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# Smart Food Supply Chain using Blockchain Technology

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**Abstract:** Food supply chain encompass all of the activities involved in the transformation of raw materials into food products. As food supply chains become more complex, the potential for food fraud increases. Food fraud is a global issue that affects all consumers. Food traceability makes it possible to trace all the steps a food has taken from its origin, through its transformation process until it ends up with the consumer. It is an essential system for controlling the risks that can affect the food supply chain. The traditional supply chains are centralized and they depend on a third party for trading. These centralized systems lack in transparency. The Main objective of this research is to implement a blockchain-based Food (Agri-Food) supply chain that leverages the key features of blockchain and deployed over Hyperledger fabric blockchain network. Although blockchain provides immutability of data in the network, it still fails to solve some major problems in supply chain management like credibility of the involved entities, privacy of the data. The proposed system can ensure the credibility by adding the certificates that are issued by the certification authorities (e.g., GFSI, ISO, HACCP) from the food industry and data privacy by implementing system using consortium-based block chain (e.g., Hyperledger Fabric).

**Keywords:** Supply Chain, Traceability, Credibility, Blockchain, Hyperledger.

## I. INTRODUCTION

A food supply chain is a network which represents the steps it takes to get a food product from its original state to the customer. The steps include moving and transforming raw materials into finished products, transporting those products, and distributing them to the end-user. Due to the complicated global food supply chain system, tampering, misrepresentation, or deliberate substitution has grown significantly. It is very difficult to find out the cause of a problem because every participant in the food supply chain maintains their own paper-based records. Maintaining manual records are vulnerable to inaccurate updating. The food supply chain needs to increase the accuracy and transparency in food traceability and allows the public to examine each product’s source with enough details at different level of processing. With a proper food traceability procedure in place, we can avoid potentially affecting the public's health, and the economic ramifications of contaminated products making it to the market. Blockchain is the one of the important technologies which provide traceability in the food supply chain. The primary drivers for food providers to consider blockchain technology are the ability of the technology to collect data from various sources and create a single view of the transaction, transparency and its immutability.

## II. LITERATURE SURVEY

Miguel Pincheira Caro, et al. [13] develop and deploy from-farm-to-fork use case, achieve traceability using two different blockchain implementations, namely Ethereum and Hyperledger. The system compares performance of both Ethereum and Hyperledger deployments, in terms of latency, CPU, and network usage, also highlighting their main pros and cons. Even the Hyperledger based implementation had better results in terms of measured metrics with respect to the Ethereum, both implementations have different properties and capabilities that need to be considered before choosing one over the other.

Dianhui Mao, et al. [17] provides a credit evaluation system based on Neural Network-Long Short-Term Memory (LSTM)Training and Hyperledger Fabric. This system needs more exact and effective multiple classifications of multiclass emotion-tags instead of only ‘Positive’ and ‘Negative’. Each node on the blockchain network needs to store the entire history of the blockchain and the growing blockchain size then becomes a concern.

Martin Westerkamp, et al. [11] propose a blockchain-based, decentralized supply chain management system based on smart contracts by maintain the relationship between resources and products in manufacturing processes. The concept is based on two key ideas: representing physical goods in the form of digital tokens, and recipes that enable their transformation. With the current solution, a packaging process can be implemented similarly to a manufacturing process, but the extraction of the original goods is not possible, inhibiting traceability.

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Andi Arniaty Arsyad, et al. [16] links legal documentation that use the digital water marking and blockchain technology within a traceability system, with the specific application case of cacao and chocolate production in mind. The problems with this system are, there is no way to guarantee the correctness of the photographs before the digital image is in our supply chain. Another problem is how to track the growth of cocoa and ensure that the pictures of cocoa at different times of growth are consistent with the same physical objects.
Sidra Malik, et al. [10] propose a Trust Chain, as a three-layered trust management framework which uses a consortium blockchain to track interactions among supply chain participants and to dynamically assign trust and reputation scores based on these interactions. The three layers are: data, Blockchain and application with supporting components. Generating false ratings, earn high ratings on the network dishonestly are some challenges in the trust chain system.
Affaf Shahid, et al. [20] proposed solution, that presented a complete solution for blockchain based Agriculture and Food (Agri-Food) supply chain. It leverages the key features of blockchain and smart contracts, deployed over Ethereum blockchain network. The reputation system is proposed to maintain the credibility of the Agri-food supply chain entities and quality ratings of the products. Moreover, it also maintains the immutability and integrity of the transactions as these transactions are based on blockchain. The major issue with this system is the implementation of the reputation system. The reputation system stores reviews from end consumers which can be biased or fake. This system is not providing fake review detection system that will facilitate the reputation system in detecting the false reviews from the end consumers.
Based on the above literature survey, the proposed system has given a permission based blockchain solution using Hyperledger fabric for maintaining the transparency, privacy and credibility in Agri-Food supply chain systems.

## III. SMART FOOD SUPPLY CHAIN

The proposed solution utilizes Hyper Ledger Fabric framework and chain code to trace and perform transactions in Agri food supply chains. This solution eliminates the need for a trusted centralized authority and provides transactions for food supply chain management and safety with high integrity, reliability, and security.

### I. General System Overview

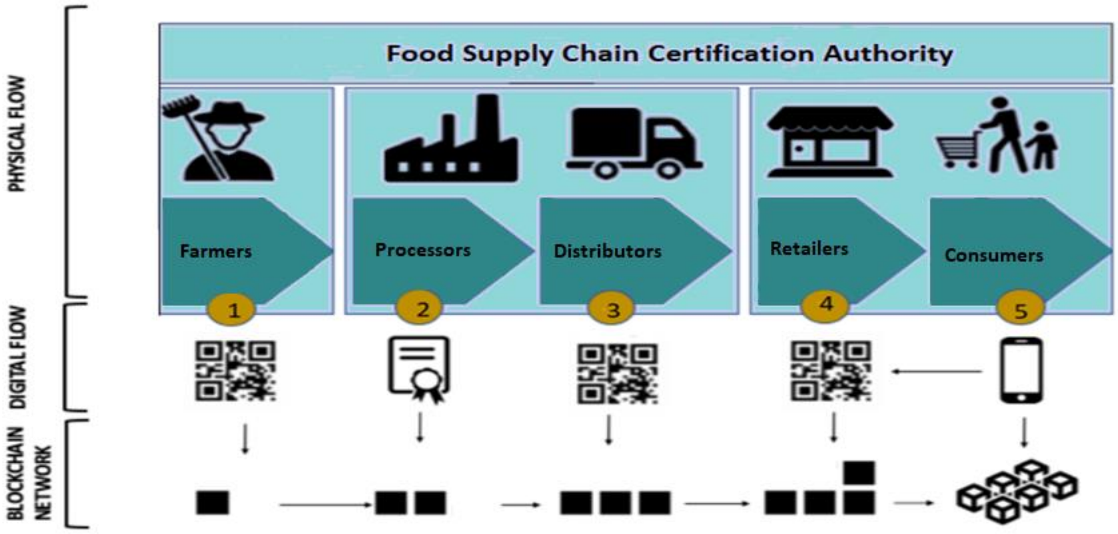


Figure 1. Blockchain based Food supply chain system.

The above diagram shows the architecture of Smart Food Supply chain system which has a three-layered architecture, that is categorized into 1. Physical Flow, 2. Digital Flow and 3. Blockchain Network. The participants in the system are, Farmers, Processors, distributors, Retailers and customers. The farmers register the item in the ledger as an initial transaction, transactions are validated and valid transactions are added in the ledger. The processor verifies the transaction based on time, quality and many factors. The distributor does transport the item from once source to another place these transactions like starting place and destination are considered as transaction also stored in ledger like any other transaction. Any flaw in the transaction between farmer and consumer via parties as processor, distributor, and retailer can be easily identify in real time. The certification authorities issue the certificate by verifying the policy check list for food safety and regularity process. The participant who got this certificate can upload it. These uploaded certificates are used to give more reputation for them.

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## IV. SYSTEM DESIGN

The different entities involved in this system are, Farmer, Processor, Distributor, Retailer and Consumer. Each entity has its own role-based access and interaction with the chain code.

1. Farmer: The farmer is responsible of the actions from seeding/planting to harvesting. Farmers store information about each stage of the process (e.g., irrigation, fertilizing, etc.) in the blockchain including amounts of inputs applied. They can also add the certificates (e.g., GAP, SQF) that they got for their good agriculture practices from the certificate authorities.

2. Processor: The processor may perform various actions, from simple packaging to more complex processes (e.g., pressing of the olives, manufacturing biscuits) They can also add the certificates (e.g., ISO, HACCP, GFSI) that they got for the food safety regulations and policies.

3. Distributor: This role is responsible of moving the output of the producer (e.g., the product) from Producer's site to retailers.

4. Retailer: The retailer is responsible of selling the products, representing it either small local stores or big supermarkets. Retailers store details about the received amount of product from distributors in the blockchain.

5. Consumer: This role is the final element of the chain. Consumers are able to transparently verify the whole history of a product before buying it using the product code (e.g., UPC, GTIN) that can be associated to each package. A consumer can also verify the credibility using the certificates attached by the entities involved in the processing of the product.

Each of the participating entities has an Entity Access ID (EA) and participates by invoking functions within the Chain code/Smart contract.

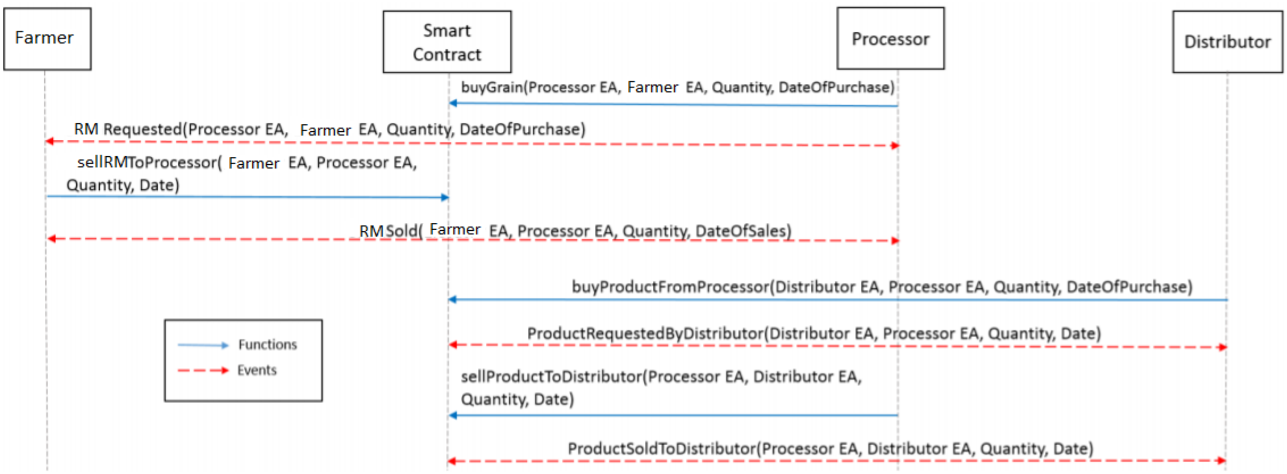


Figure 2. Sequence diagram showing interactions among farmer, smart contract, processor, and distributor.

Figure 2 represents the sequence diagram in which the processor buys Raw Material (RM) from farmer. The function buyRM() is executed by the processor by passing parameters such as the Entity Access ID(EA) of both requesting processor (Processor EA) and that of the farmer (Farmer EA), Quantity and DateOfPurchase. The distributor entity then requests to the processor in order to buy finished products from the processor. buyProductFromProcessor() function can be executed by the interested distributor.

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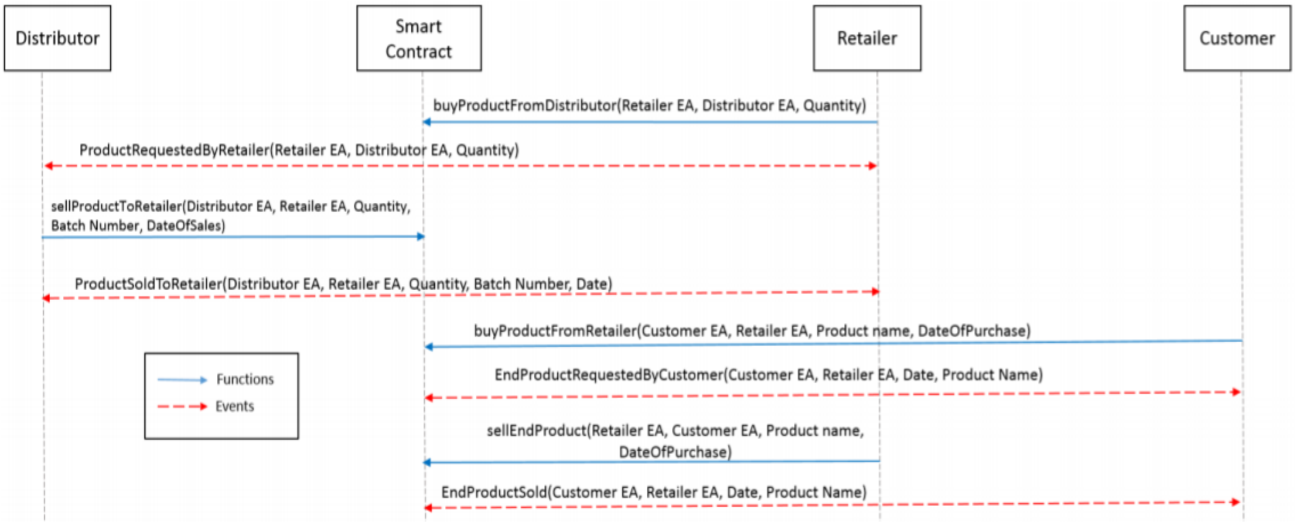


Figure 3. Sequence diagram showing interactions among distributor, smart contract, retailer and customer.

Figure 3 shows the sequence diagram in which distributor, retailer, and the customer collaborate with the smart contract (chain code). The distributor interacts with the interested retailers to sell the goods and retailers in turn request for the goods from the distributor in limited quantities. Now, the end customer buys the product from the local retailer by executing buyProductFromRetailer() function. The smart contract broadcasts the sale of the product with the EndProductSold event.

## V. IMPLEMENTATION

This section, describes the algorithm that define the working principles of Smart food supply chain. The farmer creates the smart contract. The farmer then agrees to the trading terms (offline) with one of the registered processors. Algorithm 1 describes the process of selling the raw material to Processor by Farmer.

**Algorithm 1: Processor Buys Raw Material from Farmer**

Input: 'rp' is the list of registered Processors, Entity Access ID(EA) of Processor, Entity Access ID(EA) of Farmer, Quantity, DatePurchased, Raw MaterialPrice.

1 Contract state is BuyFromFarmer
2 State of the processor is RMRequested
3 Farmer state is CropBoughtFromFarm
4 Restrict access to only rp ∈ Processor
5 if RMSale is agreed and RMPrice = paid then
6 Contract state changes to RMRequestAgreed.
7 Change State of the processor to WaitForRMFromFarmer.
8 Farmer state is SellRMToProcessor
9 Create a notification message stating sale of Raw Material to requesting processor
10 end
11 else
12 Contract state changes to RMRequestFailed.
13 State of processor is RequestFailure.
14 Farmer state is CancelRequestOfProcessor
15 Create a notification message stating request failure
16 end
17 else
18 Revert contract state and show an error.
19 end

At this stage, the contract state is BuyFromFarmer. The state of the processor is RMRequested. The contract has to check two conditions (i) if the requesting processor is a registered entity and (ii) if the sale of raw material is agreed and purchase price is paid. If these two conditions are true or satisfied, the contract state changes to RMRequestAgreed, processor state changes to WaitForRMFromFarmer, farmer state changes to SellRMToProcessor, and all the active entities are notified with a message on the sale of raw material to the processor. In the other case, if the above mentioned two conditions are

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not satisfied, contract state changes to RMRequestFailed, processor state changes to RequestFailure, farmer state changes to CancelRequestOfProcessor.

The processor then sells the finished product to the distributors. In the next level, the distributors transfer the product to retailers. The final action is the purchases made by the customer from the retailer based on Algorithm 2. The customer is the final entity in the food processing and tracing model. The smart contract restricts access to only Customers to make a purchase from the registered retailers.

**Algorithm 2: Consumer Buys Product from Retailer**

Input: Entity Access ID(EA) of Retailer, Entity Access ID (EA) of Customer, DatePurchased, Product ID, SalesID.
1 Contract state is SaleRequestAgreedSuccess
2 Retailer state is ProductDeliveredSuccessful
3 Customer state is ReadyToBuy
4 Restrict access to only Customers
5 if ProductPayment = successful then
6 Contract state changes to ProductSoldToCustomer.
7 Retailer state is ProductSaleSuccessjul
8 Customer state is SuccessfulPurchase
10 end
11 else
12 Contract state changes to SaleOfProductDenied.
13 Retailer state is ProductSaleFailure
14 Customer state is FailedPurchase
16 end
17 else
18 Revert contract state and show an error.
19 end
11 else
12 Contract state changes to SaleRequestDenied.
13 Distributor state changes to RequestFailed.
14 Retailer state is ProductDeliveryFailure
15 Create a request failure notification message.
16 end
17 else
18 Revert contract state and show an error.
19 end

The permission based distributed ledger technology, Hyper ledger can improve the food safety by connecting multiple stakeholders like farmers, processors, retailers, consumers and maintain the privacy of the data entered by them. It can also enable more transparent and accurate end-to-end tracking in the supply chain. Organizations can digitize physical assets and create a decentralized immutable record of all transactions, making it possible to track assets from production to delivery or use by end user.

Each entity in the system is identified by a unique identifier and can be associated with an Entity Access ID. Each of the participating organizations runs a peer node that maintains information about its local copy of the distributed ledger in a dedicated CouchDB database node. This system is implemented using the Hyper Ledger Fabric framework. The chain code which is used to implement the business logic of the system is written using Node.js and the front end is designed with React JavaScript library. CouchDB is used as the state database, which can store any binary data that is modelled in chain code in JSON format.

## VI. CONCLUSION AND FUTURE SCOPE

The proposed permission based blockchain implementation of food supply-chain can reasonably increases efficiency, transparency, privacy and credibility of the data entered in the system. In addition, blockchain disallows any fraudulent modifications to the data. The decentralized and permission based blockchain system can deliver real time information to all the parties such as producer and consumer ecosystem on the safety status of food products at all time. The Blockchain stores the food information as a transaction. All the transaction are stored in the blockchain are distributed and transparent to other participants. Anyone in the blockchain network can validate the transaction meanwhile all the nodes are allowed to trace food information, which achieves the transparency and traceability for food safety. Due to the characteristic of the blockchain, all the transactions will be packed in one or several blocks. All the nodes also update the

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book on native when a new block is verified and recorded on the main chain, which means all the nodes have same transaction that records all the transactions. The certificates added by the participant is used to identify the regulatory method and standards that the participants are following in their level of the food supply chain which in turn give credibility for their transactions.

This implementation can be extended to consider the accountability and auditability of the data delivered and automated payments during the trading and delivery.

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