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An Overview of Blockchain Technology for Food Safety and Agribusiness

K Mohanappriya[1*], C Vennila[2]

[1]*Assistant Professor, Department of Computer Science and Engineering, Saranathan College of Engineering, Trichy, India.*
[2]*Professor, Department of Electronics and Communication Engineering, Saranathan College of Engineering, Trichy, India.*

[*]Corresponding author

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Abstract

Blockchain technology is one of the most important developments in various agricultural applications. These uses might be able to meet the various requirements for agricultural goods.In order to better understand the impact of blockchain technology on agriculture and food supply chain management systems, this article will first identify current issues, and then go into how to address them and how blockchain might help. Blockchain technology presents a viable way to support the development of an agri-foods system that is future-proof, superior, sustainable, and dependable. It uses the decentralized architecture to store the information that helps users and customers to have transparency on records. The data is stored in a distributed ledger that is tamperproof and immutable. Based on this, this study also investigates how blockchain technology can be used to safeguard and improve food products, noting that there is still potential for its use in supply chain optimization, traceability, farmer collaboration, and lower production costs.

Keywords: Blockchain Technology, Agriculture, Food Supply Chain Management.

1. Introduction

Cultivating plants and livestock for human use is known as agriculture. Agriculture was an important factor in the emergence of the sedentary human lifestyle. In order to feed the

people living in cities, food grains and plants were first cultivated many years ago. The primary means of subsistence for members of society is agriculture. The primary means of subsistence for people is agriculture, which gives them a means of income. Agriculture is the primary source of income for the majority of people living in rural areas. In India nowadays, farming is done using both contemporary and traditional ways. Traditional farming is characterized as an antiquated method of farming that makes use of labor-intensive, traditional knowledge, equipment, natural resources, organic fertilizer, and the farmers' long-standing cultural beliefs and rituals. Modern agriculture is a dynamic approach to farming technologies and techniques that support farmers in increasing productivity and minimizing the amount of natural resources—such as energy, land, and water—necessary to meet the world's demands for food, fuel, and fiber. As we all know, modern agriculture has increased food supply, increased food affordability, guaranteed food safety, increased sustainability, and increased production of biofuels. However, because it is predicated on a high input–high output strategy that makes use of hybrid seeds of high-yielding varieties along with copious amounts of irrigation water, fertilizer, and pesticides, it also causes environmental issues. Plantation agriculture Production and distribution of all fruits and vegetables, as well as goods derived from animals, are under the purview of food supply chain management (SCM). Producers, distributors, retailers, warehouses, suppliers, and consumers are all involved in the agriculture supply chain. Moreover, it covers operations, distribution, financing, marketing, and customer support in addition to new product creation. Production, trading, processing, and purchasing entities are arranged in a coordinated supply chain. Precision agriculture companies have found a huge opportunity to grow. The size of the worldwide agriculture supply chain management market is expected to increase significantly over the next several years, according to a report released by Allied Market Research. The market is expanding in multiple ways due to a number of causes, including a sharp increase

in the demand for agricultural products, the use of advanced farming techniques, a spike in the adoption of blockchain technology, government efforts, and more.A recent report by Grand View Research, Inc. predicts the precision agriculture market to reach $43.4 billion by 2025. The emerging new generation of farmers is attracted to faster, more flexible startups that systematically maximize crop yields. Blockchain's unique decentralized structure ensures that products and methods are validated, resulting in a transparent marketplace. In simpler terms, the application of digital technologies like as blockchain in the agri-food industry seeks to alleviate sustainability issues by raising profits and relieving strain on the various players in the agri-food ecosystem.To accomplish this, a literature review methodology was used. Firstly, introduced the keywords related to agriculture were identified. Then, recent publications (less than five years) were focused. The structure of this paper is as follows: Firstly, precision agriculture and supply chain management and were briefly reviewed. The third segment discusses the problems that are now facing agri-food technologies and offers solutions. In order to guarantee transparency and traceability across the agricultural supply chain, blockchain technology is employed in the fourth sector of agri-food processing. The fifth and final section summarizes expectations for the agri-food industries' use of blockchain technology.

2. Literature Review

2.1 Precision Agriculture

With regard to farm productivity, environmental impact, food security, crop losses, and sustainability, smart agriculture offers farmers a wide range of instruments to help them tackle many difficulties in agricultural food production. Agriculture technology has undergone multiple revolutionary eras in its evolution. Initially, the employment of tractors and ploughs, among other technologies, transformed agriculture and significantly increased

production [1]. To increase food production, high-yielding crop types and synthetic fertilizers were used during the later Green Revolution. Digitization has become the main topic lately. It entails incorporating artificial intelligence (AI), the Internet of Things (IoT), sensors, GPS, drones, and other technology into agricultural methods. Real-time monitoring, data collecting, analysis, and automated decision-making are made possible by digitization, which promotes more sustainable and productive agriculture. This digitization enables real-time monitoring, data collection, analysis and automated decision-making, leading to more efficient and sustainable agriculture. The processes taking place on a farm using smart agriculture are shown as in Fig 1.

- *Data Gathering*: The sensors installed at all critical places in the farm gather and transmit data about the soil, air, etc
- *Diagnostics:* The data collected is analyzed by the system and conclusions are made regarding the status of the object or process monitored. Potential problems get identified.
- *Decision making:* Based on the problems identified in the previous steps, the software platform and/or a human managing the platform decides on actions that need to be taken.
- *Actions:* The actions identified in the previous step are performed. A new measurement on the soil, air, moisture, etc is performed by the sensors and the whole cycle starts again.

The result from this automated smart farming process is – high precision and 24/7 control, eventually leading to considerable savings in all key resources used – water, energy, fertilizers, time spent by strategic people, time spent by lower-qualification human resources.[2] The ultimate goal is increasing the quality and quantity of the crops while optimizing the human labor used.

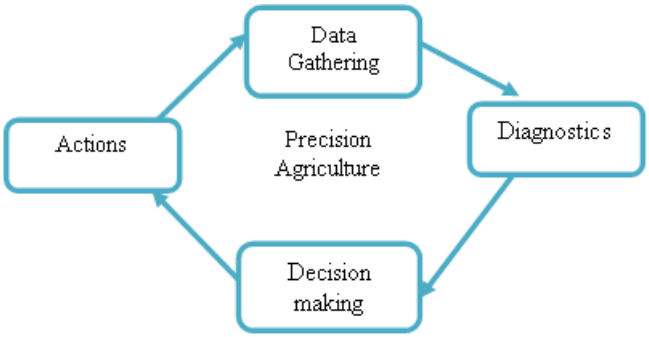

Figure.1. Precision Agriculture

2.2. Supply Chain Management

The term "supply chain" refers to the movement and flow of goods from manufacturers to ultimate consumers. A supply chain is a series of activities that occur both within and between several phases of a continuum, from manufacturing to final consumption, with the goal of satisfying end-user requirements. In addition to the producer and its suppliers, the supply chain may also comprise merchants, warehouses, carriers, transporters, and end users themselves, based on logistical flows [3]. More broadly, supply chains encompass marketing, operations, distribution, financing, customer support, and new product development. Supply chain management is an integrated process that creates value for the final customer or end user. However, because of the inherent issues with the agriculture industry, the supply chains for various agricultural commodities in India are rife with difficulties. The dominance of small marginal farmers, fragmented supply chains, lack of scale economies, low degree of processing /value addition, inadequate marketing infrastructure, etc. are some of the structural problems that define the nation's agri supply chain system.

Figure.2. Supply Chain Management

An organized, processing-based agri-supply chain is a component of a much more intricate network. The Figure 2 shows an organization-level generic supply chain in the framework of a whole supply-chain network. Every company is situated in a network layer and is a part of at least one supply chain, meaning that it typically has a number of different suppliers and customers both now and in the future [3].

2.3. The Key Components in Supply Chain Management

Supply chain management in agriculture includes fleet, inventory, and supplier management as essential elements that cooperate to keep agricultural products flowing smoothly from producers to consumers.

- *Fleet Management:* Transportation vehicles that are used to move agricultural products throughout the supply chain must be properly managed and coordinated.
- *Inventory Control:* Throughout the supply chain, agricultural items must be managed in terms of handling, storing, and transportation.
- *Supplier Management*: It is the process of establishing and preserving relationships with various suppliers of agricultural inputs and supplies.

In a Food supply chain network various stakeholders such as “Input supplier, Food producer (Farmer), Food processing units” or the food byproducts that are yielded at the time of processing the food or selling them to customer by verifying the process of attaining the desired quality and rate of food production by which a farmer gets profit by handing the crop to right destination at a given time span by making use of “government support where a farmer can sell his crop at any place and at his desired price without selling it to the middle man who controls the access of markets and this leads to the farmer to get poor prices”[4]. Since most farmers now sell their crops for less than the minimum support price, the

middleman is taking all of the farmer's income in the current situation. This means that farmers do not receive the maximum support price. The agroindustry's force chain operation has a bright future since new innovations and technologies are being developed to solve problems and improve the force chain.

3. Problems and Solution of Agri Food Chain Management

3.1. Current Issues of Agri Food Supply chain Management

The management of the agricultural supply chain is highly intricate and impacts food safety, sustainability, economic viability, and quality. The major challenges are weather dependence, its Elements like as temperature, rainfall, and sunshine have a significant impact on crop yields and quality. Supply and demand alignment is more difficult due to this uncertainty and then many agricultural goods are perishable, necessitating prompt processing and transportation to prevent spoiling [5]. Logistics and inventory management become more difficult as a result and next Variability is more difficult to standardize and maintain quality control when there are differences amongst agricultural goods in terms of size, taste, etc and With the rapid advancement of technology, seasonal demand, aging workforces, and skills gaps, agriculture frequently encounters labor shortages and finally sources, traceability, packaging, transportation, and other processes become more difficult when items must meet organic, environmentally friendly, or ethically derived criteria.

In order to manage the agri-food supply chain effectively, this article examines traceability-related difficulties and suggests using technological solutions like blockchain. It has the potential to improve traceability and transparency across the supply chain. This might guarantee fair pricing, lessen fraud, and enhance stakeholder participation.

3.2. Blockchain Technology in Agriculture

3.2.1. Overview

Blockchain technology provides a safe and secure decentralized ledger. While every computer connected to a network can operate as a single processing point, or master server, blockchain is often associated with distributed and decentralized systems, where the workload is divided among nodes in a distributed ledger. A decentralized system allows multiple nodes to share decision-making authority [6]. In the blockchain, there is a location called a block where data is stored. This block creates an immutable copy of the data, and because each block is linked to the next, the order of the blocks is maintained. Because different hashes are used between the linked blocks in the chain, if someone attempts to alter or corrupt the data of a particular block, changing its hash, this will cause a disruption in the cryptographic link. There will be a problem with data re-storage since the cryptographic link will be broken.One of the main features of blockchain technology, distributed peer-to-peer (P2P) networks are used to solve this issue. These networks significantly improve data storage technology over more conventional centralized models. A P2P distributed network is made up of many computers that are all connected to one another—either locally, wirelessly, or through cables. The more devices connected, the better. A peer-to-peer (P2P) network eliminates the need for a central server or point of storage to store and transfer data between its clients, or nodes, making the data less susceptible to loss or hacking. Through the use of the proper cryptographic key by all peers in a peer-to-peer blockchain network, the blocks of the chain can actually be copied across all of the network's computers, which could number in the thousands or millions.

Secure data storage is the goal of decentralized ledger systems like blockchain networks. Every transaction that takes place within its network is verified and documented.To get distributed nodes to agree on the blockchain's current state, it employs a consensus

mechanism that functions as a protocol. They guarantee consensus among all nodes regarding the legitimacy of transactions and the sequence in which they should be added to the blockchain.The widely used Proof of Work (PoW) consensus algorithm, which is based on the public permissionless blockchain utilized by cryptocurrencies like Bitcoin, can assist with this. For increased computational effort, it has been secured [7].

Another consensus-building technique The purpose of proof of stake (PoS) is to mitigate the problems of scalability and high energy consumption that come with proof of work (PoW). With various protocols and techniques intended to improve security, decentralization, and performance, each PoS implementation can differ greatly from the others. Because of this, Ethereum is now a more robust and capable platform for decentralized apps and smart contracts in the future.

A developer or user creates and deploys a smart contract on the blockchain. Code for the contract must be written and broadcast to the blockchain network in order for it to be deployed. Following deployment, the contract receives a distinct address on the blockchain. The blockchain nodes carry out the contract's code upon the fulfillment of its conditions. The blockchain's state is altered during execution, for example, when tokens are transferred or records are updated. There are various use cases for smart contracts. Supply chain management will be examined in this paper in order to track the flow of goods through a chain and make sure that every step is verified and recorded on the blockchain.

In terms of scalability, cost, and security, Ethereum faces considerable challenges from developers as well as users, despite the fact that it is a permissionless, public network that can only process a small number of transactions per second [8]. Ethereum smart contracts are prone to vulnerabilities and bugs. Considerable financial losses have been caused by well-known hacks and exploits.

The Hyperledger project, which serves as an umbrella project for open-source blockchain development based on private and permissioned blockchain, was introduced by the Linux Foundation in order to address these problems with blockchain technology. It works on a wide range of projects, such as Explorer, Sawtooth, Hyperledger Fabric, Indiana, and so forth. With a single source of truth, it offers data integrity while lowering data duplication and boosting security. Blockchains prevent fraud and data manipulation by requiring a quorum of members to approve any changes to the data.

One of the main advantages of the blockchain is that data contributed to it is permanently stored and distributed throughout the network. It is immune to corruption, manipulation, and hacking [9]. This proposed Hyperledger Fabric framework prioritizes trust, traceability, and transparency. The food industry may benefit from blockchain technology, which it has long lacked. Because of its immutable data, the system can offer trustworthy information about the provenance and state of each product or ingredient to manufacturers, suppliers, distributors, retailers, and customers.

It is expected that hyperledger fabric, which provides less traceability and transparency, will change force chain operations in the agriculture sector. Blockchain enables stakeholders to monitor the flow of goods in real time, from the ranch to the customer, preventing fraud and tampering. Moreover, waste reduction, fraud control, and improved food safety will all benefit from this technology. Blockchain, for instance, makes supply chains end-to-end traceable. Farmers can use shared data on a blockchain to track the origin, handling, and transit of the goods in real time. Additionally, it helps isolate disease outbreaks in crops and livestock and fosters consumer trust.

4. Proposed Framework – Hyperledger Fabric

A modular architecture-based framework with high levels of secrecy, resilience, adaptability, and scalability, Hyperledger Fabric is intended for distributed ledger applications. It is designed to handle the complexity and nuances of a financial ecosystem and enable pluggable installations of various components.

4.1. Hyperledger Fabric Model

The Figure 3 depicts a basic transaction flow diagram of the Hyperledger Fabric and lists the main components of the model [10].

- *Peer Nodes:* Peer nodes, which can be endorsers, committers, or anchor peers, are the nodes that manage the ledger, execute chaincode, and communicate with clients.
- *Ordering Service*: This group of nodes arranges and bundles transactions into blocks, which are subsequently sent to other nodes in the cluster for confirmation and committal to the ledger.
- *Membership Service:* This service manages the identities of participants in the network, including peers, orderers, and clients.
- *Consensus Service:* This service is responsible for achieving agreement on the order and validity of transactions among the nodes in the network.
- *Validation Service:* This service validates transactions submitted by clients, checking their syntax and verifying their authenticity.
- *Identity Service:* This service manages digital identities, including certificates and keys, and provides a means for nodes to authenticate each other.
- *Certificate Authorities:* These are trusted entities that issue and manage digital certificates used for identity and access control.
- *Client:* This is an entity that interacts with the network by submitting transactions to peer nodes for processing.

- *Endorser:* This is a peer node that endorses a transaction by executing the associated chaincode and verifying its correctness.
- *Committer:* This is a peer node that validates and commits transactions to the ledger.
- *Anchor Peer:* This is a special type of peer node that serves as a communication point for other nodes in the same organization.

The Transaction workflow of Hyperledger fabric as

- A client application submits a transaction proposal to peers within each organization for approval, starting the transaction flow.
- The peers confirm the identity and authorization of the submitting client to submit the transaction. The proposed transaction's outcome is then simulated, and if it turns out as expected, the client is sent an endorsement signature.

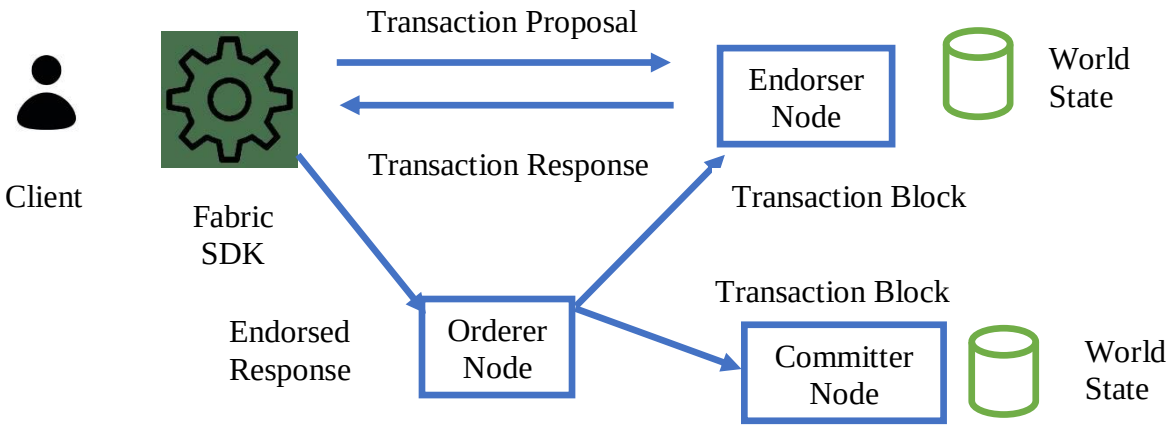

Figure.3. Hyperledger Fabric Simple Transaction Flow

- The client gathers peer endorsements and forwards the transaction to the ordering service after obtaining the required quantity of endorsements as specified in the endorsement policy.
- Finally, in order to comply with the endorsement policy, the ordering service verifies that the transaction has the required number of endorsements. The authorized

transactions are then grouped and sent to peer nodes within each organization in a chronological order.

- After receiving new transaction blocks from the ordering service, peer nodes validate each transaction in the block one last time. When this is finished, the ledger's state is updated and the new block is added. It is now committed to the new transactions.

Some key algorithms needed to function in the Hyperledger Fabric are

- *Consensus Algorithm:* The pluggable consensus model employed by Hyperledger Fabric enables the use of various consensus algorithms based on the needs of the network. A number of consensus algorithms are supported by the platform, such as Raft, Kafka, and Practical Byzantine Fault Tolerance (PBFT).
- *Membership Service Provider (MSP) Algorithm:* Hyperledger Fabric uses an MSP algorithm to manage the identities of participants in the network. The MSP algorithm allows different organizations to have different levels of access to the network, depending on their role and level of permission.
- *Chaincode Algorithm:* Hyperledger Fabric uses chaincode, which is a type of smart contract, to define the business logic of the network. Chaincode can be written in several programming languages, including Go, JavaScript, and Java.
- *Endorsement Algorithm:* Hyperledger Fabric uses an endorsement algorithm to ensure that transactions are valid and meet the requirements of the network. Endorsement policies can be defined by the network administrator to specify the required level of endorsement for a transaction to be considered valid.

The Hyperledger Fabric Model is used in the proposed framework as shown in figure 4 depicts as all stakeholders in the supply chain can access a safe, decentralized database of data created by the system using blockchain technology. Suppliers can upload product details, such as origin, shipping information, and handling protocols, to the Food Trust. An unchangeable record of the product's journey is then created by storing this data on the blockchain. Through a website or mobile app, retailers and customers can access this information, enabling them to trace the food's origin and confirm its authenticity[12].

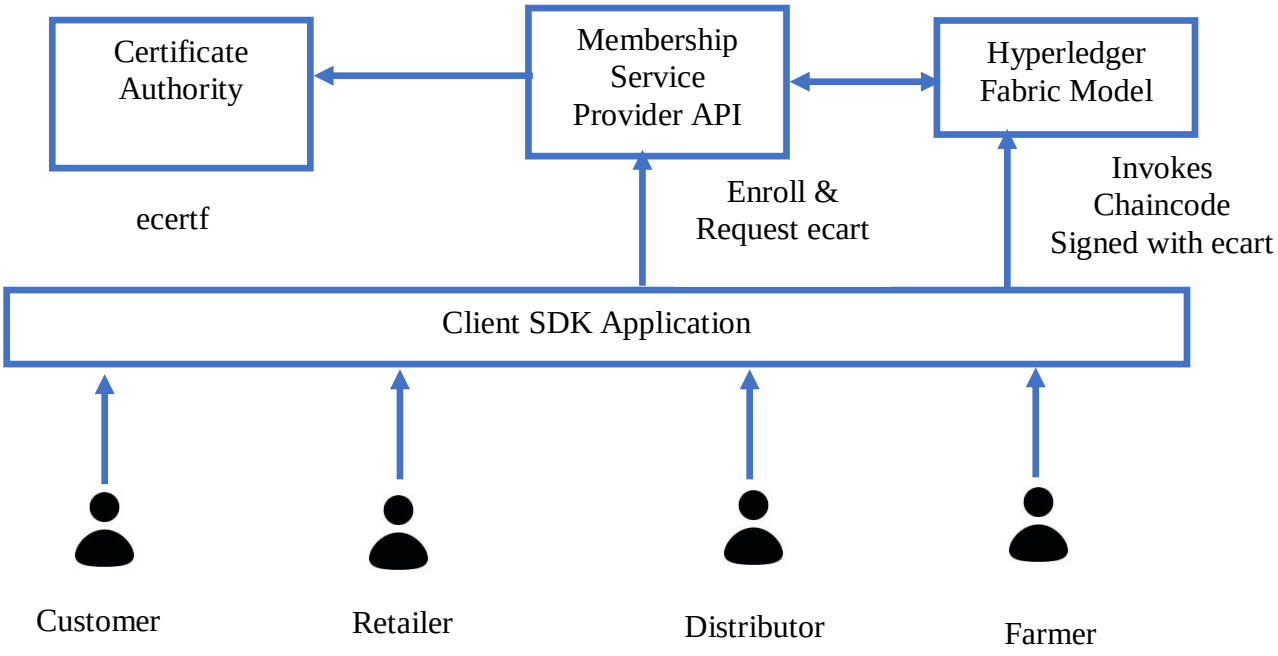

Figure.4. Hyperledger Fabric – Food Trust and Agribusiness Architecture

5. Conclusion

As blockchain technology continues to evolve, Hyperledger Fabric provides a robust, adaptable, and trustworthy foundation for enhancing food trust and agribusiness operations. Its ability to deliver traceability, transparency, efficiency, and trust makes it an invaluable tool for addressing the complex challenges of these sectors. As adoption grows and technology advances, Hyperledger Fabric will continue to play a crucial role in shaping the

future of food and agribusiness, ensuring safer, more efficient, and more transparent supply chains. It is well-positioned to support the future needs of the food trust and agribusiness industries. Advancements in IoT integration, AI-driven analytics, and more sophisticated smart contracts will further enhance the capabilities of blockchain solutions.

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