PLANNING SECURE CONSUMPTION:

FOOD SAFETY USING BLOCKCHAIN

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***Abstract* — Agriculture is the foremost form of sustenance for all living beings on the planet. Food supply chain management is the flow of agricultural products from farms, harvesters, processing, distributing, retail and finally consumers. It is a sequence that starts from food production and extends till final consumption. The existing traceability of the food supply chain isn't entirely reliable and is prone to contamination. The authenticity of each stakeholder cannot be checked manually as it is a time-taking and laborious process. Instead of trusting a centralized source, a transparent and decentralized process can be adapted through Blockchain Technology to trace the food on our plate back to its source. Blockchain is a peer-to-peer network that does not depend on a central authority and helps keep the data in the ledger tamper-proof. It would be an effortless way to prevent serious health risks from fraudulent activities and be versed in the origin, transport and sale of the products that consumers buy from stakeholders; and make sure that the transactions of both food and money are accessible to all stakeholders. In this paper, we propose a traceable food-safety with Blockchain Technology & Smart Contracts which would not only make it transparent but also tamper-proof. The information of each transaction in the supply chain is recorded in an immutable ledger and the safety is verified before proceeding to the next block, through smart contracts which are implemented in Ethereum. Through the proposed solution, a long-lasting trust is established among the consumers and the stakeholders to make it reliable, contamination-free and traceable. The entire supply chain, right from the fields to the kitchen, will be closely monitored which leaves room for no mistakes.**

Keywords* — *Food traceability, blockchain, agricultural supply chain, Ethereum, smart contracts, food safety.

I. INTRODUCTION

Since the past few decades, food safety has grown in prominence and the significance placed on food safety has risen. Consumers aspire for a more transparent and accountable system that allows them to be completely aware of the product they purchase, right from its origin to stores. Increasing food scams, fraudulent activities and contamination has riled the agricultural sector and made us more vigilant of the centralized agricultural management system. Apart from damage on a personal level, there have been economic losses that have led to financial ruin and loss of businesses. Everyone has to play a role in food safety [2] management from the government, institutions, academic professionals to industries.

The World Health Organization estimated around 420,000 deaths due to foodborne diseases every year which tend to have long term effects like cancer or neurological disorders. [12] People with a vulnerable state of health are severely affected and are prone to more danger. Contaminations can occur in many forms- during the process of farming, harvesting, transportation from fields to storage, lack of proper storage facilities or temperature variances, retail stores even before it reaches the consumer. This has made the entire process of tracing more difficult and complex as it is difficult to narrow down the exact whereabouts of the contamination.

What is "FSC"?

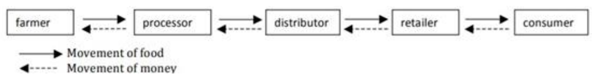

FIGURE 1: The flow of money and food in supply chain

Food supply chain refers to the processes/flow that describes how food from a farm eventually ends up on our tables. The processes consist of the following (i) production; (ii) processing; (iii) distribution; (iv) consumption; and (v) disposal. Once crops go through harvesting process, the food must be stored, transported and sent to retail stores so that it reaches the customers before it's expiration date. Every step of the supply chain calls for human and/or natural resources because if one part of the chain is affected, it automatically compromises the rest. (shown in figure 1)

How does Blockchain technology fit in?

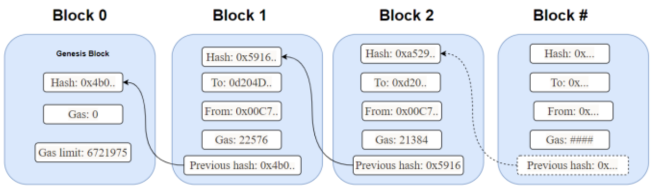

FIGURE 2: The structure of blockchain

A blockchain is a virtual ledger, as shown in figure 2, of transactions that are decentralized and peer-to-peer. [1] Each block within the chain carries some of the transactions, and whenever a brand new transaction happens at the blockchain, a file of that transaction is added to the public transparent ledger. Blockchain, occasionally called Distributed Ledger Technology (DLT)

Blockchain technology uses several advanced cryptographic techniques and hash functions to generate unique IDs and provides data authentication. Several consensus mechanisms are also designed to ensure that data is not being manipulated. Agricultural systems can be enhanced through blockchain by providing food security, quality control, funding small-scale farmers and obviously traceability.

a. The existing system-

The existing food supply chain is traced using a centralized system but these could result in fraud, contamination, tampering and false information as it is entirely based on a trusted system that depends on a third party. It has several subtle yet substantial limitations such as (i) single-point failure; (ii) hacking and tampering with data integrity; (iii) high costs for verification and monitoring of transactions by the third party.

b. The proposed system-

Almost a decade ago, the invention of Bitcoin [1] revolutionized the way the entire world looked at cashless transactions and introduced a unique, decentralized method to deal with trust-related issues.

In this paper, we present a detailed interpretation of how a decentralized public ledger system can help trace agricultural supply chains with the help of blockchain technology which guarantees tamper-proof mechanisms and data authentication.

II. METHODOLOGY

In this paper, we use permissioned blockchain to trace the agricultural supply chain from pre-production to consumption. [3] A permissioned blockchain helps add an extra layer of security and requires roles that define and control transactions of participants in the blockchain. It ensures that only known nodes are participating in the network. We use Blockchain as a service (BaaS) to host the decentralized application to trace and configure the agricultural supply chain of the products. [6] Furthermore, Smart contracts are used to ensure the implementation of food safety and help in enforcing an immutable digital contract using several blockchain frameworks. In the following subsection, we explore the roles and components of the tracing process of the supply chain.
Permissioned blockchain uses **Byzantine-Fault Tolerant protocol** (in figure 3) to form a consensus. This problem was first published in 1975 which goes in detail about a plan of two generals attacking an enemy. In this scenario, one general is a leader and the other is a follower and to defeat the common enemy they have to communicate and act at the same time but there are many factors involved that could ultimately lead the plan astray. So using Byzantine fault tolerance, we can ensure that it can tolerate failure if failures don't exceed 1/3rd of the total nodes. So in the permissioned blockchain, even if a legally accountable validator validates a wrongful transaction, the blockchain can operate without a breakdown by isolating the faulty node that spreads false information.

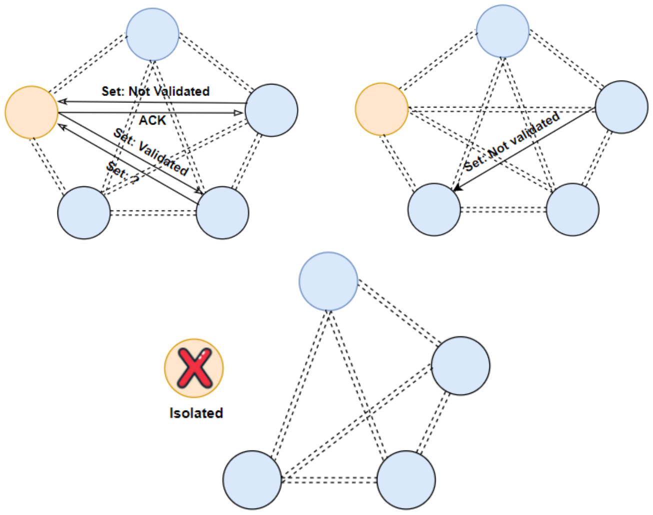

FIGURE 3: Byzantine fault tolerance mechanism

Roles involved in traceability:

1. Legally accountable validator:

A validator helps keep the entire blockchain secure by managing the lifecycle of agriculture. Several trusted and relevant organizations help in warranting the food hazards and frauds that might occur. They can access the entire permissioned blockchain network and can also assign permissioned nodes. These validators are responsible for the registration, configuration and approval of data through the decentralized app. They also have the authority to choose potential validators.

2.Farmers:

The base for the entire food supply chain is farmers. A farmer is assigned an Identification Number and registered into the application by the authorized validator and given ability to login to the application to enter the details like their ID, name, crop cultivated, temperature, the quantity of crop and expected price. Certain terms and conditions are assigned to ensure there is no scope of misleading. These details are further verified and authorized by the administrative authorities.

3. Logistics:

When a farmer submits their details, the logistics can view the entirety of the details but as mentioned above only the validator can approve. After viewing the farmer details, the details of the product are entered such as lot no., grade of the produce (assigned by the food safety department), the production date and the expiration date. There are of course certain terms and conditions that they are accountable to and must agree upon before submitting these details.

4. Consumer:

Whoever purchases the product from retail are eligible to view the details of every step that has occurred throughout the supply chain. The entirety of the operation is visible and transparent which makes the process contamination-free.

III. IMPLEMENTATION

Illustrated below is a diagram representing the process that takes place in our proposed model.

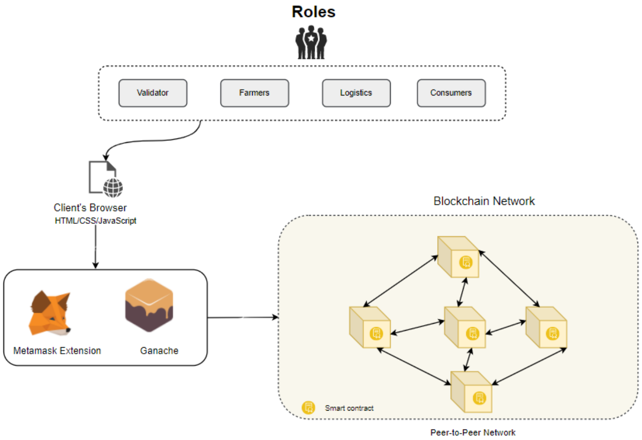

FIGURE 4: Roles and components of the proposed model

As shown in figure 4, the front-end is connected to the back-end using smart contracts which verify the blocks in the private network created. This network is called Ganache software which is responsible for storing the details of farmers, logistics and consumers into the blocks and mine them for validation. Ganache is connected to Metamask locally. A metamask is added as an extension to chrome and an account is created. Ganache workspace is set up with the same port number as metamask to connect them. The private key is copied to the import account in metamask and we obtain a default of 100 ethers which are used for approving details in a blockchain. We have kept our workspace on auto-mine mode to avoid ambiguity. These contracts are used to verify the authenticity and retain the balance ethers. In turn, they return the remaining funds and store the variables that are given as input. The storage contract is used to store all data given and later displays for the end consumer to view.

Smart Contracts-

Algorithm 1 Pseudo-code of *transactions* smart contract
Triggering smart contract with input information from nodes

Input: Validator ID,
Farmer details (ID, name, crop, price, etc)
Product details (ID, name, MRP, Exp.date, etc)
1: info(*farmer*)=checked by *Validator nodes*
2: if (transaction==true) then
3: smart contract operates and records information in block
4: end if
5:info(product)==checked by *Validator nodes*
6: if (transaction==true) then
7: smart contract operates and records information in block
8: end if

Algorithm 2 Pseudo-code of *storage* smart contract
Invoked the smart contract with farmer and lot IDs

Input: Farmer ID,
Lot ID
1: farmer ID=checked in the latest block
2: if (farmer ID == input farmer ID) and (lotID==inputlotID) then
3: Displays the farmer and product information of records in the block
4: end if

Creation: The supply chain is validated through smart contracts (as shown in figure 5) in our work. Different parts of processes are represented through smart contracts which are instantiated in the blockchain through the validators. A smart contract is defined for supply chain creation and to handle the metamask used. (as shown in figure 7)

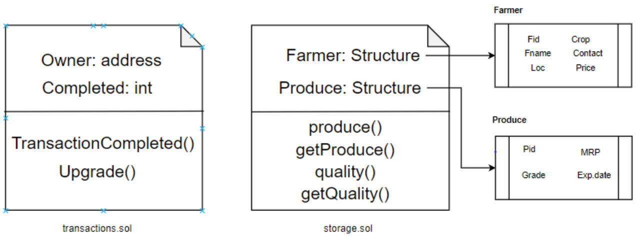

FIGURE 5: Smart contracts class diagram in dApp

a. Storage smart contract:

In our work, we created a decentralized app(dApp) and this interacts with the smart contract which is connected through ganache. The basic structures for farmers, logistics and consumers are defined and the functions are declared to define the return values after the details are approved by the administrator. This helps the end-user to view the details of the processes involved throughout every step. For instance, whatever logistics enters into dApp is stored through a function called produce() and later returned through getproduce() function.

b. Transaction smart contract:

Each transaction when getting approved gets verified through this smart contract with the help of metamask.

Farmer page takes in all the details and ensures that the farmer has not used any harmful contaminants to ensure a contamination-free product. A metamask pop-up is used to mine blocks in the ganache and verify the details of the block using a smart contract. Only after confirmation, we can proceed to the logistics page which shows the authorities farmer details and then these details get approved. The product which will further be sent to storage is taken into consideration and the details are taken in and stored in ganache block and mined. The end-consumer sees all these procedures and can understand every step of the way as all the details are furnished-from the farmer to retail to consumer.

IV. RESULTS AND DISCUSSIONS

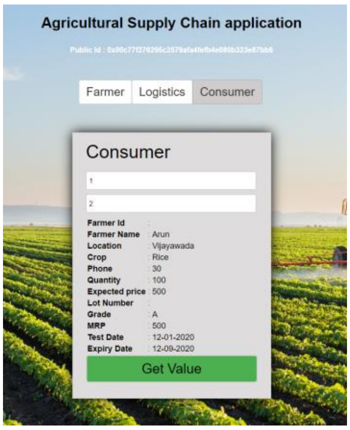

FIGURE 6: Execution in dApp

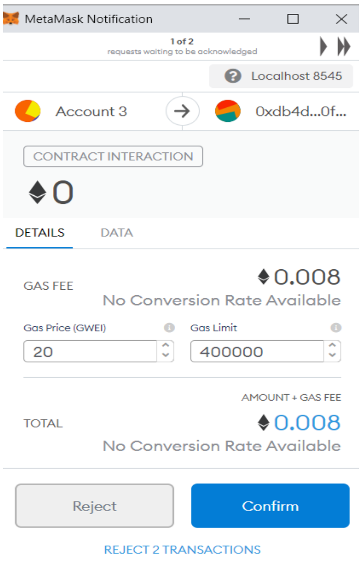

FIGURE 7: Execution in metamask (transaction validation)

When we execute the dApp, we get a farmer registration page where the farmer needs to register and later login. After logging in, the farmer must provide all the details of the crop cultivated. These details will be sent to the logistic department, and the farmer needs to wait for approval from the validator nodes so that the crops are sent for further processing.

After farmer details validation, the logistic department can view these details of the crop and transport it to a storage facility where they, in turn, will be validated based on the product they store and it's conditions. Then if everything is valid the product details are approved.

After getting validated the crops are sent for batching. Now the logistics management needs to give the Lot Number for the crops and MRP will be fixed based on the grade of the crop and also needs to provide the test date and expiry date for that particular crop. The crop is now ready to sell so it will be transported to the retail shops or supermarkets and stored in proper condition.

After getting transported it will be available for consumers to buy them. So, if any consumer wants to know the origin of the crop and more detailed information about how the crop is grown, they just need to enter the farmer ID and lot number so that all the details will be displayed, from where the consumer can know how safe is the crop and can decide whether to buy the crop or not.

This is a sample result (as shown in figure 6) which is obtained using this process so through this the consumer gets all the details of the crop and its grade and manufacture date. This will help to assure the quality of the crop to the customer.

The results obtained in this process are immutable and traceability is displayed throughout the process. The experimental results would show the details of the farmers which include farmer's name, farmer crop, fertilizers, irrigation process, and date of crop takeout. And it also shows the details of transportation and how the crops are stored. This helps the consumer to get all details required to know for him to decide whether the product is safe as his requirements. As every transaction is recorded there won't be any misleading results and due to these, there won't be any adulteration in the food.

Advantages:

(i) It ensures data privacy and integrity.
(ii) It is almost not hackable due to the fact that more than 51% of the blockchain needs to be owned by hackers to hack a blockchain.
(iii) It provides a safe, transparent and decentralized mechanism which can be easily implemented by most agricultural sectors.
(iv) The entire food supply chain is traced without any involvement or meddling of third party systems.
(v) It is entirely customer-centric to provide the utmost trust and satisfaction.

Open challenges:

Human intervention is necessary from time to time and it cannot be entirely free of these factors. To implement this system resources and customization is required which won't happen overnight because it would require efforts and vast expenses. Since blockchain technology is rather new, industries and individuals are hesitant to adopt this method.

V. CONCLUSION

Planning a secure consumption is important, now more than ever. The pandemic has changed our views entirely on safety in general and as we step into the next phase- a "post-pandemic era", we must do everything in our power to safe and secure production and management of agricultural sector products. A trusted system that overall must add great value for the stakeholders and provide revenue as well. As an efficient and immutable supply chain, it can produce more profits. It provides much more solid proof of the agreed-upon conditions by all parties and provides immutability. Our proposed system provides a holistic approach and can be redesigned in a fashion that is suitable for the global food crisis. To sum it up, the details presented in this paper can be used further for the implementation and integration of several blockchain platforms.