Blockchain Technology for Food supply chains

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Abstract – **The technology Blockchain is most emerging and widely used in almost all the applications like supply chain management systems, healthcare, banking industries, business, IT sectors, government organizations, agriculture etc. The food products are more sensitive, and it is very hard to trace the origin, buyers, sellers, farmers with the existing centralized method. The usage of blockchain technology is proposed and experimented in this work along with the features of decentralization, increased security, immutability, and tamper proof for supply chains. The proposed work uses the smart contract on Ethereum for food supply chain management systems, which avoids falsifying information, corrupting database, external attacks. The analysis of food supply chains is shown in the experimental results.**

Keywords - Ethereum, Smart contracts, Supply chains, Blockchain technology

I. INTRODUCTION

The term blockchain means the representation of data in the form of a series or a chain that holds data in blocks depending upon the type of application that uses it. The blocks are linked using cryptographic validation. It is a distributed public ledger that holds data in a secure and decentralized way without the involvement of a third party. The effectiveness of the block rely on this methods such as the alteration or modification of the data is highly impossible. The blockchain is used in almost all types of applications like Banking, Insurance, Supply Chain, Governments, IP rights etc.

Here are some of the primary significance of the applications based on blockchain:

- The information are stored as distributed. Hence the failure is resisted to a possible extend.

- The information were not prior owned by centralized server which inturn help the Invulnerability in the system. the added benefit of these system is that it does not require any specific domain or IP . The change or alteration of individual data is nearly impossible since the data is scattered and stored in nodes, provided the nodes are at different level even in different countries.

- The system has been evolved towards a new level of trust worthiness because and decentralized system can be owned or personally benefitted for a cause.

We have chosen the blockchain based supply chain management as an example. The supply chain management is a process chain where in the raw materials are moved from the manufacturer end and it gets ended up when the delivery of the same is done to the end users. The issues in centralized supply chain are i) slow due to intermediate authentication process ii) insecure due to centralized approach iii) increased fraud and

errors may also be possible and iv) expensive due to slow process, errors and lot of intermediaries. Applying the blockchain technology to the supply chain industry will be helpful for tracking of products and record keeping in the industry [3]. The tracking of products in real world time in supply chain reduces the overall moving cost of products even in the large-scale industries. The blockchain is immutable in nature which reduces errors, fraud activities and increases trust.

When we look at the vegetables or any provisions required in the grocery store, everything looks flawless, clean, neat and fresh. But you don't know about the origination of each item. How to identify whether the item is pure or adulterated? Neither the customers nor the retailers know about the origin of the item.

Due to certain problems towards existing food supply chain process, the industry is looking for new technology which furthermore enhances the food safety standards. To ensure the same, we must connect various stakeholders in the industry. The stakeholders involve farmers, retailers, and customers. The new emerging technology, blockchain combined with the food supply chain can ensure the safety of the food products [13].

In a survey by NSF, it is identified that food fraud costs more. Food frauds include the tampering or misrepresentation of food. The main damage is in the milk-related products such as seafood, honey, tea, coffee, and fresh juices. Food fraud alone costs around $49 billion each year [1]. In accordance with the world health organization fact reports, nearly 420,000 people die every year due to the consumption of adulterated food. Out of the sea foods made, nearly 24-36% of foods were of unreported origin. Illegal production of food items leads to various infectious diseases [1].

Since every stakeholder who gets involved in the food supply chain process maintain their records in a paper-based system, it is really difficult to find the source of the problem. Farmers should save the origin and type of the crop along with the sowing procedure, storage information of the crops in the blockchain. They can also include the images of the crops for showing their quality after being tested by the machine learning process.

The food processing companies receive the products from the farmers. They store the information about the crop refining in the blockchain. Wholesalers or retailers can bid for the products through smart contracts. The food processing companies transport the products to the retailers and store information about transportation in the blockchain. End consumers can ensure the safety of the products through the information in the blockchain. The food supply chain using blockchain ensures food safety, transparency, and security [15].

The real-life examples include transparent and traceable coffee, a mobile application by iFinca. It uses blockchain technology that connects all the stakeholders of the coffee production [2]. Food companies can utilize the blockchain to have a transparency in their supply chain process. Blockchain adds an additional layer of security to the food industry [1].

- Transparency

The step wise data capturing is done. The data inputted is made available to everyone within the network, so the blockchain bring transparency in the supply chain. Blockchain get rid of food frauds by recording the values from the beginning till the end of the workflow [1] [14].

- Efficiency

The way food is tracked, transported, or sold can be effectively streamlined. Blockchain overcomes inaccuracies of manual records by maintaining all the digital record of the transaction. In case of any food investigation, the process could be carried out seamlessly as blockchain offers end-to-end traceability.

- Secure and quick transactions
  With blockchain, it is possible to transfer the data very quickly and the validation can be finished within no time.

- Food Safety
  Blockchain could bring significant progress in food safety standards with proper cost effectiveness. The storage of permanent records on the blockchain avoids chances of food contamination.

A. *Stages in implementation of Food Supply Chain*

The food products we buy should be safe and should be free from adulteration. We can ensure the safety of food items by following details, where the products are grown, refined, stored and inspected? This can be accomplished by using Block chain technology in food supply chain management [11]. The distributed nature of block chain can connect stake holders like farmers, food processors, retailers and consumers. Nestle, Wal-Mart, Dole, Golden state foods, unilever are the existing companies using block chain technology in their food supply chain management.

Everyone within the food supply chain can access the data (transparency) but cannot change the data (immutable). This can be implemented in the following four stages [1].

Stage 1: Farmers store food data
Stage 2: Processor store food processing
 details
Stage 3: Wholesalers bid for processed
products
Stage 4: Consumer verification of products

Stage 1: Farmers store food data

Farmers enter the crops details like type of crop, origination, procedure used for sowing, manufacturing time and date etc. in distributed ledger. This information can be viewed by all stake holders. Finally, farmers distribute their crops to processing companies and update those details in ledger.

Stage 2: Processor store food processing
Details

After receive the food items, the processing companies bid for crops through smart contract. Smart contract contains a build in regulations to ensure the quality of crops. Once the bid is accepted, the company start the processing of crops and store those information in public block chain. This information is useful for retailers and consumers to verify if the food is properly processed or not.

Stage 3: Wholesalers bid for processed products

Once the food items are processed, it will be kept for bidding to wholesalers. Wholesalers bid the food products by smart contracts. After that, processing companies convey the food items to retailers and wholesale dealers and update the transportation details, so that the timestamp details can help the consumers while buying the product. The wholesalers then distribute the items to different retailers by specifying real-time location to block chain.

Stage 4: Consumer verification of products

Once the consumer bought the product from retailer they can see the information like farm manufacturing details, processing data, transportation details and other digital data linked to food items. All these

information are validated in each transaction stage by stack holders. After the validation, it is added to chain of transactions by creating immutable and permanent record. So the consumer can ensure the food safety by tracing the information stored in block chain. It will be helpful for government agencies for the proper audit and maintenance of record. Therefore, food supply chain management using block chain technology can prevent food fraud, illegal production and food alteration.

II. PRELIMINARIES

A. Structure of Block

Digital Transactions in a blockchain are grouped together into blocks. Blocks in blockchain are linked within their peers cryptographically. Each block will have the hash of previous block, to ensure the correct order of transactions. The first block in blockchain is called as genesis block [7].
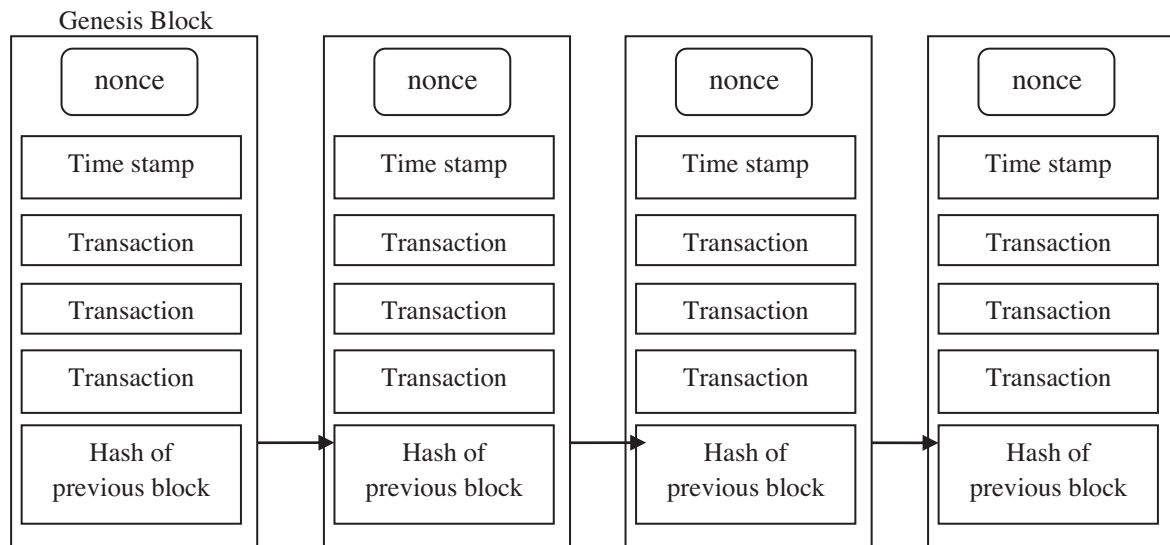
Fig.1 Structure of Block

Fig.1 depicts the overall view of blocks in blockchain. The block header contains nonce, hash of previous block and merkle root of the transaction. fig.2 shows the merkle tree, which is the list of transaction stored in tree type of data structure. In fig.2 leaf node H_A is the hash of transaction A, H_B is the hash of transaction B. The non leaf node H_{AB} is the hash of transaction A and B. Similarly, all the hash values are combined together to form a root node H_{ABCDEF}. If there is any change in any of the transaction will result in false hash value of root node.

B. Merkle tree

Food supply chain management using merkle tree: The farmers, wholesalers, processors can feed their data in blockchain. If any change has been made in

the manufacturing process, origin of the food, transportation detail or any other related details it will be directly notified. For example, the food supply chain details are stored as similar like the transactions stored in fig.2. If one of the transactions H_E is changed then the corresponding hash value will get change. The hash value of H_{EF} will also get change. Finally the root hash value will change [12]. By the merkle tree structure, the food supply chain details can easily be maintained and any change in any of the transaction will also be easily traced.
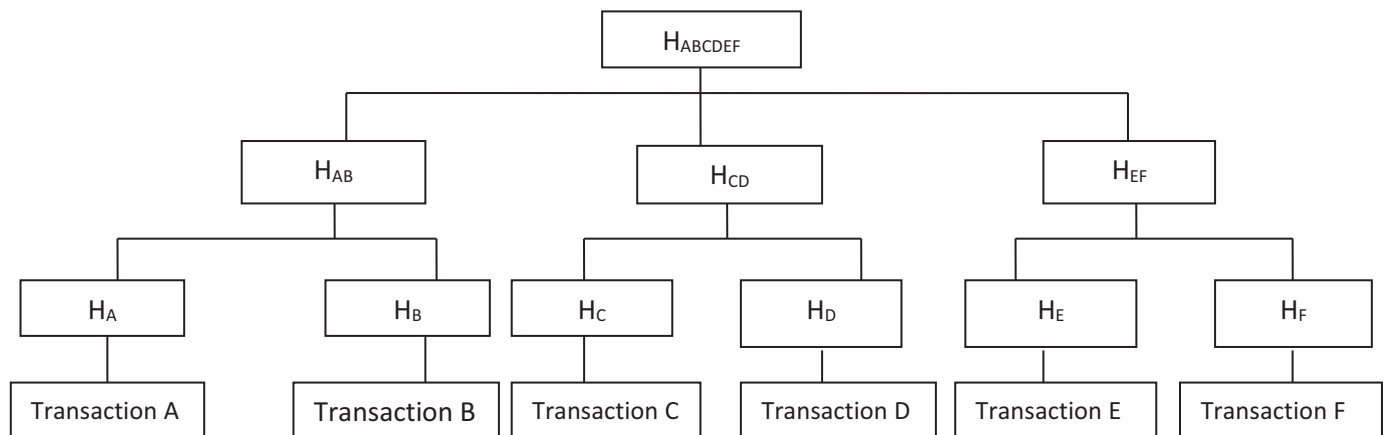
Fig.2 Merkle tree

The digital contract between two parties is known as smart contract. The transaction can be initiated and carried out among the nodes involved without any additional involvement of other nodes. using smart contract [9]. Ethereum is an blockchain environment used to execute smart contract line by line. Ethereum executes smart contract using solidity language.

III. RESULTS AND DISCUSSIONS

The ethereum is an open source platform used to execute smart contract for food supply chains. It stores the food data at different stages of food processing and can be verifiable by all the stakeholders in food supply chain [8]. The below code is written in solidity language for adding the food items in the contract. There are two functions addfood and verification in the contract. The function addfood is used to map the food item with the timestamp. The function verification is used to return the timestamp for a food item. Similarly all the related food product details can be added in the contract. The stakeholders can verify the timestamp, origin, processing, sellers details etc using this contract. If anyone tries to change the values can also be easily monitored.

```solidity
pragma solidity >=0.4.22 <0.6.0;
contract food
{
    mapping(string=>uint256) entry;
    address owner=msg.sender;
  function addfood(string memory fooditem)
  public returns(uint256 data)
   {
       require(msg.sender==owner);
       uint256 t=block.timestamp;
       entry[fooditem]=t;
       return t;
   }
  function verification(string memory fooditem)view
  public returns(uint256 data)
   {
       return entry[fooditem];
   }
}
```

In Fig.3, the food item 'wheat' is added to the blockchain and the verification function returns the correct time stamp value associated with the food item.
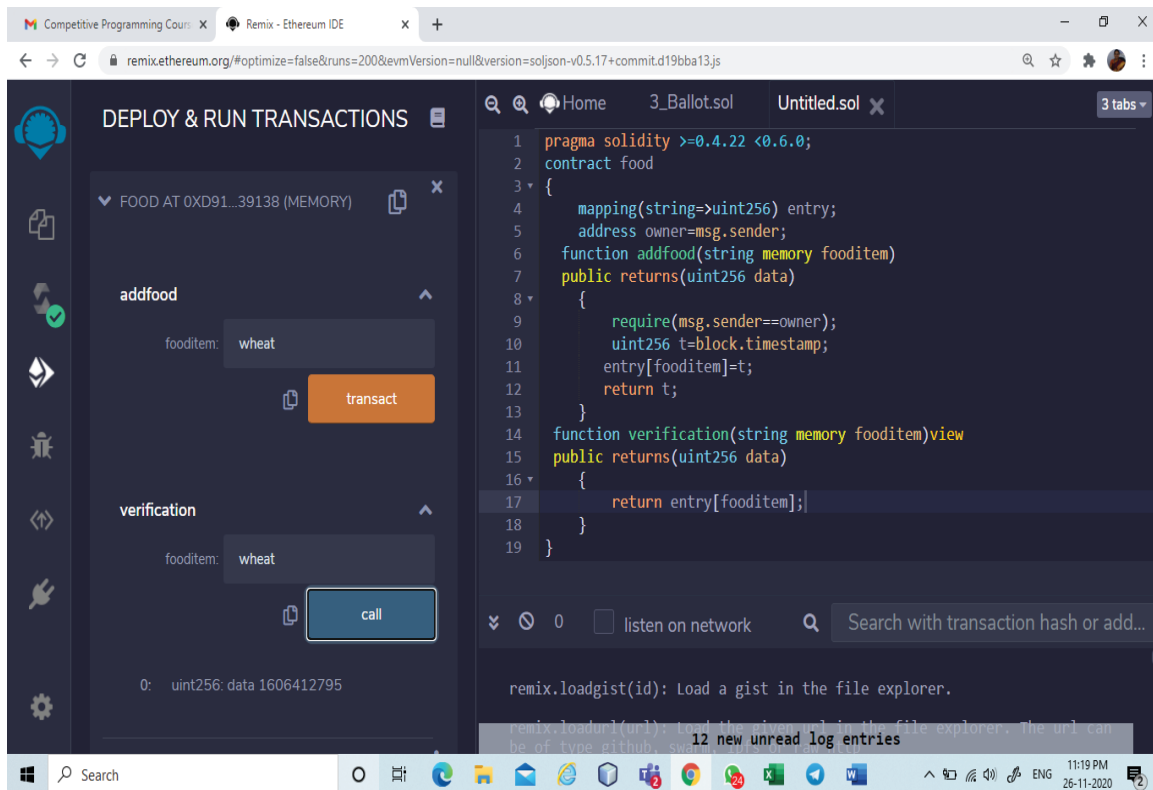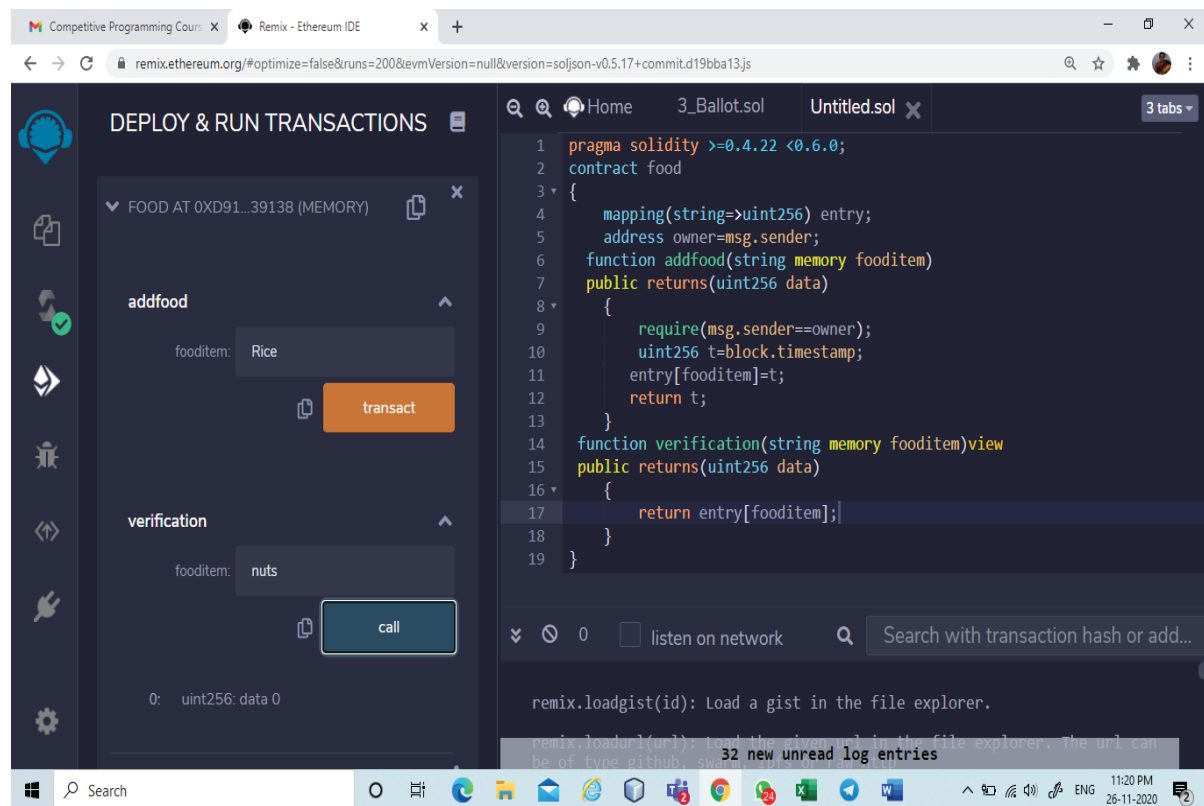
Fig.3 Verification of food item1

Fig.4 Verification of food item 2

In Fig. 4, the food item 'rice' is alone added to the blockchain for testing and the function is called by the value 'nuts', In this case verification function returns the timestamp value 0 for unknown values. Even when we add same food items to the blockchain it adds the new timestamp values

IV. ANALYSIS OF FOOD SUPPLY CHAINS

Walmart has implemented the blockchain technology for the food items, so that the consumers can trace the food origin, raw materials and the process that has undergone [4]. Walmart along with IBM ran two projects to implement the food supply eco system. One project is for mangos

sold in Walmart US and other for pork sold in China [5]. Before digitizing the food supply chain process, the tracing of food product took 7 days. After incorporating the blockchain, the food supply chain process takes 2.2 seconds [6]. Walmart has developed a blockchain based food supply chain for 25 products and can trace the origin of food products from 5 different suppliers. Walmart has planned to implement the system for all the food products and currently announced to start tracing the leafy green products and suppliers.

The food items, company implemented the blockchain technology for food supply chains and its advantages are discussed in table 1 [10].

Table 1 Companies Implemented Blockchain Technology

Food items	Company/Project	Advantages
Olive oil	OlivaCoin	Traceability, financial security, protection against price fluctuation and quality assurance
Mangoes,Pork	Walmart	Traceability
Sugarcane	Coco-Cola	Record keeping, verification
Chicken	GoGo Chicken	Continuous monitoring and verification
Rice	Oxfam	Transparency improves Cambodian farmers bargaining, livelihood and supply conditions

V. CONCLUSION AND FUTURE WORK

The paper has discussed the issues in the centralised food supply chains and how the blockchain implementation of food supply chain has resolved it. The paper has also analysed the industries implemented the blockchain for their food products. The proposed system shows a simple example for implementing the smart contract for food supply chains. Similarly, all the food items and verification of food items can be done from the origin to the market place.

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