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Research Article

Blockchain- Enabled Tamper-Proof Vaccine Distribution Records

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ABSTRACT

In a time when vaccination records are critical to public and individual health, a tamper-proof system is needed to manage and validate vaccination data. This articleoutlines a novel approach to creating an immutable, safe platform for inputting and verifying vaccination data using blockchain technology. The system uses a distributed approachfor data entry and verification, protecting user privacy while ensuring the validity and integrity of vaccination records. The major objective is to build a strong foundation that uses blockchain technology to manage vaccination records, resultingin a straightforward, secure, and efficient method of storing and validating vaccinations. Using the core concepts of blockchain,the proposed system generates a permanent chain of blocks, each containing encrypted vaccine data. ..The primary goal is to build a strong foundation that uses blockchain technology tomanage vaccination records, resulting in a simple, safe, and effective method of recording and validating vaccinations. Theproposed system uses the core concepts of blockchaintechnology to create a permanent chain of blocks, each containing protected vaccine data. By using this method, individuals can keep control over their medical records and safeguard data from unauthorized access. This outlines the conceptual design and technical framework of the blockchain- based vaccination record system, pointing out its revolutionarypotential for medical record management. The study also discusses the difficulties and moral dilemmas associated with this innovation, making it a thorough resource for legislators, technologists, and medical professionals looking to put this ground-breaking treatment into practice.

Keywords: Blockchain, Decentralized Application (DApps), COVID 19,Smart Contract, Non-fungible tokens (NFTs), Ether (ETH), Decentralized Finance (Defi)

INTRODUCTION

The global healthcare scene has undergone a major shift in recent years, particularly with the arrival of vaccines as an essential instrument for preserving public health. The COVID- 19 pandemic brought to light the importance of vaccination, and vaccine record handling acquired a lot of attention. Maintaining vaccination coverage and empowering individuals to access and share their medical records depend on the safety and confidentiality of vaccine data. However, it has been demonstrated that conventional systems for managing data are susceptible to data breaches and hacking. This highlights the possibility of disruption, with blockchain providing a unique remedy for this problem. Blockchain technology offers a decentralized, impenetrable ledger that has applications in many different fields, including medicine. It was first developed to accommodate cryptocurrencies such as Bitcoin. The idea is to create an irreversible network of knowledge blocks of information, each connected to the previous one, so that once information is recorded, it remains safe, transparent, and unchangeable.

research's objective is to use the technology of blockchain:

To create a platform for vaccine registration and proof in this regard. The key goals are:

1. **Security**: Create a tamper-proof and secure platform for collecting and organizing vaccination data to lessen the chance ofdata manipulation or misuse without authorization.

2. **Decentralization**: Transfer power from centralized authoritiesto individuals by giving them the ability to handle and share vaccination records while maintaining their privacy.
3. **Efficiency**: Create an easy-to-use and efficient system that permits people to keep control of their health information, reduces the administrative burden on doctors and hospitals, and facilitatesdata sharing.

This describes a blockchain-based vaccination record system'sarchitectural layout and execution plan, taking both technologicaland ethical considerations into account. By doing this, it hopes tocreate opportunities for a future in medical record management that is more transparent and secure, ensuring patients can rely on the accuracy of their vaccination records, medical personnel can streamline processes without compromising data security.

BACKGROUND

Blockchain and Ethereum

Blockchain and Ethereum are two distinct but related ideas in thefield of distributed database technology. The technology of distributed ledgers, or blockchain, allows data to be stored and accessed on multiple nodes or computers in a network that is decentralized. It consists of a number of blocks, each containinga set of transactions or data. Once a block has been added to the blockchain, it becomes immutable and cannot be removed, protecting the security and privacy of the data. Blockchains are used for a wide range of purposes, including financial transactions, supply chain management, and the storage of medical data. They offer transparency, security, and decentralization. Ethereum is a particular blockchain system that is capable of more than just recording transactions. Smart contracts, which are contracts that execute themselves with termsencoded directly into the code, are the intended use case for it. Ethereum originally conceived of the idea for the Virtual Machine, a distributed machine that carries out smart contracts. On the virtual currency platform, developers can create decentralized apps (DApps) using smart contracts. Ether (ETH) isthe name of the network's native cryptocurrency, Ethereum. It makes transaction processing, smart contract execution, and DApp interaction easier. Ethereum has a reputation for being adaptable, enabling designers to create a wide range of applications, including non-fungible tokens (NFTs).

in along with decentralized finance (DeFi). Ethereum is aparticular blockchain platform, with Ether as its native digitalcurrencies, that focuses on facilitating the development of smartcontracts as well as decentralized applications. Blockchain is the basic technology that forms the basis for decentralized ledgersystems. There are numerous blockchain platforms with various features and use cases; Ethereum is just one example.

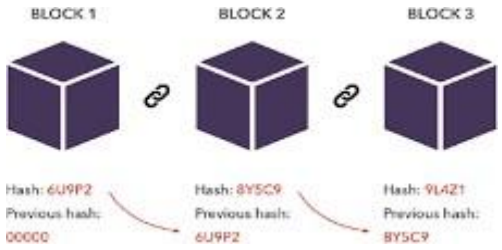

FIGURE 1 Blockchain Network [1]

Smart Contract

An autonomous contract with its terms directly encoded into a computer's code is known as a smart contract. It is a computer program which will automatically enforce, verify, or help parties in bargaining and carrying out the terms of a contract when certain conditions are met. Smart contracts can function decentralized without the need for middlemen because they aretypically implemented on blockchain systems. They offer security, automation, and transparency for a range of applications, such as contracts, supply chain management, banking, and more.

Blockchain in Vaccine Distribution

Many vaccine systems have been suggested and created thus far,most focusing on using smart contracts and blockchain technology in order to reduce manipulation and boost transparency. Blockchain technology and smart contracts can be utilized to construct a strong framework for a tamper-proof vaccine distribution system that guarantees the security and transparency of the entire process while safeguarding privacy and reducing costs. However, these systems should be carefullydesigned and implemented with legal, regulatory, and ethical considerations in mind when handling sensitive medical data and personal information.

Transparency and Security: To increase security and transparency in the vaccination distribution manipulate, use blockchain technology and smart contracts. The integrity of vaccination transportation records is guaranteed by the decentralized structure of blockchain, which makes it difficult for data to be altered or tampered with once it is recorded.

Token-Based Vaccine Control: Immunization doses should bedisplayed using tokens that are modeled after the "Voter Coin"concept. The distribution of tokens can be controlled by smart contracts, guaranteeing that only eligible recipients receive vaccinations. Every token could have a specific vaccination or dosage attached to it.

Limiting Transactions: A method to limit the number of transactions a person can make with their vaccination tokens isto use smart contracts. By ensuring that a person only receives the recommended number of vaccination doses, this reduces thepossibility of misuse.

Receipt-freeness and Privacy: Make sure that only people who have authorization can access complete information about vaccine recipients, including their medical history, in order to protect their freedom of privacy and receipt-freeness. Blockchain technology provides security and transparency for private medical data.

Reducing Costs and Increasing Involvement: To cut costs,use blockchain technology to improve vaccine distributionalong with supply chain processes. An efficient and open approach can help boost vaccination rates as well as vaccinedistribution.

Smart contract tracking: Make use of smart contracts to keep tabs on vaccine numbers, deliveries, shipping, and individual vaccination records. This guarantees the vaccination distribution process's auditability and traceability.

LITERATURE REVIEW

The proposed system uses Ethereum blockchain technology to manage COVID-19 vaccine distribution data. It enhances transparency, traceability, security, and accountability by automating the tracking process through smart contracts. The system is low-cost and secure against potential attacks. Itoutperforms existing non-blockchain and blockchain-based solutions.[2]

The proposed system discusses an ANN and IoT-based secure vaccine distribution system using a blockchain network. The integration of automotive, online storage, and IoT devices enables smart healthcare centers.[3] The paper proposes cryptographic techniques for security and transparent communication. The Distributed Application (DAPP) architecture is introduced to enhance transparency, security, and privacy among decentralized networks.

The proposed system uses a blockchain-based solution to improve the security and transparency of COVID-19 vaccine distribution. Ituses smart contracts and a "proof of delivery" consensus mechanismto ensure accountability. The authors have tested the solution on theEthereum platform and report promising results in terms of efficiency and scalability.[4]

A proposed system implemented using the Ethereum test network, considering the covid-19 vaccine distribution conditions. The results obtained for each on-chain operation can be checked and validated on the etherscan.[5] In terms of throughput and scalability,the proposed blockchain system shows promising results while the estimated cost in terms of gas for vaccination scenario based on real data remains within reasonable limits.

The proposed system represents a holistic solution that integrates both testing and vaccination processes. It incorporates a prioritization-based vaccination method and introduces a "digital vaccine passport" system, implemented through QR codes, to curtail corruption during testing and vaccination efforts. Test certificates, issued following covid-19 tests, serve as a basis for verifying an individual's health status. The same test results are used by authorities to prioritize vaccinations, efficiently allocating resourcesbased on infection rates. System is integrated with Ethereum publictext network.[6]

The proposed system uses blockchain technology, it employs distributed data storage to ensure tamper-proof and non-repudiable records, fostering trust among nodes. It uses blockchain's consensus mechanisms enhance information transmission reliability even in the face of disruptions.[7] Distributed data storage with blockchain is characterized by tamper-proof data and non-repudiation. Asymmetric encryption can be used to achieve mutual trust of vaccination information between nodes. By reducing process delays, it enables rapid network response.[8][9]

The proposed system discusses the transparency, security, andtraceability in vaccine distribution and introduces a Blockchain and IoT-based system to manage the registration, storage, and distribution of vaccines. The system aims to ensure data correctness,immutability, traceability, transparency, and security.[10]

The paper also mentions other initiatives and collaborations, including IBM's. Platform actors and interactions, smart contract functionalities, post-vaccination use, and challenges.[11]

The Vaccine Passport system is designed to combine proof of vaccination with a passport for travel. In many public places or public transportation require people to show vaccination certificates for vaccination prevention purposes.[12] So, the hash encryption and tamper-proof properties of blockchain combine the inoculation information and passport information well in an untrusted environment.[13]

The proposed system discusses the critical need for a trustworthyvaccine supply chain management system.[14] To address thesechallenges. This system aims to provide traceability and smart contract functionality for vaccines, offering solutions to problemslike vaccine expiration and record falsification. [15] Additionally, itsuggests that machine learning models can provide valuablerecommendations to immunization practitioners and recipients,enhancing the overall

immunization process. [16]

The proposed system says that how the vaccine is handled, stored,and administered, emphasizing the importance of maintaining thecold chain. Identifies several issues in the current vaccine distribution process, including physical limitations, communication problems, security concerns, and efficiency difficulties. [17]

SYSTEM DESIGN

This project aims to develop a secure and transparent system for vaccine distribution using blockchain technology and smartcontracts. The project addresses the need for a tamper-proof record-keeping system in the distribution of vaccines, ensuringthe authenticity, quality, and security of vaccines as they movethrough the supply chain.

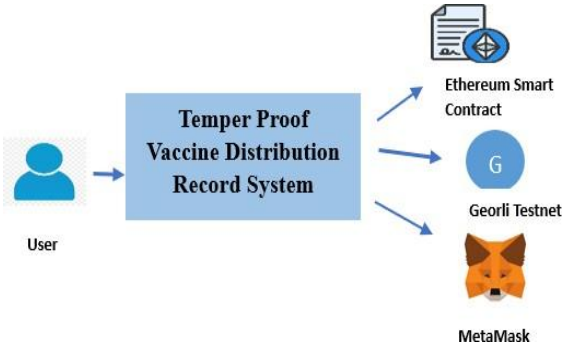

FIGURE 2- System Design for Temper Proof VaccineDistribution Record

User can buy vaccine by entering the details like Adhar number and the vaccine name then the request goes to the system of Temper proof Vaccine Distribution Record. TheSmart contract is written for accepting those values and validating it. The transaction is validating on the Georli Testnet and the system can accept or decline your transaction on MetaMask Wallet. If the transaction gets accepted then the record is interested into the smart contract of Ethereum blockchain else not. In this way the records areadded securely without any temper.

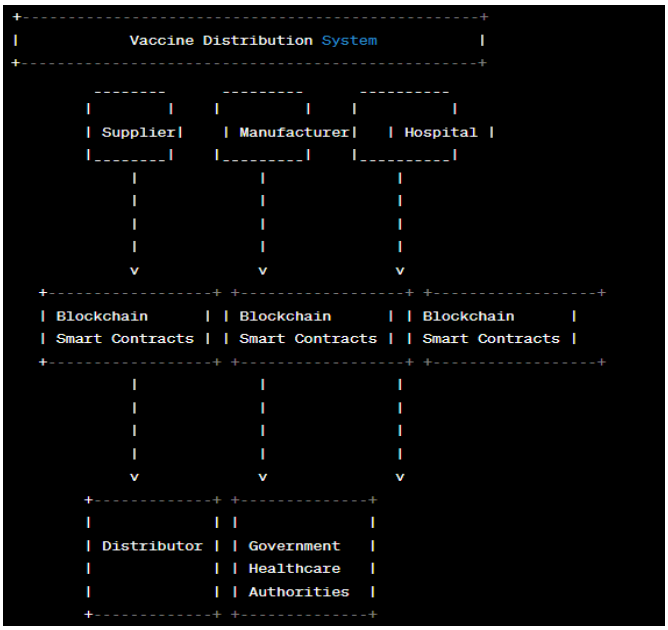

FIGURE 3- Block Diagram for Vaccine Distribution System

PROPOSED METHODOLOGY

Overview

This project aims to develop a secure and transparent system for vaccine distribution using blockchain technology and smart contracts. The project addresses the need for a tamper-proofrecord-keeping system in the distribution of vaccines, ensuring the authenticity, quality, and security of vaccines as they move through the supply chain.

Key Components

Blockchain Network - Set up a system for recording and validating vaccination distribution data based on blockchain technology. Because every record on the blockchain is linked to every other record, creating a chain that cannot be fractured without agreement, blockchain guarantees transparency and resistance to tampering.

Smart Contracts - Automate and enforce established regulations in the delivery process by using smart contracts. This removes thepossibility of manipulation or human error by ensuring that transactions are carried out precisely as intended.

Decentralized Access Control - Assign control of access to various distribution network entities. By doing this, the possibilityof a single point of failure is reduced, and it ensures that no one party has total control over the distribution records.

Immutable Timestamps - To build an orderly series of events, include timestamps for every transaction on the blockchain. Thismakes it even simpler to track the history of vaccine distribution and spot inconsistencies.

Use Case:

Blockchain-Based Tracking - Make use of blockchain technology to establish an unchangeable, transparent ledger that documents every step of the vaccine shipment procedure.

Customs Clearance Authentication - Bring together the procedures for customs clearance with the tamper-proof system. Customs officers scan the QR codes on the shipment upon arrivalto confirm the factual accuracy of the vaccinations and ensure import laws are followed.

Transparency in the supply chain: An immutable ledger tracking the path of vaccines from the producer to the final consumer can be created using blockchain technology. From manufacturing to shipping, each step in the supply chain can bemonitored, offering total transparency. The blockchain can store information on batch numbers, manufacturing dates, and temperature controls, guaranteeing the validity and caliber of vaccinations.

Secure Data Exchange: Blockchain makes it simpler for various participants in the vaccine distribution network to securely share data. Encrypted data can be selectively shared asneeded. This makes it possible to react quickly to any vaccine shortages, recalls, or quality problems that may arise.

Unchangeable Documents: Every record of vaccine distribution is stored on an unchangeable blockchain. This ensures accountability and trust by providing an account of vaccine movements that cannot be tampered with. Stakeholderscan guarantee the legitimacy and caliber of vaccines, upholdingsupply chain efficiency.

Benefits

Increased Trust and Security: By securing the accuracy of vaccination distribution records, the secure system lowers the possibility of fraud, tampering, and the production of fakevaccinations.

Real-time Access and Proactive Management: Stakeholders possess constant access to information about vaccine shipmentsthrough the use of blockchain and tracking in real-time.

Reduced Human Error and Automated Compliance: Smartcontracts automate the process of proving compliance withdistribution laws. This lessens the possibility of human error when following set guidelines, guaranteeing that the distribution process complies with national and international regulations.

International Collaboration and Standardization: By creating a norm for safe and open vaccination distribution, the execution of a tamper-proof system promotes global collaboration.

Challenges:

Technology Adoption and Infrastructure: Persuading thosewith an interest to accept the new system in areas with inadequateinfrastructure.[18]

Data Security and Privacy Issues: Preserving biometric information while ensuring adherence to privacy regulations.

Interoperability with Current Systems: Making certain that various current health and distribution systems integrate seamlessly.

Initial Implementation Costs and Ongoing Resources: Therewill be significant upfront expenses as well as ongoing maintenance resource requirements.

IMPLEMENTATION

Deploying a smart contract on the Ethereum blockchain and integrating it with a dataset involves several steps. Here is anoverview of the process:

Create a folder in Visual Studio or any other code editorfor your application.

Hardhat Installation

Hardhat has a straightforward and efficient, facilitating development, evaluation, and execution of smart contracts on the network of Ethereum. Hardhat is a task runner and development environment for creating, evaluating, and implementing Ethereum smart contracts. It has the goal to make theprocess of developing Ethereum more steps to install hardhat on terminal.

command- npm install –save-dev hardhat

-For all required file directory structure of the hardhat

command -npx hardhat

-Choose javascript project

Install all extra dependencies of hardhat

command- npm install --save-dev "hardhat@^2.19.0" "@nomicfoundation/hardhat-toolbox@^3.0.0"(According to your version)

Write a smart contract for vaccine distribution and save

.sol extension

Create a deployment script that deploys your smart contract. Youcan create a JavaScript or TypeScript file in the script's directory. **command-** npx hardhat run scripts/deploy.js**Refer** FIGURE 4 for the smart contract of Vaccine Distribution andFIGURE 5 for the deployment of smart contract

General steps to deploy a smart contract to a Goerli test-network

The primary purpose of Goerli is to provide a stable and reliable environment for developers and Ethereum users to test smart contracts, experiment with decentralized applications (DApps), andvalidate network upgrades without incurring real-world financial costs.

Set up your development environment with a suitable developmentframework like Hardhat.

Configure your development environment with the connection details for the "Goerli" Testnet. You'll need to specify the URL of the network's node or RPC endpoint.

Fund your Testnet account with test Ether (ETH) from the network's faucet or other means. Write and compile your smart contract. Do deploy smart contract on test net change your hardhatconfiguration with your Goerli Testnet URL and API key. For generating API Key and URL follow below steps

a. Create a React App Alchemy

Refer FIGURE 6 for creating Alchemy app

b. Select test network on Goerli

Refer FIGURE 7 for Goerli Test Network

c. Click on view Key to get API key and Testnet URL.

Refer FIGURE 8 for credentials of the Alchemy App

d. Step up your MetaMask wallet with Goerli test network

Refer FIGURE 9 for Meta Mask Wallet

Deploy your smart contract to the "Goerli" Testnet

using your development framework's deployment tools. **command**- npx hardhat run –network Goerli scripts/deploy.js. It will give your smart contract Address. Verify the contract on a Testnet go to Etherscan website paste your contract address.

Connect your react JS code with testnet Command- npx create-react-app<<app_name>>

cd <<app_name>>npm start

Install the ethers.js library in your React app

Run Your React AppCommand - npm start

Refer FIGURE **10 and 11** Wallet for Execution of VaccineDistribution System and **12** for meta mask

RESULTS

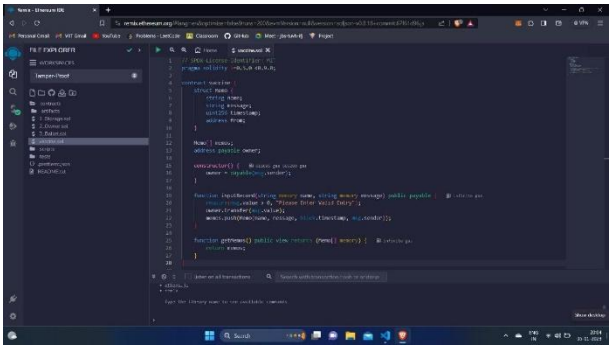

FIGURE 4- Smart Contract for vaccine distribution

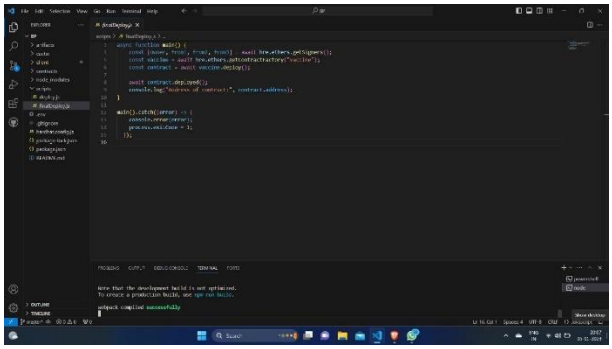

FIGURE 5 – Deploy.js file to deploy the smart Contract

General steps to deploy a smart contract to a Goerli Testnet:

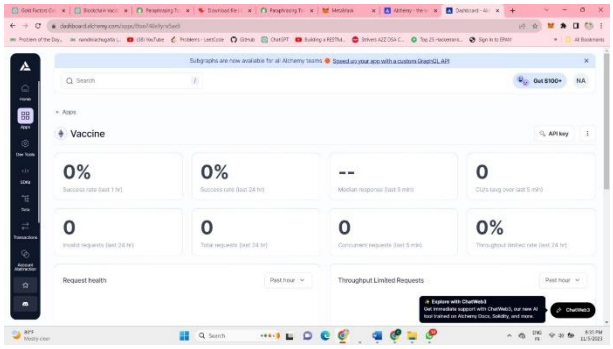

FIGURE 6 – Alchemy App for vaccine distribution.

Select test network on Goerli

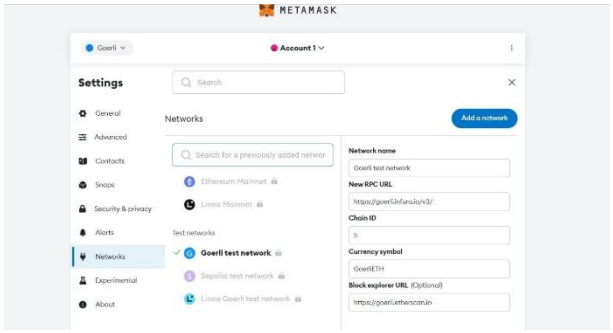

FIGURE 7- Goerli test network setup.

Click on view Key to get API key and Testnet URL.

FIGURE 8 -Alchemy App credentialsStep up your MetaMask wallet with Goerli test network

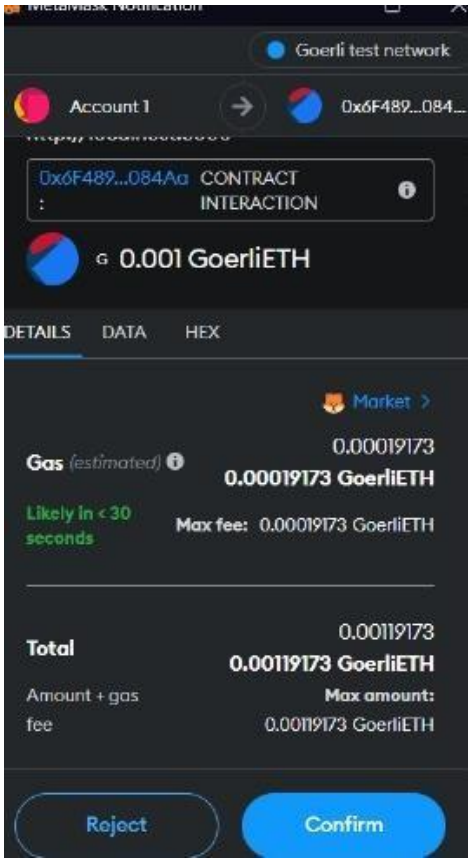

FIGURE 9 – MetaMask wallet with Goerli test network

Run Your React AppCommand npm start

Before logging to MetaMask Wallet

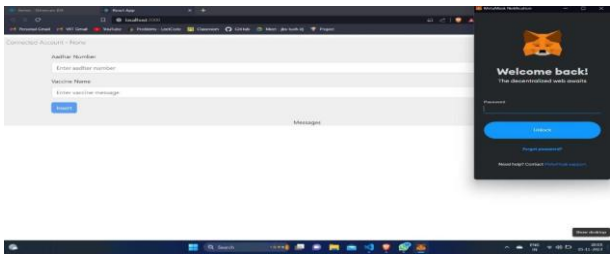

FIGURE 10 Vaccine App Results

After logging to MetaMask Wallet

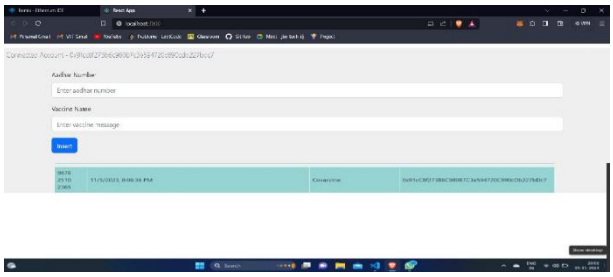

FIGURE 11 Vaccine App Results

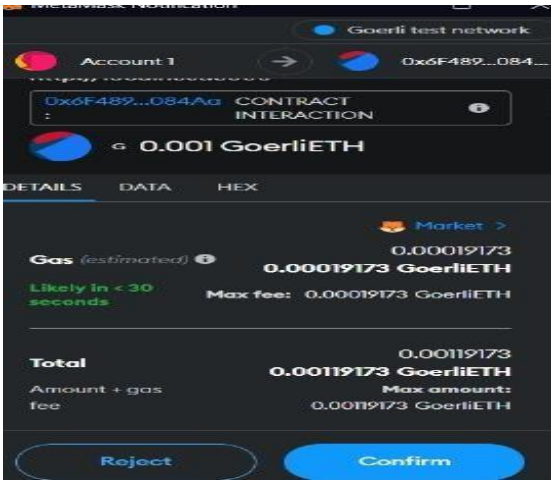

FIGURE 12Metamask Wallet After Tractions

CONCLUSION

To sum up, the blockchain system has the power to completely change how healthcare providers and organizations track thedistribution of vaccinations. It would be feasible to guarantee vaccine record accuracy and eliminate any chance of fraud or tampering by offering a secure, unalterable record of vaccine distribution. Furthermore, as blockchain-based systems aredeveloped further, stakeholders will be able to securely exchangemedical data, leading to the creation of more precise and thoroughvaccine tracking data. Thus, it is evident that the creation of tamper-proof blockchain-based vaccination distribution records isa significant and exciting development for medical care.

FUTURE SCOPE

The application of blockchain technology in vaccine distribution tracking has the potential to be a game-changer for the healthcareindustry. Going forward, blockchain-based systems can be used to securely store and share vaccine records, while also providing greater transparency to the entire process with the help of blockchain. Additionally, further development of blockchain- based systems would allow for the secure exchange of medical data among stakeholders. This would enable healthcare providersand organizations to more effectively collaborate, resulting in more accurate and comprehensive vaccine tracking.Finally, the use of blockchain-based systems has the potential to revolutionizethe way healthcare providers and organizations track and monitorvaccine distribution. By providing a secure, immutable record

of vaccine distribution, it would be possible to ensure the accuracy of vaccine records and eliminate any potential for tampering or fraud.

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