Introduction to System-on-Chip and its Applications

Individual Project Report

Agriculture Blockchain/Technologies

National Tsing Hua University
Department of Computer Science

111062575
許詠晴

Outline

1. Introduction

As time progress, it is inevitable that new technology will be introduced into the development process of modern agriculture. One trend that has emerged in recent years is the integration of blockchain technology. Unlike conventional centralized and monopolistic agricultural management systems, blockchain is a decentralized data structure that can store, retrieve and shared data with multiple untrusted users or parties. In this way, it could potentially resolve a number of serious problems in current system.

First, blockchain technology can provide transparency and traceability in the supply chain. By using blockchain. Farmers and other stakeholders in the agriculture industry can track the movement of produce from the farm to the consumer. This can help to ensure food safety and quality, as well as increase the efficiency of the supply chain. For instance, if there is a food safety issue, it can be traced back to the source using blockchain technology. This can help to minimize the impact of such incidents on consumers and the whole member who participate in this supply chain.

Secondly, blockchain can also help to increase the efficiency of agricultural operations. For example, it can be used to automate and streamline the process of tracking and recording data, and use these such data to inform statistical such as when to pesticides and fertilizers and so on. These operations can help to prevent form wasting time and money, and even allow crops to grow better than conventional farming. In addition, blockchain technology can be used to facilitate the exchange of information and resources within the agriculture industry due to the sharing of data and resources.

Not only that, thanks to the aforementioned reasons. When the entire agriculture blockchain is more fully developed, more non-agricultural industries will be able to participate in the ecosystem, such as the insurance, logistics, and even the human agency industries. This will contribute to the stability of the ecosystem. Additionally, as blockchain technology advances, more algorithms and applications will be proposed, creating more opportunities. In other words, this entire agricultural blockchain ecosystem is both flexible and extensible.

However, there are still many problems to be solved such as security and privacy, integration with existing legacy systems, and user trust in this ecosystem.

The structure of this report is organized as follows: In Section 2, the technology used in blockchain and IoT, and how to integrate these technologies into Agriculture. In Section 3, some applications will be mentioned. The analysis of this industry is also be discussed. Finally, the conclusion is drawn in Section 4.

2. Technology Analysis

In this section, some technologies of Agriculture Blockchain will be introduced, such as the behind of blockchain and IoT for Agriculture. In the last of this section, how to use these mentioned technologies in Agriculture is presented.

2.1. Blockchain

Blockchain is a distributed ledger to share transactions or sensitive data across untrusted multiple stockholders in a decentralized network. As shown in Figure 1, it is a basic data structure of a blockchain that compose the blockchain. The first distributed blockchain technology was described as fundamental component of the Bitcoin cryptocurrency. This idea proved to be a success and managed to change the model of central management. Blockchain architecture and design involves many technologies such as cryptography, peer-to-peer network (P2P), consensus algorithm, and a new concept: smart contract.

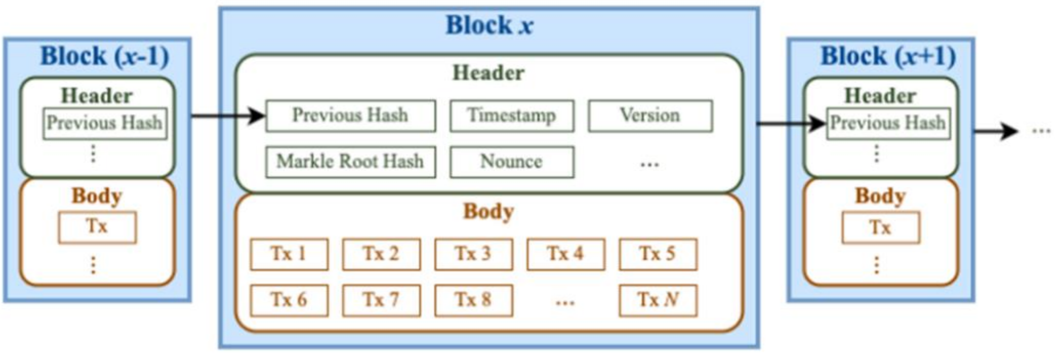

Figure 1, the data structure of a blockchain,
source: Blockchain Technology in Current Agricultural Systems: From Techniques to Applications

2.1.1. Cryptography

Cryptography is a method of securing data from unauthorized access is also made up of two ancient Greek terms, Kryptos and Graphein. The former term meaning “hidden” and the latter being “to write”. There are mainly three different categories in cryptographic algorithms, namely, **symmetric-key cryptography**, **asymmetric key cryptography**, and **hash functions**.

The difference between symmetric-key cryptography and asymmetric key cryptography is the number of keys in the two communicating users. In symmetric-key cryptography, A common key is used for both encryption as well as the decryption process; however, in the asymmetric key cryptography, there are two different keys, encryption key (public key) and a decryption key (private key). The key pair generated by this algorithm consists of a private key and a unique public key that is generated using the same algorithm.

In addition, the most important Cryptography in blockchain is hash functions. This type of encryption doesn't make use of keys. It uses a cipher to generate a hash value of a fixed length from the plaintext. It is nearly impossible for the contents of plain text to be recovered from the ciphertext. Furthermore, if the input has just a small difference, the output will become very different. Take example of the SHA-256 hash function, shown in Figure 2, adding a "!" after the input, the output varies a lot.

- **Input**: hello my friend
- **Output**: 5d575bc10fbfbf62435849d4f8d0382a5acc939e9f92492 d87e70852655d8be9
- **Input with a slight difference:** hello my friend!
- **Output:** 7f254266b011eec22f0af99bf627143bab758ae5eb 840fffb87e5d24850f1320

Figure 2, example the SHA-256 hash function

2.1.2. P2P

Blockchains are typically managed by a peer-to-peer (P2P) computer network. Not like Client-server model, there is a central server which provides clients services. In P2P, all the nodes in this network are acted as both client and server. As shown in Figure 3, it is an architecture of P2P network, peers make a portion of their resources, such as processing power, disk storage or network bandwidth, directly available to other network participants, without the need for central coordination by servers or stable hosts. If there is a request be proposed, the request is broadcast to every node. The request will be solved by some nodes which provide this service, and finally, the request is done, every node will know it if needed.

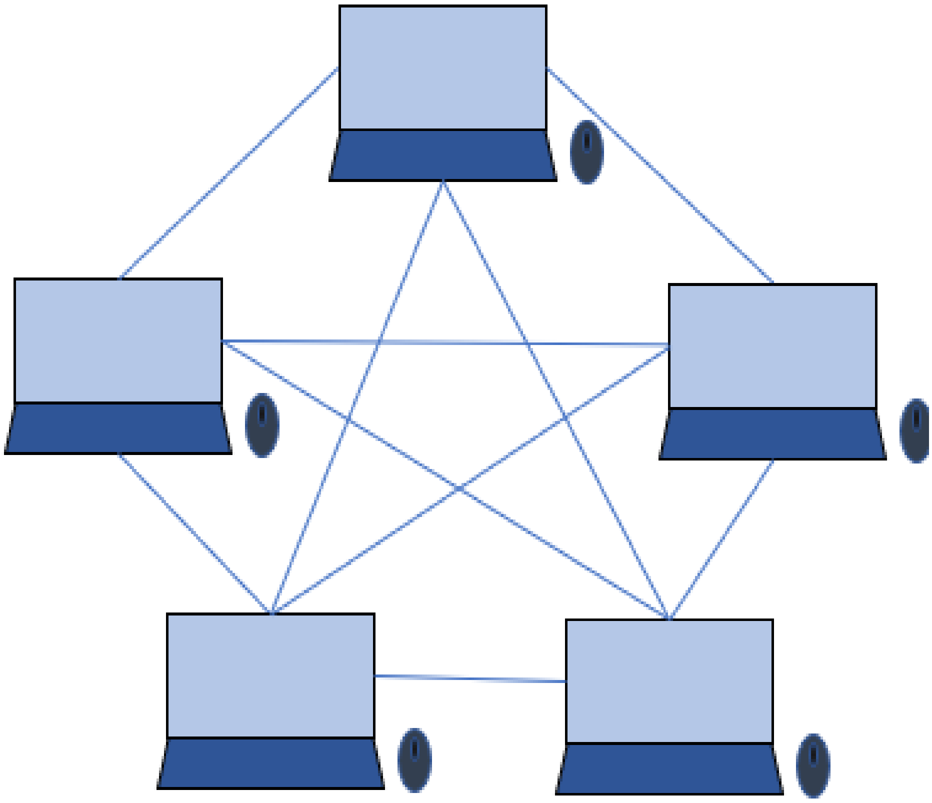

Figure 3, P2P network architecture

2.1.3. Consensus mechanisms

Consensus is one of most import part in blockchain, which is a method of authenticating and validating a value or transaction on a blockchain or a distributed ledger without the need to trust or rely on a central authority. There are several mechanisms such as PoW, PoS, DPoS, PBFT, PoET.

However, how to choose a correct consensus often depends on the type of a blockchain. If a blockchain which participating parties are more 7 trusted, then the consensus mechanisms may not be more complicated and costly. These blockchain may use PBRT or PoET that are quietly easier. But in public blockchain like Bitcoin and Ethereum, users do not know who each other is, which is a trustless blockchain. Therefore, more complex mechanisms such as PoW and PoS are used.

These more complex consensus mechanism like PoW are the reason of "miners" appearing, because Miners have to bundle up a group of transactions into a block and try to mine it (try to solve hard puzzle). In Bitcoin, the hard puzzle is defined as *"Given data A, find a number x such as that the hash of x appended to A results is a number less than B."*

The first problem-solving miner add this block into the blockchain, broadcast this new block to every node, and finally get a reward. Thus, there are lots of mining ASIC, or GPUs be used for mining. Shown in Figure 4, and Figure 5, these are two latest mining hardwares.

■ **Mining ASIC**

Bitmain
Antminer KA3 (166Th)

Manufacturer	Bitmain
Model	Antminer KA3 (166Th)
Release	September 2022
Hashrate	166Th/s
Size	195 x 290 x 430mm
Weight	16100g
Noise level	80db
Fan(s)	4
Power	3154W
Voltage	200-240V
Interface	Ethernet
Temperature	5 - 40 °C
Humidity	10 - 90 %

Figure 4, mining ASIC – Bitmain Antminer KA3 (166Th)

■ **Mining GPU**

Nvidia
Geforce RTX 3080 Ti

15.24Gh/s hashrate	Hash rate
12 GB GDDR6X	VRAM
8nm	Process size

Figure 5, GPU – RTX 3080 Ti

2.1.4. smart contract

Smart contracts are simply programs stored on a blockchain that run automatically when predetermined conditions are met. As shown in Figure 6, this is an example of how smart contract works. Decentralized application (DApp) is an combination of a series of smart contracts. With smart contract, the whole blockchain can become flexible and variable.

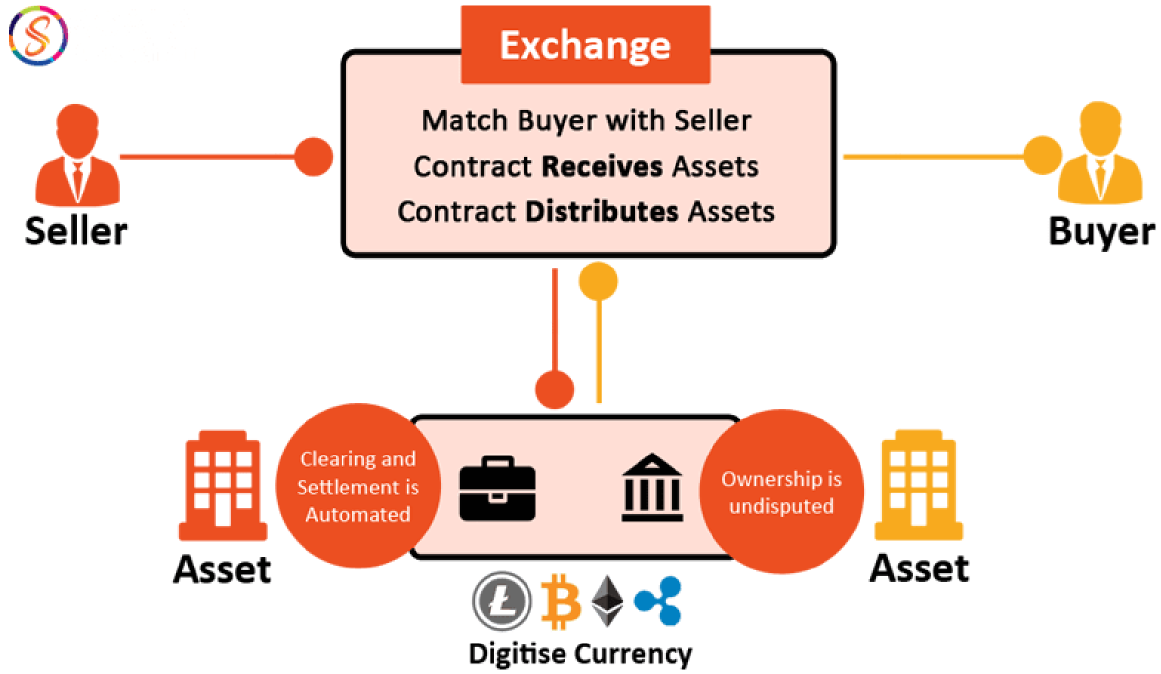

Figure 6, the example of how smart contract works,
source: https://www.scalablockchain.com/smartcontract.html

2.1.5. How blockchain works and its properties

After introducing the above contents, how blockchain works can easily be shown in Figure 7. User A firstly propose a request such as transferring money or deploy a smart contract. This request is broadcasted to every node based on P2P technology. Through a consensus mechanism the blockchain used, the request is packaged together with others requests into a block and linking this block to the blockchain. If in Bitcoin, the first miner who solve the hard puzzle will package numbers of requests into a block, adding this block into blockchain, and then broadcasting this news to every node. Finally, this request of User A is completed.

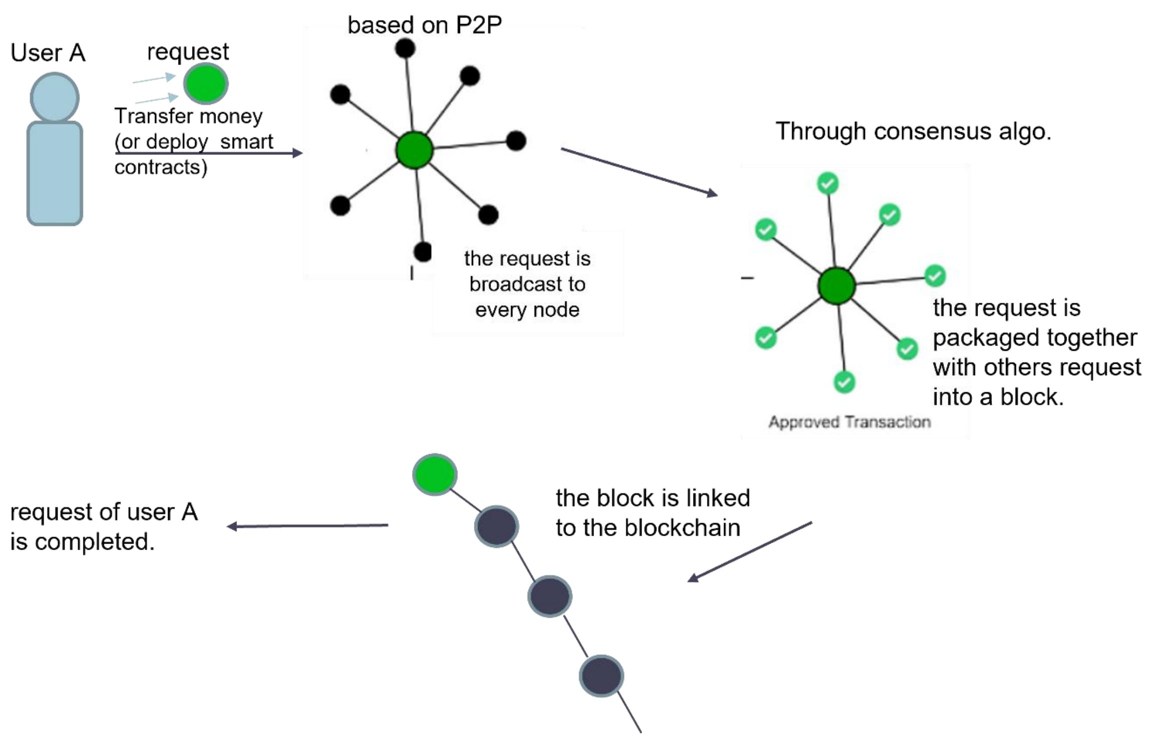

Figure 7, the flowchart of how blockchain works

Here are some properties of Blockchain,

Data Immutability and Integrity

Without the consent from the majority of nodes, no one can add/delete/edit any transaction blocks to the ledger.

Decentralized

Not like Client-Server model, managed by P2P network. It is an decentralized network. System.

Transparent

Because every node or participant in Blockchain can access to all transaction data.

Consensus-based

Every blockchain thrives because of the consensus algorithms.

Flexible

Because Smart Contract is used.

2.2. IoT in agriculture

The Internet of things (IoT) describes physical objects (or groups of such objects) with sensors, processing ability, software and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks.

IoT is not doubly important in modern Agriculture because it allows for the collection and analysis of data in real-time. This can help farmers to make more informed decisions about their operations, such as when to water, fertilize, and harvest crops. In addition, IoT can help to improve the sustainability of agriculture by enabling the use of precision farming techniques. The efficiency, profitability, and sustainability of agricultural operations can also be improved.

2.2.1. Agricultural IoT devices and protocols

The proliferation of IoT devices in agriculture has been rapidly increasing. Here are two examples. One is for home growing so can use Wifi to transmit IoT data to the web. The other one is for real farmers, entire large fields, so uses a Low Power Wide Area (LPWA) network protocol - LoRa.

As shown in Figure 8, it is an example for Soil Moisture Data Retrieval system. A Moisture sensor is connected to the ESP32 board which is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC low-power 40 nm technology. It is designed to achieve the best power and RF performance, showing robustness, versatility and reliability in a wide variety of applications and power scenarios. When the moisture data through the ESP32 board, the data is pre-processed, logged in a .csv file, and transferred to the corresponding App to display. This can prove very useful for home plantations, floriculture, horticulture, agriculture etc. where optimum soil moisture needs to be maintained for proper growth of plants.

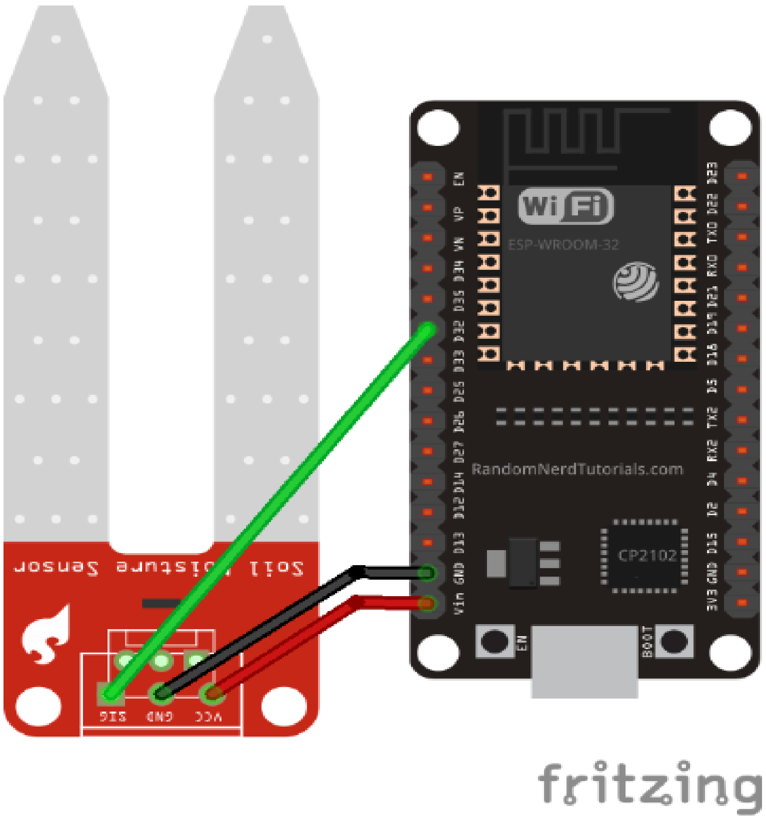

Figure 8, Soil Moisture Data Retrieval,
source: https://opencloudware.com/soil-moisture-data-retrieval-application-using-tuya-link-sdk/

The other example is for Smart Agriculture Application shown in Figure 9 using Himax WE-I Plus EVB Endpoint AI Development Board which is ultra-low power and performance solution targeting TensorFlow Lite for Microcontrollers applications. It uses a 40mmx27mm circuit board to integrate AoS™ VGA sensor, L/R stereo microphone, three-axis accelerometer, USB and SPI /I2C/UART bridge and other full functions. This application includes the use of the Himax WE-I Plus Board with SparkFun's Qwiic sensors on farms or plantations for Machine Learning (ML) based crop detection and to simultaneously obtain PHT, CO2, VOC data required in order to monitor the proper growth of plants. And all pre-processed or raw sensor data is communicated using **LoRa**.

LoRa (short for "long range") is a proprietary radio communication technology that uses spread spectrum modulation techniques based on chirp spread spectrum (CSS) technology. It was developed by Cycleo, a company based in Grenoble, France, which was later acquired by Semtech. LoRa is known for its long range capabilities, making it useful for a variety of applications including Internet of Things (IoT) networks, asset tracking, and smart city solutions. It operates in the sub-gigahertz frequency bands, which allows it to transmit data over long distances while using low power. This makes it an attractive option for low-power, low-cost wireless communication systems.

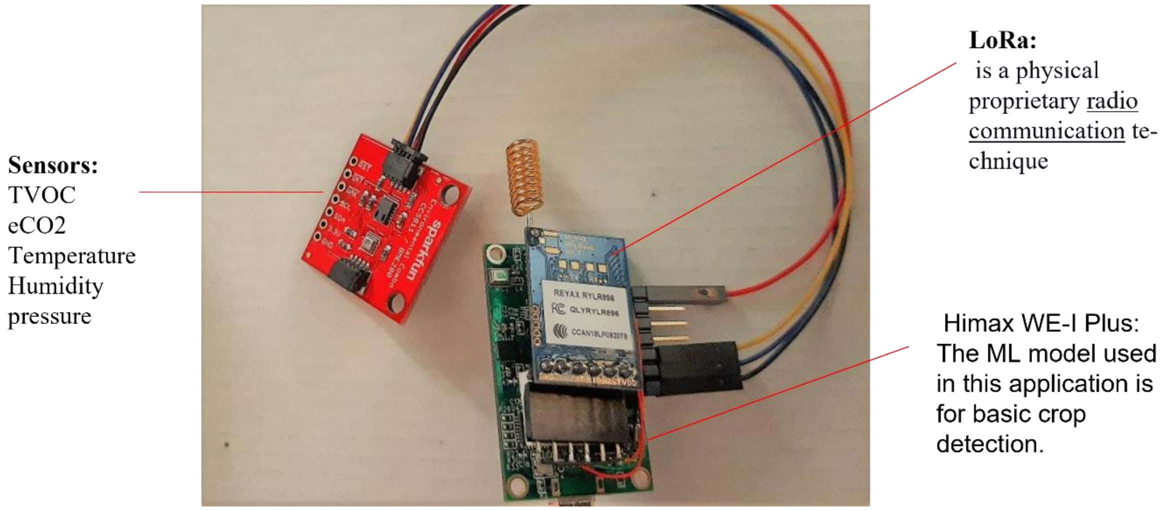

Figure 9, Himax WE-I Plus EVB Endpoint AI Development Board with SparkFun's Qwiic sensors on farms, source: https://opencloudware.com/smart-agriculture-application-using-himax-we-i-plus-evb-endpoint-ai-development-board/

2.2.2. IoT data with IPFS

IPFS (InterPlanetary File System) is a decentralized file storage system that uses distributed ledger technology to store and retrieve data. It is often used in conjunction with IoT to store and manage large amounts of data generated by IoT devices. In addition, using IPFS, the data is stored in a decentralized manner, which mean that it is not controlled by any single entity and is less vulnerable to tampering or loss.

As shown in Figure 10, it is an operation example of IPFS. A file with content "The red fox runs across the ice" is uploaded to an IPFS-based system. Then, this content will be hashed, and getting a unique key "52ED879E". This unique key can be thought of as "an URL". If anyone wants to download or access the file, using this unique key "52ED879E" to find it. That is, a person who has a key of a file can access this file.

However, if this file is a private data, but as anyone who get this unique key can get this file. It will become a secure problem. This problem is usually solved by using cryptography, by encrypting the confidential content and uploading it to IFPS, so that even if it is downloaded by unauthorized users, it cannot be deciphered. In addition, using hash function to hash the content of a file. If the file is modified and re-uploaded, the hash key will change. Thus, IPFS can manage different versions of the same files.

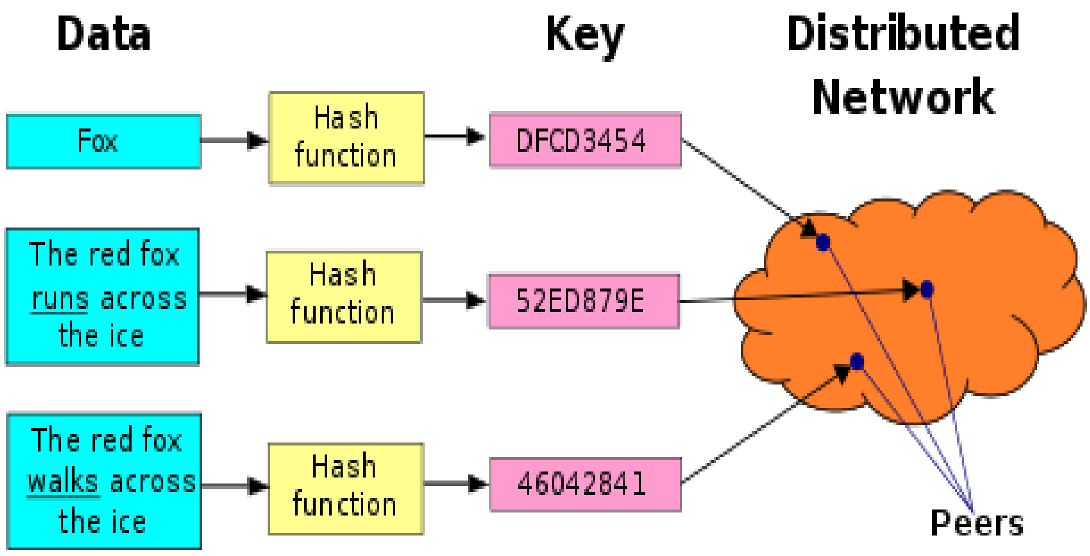

Figure 10, operation example of IPFS,
source: https://en.wikipedia.org/wiki/Distributed_hash_table

After introducing IoT data with IPFS, it can combine with blockchain. As shown in Figure 11, IoT data is too large that is hard to put them all into blockchain (high cost), so using IPFS to solve this problem. A file is uploaded to an IPFS system, a hash key is generated, and this key is put into the blockchain. Because the content in the blockchain is immutable and the key of this file is unique, it proves that the content of the file obtained by traversing the blockchain will not change.

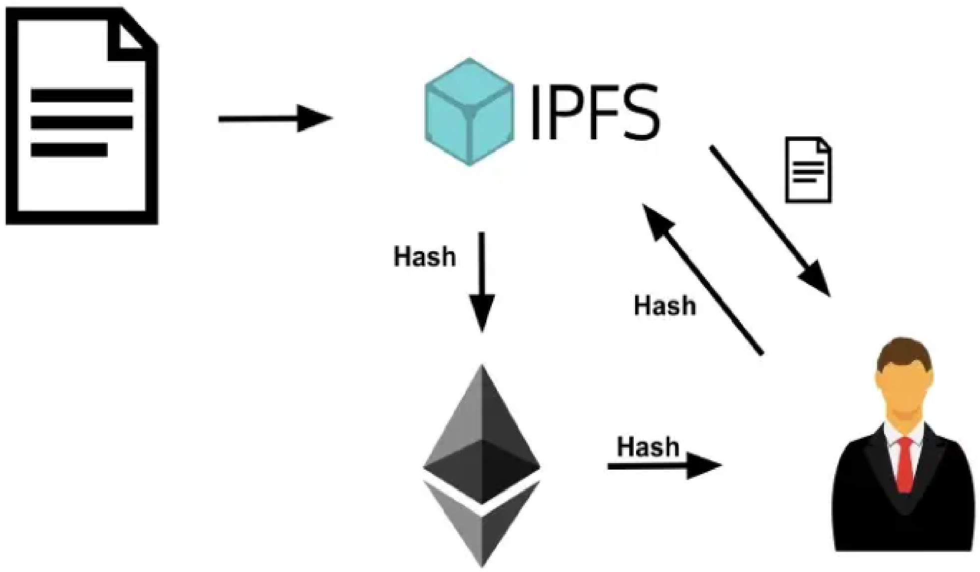

Figure 11, example of IoT data with blockchain and IPFS,
Source: https://medium.com/pinata/ethereum-and-ipfs-e816e12a3c59

2.3. The integration of Agriculture, blockchain and IoT

The integration of agriculture, blockchain, and IoT has the potential to bring numerous benefits to the industry, including increased transparency and traceability, efficiency, profitability, and sustainability.

Blockchain technology can provide transparency and traceability in the supply chain, allowing farmers and other stakeholders in the agriculture industry to track the movement of produce from the farm to the consumer. This can help to ensure food safety and quality, as well as increase the efficiency of the supply chain.

IoT technology can help to increase the efficiency of agricultural operations by automating certain tasks and reducing the need for manual labor. For example, IoT sensors can be used to monitor soil moisture levels and automatically trigger irrigation systems as needed. In addition, IoT can be used to facilitate the exchange of information and resources within the agriculture industry, such as the sharing of best practices and resources.

The integration of these technologies can also help to increase the profitability of agriculture by allowing farmers to directly connect with consumers and bypass intermediaries, such as wholesalers and retailers. This can help to increase the profit margin for farmers and provide them with more control over the prices of their produce.

Overall, the integration of agriculture, blockchain, and IoT has the potential to transform the agriculture industry and bring numerous benefits to farmers and other stakeholders.

3. Industrial Analysis

This section is Industrial Analysis, and some applications will be introduced. In which fields will the agricultural blockchain be used today or in the future? And SWOT analysis will also be presented.

3.1. Application

How the blockchain technology are deployed to achieve efficacy and integrity of agricultural applications. Based on these targeted issues, I categorize uses of blockchain into four groups. As shown in Figure 12, it is an application of blockchain in various verticals of the agriculture domain.

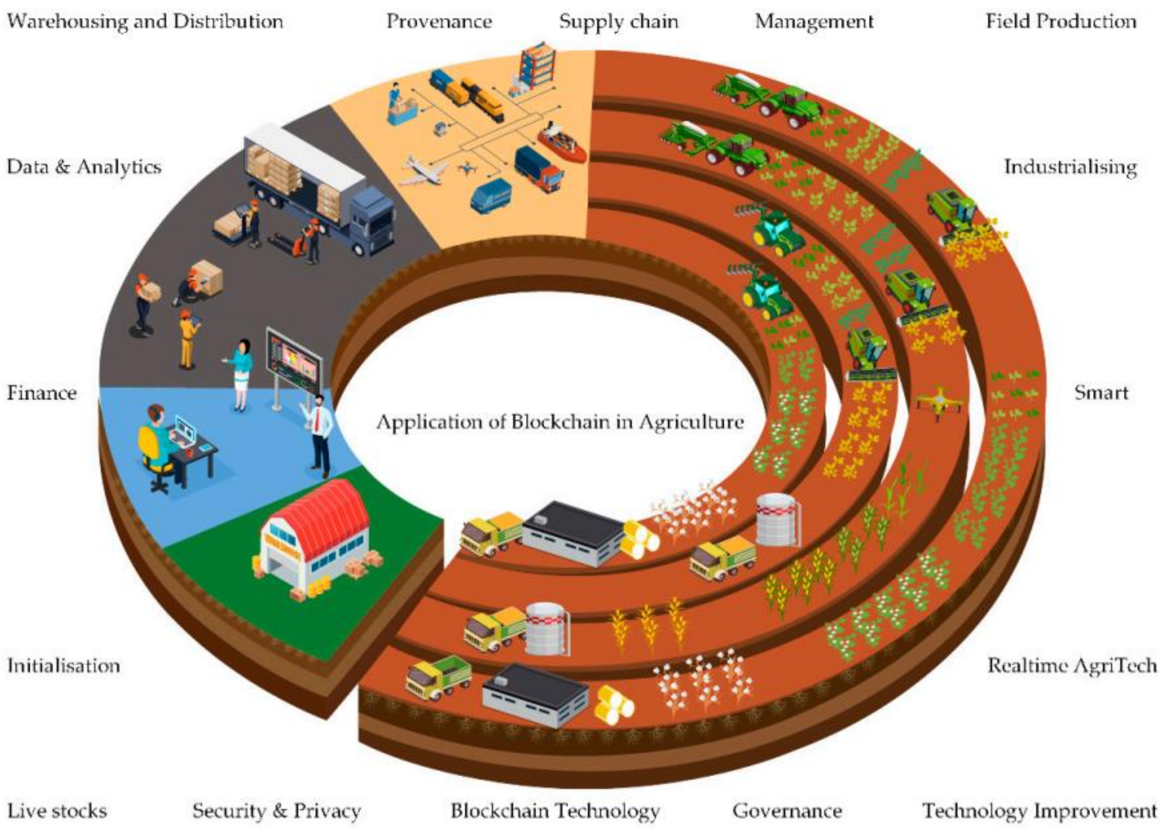

Figure 12, Application of blockchain in various verticals of the agriculture domain, source: Survey on the Applications of Blockchain in Agriculture

3.1.1. Provenance traceability and food authentication

The use of blockchain technology in agriculture for traceability and provenance in product supply chain management has become increasingly popular in recent years. This is due to the fact that it is the most efficient way to enhance food safety, reduce fraud, and prevent food scandals. By storing all relevant data related to the origin and movements of a product on a decentralized and tamper-proof platform, it is possible to ensure that the product can be traced in real-time. To implement this system, a digital token is attached to each product item when it is produced. This token contains information about the product, including its origin, production date, and any other relevant data. As the product moves through the supply chain, this information is updated in real-time, allowing stakeholders to track the product's movements and ensure that it is being handled properly, which can help to prevent food from scandals.

As shown in Figure 13, it is an agricultural stakeholders.

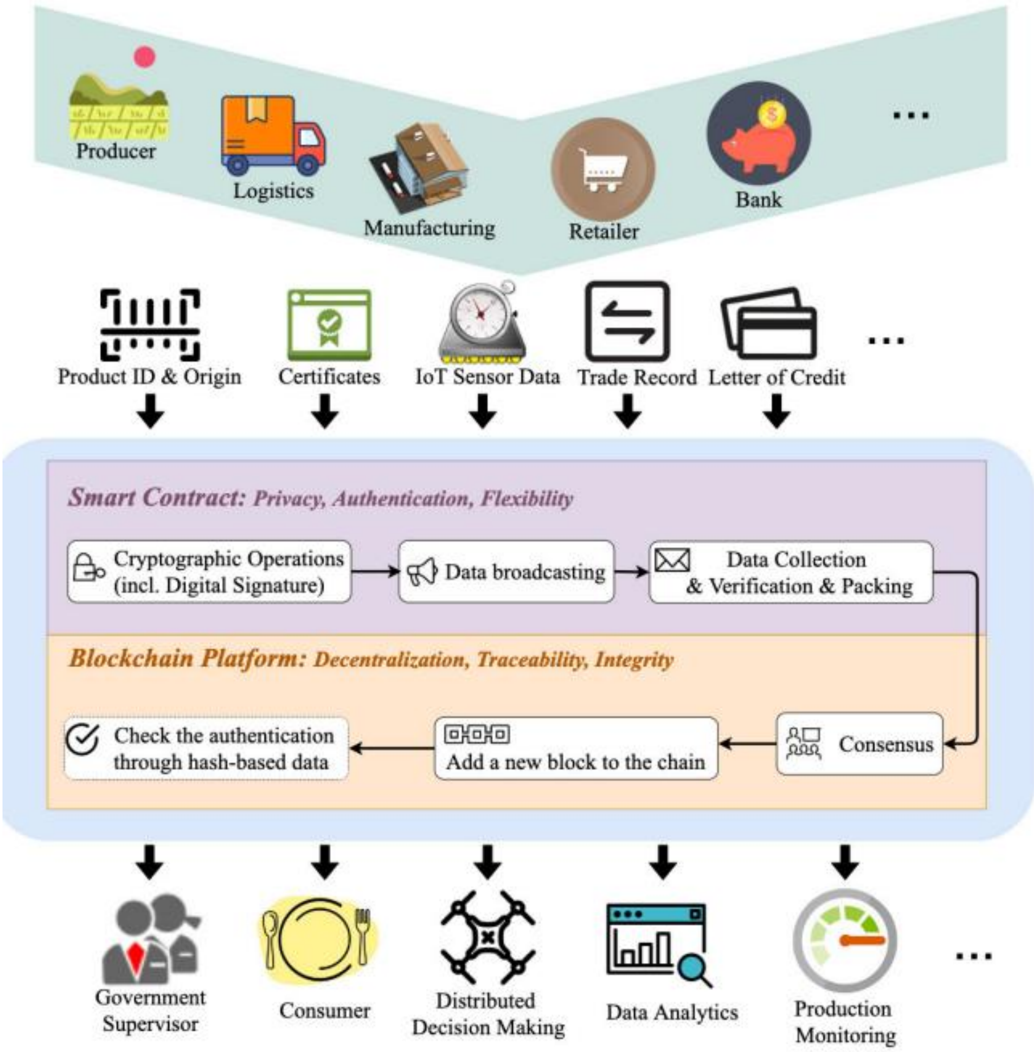

Figure 13, Agricultural stakeholders,
source: Blockchain Technology in Current Agricultural Systems: From Techniques to Applications

3.1.2. Smart farming data management and Optimization of food supply chain

IoT techniques have become increasingly popular in the agriculture industry, particularly in the realm of smart farming. These techniques can be used to improve productivity control and management by allowing farmers to collect and analyze large amounts of data in real-time.

One trend that has emerged in recent years is the migration of IoT data from centralized databases to blockchain systems. This has been done for a variety of applications, including in the agriculture industry. By storing IoT data on a decentralized and tamper-proof platform, it is possible to ensure the integrity and security of data. By analysing the data collected by IoT devices, farming operations can be optimized to increase productivity, and even optimizing the food supply chain.

3.1.3. Trad finance or Crop insurance

Blockchain was originally proposed to improve the financial efficiency, and reduce transaction cost by removing intermediaries and audit cost via improved accountability in trading business process. This feature is powerful to support small scale farmers who are suffering from high cost of trad transactions and accidental losses cause by environmental disasters or other uncertainties.

There is the most straightforward uses of blockchain in agriculture to explore its financial functions, State Farm and USAA have jointly developed a system to facilitate the automatic insurance claims process for farmers, in order to reduce the risk of fraud and improve the efficiency of the claims process.

3.1.4. Transactions

As mentioned previously, one of the original functions of blockchain technology was to improve financial efficiency by reducing transaction costs and building a trustworthy platform that can be used by all parties involved in a transaction, regardless of their identity. In the agriculture industry, many companies have been developing blockchain systems to support trading parties in supply chain management. Many agriculture related companies are developing blockchain systems to support trading parties in supply chain management. For example, an integrated food trading systems with consortium blockchain, called FTSCON, which was built to facilitate costly and easy trading of agricultural products in Shandong province, China. Based on the trial between 2014 and 2017, it was found that the total profit of different enterprises in the region increased significantly.

3.2. SWOT

As shown in Figure 14, there is a SWOT analysis of agriculture blockchain.

Strengths

Increased transparency and traceability: Blockchain technology can provide a transparent and traceable record of the movement of agricultural products from the farm to the consumer, which can help to ensure food safety and quality.

Efficiency: Blockchain technology can help to streamline and automate various processes in the agriculture industry, such as the tracking and recording of data, which can increase efficiency.

Profitability: Blockchain technology can allow farmers to directly connect with consumers and bypass intermediaries, which can increase the profit margin for farmers and provide them with more control over the prices of their produce.

Sustainability: Blockchain technology can help to increase the transparency and accountability of the agriculture industry, which can encourage the adoption of sustainable practices.

Weaknesses

Lack of awareness: There is still a lack of awareness about the potential benefits of blockchain technology in the agriculture industry, which can limit its adoption.

Technical challenges: Implementing blockchain technology in agriculture can be technically challenging, particularly for smaller farmers who may not have the resources or expertise to do so.

Regulation: There may be regulatory challenges to the use of blockchain technology in agriculture, depending on the location and specific application.

Limited adoption: The adoption of blockchain technology in agriculture has been slow, which can limit its potential impact.

Opportunities

Increased efficiency: Blockchain technology has the potential to increase the efficiency of various processes in the agriculture industry, such as the tracking and recording of data.

Improved transparency: The transparency and traceability provided by blockchain technology can help to improve the trust and confidence of consumers in the agriculture industry.

Increased profitability: By allowing farmers to directly connect with consumers, blockchain technology has the potential to increase the profitability of the agriculture industry.

Sustainability: The adoption of blockchain technology in agriculture can help to encourage the adoption of sustainable practices.

Threats

Competition: Other technologies or systems may emerge that are more efficient or effective at addressing the needs of the agriculture industry.

Regulation: Changes in regulation may impact the use of blockchain technology in agriculture.

Conventional agriculture architecture: everyone is used to existing conventional agriculture architecture.

Cybersecurity: The use of blockchain technology in agriculture may also expose the industry to cybersecurity risks.

Strengths: Increased transparency and traceability Efficiency Profitability: Sustainability	**Weakness:** Lack of awareness Technical challenges Regulation Limited adoption
Opportunity: Increased efficiency Improved transparency Increased profitability Sustainability	**Threat:** Competition Regulation Conventional agriculture architecture Cybersecurity

Figure 14, SWOT analysis of agriculture blockchain

4. Conclusion

It is clear that the integration of new technologies in the conventional agriculture sector is a trend that is expected to continue in the future. There are several directions in which this integration may progress, including traceability, optimization of the food supply chain, crop insurance, and transactions.

Overall, while the integration of new technologies in the agriculture sector is still in its infancy, there are many exciting opportunities for future development. These technologies have the potential to bring numerous benefits to the industry, including increased efficiency, profitability, and sustainability.

5. Reference

[1] BLOCKCHAIN TECHNOLOGY IN CURRENT AGRICULTURAL SYSTEMS: FROM TECHNIQUES TO APPLICATIONS

(https://ieeexplore.ieee.org/document/9159588)

[2] SURVEY ON THE APPLICATIONS OF BLOCKCHAIN IN AGRICULTURE (https://www.researchgate.net/publication/363068991_Survey_on_the_Applications_of_Blockchain_in_Agriculture)

[3] BLOCKCHAIN APPLICATIONS IN AGRICULTURE: A SCOPING REVIEW (https://www.researchgate.net/publication/360417397_Blockchain_Applications_in_Agriculture_A_Scoping_Review)

[4] WHAT IS HYPERLEDGER FABRIC?

(https://www.ibm.com/topics/Hyperledger)

[5] BLOCKCHAIN FROM WIKIPEDIA

(https://en.wikipedia.org/wiki/Blockchain)

[6] 【IPFS 技術佈道人】入門淺談：什麼是 IPFS？ (https://blockcast.it/2019/10/16/let-me-tell-you-what-is-ipfs/)

[7] INTRODUCTION TO BLOCKCHAIN TECHNOLOGY | SET 1 (https://www.geeksforgeeks.org/blockchain-technology-introduction/)

[8] BLOCKCHAIN TECHNOLOGY FOR AGRICULTURE: APPLICATIONS AND RATIONALE (https://www.frontiersin.org/articles/10.3389/fbloc.2020.00007/full)

[9] BLOCKCHAIN TECHNOLOGY IN AGRICULTURE (https://www.edengreen.com/blog-collection/blockchain-technology-in-agriculture)

[10] FOOD SYSTEM JOBS

(https://www.worldbank.org/en/topic/food-system-jobs)

[11] THE COMPLETE GUIDE FOR TYPES OF BLOCKCHAIN! (https://www.simplilearn.com/tutorials/blockchain-tutorial/types-of-blockchain)

[12] 區塊鏈 BLOCKCHAIN – HYPERLEDGER FABRIC

(https://www.samsonhoi.com/661/blockchain-hyperledger-fabric)