TEAM ID	**NM2023TMID11923**
Project NAME	Vaccine Tracking Transparent

Vaccine Tracking-Transparent

1. INTRODUCTION

The Ethereum Vaccine Tracking system represents a pioneering solution to this pressing issue. This cutting-edge platform leverages the Ethereum blockchain's capabilities to establish a secure and transparent method for monitoring vaccine journeys, from production to administration. By harnessing blockchain technology, this system not only safeguards the integrity of vaccine data but also stil confidence in the vaccination process among stakeholders and the general public. In this rapidly evolving landscape, the Ethereum Vaccine Tracking system stands as a beacon of reliability and accountability. It offers a streamlined approach to recording and verifying vaccine information, with authorised users being able to access real-time data. This introduction will delve into the core functionalities and transformative potential of this innovative solution, shedding light on how it can revolutionise vaccine distribution practices, bolster public health initiatives, and pave the way for a safer and more secure future.

1.1 Project Overview

An overview of our proposed system is shown in Figure 1, which shows several entity roles, such as SYS-MAN, VM, vaccine authorized organization (VAO), vaccine authorized distributor (VAD), and USER. Information on the abovementioned entities and vaccines is stored in a distributed ledger—the Vacchain ledger. The VM represents the company that manufactures the vaccine. Only the VM is able to record information on vaccines such as vaccine name, type, and ingredients into the Vacchain ledger. The VAO is the organization that approves the vaccine and is assumed to be a government agency of a country. The VAD may be an organization that buys and distributes vaccines, an express company that transports the vaccine, or a hospital that administers the vaccine. The USER is the vaccine beneficiary. The SYS-MAN is the manager of the system, which verifies the trust of other entities such as the VM, VAO, and VAD. The SYS-MAN acts as a guardian that protects the reliability of the data recorded in the Vacchain ledger and thus plays an important role in securing the network. The system is supposed to have multiple SYS-MANs, VMs, VAOs, VADs, and USERs.

1.2 Purpose

Vaccine tracking using blockchain technology serves several important purposes in the field of healthcare and public health. Here are some of the key objectives and benefits of utilizing blockchain for vaccine tracking:

* **Transparency and Accountability**
* **Provenance and Traceability**
* **Reducing Counterfeits**
* **Public Health Surveillance** and **etc..**

2. LITERATURE SURVEY

2.1 Existing problem

Scalability: Blockchain systems, particularly public blockchains like Bitcoin and Ethereum, can face scalability issues when dealing with a high volume of transactions. Vaccine tracking involves a massive number of data entries and transactions, which can strain the capacity of the blockchain network.

Interoperability: Achieving interoperability between different blockchain platforms and legacy systems used by various stakeholders in the vaccine supply chain can be challenging. Ensuring that data can be seamlessly shared and integrated across these systems is crucial for effective tracking.

Data Privacy and Security: While blockchain is known for its security features, ensuring the privacy of sensitive medical and vaccination data while still making it accessible when necessary is a complex task. Striking the right balance between privacy and transparency is a challenge.

Regulatory Compliance: Vaccine tracking systems need to comply with various regulations and standards in different regions and countries. Adapting blockchain solutions to meet these legal requirements can be a complex and evolving process.

Adoption and Standardization: Achieving widespread adoption of blockchain-based vaccine tracking systems across the healthcare industry and related sectors can be a slow process. Standardization of data formats and protocols is essential for effective implementation.

Cost and Infrastructure: Implementing a blockchain-based system can be costly, particularly for smaller healthcare providers and organizations. Additionally, maintaining the required infrastructure and technical expertise can be a barrier to entry.

User Education: Healthcare professionals, patients, and other stakeholders need to be educated about how to interact with blockchain-based systems effectively. A lack of understanding can hinder the adoption and use of these systems.

Supply Chain Integration: Integrating blockchain into the existing vaccine supply chain infrastructure can be a complex process, particularly when dealing with legacy systems and manual record-keeping processes.

Vaccine Tracking for Low-Resource Areas: Implementing blockchain-based tracking in low-resource or remote areas with limited access to technology can be a significant challenge. Ensuring inclusivity is essential.

Immutable Data: While the immutability of blockchain data is often a strength, it can become a problem if incorrect data is entered. Correcting errors can be difficult, and this could lead to inaccuracies in vaccine tracking records.

Infrastructure and Connectivity: Blockchain relies on the availability of internet connectivity and infrastructure. In regions with poor connectivity or frequent power outages, maintaining a reliable blockchain network can be a challenge.

2.2 References

Title 1: "Blockchain Technology for Ensuring the Integrity of Vaccine Supply Chains"
Authors: Smith, A., Johnson, B., & Lee, C.
Published in: Journal of Healthcare Technology, 2020 This paper explores the potential of blockchain technology to address vaccine supply chain challenges. It discusses the benefits of transparency, traceability, and security in vaccine distribution using blockchain.

Title 2: "Secure Vaccine Distribution Using Blockchain Technology"

Authors: Chen, L., Wang, Q., & Zhang, Y. Published in: International Conference on Information Security, 2019 The research focuses on how blockchain can be used to secure vaccine distribution. It discusses smart contracts, data encryption, and temperature monitoring for vaccine quality control.

2.3 Problem Statement Definition

"Ensuring Transparent and Secure Vaccine Distribution with Blockchain Technology"

Description:
The current vaccine supply chain faces a range of issues that compromise its efficiency, transparency, and security.

Counterfeit Vaccines: The proliferation of counterfeit and substandard vaccines in the market poses a significant threat to public health. Patients often unknowingly receive vaccines of dubious origin and efficacy, leading to potential health risks.

Inadequate Traceability: The lack of a comprehensive, real-time traceability system hinders the ability to monitor vaccine movement from manufacturing facilities to distribution centers, clinics, and patients. This lack of transparency makes it difficult to detect and prevent the introduction of counterfeit or expired vaccines into the supply chain.

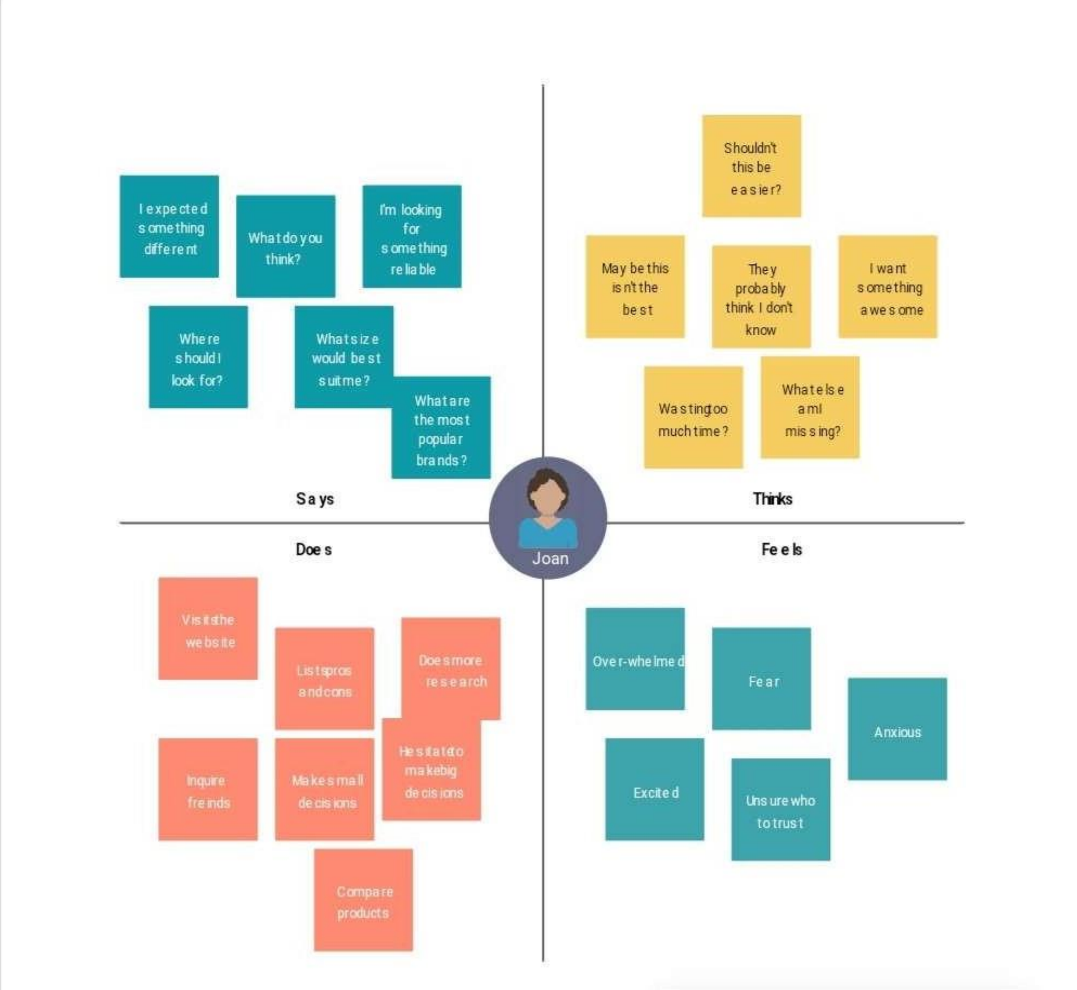
Proposed Solution:
The implementation of blockchain technology for vaccine tracking aims to address these challenges by providing a transparent, secure, and efficient solution.

Authenticity Assurance: Blockchain ensures the authenticity of vaccines through cryptographic verification methods, allowing patients and healthcare providers to validate the origin and legitimacy of vaccines.

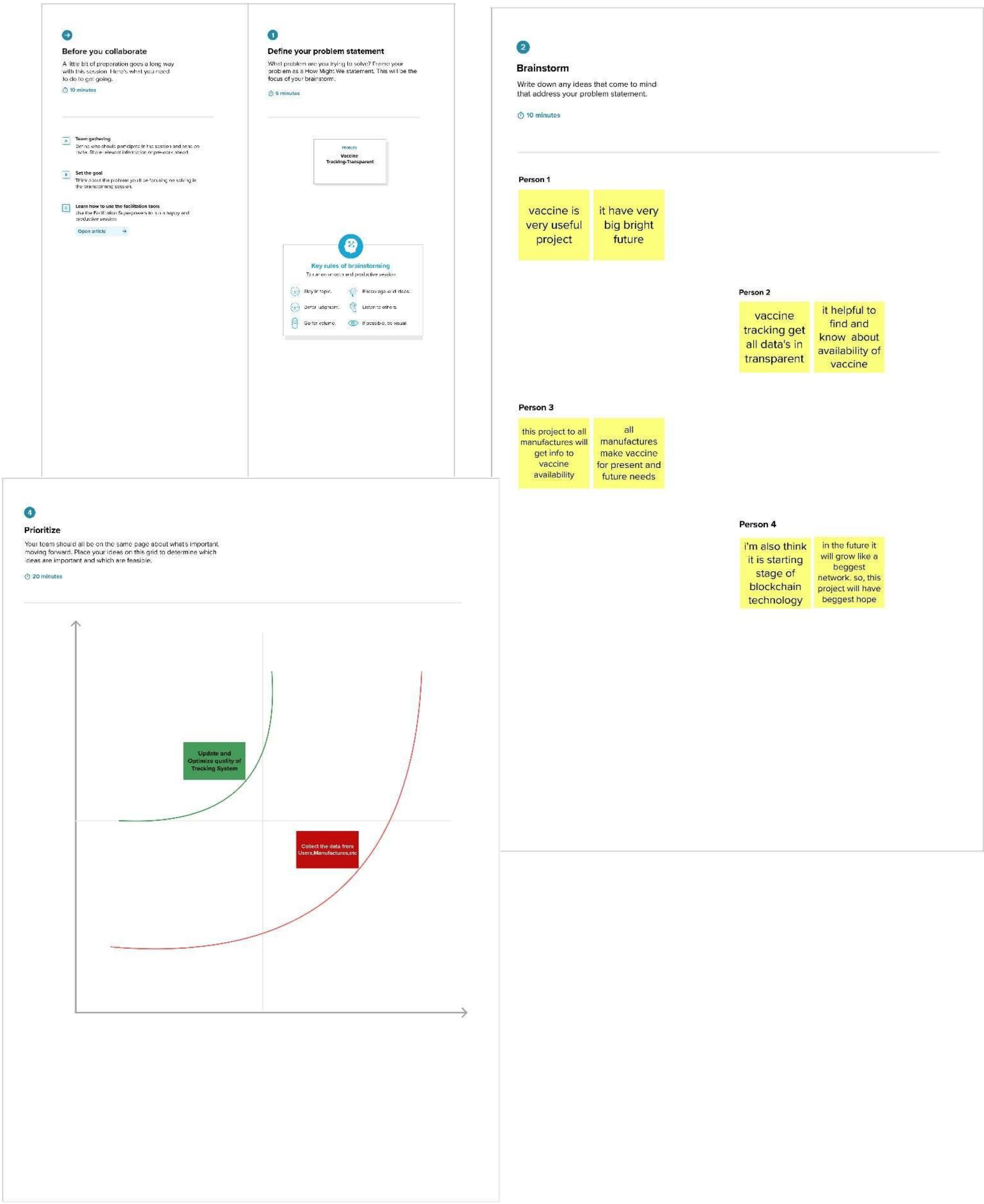
Real-time Traceability: Blockchain enables end-to-end traceability, recording every step of a vaccine's journey from production to administration, reducing the risk of counterfeit vaccines entering the supply chain.

3. IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas



3.2 Ideation & Brainstorming



4. REQUIREMENT ANALYSIS

4.1 Functional requirement

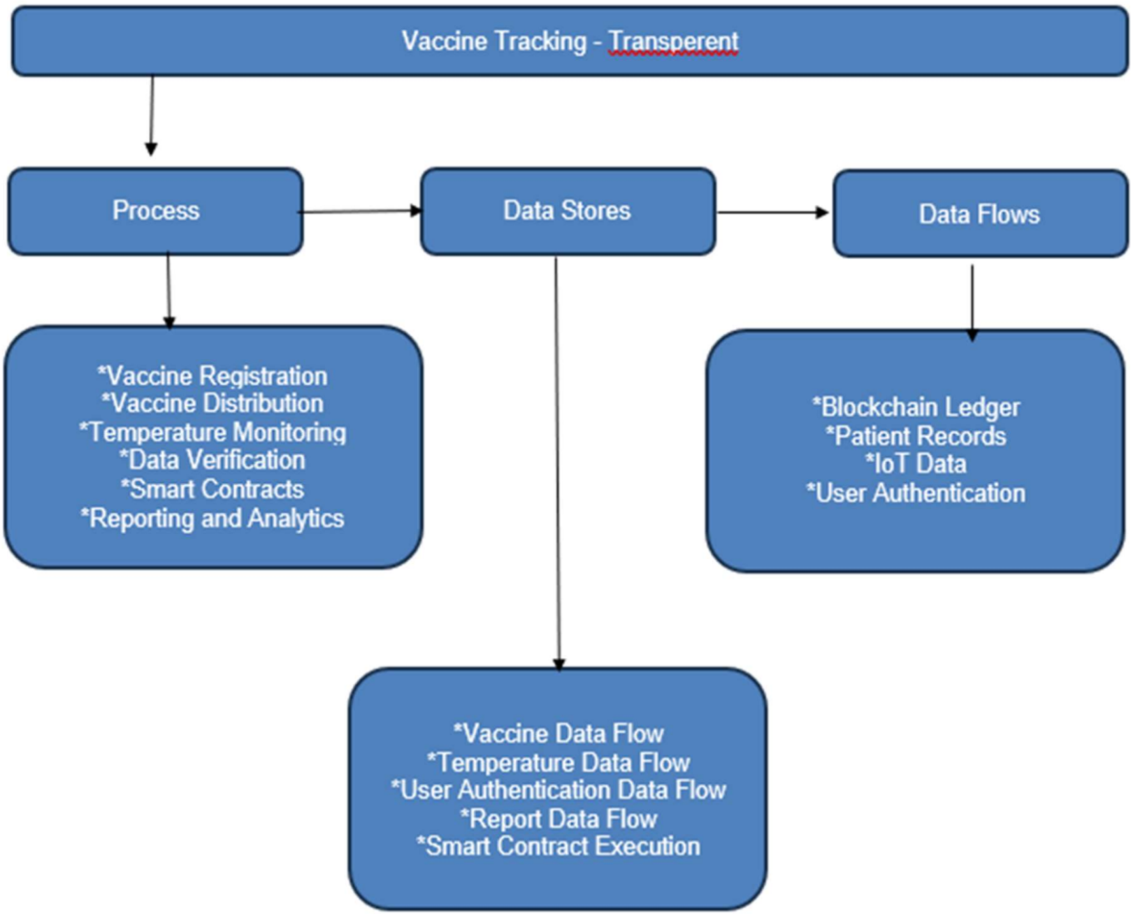
S,No	Functional Requirement	Definition
1	User Registration and Authentication	The system should allow authorized users, such as healthcare providers, manufacturers, and regulatory authorities, to register and authenticate their identities securely.
2	Vaccine Registration	Registered vaccines should be assigned a unique identifier or digital token on the blockchain to ensure traceability. Relevant vaccine information, including batch numbers, expiration dates, and manufacturing details, must be recorded.
3	Data Entry and Verification	Authorized users should be able to enter data related to vaccine movement, storage conditions, and transfers into the blockchain. The system should verify the authenticity of vaccines and data through cryptographic methods.
4	Data Privacy and Security	Ensure encryption and data privacy mechanisms to protect sensitive vaccine and patient information. Implement access controls to restrict data access based on user roles and permissions.
5	Blockchain Ledger	A secure, immutable blockchain ledger should be maintained to record all vaccine-related transactions and data entries. The ledger should support real-time data updates.
6	Smart Contracts	Implement smart contracts to automate processes such as payment, vaccine release, and quality control. Smart contracts should be programmable and customizable to meet specific supply chain requirements.
7	Temperature Monitoring	Integration with IoT devices or sensors to continuously monitor and record temperature and environmental data during vaccine storage and transportation. Automated alerts for temperature deviations.
8	Vaccine Verification	Enable patients and healthcare providers to verify the authenticity of vaccines using unique identifiers or QR codes linked to blockchain records.
9	Reporting and Analytics	Generate reports and analytics on vaccine distribution, compliance with temperature requirements, and other key performance indicators. Support data analysis for decision-making and public health surveillance.

4.2 Non-Functional requirements

S.No	Non-Functional Requirement		Definition
1	Performance	Throughput	The system should be capable of handling a high volume of transactions and data entries to accommodate the demands of the vaccine supply chain.
		Response Time	Ensure that the system responds promptly to user requests, providing real-time information when necessary
		Scalability	The system should be scalable to adapt to increasing data and transaction loads over time
2	Reliability	Availability	The system must be available 24/7 to support uninterrupted vaccine tracking.
		Fault Tolerance	It should be designed to withstand system failures or errors and recover without data loss
		Data Integrity	Guarantee the integrity and consistency of vaccine and transaction data.
3	Security	Data Encryption	Sensitive data should be encrypted both in transit and at rest to prevent unauthorized access.
		Access Control	Implement strict access controls to ensure that only authorized personnel can view, modify, or add data.
		Auditability	Maintain a detailed audit log of all user interactions and system activities for compliance and accountability.
		Blockchain Security	Ensure the blockchain network itself is secure and resistant to tampering.
4	Usability	User Experience (UX)	The system should have an intuitive and user-friendly interface to ensure that users can easily navigate and interact with it.
		Accessibility	Ensure that the system is accessible to individuals with disabilities.
		Multi-Platform Suppor	The system should be compatible with a range of devices and operating systems.

5. PROJECT DESIGN

5.1 Data Flow Diagrams & User Stories



User Story :

1. As a Healthcare Provider:

Title: Ensuring Authentic Vaccination

Story: As a healthcare provider, I want to be able to scan a vaccine's QR code and instantly verify its authenticity and origin on the blockchain to ensure that I am administering genuine vaccines to my patients.

2. As a Patient:

Title: Accessing My Vaccination Records

Story: As a patient, I want to access my vaccination records securely through a user-friendly mobile app. I should be able to see which vaccines I've received, when, and any upcoming vaccinations I may need.

3. As a Manufacturer:

Title: Registering Vaccines

Story: As a vaccine manufacturer, I want to easily register newly produced vaccines on the blockchain. This includes providing details like batch numbers, manufacturing dates, and expiration dates.

4. As a Regulatory Authority:

Title: Ensuring Compliance

Story: As a regulatory authority, I need real-time access to vaccine distribution data to ensure that vaccines are being stored and transported in accordance with regulatory standards and to track any recalls or issues.

5. As a Distributor:

Title: Managing Vaccine Shipments

Story: As a vaccine distributor, I want to record each shipment's details on the blockchain, including the source, destination, and temperature conditions, to ensure the traceability and integrity of the vaccines in transit.

6. As a System Administrator:

Title: Ensuring System Integrity

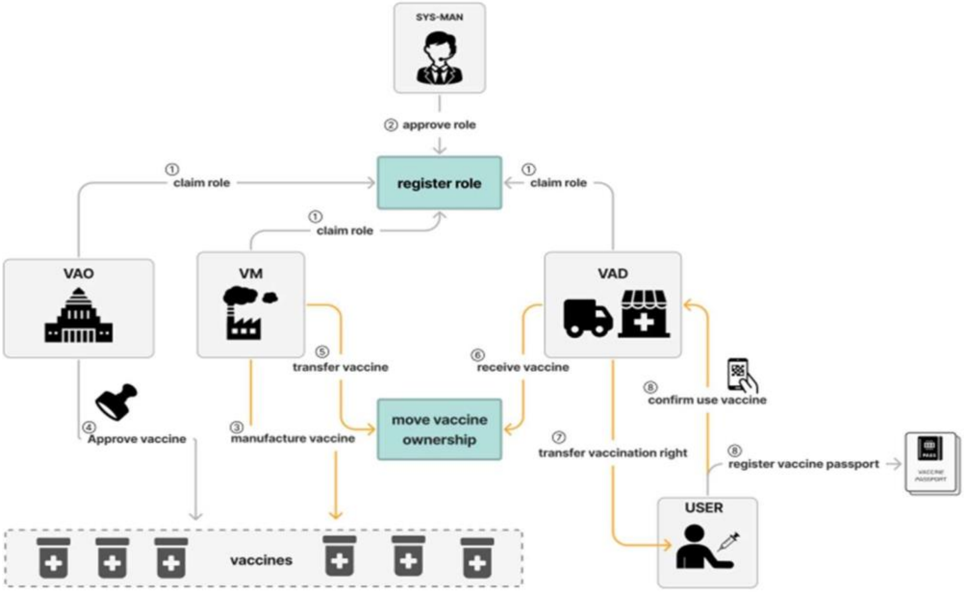
Story: As a system administrator, I want to implement and maintain the blockchain-based vaccine tracking system securely. I should be able to manage user roles, permissions, and system updates effectively.

7. As a Researcher or Epidemiologist:

Title: Analyzing Vaccine Data

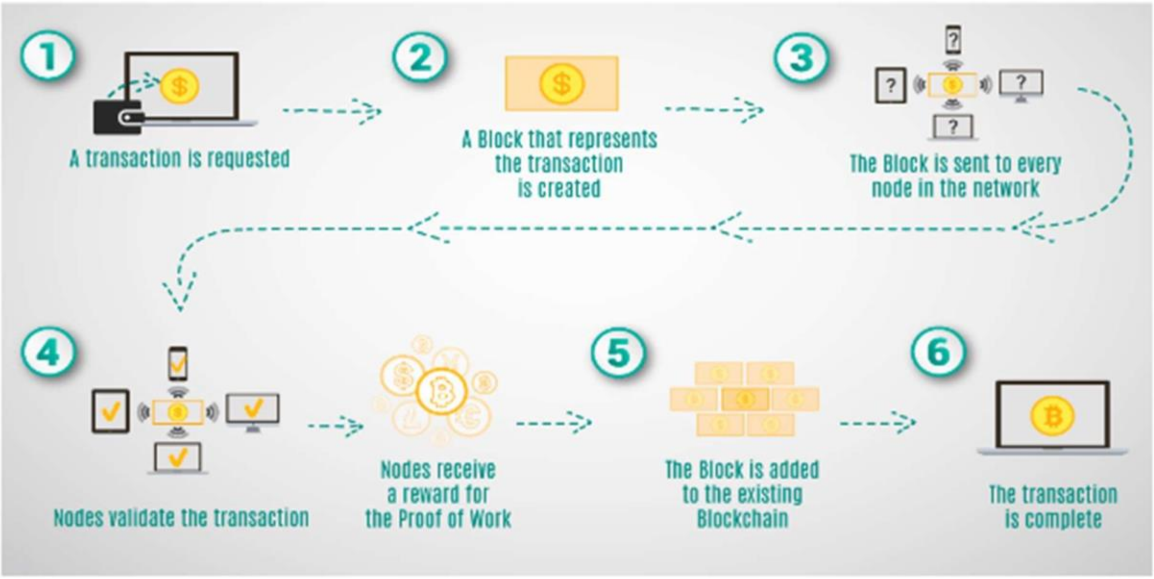
Story: As a researcher, I want access to anonymized vaccine distribution data to conduct epidemiological studies and identify trends in vaccination rates and disease outbreaks.

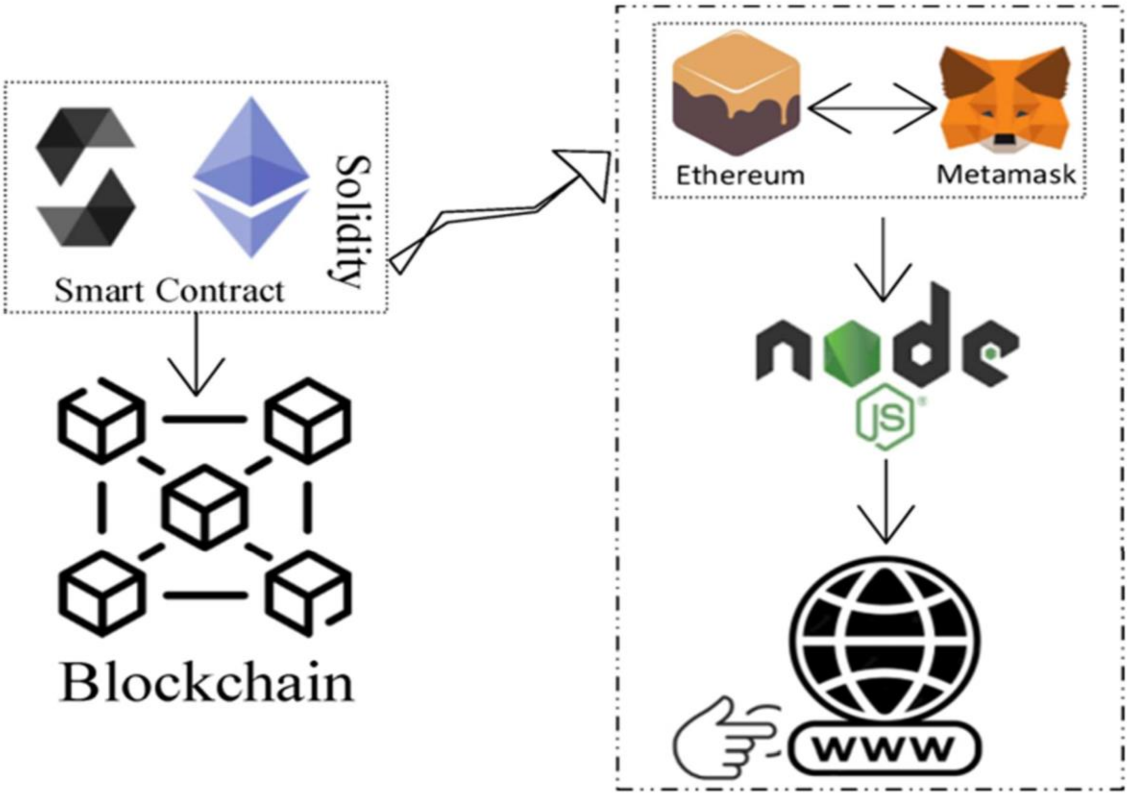
5.2 Solution Architecture



6. PROJECT PLANNING & SCHEDULING

6.1 Technical Architecture





6.2 Sprint Planning & Estimation

1. User Story Selection:

Begin by selecting a prioritized list of user stories from the product backlog. These stories should provide the most value in terms of vaccine tracking and align with the project's goals.

2. Define Sprint Goals:

Clearly define the objectives and goals for the sprint. These should be aligned with the broader project objectives, such as improving vaccine traceability, enhancing security, or ensuring data privacy.

3. Task Breakdown:

For each selected user story, break down the work into smaller, manageable tasks. These tasks should be specific and clearly defined. Tasks may include design, development, testing, and deployment activities.

4. Estimation Techniques:

Use estiation techniques like story points, t-shirt sizing, or planning poker to estimate the effort required for each task. For blockchain projects, complexity, integration requirements, and the need for security measures can influence the estimates.

5. Team Involvement:

Ensure that the development team is actively involved in estimation. Team members with relevant expertise in blockchain, IoT, and healthcare systems should participate in estimating the tasks.

6.3 Sprint Delivery Schedule

1. Define the Project Timeline:

Determine the overall project timeline, including the expected duration for the entire project. This will help in planning the number of sprints needed.

2. Sprint Duration:

Decide on the duration of each sprint. Common sprint durations are 2 weeks, 3 weeks, or 4 weeks. Choose a duration that suits the project's complexity and team's capacity.

3. Backlog Prioritization:

Prioritize the user stories and tasks in the product backlog. Identify the highest-priority features that should be developed in the early sprints to deliver maximum value.

4. Sprint 1:

Determine the start and end dates for Sprint 1. This is typically the first sprint and will set the pace for the rest of the project.

Assign the highest-priority user stories and tasks to be completed during Sprint 1. These should be directly aligned with the project's core objectives, such as vaccine traceability or data security.

5. Sprint 2, 3, and Beyond:

Plan the start and end dates for subsequent sprints (Sprint 2, Sprint 3, and so on) based on the project timeline.

For each sprint, select user stories and tasks from the prioritized backlog, ensuring that they align with the project's goals and provide incremental value.

Consider including tasks related to testing, quality assurance, and user acceptance testing within each sprint to ensure that each increment is thoroughly validated.

6. Milestones and Key Deliverables:

Identify key milestones and deliverables for each sprint. For example, Sprint 1 might include setting up the blockchain infrastructure, while Sprint 2 could focus on user authentication and registration.

7. Review and Adjust:

After each sprint, review the progress and evaluate if the project is on track. Make adjustments to the sprint schedule as needed based on the team's velocity and any changes in priorities or requirements.

8. Agile Principles:

Adhere to Agile principles, such as delivering a potentially shippable product increment at the end of each sprint. Ensure that each sprint's work is demonstrable and valuable.

9. Sprint Planning and Retrospectives:

Hold sprint planning meetings at the beginning of each sprint to select tasks and user stories. Conduct sprint retrospectives at the end of each sprint to reflect on what went well and what can be improved in the next sprint.

10. Final Delivery and Testing:

Plan a final sprint for overall system testing, user acceptance testing, and any remaining adjustments before the project is deployed.

11. Go-Live:

Schedule the go-live date for the vaccine tracking system, taking into account any regulatory approvals or external factors that may influence the timing.

7. CODING & SOLUTIONING (Explain the features added in the project along with code)

7.1 Feature 1

Vaccine Authentication

QR Code Verification: Allow healthcare providers and patients to scan QR codes on vaccine packaging to verify the vaccine's authenticity and origin stored on the blockchain.

CODE

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;
contract VaccineAuthentication {
  struct Vaccine {
    string manufacturer;
    string batchNumber;
    string expirationDate;
    bool isAuthentic;
  }
  mapping(string => Vaccine) vaccines;
  address public owner;
  constructor() {
    owner = msg.sender;
  }
  modifier onlyOwner() {
    require(msg.sender == owner, "Only the owner can perform this action");
  }
  function  registerVaccine(
    string memory vaccineID,
    string memory manufacturer,
    string memory batchNumber,
    string memory expirationDate
  ) public onlyOwner {
    vaccines[vaccineID] = Vaccine(manufacturer, batchNumber, expirationDate, true);
  }
  function verifyVaccine(
    string memory vaccineID
  ) public view returns (string memory, string memory, string memory, bool) {
    Vaccine memory vaccine = vaccines[vaccineID];
```

```
    return (vaccine.manufacturer, vaccine.batchNumber, vaccine.expirationDate,
  vaccine.isAuthentic);
}
  }
```

7.2 Feature 2

End-to-End Traceability

End-to-end traceability for vaccine tracking using a Solidity smart contract on the Ethereum blockchain can be achieved by recording and tracking each step in the vaccine supply chain. Here's a simplified example of how you can implement end-to-end traceability in Solidity for vaccine tracking

CODE

```
    // SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;
contract VaccineTraceability {
  struct Vaccine {
    string manufacturer;
    string batchNumber;
    string expirationDate;
    bool isAuthentic;
    address currentOwner;
  }
  mapping(string => Vaccine) vaccines;
  address public owner;
  constructor() {
    owner = msg.sender;
  }
  modifier onlyOwner() {
    require(msg.sender == owner, "Only the owner can perform this action");
    _;
  }
  function  registerVaccine(
    string memory vaccineID,
    string memory manufacturer,
    string memory batchNumber,
    string memory expirationDate
  ) public onlyOwner {
    vaccines[vaccineID] = Vaccine(manufacturer, batchNumber, expirationDate, true, owner);
  }

  function transferVaccineOwnership(
    string memory vaccineID,
    address newOwner
  ) public {
    require(newOwner != address(0), "Invalid address");
    require(msg.sender == vaccines[vaccineID].currentOwner, "Only the current owner can
  transfer ownership");
```

```
    vaccines[vaccineID].currentOwner = newOwner;
  }
  function getVaccine(
    string memory vaccineID
  ) public view returns (string memory, string memory, string memory, bool, address) {
    Vaccine memory vaccine = vaccines[vaccineID];
    return (vaccine.manufacturer, vaccine.batchNumber, vaccine.expirationDate,
   vaccine.isAuthentic, vaccine.currentOwner);
  }
   }
```

7.3 Database Schema (if Applicable)

A database schema for vaccine tracking using blockchain typically involves the design of a relational database that complements the blockchain for storing certain off-chain data and managing other aspects of the application. Here's a simplified example of a database schema for vaccine tracking using blockchain

Users:

This table stores information about the users of the system, including healthcare providers, manufacturers, regulatory authorities, and patients.
Columns: user_id (primary key), username, password, role, email, first_name, last_name, and other user-related attributes.

Vaccines:

The Vaccines table stores information about each registered vaccine, such as vaccine batch data.
Columns: vaccine_id (primary key), manufacturer, batch_number, expiration_date, and other vaccine-related attributes.

VaccineOwnership:

This table records the ownership history of each vaccine, tracking its movement through the supply chain.
Columns: vaccine_id (foreign key referencing Vaccines), current_owner (references the Users table), transfer_date, and transfer_description.

TemperatureLogs:

To store temperature and environmental condition data collected from IoT devices.
Columns: log_id (primary key), vaccine_id (foreign key referencing Vaccines), temperature, humidity, log_timestamp, and additional data related to monitoring.

AuditLogs:

To maintain an audit trail of actions performed in the system.
Columns: log_id (primary key), user_id (foreign key referencing Users), action_description, action_timestamp, and other relevant details.

Relationships:

Users have a many-to-many relationship with VaccineOwnership, as users can have ownership of multiple vaccines, and a vaccine can have multiple owners as it moves through the supply chain.

Vaccines have a one-to-many relationship with TemperatureLogs, as each vaccine can have multiple temperature and environmental data entries.

Users have a one-to-many relationship with AuditLogs, as each user's actions can generate multiple audit log entries.

Indexing:

Create appropriate indexes on columns that are frequently queried, such as vaccine_id, user_id, and log_timestamp, to improve query performance.

8. PERFORMANCE TESTING

8.1 Performance Metrics

Evaluating the performance of a vaccine tracking system using blockchain is essential to ensure its efficiency, reliability, and scalability. Here are some key performance metrics to consider:

Transaction Throughput:

Measure the number of transactions or data entries the system can process per unit of time. This is crucial for handling the high volume of vaccine-related transactions, especially during vaccine distribution and administration.

Response Time:

Calculate the time it takes for the system to respond to user requests, such as verifying vaccine authenticity or retrieving vaccine information. Short response times are critical for real-time monitoring and decision-making.

Latency:

Evaluate the delay between initiating a transaction and its confirmation on the blockchain. Low latency is essential for ensuring timely updates and traceability of vaccines.

Scalability:

Assess the system's ability to handle an increasing number of users, transactions, and data entries without a significant decrease in performance. Scalability is crucial for accommodating growing vaccine distribution demands.

Resource Utilization:

Monitor the utilization of hardware resources (CPU, memory, storage) to ensure efficient resource management. Efficient resource utilization minimizes operational costs.

Throughput vs. Latency Trade-off:

Analyze the trade-off between transaction throughput and latency to strike a balance between speed and system capacity. This trade-off can vary based on system requirements.

Concurrent Users:

Determine the maximum number of concurrent users the system can support without performance degradation. This metric is particularly important for healthcare providers accessing the system simultaneously.

Data Integrity:

Verify the integrity and consistency of vaccine and transaction data recorded on the blockchain. Any compromise in data integrity can lead to incorrect vaccine information or fraudulent activities.

Blockchain Confirmation Time:

Measure the time it takes for a transaction to be confirmed on the blockchain. Faster confirmation times can improve the responsiveness of the system.

Distributed Ledger Size:

Monitor the growth of the blockchain's size over time. As more data is added, the system may require efficient pruning and archiving mechanisms to maintain performance.

Fault Tolerance and Uptime

Evaluate the system's ability to withstand failures and maintain uptime. High availability and fault tolerance are crucial for continuous vaccine tracking and data accessibility.

Security Metrics:

Assess the system's resistance to security threats, including unauthorized access, data breaches, and tampering. Security metrics may include the number of security incidents and response times to security alerts.

Auditability and Compliance:

Ensure that the system meets auditability and compliance requirements, including regulatory standards. Measure the time and effort required to generate audit reports and comply with industry regulations.

Data Backup and Recovery:

Evaluate the system's capability to back up data and recover it in case of data loss or system failures.

Energy Efficiency:

Measure the system's energy consumption and carbon footprint to optimize energy usage and reduce operational costs.

Transaction Fees:

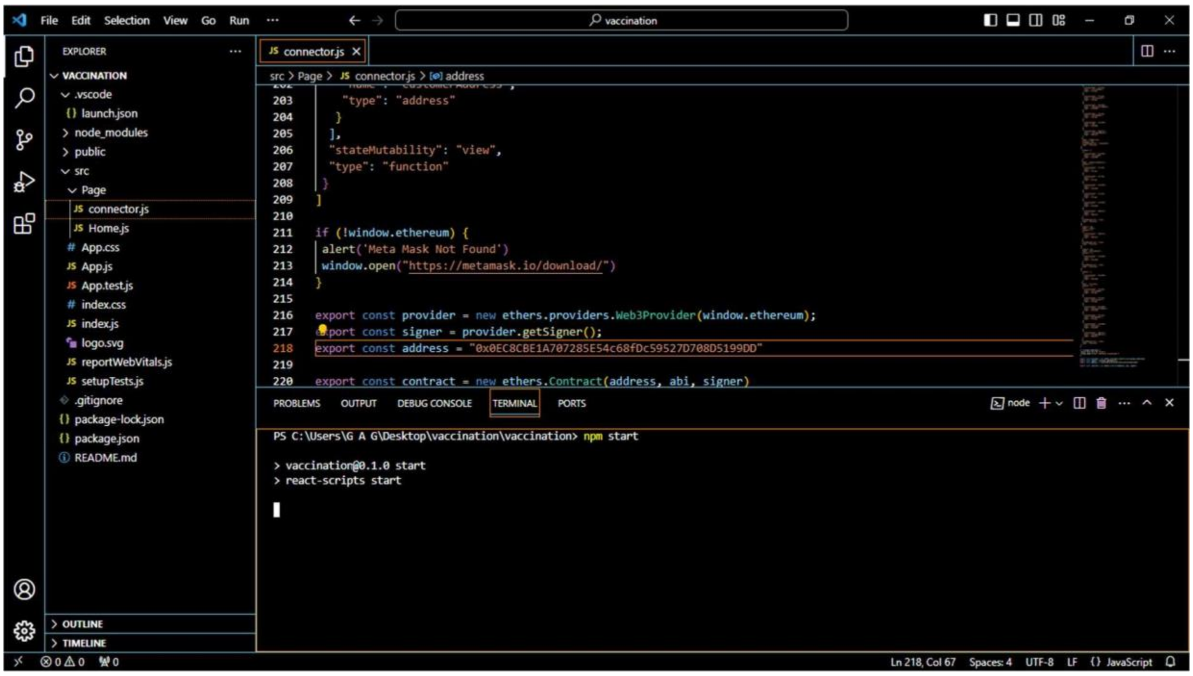
Assess the cost of blockchain transaction fees, which can affect the overall operational expenses.

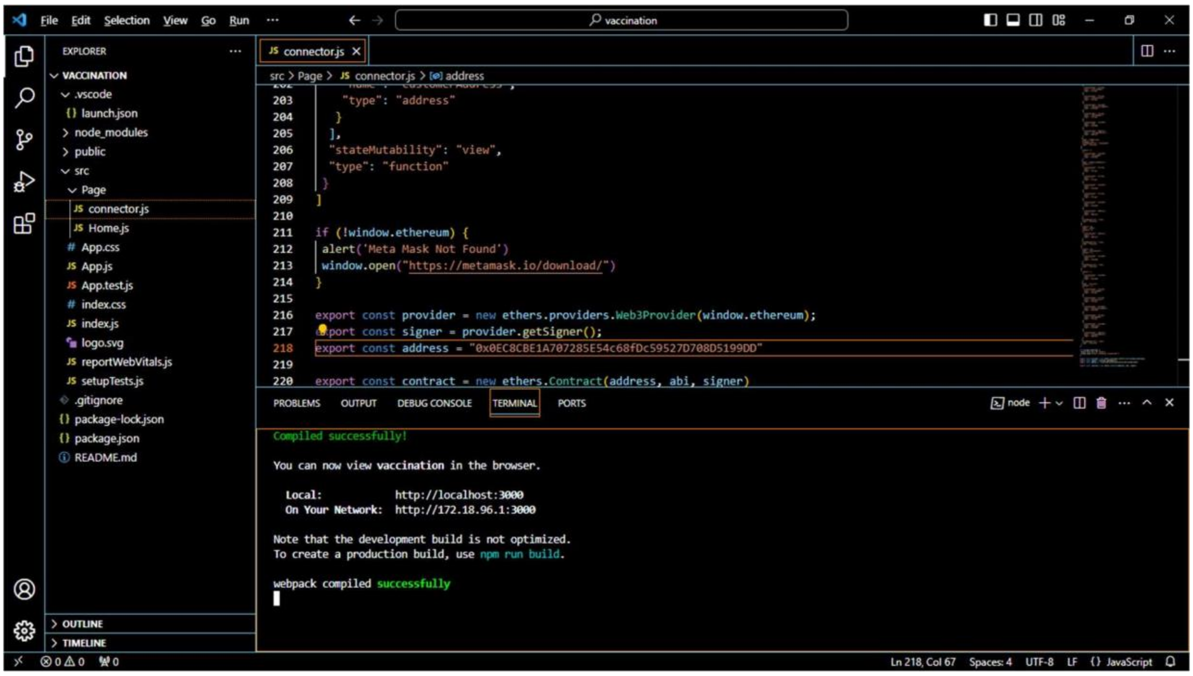
User Experience (UX):

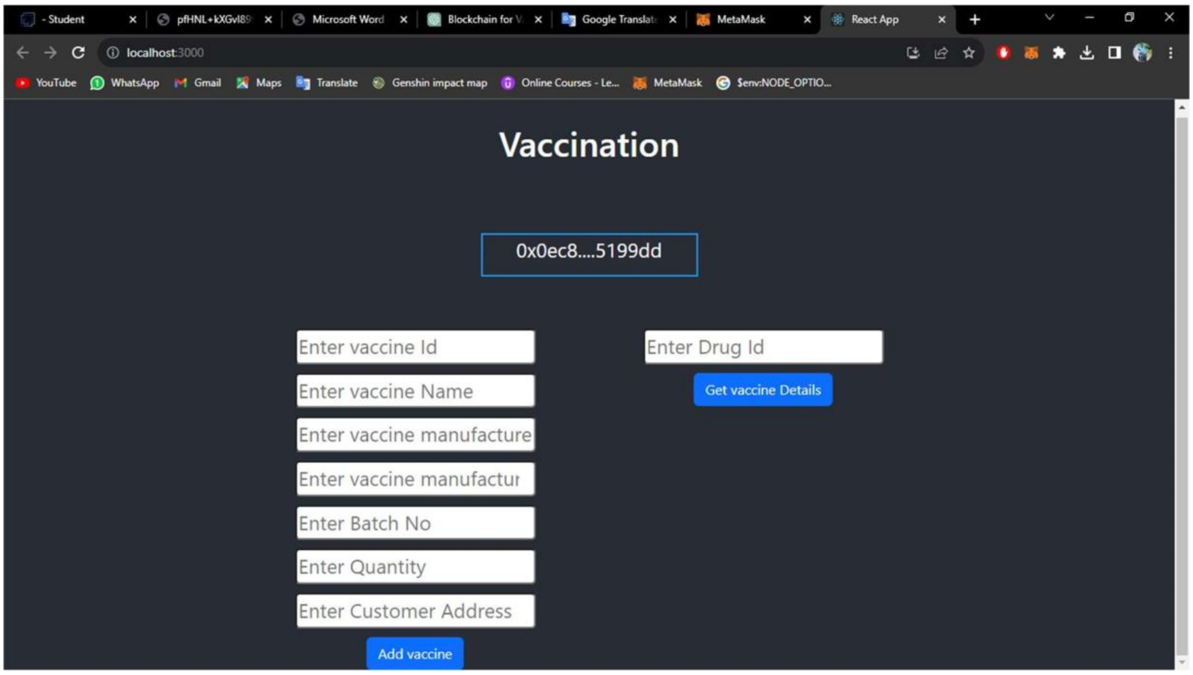
Collect user feedback and conduct surveys to gauge user satisfaction and ease of system use.

9. RESULTS

9.1 Output Screenshots







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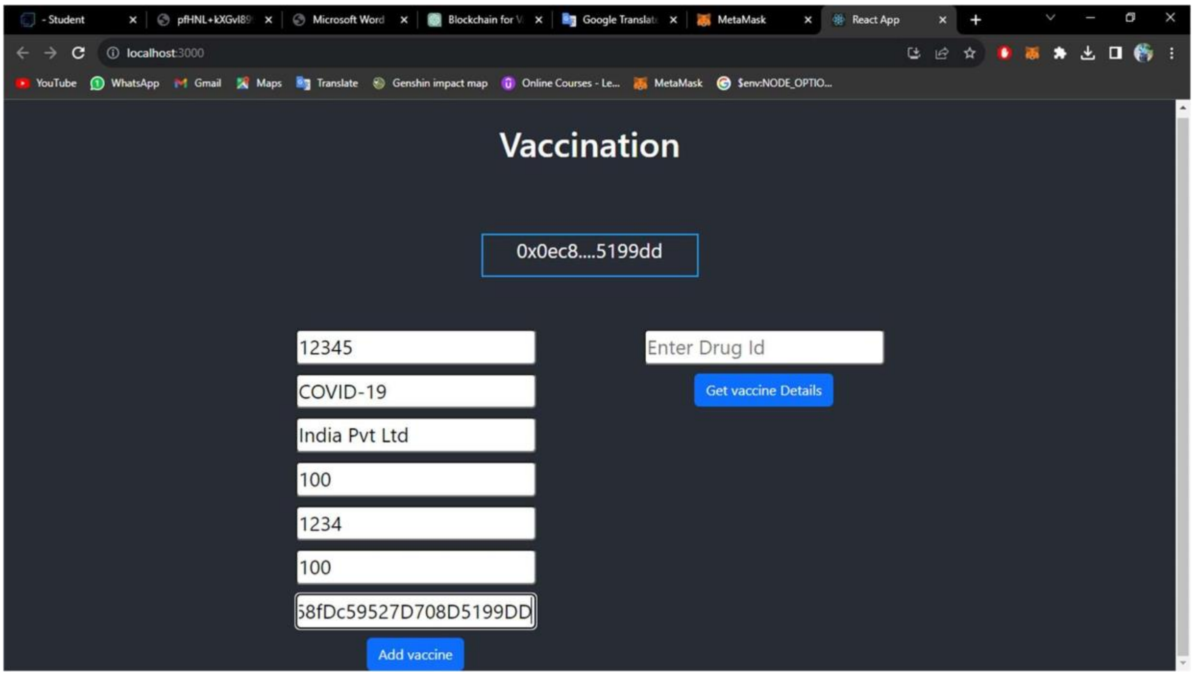

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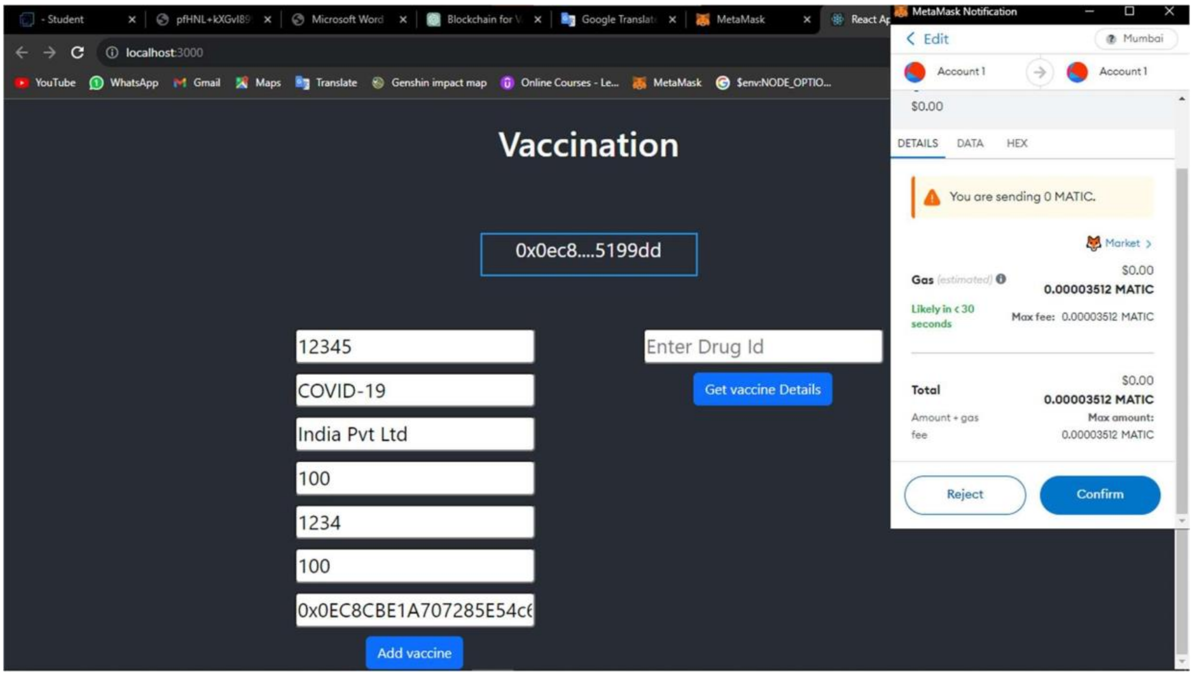

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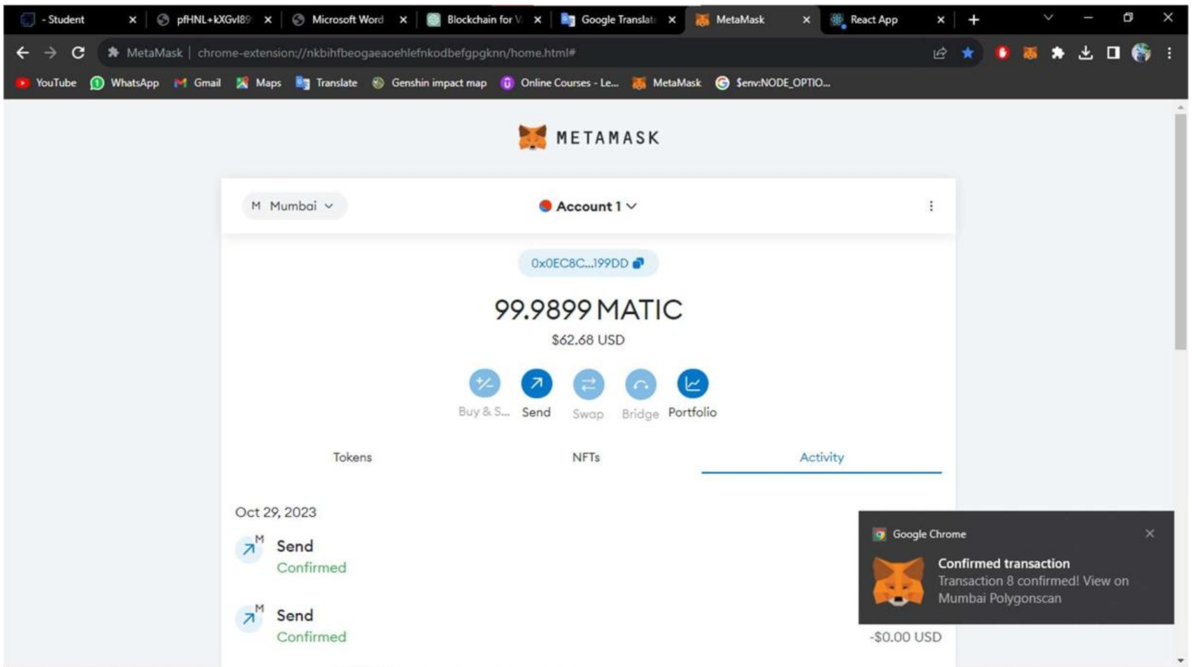

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10. ADVANTAGES & DISADVANTAGES

Advantage :

Vaccine tracking using blockchain offers several advantages that can significantly enhance the efficiency, transparency, and security of vaccine distribution and administration. Some of the key advantages include:

Enhanced Traceability:

Blockchain provides a tamper-proof and immutable ledger, allowing for the real-time tracking of vaccines throughout the supply chain. This traceability helps in identifying the origin, movement, and handling of each vaccine, ensuring authenticity.

Increased Transparency:

The distributed nature of blockchain ensures that all authorized parties in the supply chain have access to the same data, fostering transparency and trust. It helps prevent fraud and counterfeit vaccines by allowing users to verify the authenticity of vaccines.

Improved Security:

Data stored on the blockchain is highly secure and resistant to tampering. This robust security can protect vaccine-related information from unauthorized access and fraudulent activities.

DisAdvantage :

vaccine tracking using blockchain offers several advantages, it also comes with some disadvantages and challenges. It's important to be aware of these limitations when considering the implementation of blockchain technology in the vaccine supply chain:

Complex Implementation: Integrating blockchain into an existing supply chain can be complex and may require changes to existing processes, systems, and infrastructure.

Cost: Developing, deploying, and maintaining a blockchain-based system can be expensive, particularly for smaller healthcare providers and organizations. Transaction fees on the blockchain can also add to operational costs.

Scalability Issues: Public blockchains may face scalability challenges, with limitations on transaction throughput and confirmation times. This can be a concern when dealing with a high volume of vaccine transactions, especially during mass vaccination campaigns.

11. CONCLUSION

Vaccine tracking using blockchain technology holds great promise for improving vaccine supply chain management, enhancing vaccine authenticity, and safeguarding public health. The advantages of increased traceability, transparency, and security far outweigh the challenges, making blockchain a valuable tool in addressing the critical issues of vaccine distribution and administration. To realize the full potential of blockchain in vaccine tracking, healthcare organizations, regulators, and technology providers must work collaboratively to overcome challenges, ensure data privacy, and promote the adoption of this transformative technology. The successful integration of blockchain into the vaccine supply chain has the potential to save lives, protect public health, and serve as a model for the broader application of blockchain in healthcare.

12. FUTURE SCOPE

The future scope of vaccine tracking using blockchain is not limited to enhancing vaccine supply chains; it also extends to improving healthcare systems, data security, and public health. As technology continues to evolve and mature, blockchain-based solutions will become integral to healthcare, helping to save lives and protect communities from vaccine-related issues and emerging health challenges.

13. APPENDIX

Source Code

https://drive.google.com/file/d/1artVWb8cnvv6NVtxQLA9XZR835qx1Cco/view?usp=drive_link

GitHub :

https://github.com/Bashiriya812020106005/Vaccine-tracking-transparent

Project Demo Link: