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A smart contracts and tokenization enabled permissioned blockchain framework for the Food Supply Chain

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Abstract. The food supply chain is gaining a lot of attention these days. Due to the relativity of the food supply chain with human health directly, focusing on its problems and issues has become the need of the hour. Several issues like food safety, food contamination, and adulteration, food losses are some of the issues. Among these issues, food losses are critically important as they affect sustainable development as well. Among the several critical causes of this food loss problem, handling losses are most important and are very less studied. Handling losses are important as the causes of these losses are controllable and can be easily mitigated with the help of science and technology. This research is an effort in the defined direction. With the help of technology like blockchain and its capabilities, the authors in this study developed a framework for the food supply chain that if implemented can help in reducing handling losses.

Keywords: Food Supply Chain, traceability, blockchain, smart contracts, tokenization

1. Introduction

Food loss or Food waste is the biggest problem these days. There are several causes of food losses. These food losses can be categorized into harvesting loss due to mechanization, production practices, moisture, season and temperature, etc., storage losses due to deterioration, shrinkage, spoilage, moisture and time, etc., processing losses due to shrinkage, poor handling, packaging failures, transportation, etc., packaging losses due to packaging failures and transportation, etc., distribution and sales losses due to supersizing, poor inventory, dented cans, and temperature, etc., and consumption losses at customer end due to leftovers, impulsive buying, bulk purchases, and functions or parties, etc. [1]. If sets of all the causes of the losses are created and the

intersection point of maximum causes are determined, only some of the factors will be revealed as responsible for losses. Among these two issues are pretty evident i.e., transportation issue and handling issue. But as these issues are indirectly connected to other issues as well so there is a strong need to develop a solution that can mitigate this cause of food losses and have a significant impact on other causes for reducing food losses as well.

This improper handling is evident at various stages of the food supply chain. From the beginning i.e., procurement to distribution including storage at collection center or warehouse or depo or retail store, and during transportation, at all steps, there are some food losses due to human negligence or due to lack of automation [2]. Considering this problem, there is a strong need to cater to this condition and use technology like blockchain technology which has the power of transparency, trust, and most importantly immutability. Further smart contract also helps an organization to maintain the standards within limits.

This study focuses on the same problem and discusses a framework to reduce the effect of this problem. The paper is constructed as follows: Section 2 discusses the related works done in this area and proposed work, section 3 focuses on the description of the proposed framework followed by section 4 discussing academic, managerial, and future research implication related to the framework. The Paper concludes with the last section followed by the references.

2. Related Work

The smart food supply chain relies on the applicability of several advanced techniques such as IoT, Big Data, Cloud and Fog Computing, Artificial Intelligence (AI), and the most related one i.e., blockchain [3]. Blockchain has the power of creating transparency, trust by providing immutable records in a distributed ledger [4]. Due to its functionality, blockchain proves to be the most secure platform for creating supply chain visibility.

Blockchain powers the digitalization and also helps in improving the tracking and tracing capability of the food supply chain which not only enhances the provenance but also creates trust among the stakeholders. Blockchain enhances the information transactional and automational characteristics that also help in enhancing the predictive analytical capability of the stakeholders in the food supply chain [5]. This technology after getting information like temperature, humidity, production images, and other related variables, stores the information in a distributive ledger. Fig 1 shows the blockchain and its relevance with smart contracts.

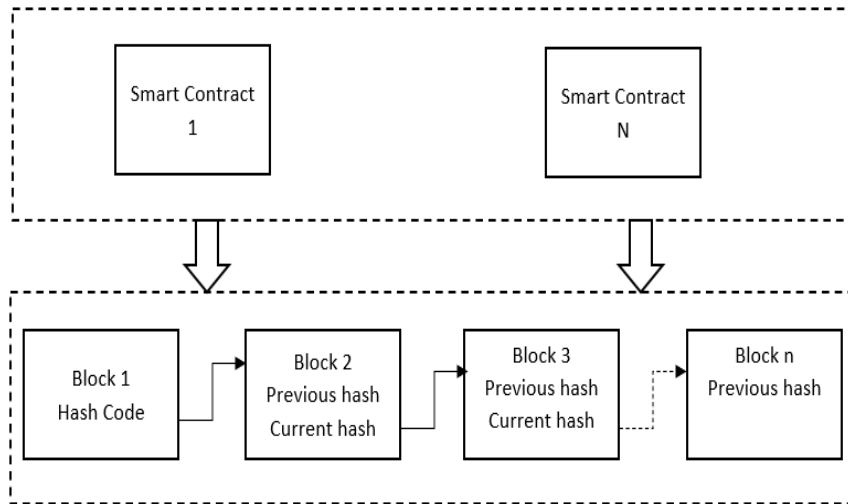


Fig 1. Smart contract and the blockchain

The use of smart contracts and tokenization adds to the efficiency of the system. Smart contracts are simply a programmed or automated agreement which triggers an action, whenever a defined variable measure beyond limits [6]. These smart contracts normally trigger a penalty or reward mechanism. To maintain this penalty and reward, there must be some digital currency or cryptocurrency. Creating this digital or cryptocurrency is known as the tokenization concept. This tokenization depends on the nature of the blockchain and the algorithm used for the consensus mechanism. Literature discusses permissioned or private and public blockchain. Classic case of blockchain i.e., bitcoin is an example of public blockchain where token was in the form of bitcoin [7]. A private or permissioned blockchain is mostly used by a closed user group where people can transact among themselves. The consensus mechanism in the public blockchain is very complicated and hence reduces the transaction speed due to a large number of stakeholders involvement whereas a private blockchain has a limited number of stakeholders involved that increases the efficiency and speed of the transactions. For the consensus mechanism of transaction, there are several algorithms like proof of work and proof of stake. The selection of these algorithms also helps in the overall performance of the blockchain. Since all the data is stored at all the nodes, it increases the space and time requirements. Therefore, proof of stake is preferred over the proof of work as it requires lesser space and time.

Many authors have reported the use case of blockchain in the food supply chain. AgriblockIoT is a fully decentralized blockchain-based traceability solution for the agri-food supply chain but lacks the safety and security aspect of the food product which is

highly required for perishable products [8]. Using smart contracts is also evident in the literature as a study focused on information asymmetry and using long short-term memory a deep learning network developed a credit evaluation system for farmers which enhances reliability and authenticity of information among the traders, this study lacked the product safety variables [9]. Another study focused on Chinese markets and tried to solve food safety issues by addressing the food traceability problem. This study again lacked the smart contract and tokenized approach [10]. Another study focused on RFID tags and blockchain technology to enhance the agri-food supply chain traceability in China. The study provided the building process of this system [11] but the study lacked the penalties mechanism which acts as a reinforcement technique for the betterment [12]. A study focused over-application of blockchain and other necessary conditions and discussed the boundary conditions along with standardization and data governance related to information sharing [13]. Another study focused on RFID-based information architecture where a proof of object authentication protocol is used which is analogous to the proof of work protocol. Also, the author conducted a detailed security analysis to test the vulnerability from cyber-attacks [14]. Another author in his study discussed blockchain-based agri-food supply chain and authored it as a complete solution where authors focused on the need for a reliable system and recorded transaction to the blockchain which uploads the data to interplanetary file storage system (IPFS). Also, the study includes smart contracts for security and vulnerability analysis but unfortunately, it lacked the provenance aspects of the food products.

Therefore, after reviewing the related work in the literature, the author here proposes a study providing a framework that focuses on smart contract and tokenization enabled permissioned blockchain-based smart food supply chain fulfilling all research gaps evident in our review for the related work.

3. Proposed framework

The given framework is a conceptual framework of a permissioned blockchain where consent for every transaction will be given by the manager as a consensus mechanism. Framework consists of farmers or producers termed as 'F', collection centers for collection purposes from F, storage centers to be used as the hub for distribution to stores termed as 'S'.

3.1 Smart Contract and Tokenization enabled Blockchain-based smart food supply chain system

Blockchain technology is a distributed ledger technology that records the transactions among various nodes. Hence here transactions are done among the stakeholders, who are acting as a node, and a self-developed cryptocurrency called tokens is used for circulation in the supply chain.

Smart contracts are programmed contracts with defined limits of variables, if at any point of the supply chain, the variable value goes beyond the limit; it will trigger the penalty to be imposed on the concerned stakeholder of the supply chain. This penalty will be compensated by paying the additional tokens. Hence here a proof of stake algorithm will be used, it will record the transactions in the blocks. It also makes the system more efficient and robust as it will help in reducing the time and space complexity of the system.

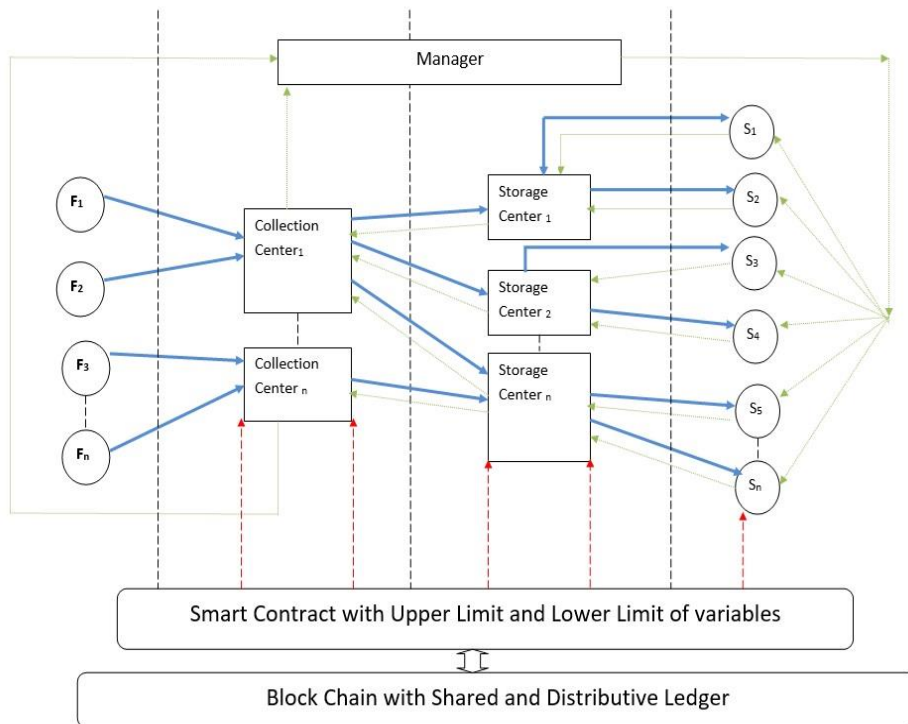


Fig 2. Smart contract enabled permissioned blockchain framework

3.2 Framework Description

In the framework shown in fig 2, Blue (solid) arrows represent the flow of goods, green (dotted) arrow represents the flow of cryptocurrency or tokens and red (dashed) arrow represents the point of smart contracts. Location, Temperature, etc. are the variable that can be monitored and act as triggering variables for smart contracts.

As per the budgetary calculation, Supply Chain Manager will send or allot cryptocurrency or tokens to the stores for purchasing purposes and physical currency to the collection centers for payments to the seller. The physical currency will be issued against the cryptocurrency or tokens, centers will return to the manager. Farmers or sellers will approach defined centers to sell their perishable produce with defined standards. Designated centers will collect the product, monitors the variables either

using IOT devices or some other devices and pay farmers or producers accordingly with the permission of the manager. This transaction along with the variables will be noted in the distributed ledger of the supply chain which is with every stakeholder of the supply chain. Store-based on their demand forecasts will place the order to the storage center and will initiate the transaction. The storage center based on order will complete the transaction by receiving cryptocurrency and releasing the goods. Here Variables will be again monitored before loading and unloading by the logistics partner. The storage center when required will place the order to center and initiate the transaction. Center on receiving the order will send the goods and receive the cryptocurrency. The same process of measuring variables using devices will be done here also. This transaction along with measured variables will be entered into the distributive ledger. Throughout this process, there will be active smart contracts that will get triggered only by getting a variable value beyond limits.

This framework will help to resolve the issue of

1. Demand and supply uncertainty by providing the industry capability to improve the accuracy of forecasting employing enhanced visibility.
2. Food losses due to improper handling by enabling industries to monitor handling data during product movement and also because of the use of smart contracts that triggers whenever the decided variable crosses the limits.
3. Customer dissatisfaction because of lack of provenance enabling them to track and trace the variables like location, temperature setting, etc.
4. Lack of Supply chain Visibility by storing all the transactional data to the blockchain platform in the form of blocks.
5. Transparency, Trust, and data immutability are developed in the system as the data is stored in the blocks as per the transactions and this data can only be tampered with by the authority of the blockchain platform i.e., the manager.
6. Inventory losses as this framework supports implementation of First Expired First Out and accordingly pricing can be used.

4. Implications

4.1 Managerial and Academic

With the completion of one cycle of product and currency flow, it will ensure the following things:

1. It can help in spoilage as it records the variable data of products related to perishability measures and hence FIFO policy (first in first out policy) can be implemented.
2. The product is moving safely
3. As perishability is a matter of concern, variables are monitored seriously.

4. All the transactions (Distributive ledger) can also be shared with customers to increase responsiveness.
5. Implementation of smart contracts enabled penalty can act as reinforcement to stakeholders and will reduce the losses because of improper handling.
6. Once losses will be reduced, customer satisfaction will increase.
7. Improved efficiency and responsiveness.
8. Overall waste will be reduced and social, environmental, and economic performance will be enhanced.
9. The information sharing is done using this framework; therefore, uncertainty can be handled and in case of excess demand, it can be fulfilled with the center having greater availability.
10. This framework can provide traceability of the goods, transparency in the supply chain, and trust among the stakeholders.

4.2 Future research

1. The proposed framework can be used by the supermarket retail industry and Dairy industry as these two industries follow such kind of supply chain model but without blockchain and IoT devices. With little modifications, it can be applied to the healthcare industry for medicine supplies especially vaccines too.
2. Optimization of the above framework can also be done to determine the total cost, minimized waste quantity, and other related sustainability parameters.
3. Other measuring parameters like response time, moisture content, elapsed duration after first received can be used as triggers for smart contracts.

5. Conclusion

To the best of the authors knowledge, this is the first framework based on tokenization mechanism and smart contract enabled permissioned blockchain for the food supply chain. Tracking and tracing is one of the important aspects of the food supply chain. Most of the studies are focusing on this aspect of the food supply chain but perishability and causes of perishability are rarely considered. This study considered perishability, causes of perishability along with some reinforcement measures to mitigate the causes of food waste by using a smart contract-based penalty mechanism. The conceptual framework represented in the study considers almost all aspects of blockchain to enhance the efficiency and responsiveness of the food supply chain. Implementing this framework will help in reducing food wastes but will ensure the handling of the food products. This can help an origination in getting a competitive advantage and can help their customers to track and trace the product, not in terms of geographical locations but also handling conditions quantitatively.

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