International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Smart Contract System of the Food Supply Chain Through Blockchain-Based Interplanetary File System

I. Mohammed Musthafa Sheriff *[1], D. John Aravindhar[2]

Submitted: 27/01/2024 **Revised**: 05/03/2024 **Accepted**: 13/03/2024

Abstract: Agricultural food products form the central segment of human life as they govern all human body aspects. Many complexities prevail in the supply chain, making it difficult to understand and track it. The existing food supply chain tracking systems have a few drawbacks, such as the increased number of participants, improper communication between the participants, a centralized network, and so on. The proposed system overcomes these drawbacks. The point-to-point issue can be better resolved by using blockchain technology. The proposed work implements an innovative contract system is implemented, breaking information into smaller segments between the enterprises. This avoids needing a centralized system and is much more reliable and secure. The details of the farmers are recorded using the Interplanetary file system. The interplanetary file system helps to provide better throughput than the other systems available. It is capable of the secure transfer of information without having any central organization. Despite having a low query efficiency, the use of a single blockchain can see the entire data due to the topology of the entire system. To overcome this drawback, the proposed system uses the encrypted storage system for private data and hash function-based storage data for public data. The primary supply chain components are the agriculturalist, processor, distributor, vendor, and user. The functioning of each of these components has been pointed out in the proposed work. Algorithms have been put forth for the transfer of crops from the farmers to the processor, the transfer of crops from the distributors to the retailers, and the transfer of crops from the vendors to the users.

Keywords: *blockchain, Interplanetary, farmers, processor, distributor, vendor, users.*

1. Introduction

Everyone is incredibly excited about the next meal, but at the same time, they are all curious about what exactly will be served. This is because the processes involved are so complicated that mistakes can happen at any point in the food supply chain [1]. By making sure that transaction records can be accessed

from all network nodes, blockchain technology could give us useful information about how goods blockchain enables full-fledged traceability at every stage of the process. This function is beneficial move through a supply chain. When applied to the food supply chain, technology that is enabled by whenever there are questions or recalls regarding food. Coordinating the processes that go into making a product from its parts is the primary objective of supply chain management. The objective of this initiative is to enhance customer value and sustain a competitive edge in the long run. Supply chains encompass individuals, enterprises, and entities that contribute to the conversion of raw materials into finalized products[2]. This can be anywhere from a single person to an entire nation. Even though national traceability requirements for well-known products have been implemented, the market is still rife with inferior quality fakes and alternatives. Because of this, several issues relating to food security have contributed to the worsening of a crisis in consumer confidence, which has made it significantly more challenging to put into practice national efforts aimed at developing a society that people can rely on [3].

The NP agro-food monitoring program can track the whereabouts of food and provide information that is both comprehensive and detailed regarding its production and distribution. The various stages involved in the supply chain of agricultural commodities, including production, processing, transportation, and commercialization, are integral components that facilitate the movement of these goods from the farm to the consumer's table. The occurrence of fraudulent activities within these supply chains has the potential to significantly jeopardize the safety of the food, potentially leading to human fatalities. Consequently, many new management strategies that use novel insights, automation, and the Internet of Things (IoT) have existed [4]. Even though these systems are capable of monitoring the entire process on their own, they are still susceptible to challenges such as the manipulation of data and the occurrence of foodborne illnesses. The reason for this is that when using the conventional approach to storing information, there is always the possibility that the data will become

1Research Scholar, Department of Computer Science and Technology Hindustan Institute of Technology and Science Chennai, India
Musthafa.sheriff@gmail.com ,

corrupted or deleted. To combat these issues and guarantee the safety of the data that has been stored, researchers have been conducting experiments with blockchain technology [5]. The system aims to create a decentralized blockchain infrastructure to track agricultural produce provenance. Due to IoT compatibility, agricultural commodities can autonomously transmit data to a network.

The server will process the data, which will be dynamically saved to the blockchain[6]. In such situations, blockchain technology is utilized to create a secure database for storing provenance data, thereby ensuring the data's safety and security. This logic suggests that the data derived from the source are highly likely to be accurate and trustworthy. It is anticipated that the provenance monitoring system will incorporate a substantially larger number of agricultural products, resulting in the accumulation of a substantial volume of real-time data. The primary motivation behind the development of blockchain technology was to improve the efficiency and convenience of digital currency transactions.

On the other hand, real-time monitoring allows for collecting a significantly larger quantity of data. Because of this, keeping a consistent rate of block construction while also storing traceability data becomes challenging [7]. As a direct consequence, the blockchain's current implementation does not live up to expectations. Our proposed solution creates a safe data storage and query system for agricultural traceability by utilizing blockchain and IPFS. The overarching objective of IPFS is to integrate all computer systems into a single, standardized file system across the globe. This is made possible by the distributed and peer-to-peer nature of the network's architecture. In the first version of the proposal, data storage was envisioned as a model combining IPFS and blockchain-based systems [8]. Images, videos, and readings from sensors can all be encoded and interpreted by the current model entirely independently of any involvement from a human. IPFS will then obtain the information mentioned above, after which the blockchain will be updated to include the hash addresses associated with the information. The hash values associated with the blockchain transaction are then added to the database after completing this step. Clients can use the content of previously completed transactions stored on the blockchain to access the provenance information. In order to accomplish this, you will need to query the IPFS for the hash address of the authenticity database associated with the item in question[9]. The supply chain comprises many interconnected entities, such as wholesalers, retailers, processors, suppliers, logistics providers, and end users, who collaborate to create a complex network chain structure. These entities include wholesalers, retailers, processors, suppliers, and end users. This particular supply chain could have dozens or even hundreds of links, and each one could necessitate a significant time commitment and cover ground in more than one region. Tracing the product is made significantly more difficult because there are significant problems with the product's quality and safety[10]. The procedure that has been implemented ensures the traceability of the final products, thereby protecting the consumers' health and safety. Because of this, there is increased trust in both the product and the company, which is particularly significant in the agricultural food supply chain.

Despite this, monitoring and tracing issues within a specific link in agricultural food supply chains is inherently difficult because of factors such as lengthy life cycles, complex and interconnected links, and the dynamic nature of information in contemporary systems[11]. For example, wheat, sorghum, rice, peanuts, and corn are just some of the numerous crops that can be cultivated through agricultural practices and are categorized as "agricultural foods." Every day, people depend on the foodstuffs that have been manufactured, and the production of those foodstuffs is ongoing. Therefore, it is of the utmost importance that we establish a reliable "from farm to fork" system for tracing the origin of our food from farms to restaurants as soon as possible. It is clear from the variety of citations that the user is drawing from more than one source because they have been provided[12].Three primary issues stem from agricultural practices currently affecting the food supply chains in various forms. The supply chain is comprised of a large number of distinct parties, all of which are sometimes unable to communicate effectively, which causes the whole process to move more slowly. There is insufficient communication, and there is some mistrust of the data being shared because so many people are involved, and they are spread out across many different channels. The agricultural food supply chain is, when it comes down to it, a centralized system in which data manipulation is simple, and authority is held squarely in the hands of a single manager[13]. Even though individual government departments are responsible for central management, inherent flaws in human oversight remain. The examination of advanced traceability technology and its accompanying systems holds considerable importance in guaranteeing the superior quality and safety of agricultural food.

Despite the efforts of many researchers, supply chain traceability systems such as radio frequency identification (RFID), barcodes, and QR codes continue to struggle with several challenges. Existing traceability systems are primarily designed to serve a single enterprise. This results in the sharing of data within the company but creates challenges when attempting to share that data with third parties[14]. The data is also skewed and unclear, both contributing to a decreased level of trust in it and increasing the likelihood that the authorities will manipulate it. In addition, most traceability systems are built using a top-down method during the development process. In conclusion, it is important to note that the current traceability systems have a single point of failure, which means that if one node fails, the whole system stops working. There are some problems with the current food supply chain traceability systems that can be fixed by using blockchain technology [15]. The blockchain is a decentralised database that is organised by time and spread across computers in a network that are all connected to each other. A different way to describe the system in question is as a distributed ledger. There is transparency, immutability, and resistance to modification and distribution in the system because of these traits. Implementing blockchain technology has made it easier to keep track of and record all the steps in the food supply chain for agriculture. Making use of this technology has many positive effects, such as lower costs for management, more reliable data, the ability to show supply chain data visually, and easier tracking of information.

2. Literature Review

Hyperledger was utilized in [16] in order to establish provenance links in-database processing. This was done to circumvent the blockchain's restricted capacity for storing large volumes of data. Several factors contribute to the drawbacks of IPFS data storage, including higher costs, data transfer rates that are less than ideal, and inadequate protections for users' privacy. To prevent retailers from gaining access to sensitive data regarding product security and other factors, it is essential to implement a feature that allows for feedback from customers. Blockchain technology, sensor networks, and intelligent farming practices were utilized in [17] system design to efficiently monitor the quality and safety of various aspects of the tea production process. The development of cutting-edge technologies that enable the monitoring of preventative measures and the evaluation of risks has also significantly contributed to the culinary arts field. To enhance the effectiveness of the restaurant safety measures that are already in place, these innovations draw on the characteristics of possible hazards.

Researchers used the Ethereum (ETH) platform to put Internet of Things (IoT) technology to use for tracking agricultural products. The main goal of their investigation was to lower the risks that could come from changing or losing data [18]. If you use blockchain technology to store files, the amount of data you store will probably grow, which will make the network load higher. Within the year [19], an investigation was carried out to learn more about how blockchain technology and the Internet of Things (IoT) could work together to make real-time product tracking more effective. A distributed ledger system was put into use in the egg supply chain of a Midwest-based company to show what blockchain technology could do. The demonstration showed how blockchain technology could improve transparency and traceability along the whole supply chain, from the farmers to the final consumer. According to the study's results, it would be helpful to add another database so that the collected data can be analysed better. For this reason, the chicken claw ring can't be sold again because its teeth are set up backwards. Modern technologies can get important data and information from the ring by scanning the Quick Response (QR) code that is built into it [20]. The InterPlanetary File System (IPFS) makes it possible to create a cohesive file system that makes it easier for devices that are connected to each other to talk to each other. A peer-to-peer network runs the InterPlanetary File System (IPFS), which is a decentralised file system. The system's main way of working is through a content-addressed approach. The main problems with cloud storage right now are caused by bad server management and maintenance practises used by cloud storage providers, whether they work in a centralised or dispersed way [21]. It is possible for the backup and original files, which use the same storage system, to occupy the exact physical location on the hard drives when the cloud hard drives are consolidated, even though they share the same storage system. As a result, the only choice to be made in case of a power outage or some other problem is to wait until the server's functionality is restored. As a direct consequence, the servers are affected by issues and rendered inaccessible to the general public[22]. The HyperText Transfer Protocol (HTTP) is an older version of the Internet technology known as the InterPlanetary File System (IPFS). IPFS is a cutting-edge Internet technology that demonstrates a striking lack of limitations compared to HTTP. This technique is based on the premise that files can be segmented and dispersed across a network in such a way as to make possible the sequential retrieval of data from multiple servers through the use of P2P. Users who are not part of the system are still able to connect to the network and access their data, even if some of the servers making up the system are temporarily unavailable. If an error occurs that results in the total loss of data on specific nodes, the network displays several backup mechanisms as an additional perk for added peace of mind[23]. The IPFS platform offers several advantages that may be able to assist in the resolution of issues that are associated with traditional centralized public cloud infrastructures. Data loss is a problem, as is relying on obsolete computer systems and receiving input from users on an infrequent basis.

Robust transaction data backup protocols are imperative to effectively monitor the movement of agricultural goods between different locations. Due to its decentralised nature, IPFS effectively partitions files and distributes them across the network, rendering it a more dependable method for data backup in comparison to cloud storage.The utilisation of blockchain technology in agricultural supply chains has been found to enhance traceability [24]. The reason for the verification of IPFS data is attributed to the utilisation of blockchain technology. The utilisation of blockchain technology is employed for the purpose of monitoring and regulating transactions within the agricultural supply chain of the NP industry. The significance of the centralised database utilised for these tasks was diminished as a result of this. One potential solution to address this issue involves the utilisation of smart contracts and IPFS transaction records. The feasibility of achieving this objective can be realised through the utilisation of smart contracts and IPFS transaction records. There is an increasing focus on food safety due to its critical significance for human health and overall well-being [25]. The author developed a system utilising QR codes to facilitate the tracking of food within the dairy supply chain. The primary objective of this system is to enhance clarity across various stages, encompassing production, sales, and facilitating seamless food tracking. Multiple components will be utilised to accomplish this task. Nevertheless, the presence of pollution in the environment has the potential to adversely affect QR codes, rendering them ineffectual in their application for living organisms such as chickens and ducks. RFID technology plays a pivotal role in enabling food tracking within the context of the Internet of Things [26]. This is attributed to its compact size and relatively low cost. In order to ensure the accuracy of all data pertaining to the pig farming operation, a comprehensive network of tracking and monitoring systems was established. These systems employ state-of-the-art identification technology and are built on the foundation of SQL Server 2000. The fault-tolerant mechanism of RFID ensures the long-term functionality and reliability of the system. RFID, an acronym for radio frequency identification, refers to a technology that utilises radio waves to identify and track objects. The authors implemented a food distribution system that incorporated object-based validation protocols, real-time monitoring of quality using RFID sensors, and the utilisation of blockchain technology to enhance the reliability of the network [27].

On the other hand, radio frequency identification (RFID) technology has some drawbacks, including insufficient safety precautions, high costs, a lack of standardized technical protocols, and an insufficiently developed technological infrastructure. In addition, the IoT's traceability system stores a significant amount of its data in centralized databases, specifically SQL Server, which is the most widely used of these databases. The practice of centralized data storage has become more expensive due to the asymmetry of information, the alteration of data, and the ever-increasing volume of data[28]. Blockchain technology possesses the inherent ability to be traced, rendering it resistant to alterations, incorporating anti-tampering mechanisms, and distributing data across multiple locations. The utilisation of blockchain technology in agri-food safety traceability systems has the potential to address the prevailing challenges associated with food traceability in contemporary times. The process involves securely storing and organising traceable data.

In recent years, there has been an increasing utilisation of blockchain technology in the domain of food traceability. The notion was supported by the principles of HACCP, which involve conducting hazard analysis and identifying critical control points. The utilisation of the Internet of Things (IoT) for the automation of data collection and storage enhances food safety protocols through the improvement of data reliability [29]. The immutability of data within a blockchain may enhance its reliability. Once an item has been added, it becomes immutable and cannot be altered. The capacity of the blockchain is limited by its data storage capacity, beyond which it becomes excessively large. The utilisation of a decentralised file system architecture in IPFS facilitates the storage and dissemination of data. The inclusion of this feature was deemed essential in the design of the system. In order to retrieve IPFS data, it is necessary to obtain the transaction hash from the secondary database, followed by acquiring the IPFS hash from the blockchain. The proposed approach offers a potential solution to address the challenge of exponential growth in data within blockchains [30]. It is imperative to comprehend that in the event of a failure in the secondary database, the entire system will be rendered inoperable. The utilisation of blockchain and EPCIS technologies facilitated the development of a collaborative system aimed at monitoring and ensuring food safety [31]. The present system is in place. Smart contracts have been employed by businesses to address concerns such as privacy breaches, alterations in trust, and modifications in data. In order to mitigate the issue of excessive data, the system employs dynamic data management tools both within and outside the blockchain network. The primary objective of this study was to identify strategies for enhancing business performance. This proposed solution primarily focuses on the monitoring and administration of commercial transactions among individuals involved in the soybean supply chain [32]. This objective can be achieved through the elimination of a singular point of vulnerability, the maintenance of comprehensive transactional documentation, and the utilisation of intelligent contracts.

Transactions along the soybean supply chain are meticulously documented and securely stored on the blockchain. This makes it possible for all parties involved to quickly and easily access the information[33]. The system's dependability in terms of openness and tracking is preserved thanks to the combination of these two factors. Not only can the traceability of food safety be improved by using smart contracts, but the benefits of using them go far beyond that. The proposed solution leverages the Ethereum smart contract platform and a decentralised data storage system as fundamental components of its blockchain-based methodology. This method captures the complex algorithmic dynamics of stakeholder interaction across the supply chain by automating processes, thereby making it easier for stakeholders to share information and improving information sharing. In conclusion, this mode of communication is an appealing choice because it is brief, safe, dependable, and open. The fact that the proposed model is capable of dynamically adjusting the excitation parameters makes it possible for it to maintain users' interest in data-sharing activities over the long term.

Blockchain technology has spawned an offshoot known as the consortium chain, in which multiple institutions or organizations collaborate to share authority over the distributed ledger and retain sole ownership rights to the information it stores[34]. The present scenario presents an opportune context for the implementation of agricultural food safety traceability systems, as it poses challenges to the exchange of information among businesses. In recent years, there has been significant discourse surrounding Ethereum and Hyperledger, which are both prominent consortium chain platforms based on Ethereum. The system in question was utilised for the purpose of monitoring and documenting financial transactions [35]. The present implementation utilises blockchain technology and its fundamental elements, including smart contracts. Furthermore, a lack of centralised control is evident. IPFS presents itself as a feasible solution for effectively tackling the aforementioned concerns, owing to its decentralised structure. The data undergoes the application of a file encryption algorithm prior to its storage in IPFS. When encrypted text is uploaded to IPFS, a hash value that is specific to the file is generated. The resulting hash value will subsequently be stored on the Ethereum network.

3. Proposed Work

Food is the basic need of the human beings to survive on earth. Traceability of the food is necessary for the proper manufacturing and the usage of the agro products in an efficient manner. Block chain is a data base system that is not centralized. It has become a crucial topic in the recent years. It encompasses the encryption methods, the point-to-point network protocols, and many such mechanisms. The figure 1 depicts the basic block diagram of the blockchain mechanism.

3.1 Blockchain Flow Model

The hash function employed in the preceding blocks is utilised to establish new linkages with the forthcoming blocks. The establishment of the connection is facilitated through the utilisation of the parental hash function. This process facilitates the generation of comparable frameworks. The header and the body are the two essential components of every block. Sequenced version number, Nonce, Time imprint, the Hash function of the prior block, Merkle branching and difficulty of the block are the segments of the header part of the block. The toughness level in mining the data defines the block's difficulty.

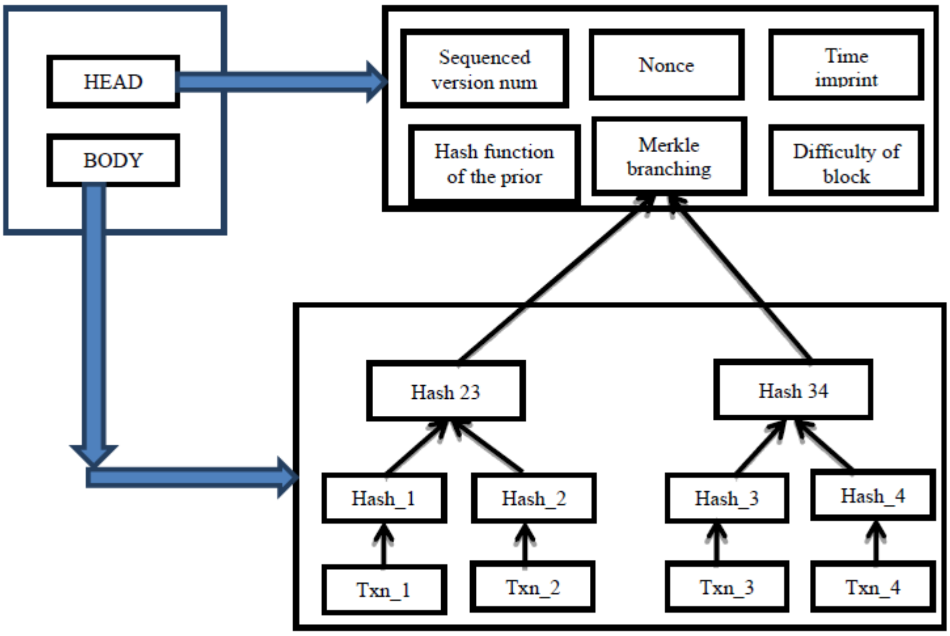

Fig 1: basic block diagram of the blockchain mechanism

The time stamp represents the time taken for the formation of each block. The Merkle tree is almost similar to the binary tree. It is responsible for all the transaction-related activities of the block.

3.2Smart agreement system

Figure 2 shows the block diagram of the smart agreement system. The key components of the smart agreement system are the agriculturalist, processor, distributor, vendor, and the users.

3.3 Bureau of farming and monitoring:

The agriculturalist is the prominent factor in the entire food supply chain. They form the source of the entire system. The information about the agriculturalists, so-called farmers, is maintained by the agricultural bureau. The agricultural bureau maintains related to the farmers' farms, the yield they produce each year, their profit, and other such information.

3.4 Agriculturalist

The farmers are responsible for growing the plants, watering them, nourishing them with good soil, and managing the farms. They also monitor the conditioning of both the plants and the environmental changes by using monitoring devices. The climatic conditions are not controlled by farmers, but they can take necessary measures to protect the crops to some extent in case of unexpected climatic changes.

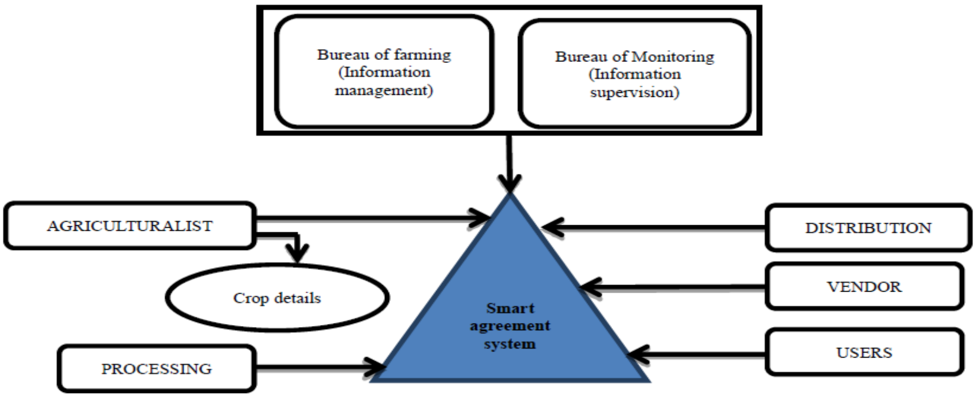

Fig 2: Smart agreement system

3.5 Processor

The processors are the group of people who buy the raw crops or products from the farmers and convert them to a form suitable for the end users. They further sell those crops to the distributors by having some marginal value. It is the responsibility of the processing team to buy the crops from the customers at a reasonable price so that they do not face any losses and the cycle continues effectively year after year.

3.6 Distributor

The distributors are the people who act as the intermediate sources for the transfer of the products from the processor to the retailer. They are responsible for storing information related to the company's details, what products they manufacture, the price that can be fixed for selling, and other such information. All these data are stored using blockchain technology.

3.7 Vendor/Retailer

The retailers are the intermediate people between the distributors and the actual customers. They have information related to the number of products sold, the needs of the customers, and the improvements that the customers expect in the products they sell. These suggestions from the customers can be given to the higher degrees to implement it if possible.

3.8User/Customer

The customers form the end of the entire food supply chain. They are the ones who use the products. The customers get access to the products from the retailers.

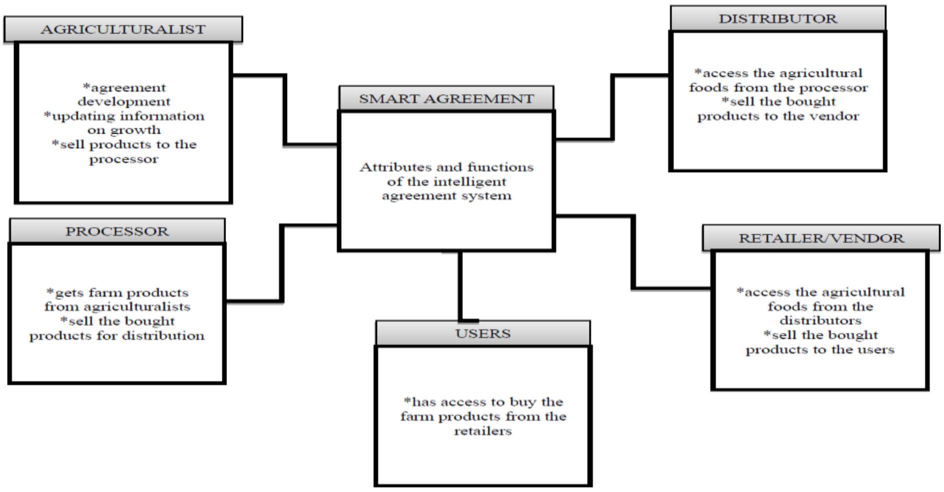

Fig 3: Relationship sketch of the entities

Figure 3 depicts the relationship sketch of the entities.The agriculturalist is responsible for the agreement development, updating information on growth, and selling products to the processor. The processor gets farm products from agriculturalists. They sell the bought products for distribution to the distributors. The distributors access the agricultural foods from the processor and sell the bought products to the vendors. The vendors are also known as retailers. They access the agricultural foods from the distributors and sell the bought products to the users. The customers have access to buy the farm products from the retailers.

Algorithm: 1 Transfer of crops from the farmers to the processor

State of contract:processors buy crops from the agriculturalists.

State of the processor: request crops from the agriculturalists.

State of agriculturalist: Wait for transfer crops to the processor.

Access restriction to the registered processors

If the sale of the crop is accepted and the amount is paid:

State of contract: agreement accepted for sale of crops

State of the processor: wait for the products from agriculturalists

State of agriculturalist: Transfer crops to the processor.

Processor receives a positive acknowledgement

End

Else if the sale of the crop is not accepted and the amount is not paid:

State of contract: agreement rejected for sale of crops

State of the processor: The request has been denied

State of agriculturalist:request termination of the processor

The processor receives a negative acknowledgment

End

Else:

Send a requisition message for the creation of the contract

End

Algorithm: 2 Transfer of crops from the distributors to the retailers

State of contract:vendors buy crops from the distributors.

State of the distributor:reception of farm food from the processor.

State of vendor: Wait for the purchase of the farm food.

Access is restricted to the registered vendors.

If the sale of the crop is accepted and the amount is paid:

State of contract: The buying request is accepted.

State of the distributor:farm food has been sold to the vendors

State of vendor:successfully received the farm foods

Retailer receives positive acknowledgement

End

Else, if the sale of the crop is not accepted and the amount is not paid:

State of contract: The selling request has been denied.

State of the distributor: request acceptance is unsuccessful.

State of vendor: farm food reception is unsuccessful.

The retailer receives a negative acknowledgment.

End

Else:

Send a requisition message for the recreation of the contract and put forth an error message.

End

Algorithm:3 Transfer of crops from the vendors to the users

State of contract: The selling request agreement is prosperous.

State of the vendor:successful delivery of agri products.

State of users: Wait to buy agri products

Access is restricted to the registered customers.

If the sale of the crop is accepted and the amount is paid:

State of contract: Selling products to the customers has been successfully done.

State of the vendors: Selling of farm food is prosperous.

State of users:the products have been successfully received.

Users receive a positive acknowledgement

End

Else, if the sale of the crop is not accepted and the amount is not paid:

State of contract:denial of the food sale.

State of the vendors:sales are unsuccessful

State of users:farm food purchase is unsuccessful.

Users receive a negative acknowledgment

End

Else:

Send a requisition message for the recreation of the contract and put forth an error message.

End

3.9 Blockchain: inter-planetary file system

Blockchain functions by performing links between different blocks. The data keeps adding to the link; new blocks will also be created. The Merkle tree is an essential blockchain component based on the hash function. The following equation gives the collection of the systems in the entire hierarchy of the blockchain.

$$R = h\, f_T(N, z) \tag{1}$$

$$R = h\, f_T(M, z) \tag{2}$$

$$g_0 = H(a_0), b_1 = H(b \,||\, a_1).....b_N = H(b_N - 1 \,||\, a_N - 1) \tag{3}$$

The interplanetary file system helps to provide better throughput than the other systems available. It is capable of the secure transfer of information without having any central organization. The files are shared among the network. The system is identified by using the cryptographic hash function. Figure 4 shows the public and private data storage.

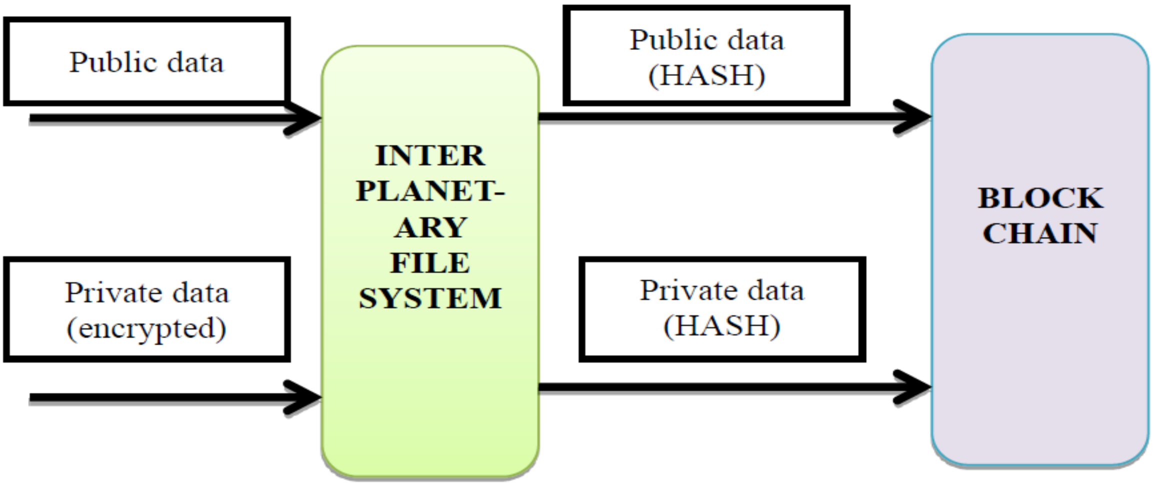

Fig4: public and private data storage

The interplanetary file system relies on data being distributed over various parts of the network obtained from several sources. It is more accessible to build trust among the users if the whole information is provided to them through a proper traceability system. The blockchain system of traceability provides easier access to data writing of the agricultural goods in the blockchain. As more data is being gathered, the blockchain's node count also keeps increasing.

Despite low query efficiency, a single blockchain can see the entire data due to the topology of the entire system. To overcome this drawback, the proposed system uses an encrypted storage system for the private data and a hash function-based storage data for the public data.The public information could be related to the manufacturing company, its reputation, its manufacturing units, date of expiry, and so on. The confidential information may pertain to the company's finances, such as its income and revenue. Using a smart contract system, a random selection of the data encryption key is performed. The network is assigned a substitution cypher. The key is encrypted using critical encryption, a cryptographic technique. Utilising the public key, the observable node is encrypted. Within the interplanetary file system, confidential information is transmitted.

4. Results and Discussion

Table 1 shows the latency of the transaction concerning its count, and Figure 5 depicts the graphical representation of the latency of the transaction concerning its count. When the transaction count is 100, the transaction latency is observed to be 3500 milliseconds.

Table 1: Latency of transaction concerning its count

S.No.	Count of transactions	Latency of transactions
1.	100	3500
2.	200	3800
3.	300	4400

4.	400	4700
5.	500	4800
6.	600	5000

When the transaction count is 200, the latency of the transaction is observed to be 3800 milliseconds. When the transaction count is 300, the transaction latency is observed to be 4400 milliseconds.

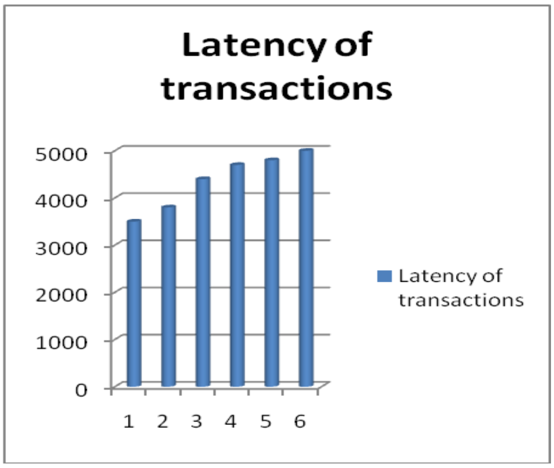

Fig 5: Graphical representation of latency of transaction concerning its count

When the transaction count is 400, the transaction latency is observed to be 4700 milliseconds. When the transaction count is 500, the transaction latency is observed to be 4800 milliseconds. When the transaction count is 600, the transaction latency is observed to be 5000 milliseconds. Table 2 shows the throughput of the transaction concerning its count, and Figure 6 depicts the graphical representation of the throughput of the transaction concerning its count. The throughput of the transaction is 40 percent when the transaction count is 100.

Table 2: Throughput of transaction concerning its count

S.No	**Count of transactions**	**Throughput of transactions**
1.	100	40
2.	200	43
3.	300	55
4.	400	58
5.	500	60
.	600	67

The throughput of the transaction is 43 percent when the transaction count is 200. The throughput of the transaction is 55 percent when the transaction count is 300.The throughput of the transaction is 58 percent when the transaction count is 400. The throughput of the transaction is 60 percent when the transaction count is 500. The throughput of the transaction is 67 percent when the transaction count is 600.

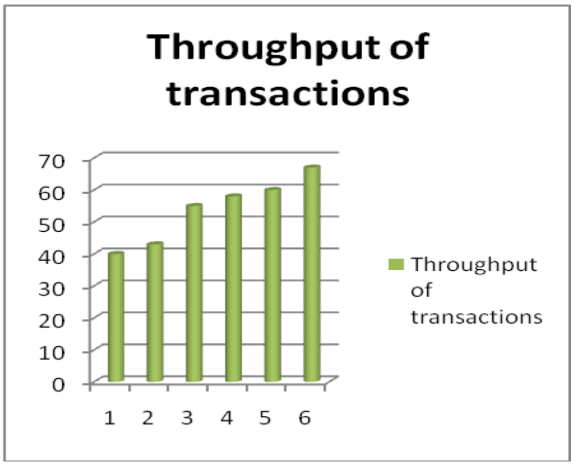

Fig 6: Graphical representation ofthroughput of transaction concerning its count

Table 3 lists the latency of reading with varying data sizes, and figure 7 gives the graphical representation of the reading latency with varying data sizes. For 25 Mega Bytes of data, the latency for the time duration of 10 is 0.365. For 25 Mega Bytes of data, the latency for the time duration of 20ms is 0.523. For 25 Mega Bytes of data, the latency for the time duration of 30ms is 0.741. For 25 Mega Bytes of data, the latency for the time duration of 40ms is 0.856.

Table 3: Latency of reading with varying data sizes

S. No	**Latency of reading**	**10ms**	**20ms**	**30ms**	**40ms**
1.	25MB	0.365	0.523	0.741	0.856
2.	50MB	1.234	0.136	1.762	1.654
3.	100MB	1.523	0.527	1.965	1.892
4.	1GB	13.62	13.92	14.26	15.24

For 50 Mega Bytes of data, the latency for the time duration of 10ms is 1.234. For 50 Mega Bytes of data, the latency for the time duration of 20ms is 0.136. For 50 Mega Bytes of data, the latency for the time duration of

30ms is 1.762. For 50 Mega Bytes of data, the latency for the time duration of 40ms is 1.654.For 100 Mega Bytes of data, the latency for the time duration of 10ms is 1.523. For 100 Mega Bytes of data, the latency for the time duration of 20ms is 0.527. For 100 Mega Bytes of data, the latency for the time duration of 30ms is 1.965. For 100 Mega Bytes of data, the latency for the time duration of 40ms is 1.892.For 1 Giga Byte of data, the latency for the time duration of 10ms is 13.62. For 1 Giga Byte of data, the latency for the time duration of 20ms is 13.92. For 1 Giga Byte of data, the latency for the time duration of 30ms is 14.26. For 1 Giga Byte of data, the latency for the time duration of 40ms is 15.24.

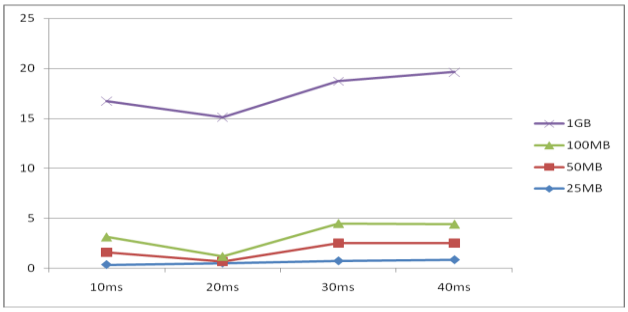

Fig 7: Graphical representation of latency of reading with varying data sizes

Table 4 lists the latency of writing with varying data sizes, and Figure 8 gives the graphical representation of the latency of writing with varying data sizes. For 25 Mega Bytes of data, the latency for the time duration of 10ms is 0.452. For 25 Mega Bytes of data, the latency for the time duration of 20ms is 0.482.For 25 Mega Bytes of data, the latency for the time duration of 30ms is 0.758. For 25 Mega Bytes of data, the latency for the time duration of 40ms is 0.761.

Table 4: Latency of writing with varying data sizes

S. No	**Latency of writing**	**10ms**	**20ms**	**30ms**	**40ms**
1.	25MB	0.452	0.482	0.758	0.761
2.	50MB	1.426	1.465	1.659	1.862
3.	100MB	1.597	1.682	1.824	1.923
4.	1GB	14.56	14.67	15.64	15.62

For 50 Mega Bytes of data, the latency for the time duration of 10ms is 1.426. For 50 Mega Bytes of data, the latency for the time duration of 20ms is 1.465. For 50 Mega Bytes of data, the latency for the time duration of 30ms is 1.659. For 50 Mega Bytes of data, the latency for the time duration of 40ms is 1.862. For 100 Mega Bytes of data, the latency for the time duration of 10ms is 1.597. For 100 Mega Bytes of data, the latency for the time duration of 20ms is 1.682. For 100 Mega Bytes of data, the latency for the time duration of 30ms is 1.824. For 100 Mega Bytes of data, the latency for the time duration of 40ms is 1.923.For 1 Giga Byte of data, the latency for the time duration of 10ms is 14.56. For 1 Giga Byte of data, the latency for the time duration of 20ms is 14.67. For 1 Giga Byte of data, the latency for the time duration of 30ms is 15.64. For 1 Giga Byte of data, the latency for the time duration of 40ms is 15.62.

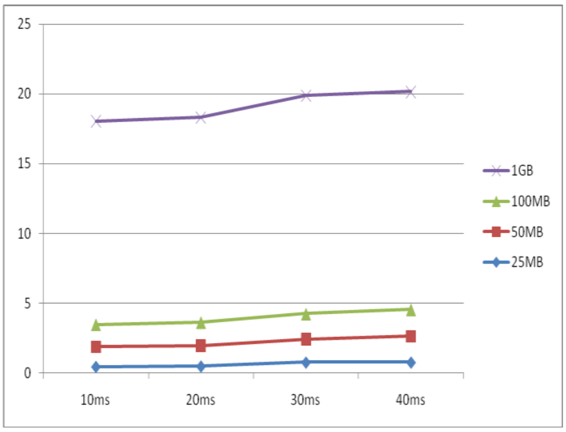

Fig 8: Graphical representation of latency by varying data sizes

Table 5 gives the parametrical comparison between usual and blockchain-based tracing techniques. The tracing efficiency of the usual tracing techniques is moderate, and the tracing efficiency of the blockchain-based tracing techniques is significant.The monitoring of the usual tracing techniques is moderate, and the monitoring of the blockchain based tracing techniques is extensive.The reliability of the usual tracing techniques is less, and the reliability of the blockchain-based tracing techniques is significant.The storing space of the usual tracing techniques is moderate, and the storing space of the blockchain-based tracing techniques is moderate.

Table 5: Parametrical comparison between usual tracing techniques and blockchain-based tracing techniques

S.No	**parameters**	**Usual tracing techniques**	**Blockchain-based tracing techniques**
1.	Tracing efficiency	moderate	maximum
2.	Monitoring	moderate	maximum
3.	Reliability	minimum	maximum
4.	Storing space	moderate	moderate

5.	Data passage ability	moderate	maximum
6.	Expandability	minimum	moderate
7.	Question rate	maximum	moderate

The Data passage ability of the usual tracing techniques is moderate, and the Data passage ability of the blockchain-based tracing techniques is large.The Expandability of the usual tracing techniques is less, and the blockchain-based tracing techniques are moderate.The Question rate of the usual tracing techniques is large, and the Question rate of the blockchain-based tracing techniques is moderate.Table 6 compares the accuracy, recall, and F1_score of different algorithms, and Figure 9 depicts the graphical representation of a comparison of the accuracy, recall, and F1_score of different algorithms. The accuracy of the isolated forest algorithm is 0.36. The isolated algorithm's recall and F1_score are 0.34 and 0.38, respectively.

Table 6: Comparison of accuracy, recall, and F1_score of different algorithms

S.No	ML Algorithms	Accuracy	Recall	F1_score
1.	Isolated forest	0.36	0.34	0.38
2.	Random forest	0.85	0.72	0.73
3.	Proposed model	0.96	0.95	0.91

The accuracy of the random forest algorithm is 0.85. The isolated algorithm's recall and F1_score are 0.72 and 0.73, respectively. The accuracy of the isolated forest algorithm is 0.96. The isolated algorithm's recall and F1_score are 0.95 and 0.91, respectively.

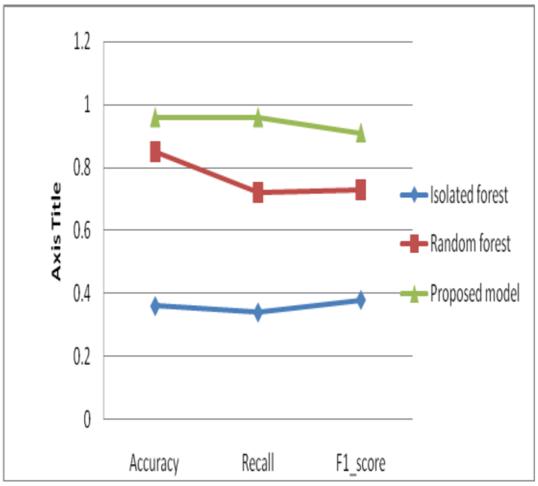

Fig 9: Graphical representation of a comparison of accuracy, recall, and F1_score of different algorithms

Table 7 gives the comparison of the effect of the detection of different layers, and Figure 10 illustrates the graphical depiction of the comparative analysis regarding the impact of detecting various layers. The precision of layer 1 is 0.37. The recall and F1_score of layer 1 are 0.36 and 0.34, respectively. The layer 2 exhibits a precision rate of 0.92. The recall and F1_score of layer 2 are 0.92 and 0.86, respectively. The layer 3 exhibits a precision rate of 0.94. The recall and F1_score values for layer 3 are 0.97 and 0.92, respectively.

Table 7: Comparison of the effect of detection of different layers

S.No	Layer number	Accuracy	Recall	F1_score
1.	Layer 1	0.37	0.36	0.34
2.	Layer 2	0.92	0.92	0.86
3.	Layer 3	0.94	0.97	0.92

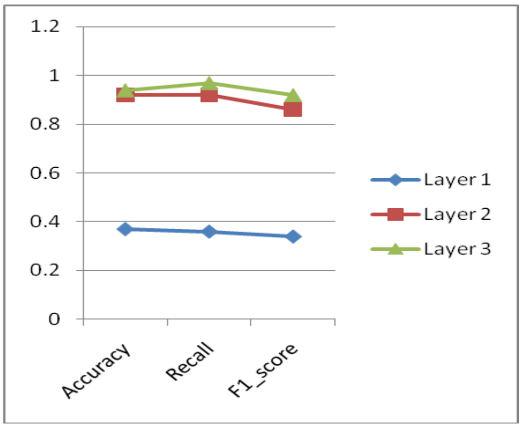

Fig 10: Graphical representation of a comparison of the effect of detection of different layers

Table 8 gives the latency of the query in seconds. Figure 11 depicts the graphical representation of the average value of the query in seconds. When the test count is 1, the average latency of the public and private data query is 0.21 seconds and 0.92 seconds, respectively. When the test count is 2, the average latency of the public and private data query is 0.36 seconds and 0.90 seconds, respectively.When the test count is 3, the average latency of the public and private data query is 0.13 seconds and 0.76 seconds, respectively.When the test count is 4, the average public and private data query latency is 0.22 seconds and 0.79 seconds, respectively.When the test count is 5, the average public and private data query latency is 0.46 seconds and 0.92 seconds, respectively.

Table 8: Latency of query (average value in seconds)

Test count	**Latency of query (average value in seconds)**	
	Public data	**Private data**
1	0.21	0.92
2	0.36	0.90
3	0.13	0.76
4	0.22	0.79
5	0.46	0.92
6	0.62	0.71
7	0.58	0.93
8	0.54	0.81
9	0.46	0.83
10	0.42	0.98

When the test count is 6, the average public and private data query latency is 0.62 seconds and 0.71 seconds, respectively. When the test count is 7, the average public and private data query latency is 0.58 seconds and 0.93 seconds, respectively. When the test count is 8, the average latency of the public and private data query is 0.54 seconds and 0.81 seconds, respectively. When the test count is 9, the average public and private data query latency is 0.46 seconds and 0.83 seconds, respectively. When the test count is 10, the average public and private data query latency is 0.42 seconds and 0.98 seconds, respectively.

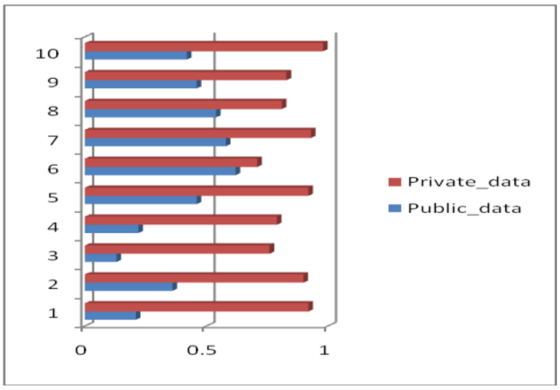

Fig 11: Graphical representation oflatency of query (average value in seconds)

Table 9 gives the average value of the rate of latency recovery in seconds. Figure 12 gives the graphical representation of the average value of the rate of latency recovery. For the test count of one, the average value of the rate of latency recovery is 1.52.

Table 9: Recovery of latency (average value in seconds)

Test count	1	2	3	4	5	6	7	8	9	10
Recovery of latency (average value in seconds)	1.52	0.91	1.36	1.32	0.97	1.16	1.23	1.28	1.82	1.74

For the test count of two, the average value of the rate of latency recovery is 0.91. For the test count of three, the average value of the rate of latency recovery is 1.36. For the test count of four, the average value of the rate of latency recovery is 1.32. For the test count of five, the average value of the rate of latency recovery is 0.97.

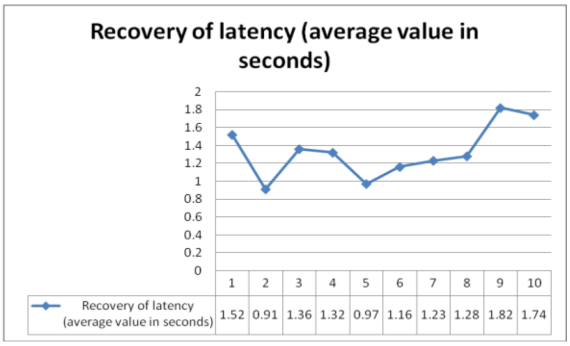

Fig 12: Graphical representation ofRecovery of latency (average value in seconds)

For the test count of six, the average value of the rate of latency recovery is 1.16. For the test count of seven, the average value of the rate of latency recovery is 1.23. For the test count of eight, the average value of the rate of latency recovery is 1.28. For the test count of nine, the average value of the rate of latency recovery is 1.82. For the test count of ten, the average value of the rate of latency recovery is 1.74.

5. Conclusion

Food is a critical component for the human beings. A smart contract-based traceability system has been proposed in this paper. This is done using the blockchain technology and the Interplanetary file system. The encryption of the public data and the private data is done using different fundamental exchange mechanisms. The critical factors of the food supply chain are the farmers, processors, distributors, vendors, and users. The transfer of agricultural goods among these critical components has been listed in this paper. Algorithms have been put forth to portrait the communication mechanisms between these entities.

References

[1] Ralston, Peter, and Jennifer Blackhurst. "Industry 4.0 and resilience in the supply chain: a driver of capability enhancement or capability loss?." International Journal of Production Research 58, no. 16 (2020): 5006-5019.

[2] Gereffi, Gary. "Global value chains, development, and emerging economies." Business and development studies. Routledge (2019): 125-158.

[3] Funk, Chris C., and Molly E. Brown. "Declining global per capita agricultural production and warming oceans threaten food security." Food Security 1 (2009): 271-289.

[4] Uden, Lorna, and Wu He. "How the Internet of Things can help knowledge management: a case study from the automotive domain." Journal of Knowledge Management 21, no. 1 (2017): 57-70.

[5] Zhao, Guoqing, Shaofeng Liu, Carmen Lopez, Haiyan Lu, Sebastian Elgueta, Huilan Chen, and BiljanaMilevaBoshkoska. "Blockchain technology in agri-food value chain management: A synthesis of applications, challenges, and future research directions." Computers in Industry 109 (2019): 83-99.

[6] Rathee, Geetanjali, Ashutosh Sharma, Hemraj Saini, Rajiv Kumar, and Razi Iqbal. "A hybrid framework for multimedia data processing in IoT-healthcare using blockchain technology." Multimedia Tools and Applications 79, no. 15-16 (2020): 9711-9733.

[7] Khalaf, Osamah Ibrahim, and GhaidaMuttasharAbdulsahib. "Optimized dynamic storage of data (ODSD) in IoT based on blockchain for wireless sensor networks." Peer-to-Peer Networking and Applications 14 (2021): 2858-2873.

[8] Goodhope, Ken, Joel Koshy, Jay Kreps, NehaNarkhede, Richard Park, Jun Rao, and Victor Yang Ye. "Building LinkedIn's Real-time Activity Data Pipeline." IEEE Data Eng. Bull. 35, no. 2 (2012): 33-45.

[9] Hao, J., Yan Sun, and Hong Luo. "A safe and efficient storage scheme based on blockchain and IPFS for agricultural products tracking." J. Comput 29, no. 6 (2018): 158-167.

[10] Galvez, Juan F., Juan C. Mejuto, and Jesus Simal-Gandara. "Future challenges on the use of blockchain for food traceability analysis." TrAC Trends in Analytical Chemistry 107 (2018): 222-232.

[11] Franco, Maria A. "Circular economy at the micro level: A dynamic view of incumbents’ struggles and challenges in the textile industry." Journal of cleaner production 168 (2017): 833-845.

[12] Astill, Jake, Rozita A. Dara, Malcolm Campbell, Jeffrey M. Farber, Evan DG Fraser, Shayan Sharif, and Rickey Y. Yada. "Transparency in food supply chains: A review of enabling technology solutions." Trends in Food Science & Technology 91 (2019): 240-247.

[13] Blanchard, David. Supply chain management best practices. John Wiley & Sons, 2021.

[14] Wang, Shangping, Dongyi Li, Yaling Zhang, and Juanjuan Chen. "Smart contract-based product traceability system in the supply chain scenario." IEEE Access 7 (2019): 115122-115133.

[15] Tian, Feng. "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), pp. 1-6. IEEE, 2016.

[16] Aggarwal, Shubhani, and Neeraj Kumar. "Hyperledger." In Advances in Computers, vol. 121, pp. 323-343. Elsevier, 2021.

[17] Abdollahi, Alireza, KarimRejeb, AbderahmanRejeb, Mohamed M. Mostafa, and SuhaizaZailani. "Wireless sensor networks in agriculture: Insights from bibliometric analysis." Sustainability 13, no. 21 (2021): 12011.

[18] Latif, Shahid, Zeba Idrees, Zil e Huma, and Jawad Ahmad. "Blockchain technology for the industrial Internet of Things: A comprehensive survey on security challenges, architectures, applications, and future research directions." Transactions on Emerging Telecommunications Technologies 32, no. 11 (2021): e4337.

[19] Sundaresan, S., K. Suresh Kumar, T. Ananth Kumar, V. Ashok, and E. Golden Julie. "Blockchain architecture for intelligent water management system in smart cities." In Blockchain for Smart Cities, pp. 57-80. Elsevier, 2021.

[20] Babu, Subashini, and Hemavathi Devarajan. "Agro-Food Supply Chain Traceability using Blockchain and IPFS." International Journal of Advanced Computer Science and Applications 14, no. 1 (2023).

[21] Naz, Muqaddas, Fahad A. Al-zahrani, Rabiya Khalid, Nadeem Javaid, Ali Mustafa Qamar, Muhammad Khalil Afzal, and Muhammad Shafiq. "A secure data sharing platform using blockchain and interplanetary file system." Sustainability 11, no. 24 (2019): 7054.

[22] Fernandes, Diogo AB, Liliana FB Soares, João V. Gomes, Mário M. Freire, and Pedro RM Inácio. "Security issues in cloud environments: a survey." International journal of information security 13 (2014): 113-170.

[23] Berdik, David, SafaOtoum, Nikolas Schmidt, Dylan Porter, and YaserJararweh. "A survey on blockchain for information systems management and security." Information Processing & Management 58, no. 1 (2021): 102397.

[24] Kaur, Ravneet, Inderveer Chana, and Jhilik Bhattacharya. "Data deduplication techniques for efficient cloud storage management: a systematic review." The Journal of Supercomputing 74 (2018): 2035-2085.

[25] Suresh Kumar, K., and C. Helen Sulochana. "Local search five-element cycle optimized reLU-BiLSTM for multilingual aspect-based text classification." Concurrency and Computation: Practice and Experience 34, no. 28 (2022): e7374.

[26] Verdouw, Cor N., J. Wolfert, A. J. M. Beulens, and AgatheRialland. "Virtualization of food supply chains with the internet of things." Journal of Food Engineering 176 (2016): 128-136.

[27] Mondal, Saikat, Kanishka P. Wijewardena, SaranrajKaruppuswami, NityaKriti, Deepak Kumar, and Premjeet Chahal. "Blockchain inspired RFID-based information architecture for food supply chain." IEEE Internet of Things Journal 6, no. 3 (2019): 5803-5813.

[28] Gao, Robert X., Lihui Wang, MoneerHelu, and Roberto Teti. "Big data analytics for smart factories of the future." CIRP annals 69, no. 2 (2020): 668-692.

[29] Thibaud, Montbel, Huihui Chi, Wei Zhou, and Selwyn Piramuthu. "Internet of Things (IoT) in high-risk Environment, Health and Safety (EHS) industries: A comprehensive review." Decision Support Systems 108 (2018): 79-95.

[30] Jayabalan, Jayapriya, and N. Jeyanthi. "Scalable blockchain model using off-chain IPFS storage for healthcare data security and privacy." Journal of Parallel and Distributed Computing 164 (2022): 152-167.

[31] Lin, Qijun, Huaizhen Wang, Xiaofu Pei, and Junyu Wang. "Food safety traceability system based on blockchain and EPCIS." IEEE access 7 (2019): 20698-20707.

[32] Agarwal, Udit, VinayRishiwal, SudeepTanwar, RashmiChaudhary, Gulshan Sharma, Pitshou N. Bokoro, and Ravi Sharma. "Blockchain technology for secure supply chain management: A comprehensive review." IEEE Access (2022).

[33] Shahid, Affaf, Ahmad Almogren, NadeemJavaid, Fahad Ahmad Al-Zahrani, Mansour Zuair, and MasoomAlam. "Blockchain-based agri-food supply chain: A complete solution." Ieee Access 8 (2020): 69230-69243.

[34] Bollier, David, and Pat Conaty. "Democratic money and capital for the commons." In Commons Strategies Group Workshop Report, Berlin, Germany, pp. 8-10. 2015.

[35] Zhu, Qingyi, Seng W. Loke, Rolando Trujillo-Rasua, Frank Jiang, and Yong Xiang. "Applications of distributed ledger technologies to the internet of things: A survey." ACM computing surveys (CSUR) 52, no. 6 (2019): 1-34.