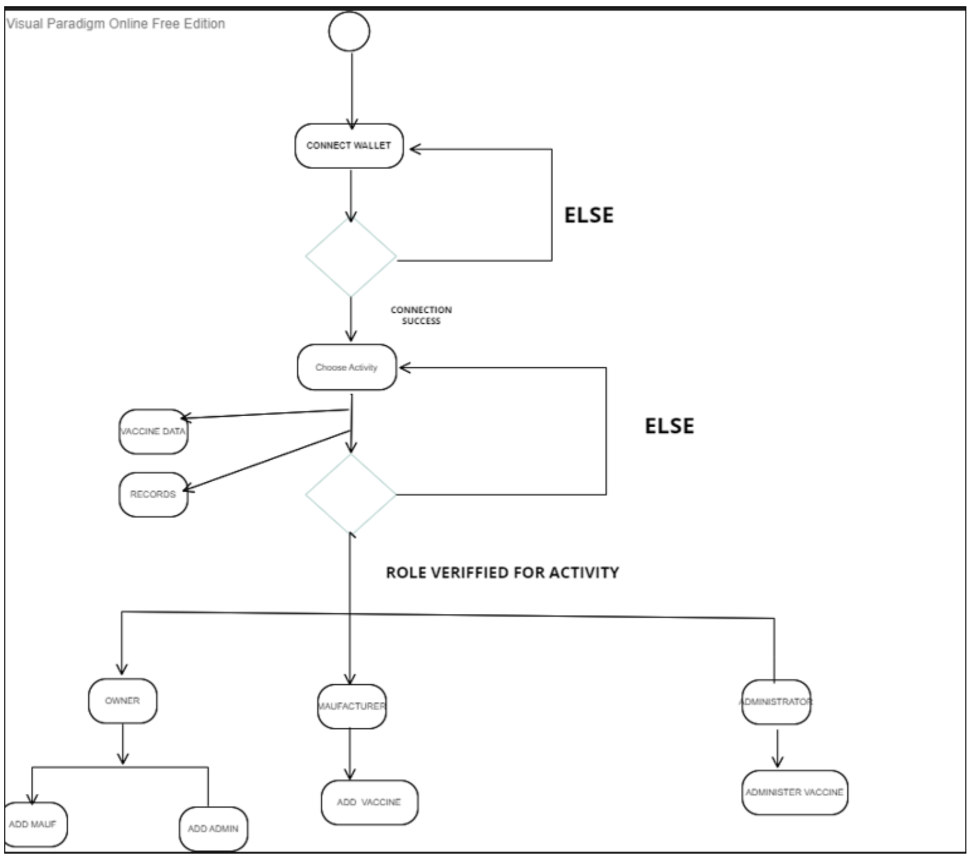


Figure 7: Activity Diagram

4.7 Low Level Design

This method of designing at the component level is called Low-Level Design (LLD), and it proceeds forward in a manner that is step-by-step.

4.7.1 Data Flow Diagram

Context Diagrams are another name for DFD. This diagram basically provides a general summary of our entire system that has been modelled. The system is being displayed as a single, high-level process, together with its relationship to its users, while providing an overview view.

Figure 8 shows the zero level data flow diagram in which basic overview of the whole system is being analyzed.

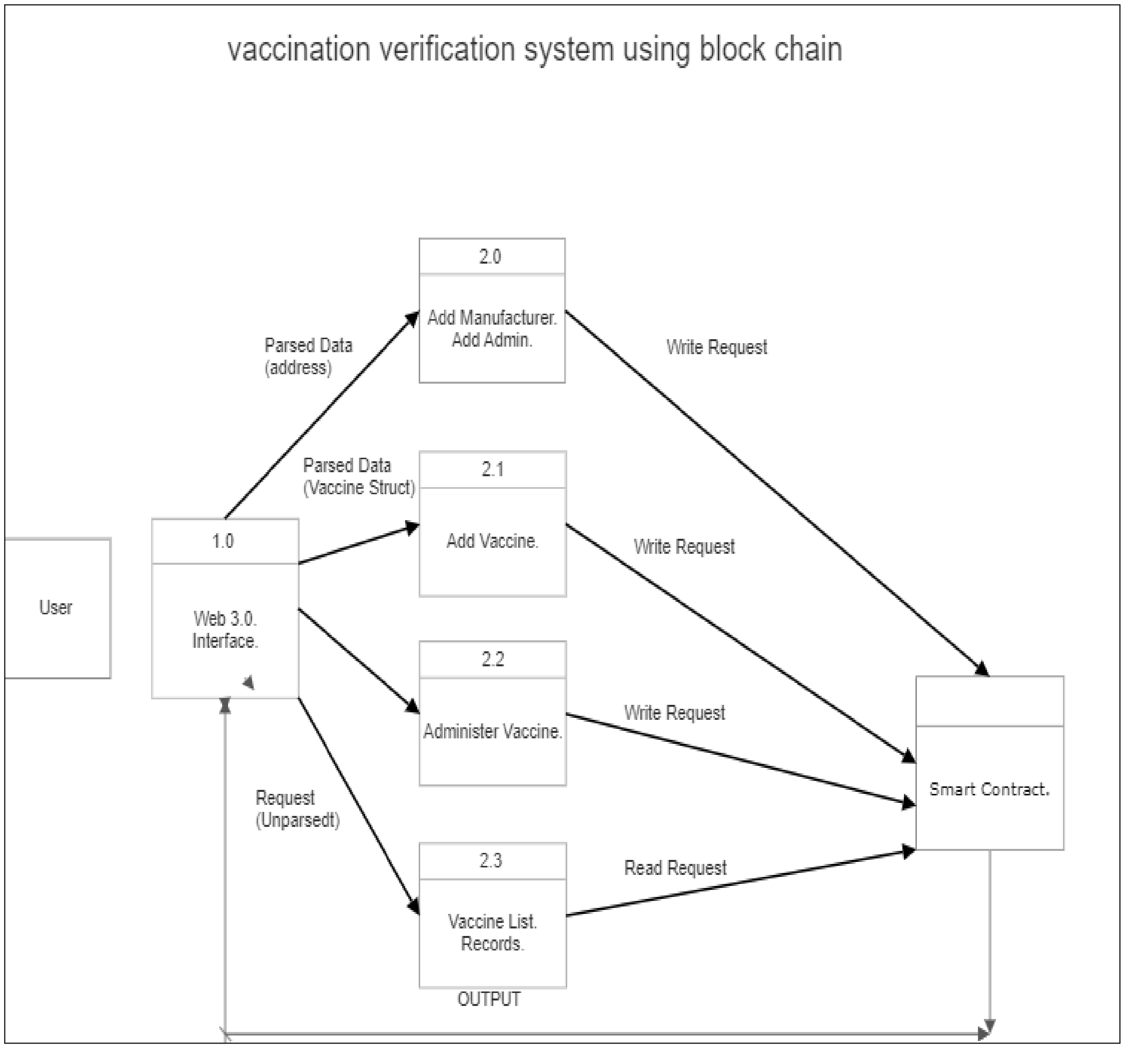


Figure 8: Data Flow Diagram

4.7.2 Sequence Diagram

This diagram basically illustrates the interactions between the user and the application while adding vaccine data, and also defines the order in which they occur, a sequence diagram is a form of interaction diagram. It clearly shows the interaction of user with each module of the application and at which sequence they occur.

Figure 9 shows the sequence diagram of app, it shows the process interactions arranged in time sequence when the user interact with the system.

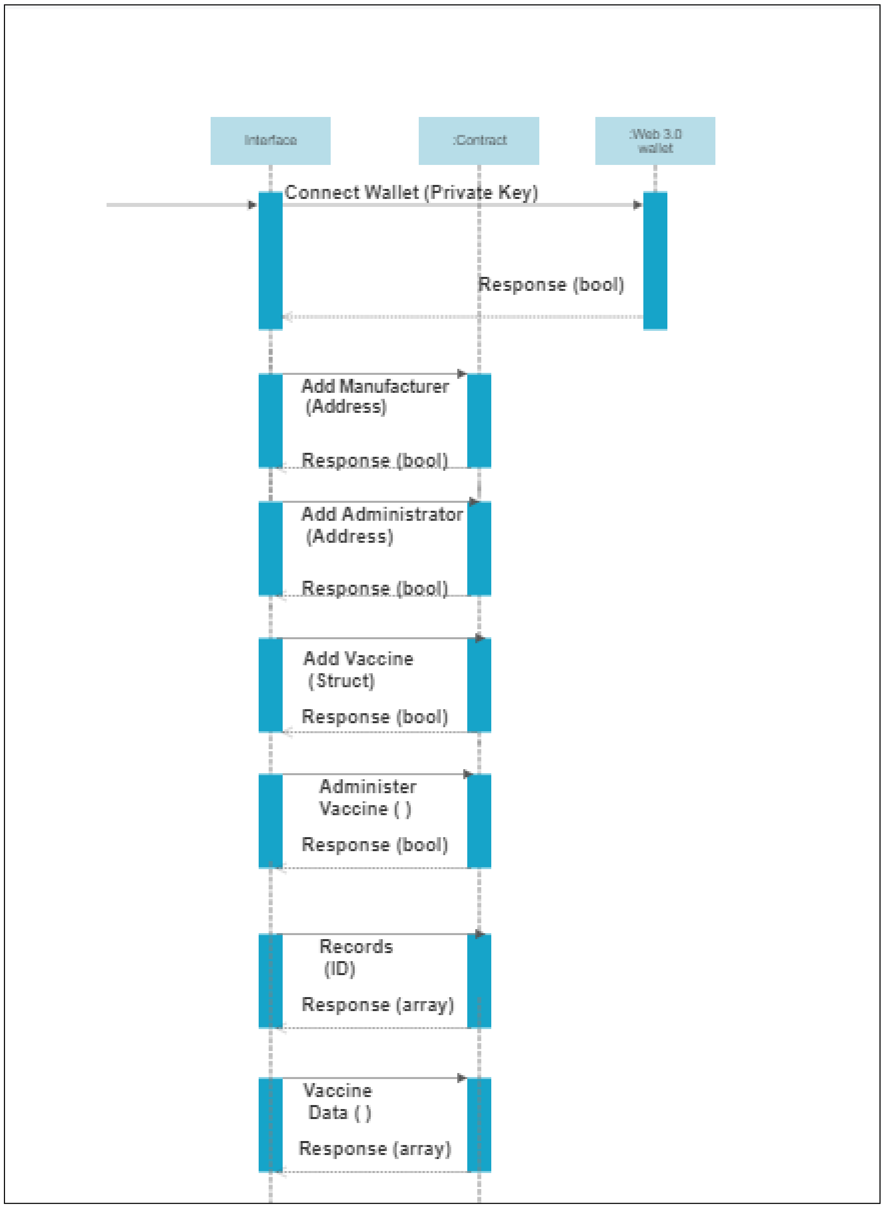


Figure 9: Sequence Diagram

4.8 State Diagram

An depiction of the states an object in the UML can reach as well as the transitions between those states is called a state diagram, also known as a state machine diagram or state chart diagram.

Figure 10 is the state diagram for our system, it is representation of the states an object can attain during processing as well as the transitions between those states in the UML.

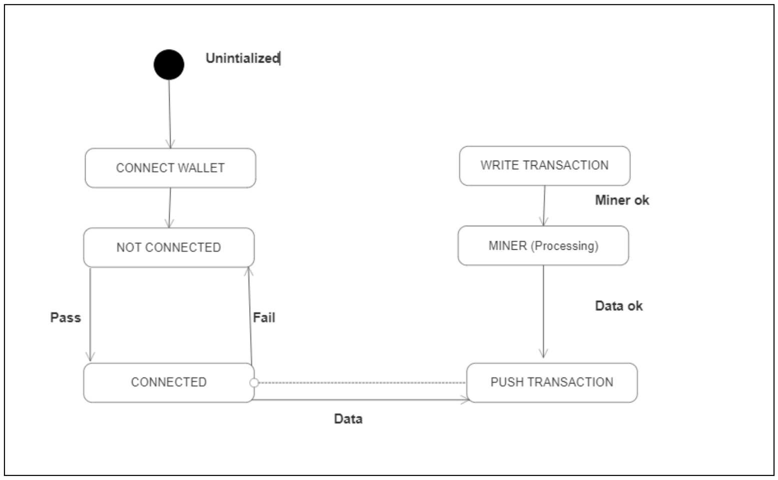


Figure 10: State Diagram

5 Chapter 5

Implementation

This chapter includes information regarding the tools and technologies that are used in our project. System implementation is the realization of techniques, algorithms, software components, or other systems through programming and deployment.

5.1 System Architecture

5.2 Languages Used for Development

We have used two languages mainly and those are as follows:

- Java Script

  Java Script is a lightweight, interpreted, object-oriented programming language and is best known as the scripting langauge for web pages.

- Solidity

  Solidity is an object-oriented programming language used to build intelligent contracts on several blockchain platforms, including Ethereum. Christian Reitwiessner, Alex Beregszaszi, and numerous former Ethereum core developers created it. Solidity programs execute on Ethereum Virtual Machine.

5.3 Application Security

Our application is secure and safe as we have used blockchain in its development. So nothing can be changed or hacked.

Figure 11: Application Security

5.4 Architecture and Component Integration

The system architecture is the model that describes the proposed system's structure, behavior, and various views. It also describes the system's internal components and the functionalities of the various system components. The proposed system is implemented using a variety of tools and technologies.

5.5 System Implementation

This section includes the implementation of our project in which a web application for vaccine verification was developed. The front-end of the application (UI) is designed in Java, and for the back-end, solidity language is used.

5.5.1 Application GUI

This illustrate the UI design of our Web Application. The UI of the application is displayed below

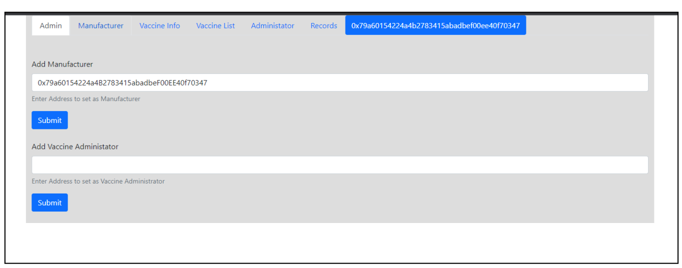


Figure 12: UI of Application

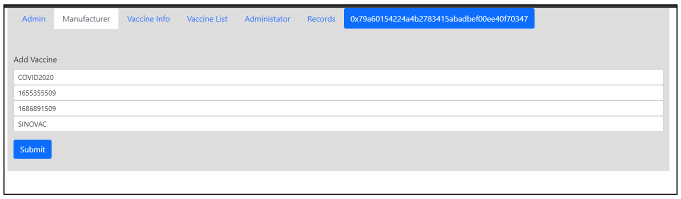


Figure 13: Manufacturer Role of Application

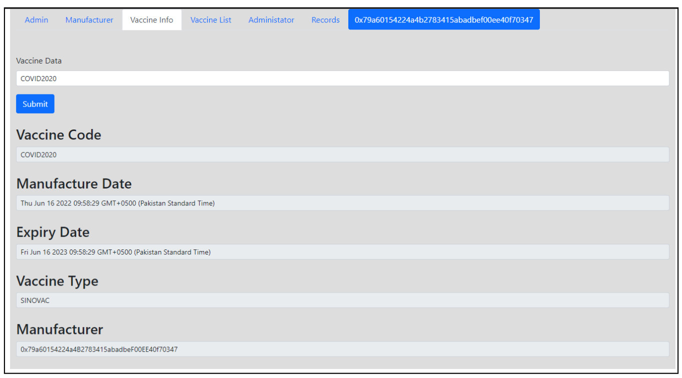


Figure 14: Vaccine Info Option of Application

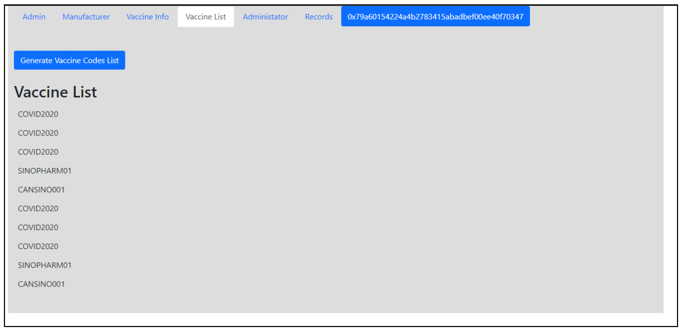


Figure 15: Vaccine List Option of Application

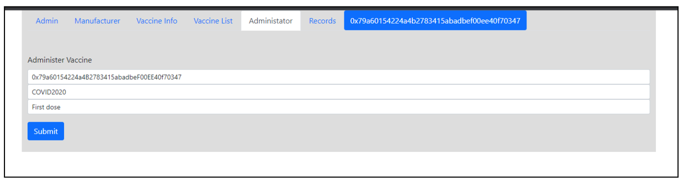


Figure 16: Administrator Role of Application

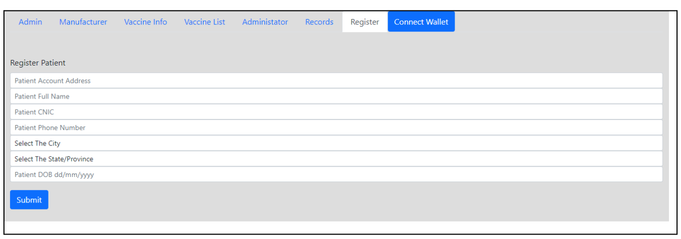


Figure 17: Registering Patient Option Of Application

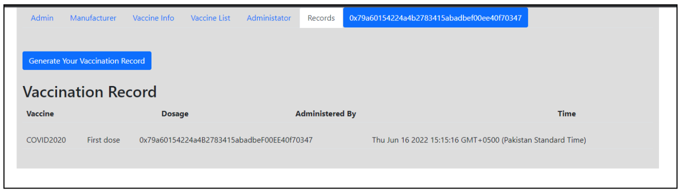


Figure 18: Record Option of Application

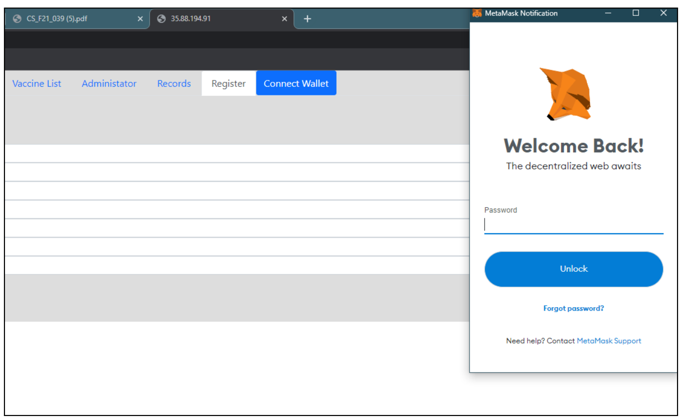


Figure 19: Connect Wallet Option of Application

5.5.2 Tools and Technologies

The applications were created in Java Script and solidity on block chain network etherum.These are the tools and technologies used in the development of our project.

- Metamask Wallet
- EVM
- Remix
- Solidity Compiler
- Java Script
- CSS

6 Chapter 6

System Testing and Evaluation

Test and evaluation is the process of resembling a system or component to requirements and specifications via testing. The results are analyzed to determine, among other things, the design's progress, performance, and maintainability. We'll discuss the methodologies and test cases that we used to put our application through its paces in this chapter. System testing is critical for any system because it ensures that the software will perform as expected and will function properly.

6.1 GUI Testing

GUI testing is the process of ensuring that a product's graphical user interface (GUI) adheres to its specifications. This type of testing ensures that the application under test acts as expected when a user executes a specific action or documents a specific input and generates the appropriate program output. In our application, we tested the buttons to see how they responded.

6.2 Usability Testing

In user-centered interaction design, one method for evaluating a product is called usability testing, which involves testing the product on actual users. This might be considered a crucial usability strategy due to the fact that it provides direct feedback on how actual users interact with the system.

6.3 Compatibility Testing

Compatibility testing is a non-functional testing type performed on application software to ensure compatibility with various computing environments. Because different software is available in different versions, some may support libraries while others may not, it is possible for an application to encounter errors, or some may be outdated or more up-to-date versions. With the help of compatibility testing, we can evaluate the performance of our application. Our app is for Web. This app is designed specifically for web. As a result, it cannot be used on the android devices.

6.4 Performance Testing

In general, performance testing is a technique used to specify a system's responsiveness and stability under a particular workload. For this test, we attempted to add a large number of vaccination data, producing the desired results.

6.5 Security Testing

Security testing is a procedure designed to identify vulnerabilities in an information system's security measures that safeguard data and maintain functionality.

6.6 Installation Testing

Installation testing verifies that the software application was installed correctly and is operating as expected. This is the testing phase that occurs prior to the first time an end user interacts with the application. During this testing, we use our app on the user's end and ensured that the user had no problems using the app and that all functionalities were complete. We tried our app on different web devices with different operating systems, and it worked perfectly.

6.7 Test Cases

A test case is a series of operations carried out on a system to see if it complies with software requirements and operates properly. For our project we have used different types of test cases that are used to measure the validity and robustness of our project.

Test case ID	01
Test case Title	Running of Application
Description	Check the Application is Running.
Test Steps	1. - Run the app on web. 2. - Check the application is running
Expected Output	Application must open without crashing
Status	Successful

Table 5: Test Case for Running of Application

Table 5 shows the test case of working of application.

Test case ID	02
Test case Title	Working of Screen
Description	Check the screen is working.
Test Steps	1. - Run the app on web. 2. - Check the screen
Expected Output	Screens is working
Status	Successful

Table 6: Test Case for Working of Screen

Table 6 shows the test case of correct working of all screens including the user manual of the application

Test case ID	03
Test case Title	Add Manufacturer
Description	Check if manufacturer address is adding or not.
Test Steps	1. - Add manufacturer wallet address. 2. - Click on submit.
Expected Output	Address is added
Status	Successful

Table 7: Test Case for Adding Manufacturer

Table 7 shows the test case of adding manufacturer it shows while adding manufacturer address its connecting to wallet or not.

Test case ID	04
Test case Title	Add Administrator
Description	Check if Administrator address is adding or not.
Test Steps	1. - Add Administrator wallet address. 2. - Click on submit.
Expected Output	Address is added
Status	Successful

Table 8: Test Case for Adding Administrator

Table 8 shows the test case of adding administrator it shows while adding administrator address its connecting to wallet or not.

Test case ID	05
Test case Title	Add Vaccine Info
Description	Check Vaccine info is adding or not.
Test Steps	1. - Select the manufacturer option in application. 2. - Add vaccine data.
Expected Output	Vaccine info is submitted.
Status	Successful

Table 9: Test Case for Add Vaccine Info

Table 9 shows the test case of working vaccine info submission weather it is submitting or not.

Test case ID	06
Test case Title	Displaying Vaccine Record
Description	Displaying vaccine Record.
Test Steps	1. - Select the option Record on web app. 2. - Click on Generate Vaccine Record option.
Expected Output	Vaccine Record is displayed.
Status	Successful

Table 10: Test Case for Displaying Vaccine Record

Table 6.2 shows the test case of displaying vaccine record that will be used for checking correct record of vaccine is displayed or not .

7 Chapter 7

Conclusion and Future Work

7.1 Conclusion

In this project, we show the application of blockchain technology in the fight against the COVID-19 epidemic. This pandemic's control is the primary purpose of blockchain technology. During this pandemic crisis, this technology can give enhanced solutions, outbreak tracking, user privacy protection, medical supply chain performance, donation tracking, and safe day-to-day operations. The implementation of blockchain technology should reduce network latency and safeguard the storage and transmission of sensitive data. The ultimate convergence of blockchain technology with other developing technologies, such as artificial intelligence, big data, and Cloud computing, can effectively battle coronavirus pandemics.

7.2 Future Work

Enhance Blockchain technology to minimize network latency and provide a more secure environment for storing and transferring sensitive data. Lightweight blockchain architecture is necessary to maximize data verification and transaction communication in the healthcare industry. Creating customized ledgers that can be placed on local servers in the outbreak zone enhances the blockchain's performance. In the future, blockchain technology combined with other emerging technologies such as artificial intelligence (AI), big data, and Cloud computing can be a highly effective technique for combatting pandemics such as coronavirus. Recently, Taiwan exploited big data and AI to contain a virus's spread (Waltz, 2020). China has recently employed drones to improve the delivery of medical supplies (Chi-Nguyen et al., 2018). Alibaba has also combined AI and Cloud computing to assist with the analysis of coronavirus data.

8 Chapter

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