Ensuring Food Safety Through Blockchain

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Certificate

The undersigned certify that **Mr. Alok Kumar Ravi (Roll. No. 1507006)** and **Mr. Vineet Kumar (Roll. No. 1507041)** is registered student for the Bachelor's program in **Department of Computer Science and Engineering** with specialization in **Information Technology** under my supervision.
I hereby recommend that the dissertation entitled, **"Ensuring Food Safety Through Blockchain"** be accepted as the fulfillment of the requirements for evaluation and award of the B.Tech. Degree.

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Declaration

We, **"Alok Kumar Ravi"** and **"Vineet Kumar"**, declare that this Dissertation entitled, **"Ensuring Food Safety Through Blockchain"** is our own original work and it has not been presented and will not be presented to any other University/ Institute for a similar or any other degree award.

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Abstract

The aim of this research is to develop a model to track food through various stages of supply chain. Noting every possible detail of the food at all stages of food supply chain will build trust among customers regarding what they have been consuming. Many diseases are transmitted through contaminated food, also food poisoning is a common dangerous problem of contaminated food. In order to prevent such type of food diseases, blockchain can be helpful in securing it and making it corruption proof. In this thesis, we have proposed a model which is based on blockchain technology for food safety and security.

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Abbreviations

SHA	**S**ecure **H**ash **A**lgorithm
RSA	**R**ivest **S**hamir **A**dleman
RFID	**R**adio **F**requency **ID**entification
EPCIS	**E**lectronic **P**roduct **C**ode **I**nformation **S**ervice
MB	**M**ega **B**yte
API	**A**pplication **P**rogamming **I**nterface
JSON	**J**avascript **S**cript **O**bject **N**otation

Chapter 1

Introduction

With the rise in global markets, where food provenance from one part of the globe and is consumed on the other part, there comes this great need to build trust among consumers on the food and more so over with certain revelations regarding food contamination and lower standards of quality. One way is to introduce a higher level of transparency to the supply chain of food, which exposes all stages in Supply Chain and various processes that their food have been through. As new technology arises, it gives more options to look at in order to improve existing systems and the same is with blockchain. Blockchain, the core of bitcoin cryptocurrency (you might know of), comes with this new tool to look at our existing problem differently. It comes with new levels of trust among peers, where we can rely on data accessible to us and there's no mediation as such i.e. no compromise with data. If done with the conventional method, that slows down the supply chain significantly, introduces various intermediaries increasing the cost as such and the data still cannot be trusted even if the transparency is maintained.

Based on the evidences its best to make our food traceability system upon blockchain technology. With the help of blockchain technology, which provides features such as immutability, consensus, disintermediation and distributed storage. We have made a food chain blockchain where all the participants can beaudited by dedicated authority and add details to blockchain database securelyusing their public and private keys. Food items will be given unique ID's atorigin and their details can be accessed using that ID from the blockchain likewhere all it have been and what all it have been through. Only the peer having been received that product can forward it if it haven't been originated. On theother end, the customer scan QR code of the product to get details.

This thesis is structured as follows. We begin with discussion on background in section 2 with an overview of SC of food, it's pitfalls and how we can enhance andovercome them along with Blockchain technology and its features and other related work. In next section 3 we discussed problem statement and in section 4, we demonstrate proposed architecture of food blockchain and the available operations on it. And in section 5 we have briefly explained the implementation of our blockchain with system and security analysis. Finally, in section 5 we have made a concise conclusion and discussed future scope.

Chapter 2

Background

With the rising demand of consumers safety needs to be provided at a next level, where they can trust the information provided. Up until now people relied solely on health officials, that their food has been inspected and undergone various safety measures. But with recent food hazards their position on food safety seems to be slipping. As defined by ISO "a technical tool to assist an organization to determine the history or location of a product or its relevant components". In general, it traces all information of food from raw material, soil, origin, processing, manufacturing, transportation and safety measures they have been through. Ethical firms in supply chain are ready to take this extra step to build trust among customers, and to meet their customers requirements. Conventional food tracking is done using various identification tags and other sensors with all the access rights to data in providers hand. While food outbreaks happen from time to time we want to give more control to consumers on what they eat, what affects them the most rather than solely to providers.

2.1 Food Supply Chain

A food supply chain refers to the system through which food goes before ending up on our tables from provenance. The processes include production, processing, distribution and consumption. The food supply chain connects three main sectors the agricultural sector, the food processing industry and the distribution sectors(wholesale and retail). The food product before reaching the customers goes through various substantial alterations. The food supply chain may improve where interactions between firms take place and where different regulations may have an impact. With the rising pace of globalization in various industries, food industry is also globalizing significantly. According to figures from the World Trade Organization (WTO), global exports of food products have increased from US224,000 million in 1980 to US 913,000 million in 2007 (WTO, 2009)[**?**]. Looking at it with management of a supply chain in mind, globalization introduces longer

and more fragmented chains, which have significant implications and tend to be more difficult to manage[4]. Longer chains require more transport, and many points of disruptions with more interconnected food system.

2.1.1 Track and Trace

Traceability, or the ability to track the food product and numerous details about processes through all stages of the supply chain, is now Ensuring Food Safety Through Blockchain more in demand then ever among customers. Many consumers now want to know where all products and their ingredients, come from and the alterations that their product have gone through from provenance. To enhances food safety, to strengthen brand integrity and increases customer loyalty, sharing information about product at every step of food supply chain is a necessity. Lack of traceability and transparency can weaken consumers trust in your brand, which can translate into lower sales and profits. Some products must be segregated within the food supply chain, the ability to monitor, track and trace products to prevent cross contamination is crucial. The ability to track products from farm to fork throughout the supply chain enables food distribution companies to quickly call back only the items that are actually affected. One reason to use blockchain is that information once added to it cannot be hacked, manipulated or corrupted in any way, it is distributed within the network and it becomes permanent. This technology can deliver the transparency, traceability, and trust better than anything else we could think of and enhance the food industry for real good. Due to its unalterable and trustworthy data, the producers, suppliers, distributors, retailers, and consumers can deal with each other more trustfully with access to trusted information about origin and state of each product at each step.

2.1.2 Safety and Quality of Products

It is challenging today, for the manufacturers to produce and distribute products that are of high quality and safe. There are few things that affect the food products, their quality and their safety. They are transportation delays, poor storage facilities, changing weather, food hygiene. Due to reasons mentioned above, food recall cases continue to grow. In this case, Blockchain proves to be of real help. It will keep record of all the details which will bring transparency and aid in customer's trust. From the perspective of the auditor, they will ensure the better quality and safety of food products.

2.2 Blockchain Technology

A blockchain, originally block chain, is a growing list of records, called blocks, which are linked using cryptography. Each block contains a data (generally represented as a Merkle tree) and previous block's hash linking them together with timestamp[5]. Basically, blockchain is a database that is shared across a network of computers and to update blockchain, everyone's consensus is required.

2.2.1 Features of Blockchain

Cannot be corrupted- Every node on the network has a digital copy of whole data. To add a transaction every node validates it and if the majority thinks it's valid, then it's added to the ledger. This makes it hard to corrupt and data is transparent to the whole network.

- Decentralized Technology- The network is decentralized meaning it doesn't have any governing authority or a single person looking after the framework. Instead, a group of nodes maintain the network making it decentralized.
- Enhanced Security- As it eliminates the need for central authority, no single entity can tamper with and encryption ensures another layer of security.
- Distributed Ledgers- The ledger on the network is maintained by all other users on the system. This distributes the computational power across the computers to ensure a better outcome.

- Consensus- There are consensus algorithm which enables all of them agree on a state.
- Faster Settlement- Blockchain offers a faster settlement compared to traditional banking system.

2.3 Related Work

Conventional Food Chain with expensive and less decentralised private blockchain processes are not sufficient enough to take care of the food safety and win trust of its consumers. Due to inefficiencies and traditional supply chain problems such as food fraud, foodborne illness, illegal production and food recalls, the public, freely accessible, with utterly distributed trust comprising blockchain could be the only solution which can maintain the traceability of immutable records. It has been proposed earlier to establish an agri-food supply chain traceability system based on RFID and blockchain technology to enhance food safety and quality and to significantly reduce the losses during the logisticsprocess[13]. The information science, management science, system science and empirical research methods, making use of reasoning, comparison, theory and demonstration of research methods to study theBlockchain in the food supply chain[14].

Earlier systems of food safety traceability have implemented as a combination of blockchain and EPCIS, since it can guarantee the tamper-proof characteristic of sensitive information while ensuring the scalability of whole system. Used a enterprise-level smart contract to solve the issues of sensitive information disclosure, data tampering, and trust transfer[15]. Walmart chose IBMs blockchain solution because it was not recre-ating supply chain, but leveraging existing technologies to enhance supply chaintraceability using Hyperledger (Burkitt, 2014). Like Walmarts blockchain pilot,traceability systems that are integrated with existing company business practicesare more likely to be maintained and more likely to be accurate than stand-alonetraceability systems[16].

Chapter 3

Problem Statement

3.1 Drawbacks in current system

With rise in food safety related issues including food contamination and poor food quality due to reasons like:

- Use of fertilizers, pesticides and other susbstances in vegetables and fruits
- Heavy metal contamination in food
- Use of inferior raw materials in manufacturing and processing
- Excessive food additives and other chemical prouducts

3.2 Problem Statement

One solution to rectify above problems is to build a traceability system which provides details regarding all stages a food goes through, to everyone concerned with the food. A system which is reliable, can be trusted and accessible to all stakeholders can prove to be of great use.

Thus our problem statement is to develop a traceable system for ensuring food security through blockchain.

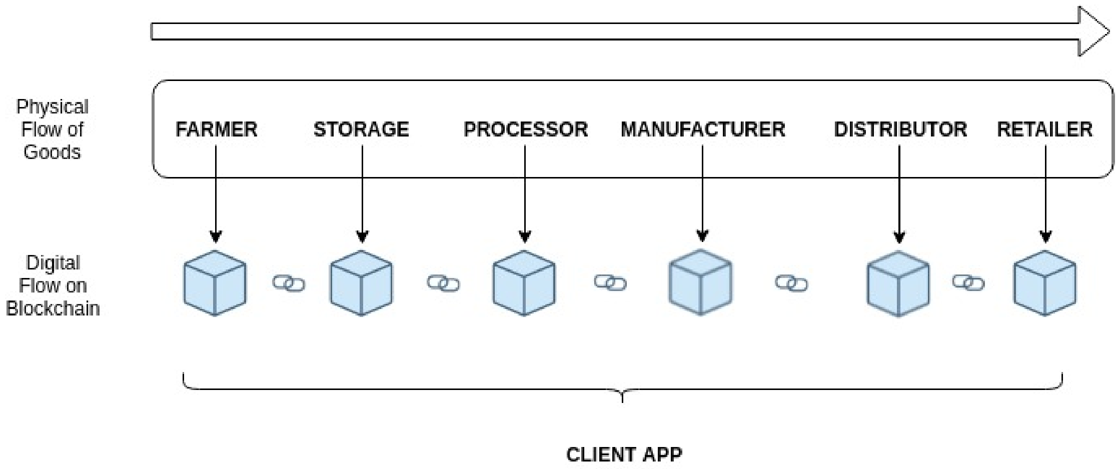

Figure 3.1: Food Chain Blockchain

Chapter 4

Proposed Architecture of Food Blockchain

Here a permissionless blockchain network is used as the users of a public blockchain do not have to place their trust in a third party in order to use the blockchain. Instead, any user of a public blockchain can trust the blockchain itself. The information about the product is authenticated by means of some form of agreement between the blockchain itself. To use the blockchain, stakeholders have to connect to the network by using their RSA generated public and private key pair, using which they're going to upload their product information aka transactions. The products will be given a 256 bit unique identity at provenance, which haven't been used earlier and will remain same throughout the supply chain for that product and will be used to track that item on blockchain. Others details can also be attached along with sender, receiver and product id, like lot number, pack date, quantity shipped, unit of measure, puchase order number, shipment identifiers, harvest date, etc. The copy of all this is with everyone on the network and with the trust of everyone. The details entered are audited by an auditor before uploading and cannot be tampered later on, the changes are permanent.

On receiving the product, they can see the complete history of product with help of the unique id of product. The application built on the user side will give complete detail analysis like where and what all it have been gone through.

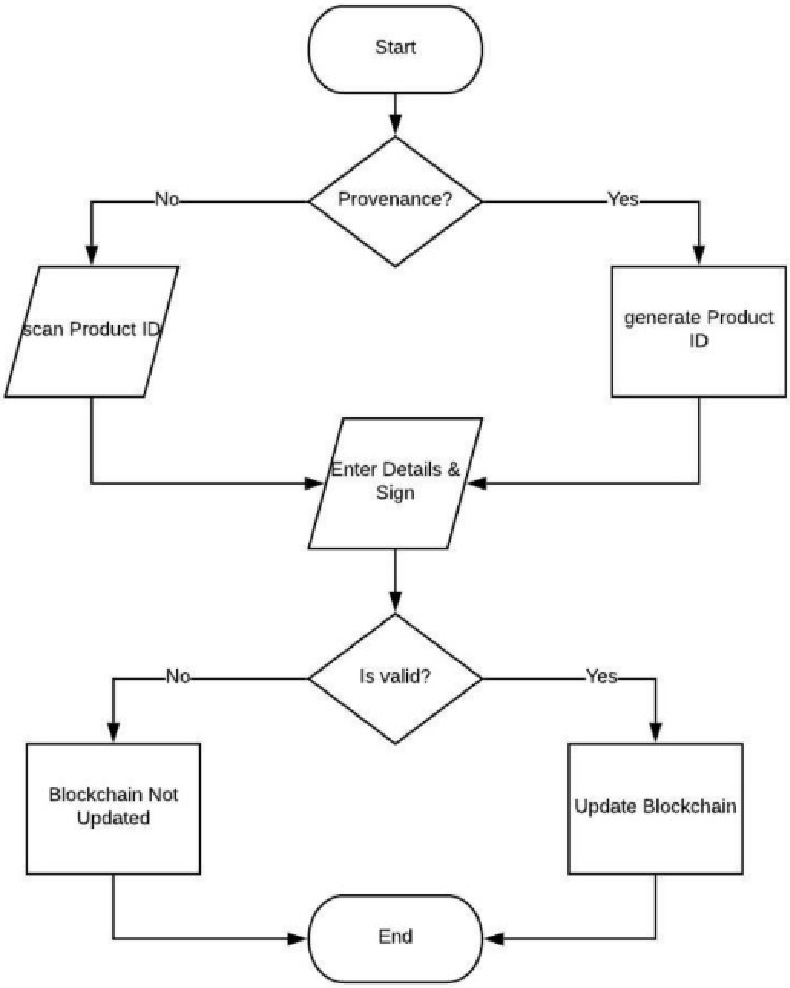

FIGURE 4.1: Flow Chart Provider End

```
@app.route('/mine_block', methods= ['GET'])
@app.route('/get_chain', methods= ['GET'])
@app.route('/is_valid', methods= ['GET'])
@app.route('/add_transaction', methods = ['POST'])
@app.route('/add_nodes', methods = ['POST'])
@app.route('/update_chain', methods=['GET'])

app.run(host= '0.0.0.0', port= 5000)
```

FIGURE 4.2: Blockchain Operations.

4.1 Blockchain Operations (Technical) control access

Various operations you can run on Food Chain Blockchain :

- Mine Block - It is used to make and add the next block to blockchain by including all the remaining transactions from meme pool, linking it to previous block by storing its hash, generating merkle root and doing the proof of work. On a GET call, it returns a json object with message, index, proof, merkle root, timestamp, previous hash and transaction details. While mining a proof of work is done with fixed complexity of generating a hash by changing nonce such that hash is with eight zeroes in the beginning.

```python
# Mining a Blockchain
@app.route('/mine_block', methods= ['GET'])
def mine_block():
    previous_block= blockchain.get_previous_block()
    new_proof= blockchain.proof_of_work(previous_block['proof'])
    previous_hash= blockchain.hash(previous_block)
    # blockchain.add_transaction(sender= 'reward', receiver= 'Satoshi', amount= 1000)
    block= blockchain.create_block(new_proof, previous_hash)
    response= {'message': 'Congratulations, you just mined a block!',
               'index': block['index'],
               'proof': block['proof'],
               'merkle_root': block['merkle_root'],
               'timestamp': block['timestamp'],
               'previous_hash': block['previous_hash'],
               'transactions': block['transactions']}
    return jsonify(response), 200
```

FIGURE 4.3: mine block

- Get Chain - This operation returns the complete blockchain i.e. all the data saved on blockchain which can be used for checking details of product and to do analysis on that data. On the user side that data can be used to different layout data according to user needs.

```python
# Getting the full Blockchain
@app.route('/get_chain', methods= ['GET'])
def get_chain():
    response= {'chain':blockchain.chain,
               'length': len(blockchain.chain)}
    return jsonify(response), 200
```

FIGURE 4.4: get chain

- Add Transaction - Whenever the stakeholder or anyone want to upload data to blockchain they call this. It requires user to send sender id, receiver id and product id, adding other details is up to them. The transaction is added to meme pool if it is signed correctly and if not provenance (new product id) then see if the user have received that product. A transaction is verified on the basis of signature and if the that public address has that prouduct if it is not provenance.

- Add Nodes - Whenever new node arrives, this information is sent to all nodes and keep talking to each other and become a part of the food chain blockchain network.

```
@app.route('/add_transaction', methods = ['POST'])
def add_transaction():
    json= request.get_json()
    tranasaction_keys= ['sender', 'receiver', 'pid']
    if not all(key in json for key in tranasaction_keys):
        return 'some elements are missing', 400
    index_block= blockchain.add_transaction(json['sender'], json['receiver'], json['pid'])
    response= {'message': 'This transaction will be added to block %s' % index_block}
    return jsonify(response), 200
```

FIGURE 4.5: add transaction

It is given all necessary updates of blockchain and helps making system secure by providing updates. A node is going to receive an update only if it's chain is shorter than the node it is comparing with.

```
@app.route('/add_nodes', methods = ['POST'])
def add_nodes():
    json= request.get_json()
    nodes= json.get('nodes')
    if nodes is None:
        return "No node", 400
    for node in nodes:
        blockchain.add_node(node)
    response= {'message': 'all nodes added to main chain',
                'total_nodes': list(blockchain.nodes)}
    return jsonify(response), 200
```

FIGURE 4.6: add nodes

- Update Chain - It looks around in the network for updating its chain, adding transactions and have the same blockchain as the rest of the network. In case of multiple different blockchains, the one with the highest number of blocks will be accepted as it is the one with most amount of work done. A chain will be updated with newer chain only if the arriving chain is valid i.e have all the previous hashes linked correctly, transactions signed and necessary proof of work done.

```
@app.route('/update_chain', methods=['GET'])
def update_chain():
    is_chain_replaced= blockchain.update_chain()
    if is_chain_replaced:
        response= {'message':'the chain is updated',
            'new_chain': blockchain.chain}
    else:
        response= {'message': 'No change',
            'chain': blockchain.chain}
    return jsonify(response), 200
```

FIGURE 4.7: update chain

- Check Validity - Checks if the blockchain you're having is valid or contains invalid transactions or blocks. It is optional to check validity of your chain as after you update chain it is validated internally. A chain is valid if it have all the previous hashes linked accordingly, tranasactions signed with correct merkle root and proof of work done and timestamp is in correct order.

```
# Checking if the Blockchain is valid
@app.route('/is_valid', methods= ['GET'])
def is_valid():
    is_valid= blockchain.is_chain_valid(blockchain.chain)
    if is_valid:
        response= {'message': 'All good. The blockchain is valid.'}
    else:
        response= {'message': 'Error: Blockchain Not Valid'}
    return jsonify(response),200
```

FIGURE 4.8: is valid

Chapter 5

Implementation and Result Analysis

5.1 Implementation

At the beginning we initialise the blockchain by generating genesis block in which there are no transactions. Our blocks are of size 0.5 MB which contain index number, timestamp, proof of work, previous hash and merkle root of transactions along with transactions. The transactions are stored in meme pool until the next block in not mined, these transactions are securely signed with private key of user generated using RSA asymmetric cryptography algorithm and his/her public key is used to verify that. When adding

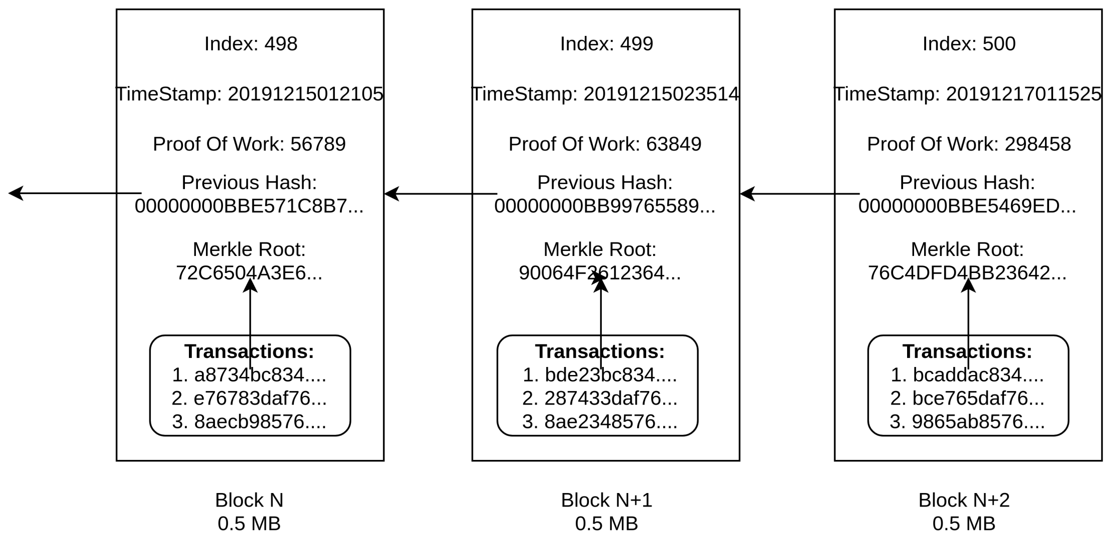

FIGURE 5.1: Block details

```python
import datetime
import hashlib
import json
from flask import Flask, jsonify, request
import requests
# from uuid import uuid4        # used for creating unique id
try:
    from urllib.parse import urlparse
except ImportError:
    from urlparse import urlparse       # for extracting url from address
```

FIGURE 5.2: Implementation operation

these transactions to the block, along with transactions their merkle root is stored in the block .A Merkle root is the hash of all the hashes of all the transactions that are part of a block in a blockchain network. The SHA 256 hash of the previous block is stored in the next block to link it to chain and when manufacturing new block a certain amount of work is to be done, which is stored in as proof of work. For our blockchain we have kept the difficulty of work to calculate SHA 256 hash to have eight zeroes at the beginning of hash. The SHA 256 is a hashing algorithm which generates a 256 bit hash of the given string input. We have implemented all above operations in python using various libraries like urlparse, datetime, hashlib, json. We have used flask WSGI(Web Server Gateway Interface) micro web framework using the python library flask. Our transaction details fetched through POST method on web server are in form of JSON and requests made through GET are also sent in JSON format[8].

5.2 System Analysis

We have tested our system at various configurations like with 5 hops where food goes from farmer to processor to manufacturer to distributor to retailer all blocks of size almost 1 MB and with 20 different food items in supply chain. On the arrival of the product at customer we have successfully back traced the whole supply chain and various details that have been added by various nodes(participants) in blockchain reliably.

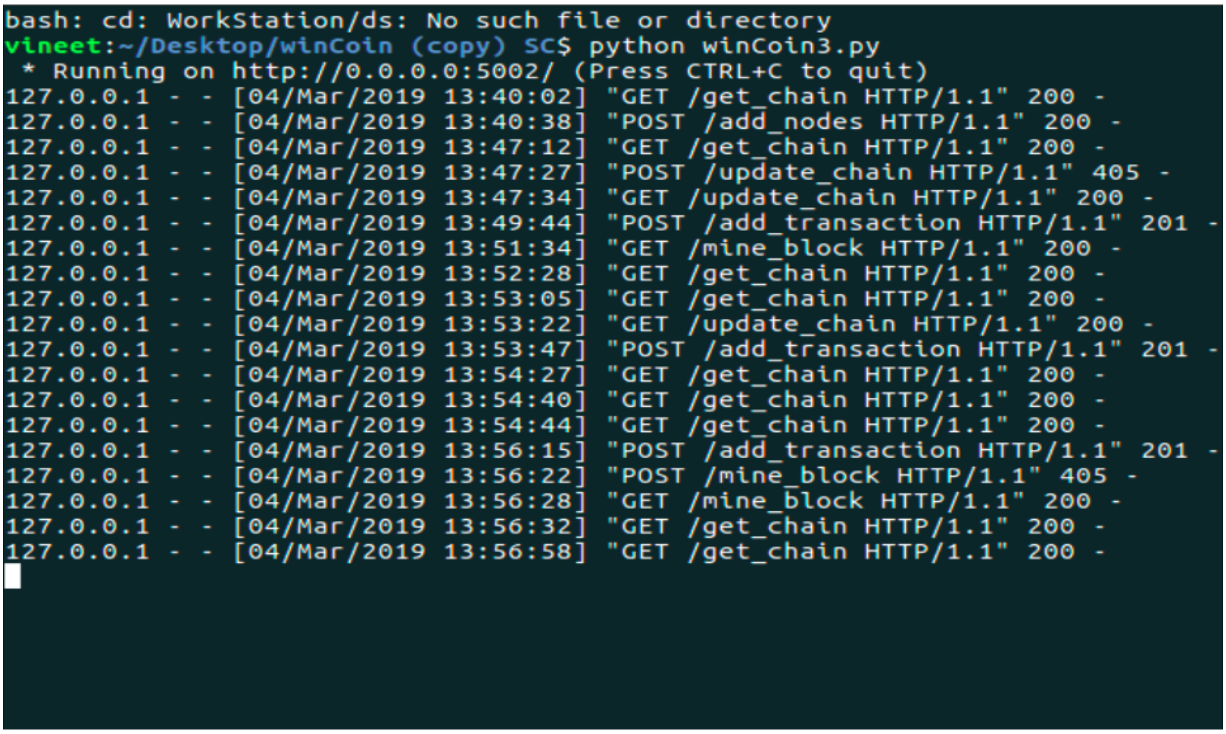

FIGURE 5.3: Running a node

5.3 Security Analysis

5.3.1 Data Tampering

The data tampering is extremly difficult as the underlying technolgy of our system is blockchain which makes a copy of whole blockchain throughout the network, so to tamper the changes have to made to the whole network. And even when tampering the blockchain should be valid with all the RSA generated public and private key combinations with SHA 256 hashing and proof of work that went into the system and form the biggest chain in network available.

5.3.2 Secure transactions

The transactions are secured with RSA generated public and private keys. You cannot sign a transaction if you don't the private key of that public address, your transaction will be verified by matching against the public key counterpart.

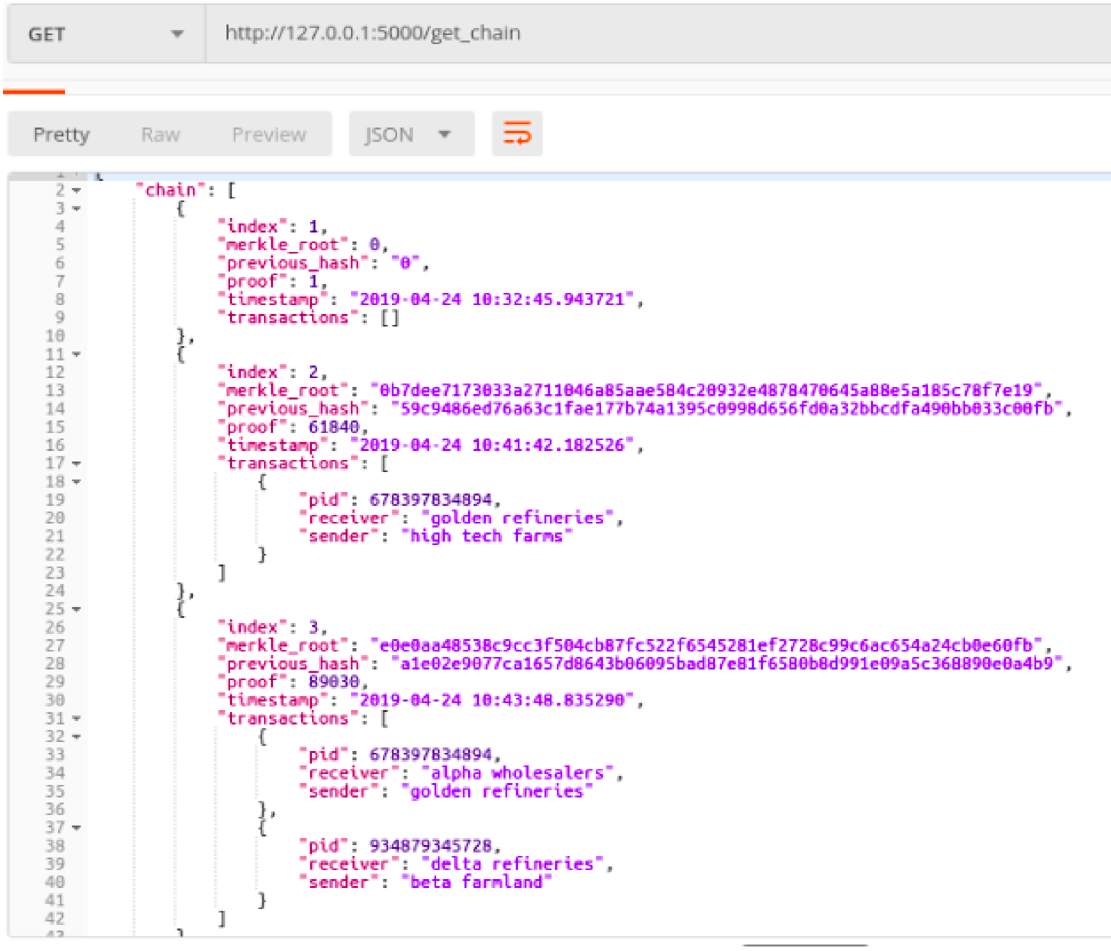

FIGURE 5.4: API calls through postman

5.3.3 System Level Attacks and Threats

Our system had gone through security analysis, checked for tampering, false updating, etc. The system proved to be resilient as during the insertion of information on blockchain the transactions are singed used RSA private keys which only the user have and verified using his public key, only the person with the product can insert information regarding that product ID. And on trying to tamper with the data, the block's previous hashes are stored along with merkle root of transactions making it extremely unlikely to be forged or manipulated.

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

In this paper, we worked on one of the overlooked benefits of food tracking system for quality and safety of products. We made it tamper proof, more authentic and secure for people to trust using blockchain. In this system all the information from all the links of food supply chain is stored on blockchain. This blockchain can be accessed by anyone and fetch product details and get assured of the quality of their food. We have made the basic model of food traceability and provided features for developers to work on the client side by giving access to food chain blockchain API (Application Programming Interface). In future work we'll add more features to our blockchain increasing its functionality, security and transparency along with privacy. With this system in hand of people will bring people and the companies closer and trust products they're consuming.

6.2 Future Scope

In future we will continue to experiment, scale, and learn from our project. We will add more features to our blockchain increasing its functionality, security and transparency along with privacy. We'll work on making it more accessible, simple to use and understand and efficient wherever possible. And as the blockchain technology improves those improvments will be pushed to our blockchain along with other top notch technological implementations. We will empahsize more on social problems rather than on the technological improvements solely.

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