Blockchain Empowered Food Traceability: Enhancing Transparency and Securityin Supply Chain

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***Abstract*—The blockchain system designed for the food supply chain in the industry of supply chain management aims to elevate security and transparency throughout the entire process. system empowers authorized participants to seamlessly track product information at every phase, ensuring enhanced food safety, reducing fraud risks, and nurturing consumer confidence. By leveraging blockchain's immutable ledger, the system enables real-time product tracking, authentication, and safeguards against tampering or fraudulent activities. The system boosts confidence among consumers regarding product authenticity and quality while supporting regulatory efforts to enforce stringent food safety standards. Ultimately, this blockchain-based approach serves as a robust tool to fortify the integrity of the food supply chain, mitigating risks, countering fraudulent practices, and significantly reinforcing consumer trust in the safety and legitimacy of food products. The food industry faced a big problem in how it manages its supply chain. There were issues with disorganized data, not everyone having the same information, and problems keeping track of where products came from. This led to unsafe food, a lot of dishonest practices, and difficultiesin maintaining high-quality standards. This crisis damaged the trust of consumers and put public health at risk. To solve these problems, people started realizing that using blockchain technology in the food industry could help. Blockchain, which is like a secure digital ledger, could completely change how things are done. It could make sure we know exactly where our food comes from, prevent fake products, and reduce the risks of unsafefood. Blockchain's unchangeable nature means that everyone involved can see the same real-time information, making it easierto control and ensure the safety and quality of food.**

***Index Terms*—Food Supplychain, Security, Blockchain, Tracking, Ethereum, Ganache**

I. INTRODUCTION

Blockchain technology has emerged as a transformative tool in addressing critical challenges within the food industry, particularly in the realm of supply chain management, where ensuring food security is of paramount importance. In the context of the food sector, supply chain transparency, and traceability are indispensable elements to guarantee the safety and authenticity of products from farm to table. Blockchain, with its decentralized and immutable ledger system, offers a groundbreaking solution to these issues. By recording every transaction and movement of food products on a secure and transparent blockchain, stakeholders across the supply chain, including farmers, manufacturers, distributors, and retailers, can access real-time and tamper-resistant information. This notonly enhances accountability but also enables swift identification and mitigation of potential issues such as contamination or fraud. The implementation of blockchain technology in the food industry thus establishes a robust foundation for ensuring food security by fostering trust, minimizing risks, and providing consumers with reliable information about the origin and journey of the products they consume.

II. BLOCKCHAIN OVERVIEW

1) Definition of blockchain: It is known to be a string of encrypted data blocks where the blocks have the information that is the data, and the information is locked so that whoever has the key can access the information[6]. The chain consists of many documents related to each other and every of the documents consists of facts which includes a timestamp that speaks approximately whilst the information is created and the historical information about the blocks in the blockchain[7]. All the blocks collectively are called

the blockchain.

2) Blockchain infrastructure: Blockchain can only be accessed over a computer, laptop, or server connected to the internet. All the devices when connected are known as nodes of the blockchain. Blockchain is stored by the nodes and permission is given to certain users that will be discussed in the study of blockchain in the supply chain[8]. A ledger is created when the blockchain is stored across the nodes which are recognized as a system where the data is stored and shared across various sites, countries, or institutions[6]. Traditional databases are used to contrast the distributed ledger where the digital data is enclosed in a centralized location and blockchain, where the nodes store identical data.

3) Adding to the blockchain: To add data to the block of the blockchain, it is required to send a node out a transition request with the data that is added to other nodes of the network of the blockchain for the creation of the block[7]. It is necessary to agree to the addition of the new block to the blockchain before the block is added to the chain. At the time of the validation of the new block, the node mist confirms that the block is correctly formatted and there is no duplicate transaction in the block[9]. Once the block is validated, an encrypted block is added to the blockchain, and in the blockchain network; it is stored by the other nodes. Due to the encryption nature of the blockchain and disbursed ledger format, the facts at the blockchain aren't hackable and as a result, there is lots of acceptance as true and confidence in the data that is stored on the blockchain[10].

III. LITERATURE SURVEY

[1], here the focus is on demonstrating the potential of blockchain to optimize the food supply chain by preventing the duplication of crucial product information such as origin and certificates. The study likely delves into the application of blockchain technology within the context of the food industry, emphasizing its role in ensuring data integrity, transparency, and traceability throughout the supply chain.The study aims to show how blockchain can enhance the food supply chain by preventing the duplication of product information like origin and certificates and allows all actors to see transaction, which decreases latency.

[2], they examining the potential of blockchain to address global challenges within the food supply chain. The study likely explores practical applications of blockchain technology in this context and provides real-world examples where it is being tested.One challenge to address is resistance to change in existing supply chain systems. Introducing blockchain can face pushback from established practices and stakeholders. Hence reduces efficiency.

[3], the research underscores the potential of blockchain technology, particularly in the context of perishable goods like live fish within the cold supply chain. The authors likely explore the application of blockchain to enhance supply chain visibility, aiming to ensure the safety of perishable food products.Challenges with autonomous vehicles include tech complexity, regulations, and job impacts. Also, blockchain needs attention for security and scalability to manage supply chains effectively.

[4], the study centers on the deployment of a traceability model on the Hyperledger Fabric (HLF) platform. Notably, the research yields significant results, highlighting that the network maintains minimal response times even with an increased number of transactions. The maximum organizations that can be hosted in the network is 6 with low latency value.

[5], the study emphasized the utilization of the SHA256 algorithm for securing transactions between stakeholders within smart contracts. This cryptographic algorithm not only ensures the integrity of data but also provides a robust foundation for secure and transparent transactions in the agri-food supply chain. The use of peer-to-peer networks is also highlighted, reflecting a decentralized approach that contributes to the reliability and efficiency of the supply chain.The paper has a limitations of setup and adoption cost Expensive for small-scale farmers or underdeveloped regions.

[6], here the focus is on addressing challenges in food traceability and highlighting the potential applications of blockchain technology in this domain. The research likely provides insights into how blockchain can be effectively utilized at various phases of the food supply chain to enhance traceability.It has a litimitations of Lack of Technology in the adoption of Blockchain.

[7], the study delves into the application of blockchain technology to monitor and document the movement of products throughout the supply chain. It utilizes a

distributed ledger to record all transactions, emphasizing key themes such as compliance, immutability, traceability, and transparency.The slow progress of blockchain technology in the supply chain integration dilemmas, regulatory uncertainties, and ongoing tactical and technological issues.

[8], the emphasis lies in proposing a user-friendly interface for blockchain-based agri-food traceability. The study advocates for the creation of an accessible platform, simplifying the tracking process for both consumers and stakeholders. This approach aims to enhance transparency in the supply chain and cultivate trust among users. Challenges may arise from user unfamiliarity with blockchain, data privacy worries, scalability problems, and the necessity for broad adoption among food industry players.

[9], here the exploration centers on the latest trends and practical applications of blockchain technology within patent databases. The paper focuses on real-world use cases, intending to provide insights into the evolving landscape of blockchain innovation and its applications in intellectual property protection. Challenges include privacy and security concerns due to putting patents on a public blockchain, the fast-paced nature of blockchain making patents outdated, legal issues in patenting blockchain.

[10], the study investigates the factors and impacts of integrating blockchain technology into food supply chains. The authors propose potential avenues for future research, suggesting the exploration of synergies between blockchain and other technologies like AI, IoT, and Machine Learning to develop more robust solutions in the food supply chain.A drawback is that limited blockchain adoption in the food industry may restrict the applicability of findings to a broader range of supply chain situations.

[11], the study systematically evaluates the application of blockchain in supply chain management, conducting an analysis of its advantages, obstacles, and overall impact on transparency, security, and efficiency.A drawback is the high initial costs and technical challenges, which can deter smaller businesses with limited resources from using blockchain in their supply chain.

[12], the research explores the integration of blockchain, QR codes, and NFC technology to enhance the tracking of food in the supply chain. This innovative approach aims to simplify the monitoring process and could instill confidence in food safety practices for NGOs while fostering sustainability. Since different stack holders uses different platforms, The lack of standardization among stakeholders could make it hard to smoothly use blockchain, QR codes, and NFC in the supply chain.

[13], the focus is on implementing blockchain technology to establish a secure and immutable record of every stage in the food production and distribution chain, ensuring transparency and traceability from farm to fork. This strategy empowers stakeholders, including farmers, distributors, retailers, and consumers, with real-time access to information regarding the origin, quality, and safety of food products. Moreover, the use of smart contracts within the blockchain system is proposed to automate and streamline processes, mitigating delays and minimizing the risks associated with fraud or contamination.The limitations are the implementation of blockchain technology requires substantial infrastructure development, including access to reliable internet connectivity, which may be a challenge in certain remote or underdeveloped areas.

[14], the vision is set for a future where blockchain technology plays a pivotal role in enhancing food chain transparency, safety, and sustainability. The paper envisions blockchain as a solution capable of effectively tracking the journey of food products, improving quality control, reducing waste, and empowering stakeholders across the supply chain. However, the review acknowledges existing challenges such as scalability, cost implications, and regulatory hurdles that must be addressed for the realization of this transformative vision. The envisioned transformative role of blockchain in food supply chains faces challenges, including scalability issues, cost considerations, and regulatory complexities, which need to be effectively addressed to fully realize its potential.

A. . Research Objective

The purpose of the research is to discuss blockchain technology and how it can help logistics companies. Blockchain technology is a new technology, and most people are not familiar with this innovation. However, the paper has helpedthe readers to know about the introduction of blockchain technology and how it can help in supply chain management.

B. Research Question

- How can technology help to find a solution to

some ofthe supply chain challenges?
- How scalable applications can be created using Blockchain?

C. Research Motivation

In the field of the supply chain, there are a lot of products that are delivered to the customer that comprises independent farms. Because of those reasons, the commercial enterprise fails to compete as remoted companies, however, they're additionally part of the big delivery chain network. Moreover, companies are also encountering uncertainty challenges because of globalization and high expectations of the customer. There is also huge market competition and a complex supply chain that demands cooperation across the supply chains. Supply chains are fragmented due to inner opposition and confined records exchange. Apart from this, these constraints also have a huge influence on business performance and give rise to challenges and constraints like high operation costs and capacity storage that can be easily resolved by blockchain technology.

D. Research Gap

The blockchain era gives plenty of advantages however it's now no longer a complete answer inside the delivery chain control field. There are many troubles with blockchain-primarily based total generation and different associated technologies. The project must realize challenges in the supply change domain and the supply chain system that a blockchain-based system requires various legislative resolutions. Moreover, the prevailing blockchain platform fails to fulfill the excessive stage of transaction throughput requirement of the delivery chain system. The supply chain comprises diverse participants. Hence, it is necessary to provide incentives like efficiency gains to improve liquidity as well as data security so that the participants are well motivated.

IV. OBJECTIVES

a) Enhancing Security in the Food Industry Implement- ing blockchain technology creates an immutable ledger that records every transaction and movement within the supply chain. This transparency ensures the authenticity of food products by enabling stakeholders to trace each item's journey fromfarm to table. With cryptographic verification and timestampedentries, the system establishes a secure and tamper-proof record, minimizing the risk of counterfeit or contaminated goods entering the market.:

A. Mitigating Fraudulence

Mitigating Fraudulence: Blockchain's traceability significantly reduces the potential for fraudulent activities within thefood supply chain. Smart contracts can automate compliance checks, ensuring that products adhere to safety standards and regulatory requirements at each stage. Any attempt to manipulate data or introduce inauthentic products can be quickly identified and addressed, safeguarding consumer trust and the integrity of the supply chain.
Developing a Scalable Decentralized Application (DApp):Designing a decentralized application on the blockchain offers scalability and accessibility to all participants in the food supply chain. Utilizing decentralized storage and consensusmechanisms, the DApp can accommodate a growing network of producers, distributors, retailers, and consumers without compromising on performance or security. This scalabilityensures that the system remains robust as the industry expands. Creating an Efficient Application: The application's architecture prioritizes efficiency by streamlining processes and reducing redundancies. Through smart contracts and real-time data updates, stakeholders gain instant access to relevant information, optimizing inventory management, reducing delays, and minimizing waste. This efficiency not only benefits businesses by improving operational processes but also ensures fresher and safer products for consumers.
Implementing Blockchain Technology in Supply Chain Management (Food Industry): Integrating blockchain into supply chain management revolutionizes the food industry by introducing a transparent, trust-based ecosystem. Each node inthe supply chain, including farmers, processors, distributors, retailers, and end consumers, can securely access pertinent information regarding product origins, handling, and quality. This implementation empowers consumers to make informed choices while fostering accountability and integrity amongindustry participants.

B. Figures

The blockchain-based application provides a

comprehensive solution for the supply chain. It begins with the organization owner registering the supply chain actors into the decentralized application by the smart contract. Smart contracts are typically used to automate the execution of an agreement so that all participants can be immediately certain of the outcome, without any intermediary's involvement or time loss. After the contract is created, it is then deployed into the blockchain. In later stages, if the actors are to be added to the blockchain system then the owner must verify the actor and add them to the chain. The system consists of various stages which show the status of the product.

The farmer registers the product on the blockchain system. The manufacturer receives the raw material from the farmer and confirms the order on the blockchain system. The manufacturer updatesthe product data on the blockchain system. The supplier receives the product from the manufacturer and acknowledgesthe data on the blockchain system. The supplier updates the warehouse data on the blockchain system. The retailer buysthe product from the supplier and acknowledges the data on the blockchain system. The retailer updates the data on the blockchain system. The regulatory authority supervises and authenticates the food products on the blockchain system. Theconsumer buys the product from the retailer and can request information about the product from the blockchain system.The use of blockchain technology in this system makes it possible to track food products from farm to table. This can help to improve food safety and transparency and to build trust between consumers and producers.

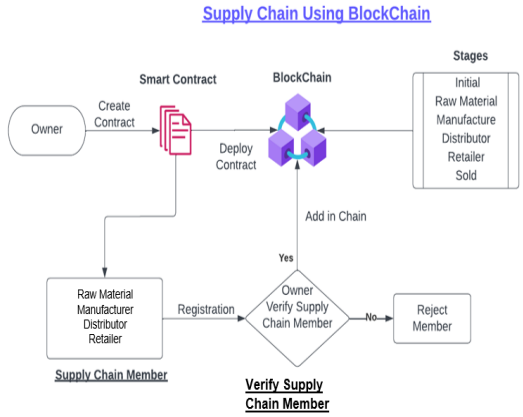

Fig.Flow diagram

The journey of food products from farm to table begins with farmers transferring raw materials to manufacturers while registering product information on the blockchain. Manufacturers then update product status, such as processing stages and quality checks, on the blockchain. Finished products are transferred to suppliers based on demand, and suppliers update warehouse data, including product availability on the blockchain. Retailers receive products from suppliers for sale and provide product status information to consumers. Regulatory authorities supervise and verify product information on the blockchain, conducting quality checks to ensure food safety. Consumers can request verification of product information from regulatory authorities, promoting transparency and trust in the system.

The Modules used within the project are:

Supply Chain Management: This module encompasses the overall process of managing the flow of goods and information from the farmer to the consumer.

Blockchain: This module serves as a decentralized, secure, and transparent ledger that records all transactions and product information within the supply chain.

Actors:

Farmer: The producer of the raw materials (agricultural products).

Manufacturer: The entity that processes the raw materials into finished products.

Supplier: The entity that stores and distributes the finished products.

Retailer: The seller of the products to consumers.

Consumer: The end user of the products.

Regulatory Authority: The government body responsible for overseeing food safety and quality standards.

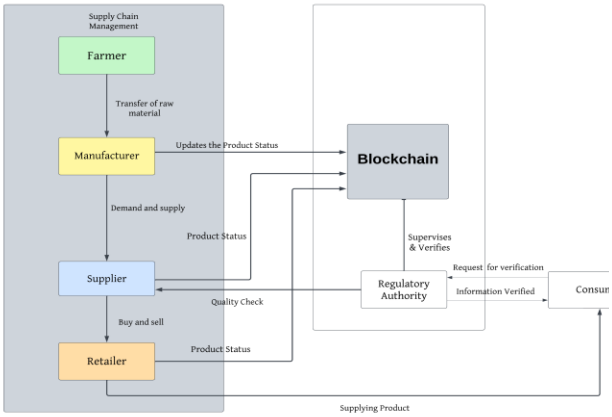

Fig. Architecture

Consumer: The consumer buys the product from the retailer and can request information about the product from the blockchain system.

The farmer registers the product on the blockchain system. The manufacturer receives the raw material from the farmer and confirms the order on the blockchain system.

The manufacturer updates the product data on the blockchain system. The supplier receives the product from the manufacturer and acknowledges the data on the blockchain system.

The supplier updates the warehouse data on the blockchain system. The retailer buys the product from the supplier and acknowledges the data on the blockchain system. The retailer updates the data on the blockchain system. The regulatory authority supervises and authenticates the food products on the blockchain system. The consumer buys the product from the retailer and can request information about the product from the blockchain system.

The use of blockchain technology in this system makes it possible to track food products from farm to table. This can help to improve food safety and transparency and to build trust between consumers and producers.

Here are some of the benefits of using blockchain for food traceability:

➢ Improved food safety: Blockchain can help to improve food safety by providing a tamper-proof record of the food's journey from farm to table. This can help to identify and prevent foodborne illnesses.

➢ Increased transparency: Blockchain can help to increase transparency in the food supply chain. This can give consumers more confidence in the food they eat.

➢ Reduced food waste: Blockchain can help to reduce food waste by making it easier to track and manage food inventory.

➢Improved efficiency: Blockchain can help to improve efficiency in the food supply chain by automating tasks and processes.

Overall, blockchain has the potential to revolutionize the food industry by making it more safe, transparent, and efficient.

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VI. CONCLUSION

The proposed blockchain-based system stands as a robust and innovative solution to the multifaceted challenges plaguing the food supply chain. By harnessing the power of blockchain technology, the system creates an unalterable and transparent ledger, meticulously documenting each stage of a food product's journey through the supply chain. Authorized participants, from farmers to retailers, gain access to this decentralized ledger, ensuring a shared and verifiable record. The system's primary objectives include enhancing security by establishing cryptographic verification and timestamped entries, thereby minimizing the risks associated with

counterfeit or contaminated goods. The integration of smart contracts adds a layer of automation to compliance checks, ensuring that safety standards and regulatory requirements are consistently met. This not only makes the way things move through the supply chain smoother but also helps stop dishonest actions, keeping consumers' trust safe. Moreover, the emphasis on developing a scalable decentralized application underscores the commitment to accommodating the growing network of industry participants without compromising on performance or security. In essence, this proposed solution seeks to revolutionize the food supply chain, fostering transparency, security, and efficiency, ultimately restoring confidence among consumers and stakeholders alike.

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