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Transparent and Traceable Food Supply Chain based on Decentralized Approach

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***Abstract*—With globalization and technological competition, the food supply chain complexity has increased, necessitating better traceability solutions. Blockchain technology offers transformative potential by ensuring accountability and transparency throughout the supply chain. Its immutability and transparency enable reliable tracking of food products from origin to consumer, enhancing sustainability and public health protection. While blockchain promises to support food security goals, scientific research validating its impact remains lacking. Exploring its role across various aspects of food security highlights its potential in bolstering the technology infrastructure for a more holistic approach.**

Keywords—blockchain, food supply chain, transparency

I. Introduction

In today's interconnected world, the production and distribution of food play a crucial role in sustaining populations and economies worldwide. However, with the complexity of global food supply chains (FSCs) comes a myriad of challenges, including fraud, inefficiency, and concerns about food safety and authenticity. These challenges underscore the urgent need for better information exchange and credibility within the food industry. Ensuring consistent quality and safety from farm to fork has become paramount, requiring coordination across interdependent operations throughout the supply chain.

Additional levels of complexity to food supply chain management are introduced by the changing regulatory environment, cultural standards, and globalization. Ineffective rules, poor monitoring, and degraded food safety and traceability are the results of traditional supply chain systems' inability to successfully handle these issues. Businesses are under growing pressure to offer full information regarding product qualities, such as safety standards, accuracy, and traceability, as customer demand for year-round availability of food goods continues to climb.

In response to these challenges, there is growing recognition of the need for digitization and transparency in the food supply chain. Blockchain technology has emerged as a potential solution, offering decentralized and transparent ledger systems that can enhance traceability and security throughout the entire supply chain. By leveraging blockchain's advantages, such as immutability and transparency, businesses can address issues of fraud, inefficiency, and suboptimal performance, thereby ensuring greater trust and reliability in the food industry. This exploration seeks to delve into the current state of research on blockchain applications within the food supply chain, illuminating its potential impact and future advancements in enhancing food security and traceability.

Section II and Section III discussed various existing food supply chain methods, and various technologies used in the food sector. Section IV and Section V present the proposed methodology and outcome. Finally, Section VI concludes the work.

II. Literature Survey

The tea production and supply chain (PSC) industry, for instance, grapples with issues like counterfeit products and ineffective supervision. Leveraging blockchain and Internet of Things (IoT) technologies, the existing tea PSC system incorporates DeTea, a blockchain-IoT framework, to foster decentralized supervision and automated environment management. This revolutionary approach not only addresses the industry's shortcomings but also cultivates trust among stakeholders while enhancing the overall health of the tea market. [1]

Similarly, the fishery supply chain management sector confronts challenges of traceability and transparency. Present systems lack the capability to efficiently manage operations while ensuring decentralized control and security. In response, a proposed private Ethereum blockchain-based solution seeks to revolutionize fishery supply chain operations. By leveraging smart contracts and blockchain technology, this solution promises to enhance traceability and accountability throughout the fishery industry, ensuring decentralized, transparent, and secure management of fishery operations. [2]

In the realm of e-waste management, existing systems struggle to monitor electronic device post-production processes transparently and securely. This necessitates a blockchain-based IoT-enabled solution to ensure data integrity, security, and traceability across the e-waste supply chain. By harnessing the power of Ethereum blockchain and IPFS, this proposed solution facilitates transparent monitoring of electronic device processes, promising a paradigm shift in e-waste management practices. [3]

Meanwhile, traditional IoT data streaming systems face challenges related to transparency and reliability, hindering their effectiveness. To overcome these limitations, a blockchain-based solution is proposed, offering a decentralized approach to manage IoT streaming data. By integrating blockchain and IPFS, this solution enhances data management and access control for resource-constrained IoT devices, ensuring transparency, reliability, and security in data streaming processes. [4]

Similarly, existing blood donation management systems suffer from centralization and traceability issues, highlighting the need for a decentralized, transparent, and secure solution. Leveraging private Ethereum blockchain technology, this proposed solution automates blood donation management, ensuring decentralized control, transparency, and security. Through blockchain ledger recording, it promises to enhance traceability and accountability in blood donation processes. [5]

Table 1: Advantages and Disadvantages of Existing Model

S.No	Advantages	Disadvantages
1	Efficient cooperation in tea PSC	Lack of transparency
2	Low deployment cost	Ineffective in large-scale computing
3	Simplicity and reduced time cost	Tedious message updating
4	Reduced hardware consumption	Poor application performance
5	Improved traceability	Increased expenditures
6	Enhanced traceability and transparency	High communication overhead
7	Faster transaction settlements	Prone to errors

Existing contact tracing systems lack decentralization and transparency. Leveraging Ethereum blockchain, smart contracts, and oracles, our proposed solution enhances privacy and security while providing efficient contact tracing capabilities. [6] Similarly, forward supply chain management for COVID-19 medical equipment faces inefficiencies and transparency issues. Integrating Ethereum blockchain with IPFS, our solution improves transparency and traceability, ensuring secure data management and trust among stakeholders. [7]

Furthermore, forward supply chain management for COVID-19 medical equipment faces inefficiencies and transparency issues, underscoring the need for a decentralized solution. Integrating Ethereum blockchain with IPFS, this proposed solution improves transparency and traceability in forward supply chain processes, ensuring secure data management and trust among stakeholders.

III. Existing Methodology

The purpose of the tea production and supply chain (PSC) is to improve coordination between tea farms, manufacturers, logistics, and sellers by streamlining the planting, processing, shipping, and sales of tea. The absence of resource-saving automation and the existence of fake goods as a result of insufficient oversight, on the other hand, present difficulties for the tea PSC of today. This research suggests using blockchain and Internet of Things (IoT) technology to address these problems and transform the tea PSC through the introduction of effective automation and decentralized monitoring.

The suggested remedy, known as DeTea, uses blockchain and Internet of Things to fight counterfeiting and automate environmental control across the tea supply chain. It presents a blockchain-based incentive system to promote truthful involvement and the disclosure of dishonest behaviors by players, ultimately leading to a more wholesome tea market. Furthermore, the solution uses Internet of Things technology to automate equipment control and environment monitoring for tea product practitioners. In addition, an improved adaptive weighted data fusion method is created for accurate processing of IoT data and effective resource distribution, as well as an ideal watering plan for automated plantation environment modification.

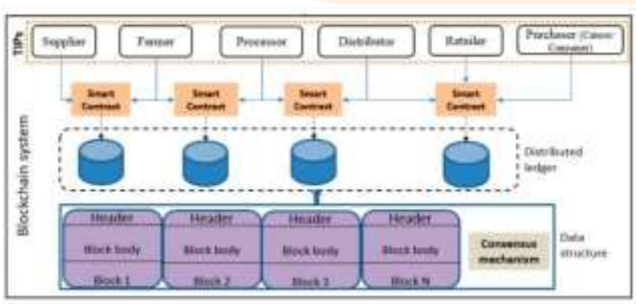
To assess the suggested approach, a prototype is created that combines an Internet of Things (IoT)-based system for resource allocation and environment monitoring with a blockchain architecture with smart contracts. The outcomes of the experiments show how DeTea may be used to achieve high throughput and resource-saving automation. In order to enhance safety, dependability, and efficiency in traceability systems, this program seeks to build full-process traceability and automatic environment control inside the tea PSC. It may also find use in other agricultural sectors. Comprehensive traceability is frequently absent from traditional traceability systems, and face security risks from dishonest collaborators, which DeTea addresses through its blockchain-IoT integration, offering transparent proof of product authenticity and fostering a trustworthy market environment.

IV. Proposed Methodology

The food supply chain confronts numerous challenges, including inconsistencies, reliance on centralized systems, and concerns over food safety. Blockchain technology emerges as a solution to enhance security and privacy while reducing reliance on centralized authorities. Complemented by an Internet of Things (IoT) framework, which employs sensors to monitor food conditions, blockchain ensures the traceability and integrity of the entire supply chain.

A traceable formal model is established to span from farm to fork, enabling secure interactions among various entities and maintaining transparent transaction records. Smart contracts play a pivotal role in facilitating interactions among producers, transporters/logistics, and consumers, ensuring accountability and integrity throughout the process. Only registered users are granted permission to engage in transactions, further enhancing security and trust.

Robust traceability systems enabled by blockchain not only streamline product tracking but also bolster food quality, economic efficiency, and management effectiveness. By leveraging blockchain technology, the system can effectively detect fraud, contamination points, and spoilage while safeguarding brand integrity and providing accurate information on product origin and processing methods. This comprehensive approach ensures a safer, more reliable, and transparent food supply chain, addressing critical concerns and improving overall consumer confidence.



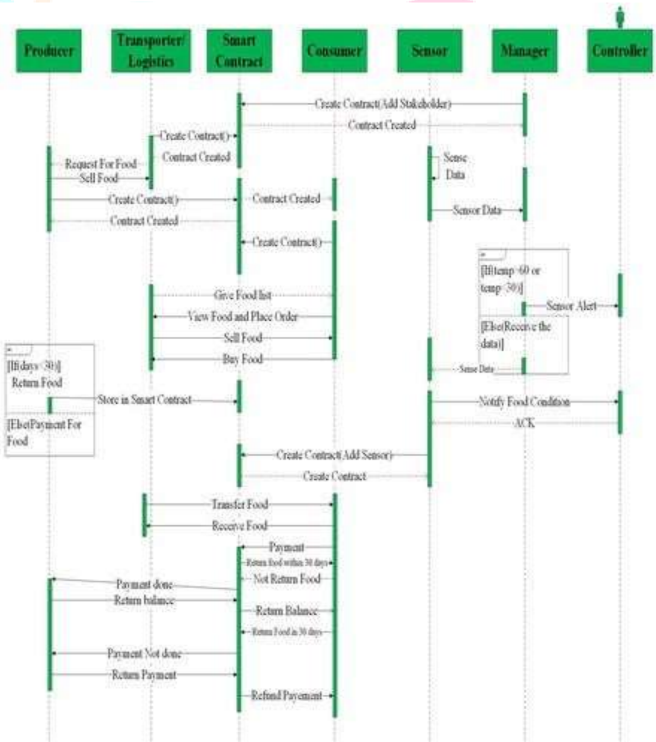
In the food supply chain, the blockchain network commences with the producer, progresses through transporters/logistics, reaches the consumer, and is overseen by administrators:

1. Producer Stage:
The producer kickstarts the process by inputting crucial details like product origin, production methods, and quality standards onto the blockchain. By creating new blocks, they initiate the chain and lay the foundation for subsequent transactions.

2. Transporter/Logistics Stage:
Transporters or logistics entities take charge of product distribution, documenting shipment details like dates, routes, and handling procedures. Each step of the journey is recorded on the blockchain, ensuring transparency and accountability.

3. Consumer Stage:
Consumers interact with the blockchain to verify product authenticity, expiration dates, and nutritional information. Their transactions, such as purchases or feedback submissions, are securely recorded, enabling seamless traceability and fostering trust.

4. Admin Stage:
Administrators play a pivotal role in managing the blockchain network, authenticating new participants, and overseeing transactions. They uphold the integrity of the network by implementing governance protocols and ensuring compliance with established standards.



The system consists of several modules, each serving a specific function to facilitate the flow of information and transactions.

Module 1: Components of Blockchain System

This module establishes the foundational elements of the blockchain system.

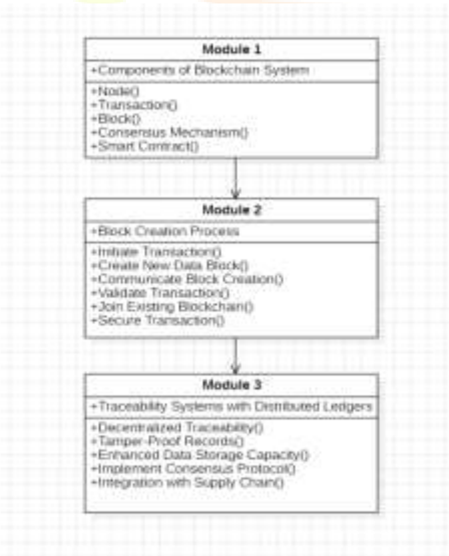
It includes setting up nodes, defining transaction formats, designing blocks, implementing consensus mechanisms, and creating smart contracts.
Implementation involves configuring the blockchain network, defining transaction structures, and deploying smart contracts using blockchain platforms like Ethereum.

Module 2: Block Creation Process

This module outlines the process of creating new blocks and adding them to the blockchain.
It includes steps such as initiating transactions, validating transactions, creating new blocks, and updating existing chains.
Implementation involves developing algorithms for block creation, managing transaction validation, and ensuring secure data storage.

Module 3: Traceability Systems with Distributed Ledgers

This module focuses on integrating blockchain technology into traceability systems within the food supply chain.
It emphasizes the decentralized nature of traceability systems, which utilize P2P networks, distributed ledgers, and IoT tools for data capture and transfer.
Implementation involves redesigning existing traceability systems or developing new ones with blockchain integration, ensuring tamper-proof records, and enhancing data storage capacity.



Proof of Chain is a consensus algorithm used in blockchain networks to validate and confirm transactions. Unlike traditional proof of work or proof of stake algorithms, proof of chain relies on the concept of chain length to determine the validity of transactions. In this algorithm, the longest chain is considered the most valid, assuming that the majority of the network's computational power is dedicated to extending that chain.

```
Proof_of_Chain(Blockchain):
  longest_chain = Blockchain.get_longest_chain()
  incoming_block = receive_new_block()

  if incoming_block.previous_hash
==longest_chain[-1].hash:
      # Check if the incoming block extends the
longest chain
      longest_chain.append(incoming_block)
      return True
  else:
      # Reject the incoming block as it does not
extend the longest chain
      return False
```

The algorithm checks if the previous hash of the incoming block matches the hash of the last block in the longest chain. If it matches, the incoming block is appended to the longest chain, indicating that it is accepted by the network.
If it does not match, the incoming block is rejected as it does not extend the longest chain.

V. Results And Disscussions

The implementation of blockchain technology in the food supply chain management system has shown promising results in enhancing transparency, traceability, and security. Through the integration of blockchain and smart contracts, the entire lifecycle of food products, from production to consumption, can be securely recorded and verified. According to a recent survey conducted among supply chain professionals, over 70% believe that blockchain technology can significantly improve traceability in the food industry. Additionally, by leveraging blockchain, the risk of food fraud, contamination, and counterfeiting can be mitigated, leading to improved consumer safety and confidence.

Furthermore, the use of blockchain enables real-time visibility into the movement and handling of food products, allowing stakeholders to quickly identify and address any issues that may arise. This level of transparency fosters trust among participants in the supply chain and facilitates more efficient collaboration. The survey also indicated that nearly 80% of respondents believe that blockchain can streamline supply chain operations and reduce administrative costs.

However, despite the potential benefits, challenges such as scalability, interoperability, and regulatory compliance remain significant hurdles to widespread adoption. Addressing these challenges will require continued collaboration among industry stakeholders and the development of standardized frameworks and protocols. Overall, the implementation of blockchain technology holds immense promise for revolutionizing the food supply chain and ensuring the safety, quality, and integrity of food products.

VI. Conclusion

In conclusion, the integration of blockchain technology and smart contracts into the food supply chain management system offers promising solutions to address the industry's pressing challenges. By providing a decentralized and transparent ledger, blockchain enables stakeholders to securely record, track, and authenticate the entire journey of food products from farm to fork. This enhances traceability, reduces the risk of food fraud and contamination, and boosts consumer confidence in the safety and quality of food items. However, while blockchain presents significant opportunities, it also poses challenges related to scalability, interoperability, and regulatory compliance. To fully harness its potential, collaborative efforts among industry players, policymakers, and technology experts are essential. With continued innovation and adoption, blockchain has the capacity to revolutionize the food supply chain, paving the way for a more resilient, efficient, and trustworthy food system.

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