Utilizing Blockchain Technology to Enhance the Transparency and Traceability of Pharmaceutical Products Throughout the Supply Chain

Submitted By

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Utilizing Blockchain Technology to Enhance the Transparency and Traceability of Pharmaceutical Products Throughout the Supply Chain

Major Project - II

Submitted in partial fulfillment of the requirements

for the degree of

Master of Technology in Computer Science and Engineering (Data Science)

Submitted By

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Certificate

This is to certify that the major project entitled **Utilizing Blockchain Technology to Enhance the Transparency and Traceability of Pharmaceutical Products Throughout the Supply Chain** submitted by **Maitri Mehulkumar Naik (Roll No: 21MCED04)**, towards the partial fulfillment of the requirements for the award of degree of Master of Technology in Computer Science and Engineering (Data Science) of Nirma University, Ahmedabad, is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project part-II, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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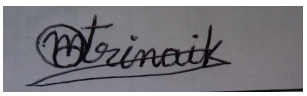
Statement of Originality

I, **Maitri Mehulkumar Naik**, Roll. No. **21MCED04**, give undertaking that the Major Project entitled "**Utilizing blockchain technology to enhance the transparency and traceability of pharmaceutical products throughout the supply chain**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Computer Science & Engineering (Data Science)** of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made.It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.



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- Maitri Mehulkumar Naik

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Abstract

Blockchain is one of the technologies that follows a decentralised approach. In the industry, the medical field is the most crucial. There are numerous aspects of the medical sector that are controlled digitally, including the production and distribution of medications, the storage of patient information and data, hospital records and invoices, etc. Tracking and tracing tools are now available across the supply chain, but issues with security, privacy, and transparency still exist. In this study, supply chains employ blockchain technology to promote transparency and trust. Blockchain, on the other hand, operates on decentralised and hashing concepts to establish trust, security, and anonymity. Numerous organisations, including the administration, manufacturer, hospital, client, supplier, retailer, etc., are included in the supply chain. Therefore, there is a possibility of trust issues and different points of view to bring up the most relevant subjects. In this study, the idea of smart contracts is employed, and by using blockchain, we can decrease the trust difficulties and ensure the quality of medicines.

KEYWORDS

Blockchain, Decentralise system, Smart contract, Medicines transportation, Blockchain in healthcare, Medical industry, metamask, Transparency, Traceability

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Chapter 1

Introduction

There are many areas or industries which are focuses on the use of technology. In trending, Internet of Technology, Blockchain, Cloud Computing, Cyber Security etc. many technologies are available. There are many areas like Banking, Insurance, Government, Identification, Data storage, Gaming, Agriculture, Healthcare which focuses on the Blockchain to achieve their goals like security, authentication, privacy etc. In the all the sectors the most important and critical section is health care. The Healthcare industry is completely responsible for the life of any animal and humans. Medicines are most important part of the field of Healthcare. The ingredients of medicines must not be less or high and some medicines need some accurate temperature. If there are any abnormal process happens then the medicines causes less or high bad impact like skin disease, headache, infections or in some cases the loss of life. As medicines are basic need and to fulfill the demand the manufacturer needs to supply the medicines. In medicines supply chain security, privacy, quality of medicines, fraud, trust issues question raised. To solve these questions a lot of researches are on going. To solve these questions the one of way is adopt the blockchain in supply chain.

1.1 Motivation

The simple meaning of medicine transportation is to move medicines like drugs, syrups, vaccines, etc. from one place to another. The movement of one place to another place will

be through trains, buses, cars, person-to-person, or cargo. So from that transportation, many problems arise, like delays in delivery, traffic, poor quality at delivery time, possible damage, fraud, changing the product, etc. It is necessary to find some solution to these problems. Some problems, like fraud or delays in delivery, may be solved by using the concepts of transparency and security in the system. In the medicine supply chain, many entities are present, like suppliers, manufacturers, hospitals, pharmacists, customers, etc. Dealing with multiple entities with secure and transparent data is a very complicated task. In the transportation of medicines, there are other threats like lack of data integrity, high price of centralised data storage, lack of data ownership, lack of trust, etc. Demand forecasting and procurement, cold storage requirements, distribution, tracking, reporting, and integration with vaccination (medical equipment) records are logistical challenges. Blockchain is one type of distributed system, so multiple systems have access to data, and blockchain works on hashing for data security. In the architecture of the blockchain, all the transactions will be saved in every block, so transparency will be there.

1.2 Problem Statement

In real life, there are many problems that we need to deal with. We can see problems that can be solved digitally in many fields like banking, shopping, marketing, education, security, transportation, medical, architecture, the government sector, etc. In this paper, we will discuss the problem in the medical industry. There are many problems in the medical industry, but one of the biggest is the transportation of medicines from one place to another. The concept of the supply chain generally focuses on the satisfaction of the customer at a low cost for the producer, supplier, and retailer. There are some needs for a supply chain that includes the minimum cost from transactions and transportation and the end point of the customer getting the best quality and the best experience during the delivery of the product. There are several touch points in the drug supply chain where deception may take place, notably at the following 4 levels.

- Level 1: To manufacture the medicines or drugs the manufacturer uses raw material and this the initial point where the possibility of fraud or problem raise. There are

possibilities that cheap quality or expired material use to make the drug.

- Level 2: The second possibility is possible from the manufacturer side. There are multiple ways for drug quality to be compromised. The different ways are using wrong ingredients, the drug dosage may differ, and occasionally an error may occur with the packing, the duplicate drug supplied instead of original drug.

- Level 3: The level 3 includes Distributor. Distributor is the third component of the drug supply chain management system. The production of drugs is now the main objective of drug counterfeiters. Direct sales of pharmaceuticals from the producer to the distributor. As a result, phoney networks must be built for it. These activities are frequently very sophisticated, such as the use of tracking technologies to penetrate legal networks that already exist in locations with lax security or barcode scams that profit on mass scan delays. However, such activities might also be relatively straightforward, for example, when it comes to shipping medications.

- Level 4: There are chances of fraud made by Pharmacies.Due to cheaper rates, many people are drawn to buying medicines online today. The majority of the time, these medicines will come from several nations with the promise of distinct labelling for the same substance. It might not be the same, though. Online pharmacies, particularly those located in nations with liberal rules, have plenty of motivation to offer a poor or fake product because the profit is still huge. Governments have frequently shut down online pharmacies, yet due to the lower prices they provide, they keep operating. [9]

Above we discussed how the fraud takes place by different entities which are present in supply chain. There is a Lack of transparency, and Pharmaceutical fraud, Security, and trust issues many problems exist. in this paper we are trying to solve some issues using blockchain. Our problem statement is Utilizing blockchain technology to enhance the transparency and traceability of pharmaceutical products throughout the supply chain.

1.3 Scope

In the medicine supply chain, security must be achieved, which will be achieved by blockchain. In the supply chain, manufacturers, hospitals, pharmacists, patients, and suppliers are all present. In a system where multiple entities are present, trust issues are raised, and in medicine transportation, quality questions are raised. The scope of the medicine transportation using blockchain project is to make a smart contract. Utilizing the smart contract with the blockchain we try to solve the supply chain problems.

Chapter 2

Blockchain

We are solving the supply chain problem using blockchain technology. Let's look up the blockchain.

2.1 What is Blockchain ?

Block chain is one type of distributed system in which the digital data will be stored. These digital can be anything like documents, record, policies, currency, transactions, details etc. The structure of the blockchain is more similar to the Link List data structure. The blockchain is made from blocks.

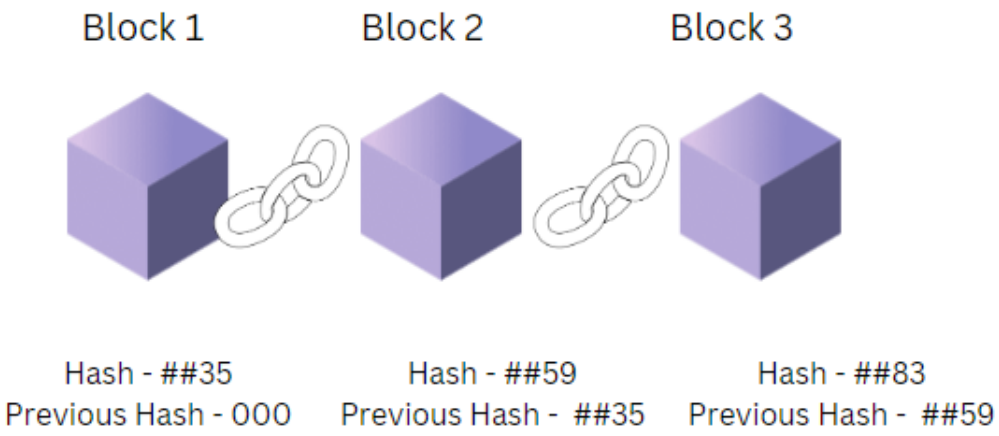

Figure 2.1: Structure of Blockchain

The figure 2.1 [20] include the visual picture of the blockchain. A block is a basic part of the blockchain. A simple word for blockchain is a chain of blocks. Each block contains many parts like nounce, index, data, previous hash, markleroot index, version, time etc.

- hashPrevBlock: This field size is 32-byte that contains a 256-bits hash value. This field stores the previous block's hash values.
- hashMerkleRoot: Size of this field is 256 bits which contains the hash value of markle tree root.
- Time: The current block's timestamp, which is used to place it chronologically in the blockchain, is stored in this 4-byte field.
- Hash: In a blockchain to identify a particular block the hash value is given to particular block. The size of this field is 256-bit.
- Data: Each block contains a piece of digital information.
- Nonce: Nounce is a number which is used for the verification of blocks.

2.2 Features of Blockchain :

- Distributed : There is no central authority present in this network. All the entities have all the records. In the blockchain, all blocks have all the transaction records. A one block indicate a one node present in the blockchain.
- Immutable : Immutability means the data are not being able to be altered or modified. This is one of the best characteristics of the blockchain that safeguards the technology will continue to operate as a trusted, irreversible network. Once a transaction is uploaded to the blockchain, it is unable to altered or deleted.
- Consensus :The brains behind this system, which is effectively constructed, are consensus algorithms. Every blockchain includes a consensus process that assists the network determine choices or decisions. Simply said, the network's active nodes use the consensus as a mechanism of decision-making. In this case, the nodes can come to an agreement rather quickly. A consensus is unavoidably necessary for a

system to operate successfully when millions of nodes have verified a transaction. Think of it as a voting system where the majority gets to decide and the minority has to agree.

- Secure :Every piece of data on the blockchain is separately encrypted. By doing the use of encryption, the entire blockchain network process is made more secure. Since it has no centralised authority, it is not logical that one can just add, edit, or delete data on the network. Each piece of data located on the blockchain has an individual presence on the network thanks to cryptographical hashing. There is a unique hash for each block as well as a hash for the previous block. Because of this property, the blocks are cryptographically dependent on one another. Every hash ID would need to be changed in order to update the data, which is just not possible. [19] [22]

2.3 Applications of Blockchain :

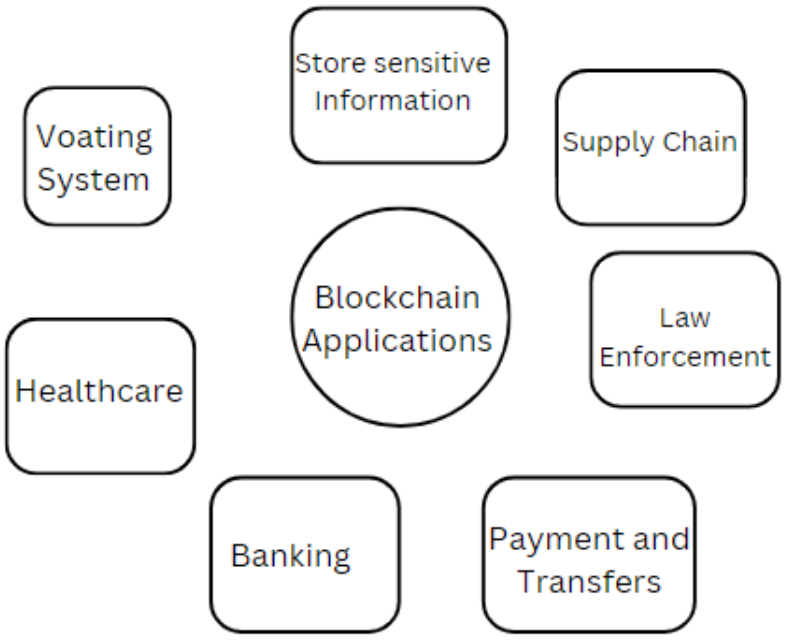

Figure 2.2: Applications of Blockcgain

Figure 2.2 [21] gave some idea of the blockchain applications.

- Money transactions : In the transfer money process there are third parties involved

like banks, anydesk, brokers, other softwares etc. Using the blockchain we can transfer the money without any Third party. It is less expensive and secure.

- Law : We can also make contracts digitally. These digital contacts are known as smart contracts. The lenders , partnerships , architecture contacts etc. will be stored in blockchain. So that no one can modify the contact and no third party like court, police involved so it is cheap and secured also.

- Personal Information : In the blocks we can store our personal information like identity information, security details etc. We can also store our property papers, health reports, education certificates etc. From blockchain we can access that information from anywhere and anytime and no one can modify it.

- Healthcare : The Healthcare industries also use a blockchain to store data like patients information, hospital records, medicines records and researchers also store their new medical inventions or new medicines formulas.

- Insurance : Insurance is achieved by using smart contracts. This contact plays a major role for customers and insurers to manage claims and maintain transparency between them. All claims recorded by blockchain and validated by the network.

- Bitcoin : Bitcoin is a digital currency. Bitcoin uses a public blockchain to make transactions peer to peer. Examples : BitnPlay, Bitbond etc.

- Hyperledger : It is a project which is developed by Linux. This project supports only registered members to use the blockchain. This project is hosted by linux in collaboration with leaders in banking, finance, IOT, supply chains. [21]

2.4 Why we used the blockchain in supply chain ?

The investigation pinpointed some characteristics of the blockchain that might support SCM and give it a distinct identity:

- Due to the spread network of people and organisational entities that makes up the supply chain, it naturally contains activities and transactions that are dispersed

over time and place. In order to achieve SCM's core goal of improving supply chain performance, it is essential to be able to increase supply chain transparency. BCT has the potential for sharing data among peer-to-peer nodes in a distributed network. Second, the immutability of data is promised by the encryption system, which also makes it possible to follow data and business transaction chains across time. Third, data consistency in the distributed ledgers is made possible via the consensus mechanism of blockchain.

- Better coordination is made possible by understanding BCT. Each party in the supply chain will be able to track the movement of the goods as they move along the chain thanks to greater visibility. Each participant will be able to determine the whereabouts of certain goods or containers during transit . Participants can also read and access various kinds of data in real time. According to the reasoning, doing so will facilitate coordination and planning for the movement of items and documents throughout the supply chain, potentially leading to an increase in efficiency.

- Supply chain agreements may be reached and enforced with lower transaction costs thanks to blockchain technology and smart contracts. This makes it possible for agreements throughout the supply chain to be formalised and enforced. The rights and liabilities set in the smart contract can be automatically carried out by the blockchain as soon as the parties reach an agreement and comply with its terms.

- The central authority, whose primary duty is to approve transactions, is one important type of middleman that could possibly be eliminated. BCT enables parties to a transaction to exchange and store value without the use of a conventional middleman. Value representations won't be limited to a local area anymore; instead, they'll be a part of the distributed ledger that is accessible to all parties who need them. As a result, the blockchain may make it unnecessary for a centralised authority to approve transactions, resulting in significant supply chain efficiency gains. When the network validates the transaction, transaction costs associated with contract enforcement, such as those incurred after a sale, can be eliminated. This enables significant cost savings on enforcement-related charges such staff costs, legal fees, and court.

Chapter 3

Methodology and Literature Survey

This chapter includes the methodology we followed to prepared a research paper and the research work we done.

3.1 Methodology

The method we used for this paper is based on 3 steps : In first step We searched keywords related research topic like "blockchain", "distributed ledger", "supply chain", "medicines" etc. which are synonyms of topic. The second step is to identify the papers which are help us into research. The papers are based on blockchain and its working and the study to discuss using of blockchain in supply chain or in food supply or to store data. In the descriptive information the included sources material was form academic material.

3.2 Literature survey

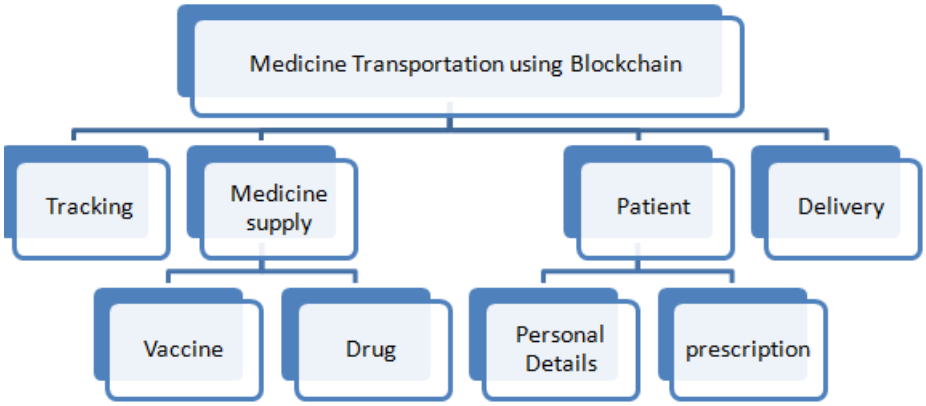

Figure 3.1: Taxonomy of medicines supply chain

Figure 3.1 describes the taxonomy of the research papers which we refer during the research. From the taxonomy we can get idea of the different areas related to the research paper.

Liu et. al. in [1] uses the two technologies blockchain and IoT to track the medicines supply chain. The golang language is used for the smart contact. To track the vehicle the customer or any other who wants to track need to enter the QR code or tracking number. There is a five layer architecture of the system. The blockchain offers the transparency and safety of the gadget. While the use of the IoT aspect RFID tag and Qr code customers can see the statistics and the place of product. He additionally stated that Using only IoT tool we get privacy and safety or the use of blockchain we get scalability, authenticity, sharing, Transparency only. But using the IoT and Blockchain each scalability, privacy, access, sharing, Authenticity, Security, Transparency achieved.

Rong Wang et. al in[2] The data sharing of this system is depend on permissioned blockhain. This blockchain consist of data processing layer, application, storage layer, business processing layer and identity authentication layer and blockchain also. Multiple databases, including MySQL, HBase, and LevelDB, are supported by the data storage layer. The dual-chain design used in this paper. The scalability is provided by the ABC and TBC architecture. The transaction's confidentiality and privacy are guaranteed

by the encryption algorithm. Users are able to set up multiple access permissions for medical data using smart contract technology. This paper's shortcoming is the absence of a prediction module and a substantial data storing capability.

Niya et al.[3] in advanced a Dapp "ASPIR" which incorporates a public blockchain."ASPIR" blanketed product licences, moves at every step inside deliver chain, place, time, hash of all facts. The gadget used QR code for statistics store. All facts saved in DB and for every file one QR available. From this writer can were given the transparency and safety and integrity. The trouble of this paper is privacy and it's time consuming.

Thomas Bocek et al.[4] in To guarantee quality control, the medical business employs numerous intricate and stringent environmental control procedures (such as temperature and humidity). By fusing IoT (Internet of Things) sensors with blockchain technology, Modum.io AG is keeping track of all pertinent data during the transportation of pharmaceuticals. The outcomes are made public and communicated to both the distributor and the recipient. In the future, it is anticipated that customers would have access to temperature monitoring. A serial number for each medicinal package must first be mandated, though. In the backend, Solidity-written smart contracts guarantee temperature compliance, while in the front end, Android clients connect to the server using the REST (Representational State Transfer) API, which uses JSON to encrypt and decrypt requests and responses. The project's restrictions include the requirement that the warehouse be online and the requirement that the vehicle being transported have offline technology from which it may transmit temperature and position information.

Nair et al. in [5] mentioned approximately the state of affairs of COVID19 and mentioned the issues human beings confronted for vaccine and drugs and located certainly considered one among answers had been blockchain. The intention of creator had been to make a device wherein the vaccine transportation and distribution viable the usage of blockchain in order that with inside the transportation device the transparency, safety might increased and decreased fraud. Author proposed "FAIR" device that is primarily based totally on blockchain and based on the clever contract. In this device all of the events encompass with inside the deliver chain or device with the usage of the blockchain. This device additionally covered touchy information like adhar number, facts associated vaccine requirement, distribution etc. It is just too complicated for put into effect in

actual life.

Thejaswini S et al. in [6] Elimination of fake medications using a blockchain is the main goal of the suggested approach. By adopting encrypted QR code technology, which can only be accessed by authorised parties, the pharmaceutical supply chain management system can increase drug safety and transparency. The system combines encrypted QR code technology in addition to Ethereum blockchain technology to further strengthen the system's ability to track, trace, and secure the pharmaceuticals supply chain. The suggested solution was developed using Ganache on a private blockchain network. The limitations is the combination of IoT and blockchain result is better than QR.

R. Gupta et al. [7] the use of secure third-party systems between the communication parties is done away with by VAHAK. Using the IPFS standard for data storage lowers the cost of shipping while increasing throughput and latency. The suggested system is composed of four working layers: layers for data collection, processing, transport, and application. The multiple sub layers all exchange data in JSON form on a consistent basis. Compared to XML, JSON provides better readability, a map-data structure, aligned code, and a lightweight data sharing method. A supply chain is formed between each tier in the data gathering layer to build trust between entities. Utilising the Solidity programming language, they utilised to create the supply chain and store data on the blockchain. The hospital receives the patient's information in the data processing layer, where they will discover the patient's serious condition. They decide whether to deliver to the patient based on the crucial level. The 4th layer is in charge of using the 5G-enabled TI communication channel to convey medical goods via UAVs. The healthcare supplies are delivered by the UAV to the requestor, and both the UAV and the patient acknowledge delivery status via SC, changing the state to DELIVERED. The VAHAK system uses the drones and blockchain to achieve the security, traceability and transparency.

Pham et al.[13] separate the system into three primary phases: deployment, registration, and management of medicine ownership. 1) Deployment Phase: The Government must have the top position in Medicines supply chain (MSC) in order to build the strict management of the medication supply chain system. The Government must implement MSC on the ethereum Blockchain network utilising G.EOA/G.EPK (Government) in order to manipulate this authority.in the Registration Phase, the Government must register

the GS1 office, the manufacturer, distributor, and pharmacy in order for them to carry out the MSC's duties. To be more precise, O.EOA (GS1 officer), M.EOA (Manufacturer), D.EOA (Distributor), and P.EOA (pharmacy) are permitted to carry out the designated MSC functions. Furthermore, O.EOA, M.EOA, D.EOA, and P.EOA, respectively, must be related with public legal information of the GS1 office, medicine manufacturer, distributor, and pharmacy. Medicine Ownership Management is where we show our suggested Blockchain-based system for managing medicine ownership. AddGTINOwnership() is the specific function used to initialise ownership for a group of RMs sharing the same GTIN (Global Trade Identification Number). The function to initialise ownership for RM with the same GTIN is called AddGTINOwnership(). The AddGTINOwnership() function must be used by the pharmaceutical maker so that interested parties can identify the original owner of the drug. Additionally, the GTINTransfer() function allows for the transfer of GTIN ownership along the whole medication supply chain. Regarding the architecture of Dapps, we programme five major layers using the Javascript ReactJS language to control data flow. The user interface for user interaction is specifically found in the first layer. Additionally, the data layer is in charge of turning interface layer input data into JSON data strings.The JSON data string is kept on the IPFS storage network on the third layer, which is the IPFS protocol. The smart contract layer that contains MSC is the one after that. The web3.js layer is in charge of establishing a connection to the Ethereum Blockchain network.

Haq et al.[15] suggested system, every user will be acknowledged on the network by their unique key combination. Medicines will be the property, and each medicine will have a distinct key (or hash). A QR Code for the ID will be delivered with the medicine. Each new product will have an individual hash generated by a manufacturer and handed over it when it is made. The product will be published on the blockchain using its hash (unique ID). The object will be viewed as a digital asset on the blockchain network, and its hash will be used to track it at any time. Any additional product data may be kept on-chain or off-chain depending on the company's preferences.Off-chain data will be merged with on-chain data using some kind of identifier. In order to complete the wholesaler's request for the pharmaceuticals, the producer will physically deliver the items to the retailer, and at the same time, a transfer transaction will be recorded on the blockchain. The wholesaler and distributor will transfer the drugs to the pharmacy using the same

process. The distinctive nature of the product can be confirmed by the consumer through history.

Madumidha et al. [16] employing blockchain technology, it is possible to prevent such illicit acts from occurring in the supply chain and to advance its development. All of the individuals communication is open and transparent. The traceable system receives excellent authentication and security from this system.The first users of the blockchain technology in the system will be the producers who make the raw materials and provide them to the processors because they are the ones who will create the initial blocks of data. The cloud is updated with the information provided. The processors then update the information that has been processed with all of the details in the next block by resolving the proof of work. The IoT-based RFID technology is used to detect and record the products. Every object has a chip inside of it that is special and allows for interruption-free tracking. Products have RFID tags affixed to them that regularly transmit a frequency signal. The required data is read by the RFID reader and stored. This tracking system begins by storing details about the product's origin and subsequent suppliers up to the merchants. The goods is provided to the stores by the wholesalers. While customers may transparently verify a product's complete history before purchasing, retailers store information about the sold-out products in the blockchain. Using the RFID and blockchain the transparency and traceability achieved in this paper.

Jadhav et al.[17]proposed system consists of three main parts: a cloud/database, an Android app for the manufacturer or business, and application of android is for the consumer or user. The first to apply are manufacturers and businesses, and we must first register with them. If they choose to display the order, they can look over the customer's order information and then decide whether to approve or reject the transaction. The manufacturer may conduct additional checks to determine whether the products are delivered. The Customer application is a second programme that requires registration of the application before signing in with an user's id and password. Users of this programme can access a function that displays product details such the name, quantity, price, and manufacturer. By entering the product's quantity, we can then generate a product book. With the use of this feature, we can see product information like name, quantity, date, time, price, and the status of a manufactured product, including the item is deliver or

not. This programme also include the QR code scanner that enables us to scan a product's QR code and assess whether or not it is authentic. In blockchain technology, the manufacturer creates a QR code using the SHA-256 algorithm. To determine if the item is authentic or a fake, the user scans the QR code.

Ahmadi et al.[18] examine the innovative IoT and Blockchain-based pharmaceutical governance. Blockchain technology based on the Internet of Things (IoT) is a sort of distributed ledger (DLT) that keeps the record of immutable all transaction data that cannot be altered and is available to all participants. By implementing an IoT-based blockchain system, the pharmaceutical industry would have the resources necessary to enhance drug governance throughout the supply chain, improving the effectiveness and dependability of healthcare. We also identified other advantages of blockchain which is based on IoT that would address other facets of the pharmaceutical sector, such as privacy and minimising theft and diversion, in addition to solving the problem of counterfeit medications in the supply chain.

3.2.1 Analysis of technologies approaches

Table 3.1 includes the different approaches of the various research papers. This table includes the different technologies or their combinations and its result and impacts. In this table we analyse different parameters like Transparency, traceability, scalable, cost, trust issues between multiple parties. The comparision table gives us some idea which technology and its combinations are useful and efficient.

Table 3.1: Analysis of technologies approaches

Supply chain approach	Transparent	Traceable	scalable	Security	Cost	Trust issues between multiple parties
IoT + database (GE IntelliMotion) [10]	No	Yes	No	No	Low	Yes
RFID + Cloud computing system [11]	Yes	Yes	Yes	Moderate	Medium	Yes
IoT sensors + ML + webapp + cloud [12] [17]	Yes	Yes	Moderate	Moderate	high	Yes
Blockchain [14]	Yes	No	No	Yes	No	No
Blockchain + IoT [4] [1] [16]	Yes	Yes	No	Yes	High	No
Blockchain + QR [6] [3] [15]	Yes	Moderate	Moderate	Yes	Low	No
Blockchain + Drones [7]	Yes	Yes	No	Moderate	High	No

Chapter 4

System Architecture

The proposed system architecture to achieve traceability and transparency is below.

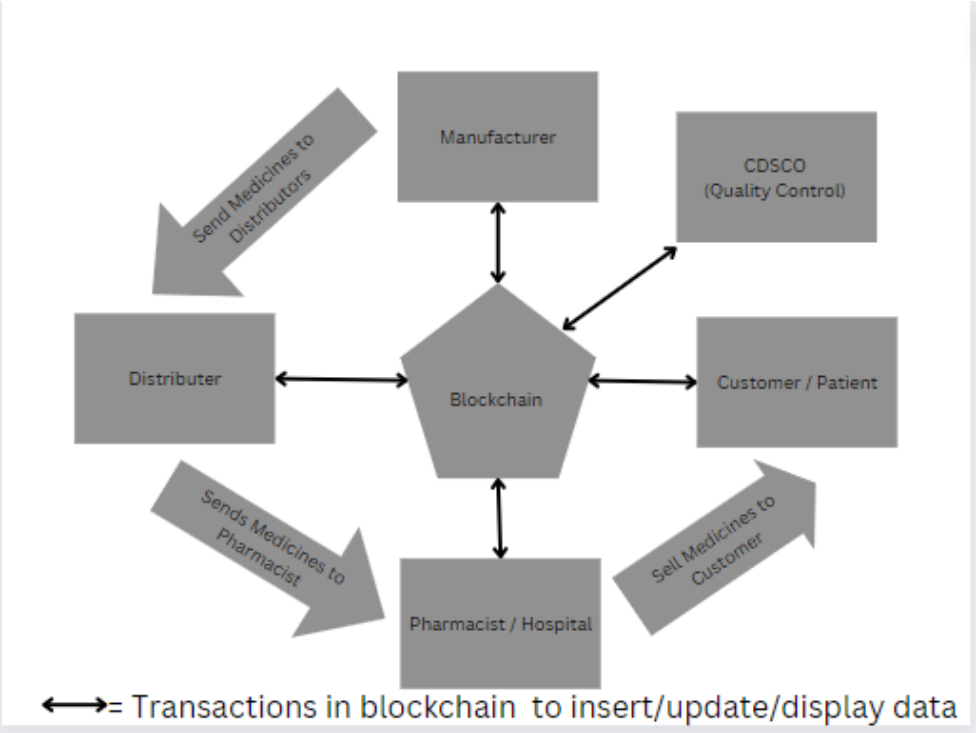

Figure 4.1: Architecture of System

Figure 4.1[7] includes various parties which completes the supply chain and additionally it includes the blockchain. We will discuss all the entities roles in detail.

4.1 Manufacturer

Manufacturer is initial step of system. A manufacturer, first produce the medicines or drugs must process the quality assurance test. After the production, the details of medicines will store on blockchain by the manufacturer with a particular id of a medicines. The role of manufacturer is accept or cancel the order from another entities in system and insert a medicines details as well as order details.

4.2 Distributor

In a supply chain the manufacturer supplies the product and it will receive by distributor. From the distributor product again supply on another place. In this medicines supply chain the distributor can insert the updated information of medicines like location and time of supply medicines. Distributors also can see the orders and track the product.

4.3 Pharmacist / Hospital

The medicines which are supplied is delivered at the Pharmacy shop or in hospital. In a system pharmacist / Hospital can insert the data on blockchain about confirmation and location and time. They can track the product from blockchain data. They also see the data and verify the quality of medicines which they received using blockchain.

4.4 Customer

Customer can purchase medicines from pharmacist or direct from manufacturer. Customer can see the medicines details and ensure about its quality.

4.5 CDSO : Central Drugs Standard Control Organization

The work of the CDSCO is to check the quality of the medicines and give the true quality result of medicines so that, the medicines quality control achieved. In this system CDSCO see the details of medicines from the blockchain it upload the quality details of medicines. CDSCO will insert the medicines certificate of quality so all the entities are sure about the quality of medicines.

4.6 Blockchain and Smart Contract

A blockchain is a distributed system. In the blockchain all the data stored in the blocks and all blocks are immutable and data stored are using the hash technology. Using the blockchain we can ensures the data security, privacy and reduce the trust issues using blockchain. This system use the smart contract which stored and executed on blockchain.

4.6.1 Smart Contract :

As name suggest, the contract is a use to in written form with conditions to reduce the trust issues between multiple parties. A smart contract is a digital form of the contract. The meaning of smart contract is just a code. The smart contract is a program which works on the conditions and the condition is a decided by the all the parties which include in the smart contract. A smart contract is stored on blockchain so all the parties have a copy of contract and no one will change the contract then after. A smart contract runs automatically when conditions are matched. The smart contract runs on blockchain so, it reduces the trust issues between multiple parties.

There are many applications present which includes the smart contract. The creation of securities, digital identification and signature, the capture of financial data, insurance, and escrow mechanisms are a few examples of smart contract use cases. The loans or funds , government or public systems, trading, medical applications, supply chain administration, and international transactions and payments are referrals to financial

services.[23]

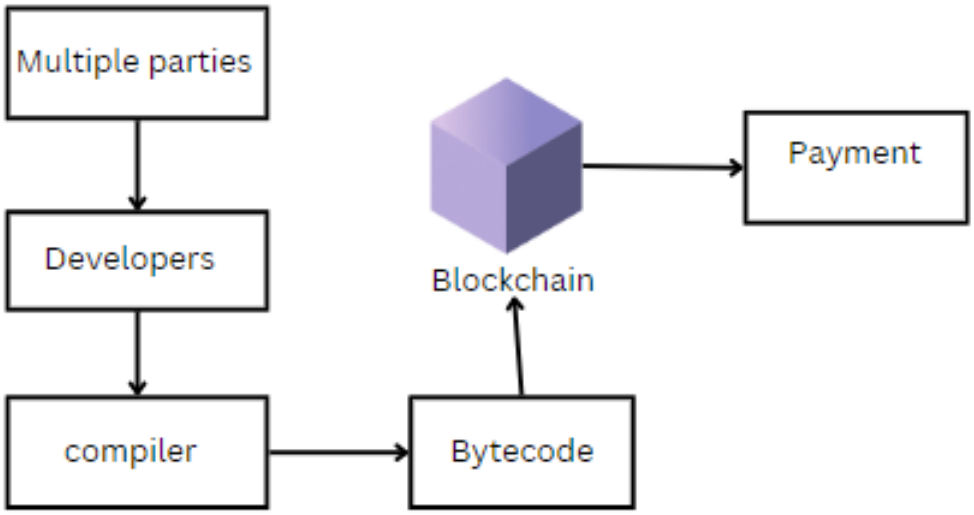

Figure 4.2: Smart contract workflow

Figure 4.2[8] describes the smart contract workflow. The developer developed the code for smart contract. Smart contract can be code in many languages like nodejs, solidity, javascript, Rust etc. We implemented using solidity. The code will be executed in the virtual machine and stored in the blockchain. The smart contract runs on blockchain so it is immutable and can be shareable to all the parties and it is transparent.

The proposed system architecture includes the smart contract to maintain the transparency between multiple entities like manufacturer, supplier, retailer, pharmacist, hospital, customer. We used solidity language to develop the smart contract. The createParticipant, getParticipant, newProduct, getProduct_details, transferOwnership_product, getProduct_trackindex function included smart contract in this system.

Chapter 5

Implementation

For any implementations there are few or more hardware or software requirements present. For this paper implementation the requirements are below :

5.1 Hardware Requirements

Any system which able to connect with internet

5.2 Software Requirements

- OS : Windows or Linux any
- Remix-IDE
- Crypto wallet
- Node.js
- Infura

A few terms in the requested list must be understood.

5.2.1 Remix-IDE

The Remix IDE is used by users of any level of ability during the entire process of building a smart contract. It supports a short development cycle, has no setup requirements, and offers a large selection of plugins with user-friendly GUIs. The IDE is accessible as a web app, desktop application, and VSCode addon.

5.2.2 Solidity Language

Solidity is an object-oriented programming language that was created expressly by the ethereum Network team for use in building and running smart contracts on blockchain systems.It is fairly simple to understand and master, and it is very comparable to C and C++. For instance, a "main" function in C is equivalent to a "contract" in Solidity. The solidity language has the following benefits:

- To achieve safety, it offers an Application Binary Interface (ABI). The ABI produces an error if the compiler finds a data type invalid or not matched for any variable.
- It refers to the 'Natural Language Specification,' which is used to translate user-centric specifications into language that computers can comprehend.

[24] In the blockchain system, it is used to build smart contracts that includes the business logic and generate the transaction records string. It is used to write machine-level code and compile it for the Ethereum Virtual Machine (EVM).

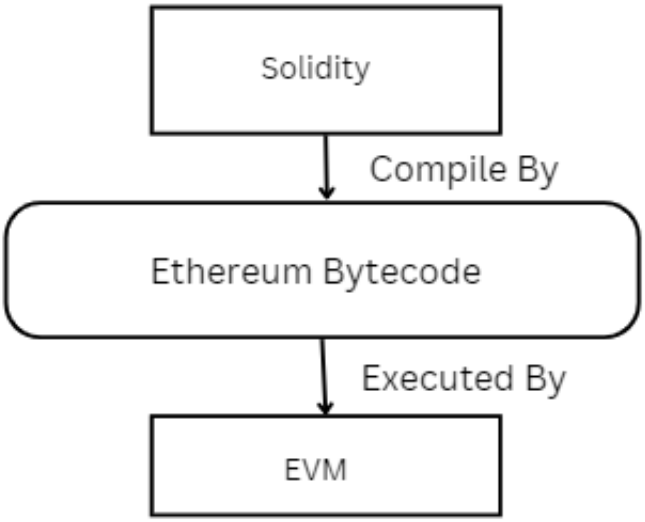

Figure 5.1: Solidity and EVM

Figure 5.1[24] describes the execution flow of the solidity contract. The solidity code first compile and converts into the form of bytecode then the bytecode executed on the ethereum VM (EVM). EVM is used for security purpose. With a focus on mitigating Denial-of-Service attacks, EVM ensures that the programme cannot access each other's state and that communication between them is uninterrupted.

5.2.3 Crypto wallet

people may receive and pay crypto currencies like ethereum or bitcoin by utilising of crypto wallets, which keep your private keys, or the passwords that let you access to your crypto currency, safe and effortlessly available. guarda, metamask, exodus, coinbase and trust Wallet, atomic and electrum are a few examples of wallets. We used metamask as a crypto wallet.

Metamask :

Metamask is one of the crypto-wallets. It lets users use a extension of browser or a application of any mobile to access their ethereum wallet. Metamask is an important part

of the ethereum ecosystem because it gives users a safe and convenient way to manage their ethereum accounts and connect with decentralised applications. It bridges the gap between standard web browsers and the decentralised world of blockchain, allowing ethereum-based innovations to be widely adopted.[25]

5.2.4 Node.js

Node.js is a avaScript run time environment which is executed at server-side and an open source platform. Node.js, coupled with multiple libraries and frameworks, can be used to interface with the ethereum blockchain when deploying a smart contract. Node.js provides a strong environment for building, deploying, and interacting with ethereum smart contracts. Because of its ability to run JavaScript code outside of a browser, it is a popular alternative for developing decentralised applications (DApps) and serving as a backend for blockchain-related services.[26]

5.2.5 Infura

Decentralised apps (DApps) and developers working with the Ethereum blockchain can access Infura's robust infrastructure. Developers can connect to the ethereum network using its simple API without having to host their own ethereum node. Instead than setting up and maintaining their own ethereum nodes, developers can concentrate on creating their applications and communicating with smart contracts by using Infura. The infrastructure of Infura facilitates development, enhances scalability, and offers dependable access to the ethereum network.[27]

5.3 Implementation Flow

We implemented and deploy the smart contract to employeeing the solidity, metamask, Infura and node.js.

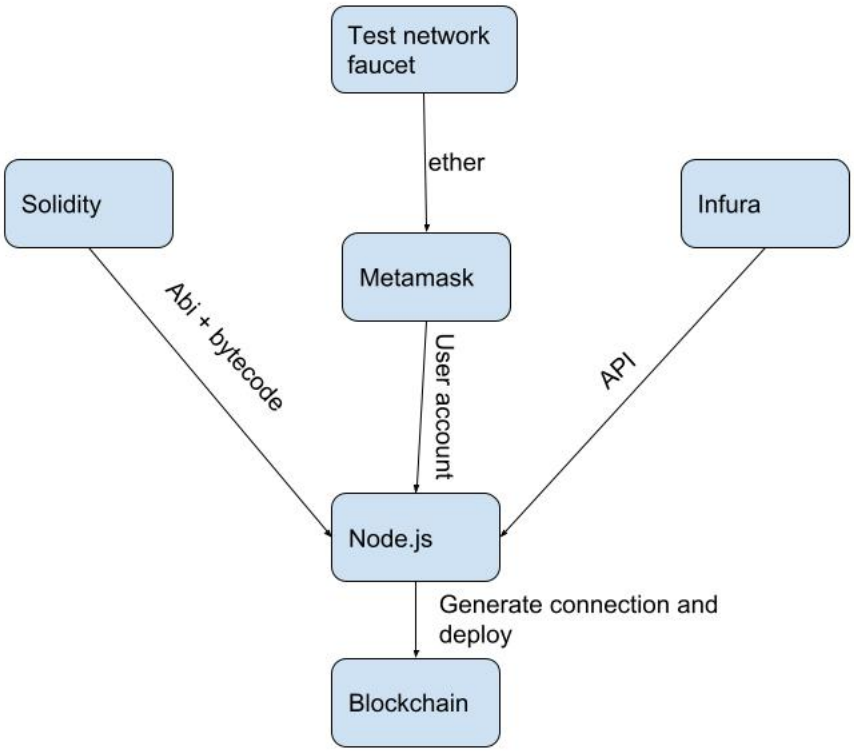

Figure 5.2: Implementation flow

Figure 5.2 describes the implementation flow. Using the solidity language we developed the ethereum code and compile it in REMIX-IDE compiler.After the compile , we get the abi and bytecode of the smart contract. The abi is a json file content which include the whole smart contact detail and the bytecode is the byte form of the contract. Using this both we can achieve the security and surety that there is nothing change or remediation happen with code. The node.js is a framework of the javascript. The javascript help us to link the solidity contact and the metamask account so, the transaction done in the blockchain easily. javascript code provide the connection of the API which is provided by infura. Using this tools the development is achieved easily without any storage in local. Below are the few screenshot of the implementation.

The solidity compiler is parted in the different panel like terminal, main panel in which we can write a code.

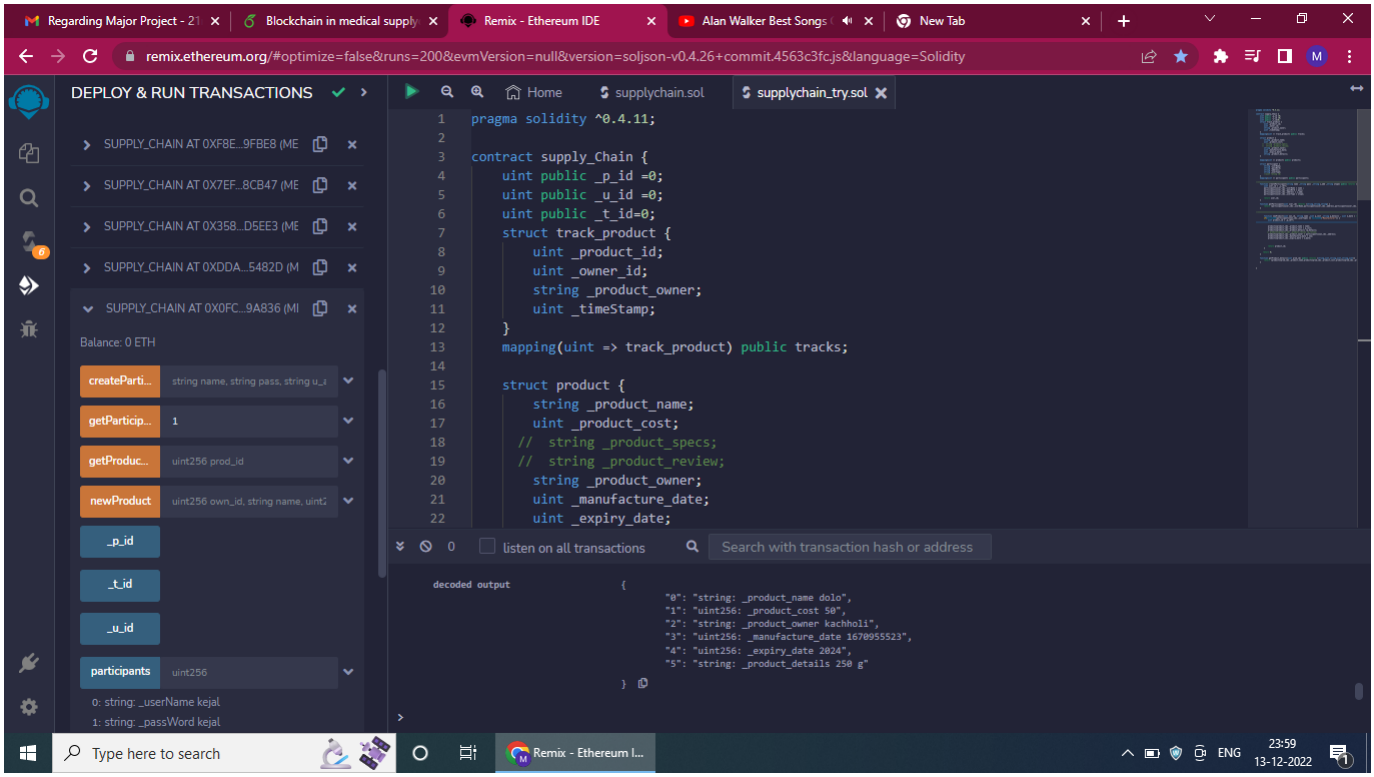

Figure 5.3: Smart Contract

Figure 5.3 is image of the solidity compiler. The smart contract we develop in solidity which includes the functions add participant, new product, display all participants and product functionalities.

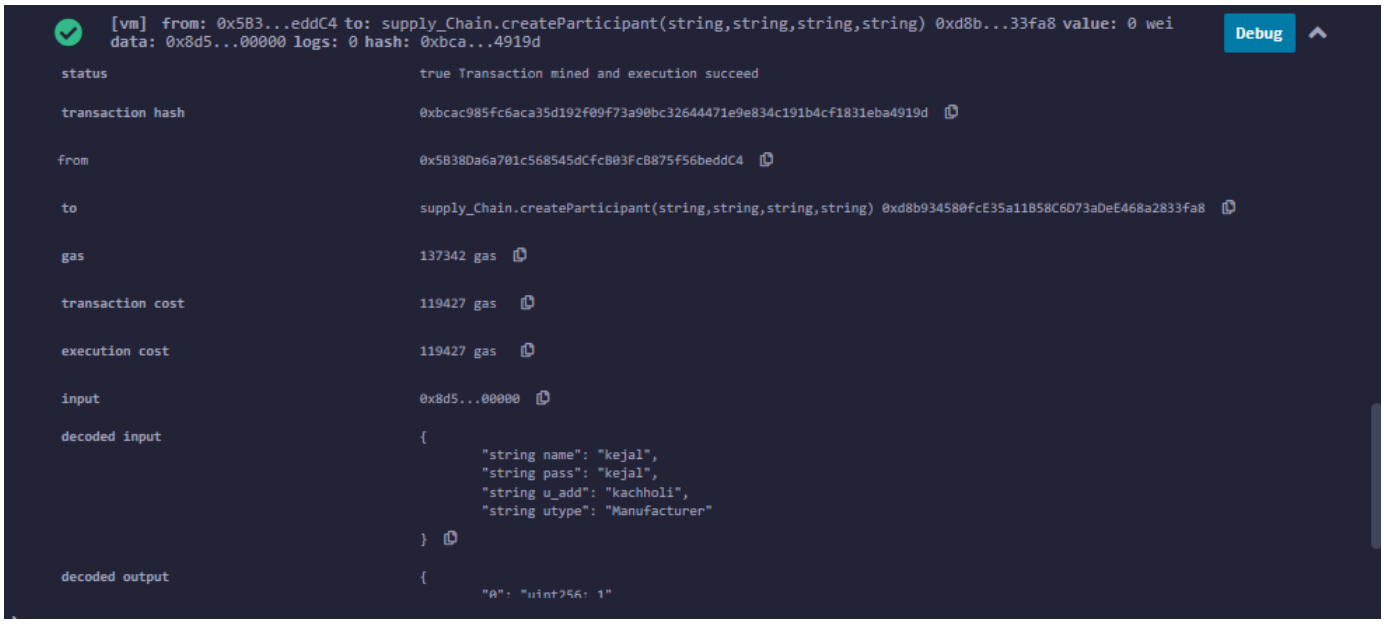

Figure 5.4: New Participant Created

Figure 5.4 include the output of the add_participant function in solidity. In the output there are few another words we need to understand. we can see the participant add successfully in supply chain. In the output the gas, transaction cost, transaction has values also present. The amount of cost required by the ethereum network for the validation and processing of transactions and smart contracts is measured in gas. A certain amount of gas is used for each action or instruction in a smart contract. The blockchain generates the hash value for each function. The hash value gives assurance in blockchain for data integrity.

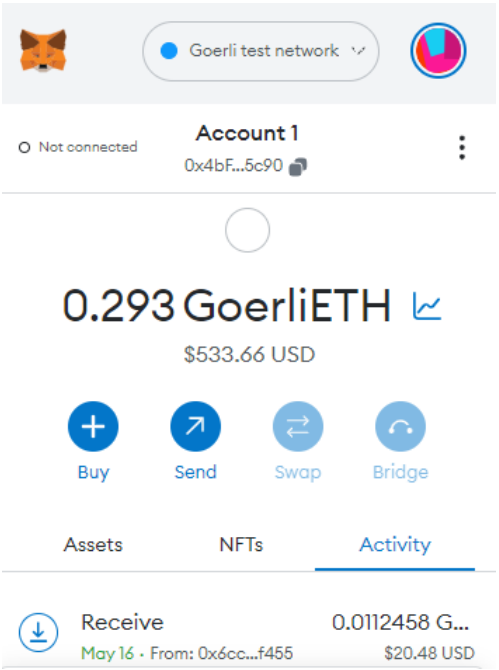

Figure 5.5: Metamask

Figure 5.5 is image of metamask wallet. Metamask can handle the ether transaction and we can view the transactions also.

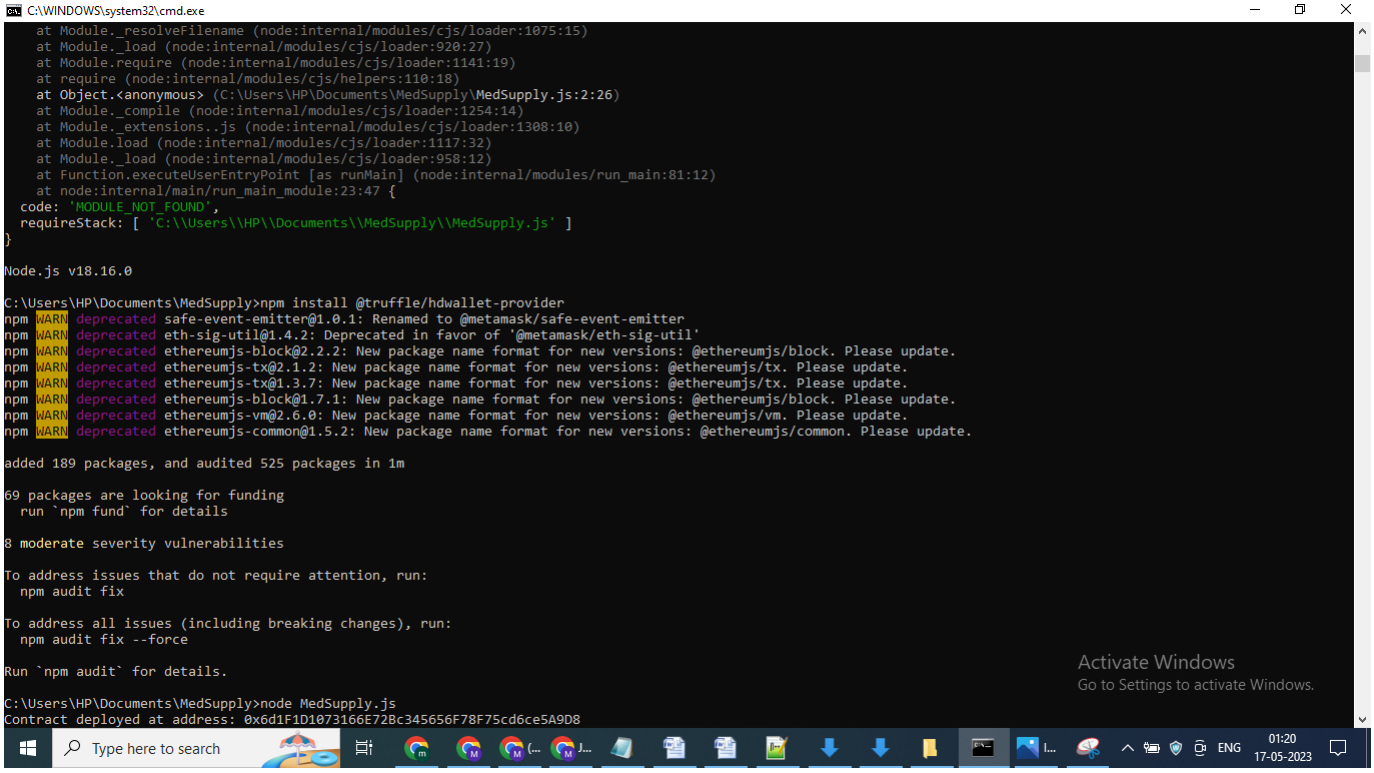

Figure 5.6: Contract Deployment

Figure 5.6 include the screenshot of the java script execution and it's output. The javascript execution gives us a hash value which indicate our smart contract deployment address.

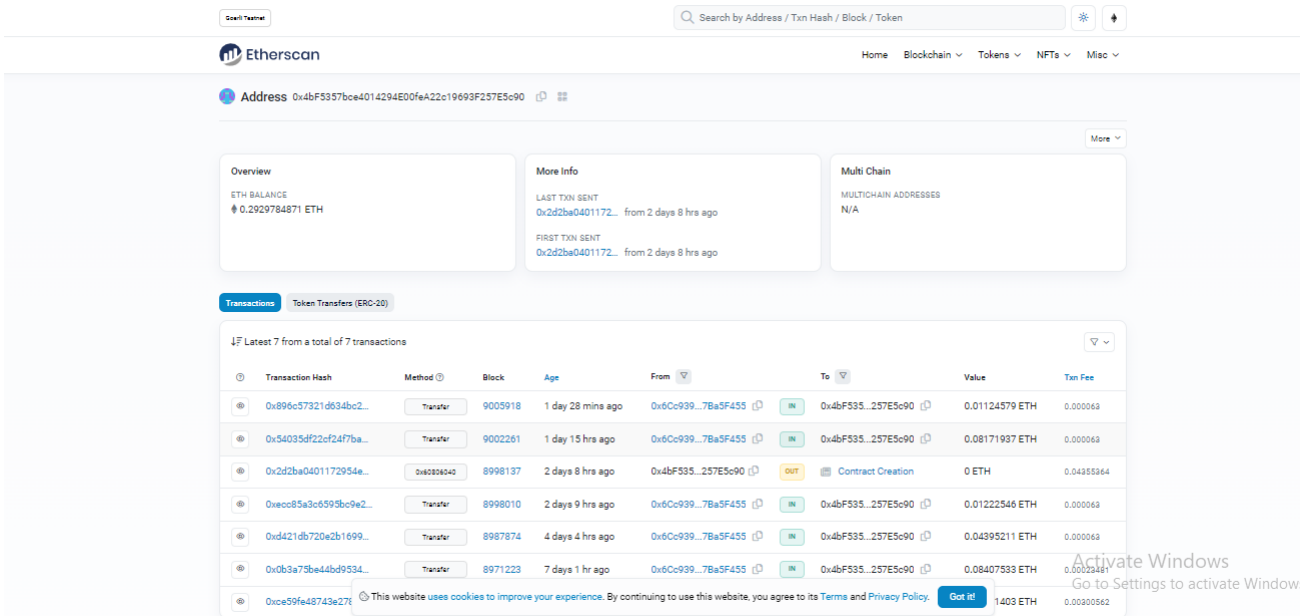

Figure 5.7: Blockchain transactions

Figure 5.7 refers the blockchain transactions of the Goerli test network. Currently, we are working on the code so we used the test network. If user wants to do transaction in main network they can do the transaction. In the figure , there are many transactions available. Some transaction indicate the ether add and some transaction indicates the smart contract deployment transaction with the address which confirms that the smat contract deploy successfully in blockchain. Once the contract deploy another entities also can join and do the transactions.

Chapter 6

Conclusion and Future work

6.1 Conclusion

In this article, we adopt blockchain technology for the supply chain in the healthcare industry. In the healthcare field, several frauds might be found during transportation. We created the smart contract while trying to find a solution to stop these scams, avoid trust difficulties in the supply chain, and increase transparency and traceability. Even though we can strive to decrease the issue, it won't be fully resolved. Metamask, Node.js, Infura, and Remix-IDE were the technologies we used to construct and deploy the smart contract on the blockchain. By using these techniques, we may also achieve security and privacy. Although it is only a portion of the solution, this is not the entire answer. We could see the numerous study articles and their methodologies in the analysis table. This research report makes a little addition to the effort to address the supply chain issue.

6.2 Future work

In future following work will be possible :

- Use the IoT sensors and trackers to achieve advance traceability
- Add the sensors for checking the medicines temperature

- add functional features which helps to automatic check and validating the medicines quality

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