Exploratory project
on

IMPLEMENTATION OF BLOCKCHAIN IN COVID 19 VACCINE SUPPLY CHAIN

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ABSTRACT

This project aims to explore the potential of blockchain technology in improving the transparency, efficiency and security of the COVID-19 vaccine supply chain.
It investigates how blockchain can be used to track and trace vaccines from manufacturers to distributors and ultimately to patients, as well as to verify the authenticity of vaccines and ensure that they are stored and transported under appropriate conditions

MOTIVATION

- During the COVID-19 pandemic lot of reports came regarding the inefficient management of vaccine rollout , lack of communication between all the stakeholders , poor planning and no transparency in the vaccine supply chain
- We had recently learnt of blockchain technology and studying it in more detail we realized that many of its advantages can be used in vaccine supply chain to manage it more efficiently and increase trust

INTRODUCTION

The COVID-19 outbreak in late 2019 caused a global health emergency around the world. The number of cases escalated to more than a million worldwide within a span of 3 months. Consequently, the pandemic enforced lockdowns and social distancing guidelines affecting global economy negatively. For example, it led to the deferment of many important world's activities including sporting events such as the Tokyo Olympics and Dubai Expo. Understanding the dynamics of the pandemic requires good data to predict how fast the disease spreads, whether the countermeasures are effective or not, and the impact it has on the lives of people. However, data available online may not be perfect as it is susceptible to data manipulation.

INTRODUCTION

Hence, innovative technologies such as deep learning, machine learning, artificial intelligence (AI) and blockchain could help combat the crisis. Blockchain technology can be used to simplify the clinical trial processes for vaccines and drugs, raise public awareness, transparently track donations and fundraising activities and act as a reliable data tracker.

We will explore how blockchain will improve the supply chain management of covid 19 vaccines . It can eliminate the problems faced by centralized data systems. It introduces immutability and data provenance while removing single point of failure in the system.

Aspects	Traditional Centralized Platform		Blockchain Platform	
Authority	Controlled by the administrator (centralized)	×	Decentralized even in private blockchains	✓
Data Integrity	Data can be altered	×	Data are immutable and auditable	✓
Data Privacy	High chances of malicious cyberattacks	×	Data are stored using cryptography technology	✓
Transparency	Databases are not transparent	×	Data are stored in a distributed network	✓
Quality Assurance	Administrators are needed to authenticate data (data provenance not applicable)	×	Data can be tracked and traced right from its origin using cryptography technology	✓
Fault tolerance	High risk of single point of failure	×	Distributed ledger is highly fault-tolerant.	✓
Cost	Easy to implement and maintain as it is an old technology	✓	Uncertainty in the operating and maintenance costs	×
Performance	Fast (more transactions processed per second) and offer great scalability	✓	Can handle minimal transactions per second, and scalability is a challenge as blockchain is at its developing stage	×

BACKGROUND

Supply Chain:

A supply chain is the network of all the individuals, organizations, resources, activities and technology involved in the creation and sale of a product. A supply chain encompasses everything from the delivery of source materials from the supplier to the manufacturer through to its eventual delivery to the end user.

The supply chain segment involved with getting the finished product from the manufacturer to the consumer is known as the distribution channel

Vaccines require a specific temperature to maintain efficacy. A low temperature-controlled supply chain network used to ensure and extend the shelf life of products is called cold chain.

BACKGROUND

Lets take a example of Pfizer vaccine to understand the vaccine distribution chain

Once vaccines are manufactured, Pfizer packages them in special thermal boxes with dry ice to maintain their efficacy and cold temperature. These boxes are then shipped by third-party logistics providers directly to the location where they will be administered. The location and temperature sensor inside each box allow Pfizer to detect any potential damage that could lead to spoilage of the vaccines

BACKGROUND

At the administration site inventory of the incoming shipment is taken and each batch is stored in a special refrigerator or freezer. The daily minimum and maximum temperatures reached by each freezer are recorded and weekly inventory balance calculations are performed. The final step in the vaccine distribution chain is the administration of the vaccine to the patient. After the doctor prepares and issues a dose to the patient, they must create and submit a COVID-19 Vaccination report to the Vaccine Administration Management System (VAMS) according to CDC guidelines.

BACKGROUND

Distribution challenges in vaccine distribution chain :

The problems with the existing vaccination distribution procedure can be divided into four categories:

i) physical constraints

ii) communication challenges,

iii) security problems

iv) efficiency issues,

Some of these difficulties, such as communication, security, and inefficiency, can be addressed by blockchain technology

WHY BLOCKCHAIN

Before coming to Blockchain technology we need to understand why we need blockchain when we have Internet. We need blockchain because there are certain issues with the Internet that we use today. They are controlled by Major companies like Google, Facebook, Amazon. And we don't want centralization of the internet. So here comes blockchain with its decentralized features.

BLOCKCHAIN

Blockchain is a decentralized and distributed ledger technology that allows parties to store and transfer data securely and transparently without the need for a centralized intermediary.

It is cutting edge technology that brings trust in different parties exchanging data.

It stores data in blocks and hashes.

It is decentralized in nature.

It works on Peer to Peer Network

COMPONENTS OF BLOCKCHAIN

1. DATA BLOCK

It can be described as a sequence of blocks interconnecting each newly updated block to its previous block . This prevents any risk of modification as each block is strongly linked to the previous one.

2. DISTRIBUTED LEDGER

It is also known as a database that records and stores transactions generated by users. Each transaction contains a unique cryptographic signature decoupled with a timestamp, making the ledger resistant to alterations

COMPONENTS OF BLOCKCHAIN

3. CONSENSUS ALGORITHM

No entity should be able to control the process of transacting a block over the chain so that each block is managed by all members who share equal rights to overcome security problems. Validation of new block is achieved by nodes joining in the mining process and competing with one another to verify the block to receive a fee as a reward in return for their mining effort Proof of work : It is a consensus algorithm .When we want to add a new block , it takes 10 minutes to add a block in blockchain. Whenever new blocks comes, a complex puzzle is required to be solved by the old blocks, whichever blocks solve the puzzle gets the chance to add the new block.

FEATURES OF BLOCKCHAIN

End to end traceability

Reduced risk of tampered data

Transparent data

Decentralized data

Secure and reliable data exchange

Brings trust in different parties

USE CASES FOR COVID-19

1.Clinical trial management

It ensure transparency and traceability of patient records.
Facilitate data sharing and ensure regulatory compliance.
For example : Civitas, an app launched by a Canadian start-up that engages in blockchain solutions, assists various government officials in controlling the COVID-19 outbreak. It associates each person's ID with its corresponding blockchain records anonymously without disclosing their identity. It can find out whether a person has left his home or not.

2.Medical supply chain

Trace medical equipment, streamline communication between stakeholders.
Eg: The VeChain platform is ensuring that new KN95 masks imported from China are credible and reliable while working inseparably with production offices and facilities. From codes to packages, and materials, all tasks related to vaccine production are noted and kept in allocated ledgers

USE CASES FOR COVID-19

3.)User privacy protection

Protect user identity and limits sharing of information. Also grants users permission to selectively share information.
For example : A group of privacy specialists across Europe devised a blockchain-based framework for COVID-19 contact tracing utilizing Bluetooth. Moreover, German tech scale-up MYNXG has made a blockchain-based arrangement that uses cell phones while safeguarding client security

4) Data aggregation

Efficient data collection , build real time audit trail.
For example : MiPasa, worldwide scale control and correspondence system controlled by blockchain innovation, which assists with gathering, collating, and studying data about the virus's spread and containment, was launched by WHO. It is an asset that has expectations to help public health officials, the scientific and business network, and people in general

USE CASES FOR COVID-19

5.)Donation tracking

Reduce corruption , enables transparency of donation process, improve social trust among citizens.

For example : Hyperchain is a blockchain-based network that aims to counter the coronavirus outbreak by specializing in uniquely tracking donations. This network ensures that the donation process remains unchangeable, efficient, and traceable. It provides a transparent platform that allows donors to monitor where their funds were used.

Methodology to implement Blockchain in Vaccine Supply Chain

1: Some news reports

A: Vaccine passport: Almost 300 fraudulent claims rejected

Link - https://www.bbc.com/news/uk-northern-ireland-58054973

B: FG shocked as Nigeria loses out of UK recognised COVID-19 vaccine certificates

https://www.vanguardngr.com/2021/10/fg-shocked-as-nigeria-loses-out-of-uk-recognised-covid-19-vaccine-certificates/

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HEALTH

October 5, 2021

FG shocked as Nigeria loses out of UK recognised COVID-19 vaccine certificates

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See justice as tool to address national issues —Group tells Tinubu

Terrorists attack Kaduna church, abduct 40

C: Russia Pushes Ahead with Open License Approach to Sputnik V , Despite WHO Concerns Over Manufacturing Practices

Link - https://healthpolicy-watch.news/russia-pushes-ahead-with-open-license-approach-to-sputnik-v-despite-who-concerns-over-manufacturing-practices/

1) Goal :

Design and implement a system that solves a known problem of trust in the COVID-19 vaccine supply chain

2) Requirements Gathering. :

2.1) Vaccine Cold Chain – Manufacturer -> National Storage Facility -> Regional Hospital -> Health Center -> Vaccination Outreach

2.2) System Actors :

1) Manufacturer - process raw materials into vaccines

2) Distributor - transports vaccines between locations

3) Inspector - performs quality checks on vaccines & performs quality checks on manufacturing plants

4) Storage Facility - store vaccines in cold temperatures

5) Immunizer (the doctors, nurses) - vaccinates people & provides vaccine passport/certificates

6) Traveller (the patient): - receives vaccine & receives vaccine certificate &presents vaccine certificate at the border of the destination country

7) Border Agent - verifies the vaccine certificates/passports

2.3) Problem-Solution Map

No.	Problems	Affected Actors	Proposed Solutions
1	Vaccine passports can be falsified	• Border Agent	• Cryptographically verify using on-chain data
2	Key facilities may not meet quality standards	• All	• Publish inspection results to blockchain • Verify presented inspection results
3	Vaccine passports may not be recognized by destination countries	• Distributor • Traveller • Immunizer	• Verify signatures in presented certificates

2.4) Why Blockchain ? :

A: Tamper-Proof Provenance - does the label on the vaccine's vial accurately represent its contents? did the vaccine come from an inspected batch?

B: Credential Issuance & Verification - cryptographic signatures that are easily verified with on-chain identities

C: Data Redundancy- the data can't be lost even if a Traveller "misplaces" their device & the data can't be lost even if the vials are damaged

3) System Design

3.1) Flow -

1: Inspector issues certificate for batch to Manufacturer
<batch status updated to MANUFACTURED>

2: Manufacturer presents certificate to Distributor

3: Distributor verifies each certificate
<batch status updated to DELIVERING_INTERNATIONAL>

4: Distributor presents updated certificate to Storage Facility

5: Storage Facility verifies each batch certificate
<batch status updated to STORED>

6: Storage Facility presents certificates to Distributor

7: Distributor verifies each certificate
<batch status updated to DELIVERING_LOCAL>

8: Distributor presents updated certificate to Immunizer

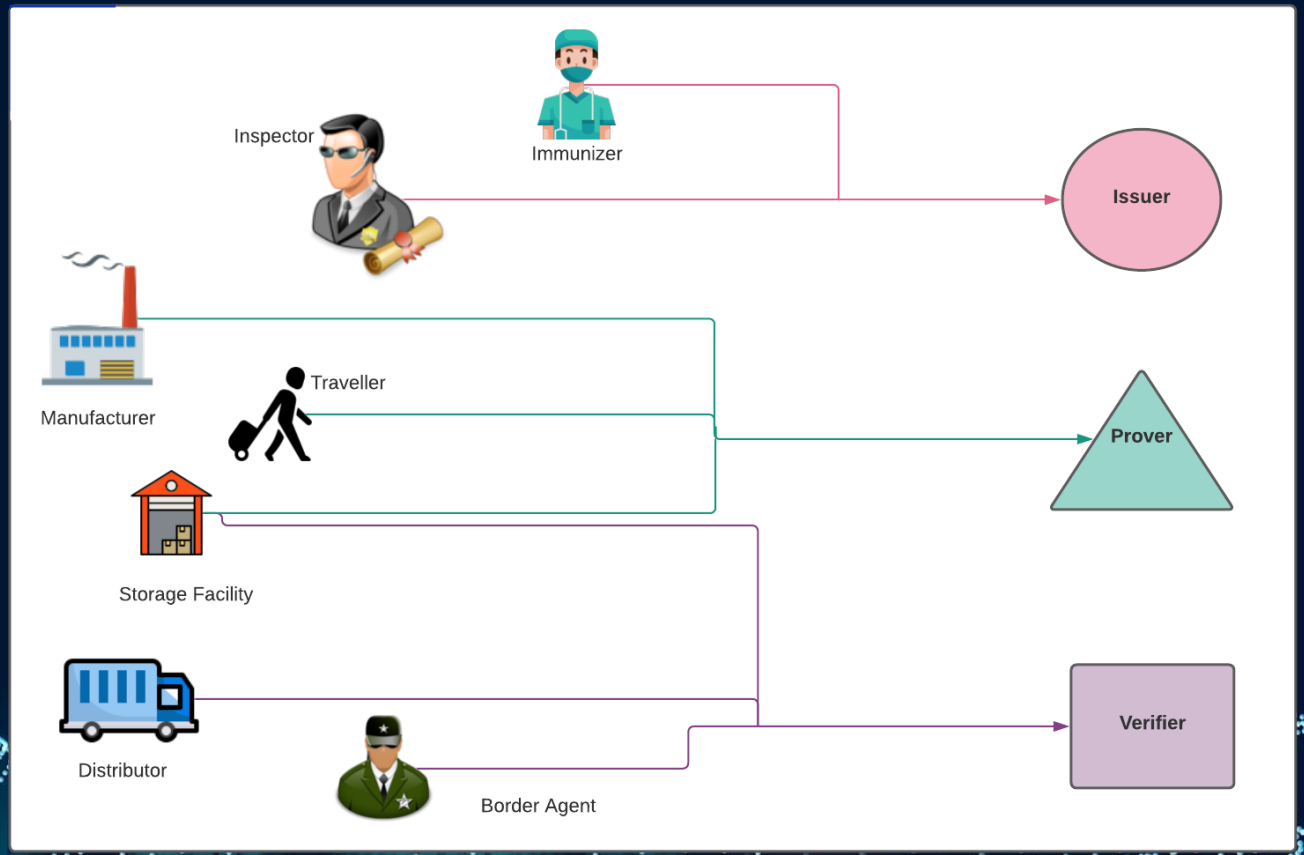
9: Immunizer verifies certificates
<batch status updated to DELIVERED>

10: Immunizer vaccinates Traveller and issues vaccine passport
<certificate issued with status VACCINATED>

11: Traveller presents vaccine passport to Border Agent

12: Border Agent verifies vaccine passport

3.2) User Classification



3.3) Out of Scope

- Payments between system agents;
- Dishonest doctors/immunizers;
- Suppliers of raw materials to the manufacturers;
- Image capture & QR code scanning;
- Scalability;
- Distribution to areas without internet access;
- IoT;
- Machine learning;
- Regulatory compliance (e.g. GDPR, HIPAA, etc.);

Github Repo :

- https://github.com/alienishi/ColdChain

COST ANALYSIS

The Ethereum gas is the unit used to measure the computational effort required for transaction executions. For operations to get executed successfully, a gas fee is required to be paid by stakeholders in the network. Hence, every line of code that is written in Solidity requires a certain amount of gas to get executed. Ethereum transactions incur two types of costs during their execution. First, execution cost is related to the costs of changing states in the contract and internal storage, while second is transaction cost, which includes the execution cost along with the cost of sending data such as contract deployment and transaction input cost.

Function Name	Transaction gas	Execution gas	Avg transaction fee
Deployment	1,521,652	1,116,836	3.21
registerOracle()	107,675	84,995	0.20
inputOracle()	50,682	28,770	0.08
calculateStatistics()	251,348	230,076	0.50
computeReputation()	36,607	13,927	0.04

Transaction cost incurred at an average gas price at an exchange rate of 1 ETH = 158.10 USD

This gas amount is calculated by considering both the gas price and gas limit, respectively. The former refers to the gas consumed in the contract, and the latter refers to the total gallons of gas placed inside the smart contract gas tank . Moreover, it should be noted that as the gas price increases, the rate of adding verified transactions to each block increases. Accordingly, this price is expected to increase during high network traffic as miners compete to add transactions in the blocks to receive transaction fees. Table above shows the transaction and execution gases along with the corresponding transaction fees for deploying the contract and executing the major functions. This transaction fee was converted to US dollars at an Ether exchange rate of 1 ETH = 158.10 USD. We notice that the cost incurred by the stakeholders does not even exceed 5 USD. This implies that implementing the pro- posed solution is feasible and encourages cost savings to all stakeholders in the network.

SECURITY ANALYSIS

1. INTEGRITY

It is important to guarantee integrity and maintain data consistency . It basically means that data should not be tampered

2. ACCOUNTABILITY

Every user or stakeholder is held responsible for their actions on the ledger.

SECURITY ANALYSIS

3. NON-REPUDIATION

All transactions are digitally signed and timestamped when added to the blockchain. This indicates that users or organizations can trace back a particular transaction at a specific time and accordingly identify the user behind that transaction using their public address

4. AUTHORIZATION

Securing data access in blockchain networks is essential for ensuring that only users with authorized access can participate and add appropriate data accordingly. Only authorized users can decrypt and see this information through the use of their private keys.

CHALLENGES TO BLOCKCHAIN

1. Shortage of skilled workforce

Building a blockchain platform requires a variety of skill sets ranging from security, app development to business and engineering, and other related areas.

2. Scalability

Every node on the blockchain has to store all validated transactions, and this becomes an obstacle as there is a restriction on the block size and time interval used to create a new block. Current blockchain platforms process only a few transactions per second,

CHALLENGES TO BLOCKCHAIN

3. Selfish miners :

Blockchain is vulnerable to attacks plotted by selfish miners. The strategy used by selfish miners is that they create a private branch by mining blocks without broadcasting, and they publish the private chain only when it is longer than the current public chain. As a result, by doing so, selfish miners earn more revenue.

4. Legal issues :

Blockchain technology is still a relatively new and rapidly evolving area, and its legal implications are still being explored and developed. Different countries have different laws and regulations regarding the use of blockchain. Their enforceability and legal status remain uncertain in many jurisdictions

CHALLENGES TO BLOCKCHAIN

5. PRIVACY CONCERNS

Blockchain technology is vulnerable to privacy breaches due to the transparency of balances and key details available to all network members. Blockchain is available to everyone

CONCLUSION

- In this project we investigated all problems and issues pre-existing in the COVID-19 vaccine supply chain and how blockchain technology can be used to tackle some of the issues
- Then we proposed our own methodology to implement blockchain in COVID-19 vaccine supply chain
- Our proposed blockchain-based implementation promotes trust, transparency and traceability between stakeholders in the network.
- It addresses the problems faced in the pandemic crisis, such as miscommunication, data manipulation, and single point of failure. Furthermore, it mitigates malicious activities due to its inherent cryptography security features .
- We also presented a detailed cost analysis to compute the transaction costs incurred by stakeholders when interacting with the smart contract.
- Furthermore, we presented security analysis pertaining to integrity, accountability, authorization, non-repudiation, and resilience to common forms of cyberattacks

FUTURE SCOPE

- Our presented solution can be easily generalized for tracking various vaccines for other infectious diseases.
- We can incorporate IoT to provide better tracking of vaccine cold chain
- Image capture techniques and QR code scanning to minimise human error can also be included
- Machine Learning can also be used in tandem with our project to improve vaccine supply chain in areas like demand forecasting , route optimisation ,inventory management etc.

THANK YOU