

# FOOD TRACEABILITY SYSTEM USING BLOCKCHAIN

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**Abstract-** In recent year, many food scandals emerged one after another in Taiwan, such as the plasticizer tainted food and the drainage oil. As people start to focus on food safety, building up a food traceability system has become more and more important in every countries. Therefore, we tried to build a food traceability system. With the advantage of blockchain such as immutability, consensus, disintermediation and distributed ledgers we can establish a trusted food traceability system by these important characteristics. In this paper, we will study the blockchain technology and the background of food traceability system first, and then display the conceptual framework of food traceability system using blockchain and Ethereum. Finally, we demonstrate the building process of the system. With the trusted information in traceability, it would effectively enhance the food safety by the track of production to the selling links.

**Keywords-** Blockchain, Food Safety, Traceability System, Smart Contract, Ethereum.

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## I. INTRODUCTION

With the development of Taiwan's economy, people's living standard has been improved, which increase the demand of food safety and quality. However, more and more food scandals occurred in Taiwan, such as the plasticizer-contaminated food [1] in 2011 and the gutter oil in 2014. These incidents cause damage to people's health and lost their trust to food industry market. In recent years, the government tries to build up a food traceability system in order to let people know more information of product. It can not only increase the reliability of food safety, but also track back to the process of production when the food safety event occurs.

Since the emergence of bitcoin in 2008 designed by Satoshi Nakamoto [2], lots of people invested in bitcoin. Bitcoin starts a technological revolution because it is the first digital currency that the double-spending problem can be solved without the requirement of third party and all the transaction in bitcoin economy is registered in a public, distributed ledger, which is called Blockchain [3]. After success of bitcoin, people start to use the blockchain technology to establish more invention. With the characteristics of blockchain, such as Disintermediation, Consensus, Provenance, Immutability, Finality, it can not only apply on financial industry, but also be extended to many other industries [4, 5, 6].

In Taiwan, government have established Taiwan agricultural product traceability in 2007. To have a traceability label for its products, farmers must grow the raw materials in accordance with Taiwan Good Agricultural Practice before entering the item's production history into an information system, and the item's production information must also be independently verified by an international third-party certification organization. Only if it pass the process,

it can have the traceability label. To sum up, it is too complicated that the process concerns many department and the cost-effectiveness is inefficient [7].

Base on the reasons above, the primary purpose of this paper is to establish a food traceability system based on blockchain technology for helping Taiwan food market to promote their food safety and quality. This paper is structured as followed. We begin with an overview of blockchain technology and the background of food traceability in section 2. Next, we demonstrate the conceptual framework of blockchain and Ethereum in section 3. Then we discuss the use case of food traceability system using blockchain technology in section 4. After that, we demonstrate the deployment process in section 5. Finally, we make a concise conclusion in section 6.

## II. LITERATURE REVIEW

Along with living standards improved, food spices and additives result in varied manufactured food on the market. Some ignorant manufacturers that want to lower the cost and increase yield may lead to more uncertainty of food safety. Since food safety scandals continued to happen, food traceability has been highlighted as an important measure to get rid of the impact to the industry.

According to the definition of the CODEX Alimentarius, food traceability is "the ability to follow the movement of a food through specified stage(s) of production, processing and distribution" [8]. Food traceability system is also defined by ISO 22005:2007 as "a technical tool to assist an organization to determine the history or location of a product or its relevant components." [9]

In general, food traceability is to record food related information in its every stage, from raw materials, soil, farming or planting, harvesting, processing,

manufacturing, transportation and sale. For the demand of safety and health, consumers have the rights to know where the food came from, when the food was being delivered, who should take the responsibility once problems occurred. Ethical firms will provide as much information as they can to let consumers determine goods that meet their needs, establishing transparent food traceability “from farm to fork”.

In terms of current existing supply chain technologies, fundamental technologies for tracking physical goods have been around for years, such as bar codes, radio frequency identification tags and other data-collecting sensors. While food scandal happens from time to time, we propose an outline of food traceability system based on blockchain technology and Ethereum platform to build up smart contracts.

### III. CONCEPTUAL FRAMEWORK OF BLOCKCHAIN AND ETHEREUM

#### 1.1 Introduction of Blockchain Technology

##### 1.1.1 Basic Concept of Blockchain

Bitcoin, a peer-to-peer electronic cash system [2], is a cryptocurrency and the first application based on blockchain technology. Blockchain is essentially a decentralized distributed ledger database which consists of a chain formed by cryptographic data blocks, each data block contains transaction data that already been confirmed. Blockchain puts data stored in different blocks in a peer-to-peer network where non-trusting nodes can interact with each other without a trusted intermediary and they supervise mutually. Any data change needs consent agreement from other blocks. Thus, blockchain is also be known as a Trust Machine [10].

Blockchain's decentralized consensus process requires nodes in the network to continuously attempt to produce packages of transactions called "blocks". The network is intended to create one block approximately every ten minutes, with each block containing a timestamp, a nonce, a reference to (i.e., hash of) the previous block and a list of all of the transactions that have taken place since the previous block. Over time, this creates a persistent, ever-growing, "blockchain" that continually updates to represent the latest state of the blockchain ledger [11].

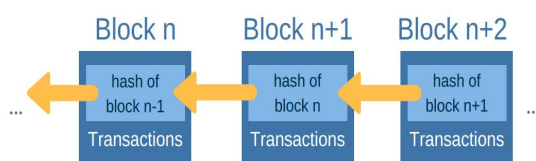


FIGURE 1. Each block in the chain carries a list of transactions and a hash to the previous block.

Blockchain's consensus is created through a process called "mining". Whenever encrypted transactions happen, miners with powerful computing capability start to authenticate transactions by using algorithms for decryption to create new blocks to record newest transaction.

New block then being extended to the tail of the blockchain in sequence chronologically, and the chain will be increased and prolonged continuously. To prevent blocks from being viciously manipulated, each block must satisfy with consensus mechanism, any arbitrary modification will ended up invalid. Unless one dominates 51% of the computing power simultaneously, the transaction data will stay immutable.

There are three types of blockchains that have been widely accepted, which are Public Blockchain, Private Blockchain and Association Blockchain. Public Blockchain acts as an open access structure without central management. Anyone could join the network anonymously without certification and authenticate transactions automatically. Private Blockchain is also known as the Permissioned Blockchain which is usually used by companies or governments.

Because of internal secret information within the organizations, the usage and related workers of Private Blockchain are limited. Association Blockchain combined the features of Public Blockchain and Private Blockchain, usually lead by core members of an association to form an industries with similar services and required interoperability. The association formulate their own rules and work flows, follow-up participants need to be approved by core members and to comply regulations and By-Laws set out by the association.

##### 1.1.2 Decentralization

Instead of relying on a third party to mediate transaction, such as a financial institution, member nodes in a blockchain network use a consensus protocol to agree on ledger content, and cryptographic hashes and digital signatures to ensure the integrity of transactions.

The decentralized peer-to-peer blockchain network prevents any single participant or group of participants from controlling the underlying infrastructure or undermining the entire system. Participants in the network are all equal, adhering to the same protocols. They can be individuals, state actors, organizations, or a combination of all these types of participants.

At its core, the system records the chronological order of transactions with all nodes agreeing to the validity of transactions using the chosen consensus model. The result is transactions that are irreversible and agreed to by all members in the network [12].



FIGURE 2. A food supply chain system using centralized method to track food flow between nodes



FIGURE 3. A decentralized system is formed to substitute intermediate, multiple nodes compute and validate together to prevent data from unexpected modification

### 1.1.3 Distributed Ledgers

Current business ledgers in use nowadays are inefficient, costly, non-transparent, and subject to fraud and misuse. These problems caused from reliance on centralized, trust-based, third-party systems, such as financial institutions, clearinghouses, and other intermediaries of existing institutions. In traditional business networks, all participants maintain their own ledgers with duplication and discrepancies that result in disputes, increased settlement times, and the need for intermediaries with their associated overhead costs [12].

Distributed ledgers are blockchain-based ledgers where transactions are distributed into different nodes and each node cannot be altered once validation has been written in the ledgers by consensus algorithms, hence every node can participate in supervising transaction legitimacy. In fact, each ledger contains others transaction data, consensus ensures that the shared ledgers are exact same copies. Although their values and addresses are visible, dealer's real identity will be unknown without other technical method.

Different from traditional centralized transaction ledgers, none of the nodes can record transaction on its own, thus avoiding one from being rigged in order to create fake transaction. On the other hand, since there are enough nodes of ledgers, it is theoretically impossible to destroy the transaction data which improved record keeping. Blockchain technology leads to increased trust and integrity in the flow of transaction information among the participating members, now businesses can save time and costs while reducing risks.

### Current Status

Origination Farm's Ledger	Processing Factory's Ledger	Sales Market's Ledger
Raw materials detail ...	Origination farm's detail additives detail ...	Delivery detail Warehouse information ...

### Blockchain

Shared Ledger		
Copy of Origination Farm's Ledger	Copy of Processing Factory's Ledger	Copy of Sales Market's Ledger
Raw materials detail Additives detail Delivery detail Warehouse information	Raw materials detail Additives detail Delivery detail Warehouse information	Raw materials detail Additives detail Delivery detail Warehouse information

FIGURE 4. Separated ledgers in current status in comparison to shared ledger in blockchain

## 1.2 Introduction of Ethereum

### 1.2.1 Building up Smart Contracts on Ethereum

Proposed by Vitalik Buterin in 2014, Ethereum is a public blockchain network optimized for smart contracts that uses its own cryptocurrency called Ether. Ethereum supports numerous functions, including cryptocurrencies, smart contracts, decentralized transactions. It is believed that Ethereum is the first application of Decentralized Autonomous Organizations (DAOs).

Ethereum intends to provide a blockchain with a fully built Turing-complete programming language that can be used to create smart contracts simply by writing up the logic in a few lines of code. This allows users to create any of the systems they want, as well as other applications that are not related to cryptocurrency. Ethereum would not support any of the applications directly, but the existence of a Turing-complete programming language means that contracts can theoretically be created for any transaction type or application. A contract is like an automatic agency that execute specific script whenever it receive a transaction. The script then alters data storage from the contract or transmits a

transaction. What is more interesting about ethereum, however, is that the ethereum moves far beyond just currency. Ethereum have the potential to substantially increase the efficiency of the computational industry, and provide a massive boost to other peer-to-peer protocols [11].

### 1.2.2 How Smart Contract Works

The smart contract could be seen as a digital contract that runs contract terms automatically. Smart contract consist of scripts embedded within the blockchain. It receives information from other participants, store the value and response with a result. Smart contract are triggered by receiving transactions. Then it executes the default condition with every node in the blockchain network according to the transaction contents [13, 14]. If the transaction contents are in compliance of the smart contract, it the transaction is completed automatically; else, the transaction fails. Any business models that include contract have the potential to use smart contracts to reduce response time. Such as real estate where people find an apartment through real estate agent. By using smart contract, there is no need for landlord to pay extra fee to the middlemen. Even automobile company is interested in investing money in blockchain and smart contract. Insurance companies are happy to see the technology development since they can give out different insurance contracts based on driver's driving habit. Along with big data, insurance companies can set out more precise and more reasonable contract content [15].

## IV. FOOD TRACEABILITY SYSTEM USING BLOCKCHAIN TECHNOLOGY

### 1.3 Use Cases of Food Traceability System Using Blockchain Technology

A project of collaboration between Walmart, IBM and Beijing Tsinghua University was unveiled in October, 2016. The project aimed to create a new model using blockchain technology for food traceability, supply chain transparency and auditability, and it was initially planned to track and trace Chinese pork. They hope to enhance the safety of food by the power of blockchain technology designed to generate transparency and efficiency in supply chain record keeping [16].

The project will be using the IBM and Linux Foundation-led Hyperledger Project architecture. Food production flow can now be digitally tracked in an immutable environment under the distributed ledger framework. The tracking information includes storage temperatures, expiration date, shipping details, origination farm details, batch number and much more relevant data when the food being delivered worldwide. The data are digitally connected to food items and the information is entered into the blockchain along with every step of the process.

A Hackthon event was also organized by the NTU

collaborating with Ministry of Health and Welfare of Taiwan in August, 2016. The event was called "2016 2B Hack for food" which 2B stood for Blockchain and Big Data. They wish to create a food traceability system by using blockchain technology to link upstream manufacturers and downstream merchants closely, preventing them from making fake food production resume and let customers know where the food come from. In the future, the Government will use the information management of food safety to link up cross-sector information systems related to food management, from the examination, border inspection and food industry registration system into a "food cloud".

### 1.4 Advantages and Disadvantages of Food Traceability System Using Blockchain Technology

Image that a food safety problem happens, the food on the market needs to be investigated to determine who should be penalized. Under current food traceability system, there are numerous departments involved as the investigation institute, such as the FDA (Food and Drug Administration), the COA (Council of Agriculture) and the EPA (Environment Protection Administration). However, what if whole batch of affected food are from different suppliers, or even some tracking data have been altered. For this case, these departments have to investigate multiple times with a lot of manpower and resources in an inefficient way. From another perspective, there are several regular audits to make sure manufacturers comply with the regulations. With FDA, COA and EPA having jurisdiction over hundreds or thousands of manufacturers at the same time, the overall investigation cost is tremendous. With the implementation of blockchain, data from sensors or other data-collecting machine will be uploaded in real time through blockchain network. The related departments can now receive the newest updates according to the shared ledger, saving a lot of time and energy.

In a traditional centralized structure, the COA has a database that stores data of food track. When a food producer gives detailed information of the products to a manufacturer, the COA will search for its database to make sure the information which the food producer provides is correct. While the food traceability system using blockchain, food information is uploaded on the distributed ledger by food producers. Manufacturers can now fetch data from the shared ledger to ensure the food is safe. The transaction is automatically done once the smart contract is in effect. Because of consensus mechanism, the whole transaction process do not need intermediates and the production record will kept immutable.

Although the food traceability using blockchain technology looks promising, there are still several practicability and limits should be consider before importing the new technology. One of the issue worth noticing is that we are still relying on sensors such as

RFID tags or barcodes to scan food tracking data, and the data collecting sensors are connected to the blockchain network. Even though the data stay immutable, the blockchain does not have a verification mechanism to prove whether the raw data is correct. If one tampers with the sensor, the blockchain have nothing to do with detection. Another issue is that the overall cost would be unpredictable, especially when the existing supply chain system have been used for many years. Implementing new technology in such mature system is influential. On the other hand, what kind of data should be publicize and what kind of data should not. Manufacturers that think of its formula as business secret will confronted a contradiction between revealing it or not, without a clear policy, the legality

line will be ambiguous [17].

### 1.5 Building up Food Traceability Smart Contracts on Ethereum

Production Contract records every stage from origination information, purchasing raw materials, farming or planting to harvesting. RFID tags are used on agricultural machineries and vehicles to trace their schedule. Sensors are used in an IoT model to track fertilization and pesticides condition. Smart contract then based on its predetermined conditions, weather forecast water, soil and other production conditions to decide operation of agricultural machineries and vehicles.

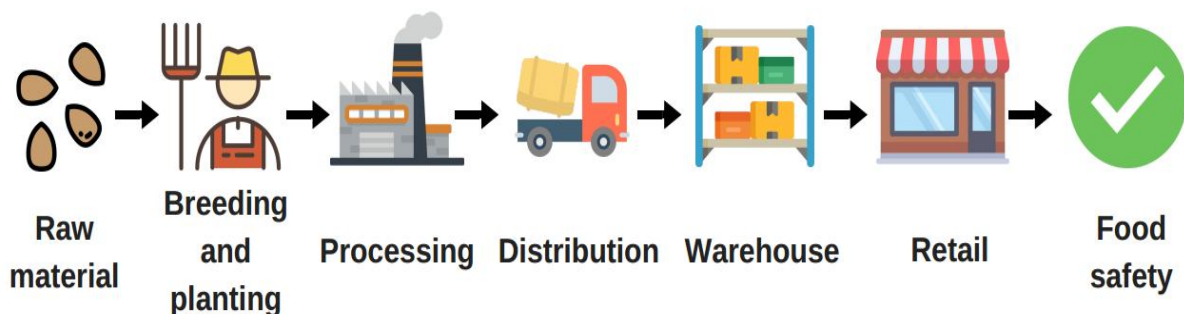


FIGURE 5. Using smart contracts to link up every process within food traceability stage

Processing contract is another key role of the food traceability system. Processing manufactories can fetch production data by looking up the distributed ledger. After processing, such as meat being slaughtered and adding additives, the related data are uploaded through RFID tags again immediately.

Delivery contract relies on IoT sensors with wireless network connection. The shipping time and arrival time are written in the blockchain in real time. With GPS positioning the location of the delivery plane, ship or truck, managers can easily trace back once accident occurs. Cold chain distribution much more concerned about temperature and humidity, if one of them reach the limit regulated on the smart contract, manager will be notified by alert to adjust the delivery condition.

Sales contract is the last step of food traceability system. Consumers scan the bar codes to obtain the data from production, processing to delivery. A typical food resume includes batch number, verification mark, producer, expiration date and barcode. Transparent food information not only enhance food traceability, but also increase consumers' confidence and activate their will to buy trustworthy food [18].

## V. DEPLOYMENT PROCESS

From the perspective of blockchain, when miners receive a command containing the created smart contract, they will put the received value into the

chain. The miners will return these values plus the time of the hash at the same time, as the smart contract id. In the case of a command, when miners receives a new smart contract command that specifies the id of the smart contract, they firstly find the status of the smart contract from the blockchain, based on current status and immediate command to do the operation. The result of the calculation is put into the block they are working on [15].

To run smart contracts, we needs smart money, smart wallet, then need to learn Solidity, a new language for smart contracts, Solidity create a tradeable digital token that can be used as a currency, a representation of an asset, a virtual share, a proof of membership or anything at all.

The followingintroductions are some of the tools will be used to deploy the smart contract:

- 1) MinerGate: MinerGate is your gateway to mine cryptocurrencies easily, quickly and with no hassle, you don't need to be an expert programmer asMinerGate will guide you through the process.
- 2) Mist: Ethereum wallet, behind the need to have a full node support. Mist provides an interface bag that makes it easier for users to interact with the underlying nodes.
- 3) Solidity real-time compiler
- 4) etherscan.io
- 5) ethstats.net

When the items enter the factory, we need to type in their id,the time they arrived, and then record the data from the sensors such as temperature or humidity, to



make sure the food is fresh. When the process is finished, we need to type in the time, temperature and humidity again, then package them. When they leave, we need to type in the time they leave.

```
function bond(uint _id,string _company,uint _starttime,
uint _leavetime,
uint _temperature,uint _sensor)
{
    if(SenderCheck==true || ended==true)throw;
    Sender=msg.sender;
    SendTime=now;
    starttime= _starttime;
    //Time of arrival
    company=_company;
    //company's name
    id=_id;
    //item's id
    temperture= _temperature;
    //temperture
    sensor=_sensor;
    //sensor's data
    leavetime= _leavetime;
    //leave time
    SenderCheck=true;
}
```

FIGURE 6. Example of smart contract codes

## CONCLUSION

In this paper, a food traceability system is established, based on the blockchain technology. This system records the information of every links in food supply chain and integrates all the details using blockchain, which realizes the traceability management for quality and safety food supply. As proof of concept, we are starting with the basic method of food traceability system using blockchain technology. In further studies, we would like to build up a complete food traceability system after we study the practicality and limit of the system in the future. With the improvement of food traceability system, we hope that people do not need to worry about food safety problems.

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