# EFFICIENT CREATION OF SMART CONTRACTS USING BSC FOR AGRI-FOOD TRACEABILITY SYSTEM

## PROJECT REPORT

#### (PHASE- I)

Submitted by

#### M.A.SHAHAE MEERAN REG.NO: 20TH0218

#### Under the Guidance of

**Mr. S. Uthayashangar M.Tech.,**

Assistant Professor

*in partial fulfillment for the award of the degree of*

#### BACHELOR OF TECHNOLOGY

**in**

**DEPARTMENT OF INFORMATION TECHNOLOGY**



## MANAKULA VINAYAGAR INSTITUTE OF TECHNOLOGY

#### KALITHEERTHALKUPPAM, PUDUCHERRY- 605 107.

**PONDICHERRY UNIVERSITY INDIA**

**FEBRUARY-2024**

# MANAKULA VINAYAGAR INSTITUTE OF TECHNOLOGY

## PONDICHERRY UNIVERSITY DEPARTMENT OF INFORMATION TECHNOLOGY

**BONAFIDE CERTIFICATE**

This is to certify that the Project work titled **“EFFICIENT CREATION OF SMART CONTRACTS USING BSC FOR AGRI-FOOD TRACEABILITY SYSTEM”** is a bonafide work done by**, M.A.SHAHAE MEERAN [REG.NO: 20TH0218]** in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Information Technology by Pondicherry University during the academic year 2022-23.

# HEAD OF THE DEPARTMENT PROJECT GUIDE

#### (Dr. P. Sivakumar) (Mr. S. Uthayashangar)

*Submitted for the project work- Phase-I- Viva Voce Examination held on*.............................

**ACKNOWLEDGEMENT**

We express my sincere thanks to our Chairman and Managing Director **Shri. M. DHANASEKARAN,** for all his encouragement and moral support. We thank our Vice Chairman **Shri.** S.**V. SUGUMARAN,** our secretary **Dr. K. NARAYANASAMY and** our Treasurer **Shri..**

**D. RAJARAJAN** for their constant encouragement.

It gives us great pleasure to convey our deep and sincere thanks to our Principal **Dr. S. MALARKKAN**, for giving constant motivation in succeeding our goal.

We extend our sincere and heartfelt thanks to our Head of Department **Dr. P. SIVAKUMAR,** Professor**,** Department of Information Technology, for providing the right ambience for carrying out this project work.

We would like to thank our guide **Mr.S.Uthayashangar**, Assistant Professor, Department of Information Technology, providing his valuable guidance and suggestions for our project work. We thank his for the continuous encouragement and the interest shown on us to bring out our project work successfully.

We would like to express my gratitude to all teaching and non-teaching staff members of our department. And above all, the blessings of the Almighty have kept up my spirit and enabled me to complete my study successfully.

**T.BHARATHKUMAR P.BUVANESWARAN**

**M.A.SHAHAEMEERAN**

**S.VIGNEASWARAN**

## TABLE OF CONTENTS

|  |  |  |
| --- | --- | --- |
| **CHAPTER NO** | **TITLE** | **PAGE NO** |
|  | **BONAFIDE CERTIFICATE** | ***ii*** |
|  | **ACKNOWLEDGEMENT** | ***iii*** |
|  | **TABLE OF CONTENTS** | ***iv*** |
|  | **LIST OF FIGURES** | ***vii*** |
| **1** | **INTRODUCTION** | 1 |
|  | 1.1 OVERVIEW | 1 |
|  | 1.2 CHALLENGES IN DOMAIN | 1 |
|  | 1.3 OBJECTIVE AND SCOPE OF PROPOSED WORK | 2 |
|  | 1.3.1 OBJECTIVE OF THE PROJECT WORK | 2 |
|  | 1..3.2 NEED/SCOPE FOR THE PROJECT WORK | 3 |
| **2** | **LITERATURE REVIEW** | 4 |
|  | 2.1 SURVEY OF THE RELATED WORKS | 4 |
|  | 2.1.1 Automatic Generation of Ethereum-Based Smart Contracts for Agri-Food Traceability System | 4 |
|  | 2.1.2 Blockchain in Agriculture Traceability Systems: A Review | 5 |
|  | 2.1.3Smart Contract Security: A Software Lifecycle Perspective | 6 |
|  | 2.1.4 Smart Contract-Based Product Traceability System in the Supply Chain Scenario | 7 |
|  | 2.1.5 B-MERODE: A Model-Driven Engineering and Artifact-Centric Approach to Generate Smart Contracts | 8 |
|  | 2.1.6 User Interface of Blockchain-Based Agri-Food Traceability Applications: A Review | 9 |

|  |  |  |
| --- | --- | --- |
|  | 2.1.7 Effective Management for Blockchain-Based Agri-Food Supply Chains Using Deep Reinforcement Learning | 10 |
|  | 2.2 SUMMARY OF LITERATURE REVIEW | 11 |
| **4** | **EXISTING SYSTEM** | 14 |
|  | 3.1 EXISTING WORK | 14 |
|  | 3.2 PROBLEM STATEMENT | 15 |
| **5** | **PROPOSED SYSTEM** | 17 |
|  | 5.1 PROPOSED WORK | 17 |
|  | 5.2 PROPOSED SYSTEM METHODOLOGY | 17 |
|  | 5.3 SYSTEM REQUIREMENTS | 18 |
|  | 5.4 PROPOSED ARCHITECTURE DIAGRAM | 19 |
|  | 5.5 WORKING | 24 |
|  | 5.6 PERFOMANCE ANALYSIS | 26 |
| **6** | **MODULE AND MODULE**  **DESCRIPTION** | 28 |
|  | 6.1 MODULE CLASSIFIATION | 28 |
|  | 6.2 NODE AND ROBOT | 28 |
| **7** | **CONCLUSION** | 32 |
| **8** | **REFERENCES** | 33 |

**LIST OF FIGURES**

|  |  |  |
| --- | --- | --- |
| **FIGURE NO** | **TITLE** | **PAGE NO** |
| Figure 1 | AURDINO UNO | 14 |
| Figure 2 | ROBOT ARCHITECTURE | 15 |
| Figure 3 | NODE ARCHITECTURE | 16 |
| Figure-4 | ARCHITECTURE DIAGRAM AT TX SIDE |  |
| Figure-5 | ARCHITECTURE DIAGRAM AT RX SIDE | 17 |
| Figure-6 | OVERALL WORKING ARCHITECTURE OF PROPOSED WORK |  |
| Figure-7 | WORK-FLOW ARCHITECTURE | 18 |

**ABSTRACT**

The increasing demand for transparency in the agri-food industry, fuelled by both customer expectations and government regulations, has led to the rapid adoption of blockchain technology. This innovative approach ensures secure traceability, combats food fraud, and provides consumers with valuable information about the origin of their food products. The trust and immutability inherent in blockchain make it a perfect fit for agri-food chain management, where maintaining the integrity of the supply chain is crucial.

In the existing system, Ethereum-based smart contracts play a key role in facilitating transparent and secure transactions. However, upgrading these smart contracts on Ethereum can be a complex and disruptive process. Migration of data and users to new contracts poses challenges that can potentially disrupt the entire ecosystem. To overcome these disadvantages, Binance Smart Chain (BSC) as a viable alternative.

Binance Smart Chain offers several advantages, including quicker transaction confirmation times compared to Ethereum. Its different consensus mechanism and shorter block times contribute to a more efficient and scalable solution for agri-food chain management. The adoption of BSC not only addresses the challenges of upgrading smart contracts but also enhances the overall speed and reliability of the blockchain-based system in ensuring transparency and traceability throughout the agri-food supply chain.

***KEYWORDS: Binance Smart Chain, agri-food traceability system, smart contracts***

**LIST OF ABBREVIATIONS**

STARKs Scalable Transparent Arguments of Knowledge

SSL Secure Sockets Layer

WETH Wrapped Ether

WP Whitepaper

ENS Ethereum Name Service

EOA Externally owned account

ERC Ethereum Request for Comments

ERC-20 Token standard for Ethereum.

TVL Total value locked.

BSC Binance Smart Chain

**CHAPTER I**

**INTRODUCTION**

**1.1 OVERVIEW**

The term "agri-food" is a combination of "agriculture" and "food," and it refers to the entire value chain involved in producing, processing, distributing, and consuming food products. This comprehensive term encompasses various stages of food production, from the cultivation of crops and livestock to the delivery of finished food products to consumers. In the agri-food industry, agriculture serves as the initial stage, involving activities such as farming, fishing, and livestock breeding. This sector focuses on producing raw materials like crops, fruits, vegetables, meat, and dairy products. Following the production phase, these raw materials undergo processing, where they are transformed into packaged goods, processed foods, or other consumable products.

Distribution is another critical aspect of the agri-food industry, involving the transportation, storage, and logistics of food products from producers to retailers, wholesalers, and ultimately to consumers. The entire supply chain is tightly regulated to ensure food safety, quality, and compliance with various standards and regulations. Consumer demands for transparency, sustainability, and information about the origin of food products have driven innovations in the agri-food sector. Technologies like blockchain are increasingly being adopted to provide secure traceability, prevent fraud, and enhance overall transparency in the supply chain.

In summary, the agri-food industry encompasses the complete cycle of food production, from cultivation to consumption, and it plays a crucial role in meeting the nutritional needs of the global population. As the industry evolves, technologies and practices are being implemented to address challenges and meet the growing demands for transparency and sustainability.

**1.2 INTRODUCTION**

The Blockchain is an encrypted, distributed database that records data, or in other words it is a digital ledger of any transactions, contracts - that needs to be independently recorded. One of the key features of Blockchain is that this digital ledger is accessible across several hundreds and thousands of computers and is not bound to be kept in a single place. Blockchain chain has already started disrupting the ﬁnancial services sector, and it is this technology which underpins the digital currency- bitcoin transaction.

With Blockchain technology in ﬁnancial sector, the participants can interact directly and can make transactions across the internet without the interference of a third party. Such transactions through Blockchain will not share any personal information regarding the participants and it creates a transaction record by encrypting the identifying information. The most exciting feature of Blockchain is that it greatly reduces the possibilities of a data breach. In contrast with the traditional processes, in Blockchain there are multiple shared copies of the same data base which makes it challenging to wage a data breach attack or cyber-attack . With all the fraud resistant features, the block chain technology holds the potential to revolutionize various business sectors and make processes smarter, secure, transparent, and more eﬃcient compared to the traditional business processes.

You get a history of activity, not just a snapshot in time. When you look at a regular database, you're getting a snapshot of data that's up to date in that moment in time. Blockchains do this too, but they also maintain a record of all the information that existed before. It's a database with history if you like.

There's no one, central point of attack. The fact that blockchain is a decentralized way of storing and accessing data makes the whole system incredibly secure - because, unlike a centralized database, there's no one single point of entry for hackers. This makes it particularly useful for recording transactions in a secure manner.

And no centralized control. Because the system of record is decentralized and replicated in its entirety in multiple places, there's no need for a central administrator and all the costs and infrastructure that comes with it.

Blockchain technology is revolutionizing a wide range of industries. Forbes' Bernard Marr highlights several Blockchain applications, including entertainment, such as music-streaming service Spotify; the food industry, such as for supply-chain logistics; and healthcare, such as for storage and use of medical records. While the possibilities for blockchain's applications may constantly be growing, however, the best known may still be bitcoin.

Imagine two friends living far away from each other, and one would like to transfer money to the other using blockchain technology. As mentioned, blockchain is a decentralized system of secure and trusted distributed databases. It's a distributed ledger that records and shares the transaction details across many nodes (computers) that are part of the network. Every participant has the same copy of the ledger, and it's immutable once a record or a transaction is registered, it cannot be modiﬁed.

Blockchain was initially introduced to timestamp digital documents and prevent tampering of records. In simple terms, a chain of blocks that contain information is called a blockchain. When a transaction occurs, its related information is recorded into a block. A transaction initiated in one corner of the globe can get registered on the block, and then that block is veriﬁed (validated) by the miners and then added to the main blockchain. A block contains aggregated transactions that a miner has to validate, and for doing that, the miner gets rewarded.

**DATA**

This consists of the transaction data. There could be multiple transactions among multiple senders and receivers, so each block consists of any number of transactions, and each transaction will have a sender's address, a receiver's address, and a transactional nonce.

**PREVIOUS HASH**

The previous hash is the attribute that connects a block to its previous block. It consists of the hash value of the previous block. Nonce Bitcoin uses a proof-of-work algorithm, and to execute the algorithm, a random value is used to vary the output of the hash value; this is called the nonce. Proof of work is the process of transaction veriﬁcation.

**HASH**

The hash is like a digital ﬁngerprint. To get the hash for the current block, the process takes an input value (the previous hash, the data, and the nonce) and produces an output value of a ﬁxed length. Bitcoin uses the SHA-256 hashing algorithm to generate a 256-bitlength hash. It looks something like a hexadecimal value.

**PUBLIC DISTRIBUTED LEDGER**

To recap, a blockchain is a decentralized public distributed ledger that is used to record transactions across many computers. For example, user A transfer’s money to user B, user B transfers to C, and C transfers to B. A distributed ledger is a database that is shared among all the users who are part of the blockchain network. The transactions are accessed and veriﬁed by users of the bitcoin network, thereby making it less prone to a cyber-attack.

Let's take an example in which bitcoin users are transferring money: Bella is trying to transfer money to John, John is trying to transfer money to Elsa, and Elsa is trying to transfer money to Jack. So these are the three transactions to be initiated.

If these transactions were happening on a central ledger, it could get corrupted, and there is the chance of data tampering. To solve this problem, a public distributed ledger plays a vital role: It ensures that each user who is part of the cycle has a copy of the transaction details. In our example, Bella, John, Elsa, and jack all have the same ledger â the distributed ledger.

**ENCRYPTION**

Blockchain eliminates unauthorized access by using the cryptographic algorithm SHA-256 to ensure that the blocks are kept secure. Each user in the blockchain has his or her keys: a private one and a public one. The private key is known only to the sender; it is also used to conﬁrm if the origin of the transaction is legitimate. The public key is also used to identify the user.

uniquely, but the sender shares it with every transaction. It ﬂoats on the blockchain network. Let's look at a typical transaction veriﬁcation process. Suppose a sender wants to send a message. The sender will pass the message through the hash function and generate a hash value of the message. After the hash value has been created, it is passed through a signature algorithm, and with the private key, a digitally signed document is created.

The original message, the digitally signed document, and the public key are then transmitted to the receiver. At the receiver's end, the transaction message is passed through a hash function to get a hash value, and that hash value is compared with the hash value obtained bypassing the digital signature and public key through a veriﬁcation function.

The hash function creates a unique digital ﬁngerprint of data. The message is passed through the hashing function, and it generates a hash value. This hash value is called a digital print, and it has a unique property: Any hashing function is a one-way function; it cannot be reversed. You cannot decode the original value from the hashed value.

A blockchain is a continuously growing collection of blocks that are chained together to form an open ledger by using cryptography as a key ingredient. Each block in the blockchain is given an identity to mark that block as unique, and this is achieved by using the hash functions that will generate a digest for that block. The collision resistance property of the cryptographic hash function, A Bit of Cryptography, ensures that it is infeasible to ﬁnd two blocks that will result in the same hash value. As a result, the hash function guarantees the uniqueness of the identity created for the block. When a new block is created, it will backreference the previous block using the digest of the previous block, thus linking that block to the blockchain. Modifying any of the blocks would change the identity of that block due to the new hash value. As a result, this would break the chain, as one of the block references will be invalid due to the newly generated hash value. Therefore, it's infeasible to modify a block such that it generates the same hash value as before. This is due to the pre-image resistance property of the cryptographic hash function, which ensures that the data of the blocks cannot be predicted even if we possess the hash value. This is why, once a chain of blocks is created, the integrity of the chain is ensured as each block references the previous block. The only way to modify the data of a block is by modifying all the subsequent blocks by updating its reference to the previous block.

The block linking process consists of several elements, such as creating a structure from the information, calculating the hash of the block, and appending it to the blockchain.

The preceding code snippet deﬁnes a Python class called Block that has all the basic attributes of a blockchain block. Usually, a block will contain both a header and a body, with the header containing metadata about the block. However, the preceding example doesn't distinguish between the header and the body. A typical blockchain application, such as Bitcoin, will have a huge set of data that could be in the form of transactions, but in the example, we will consider the data to be of a string type.

A typical block will also contain a nonce and a diﬃculty target in the header. This information is used in consensus algorithms, such as Proof of stack.

Digital signatures are used in transactions due to their properties that ensure the integrity of the transaction contents and nonrepudiation of any events in the transaction. A transaction embedded into the block will contain a certain action that is being signed by someone who possesses the private key.

Owning the private key thus proves the identity of the signer. The transaction can only be signed by the owner of the corresponding private key of the public key. The transactions of Bitcoin and other blockchain platforms have several ﬁelds in the transaction to perform value transfer.

A blockchain network is a decentralized peer-to-peer network, where nodes communicate with each other to create, exchange, and validate blocks. Most of the users in the blockchain network are interested in the application layer of the blockchain where operations can be performed by creating transactions. An identity can easily be created in the network, as we saw in the previous section of this chapter. Nodes can perform operations such as asset creation or asset transfer. Each operation that deals with assets is valid if they are approved by the asset owner. The asset owners prove their identity by signing the transactions using their private key. Asset management operations, such as transferring the asset, can only be performed by the owner, but it can be veriﬁed by anyone in the network. All the operation details are embedded in transactions, and digital signatures are used by the asset owners to sign those transactions. They then broadcast these transactions to every node in the blockchain so that they are included in the next block to be appended to the blockchain ledger. The ownership of an asset can be proven by possession of the private key for an address (public key) to which the asset belongs.

Whenever the ownership of an asset needs to be transferred, users use their private key to sign the transaction, ﬁrstly proving their ownership, and from there transferring the ownership to the desired user. A blockchain wallet is a piece of software that holds all the private keys owned by a particular user. While physical wallets hold hard cash, blockchain wallets hold all the private keys a user possesses, which will help the user claim assets that belong to them. A single wallet can store any number of keys, which means a node can have multiple destination addresses. These keys are created in two distinct ways: deterministically and non-deterministically.

–

A non-deterministic wallet is a collection of randomly created private keys that bear no relation to each other. Private keys created with these wallets are diﬃcult to maintain because it is diﬃcult to reconstruct the keys in the event that they are lost. So, every key in the wallet has to be backed up to prevent any loss that could take place in the event of a wallet failure. A deterministic wallet is also called a seed wallet because all the keys in this wallet are derived from a single seed. All the keys can easily be reproduced just by accessing the seed.

All the keys in a simple deterministic wallet are created by hashing a string and an incremental nonce. In the case of wallet failure, seed information alone is suﬃcient to recover the private keys, so there is no need to back up all the keys in the wallet. The basic deﬁnition of a P2P network is a network where groups of independent computers called nodes are interconnected, sharing data without the assistance of any centralized servers. It is an architecture on top of the internet. Participants or nodes in this type of network are called peers because they are all equal and have equal responsibility within the network. Since there are no special nodes in a P2P network, each peer is both a service provider and a consumer.

P2P networking is an architecture where each peer acts as a server and a client simultaneously. Since a blockchain network is often implemented on a public network, it is diﬃcult to create a physical topology that is suitable for P2P networking. To create this kind of architecture, a virtual or logical network overlay has to be constructed over the actual physical network topology. A logical network is created to achieve a convenient index of resources and peer discovery in a public network. Although an overlay is formed, data will be exchanged over the TCP/IP network.

Although the underlying physical network could follow any networking topology, the logical network in a P2P architecture will form a mesh-like topology in order to achieve better communication between the peers.

There are two main classiﬁcations of a P2P network, based on how the nodes are linked: unstructured and structured P2P networks. In an unstructured network, the peers aren't linked to each other in an organized way. Each node is randomly connected to the peers, forming a logical mesh. It is easy to build unstructured networks, and they are very robust due to the redundant distribution of nodes. However, these networks have drawbacks, such as the possibility of request ﬂooding, an eﬀect caused by a lack of knowledge about the distribution of resources.

A structured P2P network overlay is formed by following a speciﬁc network topology to make sure that nodes can eﬃciently perform activities on the network. Creating a structured network ensures that a resource can be fetched from somewhere on the network in a certain time. A distributed hash table (DHT) is a widely used structured network implementation that provides decentralized lookup service. Resource information in a DHT can be retrieved from hash tables using the key of a key/value pair stored in the table. The value associated with the key provides information about the peer that owns the resource. DHTs are also used in the BitTorrent ﬁlesharing protocol as a substitute for centralized lookup services, such as trackers.

Network discovery in a P2P network is crucial. No network is deﬁned when a new node boots up. The new node must detect at least one blockchain node to be a part of the network. There are several ways in which a node can identify peers and thus discover a network. Diﬀerent blockchain frameworks use their own protocols to perform peer discovery and eﬃcient routing. We're going to start by exploring basic P2P network discovery by taking a look at Bitcoin's original implementation. The simplest way to ﬁnd the list of peers to connect to is by hardcoding a few of the well-known peers. Using a central server that maintains a list of peers is another approach. Bitcoin holds information about DNS seeds, which provide a high level of reliability when a node is initially set up, and will respond with a list of the IP addresses of the Bitcoin nodes. Once a seed node is detected, the node will establish a TCP connection to perform a handshake with that node. The handshake validates the node by sending the version, the address, local blockchain information, and any other relevant information.

Once a connection is set up between peers that have been discovered by the node, the node can query for information about other nodes that are connected to its peer. Similarly, the node can broadcast its own address information to the connected peers to improve its reachability. Each node also makes sure to maintain a threshold for the number of active connections to avoid unnecessary bandwidth usage.

Some blockchain platforms, such as Ethereum, use a cryptographic P2P networking protocol suite called RLPx, which provides a general-purpose transport and interface for applications to communicate via a P2P network. RLPx utilizes a Kademlia-like routing to ensure uniform network formation. After the initial node handshake, packets are encapsulated as frames, which are then encrypted.

Each node that joins the blockchain network needs to update its local copy of the blockchain to synchronize its state with the global state of the rest of the network. This is achieved by block synchronization. A node that needs to update its blockchain sends a message consisting of blockchain height information. Any peer that has a longer blockchain sends an inventory consisting of metadata about the ﬁxed number of blocks that needs to be added to the host node. Now the node makes a request to all its peers to fetch individual blocks by referring to the inventory it received. The node should make sure not to ﬂood the network with block requests by maintaining a cap on the number of block requests it sends.

Block synchronization is a long process for a newly joined node. However, once all the blocks are up to date, it can verify the information in the block, such as the transactions on assets. The block synchronization process can be reinitialized whenever the node comes online after being inactive.

**PROOF OF STACK ALGORITHM**

Proof of Stake (PoS) is a type of algorithm which aims to achieve distributed consensus in a Blockchain. This way to achieve consensus was first suggested by Quantum Mechanic here and later Sunny King and his peer wrote a paper on it. This led to Proof-of-Stake (PoS) based Peercoin.

Before proof of stake, the most popular way to achieve distributed consensus was through Proof-of-Work (implemented in [Bitcoin](https://www.geeksforgeeks.org/what-is-bitcoin/)). But Proof-of-Work is quite energy(electrical energy in mining a bitcoin) intensive. So, a proof-of-work based consensus mechanism increases an entity’s chances of mining a new block if it has more computation resources. Apart from the upper two points, there are other weaknesses of a PoW based consensus mechanism which we will discuss later. In such a scenario, a Proof-of-Stake based mechanism holds merit.

As understandable from the name, nodes on a network stake an amount of [cryptocurrency](https://www.geeksforgeeks.org/what-is-a-cryptocurrency/) to become candidates to validate the new block and earn the fee from it. Then, an algorithm chooses from the pool of candidates the node which will validate the new block. This selection algorithm combines the quantity of stake (amount of cryptocurrency) with other factors (like coinage-based selection, randomization process) to make the selection fair to everyone on the network.

**A TYPICAL POS BASED MECHANISM WORKFLOW**

Nodes make transactions. The Pos algorithm puts all these transactions in a pool. All the nodes contending to become validator for the next block raise a stake. This stake is combined with other factors like ‘coinage’ or ‘randomized block selection’ to select the validator. The validator verifies all the transactions and publishes the block. His stake remains locked, and the forging reward is also not granted yet. This is so that the nodes on the network can ‘OK’ the new block. If the block is ‘OK’-ed, the validator gets the stake back and the reward too. If the algorithm is using a coinage-based mechanism to select validators, the validator for the current block’s has its coinage reset to 0. This puts him in a low priority for the next validator election. If the block is not verified by other nodes on the network, the validator loses its stake and is marked as ‘bad’ by the algorithm. The process again starts from step 1 to forge the new block.

**FEATURES**

**FIXED COINS IN EXISTENCE**

There is only a finite number of coins that always circulate in the network. There is no existence of bringing new coins into existence(as in by mining in case of bitcoin and other PoW based systems). Note that the network starts with a finite number of coins or ‘initially starts with PoW, then shifts to ‘PoS’ in some cases. This initiation with PoW is meant to bring coins/cryptocurrency in the network.

**TRANSACTION FEE AS REWARD TO MINTERS/FORGERS:**Every transaction is charged some amount of fee. This is accumulated and given to the entity who forges the new block. Note that if the forged block is found fraudulent, the transaction fee is not rewarded. Moreover, the stake of the validator is also lost(which is also known as slashing).

**IMPRACTICALITY OF THE 51% ATTACK**

To conduct a 51% attack, the attacker will have to own 51% of the total cryptocurrency in the network which is quite expensive. This deems doing the attack too tedious, expensive, and not so profitable. There will occur problems when amassing such a share of total cryptocurrency as there might not be so much currency to buy, also that buying more and more coins/value will become more expensive. Also validating wrong transactions will cause the validator to lose its stake, thereby being reward negative.

**ADVANTAGES OF POS**

**ENERGY-EFFICIENT**As all the nodes are not competing against each other to attach a new block to the blockchain, energy is saved. Also, no problem must be solved(as in case of Proof-of-Work system) thus saving the energy.

**DECENTRALIZATION**In blockchains like Bitcoin (Proof of Work system to achieve distributed consensus), an extra incentive of exponential rewards is in place to join a mining pool leading to a more centralized nature of blockchain. In the case of a Proof-of-Stake based system (like Peercoin), rewards are proportional(linear) to the amount of stake. So, it provides absolutely no extra edge to join a mining pool; thus promoting decentralization.

**SECURITY**A person attempting to attack a network will have to own 51% of the stakes (expensive). This leads to a secure network.

**PROOF OF AUTHORITY**

Proof of Authority (PoA) is a reputation-based consensus algorithm that introduces a practical and efficient solution for blockchain networks (especially the private ones).

The PoA consensus algorithm leverages the value of identities, which means that block validators are not staking coins but their own reputation instead. Therefore, PoA blockchains are secured by the validating nodes that are arbitrarily selected as trustworthy entities.

The Proof of Authority model relies on a limited number of block validators, and this is what makes it a highly scalable system.

Blocks and transactions are verified by pre-approved participants, who act as moderators of the system.

**POA REQUIRES THREE CONDITIONS TO BE MET**

1. Formal identification on-chain for validators.

2. Eligibility based on certain criteria, including but not limited to, association with the organization or good reputation, etc.

3. Complete conformance to defined procedures required for producing blocks and validating on the network.

**1.2 SCOPE OF THE PROPOSED WORK**

**1.2.1 THE MOTIVATIONS BEHIND THIS SYSTEM**

The motivation behind the agri-food industry's adoption of blockchain technology, specifically the transition to the Binance Smart Chain (BSC), lies in addressing the increasing demands for transparency and security. With consumers and governments emphasizing the need for trustworthy information about the origin and integrity of food products, blockchain provides an immutable and transparent ledger that ensures the traceability of items throughout the supply chain. The decision to migrate from Ethereum-based smart contracts to BSC is fuelled by the desire to overcome complexities in contract upgrades and enhance overall efficiency. BSC's quicker transaction confirmation times and different consensus mechanism offer a pragmatic solution, empowering the agri-food industry to meet these demands seamlessly while ensuring the reliability of the entire ecosystem.

**1..3.2 NEED/SCOPE FOR THE PROJECT WORK:**

Agri-food supply chains require improved traceability, cost containment, and data security. This project, "Efficient Creation of Smart Contracts using BSC for Agri-Food Traceability System," aims to address these needs. The system enables the automation of transactions, guarantees data integrity via blockchain technology, and conforms to industry standards by utilizing the Binance Smart Chain (BSC). Developing smart contracts, designing an intuitive user interface, integrating IoT devices for real-time data, putting strong security measures in place, and scaling optimization are all included in the scope. In the end, the project hopes to improve market access and reputation for producers and suppliers by streamlining agri-food processes, cutting costs, and giving stakeholders transparent, up-to-date information.

**CHAPTER II**

**LITERATURE SURVEY**

**Paper 1:** Automatic Generation of Ethereum-Based Smart Contracts for Agri-Food Traceability System

**AUTHOR:** SLODOVICA MARCHESI , KATIUSCIA MANNARO , MICHELE MARCHESI , AND ROBERTO TONELLI

**Year: IEEE Access · January 2022**

**DESCRIPTION:**

The authors intend to extend their approach beyond agri-food to encompass other supply chains. While initially centered on Ethereum, their approach aims to be adaptable to other blockchain platforms, enhancing versatility. These cutting-edge traceability technologies have the potential to revolutionize the industry by providing comprehensive insights into the origin and journey of food products.

However, the widespread adoption of these technologies faces impediments stemming from various factors, including limited resources, low awareness, inadequate training, inconsistent standards, challenges in data management, and issues related to the scalability of technology. This chapter delves into a comprehensive review of the advances in agri-food traceability systems and technologies, shedding light on the barriers that hinder their effective implementation. Furthermore, it explores potential improvement pathways and policy interventions that can facilitate the widespread deployment of advanced food traceability systems. By addressing these challenges, the industry can not only enhance food safety but also build trust among consumers and establish resilient food supply chains.

**Paper 2:** Blockchain in Agriculture Traceability Systems: A Review

**AUTHOR:** Konstantinos Demestichas , Nikolaos Peppes, Theodoros Alexakis and Evgenia Adamopoulou

**Year: MDPI- JUNE 2020**

**DESCRIPTION:**

The agri-food industry is witnessing a significant shift towards electronic traceability (e-traceability), driven by the compelling advantages it offers in terms of improved transparency, accountability, and a reduced risk of foodborne illnesses. E-traceability involves the use of electronic systems to trace products seamlessly throughout the entire supply chain, providing clear and verifiable records of product origins, quality, and sustainability. The drivers behind the adoption of e-traceability in the agri-food supply chain are multifaceted, encompassing factors that motivate companies to embrace electronic systems for product tracking. These motivations include the enhancement of visibility, minimization of risks, ensuring regulatory compliance, and promoting overall safety, sustainability, and efficiency.

Relevant challenges associated with implementing blockchain in the agri-food sector are discussed, and prospects for this technology's application are highlighted. The study's findings highlight those crucial drivers such as supply chain efficiency, technology development, and sustainability emerge as the most important factors. These drivers not only play a pivotal role but also significantly influence the successful implementation and adoption of e-traceability strategies in the agri-food sector, underlining the industry's commitment to leveraging technology for improved safety, efficiency, and consumer trust.

**Paper 3:** Smart Contract Security: A Software Lifecycle Perspective

**AUTHOR:** MYONGFENG HUANG 1,3, YIYANG BIAN2,3, RENPU LI1 , J. LEON ZHAO3 , AND PEIZHONG SHI 1,3

**Year:** IEEE-OCTOBER 2019

**DESCRIPTION:**

The focus is on Ethereum, the leading public blockchain platform for smart contracts.

The agriculture field is also affected by these technological advances, resulting in better water and fertilizers’ usage and so huge improvements of both quality and yield of the crops. In this manuscript, the development of smart traceability and farm management system is described, which calibrates the irrigations and fertigation operations as a function of crop typology, growth phase, soil and environment parameters and weather information; a suitable software architecture was developed to support the system decision-making process, also based on data collected on-field by a properly designed solar-powered wireless sensor network (WSN). The WSN nodes were realized by using the ESP8266 NodeMCU module exploiting its microcontroller functionalities and Wi-Fi connectivity. Smart contracts introduce new security challenges due to their decentralized and tamper-proof nature, open-source code, public ledgers, immaturity of blockchain platforms and smart contract languages, and misunderstandings to be applied into the containers of agri-food products, just collected from the fields, or already processed, to monitor the main parameters indicative of any failure or spoiling over time along the supply chain. A mobile application was developed for monitoring the tracking information and storing conditions of the agri-food products. Test results in real-operative scenarios demonstrate the proper operation of the BLE smart tag prototype and tracking system.

Paper 4**:** Smart Contract-Based Product Traceability System in the Supply Chain Scenario

**AUTHOR:** SHANGPING WANG1 , DONGYI LI1 , YALING ZHANG2 , AND JUANJUAN CHEN1

**Year:** IEEE-AUGUST 2019

**DESCRIPTION:**

It includes decentralization, transparency, and efficiency. Decentralization makes the system more secure and resistant to fraud. Transparency allows stakeholders to track the movement of products. Efficiency makes the system easy to implement and maintain... A survey was conducted to gain insights into the Indian food supply chain, focusing on aspects such as product identification, traceability, industry preparedness for recalls across various food categories, identification of existing gaps, and recommendations for the way forward. The examination of IT-based traceability systems specifically geared towards export supply chains was also a key component of the study.

The findings of the survey revealed that barcodes are predominantly utilized for price displays, indicating a low awareness within the industry regarding the importance of food traceability systems in assuring food safety. This observation underscores a critical need for increased awareness and education within the Indian food supply chain about the role and significance of traceability systems. Addressing this gap in understanding is vital for fostering a culture of safety, instilling confidence among consumers, and meeting regulatory standards to ensure the integrity and safety of the food supply chain in India**.**

Paper 5**:** B-MERODE: A Model-Driven Engineering and Artifact-Centric Approach to Generate Smart Contracts

**AUTHOR:**  V.A. de Sousa, C. Burnay, and M. Snoeck

**Year:** Proceedings of the Conference on Advanced Information Systems Engineering (CAiSE), Cham, Switzerland: Springer, 2020, pp. 1-15.

**DESCRIPTION:**

This paper proposes B-MERODE, a novel approach to generating smart contracts using model-driven engineering and an artifact-centric perspective.

The imperative for food safety has become increasingly evident due to the heightened awareness among consumers and the growing concerns of regulators regarding the quality, hygiene, and authenticity of food supplies. In response to these concerns, one of the crucial tools employed to ensure quality and safety throughout the entire food supply chain is the implementation of reliable traceability systems. A survey was conducted to gain insights into the Indian food supply chain, focusing on aspects such as product identification, traceability, industry preparedness for recalls across various food categories, identification of existing gaps, and recommendations for the way forward. While B-MERODE presents a promising model-driven approach for generating smart contracts, potential issues exist. Creating comprehensive models can be difficult, and the approaches.

Paper 6: User Interface of Blockchain-Based Agri-Food Traceability Applications: A Review

**AUTHOR:**  AtimaTharatipyakul, Suporn Pongnumkul

**Year:** IEEE- JUNE 2021

**DESCRIPTION:**

This paper likely focuses on the user interface (UI) aspect of applications that use blockchain technology to track the journey of food products in the agri-food industry. It might explore how these applications present information.The primary objectives of these systems extend beyond merely tracking and storing orders and deliveries; they aim to guarantee transparency and traceability throughout the entire food production and transformation process. In contrast to traditional supply chains that rely on centralized systems, this paper introduces a novel and fully distributed approach, leveraging blockchain technology to redefine the supply chain management system. The proposed framework, based on Hyperledger Fabric technology—a permissioned blockchain system—offers a decentralized solution to enhance the quality, integrity, and traceability of the entire supply chain process. The development of a prototype and the demonstration of its effectiveness through various use cases underscore the potential of this blockchain-based approach to revolutionize Agri-Food supply chain management.

It's possible the paper identifies challenges related to user interface design in this context, such as complexity, lack of user-friendliness, or limited accessibility.

It might suggest areas for improvement in UI design to enhance user experience.

The paper's exploration of use cases not only showcases the feasibility of the proposed framework but also highlights its potential to address the evolving demands of the Agri-Food industry, where ensuring product quality and traceability is paramount for both consumer well-being and market competitiveness.

Paper 7 : Effective Management for Blockchain-Based Agri-Food Supply Chains Using Deep Reinforcement Learning

AUTHOR**:**  HUILIN CHEN1,2, ZHEYI CHEN 3 , FEITING LIN1,4, AND PEIFEN ZHUANG1

**Year:** IEEE- FEBRUARY 2021

**DESCRIPTION:**

Explores an innovative approach to managing these chains by marrying blockchain and Deep Reinforcement Learning (DRL). Blockchain shines in ensuring secure and transparent record-keeping for food origin, production, and transportation. . In response to these challenges, the swift withdrawal or recall of unsafe products has become crucial to protect the public from potential foodborne diseases. Traceability emerges as a pivotal risk-management tool in this context, providing a means for food business operators and authorities to respond effectively to the need for quick action. It acts as a cornerstone in the food safety policies of nations, enabling the systematic tracking and documentation of the entire journey of food and agricultural products throughout the supply chain.

While the title "Effective Management for Blockchain-Based Agri-Food Supply Chains Using Deep Reinforcement Learning" suggests a promising solution, challenges loom in the creation of the smart contracts.

By providing insights into traceability practices and regulations, the bulletin seeks to contribute to the global efforts aimed at creating a safer and more secure food supply chain, ultimately ensuring the well-being of consumers worldwide.

Paper 8 : A Blockchain-Based Traceability System in Agri-Food SME: Case Study of a Traditional Bakery

AUTHOR: LUISANNA COCCO 1 , KATIUSCIA MANNARO 1 , ROBERTO TONELLI 1 , LORENA MARIANI2,3, MATTEO B. LODI 2 ,ANDREA MELIS2 , MARCO SIMONE 2 , AND ALESSANDRO FANTI 2

Year: IEEE- APRIL 2021

DESCRIPTION:

"A Blockchain-Based Traceability System in Agri-Food SME: Case Study of a Traditional Bakery" examines the implementation of blockchain technology for food traceability in a small bakery.

Due it is difficult to acquire full traceability information, and there are risks of information loss and data tampering. To address these challenges, research on the application of blockchain technology (BCT) for traceability systems in the agri-food sector is increasing, and startup companies have emerged in recent years. However, there have been only a limited number of reviews on the application of BCT in the agriculture sector, especially those that focus on the BCT-based traceability of agricultural goods.

To bridge this knowledge gap, we reviewed 78 studies that integrated BCT into traceability systems in AFSCs and additional relevant papers, mapping out the main types of food traceability information. The findings indicated that the existing BCT-based traceability systems focus more on fruit and vegetables, meat, dairy, and milk. A BCT-based traceability system enables one to develop and implement a decentralized, immutable, transparent, and reliable system in which process automation facilitates the monitoring of real-time data and decision-making activities. The status of research of Blockchain technology in logistic and supply chain management concluding that RFID, smartphones, and other IoT applications might fix the data quality gap that most supply chains still face.

**Paper 9 :** Blockchain Adoption in Food Supply Chains: A Systematic Literature Review on Enablers, Benefits, and Barriers

**AUTHOR:** ABUBAKAR MOHAMMED 1 , VIDYASAGAR POTDAR 1,2, MOHAMMED QUADDUS 1 , AND WENDY HUI 3

**Year:** IEEE- OCTOBER 2022

**DESCRIPTION:**

Globalization of the food supply chain (FSC) has brought significant challenges to the food system, such as fraud, safety, security, and quality issues, due to information asymmetry. The inherent features of blockchain, including immutability and transparency, create a dependable and secure system for tracking food products across the whole supply chain, ensuring total control over their traceability from the origin to the final consumer.

This research offers a comprehensive overview of multiple models to understand how the integration of blockchain and other digital technologies has transformed the food supply chain. This comprehensive systematic review of blockchain-based food-supply-chain frameworks aimed to uncover the capability of blockchain technology to revolutionize the industry and examined the current landscape of blockchain-based food traceability solutions to identify areas for improvement. While the paper "Blockchain Adoption in Food Supply Chains: A Systematic Literature Review on Enablers, Benefits, and Barriers" provides valuable insights, it might have some limitations to. The review's scope might be restricted, focusing on specific aspects of blockchain adoption.

Potential synergies between blockchain and other emerging technologies of Industry 4.0 and Web 3.0 are digitizing food supply chains, which results in better management, automation, efficiencies, sustainability, verifiability, auditability, accountability, traceability, transparency, tracking, monitoring, response times and provenance across food supply chains.

**Paper 10 :** Blockchain-Driven IoT for Food Traceability With an Integrated Consensus Mechanism

**AUTHOR:** YUNG PO TSANG 1 , KING LUN CHOY 1 , CHUN HO WU 2 , (Member, IEEE), GEORGE TO SUM HO2 , (Member, IEEE), AND HOI YAN LAM2

**Year:** IEEE- SEPTEMBER 2019

**DESCRIPTION**

To alleviate these concerns, blockchain technology is promising to create a new ontology for supply chain traceability. However, most consensus mechanisms and data flow in blockchain are developed for cryptocurrency, not for supply chain traceability.

Algorithms and derived models are employed as support systems to enhance decision-making processes or are integrated into automatic control procedures and robotics to alleviate laborious tasks.

This study delves into the intricacies of sensing and data collection across various agri-food sectors, illustrating how data can contribute to improved management and decision-making in both crop and animal production. Further, customers and supply chain stakeholders rely heavily on this information to make their decisions. Due to the rapid development of e-commerce businesses, the perishable food e-commerce sector.

––

**CHAPTER III**

**SYSTEM STUDY**

**3.1 EXISTING SYSTEM**

The rapid adoption of blockchain technology in the agri-food industry is transforming the landscape by providing enhanced traceability and security throughout the entire supply chain. Blockchain's inherent capability to establish secure and immutable records plays a pivotal role in preventing food fraud and ensuring the accuracy of product information. By leveraging distributed ledger technology, stakeholders in the agri-food chain can create a transparent and tamper-resistant system, building trust among consumers and addressing the increasing demands for accountability.

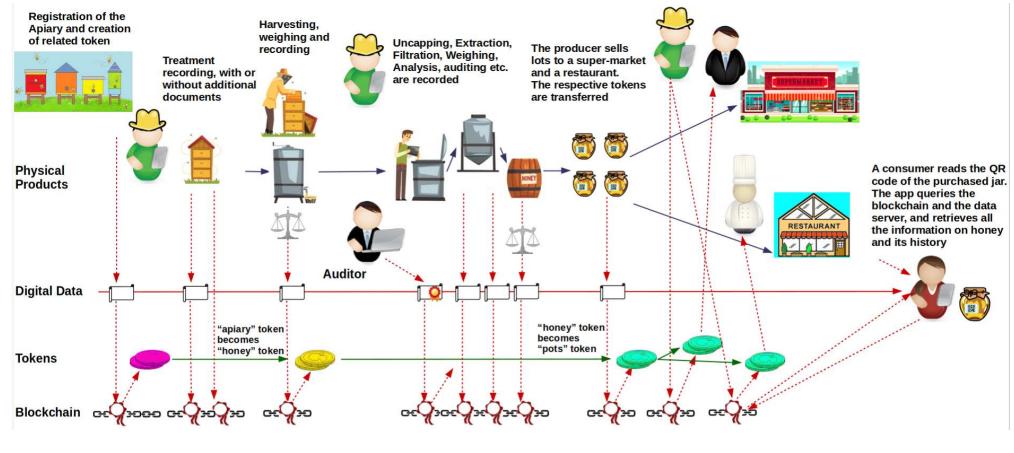
However, in the existing approach, there is a focus on developing customizable and generalizable Ethereum-based smart contracts specifically tailored for the agri-food industry. While Ethereum has been a popular choice, the challenge arises from the potential lack of direct compatibility with other blockchain platforms. This limitation hinders seamless cross-chain integration, as smart contracts designed for Ethereum may not readily interface with alternative blockchain networks. This interoperability gap could pose challenges in achieving a unified and standardized approach to blockchain adoption in the agri-food sector.

To overcome these compatibility issues and enhance the flexibility of smart contracts, stakeholders may explore alternative solutions such as developing industry standards or adopting blockchain platforms that prioritize interoperability. These considerations are crucial for ensuring that the benefits of blockchain technology, such as improved traceability and security, can be maximized across diverse blockchain ecosystems within the agri-food industry.

**3.2 ISSUES IN THE EXISTING SYSTEM**

* In the realm of Ethereum transactions, the necessity for gas fees introduces a layer of complexity and cost that can become particularly pronounced during periods of network congestion.
* This volatility and expense pose challenges, especially for frequent or small transactions, where the relative fees may outweigh the value of the transaction itself.
* This aspect of Ethereum's transaction model underscores the need for users and developers to carefully consider the economic implications of their interactions with the network, balancing the benefits of decentralization with the practicalities of transaction costs.
* While the immutability of data on the Ethereum blockchain is a fundamental feature, it also harbours certain drawbacks.
* Once a smart contract is deployed and recorded on the blockchain, any modifications become a non-trivial task.
* This lack of flexibility can pose challenges in scenarios where errors or vulnerabilities are discovered post-deployment.

**3.3 EXISTING SYSTEM AND IT'S ARCHITECTURE**



**3.4 PROPOSED SYSTEM**

The agri-food industry is witnessing a surge in the adoption of blockchain technology, fuelled by the escalating demand for transparency from both consumers and government authorities. Blockchain is being leveraged to establish secure traceability, combat food fraud, and provide crucial information about the origins of food products. The intrinsic characteristics of trust and immutability embedded in blockchain technology are proving to be pivotal in elevating chain management within the agri-food sector. However, the complexity and potential disruption associated with upgrading smart contracts on the Ethereum platform have led industry stakeholders to explore alternative solutions.

One notable alternative gaining prominence is the Binance Smart Chain (BSC). BSC addresses the challenges posed by Ethereum's smart contract upgrades by offering distinct advantages. Notably, BSC boasts faster transaction confirmation times compared to Ethereum, enhancing the efficiency of the entire system. The platform's unique consensus mechanism and shorter block times contribute to this swift and responsive transaction processing. As the agri-food industry seeks streamlined and reliable solutions for transparent supply chain management, the adoption of blockchain on platforms like BSC presents a promising avenue to meet the evolving demands of the sector.

**3.5 ADVANTAGE OF THE PROPOSED SYSTEM**

* BSC's integration with wallets and tools from the Binance ecosystem can provide a user-friendly experience for individuals already accustomed to using these platforms.
* BSC supports smart contracts, allowing developers to create decentralized applications (dApps) that streamline processes within the agri-food supply chain.
* BSC aims to balance decentralization with efficiency.
* BSC typically boasts lower transaction fees than Ethereum.

**CHAPTER IV**

**SYSTEM REQUIREMENTS**

**HARDWARE REQUIREMENTS**

* + - OS : Windows 10 (or above)
    - Processor : Intel(R) core(TM) i5-10th GEN (or above)
    - Ram: 4 GB (or above)
    - Processor speed: 2 GHz
    - Hard disk: 256 GB SSD (or above)

**SOFTWARE REQUIREMENTS**

* Operating System: Windows 10 and above
* Ram: 4GB and above
* Coding language: Python 3.7 and above
* Front End: HTML, CSS, JavaScript
* Back End: SQL lite
* Model Creation: Jupyter Notebook

**Feasibility study**

The Feasibility of the project is analyzed in this phase and business proposal is put forth with a very general plan for the project and some cost estimates. During system Analysis the feasibility study of the proposed system is to be carried out. This is to ensure that the proposed system is not a burden to the company. For Feasibility analysis, some Understanding of the major requirements for the system is essential.

* Economic Feasibility
* Technical Feasibility
* Social Feasibility

**Economic Feasibility**

Economic analysis is the most frequently used method for evaluating the effectiveness of a candidate system. More commonly known as cost/benefit analysis, the procedure is to determine the benefits and savings that are expected from a candidate system and compare them with costs. If benefits outweigh cost, then the decision is made to design and implement the system.

**Technical Feasibility**

This involves questions such as whether the technology needed for the system exits, how different it will be to build, and whether the firm has enough experience using that technology. The assessment is based on an outline design of system requirements in terms of Input, processes, output, fields, programs, and procedures. This can be quantified in terms of volumes of data, trends, frequency of updating, etc. in order to estimate if the new system will perform adequately or not.

**Social Feasibility**

Determines whether the proposed system conflicts with legal requirements, (e.g., A data processing system must comply with the local data protection acts). When an organization has either internal or external legal counsel, such reviews are typically standard. However, a project may face legal issues after completion if this factor is not considered at this stage. If is about the authorization.

**FEATURES OF WINDOWS 10**

One of the primaries aims of Windows 10 is to unify the Windows experience across multiple devices, such desktop computers, tablets, and smartphones. As part of this effort, Microsoft developed Windows 10 Mobile alongside Windows 10 to replace Windows Phone – Microsoft's previous mobile OS.

**FEATURES OF PYTHON IDLE**

Python IDLE Software is an integrated development environment for Programming language python. It is beginner’s level Programming Language because of its simplicity and easiness. From developing to deploying and maintaining python wants their developers to be more productive. Python has a huge collection of libraries sklearn, azure, flask, json.

**USED PYTHON PACKAGES**

**SKLEARN**

* + In python, sklearn is a machine learning package which include a lot of ML algorithms.
  + Here, we are using some of its modules like train\_test\_split, DecisionTreeClassifier or Logistic Regression and accuracy\_score.

**FLASK**

* It is a micro [web framework](https://en.wikipedia.org/wiki/Web_framework) written in [Python](https://en.wikipedia.org/wiki/Python_(programming_language)). It is classified as a [microframework](https://en.wikipedia.org/wiki/Microframework) because it does not require tools for libraries.
* It has no [database](https://en.wikipedia.org/wiki/Database) abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common function.

**JSON**

* JSON (JavaScript Object Notation) is an [open standard](https://en.wikipedia.org/wiki/Open_standard) [file format](https://en.wikipedia.org/wiki/File_format) and [data interchange](https://en.wikipedia.org/wiki/Electronic_data_interchange) format that uses [human-readable](https://en.wikipedia.org/wiki/Human-readable_medium) text to store and transmit data objects consisting of [attribute–value pairs](https://en.wikipedia.org/wiki/Attribute%E2%80%93value_pair) and [arrays](https://en.wikipedia.org/wiki/Array_data_type) (or other [serializable](https://en.wikipedia.org/wiki/Serialization) values).
* It is a common data format with diverse uses in [electronic data interchange](https://en.wikipedia.org/wiki/Electronic_data_interchange), including that of [web applications](https://en.wikipedia.org/wiki/Web_application) with [servers](https://en.wikipedia.org/wiki/Server_(computing)).
* JSON is a [language-independent](https://en.wikipedia.org/wiki/Language-independent_specification) data format. It was derived from [JavaScript](https://en.wikipedia.org/wiki/JavaScript), but many modern [programming languages](https://en.wikipedia.org/wiki/Programming_language) include code to generate and [parse](https://en.wikipedia.org/wiki/Parsing) JSON-format data. JSON filenames use the extension(.json)

**REACT JS**

ReactJS is a popular JavaScript library for building user interfaces. It was developed by Facebook and has gained a lot of popularity in recent years due to its simplicity, flexibility, and high performance.

One of the key benefits of ReactJS is that it allows developers to build reusable UI components, which can save time and make it easier to maintain large-scale applications. ReactJS also uses a virtual DOM (Document Object Model) which allows for faster updates and better performance compared to traditional DOM manipulation.

ReactJS uses a declarative approach to building user interfaces, which means that developers can focus on describing what they want the UI to look like, rather than worrying about how to manipulate the DOM. This makes it easier to reason about the code and can reduce the likelihood of errors.

Another benefit of ReactJS is its large and active community, which provides access to a wealth of resources, including tutorials, libraries, and plugins. This community also helps ensure that ReactJS is constantly evolving and improving, making it a powerful tool for building modern web applications.

**FLASK**

Flask is a Micro Web framework written in Python. it is Classified as a microframework because it doesn’t require tools or libraries. it has no Database abstraction layer, form validation, or any other components where pre-existing third- party libraries provide common function.

**PYTHON 3.7**

Python is an Interpreted, Object Oriented, High-level Programming Language With Dynamic Semantics developed by Guido van Rossum, It was originally released in 1991. Designed to be easy as well as fun, the name “Python” is a nod to the British comedy group Monty Python. Python has a reputation as a beginner-friendly language, replacing Java as the most widely used introductory language because it handles much of the complexity for the user, allowing beginners to focus on fully grasping programming concepts rather than minute details.

Python is used for server-side web development, software development, mathematics, and system scripting, and is popular for Rapid Application. Development and as a scripting or glue language to tie existing components because of its high-level, built-in data structures, dynamic typing, and dynamic binding. Program maintenance costs are reduced with Python due to the easily learned syntax and emphasis on readability.

Additionally, Python's support of modules and packages facilitates modular programs and reuse of code. Python is an Opensource community language, so numerous independent programmers are continually building libraries and functionality for it.

**FRONTEND**

In the front end of the project, we have using HTML, CSS, and JAVA Script with the Visual studio Framework.

**HTML**

HTML stands for “Hyper Text Markup Language” It was invented in 1990 by a Scientist called Tim Berners Lee. It is a Computer Language that allows website creation. This website can be viewed by anyone else connected to the internet. It is relatively easy to learn. It is constantly undergoing revision and evaluation to meet the demands &requirements of the growing internet audience under the direction of the LO3C (World Wide Web consortium) the organization change with designing and maintain the language. HTML is the mother tongue of the browser. For example, it specifies text, images, and other objects and can also specify the appearance of text, such as bold or italic text.

The World Wide Web Consortium (W3C) defines the specification for HTML. The current versions of HTML are HTML5 and XHTML5.

**Note:** DHTML stands for Dynamic HTML. DHTML combines cascading style sheets (CSS) and scripting to create animated Webpages and page elements that respond to user interaction.

**FEATURES**

* It is easy to learn and easy to use.
* It is platform-Independent.
* Images ,Video, and Audio can be added to a web page.
* Hypertext can be added to the text.
* It is a markup language.

**JAVA Script**

Java Script (often shortened to JS) is a lightweight, interpreted, objects-oriented language with first class functions and is best known as the scripting language for web pages, but it’s used in, many non-browser environments as well. It is a prototype based; multi-paradigm scripting language that is dynamic & supports object-oriented, imperative, & functional programming styles. Java script runs on the client side of the web which can be used to design program how the web pages behave on the occurrence of an event, Java script is an easy to learn & also powerful scripting language, widely used for controlling web page behaviour.

**FEATURES**

* Object -centred Script Language.
* Client Edge Technology.
* Validation of user's Input.
* Interpreter centred.
* Ability to perform in Build Function.
* Case Sensitive Format.
* Light Weight and Delicate.
* Handling Event.

**CSS**

CSS stands for Cascading Style Sheets. CSS describes how HTML elements are to be displayed on screen, paper, or in other media. CSS saves a lot of work. It can control the layout of multiple web pages all at once. External style sheets are stored in CSS files.

CSS helps Web developers create a uniform look across several pages of a website. Instead of defining the style of each table and each block of text within a page's HTML, commonly usedstylesneedtobedefinedonlyonceinaCSSdocument.Oncethestyleisdefinedincascadingstylesheet, it can be used by any page that references the CSS file. Plus, CSS makes it easy to change styles across several pages at once.

**FEATURES**

* CSS saves time.
* Pages load faster.
* Easy maintenance.
* Superior Style to HTML.
* Multiple Device Compatibility.
* Global Web Standards.

**2.7.2 Backend**

In the back end of the project, we have using SQLite with the Python3.7 and Flask Framework.

**SQL**

SQLite is an in-process library that implements a self-contained, serverless, zero-configuration, transaction SQL database engine. It is a database, which is zero-configured, which means like other databases you do not need to configure it in your system.

SQLite engine is not a standalone process like other databases, you can link it statically or dynamically as per your requirement with your application. SQLite accesses its storage files directly.

**BLOCK CHAIN**

Blockchain technology brings many benefits to asset transaction management. We list a few of them in the following subsections:

**ADVANCED SECURITY**

Blockchain systems provide the high level of security and trust that modern digital transactions require. There is always a fear that someone will manipulate underlying software to generate fake money for themselves. But blockchain uses the three principles of cryptography, decentralization, and consensus to create a highly secure underlying software system that is nearly impossible to tamper with. There is no single point of failure, and a single user cannot change the transaction records.

**IMPROVED EFFICIENCY**

Business-to-business transactions can take a lot of time and create operational bottlenecks, especially when compliance and third-party regulatory bodies are involved. Transparency and smart contracts in blockchain make such business transactions faster and more efficient.

**FASTER AUDITING**

Enterprises must be able to securely generate, exchange, archive, and reconstruct e-transactions in an auditable manner. Blockchain records are chronologically immutable, which means that all records are always ordered by time. This data transparency makes audit processing much faster.

**GANACHE**

Ganache is an Ethereum blockchain development tool that has gained significant popularity among developers in recent years. It streamlines the process of establishing a private or public Ethereum network and offers features such as pre-defined accounts with pre-defined Ether balances, rapid mining upon creation, snap shotting for very quick resetting, customizable transaction history, and much more. This basically makes it great for quickly setting up a local environment to run testing and experiments without any risk, which is very significant for all intents and purposes.

Developers may also utilize Ganache to install smart contracts on their own networks and experiment with new protocols and technologies.



Ganache’s user interface is designed for ease of use, providing detailed information about transactions and blocks, gas usage, and other technical aspects of blockchain technology. The intuitive nature of its design allows experienced users to easily get acquainted, while novices may learn the fundamentals without having to immerse themselves in elaborate tutorials.

Ganache is a local blockchain tool that is used to develop and test Ethereum applications. It is an in-memory blockchain server that emulates a full Ethereum client and allows developers to test and debug smart contracts without requiring a real blockchain. Ganache also includes an interactive graphical user interface that allows developers to quickly create and deploy new contracts, test their code, and inspect state and transaction data.

Ganache also allows developers to debug their smart contracts and view the state of the blockchain. The fact that Ganache offers tools to make debugging simpler is a great perk. Developers, for instance, may create thorough logs of all activity taking place within their workspace and view the whole transaction history. Ganache also makes it possible to utilise the web3.provider library, allowing users to interact with their generated blockchain directly from other programmes like MetaMask. As a result, during the development and testing phases, it is simple to view what is occurring on their local networks.

Ganache is a popular tool among developers who are new to Ethereum development, as it allows them to quickly set up a test environment with minimal effort. It is also used by experienced developers to quickly prototype and test their applications before deploying them to the mainnet.

Moreover, Ganache provides real-time debugging of EVM code, allowing developers to quickly trace and debug their code without worrying about running out of resources. Ganache distinguishes itself from other blockchain tools owing to its adaptability and comprehensive collection of capabilities. Its mix of simplicity and power makes it an essential tool to blockchain users of all levels, allowing them to try out their ideas securely and quickly with no effort.

The ability to customize various settings such as consensus mechanisms, difficulty levels, block intervals and so forth makes Ganache an incredibly versatile tool for creating complex dApps and exploring edge cases.

Ganache is built on top of the Ethereum Virtual Machine (EVM), which is the engine that powers Ethereum. Ganache communicates with the EVM in order to execute smart contracts. It collaborates with the network and records transactions on the blockchain. The code in the smart contracts is then executed by the EVM, and the outcomes are recorded on the blockchain. It helps developers interact with the Ethereum Virtual Machine, deploy and test their smart contracts, and debug their code. By making it easier to develop applications on the Ethereum network, Ganache is helping to accelerate the adoption of blockchain technology.

Besides that, Ganache’s protocol has a number of security features to guard against malicious actors. To ensure that only recognised addresses have access to particular services, the system employs automatic whitelisting protocols. Likewise, it makes sure that nodes are constantly active and current. Finally, it keeps track of the state of the whole blockchain network to make sure that none of the nodes are infiltrated or using outdated software.

Additionally, it provides users with access to various tools such as graphical block explorers and real-time transaction analysis which facilitate debugging and automated testing. Despite being relatively new on the scene, Ganache’s ease of use and versatility make it a valuable tool for both experienced and novice blockchain developers alike.

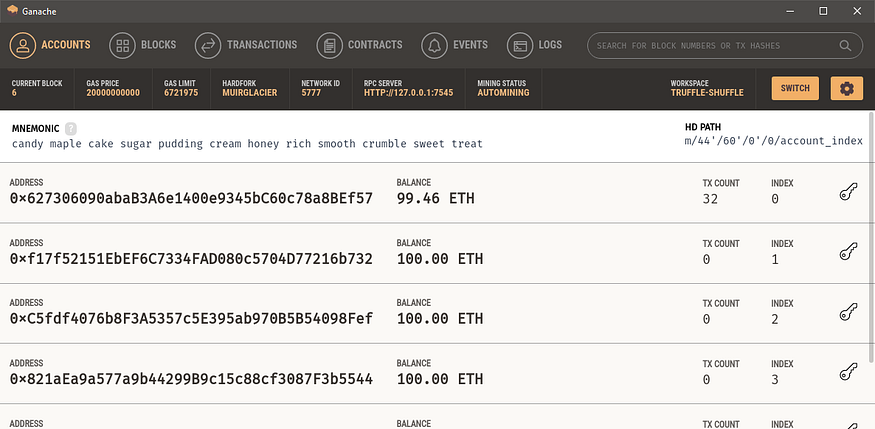
How to get started with Ganache:

The first step in utilizing it is to download the software, which supports MacOSX, Linux, and Windows operating systems. Then, install the software and then open the application. After installation, you will be presented with a customizable graphical user interface (GUI) that allows users to quickly spin up their own local Ethereum test net. From there, Ganache offers tools like chain monitoring and snapshotting to enable developers to manage their projects more effectively.

You will be able to select the option to “Create Workspace” where you can configure and customize your own local Ethereum Blockchain with whatever settings you desire. Once configured, click “Start” to initiate the process of setting up your private blockchain. This process takes just seconds, allowing you to start transacting immediately on your custom made blockchain.

To get started, it’s important to understand that Ganache provides users with 10. Pre-configured accounts with Ethers attached to them, allowing developers to easily test transactions on their own network. Ganache provides customers with a number of choices for modifying their blockchain networks in addition to its fundamental configuration.

`These include altering the mining difficulty, generating several nodes on the same network, customising the genesis block specifications, and more. A thorough examination of these parameters can open up new avenues for investigation and significantly improve your grasp of how distributed ledger systems operate. The real magic of Ganache lies in its support for popular programming languages such as Solidity, Vyper, and JavaScript. Knowing how to use these tools will enable you to develop robust apps that are supported by the Ethereum Virtual Machine (EVM).There are several tutorials accessible online that provide step-by-step directions on how to construct dApps using Ganache, helping you to further hone your knowledge base.



**WHAT ARE THE USE CASES OF GANACHE BLOCKCHAIN**

1. Creating and testing decentralised apps (dApps): Ganache is an excellent tool for creating and testing dApps since it enables developers to easily create and test their own private Ethereum blockchain.

2. The creation of smart contracts: Ganache offers programmers a simple interface for swiftly installing and testing smart contracts. Additionally, it makes it simple for developers to see and modify their smart contracts.

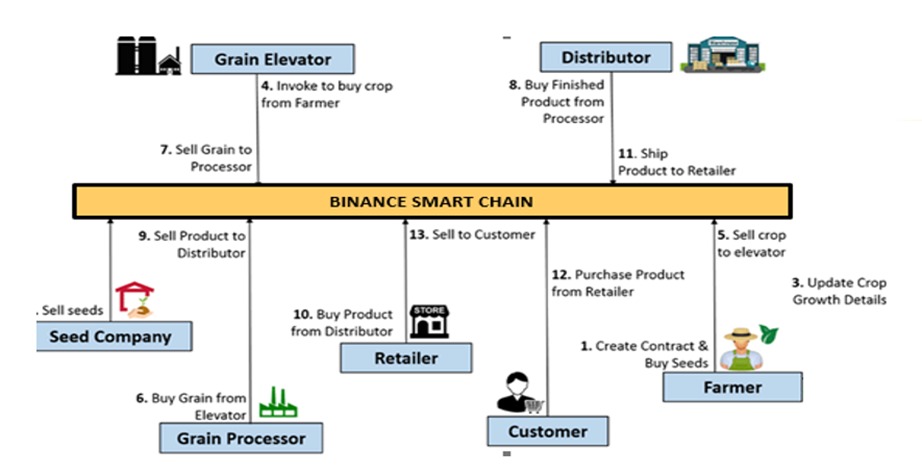
3. Transaction testing: Ganache enables programmers to test transactions without a mainnet on a private blockchain. Thus, transactions created by developers may be tested before being released to the mainnet.

4. Private consortium networks: With the help of Ganache, programmers may easily construct private consortium networks that include nodes and specialised consensus algorithms. As a result, programmers may utilise their own personal blockchain for their projects.

**WHAT ARE THE BEST RESOURCES TO LEARN MORE ABOUT GANACHE**

There are various excellent resources available for anyone interested in learning more about Ganache Blockchain. Truffle’s official documentation gives a comprehensive description of all Ganache’s features and capabilities. Furthermore, services like as Dapp University provide complete lessons on creating dApps using Ganache. For further hands-on experience, Code academy provides lessons that allow users to create their own Ganache projects. Finally, there are several channels on YouTube dedicated just to teaching people how to utilise Ganache. With these alternatives, anybody can quickly grasp the principles of Ganache.

**ARCHITECTURE DIAGRAM FOR THE PROPOSED SYSTEM**



Architecture diagrams typically depict the structure and components of a system or application, illustrating how various elements interact with each other. They often include different layers, such as the presentation layer, business logic layer, and data layer. The connections and flow of data or processes between these layers are visually represented, showcasing the overall design and functionality of the system.

In a technology context, architecture diagrams may highlight specific technologies, databases, servers, and communication protocols employed within the system. They serve as a visual aid for understanding the overall structure of the software or hardware, aiding in both development and communication among stakeholders.

**5.3 LIST OF MODULES**

**FARMER MODULE**

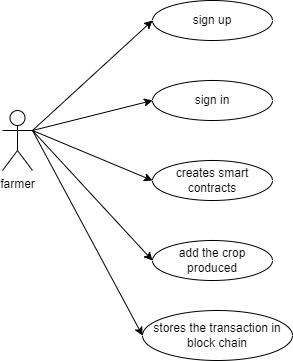
**Functionality:** Record crop cultivation details: This module allows farmers to input and store information related to crop cultivation, including planting dates, cultivation practices, and any relevant certifications.

**Smart Contracts:** Utilize BSC's smart contracts to automate agreements and ensure trust between the farmer and other participants in the supply chain.

The core functionality of this module revolves around recording and storing the complete journey of agri-food products, encompassing each stage from the farm to the end consumer. The module captures crucial data at every step, including cultivation practices, processing methods, packaging details, and transportation specifics. Through blockchain integration, the system employs this cutting-edge technology to establish a secure and immutable ledger of transactions. By utilizing blockchain, the traceability records become tamper-proof and transparent. The distributed nature of the blockchain ensures that once data is recorded, it cannot be altered, providing a reliable and verifiable source of information for all stakeholders involved. This functionality not only enhances transparency and traceability within the agri-food supply chain but also establishes a robust and trustworthy system that fosters consumer confidence and meets the stringent demands of regulatory compliance.

**Smart Contracts**

* Smart contracts are self-executing contracts written in code and deployed on a blockchain network like Ethereum or Binance Smart Chain.
* They automatically execute the terms of the agreement when predefined conditions are met, without the need for intermediaries. Smart contracts provide decentralization, immutability, and trustless transactions, enabling cost-efficient and transparent interactions across various industries such as finance, supply chain, and voting systems.
* However, careful development, testing is essential to mitigate risks associated with bugs or vulnerabilities in the code.



**CROP PRODUCTION MODULE**

**Functionality:** Record and trace the journey of each crop from the farm to the consumer, capturing data such as harvesting dates, quality checks, and transportation information.

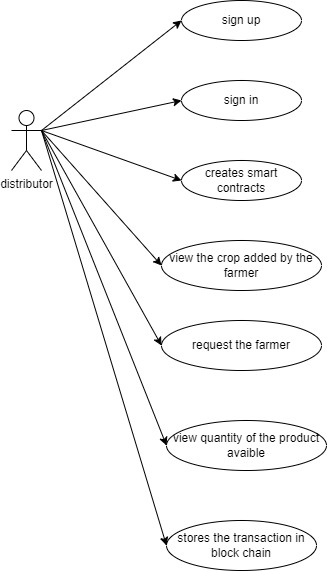
**Quality Assurance:** Implement smart contracts to store quality assurance data and certifications, providing a transparent view of the crop's quality.

The system's integral functionality involves the management and execution of smart contracts designed to automate and enforce agreements within the agri-food supply chain. These contracts encompass various aspects, such as payments, adherence to quality standards, and compliance with industry regulations. Through blockchain integration, the system optimizes the capabilities of the Binance Smart Chain (BSC) to efficiently implement and execute these smart contracts. BSC provides a decentralized and automated framework for agreements, allowing for the creation of trust less and transparent processes. Leveraging BSC ensures that smart contracts are executed in a secure and tamper-proof manner, enhancing the overall efficiency and reliability of agreements within the supply chain. This functionality not only streamlines processes but also contributes to the reduction of disputes, fostering a more transparent and automated ecosystem for stakeholders in the agri-food industry.

**DISTRIBUTOR MODULE**

**Receive and Validate:** Distributors can access the blockchain to receive information about incoming crops, ensuring the authenticity and quality of the products.

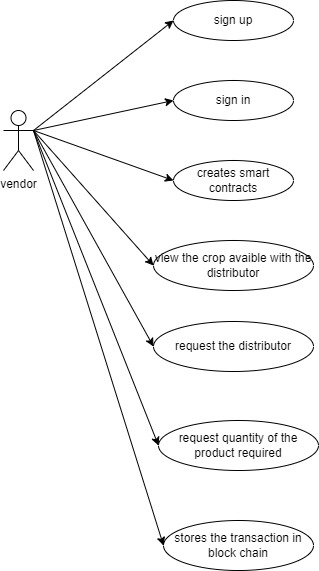
**Supply Chain Visibility:** Distributors update the blockchain with details on the transportation and storage conditions, enhancing visibility for all participants.

The system's critical functionality involves the implementation of algorithms and checks designed to identify anomalies and potential instances of food fraud within the agri-food supply chain. By leveraging blockchain's resistance to tampering, the system not only fortifies the detection mechanisms but also establishes a robust defines against potential instances of food fraud, contributing to the overall security and reliability of the traceability and transparency system in the agri-food industry. This functionality aligns with the industry's imperative to combat fraudulent activities and uphold the integrity of the supply chain.

**RETAILER MODULE**

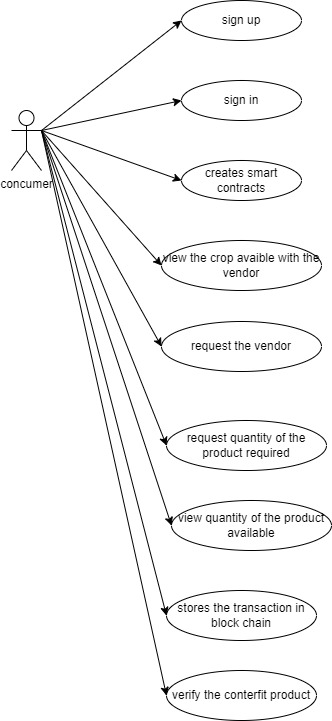
**Inventory Management:** Retailers (or) Vendor can monitor and manage their inventory through the blockchain, ensuring accurate stock levels and preventing issues like overstock or shortages.

**Price and Promotion Transparency:** Utilize smart contracts for transparent and automated pricing strategies, promotions, and discounts, benefiting both retailers and consumers**.**

The system's key functionality involves the comprehensive gathering and storage of detailed information pertaining to the origin of agri-food products. This strategic integration guarantees that the information is readily accessible, accurate, and tamper-proof, providing a trustworthy source of data for all stakeholders involved. By leveraging blockchain technology, the system not only fortifies transparency and traceability but also establishes a reliable foundation for consumer trust and adherence to regulatory standards in the agri-food supply chain. This functionality aligns with the industry's increasing emphasis on informed consumer choices and regulatory compliance, contributing to the overall efficiency and credibility of the traceability and transparency system.

**CONSUMER MODULE**

**Product Information:** Consumers can access the blockchain to retrieve detailed information about the origin, quality, and journey of the purchased products.

**Trust and Assurance:** Blockchain technology provides consumers with confidence in the authenticity of the products, reducing the risk of fraud and ensuring the quality of the food they consumer. By integrating these modules on the Binance Smart Chain, the proposed system aims to create a secure, transparent, and efficient agri-food supply chain, meeting the evolving demands for traceability and accountability in the industry.Through blockchain integration, the system capitalizes on the faster transaction confirmation times provided by the Binance Smart Chain (BSC). By leveraging BSC's efficiency, the system optimizes information flow, enabling stakeholders to access timely updates on the location, processing, and distribution of agri-food products.

**5.4 PERFORMANCE ANALYSIS**

Performance analysis of the Binance Smart Chain (BSC) involves evaluating various key metrics to understand the efficiency and reliability of the blockchain network. One crucial aspect is the transaction confirmation times, where BSC's consensus mechanism, Proof of Staked Authority (PoS), plays a pivotal role. With faster transaction confirmation times compared to networks like Ethereum, BSC demonstrates a high throughput, ensuring swift processing of transactions within the agri-food supply chain. The platform's shorter block times contribute to this efficiency, allowing for quicker validations and additions of new blocks to the blockchain. Additionally, the gas fees on BSC tend to be lower than those on Ethereum, making it a cost-effective choice for decentralized applications.

Scalability is another significant factor in BSC's performance. The ability to handle many transactions concurrently is crucial for the agri-food industry, especially as the volume of data related to supply chain activities increases. BSC's consensus mechanism, combining elements of Proof of Stake (PoS) and Proof of Authority (PoA), facilitates a scalable and responsive network.

Furthermore, the decentralized nature of BSC ensures robustness and resilience against single points of failure, enhancing the overall reliability of the blockchain. As the agri-food industry increasingly adopts blockchain for transparency and traceability, the performance analysis of BSC becomes instrumental in assessing its suitability for providing efficient, secure, and scalable solutions to meet the dynamic demands of supply chain management.

**5.5 PERFORMANCE ANALYSIS**

**TRANSACTION CONFIRMATION TIME (TCT):**

Definition: The time taken to confirm a transaction on the blockchain.

Formula: TCT = Time of Confirmation - Time of Transaction Initiation

**BLOCK TIME (BT)**

Definition: The average time taken to generate a new block on the blockchain.

Formula: BT = Total Time Elapsed / Number of Blocks Generated

**GAS FEES (GF)**

Definition: The cost associated with processing transactions or executing smart contracts.

Formula: GF = Gas Used \* Gas Price

**GAS LIMIT (GL)**

Definition: The maximum amount of gas that can be used for a block.

Formula: GL = Gas Used in a Block / Number of Transactions in the Block

**TRANSACTION THROUGHPUT (TT)**

Definition: The number of transactions processed per unit of time.

Formula: TT = Number of Transactions / Time Interval

**Transaction Fee Revenue (TFR)**

Definition: The total revenue generated from transaction fees.

Formula: TFR = Sum of Transaction Fees for All Transactions

**Network Hash Rate (NHR)**

Definition: The computational power of the network.

Formula: NHR = Number of Hashes per Second

**STAKING RATE (SR)**

Definition: The percentage of total tokens staked in the network.

Formula: SR = (Total Staked Tokens / Total Circulating Supply) \* 100

These parameters collectively provide insights into the performance, efficiency, and security of the Binance Smart Chain, helping stakeholders assess its suitability for various applications, including those in the agri-food industry. Keep in mind that the specific formulas and metrics may evolve with updates and changes to the BSC protocol.

**CHAPTER VI**

**CONCLUSION & FUTURE ENHANCEMENT**

In conclusion, the increasing demand for transparency in the agri-food industry has propelled the rapid adoption of blockchain technology, offering a robust solution to enhance traceability and security throughout the supply chain. The innate characteristics of trust and immutability embedded in blockchain have proven pivotal in addressing the industry's challenges and improving overall chain management. While Ethereum has been a significant player in this space, the complexities associated with upgrading smart contracts have led to the exploration of alternative solutions, with the Binance Smart Chain (BSC) emerging as a promising option.

BSC, with its faster transaction confirmation times and unique consensus mechanism, addresses the efficiency concerns associated with Ethereum, providing a streamlined and reliable platform for transparent supply chain management. The architecture diagram, which outlines the structure and components of the system, likely illustrates the interplay between different layers and technologies, showcasing how blockchain is integrated into the agri-food industry to meet the evolving demands for traceability and security. As the industry continues to navigate challenges and leverage technological innovations, the adoption of blockchain, particularly on platforms like BSC, signifies a transformative step towards a more transparent, secure, and efficient agri-food supply chain. This journey toward technological advancement underscores the importance of adaptability and exploration in meeting the dynamic needs of an industry vital to global food security.

**REFERENCE:**

1. Androulaki E, Barger A, Bortnikov V, et al. Hyperledger fabric: A distributed operating system for permissioned blockchains. In: Proceedings of the Thirteenth EuroSys Conference, EuroSys ’18, 2018; <https://doi.org/10.1145/3190508.3190538>
2. Antonucci F, Figorilli S, Costa C, et al. A review on blockchain applications in the agri-food sector. J Sci Food Agricult. 2019;99(14):6129–38. <https://doi.org/10.1002/jsfa.9912>.
3. Baralla G, Pinna A, Tonelli R, et al. Ensuring transparency and traceability of food local products: A blockchain application to a smart tourism region. Concurrency and Computation: Practice and Experience, 2021;33(1). <https://doi.org/10.1002/cpe.5857>
4. Biswas K, Muthukkumarasamy V, Lum W. Blockchain based wine supply chain traceability system. In: Future Technologies Conference (FTC 2017), 2017; 56–62
5. Bosona T, Gebresenbet G. Food traceability as an integral part of logistics management in food and agricultural supply chain. Food Control. 2013;33(1):32–48. <https://doi.org/10.1016/j.foodcont.2013.02.004>.
6. Caro MP, Ali MS, Vecchio M, et al. Blockchain-based traceability in agri-food supply chain management: a practical implementation. In: 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany), 2018; 1–4 <https://doi.org/10.1109/IOT-TUSCANY.2018.8373021>
7. Casino F, Kanakaris V, Dasaklis T, et al. Modeling food supply chain traceability based on blockchain technology. IFAC-PapersOnLine. 2019;52:2728–33. <https://doi.org/10.1016/j.ifacol.2019.11.620>.
8. Chen K, xin WANG X, ying SONG H,. Food safety regulatory systems in europe and china: A study of how co-regulation can improve regulatory effectiveness. J Integrative Agricult. 2015;14(11):2203–17. <https://doi.org/10.1016/S2095-3119(15)61113-3>.
9. Cocco L, Mannaro K, Tonelli R, et al. A blockchain-based traceability system in agri-food sme: case study of a traditional bakery. IEEE Access, 2021;9:62,899–62,915. <https://doi.org/10.1109/ACCESS.2021.3074874>
10. Dabbene F, Gay P, Tortia C. Traceability issues in food supply chain management: a review. Biosyst Eng. 2014;120:65–80. <https://doi.org/10.1016/j.biosystemseng.2013.09.006>.
11. Feng Tian. A supply chain traceability system for food safety based on haccp, blockchain internet of things. In: 2017 international conference on service systems and service management, 2017;1–6. <https://doi.org/10.1109/ICSSSM.2017.7996119>
12. Galvez JF, Mejuto J, Simal-Gandara J. Future challenges on the use of blockchain for food traceability analysis. TrAC Trends Anal Chem. 2018;107:222–32. <https://doi.org/10.1016/j.trac.2018.08.011>.
13. Gamage HTM, Weerasinghe HD, Dias NGJ. A survey on blockchain technology concepts, applications, and issues. SN Comput Sci. 2020;1(2):114. <https://doi.org/10.1007/s42979-020-00123-0>.
14. Kolb J, AbdelBaky M, Katz RH, et al. Core concepts, challenges, and future directions in blockchain: A centralized tutorial. ACM Comput Surv, 2020;53(1). <https://doi.org/10.1145/3366370>
15. Li D, Wang X, Chan HK, et al. Sustainable food supply chain management. Int J Prod Econ. 2014;152:1–8. <https://doi.org/10.1016/j.ijpe.2014.04.003>.
16. Malik S, Kanhere SS, Jurdak R. ProductChain: Scalable blockchain framework to support provenance in supply chains. In: NCA 2018 - 2018 IEEE 17th international symposium on network computing and applications, 2018; <https://doi.org/10.1109/NCA.2018.8548322>
17. Marchese A, Tomarchio O. An agri-food supply chain traceability management system based on hyperledger fabric blockchain. In: Proceedings of the 23rd international conference on enterprise information systems - Volume 2: ICEIS,, INSTICC. SciTePress, 2021; 648–658 <https://doi.org/10.5220/0010447606480658>
18. Marchesi L, Mannaro K, Porcu R. Automatic generation of blockchain agri-food traceability systems. In: 2021 IEEE/ACM 4th international workshop on emerging trends in software engineering for Blockchain (WETSEB), 2021;41–48. <https://doi.org/10.1109/WETSEB52558.2021.00013>
19. Nakamoto S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2008; <https://bitcoin.org/bitcoin.pdf>
20. Olsen P, Borit M. The components of a food traceability system. Trends Food Sci Technol. 2018;77:143–9. <https://doi.org/10.1016/j.tifs.2018.05.004>.
21. Ray Z, Xun X, Lihui W. Food supply chain management: systems, implementations, and future research. Ind Manag Data Syst. 2017;117(9):2085–114. <https://doi.org/10.1108/IMDS-09-2016-0391>.

[**Article**](https://doi.org/10.1108%2FIMDS-09-2016-0391)[**Google Scholar**](http://scholar.google.com/scholar_lookup?&title=Food%20supply%20chain%20management%3A%20systems%2C%20implementations%2C%20and%20future%20research&journal=Ind%20Manag%20Data%20Syst.&doi=10.1108%2FIMDS-09-2016-0391&volume=117&issue=9&pages=2085-2114&publication_year=2017&author=Ray%2CZ&author=Xun%2CX&author=Lihui%2CW)

1. Shahid A, Almogren A, Javaid N, et al. Blockchain-based agri-food supply chain: A complete solution. IEEE Access, 2020;8:69,230–69,243. <https://doi.org/10.1109/ACCESS.2020.2986257>
2. Tian F (2016) An agri-food supply chain traceability system for china based on rfid & blockchain technology. In: 2016 13th international conference on service systems and service management (ICSSSM), <https://doi.org/10.1109/ICSSSM.2016.7538424>
3. Wang S, Li D, Zhang Y, et al. Smart contract-based product traceability system in the supply chain scenario. IEEE Access, 2019;7:115,122–115,133. <https://doi.org/10.1109/ACCESS.2019.2935873>
4. Wang Y, Han JH, Beynon-Davies P. Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. Supply Chain Management: An International Journal. 2018;24. <https://doi.org/10.1108/SCM-03-2018-0148>.
5. Wüst K, Gervais A. Do you need a blockchain? In: 2018 Crypto Valley Conference on Blockchain Technology (CVCBT), 2018; 45–54. <https://doi.org/10.1109/CVCBT.2018.00011>
6. Zhao G, Liu S, Lopez C, et al. Blockchain technology in agri-food value chain management: a synthesis of applications, challenges and future research directions. Comput Ind. 2019;109:83–99. <https://doi.org/10.1016/j.compind.2019.04.002>.