ETSI GR IPE 006 V1.1.1 (2022-11)

IPv6 Enhanced innovation (IPE); IPv6 and Cloud using DataBlock Matrix for Food Supply Chain Tracking and Tracing

Reference

DGR/IPE-006

Keywords

blockchain, Cloud, IPv6

ETSI

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Sous-Préfecture de Grasse (06) N° w061004871

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) IPv6 Enhanced innovation (IPE).

Modal verbs terminology

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Executive summary

Introducing blockchain technology in the Food Supply Chain can dramatically enhance the efficiency and effectiveness of food tracking and tracing, and thus improve the current fragmented management system of the Food Supply Chain as well as the non-Food Supply Chains (such as the Cities2030 project [i.1]).

The benefits of using blockchain technology have already been demonstrated by large Food Supply Chains around the world. Now, by making it available to farmers and end users will further advance the concept.

It is a known fact that in the USA 30 % of food is lost in the transportation system from the farms to the distribution channels [i.17]. In developing countries, this loss can be up to even 40 %. Unfortunately, the cost of the negative impact is factored into the end-user price. Furthermore, in some countries, the distribution channels fix the pricing on the farmers to cut a more significant margin.

The prime benefit of Food Supply Chain will be for farmers and end-users. The former will be able to benefit from better transparency in the pricing, and the latter will know where the products are coming from and in what condition.

The Food Supply Chain is a greenfield ecosystem needing more extensive scale deployment of Internet technologies based on Blockchain technology. And the end-to-end transparency can be enhanced by using the new Internet protocol, IPv6. The present document highlights the use cases and scenarios and where IPv6 can be of great value in designing scalable IPv6-based networks with unlimited address space to cover all networks and various solutions around the world.

Introduction

The importance of the Food Supply Chain is undoubtedly related to the survival and safety of more than 6 billion people globally. Due to the wide variety of food products, their sources may be widely distributed around the world, and collection times may vary widely. Using disruptive technologies can create a new model that facilitates traceability in the food supply chain and reduces the spatial and temporal variability of food collection.

Two of the most critical and challenging aspects are tracking the sustainability and the safety of the Food Supply Chain. To that end, the sustainability and safety of tracking data needs to be ensured, which is nearly impossible for centralized data storage due to many issues such as single point failure and data sovereignty. Users of shared data favours blockchain for its distributed and immutable nature. However, there are still bottlenecks in blockchain data sharing and TPS that may hinder its use in Food Supply Chain Tracking and Tracing (FSCTT). IPv6 and Data Block Matrix technology can be used to provide robust solutions.

1 Scope

The present document discusses implementing Food Supply Chain Tracking and Tracing architecture based on IPv6/Cloud using Data Block Matrix and Blockchain technologies.

Implementation of Food Supply Chain Tracking and Tracing architecture is split into five major blocks:

- Data Sovereignty requirements
- Data Collection pre-requisites
- Data Storage implementation
- Data Processing procedure
- Related information technologies

Related information technologies used in Food Supply Chain Tracking and Tracing includes: IPv6, Cloud, Data Block Matrix, Blockchain, 5G and IoT.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

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3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

4G: fourth-generation technology standard for broadband cellular network technology

5G: fifth-generation technology standard for broadband cellular networks

Cities2030 project: the Cities2030 project will look at the Food Supply Chain with end-to-end Tracking and Tracing from the farm to the fork using Blockchain with compliance to GDPR

GAIA-X: federated and secure data infrastructure establishes an ecosystem where data is made available, collated and shared in a trustworthy environment

uCode: identification number assigned to individual objects

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

4G	4th Generation Mobile Communication Technology
5G	5th Generation Mobile Communication Technology
6LoWPAN	IPv6 over Wireless Personal Area Network
AB	Anheuser-Busch
AF	Agricultural Food
AFRM	Agricultural-Food Raw Material
AFS	Agricultural Food Supply
AFSC	Agricultural Food Supply Chain
API	Application Programming Interface
BC	Blockchain
BLE	Bluetooth® Low Energy
CCT	Cloud Computing Technology
COVID-19	Corona Virus Disease 2019
CPS	Cyber-Physical System
DNA	Deoxyribonucleic Acid
EPC	Electronic Product Code
ERP	Enterprise Resource Planning
FCM	Fuzzy Cognitive Maps
FSCTT	Food Supply Chain Tracking and Tracing
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GSF	Golden State Foods
HACCP	Hazard Analysis and Critical Control Points
HTTP	Hyper Text Transfer Protocol
IaaS	Infrastructure as s Service
IDSA	International Data Spaces Association
IOE	Internet Of Everything
IoT	Internet of Things
IP	Infrastructure Provider
IPv6	Internet Protocol version 6
ISM	Interpretive Structural Model
IT	Internet Technology
JSON-LD	JavaScript Object Notation for Linked Data
KM	Kilometre
LPWAN	Low-Power Wide-Area Network
M2M	Machine to Machine
mDNS	multicast DNS
MEC	Multi-access Edge Computing
MEMS	Micro Electro-Mechanical Systems
MQTT	Message Queueing Telemetry Transport
NFC	Near Field Communication
NIST	National Institute of Standards and Technology
OEM	Original Equipment Manufacturer

OMA-DM	Open Mobile Alliance Device Management
PaaS	Platform as a Service
PEST	Political Economic Social Technological
PLC	Programmable Logic Controllers
QR	Quick Response
RF	Radio Frequency
RFID	Radio Frequency Identification
RMS	Risk Monitoring System
SaaS	Software as a Service
SCADA	Supervisory Control and Data Acquisition
SDK	Software Development Kit
SP	Service Provider
TPS	Transactions Per Second
URLLC	Ultra-Reliable Low Latency Communication
USD	United States Dollar
WSN	Wireless Sensor Networks
XML	eXtensible Markup Language
XMPP	eXtensible Messaging and Presence Protocol

4 Food Supply Chain Tracking and Tracing overview

4.1 What is Food Supply Chain Tracking and Tracing?

Food Supply Chain Tracking and Tracing (FSCTT) has been coined to depict the activities or operations in food production, distribution, and consumption to keep the safety and quality of various food under efficient and effective modes. Food from across the world is available to consumers today, regardless of the season, location, or environment. However, the more outstanding options and accessibility are accompanied by increasing complexity in the Food Supply Chain. With the growth of data and the extension of the ecosystem within the industry, trust is more important than ever.

From the farmer, processor, and retailer to the consumer, FSCTT uses trust to build transparency. The blockchain solution works to ensure transparency in the expanding food system and provides authorized users with immediate access to actionable Food Supply Chain data from farm to store and, ultimately, the consumer. Any food item's complete history, current location and accompanying information (i.e. certifications, test data, temperature data) can be readily available in seconds. In addition, with the spread of COVID-19, many Food Supply Chains have been disrupted, and there is the need for resilient Food Supply Chains. With the capability to achieve safer food, longer product shelf life, reduced waste, faster traceability, and better accessibility to shared information, FSCTT empowers food to meet new standards of transparency and trust.

4.2 Why Food Supply Chain Tracking and Tracing is essential?

Today, technological advances have made it easier for every player in the Food Supply Chain to access multiple data streams on the Cloud on a single platform. However, the main culprit of Food Supply Chain inefficiency is siloed data. The Food Supply Chain still relies heavily on manual interventions when it comes to coordinating between players to find out the shipment location and condition. If the refrigerator fails or the food truck breaks down, it is difficult to determine and take real-time action. Data inaccessibility is affecting the overall profitability and productivity of the system, and in the worst case, it can be life-threatening.

The ability to access detailed, real-time information about the Food Supply Chain can help manufacturers prevent spoilage and manage inventory and production to ensure just-right and just-in-time supply.

With FSCTT, it will be helpful for people to have information about the food being transported through FSCTT and improve the efficiency of transport. The manufacturer packs the cases, tags each one with shipment details, and stores this data in the Cloud. This could be an RFID tag stating the date of manufacture, number of medicines per case, etc. When a buyer places an order, this tagged data makes it easy for the manufacturer to check if they have the required units, which ones are nearer expiry and are be used first, etc. When these cases are shipped, scanning these tags cross-checks the shipped cases with the order placed. Each case is placed in a vehicle with sensors for control conditions such as temperature and humidity and trackers for location. These sensors relay data to edge devices which may do some pre-processing and decision making and upload this data set to a Cloud data store. In the Cloud, the data is again processed via a set of rules and functions that send automated alerts to the manufacturers and drivers who can adjust controls in case the temperature deviates from predetermined values or notify end customers if the shipment is damaged. GPS data can also let all players in the chain know where the load is at any point in time and take appropriate action in case of delay.

Each year one in ten people fall ill due to food-borne diseases, and of those, around 420,000 die. [i.17]. Clearly, it is challenging for food companies, distributors and retailers to address these issues globally. By digitizing supply chains, Food Tracing brings the world a local shopping experience and provides proof that what one eats and drinks is authentic and traceable i.e. where it was produced and how it was processed.

In the above example, two factors are key to the success of the Food Supply Chain: the large number of IoT devices used to monitor the state of food and manipulate the food storage devices, and the Cloud that collects the data and makes predictions. To obtain food status information, many IoT sensing devices need information such as temperature, fitness, and softness. At the same time, some IoT devices need to adjust the state of the container to keep the food in good condition. IoT equipment is required to make FSCTT in the process of growing, processing, conveying, and selling food. So many IoT devices need to connect to the Cloud through IPv6 addresses. The prediction and scheduling are made by the Cloud platform.

4.3 Development of Food Supply Chain in different countries

The largest food distributor in the United States, has been using blockchain technology to digitize its supply chain and reduce the time it takes to track the source of food contamination. In 2020, an E. coli outbreak that spanned 19 US states and resulted in twenty hospitalizations was traced to leafy greens. The industry has spent millions of dollars notifying the public and tracking and removing contaminated vegetables from markets. Walmart is now requiring all leafy green vegetable suppliers to upload data to a blockchain that can trace the origin of produce. In the case of batch contamination, Walmart was able to track the contaminated food in seconds, rather than a weeks-long manual process. This is invaluable during product recalls [i.2].

The second-largest US distributor records its yellowfin tuna operations on a blockchain to improve traceability and deter fraud. The system traces the movement of the fish through the supply chain, from the moment it is caught to when it is sold in the shops. Both customers and the fishing community can view the origin and the size of the tuna. Fair-trade data is also displayed, giving customers peace of mind that their money is not being used to fund unethical practices like slavery and child labor [i.3].

Nestlé announced that an expansion in its use of blockchain technology, through its membership with the Food Trust Blockchain Initiative, to the company's luxury coffee brand Zoégas.

Nestlé launched select editions of Zoégas whole beans and roast & ground coffee in Sweden. The "Summer 2020" range is a 100 % Rainforest Alliance certified blend of arabica coffee beans from three origins - Brazil, Rwanda, and Colombia. Through blockchain-recorded data, buyers of the coffee will now be able to trace their coffee back to the different origins. By scanning the QR code on the packaging, consumers can follow the coffee journey from the growing locations to the Zoégas factory in Helsingborg, where the beans are roasted, grounded, and packed. The data includes information about farmers, time of harvest, transaction certificate for the specific shipments, and the roasting period [i.4].

Anheuser-Busch InBev (AB InBev) has partnered with multinational tech giant Fujitsu and Belgian blockchain platform firm SettleMint to help its farmers track and trace barley throughout the supply chain in France and Belgium [i.5].

At every stage in the process, supply chain workers will be required to scan a code on the materials. This creates a tamper-proof digital audit trail that enables AB InBev to ensure that suppliers are keeping to agreements on the environment and human rights and track whether any parts of the supply chain are facing challenges that it can help remedy.

Once the beer reaches bars, restaurants and retailers, consumers will be able to access the information stored using the blockchain platform by scanning on-pack QR codes. AB InBev will develop a dedicated microsite to present the information in an easy-to-understand format.

AB InBev works directly with around 60 % of its global network of farmers; the idea is that the blockchain could boost visibility on the remaining 40 %. It will be trialed by a group of barley farmers in the Northeast of France who supply a malthouse in Antwerp and a brewery in Leuven initially, and the resulting beer will be sold in France.

Norwegian seafood producer Kvarøy Arctic™ announced it had joined the IBM Food Trust to enable blockchain traceability of its farmed arctic salmon. Fish farming or aquaculture represents nearly half of the total global fish production. However, the industry has some inherent issues, such as using additives, chemicals, and hormones to raise fish. Hence aquaculture farms with good practices are keen to differentiate themselves.

5 Food Supply Chain Tracking and Tracing Architecture

5.1 FSCTT Architecture Overview

The overall architecture of FSCTT consists of five layers, namely, the data sovereignty layer, the data storage layer, the information transmission layer, the data processing layer, and the data acquisition layer.

Food Supply Chain Tracking and Tracing Architecture is divided into five sections:

1) Data Sovereignty requirements
2) Data Collection pre-requisites
3) Data Storage implementation
4) Data Processing procedure
5) Related information technologies

The illustration of the FSCTT is shown as follows:

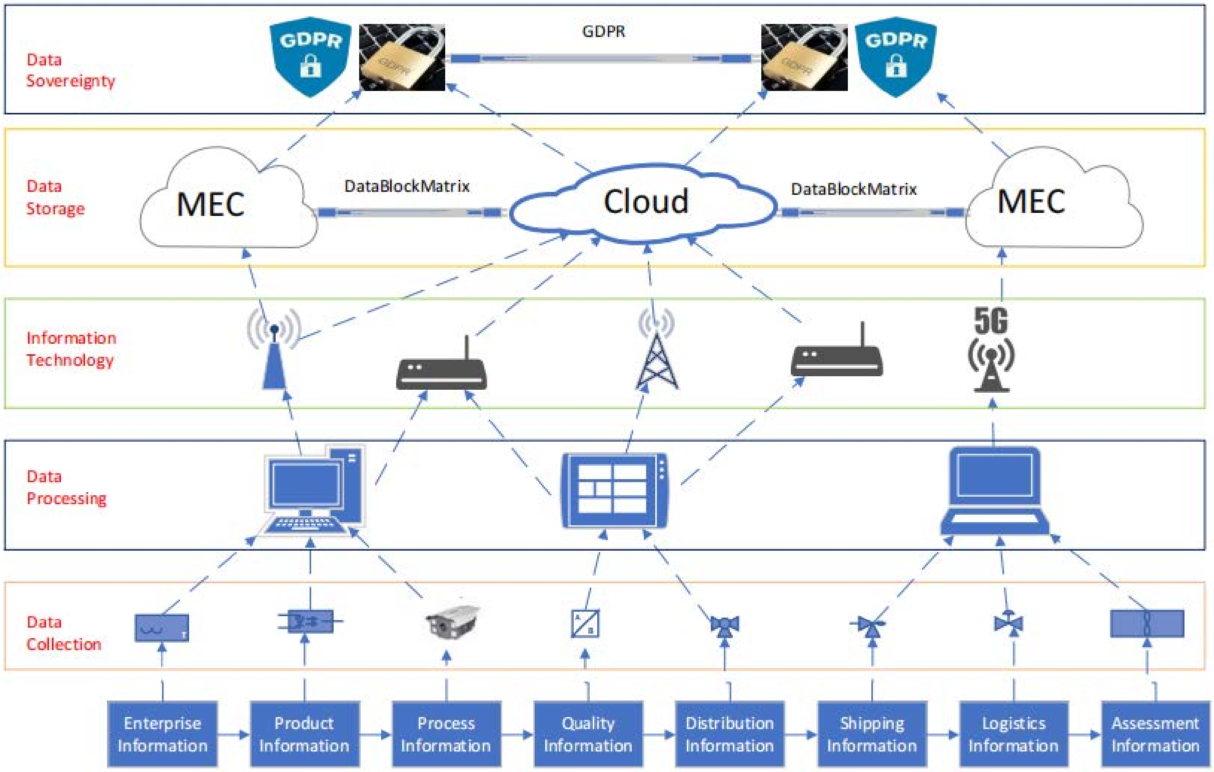

Figure 1: Food Supply Chain Tracking and Tracing Architecture

The role of the data sovereignty requirements is to make the stored data meet the requirements of data sovereignty.

The role of the data collection pre-requisites is to keep the processed data during the operation of the Food Supply Chain.

The role of the related information technologies is to use information technology, such as IoT, IPv6 [i.7], 5G and Cloud Computing [i.9], Blockchain, etc., to transmit data.

The role of the data storage implementation is to store data based on data obtained from different stages of the Food Supply Chain. The part of the data processing procedure is to collect the raw data generated during the operation of the Food Supply Chain through various IoT devices.

5.2 Data Sovereignty Requirements

Open access to modern supply chains is an essential factor to their success, improving service levels and operational efficiency across the supply chain. The vast amount of critical data collected in each supply chain link will provide end-to-end data visibility across the cold chain, allowing for innovative ways to build data services and collaborations within it. The subjectivity of data in the supply chain dictates that ensuring data sovereignty is a crucial capability. Each player in the supply chain needs to trust the way data is handled. The data space also needs to give data owners full control over their data and their digital identity and allow for sovereign and secure data exchange within a "trusted ecosystem" involving multiple participants. In addition to rights such as the right to know and access, the right to erasure is also essential for data subjects.

The European General Data Protection Regulation (GDPR) [i.6] requires organisations to be able to delete all information related to a specific individual at the request of that individual. This requirement is incompatible with blockchain data structures that ensure that the contents of a block are immutable because any change in a block of a blockchain structure can have a knock-on effect on the data information in subsequent blocks, resulting in a loss of integrity protection. Therefore, a data structure for data blocks is needed that provides the ability to delete a specified block while retaining the hash-based guarantee that other blocks remain unchanged. It is mainly designed to be implemented in licensing infrastructures to provide certain features of existing licensing blockchains.

A new data-driven economy has emerged in the wave of global digitization spawned by the Internet. A data-driven economy is an economy built around the collection, preservation, protection, implementation and understanding of different types of data. In addition to relying on data to improve the efficiency and quality of goods and services, entirely new services such as personalized medicine, applications, Cloud service providers, and artificial intelligence are built entirely on data, especially personal data, while such business models, in turn, are the foundation of a data-driven economy.

Digitalisation is chewing up the world with powerful economic and social impacts. More recently, the management of the COVID 19 crisis highlighted the power of digital tools and their impact on the interests of privacy, surveillance, transparency, and censorship. The success of the modern supply chain depends on data democratisation. Open access to the vast amount of critical data collected at each step of the supply chain will provide all stakeholders with end-to-end data visibility across the entire cold chain and create opportunities for innovation, efficiency, and just-in-time operations while enhancing the customer experience. Access to supply chain data can increase service quality and predictability across the chain while reducing dependence on manual interventions. The obvious location for this data is in the Cloud. The Cloud's base functionality of highly distributed and redundant data stores allows data to be shared globally, quickly, and easily. Again, in times of global crisis such as the COVID-19 pandemic, when data is a crucial measure of success, the Cloud is an essential element.

Succeeding in a data-driven economy requires access to vast amounts of data, which economists call "economies of scale". Multinational policymakers want common rules to encourage economies of scale while explicitly restricting the trade of certain types of data to ensure the security and privacy of their citizens. In developing this framework of rules, policymakers establish procedures to assure their citizens that a rules-based system is transparent, accountable, and open to the data citizens provide. With standard rules, the fragmentation of the Internet can be avoided; individuals can obtain, create and share more information, and can also better benefit from and have some control over their use of personal data. However, national policymakers are divided on how and where to formulate these standard rules.

Collaboration will be crucial to ensure that everyone who needs access to data has it including customers, partners, manufacturers, logistics providers, and operators. To enable this collaboration and improve overall supply chain efficiency, seamless and secure systems that support data sharing are required. Even within a single company, exchanging data is often not straightforward since data is scattered and "siloed" per business process. Exchanging data between partners is even more delicate. The primary purpose of a data space is to allow the sovereign and secure exchange of data within a "trusted ecosystem" involving multiple players. From a business perspective, the data space is designed to allow the construction of data-driven ecosystems in which independent partners (from different sizes, ecosystems, and financial strengths) have trust in how their data is handled while allowing for innovative ways to build data services and collaborations within them, thus breaking down information silos.

Europe's digital sovereignty program uses two main axes.

The first is Cloud sovereignty to have Cloud services that comply with European regulations. The solution for this sovereign Cloud infrastructure depends on the European Cloud Services Alliance of the GAIA-X [i.12] association, which aims to create a next-generation data infrastructure for Europe and its companies and citizens. This infrastructure needs to meet the highest standards in terms of digital sovereignty and is designed to foster innovation. The target infrastructure is seen as the cradle of an ecosystem where data and services can be provided, organized, and shared in a trusted environment.

The second is data sovereignty, the goal of which is to be able to share data securely among participants and will be based on the IDSA's [i.11] reference architecture model. The IDSA defines a federated technical architecture designed to secure and protect the data of all relevant participants. It establishes mutual trust between them and ensures the data sovereignty of all data providers. Thus, the data space concepts and components proposed by IDSA [i.13] are used to support the federated and interoperable infrastructure that the European project GAIA-X [i.15] aims to address.

The GDPR sets new standards for companies in the collection, storage, protection, and use of user data and promotes the enforcement of privacy regulations; on the other hand, it also gives users greater rights to handle their own data. Although the GDRP is only in effect in Europe, the "global" nature of the Internet is written into its DNA, and almost all services will be affected. The implementation of the GDPR has reawakened the world's attention to the protection of privacy and digital life in an era of confusing information in the Big Data era. The GDPR stipulates the rights of data subjects, including the right to know, the right to access, the right to rectification, the right to erasure, etc. It explicitly stipulates the user's "right to be forgotten" i.e. the user can ask the responsible party to delete their data records, so each subject in the Food Supply Chain data space is also entitled to these rights.

In any case, the future platform for utilizing data as close as possible to its production location (especially at the edge) is still to be established. Therefore, ensuring data sovereignty in FSCTT becomes an essential capability to provide data owners with complete control over the data and its digital identity in the Food Supply Chain. This requires defining data use constraints: determining who is allowed to do what in the context of the data shared by the data owner. Data sovereignty in the Food Supply Chain needs to reflect the independence and autonomy of each person in the data space as the subject of the right to control the data, manage and use the data without interference or intrusion. From the point of view of implementation, data sovereignty mainly includes two aspects of exclusive possession and the right to manage and utilize, and the biggest feature is the independence and the security and stability of safeguarding data from infringement.

5.3 Data Collection Pre-requisites

5.3.1 Internet of Things Technology Fundamental Applications

Today's IoT technology has a very wide range of applications for efficient data collection and monitoring scenarios in multiple scenarios. In particular, there has been a lot of research on the application of IoT in crop cultivation and production.

The sensor is a device which is very widely used in the field of collecting data. It can gather various types of information and convert them into signals that can be easily analyzed and processed (e.g. electrical signals). A wide variety of sensors with different functions are an important part of the IoT, and they give the most basic sensing capability to the IoT. Table 1 below describes the functional uses of some common sensors and the role they play in the FSCTT.

Table 1: Sensor devices used in the field of collecting data

Sensor	Use	FSCTT Applications
Acceleration sensor/Gyroscope (angular velocity) sensor	Measure changes in object motion (e.g. tilt, vibration, rotation, etc.)	Motion monitoring, device control
Geomagnetic sensor	Measuring the earth's magnetic force to get a sense of direction	Communication equipment, orientation monitoring
Pressure sensor	Measuring the magnitude of pressure	Liquid or other forms of pressure condition monitoring
Temperature sensor	Measurement of the temperature level	Room temperature, air temperature, object temperature monitoring
Humidity sensor	Measuring the level of humidity	Soil moisture, air moisture monitoring
Illumination sensor	Measuring the intensity of light	Light monitoring
Gas sensors	Measuring the concentration of a specific gas	Carbon dioxide monitoring, air pollution monitoring
Sound Sensors	Get audio information	Voice Monitoring
Image Sensor	Get picture or video information	Behaviour monitoring, condition monitoring
Water Quality Sensor	Measurement of the concentration of each ion in water	Water quality testing, ion monitoring

Through these sensors, FSCTT can accurately obtain all kinds of information data of the whole process of products from production, transportation to sales, and control the status of the whole process of products from production, transportation to sales, providing rich capability support for the whole system.

5.3.2 Multi-source heterogeneous data acquisition

Since there are too many data sources, signal types and data type differences involved in the whole process of data acquisition in FSCTT, the new IoT technologies may be needed to complement the heterogeneous data acquisition from multiple sources in FSCTT. Some feasible solution ideas will be introduced below.

The method of multi-source heterogeneous sensor information fusion based on IoT technology is studied in reference [i.19]. The traditional operation methods are creatively changed by four methods: innovative and optimized data collection, data abstraction and acquisition, feature fusion algorithm design for high attribute dimensional data, and feature-level information fusion methods. It can be concluded from this that the IoT data information presents new characteristics under the universal characteristics of IoT. If the high-level knowledge evolution mechanism of the information resource development chain is utilized, the state evolution of IoT information in its life cycle can be better studied.

To solve the problems of multiple data sources, large differences in data types and huge storage volume in the FSCTT acquisition process, a high-quality core data extraction method for edge computing nodes can be used similar to that proposed in reference. First, the heterogeneous data is fused with a unified model that preserves the data features of the original data. Then, the Lanczos-based incremental tensor decomposition method is used to dynamically extract the high-quality core tensor. Experiments show that the approximate tensor reconstructed from a tensor containing only 15 % of the core data can guarantee 90 % accuracy [i.37].

5.3.3 Multi-temporal-spatial dynamic data acquisition

FSCTT involves frequent changes in time, space and motion status throughout the whole process from production, transportation to sales. Different aspects of the FSCTT will have different requirements on the collection of relevant information, such as the time situation when fresh products are sold and the motion situation when the products are transported. Therefore, FSCTT needs to solve the problem of multi-temporal dynamic data collection through various new IoT technologies.

Although the traditional bar code and QR code technologies used to identify items are low-cost, easy to deploy and fast to identify, they lack the ability to change flexibly and dynamically according to the spatial and temporal conditions, making it difficult to play a role in the whole process of production, transportation and sales of FSCTT.

New IoT technologies often use Radio Frequency Identification (RFID) for the identification of items. RFID is a wireless automatic identification technology that uses radio frequency signals to identify the target and access information. RFID technology has the feature of reading multiple information data at the same time, and the information is collected more efficiently. RFID tags can also read the information, at the same time the data stored in the chip information repeatedly added, modified and deleted. This makes it easier to update information and makes the system more dynamic and flexible. RFID also has a certain penetration, allowing it to communicate through paper, wood, plastic and other materials, which expands its range of use.

The capability of a Mobile Ad Hoc Network is needed to keep the FSCTT data with multi-temporal dynamic data collection in the environment of livestock grazing, product transportation, etc. A Mobile Ad Hoc Network allows direct communication between sensing nodes in the absence of communication infrastructure. Each sensing node needs to have routing and data forwarding functions in addition to information collection and processing functions. When any one node fails, other nodes can quickly re-perform path finding and re-establish the communication path. The data collected by any node can be transmitted to the aggregation node through self-organization and multi-hop, and then the information can be transmitted to the platform for processing, analyzing and storing data.

A Mobile Ad Hoc Network is able to give the following characteristics to FSCTT's sensor networks:

First, the network is able to adapt to dynamic changes in the network topology. Any random movement of terminals, power on and off of nodes at any time, changes in RF transmitting power, and mutual interference of wireless environment may lead to changes in network topology. The Mobile Ad Hoc Network is able to adapt to the changes in network topology and establish communication paths for collecting data without the control of management nodes.

Second, the network is a decentralized network structure, and all nodes have equal status, a peer-to-peer network. Nodes are able to join and leave the network at any time, and the failure of any node will not affect the operation of the whole network, which is highly resistant to destruction.

5.3.4 Extreme harsh environment acquisition

In addition, the sensing nodes of FSCTT may be in extremely harsh environments, such as ocean transportation and natural disasters. Therefore, FSCTT needs to solve the problem of data collection in extreme environments through various new IoT technologies.

Taking ocean sensing information collection as an example, it needs the support of miniaturized ocean central control machine, hydroacoustic communication machine, narrowband IoT float, sitting-bottom test platform, portable acoustic release platform and other equipment. Above the water surface, the sensing nodes can communicate with each other through wireless narrowband communication, or directly with the network system on land through satellite communication system. Below the surface, the sensing nodes can either realize wired communication with the help of submarine optical fiber cable, or establish direct communication with nearby sensing nodes through hydroacoustic communication module.

Marine IoT will form a large-scale three-dimensional sensing network with miniaturized, low-cost, low-power and intelligent nodes. And with the progress of IoT technology, the development of IoT in other extreme harsh environments will also gradually move towards miniaturization of observation nodes, diversification of communication technology and intelligent calculation.

At the same time, to cope with the damage caused by the extreme environment, all the sensor nodes of the current sensor network have a strong resistance to destruction. The failure of any sensor node will not affect the operation of the whole network, while the complementary new sensor nodes can quickly join the whole system.

5.3.5 Power consumption and cost

The establishment of FSCTT often requires the placement of a large number of sensors and IoT communication devices in the whole process of product production, transportation and distribution. This inevitably leads to higher operating power and material costs than traditional systems. If the power and cost of IoT in FSCTT is not well addressed, then it may have the opposite effect on the green goal of reducing carbon emissions.

The good news is that with the iterative development of IoT technology, the cost of sensor devices is gradually decreasing, ultra-low power IoT communication technology is gradually becoming popular, and the overall system power consumption is also decreasing with the improvement of system design.

Mahmoud et al, researched and compared wireless communication modules for IoT applications in terms of power consumption [i.20]. The research on one hand highlights the significant advantages of low power wireless technology over traditional technologies in IoT applications. On the other hand, the research measured and compared the power consumption performance of the modules from various manufacturers in various IoT scenarios.

From the results, it can be found that most of the IoT devices today can operate on the network with very low power consumption compared to traditional devices. However, there is still a large power consumption gap between different IoT protocol modules, which is mainly affected by the different transmission distance and transmission rate of each protocol module. This requires the system to select the appropriate communication protocol module according to the application scenario.

Shadi et al, summarized and analyzed common IoT communication protocols and focused on metrics and characteristics such as power consumption [i.21]. In terms of power consumption, 6LoWPAN, ZigBee®, BLE, Z-Wave and NFC are designed for low power consumption and have excellent power performance. While cellular has significant high-power consumption compared to other technologies. In terms of distance, SigFox and Cellular have a coverage range of more than a few kilometers, while the distance of 6LoWPAN, ZigBee®, BLE, NFC, Z-Wave and RFID is less than KM level.

Danco et al, designed a power efficient and highly scalable IoT agricultural monitoring system [i.22]. The system is based on a LoRaWAN network that enables long-range, low-power data transmission from sensor nodes to Cloud services. They show preliminary results from some grape farms in a case study to demonstrate the effectiveness of the solution.

In summary, the overall power consumption level of FSCTT will not hinder the green goal of reducing carbon emissions if the overall system is designed in a rational and orderly manner and the correct protocols and standard compliant modular devices are selected.

5.4 Data Storage Implementation

Disruption in the food supply chain industry is ripe, but blockchain technology is not necessarily the most effective technology to solve this disruption, it can also be achieved through a centralized ledger.

Blockchains are beneficial when:

a) there is no overarching "systemic" actor in the supply chain (such as monetary central banks);

b) immutability features have value; and

c) anonymity has value.

Bullet points a) and b) relate to trust in the supply chain.

For a), the Food Supply Chain is based on trusting the collection device at the data collection stage, which enters the data into the ledger. Given that the machine is produced by a company, it needs to be trusted by all participants in the network. If this is the case, and this company believes it can produce IoT devices that benefit everyone, why not trust this company to keep a central ledger instead of a distributed ledger?

For b), the immutability function can be cumbersome. Mistakes in traceability in the food supply chain can damage a farmer's reputation. Even if the farmer manages to defend his case, there will be traces of error in the immutable ledger. In order to reverse this situation, one party needs to have the right to prove that a mistake was made and provide the correct data entry.

c) relates to how Bitcoin is used today, i.e. illegal transactions (e.g. "ransomware"). This does not apply in this case, as the point of the system is to provide maximum transparency and identifiability to actors in the supply chain.

In order to make the blockchain suitable for Food Supply Chain traceability, some changes should be implemented. FSCTT uses Data Block Matrix [i.7] to store data instead of blockchain. Data Block Matrix algorithm proposed by Kuhn et [i.8] al to deal with the undeletable problem of blockchain. This structure allows the deletion of arbitrary records without compromising the integrity of the hash, ensuring that other blocks remain stable.

6 Data Processing in Food Supply Chain Tracking and Tracing

6.1 Collecting and Analyzing

Traditional food is harvested, farmed, collected or fished and then sorted, and most of these processes are manual. With the development of technology, the food collection process has undergone tremendous changes.

Some companies use intelligent machines to complete the process of sorting and processing food. For example, a "bextmachine" from bext360 company uses artificial intelligence, machine learning and IoT to grade coffee bean quality at washing stations. Farmers load daily hauls of around 30 kilograms into these machines, which are equipped with optical recognition devices and sensors to sift and sort the beans. The sensors send live streams of weight, size and ripeness data on each bean to the platform's appraisal software. The grades from the production stage are then made visible to buyers who bid on the beans.

6.2 Payment

With regards to payment, personal payment transfer is the most difficult part. FSCTT uses the process of bext360 in the coffee supply chain to solve the problem of personal payment transfers.

The movement of the beans is then tracked through the supply chain, enabling all stakeholders, including farmers, roasters and consumers, to access data at every stage. This ensures that farmers can be paid fairly based on the quality, not just the quantity, of their yield. Moreover, these payouts are instantaneous. Bext360 connects to Stellar.org's blockchain technology to generate crypto tokens to track data on the origin and quality of each batch across the life span of its production. As the beans move through the supply chain, new tokens are automatically created to represent their new form and value in the production process. Small famers worldwide are paid in real-time based on these values, through the company's mobile-based payments app, making their income more reliable. The payments are made in digital currencies with Stellar's protocol. Additionally, the farmers do not have to accept payments on the spot. They could decline the initial offer made after the bean grading step and sell the beans directly on the commodities market using bext360's technology.

Stellar makes it possible to create, send, and trade digital representations of all forms of money: dollars, pesos, bitcoin. The aim of its design is to enable the world's financial systems to work together on a single network. Stellar's API and SDKs are ready to help transform the world of finance, and the network's currency connections could give even a small company the power and reach of an international bank. Stellar is used as an intermediary currency. Stellar looks for pending orders for USD exchange for Stellar Lumens on the Internet, as well as pending orders for exchange of Stellar Lumens for Euros.

2020 and 2021 were eventful years in the world of XLM and XRP, the two super-fast payment coins that are competing for a share of the global remittance market. The coins are perceived as being quite similar, leading many to ask which project is best, Stellar (XLM) or Ripple (XRP). Putting aside the question of whether XLM or XRP tokens will go up in terms of price, FSCTT can look at the recent fundamentals of both Ripple and Stellar, to see what the future might hold for these two payment coins that have such an entangled history. Perhaps the main reason that crypto enthusiasts compare these two projects is that they have a similar mission of disrupting cross-border financial payments. One of the key differences between Stellar Lumens and Ripple is the type of user each project is targeting. Stellar aims to work with unbanked individuals around the world while Ripple focusing on building close partnerships with banks to help them move money globally. Both projects were founded by Jed McCaleb Ripple and XRP was founded as a collaboration between McCaleb and software developer Ryan Fugger.

6.3 Traceability

In a recent pilot project, a U.K.-based startup Provenance traveled to Indonesia and tested tracking tuna on the blockchain, the same ultra-secure technology used to track Bitcoins.

In the pilot project, traditional fisherman sent simple text messages to register a catch, which in turn created a new 'asset' on the blockchain. Every time a batch of fish was sold to traders, and processors, brands, and supermarkets, the blockchain ID was sold with it. The digital identity also tracked the audit information proving the fish were caught legally and sustainably.

Upon the sale of the physical fish, the digital fish was transferred. This prevented the double-spending of those claims. Otherwise, there could be two claims of sustainability and social responsibility. In FSCTT, this is impossible, because it is not possible to double-spend the digital version of the fish.

With larger fish, like yellowfin tuna, weighing as much as 400 pounds, the startup tested using physical tags and tracking DNA. But it was less important to track specific fish (especially tiny skipjack tuna which was impractical and expensive to tag) than to track the certifications that go with the fish. It did not matter technically matter if fish were swapped, the key thing was that their claims were not duplicated.

While various non-profit and government agencies work on tracking fish through the supply chain, the different tracking systems cannot easily, for security reasons, share data. As blockchain can provide a secure public ledger, it is a way to ensure real transparency.

When a blockchain-tracked fish reaches a supermarket, it is more trustworthy for consumers; by choosing responsibly caught fish, consumers also help to shift demand away from the suppliers using the worst practices.

Globally, 10-15 % of commercial fisherman are estimated to work in slave-like conditions. In Southeast Asia, where three-quarters of the world's fishing fleets operate, hundreds of thousands of people have been tricked into slavery on fishing boats (sometimes forced to work for years) and in processing plants.

In February 2016, the U.S. government closed a loophole in a law that allowed imports of slave-produced goods [i.23] and proposed a new blockchain traceability program to ensure the program worked correctly. In addition, the program tracked other serious issues such as forced labor and overfishing.

In the U.K, Provenance has partnered with The Co-op, a major supermarket chain, to track fish and other types of food. The startup has received the most interest from manufacturers of high-value products, such as wine and olive oil. But it is equally committed to products that come at the highest social costs, like fish. Their ultimate goal is an open-source platform that anyone can use to customize the system for any industry.

The startup technology company Haelixa in Zurich, Switzerland released a technology to tag precious stones with snippets of DNA [i.36]. Incorporating minute levels of DNA-toting nanoparticles into a variety of products shows their origin, time of production, and can even distinguish originals from counterfeits. DNA tagging is also poised to become a tool in the energy industry, helping to track flow of oil underground, highlight the spread of fluid used in controversial hydraulic fracturing ("fracking") for natural gas, or identify leaks in nuclear plants.

In addition to Haelixa, the companies BaseTrace of Research Triangle Park, North Carolina, and Tracesa in Oxford, UK, are also developing DNA tracer technology for fluid monitoring, giving a whole new meaning to the term "DNA fingerprinting".

The downside of DNA is its fragility, especially when exposed to light or chemicals. In fact, oil companies tried to use it as a tracer during the 1990s, but those attempts failed because the nucleic acids could not survive the oil well environment.

GSF partnered with food trust to create near real-time, automated viability into cold chain temperatures and products movement using IoT sensors at every node of the supply chain [i.35].

6.4 Data sovereignty

The success of the modern supply chain depends on data democratization. Opening access to the volumes of critical data collected at each step in the supply chain will provide end-to-end data visibility across the cold chain for all stakeholders and create opportunities for innovation, efficiency, and just-in-time operations – not to mention enhance customer experience. Access to supply chain data can increase service quality and predictability across the chain while reducing dependence on manual interventions. The obvious location for this data is in the Cloud. The Cloud's base functionality of highly distributed and redundant data stores allows data to be shared globally, quickly and easily. Again, in times of global crisis such as the COVID-19 pandemic, when data is a key measure of success, Cloud is an essential element.

Exchanging data, even within a single company, is often not straightforward since data is scattered and "siloed" per business process. Exchanging data between partners is even more delicate. The main purpose of a data space is to allow the sovereign and secure exchange of data within a "trusted ecosystem" involving multiple players.

A key capability is to ensure data sovereignty, i.e. providing data owners with full control over their data and their digital identities. This requires the definition of data usage constraints: defining who is allowed to do what in which context with the data shared by the data owner.

Europe's plan for digital sovereignty uses two main axes:

- The first one is Cloud sovereignty, so that Cloud services comply with European regulation. The solution for the sovereign Cloud infrastructure hinges on the Federation of European Cloud Services along the GAIA-X Association [i.12].
- The second one is data sovereignty with the goal of being able to safely share data among participants in a consortium, the foundation of which will be the IDSA's [i.14] reference architecture model.

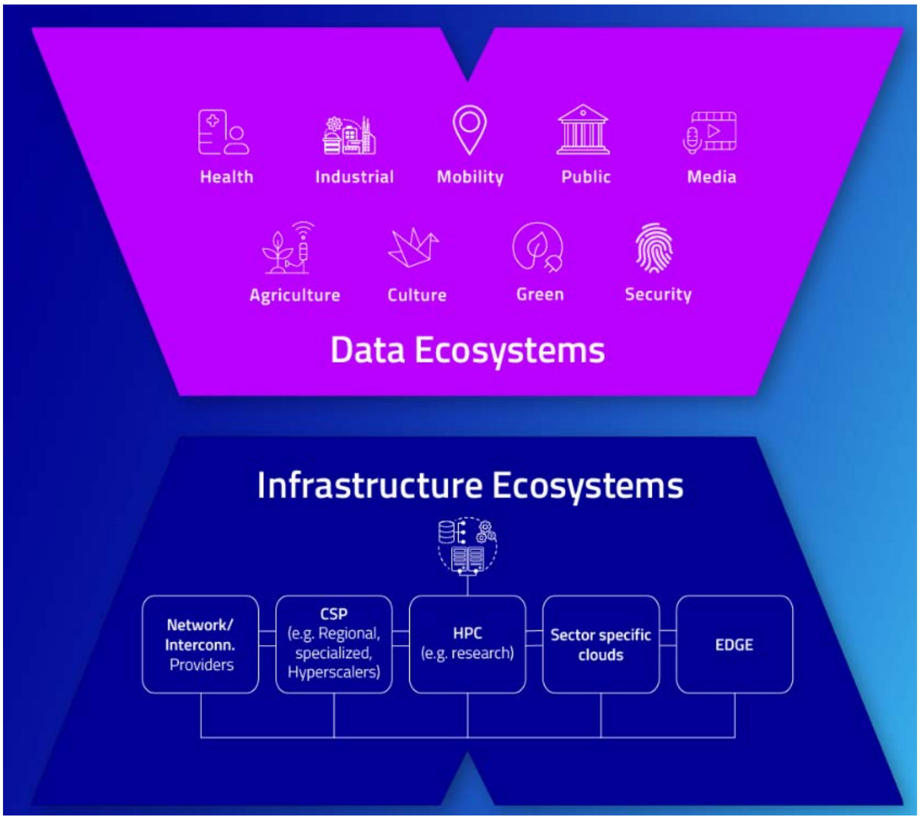

Figure 2: High-level view of the GAIA-X Framework [i.18]

6.5 Data source and exchange

The source of the data and the way the data is exchanged are the main factors when considering how Food Supply Chain data is stored in the Data Center. A large amount of food status information is transmitted to the Cloud platform through the Internet through the IOT device. As the amount of transmitted data is large, the mobility requirements are high, and there are also requirements for the transmission delay [i.34]. The 5G transport network meets these requirements.

5G Transport network is kind of network infrastructure which mainly provides connections from user equipment to a core network in 5G mobile networks. The advantage of 5G transport network is it helps operators to leverage the same access connectivity to transport any kind of traffic, including Internet access, audio, video, computation applications and status information transmitted by IOT devices. Due to mobile-fixed convergency, operators are beginning to provide fixed services to customers over the 5G transport network, as happened in the legacy 4G mobile backhaul network. In addition, Cloud has been an essential part of information infrastructure, more and more applications will be Cloudified, serving the Cloud-related scenario is a main duty of 5G transport.

The advent of IOT and 5G applications renders the need for supporting both delay-tolerant and mission-critical applications in not only centralized but also distributed fashions, thus it needs to integrate both centralized Cloud Computing and emerging Mobile-Edge Computing (MEC) with existing network infrastructures to enhance storage, processing, and caching capabilities. Traditionally, the centre or core network holds much of the computational power, this is the case with Cloud Computing providers, Telecoms, Internet providers, and large Enterprises. However, the situation is changing. For some 5G services, the network will have to deal with really high volumes of data, all at faster speeds, and coming from a small geographical area. This results in decentralizing the data centre and pushing for more powerful computational resources at the network edge. Instead of sending all data to a Cloud for processing, the network edge analyzes, processes, and stores the data. Collecting and processing data closer to the customer reduces latency and brings real-time performance to high-bandwidth applications.

End-to-end traceability is achieved using blockchain and APIs integrated with existing ERP systems. FSCTT uses a RESTful API to access bean quality and additional supply chain information. This will fuel further innovation as retailers and wholesalers can use the API to develop data-driven loyalty programs for their customers.

6.6 Blockchain vs Data Block Matrix

The challenges described when using a traditional distributed ledgers such as blockchain can be addressed by a new approached to distributed ledgers - a centralized data block matrix, a patented National Institute of Technology (NIST) technology, which provides hashed data integrity protection, with the capability to edit/delete records [i.8]. Data Block Matrix is effective solving blockchain problems in Food Supply Chain Tracking and Tracing as it meets the GDPR requirement of being able to delete all information related to a person.

Farmers, drivers, merchants and customers all need to share or delete their information in the FSCTT on a factual and verifiable basis. The FSCTT uses blockchain and Data Block Matrix to communicate information, both are globally transparent, verifiable and stored information cannot be tampered with. These two technologies have different advantages and disadvantages.

The present document analyses and compares blockchain and Data Block Matrix from the aspects of integrity protection and flexibility, and explains why Data Block Matrix is more suitable for use in the Food Supply Chain.

1) Integrity protection: A block in the blockchain is connected to the previous block using only one hash value, so each block in the middle is connected to one block before and after; and deleting one block causes the following block to lose the connection, so there is no possibility of free deletion of blocks. Data Block Matrix, on the other hand, uses two hashes to connect a block so that deleting the middle block does not compromise the integrity of subsequent blocks. Data Block Matrix enables the integrity of the blockchain to be maintained at all times without removing a large number of intermediate blocks, the feature that allows users in the FSCTT to sometimes remove blocks.

2) The flexibility: When a block is added to a blockchain, it can only be added to the end of the chain. Moreover, block deletion is not allowed in block chain and proof of work is required to sequence as a consensus. When multiple blocks want to be written into block chain, the first block to complete calculation is written into block chain, and other blocks can only be re-calculated. Therefore, Proof of work will consume a lot of computing power and cause a waste of energy. In Data Block Matrix it can be deleted and added, and blocks is sequenced to be written using the Timestamping Authority, which sequence blocks to be written on a first-come first-served basis using high-precision Timestamping. In this way, Data Block Matrix can be used in the FSCTT to enable users to have higher autonomy and smaller calculation power consumption.

6.7 How does Data Block Matrix work?

Two hashes will be used to mark a block of data in the block matrix. There are two ways to determine a hash value, as shown in Table 2. In the first method, each row and column ends with a hash, the hash value, for example, $H_{0,*}$ is hashed at the 0^{th} line. The second method uses all the hash joint values for that row and column as the hash values for that row and column.

Table 2: Block matrix [i.38], [i.39]

	0	1	2	3	4	
0						$H_{0,*}$
1						$H_{1,*}$
2						$H_{2,*}$
3			X			$H_{3,*}$
4						$H_{4,*}$
	$H_{*,0}$	$H_{*,1}$	$H_{*,2}$	$H_{*,3}$	$H_{*,4}$	

X is a block. If a block labelled "X" needed to be deleted by writing all zeros to the block or otherwise changing it. This change breaks the $H_{3,*}$ and $H_{*,2}$ hashes for row 3 and column 2. However, the integrity of all blocks except those containing "X" is still guaranteed by other hash values. That is, the columns 0, 1, 3 and 4 blocks of row 3 are contained in the hashes. Similarly, the rows 0, 1, 2, and 4 blocks for column 2 are contained in the hashes.

However, continuous deletion of blocks will result in block data corruption on the diagonal as shown in Table 3.

Table 3: Block matrix with diagonal [i.38], [i.39]

	0	1	2	3
0	1	2	5	10
1	3	4	7	12
2	6	8	9	14
3	11	13	15	16

If blocks 7 and 8 are deleted, then blocks 4 and 9 will also be unstable because the hashes for rows 1 and 2 and columns 2 and 1 are invalid. Then the cells (1,1) and (2,2) lose all their hashes.

In the Data Block Matrix algorithm blocks are added from 1 to N, adding blocks needs to start at row 0, column 1, in order to keep the blocks on the diagonal empty. The algorithm flow chart is as follows.

```
Algorithm 1: DataBlockMatrix
  while newblocks do
    if i == j then
_     addnullblock; i = 0; j + + else if i < j then
_     addnullblock; i = 0; j + + else if i > j then
      addblock(i, j); j + +; swap(i, j);
    end if
  end while
```

Figure 3: Data Block Matrix algorithm [i.38], [i.39]

Where i is the row number, j is the column number and swap (i, j) is a formula for swapping the values of i and j. Through this algorithm, the following figure is finally obtained:

Table 4: Block matrix with numbered cells [i.38], [i.39]

	0	1	2	3	4	
0	*	1	3	7	13	$H_{0,*}$
1	2	*	5	9	15	$H_{1,*}$
2	4	6	*	11	17	$H_{2,*}$
3	8	10	12	*	19	$H_{3,*}$
4	14	16	18	20	*	$H_{4,*}$
	$H_{*,0}$	$H_{*,1}$	$H_{*,2}$	$H_{*,3}$	$H_{*,4}$	Etc.

When two consecutive blocks are deleted at the same time, the stability of the other blocks are not affected since the diagonal block is empty. For example, blocks 5 and 6 are deleted consecutively, breaking H1, H2, H3 and H4. This causes both hashes to be removed for the one-row, one-column block and the two-row, two-column block, but these two blocks are empty, so there is no impact on blockchain stability. For example, blocks 5 and 6 were deleted consecutively, corrupting hashes H1, H2, H3 and H4. This results in the deletion of all hashes for both the one-row, one-column block and the two-row, two-column block, but the deletion of two empty blocks does not affect the stability of the blockchain.

7 Related information technologies used in FSCTT

7.1 IoT technologies

With the development of technology and information systems, the Internet of Things (IoT) is used in a wide variety of industries, including in the Food Supply Chain tracking and tracing. IoT is a system of connecting machines, computers and sensors. It is the physical or virtual connection of a device to a larger network, allowing the said device to be accessed anywhere within the network.

Pang & Chen.2021 [i.25] proposed a method for a value-centric business-technology system design framework which evaluated food quality forecasts and price forecasts based on the consumer data collected. A three-tier information fusion sensor network was built to collect data beyond the traditional traceable range, re-predicting shelf-life prediction and price of food through all the data processing and re-planning the Food Supply Chain in real-time.

Chen et al.2014 [i.26] designed an autonomous Food Supply Chain model, which used FCM (Fuzzy Cognitive Maps) and fuzzy rule method for product usage life cycle. With the food product problem tracing services, IoT technologies were used to support the Food Supply Chain; the goal of the model being to reduce tracing time and provide autonomous operation for food product tracing system.

Li et al.2017 [i.27] propose an effective and economical supply chain management system for prepackaged food based on IoT technology integrating the QR code and RFID technologies. The goal is subtle tracking and tracing while reducing operating costs, which uses Extensible Markup Language (XML) to make it easier to transmit information between applications and stakeholders.

Yadav & Lut [i.28], developed a structure-based systematic model of coordination in agricultural Food Supply Chain based on Interpretive Structural Model (ISM). The intention is to handle all agriculture Food Supply Chain activities relating to primary and secondary processing of food grains and products, such as logistics, warehousing and storage, customer information, management of third-party service providers and other activities at decoupling points of agriculture Food Supply Chain.

7.2 5G technologies

With the development of 5G, opportunities for subversion and innovation are of great significance to the food industry. One important reason is how it will adopt other new digital technologies across the industry.

5G network provides unprecedented bandwidth for users and companies and provides low latency data transmission for real-time information distribution. Finally, compared with 4G or even Wi-Fi®, this provides users and devices with more instant and reliable communication. Compared with 4G or 3G technology, another major advantage of 5G is its low power consumption demand, which means that the power consumption required for network communication is lower. One of the biggest advantages it brings is more powerful network capability, so it has more capacity to process multiple inputs and devices at the same time.

Here are some examples about 5G technologies used in FSCTT:

KranTi [i.29], a BC-based AFS (agricultural Food Supply Chain), designed by Nirav Patel's team, which will help the society to resolve the problem of production tracking, AF efficiency issues and makes the system more robust and transparent between the stakeholders. KranTi uses Ethereum BC to monitor transactions between stakeholders and ensuring the consistency of the AF by keeping a record of the score provided to the former stakeholder. KranTi also provides farmers with a special credit-based scheme through which they can accumulate capital for improved AFRM goods. FSCTT measured the efficiency of KranTi with the conventional method by comparing the system's network parameters and the BC performance of KranTi.

5G is Ultra-Reliable Low Latency Communication (URLLC) because of the feature of TI through it manages to get a latency of<1 millisecond with 99,99 % of reliability compared with LTE. After latency, comes the scalability of the network.

The improved scalability based on the transaction time to a number of the blocks mined during the requests processing of AFSC of the KranTi vs the traditional approach of the supply chain with BC. As the KranTi is 5G enabled, it can accommodate more number of transactions in the chain with ultra-low latency and ultra-high reliability in the same period. Hence, KranTi improves the overall scalability of the AFSC. Once the scalability is achieved, the reliability of data reaching its destination is also important. Packet loss can occur due to error in data transmission or network congestion mostly in wireless networks. Packet loss has occurred when one or more packets fail to reach their destination. 5G networks have less packet loss and are more reliable than traditional 4G networks.

Traceability plays an important role in the quality and safety management of agricultural products. The agricultural product traceability system based on Internet of Things provides a feasible solution for agricultural product quality control and information traceability. However, the current agricultural product traceability system under the Internet of Things has low information transmission efficiency and poor real-time performance, and mostly relies on centralized server-client model, making it difficult for consumers to obtain accurate transaction information and agricultural product traceability.

Therefore, Xu Miaomiao's team designed a 5G IoT agricultural products traceability platform based on blockchain [i.33]. The application of 5G technology to the traceability of agricultural products in the Internet of Things can effectively solve the problem of slow transmission of massive data generated in real-time. Blockchain can ensure that information will not be tampered with, and the consortium blockchain has strong controllability, which is suitable for the traceability system of agricultural products with multiple responsibility subjects. The team also designed a 5G agricultural products IoT traceability platform based on alliance chain.

This platform can improve the efficiency of agricultural product information traceability, provide real and reliable agricultural product information for practitioners, managers and consumers, and play a positive role in improving sustainable quality management of agricultural products.

In addition, processing enterprises in the Food Supply Chain can take advantage of the characteristics and benefits of 5G, such as large capacity, ultra-high transmission rate and ultra-low delay, to set up monitoring system and real-time broadcasting systems to control processing time, workshop temperature and other risk factors. Enterprises can also update the packaging system, using packaging robots, according to different goods automatically set different packaging and binding methods, to improve packaging speed and reduce the error rates. The application of 5G technology in IoT systems as the transmission medium of large-volume sensor data can effectively solve the problems of insufficient storage capacity and low data transmission efficiency. Information exchange is more rapid and efficient, and demand data can be fed back to the system in real time and accurately.

7.3 IPv6 technologies

With the development of IPv6 services and the increase in traffic, data centre networks face new challenges. The traditional IPv6 network provides best-effort forwarding, which does not meet the requirement of zero packet loss in computing and storage. In the Cloud era, business deployment is accelerating. Manual network deployment no longer meets the needs of rapid business development. Networks are becoming more complex and larger, beyond the limits of manual processing.

Therefore, in addition to using IPv6 technology to meet the growing demand for addresses, the network needs to further integrate advanced technologies such as Cloud Computing, artificial intelligence, and big data analysis to evolve to IPv6 [i.16]. In recent years supply chain and logistics operations have been active adopting IPv6 and IoT solutions. For example container tracking usually relies on RFID tags which are attached to containers, boxes and pallets included in the shipment and then recorded at a number of points along the way. RFID tags are widely used to track and trace different types of cargoes. The RFID tag may be attached directly to the cargo or carried by the driver/operator of a haulage vehicle. Apart from RFID, IoT can be related with more technologies such as Wireless Sensor Networks (WSN), barcodes, intelligent sensing, low energy wireless communications, Cloud Computing and others. The delivery function is one of the main important tasks of logistics which involves planning and control of flow and storage of goods and services.

Many researchers have addressed the technical aspects of IoT. For example, the work found in Postcapes provided a list of IoT protocols according to their layer in existing architectural models. These include: Infrastructure (e.g. IPv4/IPv6); Identification (e.g. EPC, uCode, IPv6); Communications/Transport (e.g. Wi-Fi®, Bluetooth®, LPWAN); Discovery (e.g. Physical Web, mDNS); Data Protocols (e.g. Websocket, Node); Device Management (e.g. TR-069, OMA-DM); Semantic (e.g. JSON-LD, Web Thing Model) and Multi-layer Frameworks (e.g. Alljoyn, IoTivity, Weave, Homekit). The work by Xu, He, and Li (2014) recognised the importance of a sound architecture to support the decentralised and heterogeneous nature of IoT [i.29].

Advanced food traceability systems help to minimize unsafe or poor quality products in Food Supply Chain through value-based process. From the emerging technologies forthcoming for industry automation, future advanced food traceability system considers not only Cyber-Physical System (CPS) and fog computing but also value-added business in Food Supply Chain [i.24].

A CPS is computational operation with the surrounding physical object across downstream/upstream industry in collaboration environment. Its capability comprises a network of physically distributed sorts of device/machine embedded sensors and equipped with computing system. A CPS can communicate to seamlessly connect and remotely control production processes, information services available over the IoT and Cloud Computing. By these advanced technologies, Cyber-Physical Systems can produce intelligent computation such as autonomous predictive management, self-diagnosis/maintenance mechanism and collaborative production planning for business performance.

In food manufacturing, Cyber-Physical Systems mainly consists of three modules: field device process, production machine process and manufacturing control process using service-oriented architecture to handle. Thus, CPS-based food manufacturing includes all the elements having industrial automation capabilities including smart PLC (programmable logic controllers), sensors, actuators, cameras, vehicles, robots, radars, control units for the subsystems, wired/wireless sensor networks, machine vision/motion control such as automated optical inspection, IPv6, RFID, Micro Electro-Mechanical Systems (MEMS) and advanced control technologies for Supervisory Control And Data Acquisition (SCADA).

To identify/capture/exchange real-time traceable data based on EPCglobal. Various traceable objects with smart devices: RFID reader and embedded RFID machine, sensor tool with a universal numbering statement as EPC code. The CPS system of each company can be linked by internet address IPv6 delivering the required information of a web service.

An Internet of Things (IoT)-based Risk Monitoring System (RMS) for managing cold supply chain risks.

The purpose of IoT RMS is to propose an Internet of Things (IoT)-based risk monitoring system for controlling product quality and occupational safety risks in cold chains. Real-time product monitoring and risk assessment in personal occupational safety can be then effectively established throughout the entire cold chain.

In the design of IoT RMS, there are three major components for risk monitoring in cold chains, namely: wireless sensor network; Cloud database services; and fuzzy logic approach. The wireless sensor network is deployed to collect ambient environmental conditions automatically, and the collected information is then managed and applied to a product quality degradation model in the Cloud database. The fuzzy logic approach is applied in evaluating the cold-associated occupational safety risk of the different cold chain parties considering specific personal health status.

Under the IoT environment, smart objects with integrating wireless communication technologies, sensors and actuators can connect to the internet and share their data, to provide real-time data acquisition in supply chain management. Sensor technologies, such as temperature sensors, can be applied to build a wireless sensor network in order to monitor warehouse environmental conditions. The feasibility of M2M protocols, such as IPv6 over Wireless Personal Area Network (6LoWPAN), Message Queueing Telemetry Transport (MQTT) and Extensible Messaging and Presence Protocol (XMPP), on Bluetooth® Low Energy (BLE) links have been investigated, while the sensors in such networks can directly communicate to the internet. By doing so, the sensor network can be operated in a scalable and efficient manner with increasing interoperability and standardization. Besides, by integrating the advantages of IPv6 and ZigBee®, the 6LoWPAN provides effective internet and internal data exchange to support several open IP standards and mesh routing development.

In addition, with the further development of IoT (IOE), the full popularity of IPv6 is particularly necessary. IPv6 allows the larger address space, faster transmission speed, more secure transmission mode, and has gradually become the preferred network interconnection between enterprises. Another important application popularized by IPv6 is the Internet identity authentication under the real-name network system.

An important reason why it is difficult to implement real name on IPv4 networks is that IP resources are insufficient. Therefore, different people share the same IP address at different times, and IP addresses cannot correspond to Internet users one by one. The emergence of IPv6 will solve this problem once and for all from the technical point of view. As IP resources will no longer be tight, when operators apply for users to access the network, they can directly assign a fixed IP address to each user to achieve one-to-one correspondence between real users and IP addresses. When the IP address of an Internet user is fixed, the online behaviour or records of the user can be checked in any period, meeting FSCTT requirements.

7.4 Blockchain technologies

Blockchain is a system of recording information in a way that makes it difficult or impossible to change, hack, or cheat the system. The Blockchain has four basic characteristics: decentralization, openness, security and privacy. Anyone can create a node in the chain to store and share this information. As in the name, it is a chain of blocks. Blockchain technology is one of the important technologies to revolutionise the Food Supply Chain Tracking and Tracing. It has been successfully applied in financial areas, such as Bitcoin, and it now triggers huge interest in multiple areas, including Food Supply Chain, property, voting, etc. Blockchain technology can be defined as "a shared, immutable ledger for recording transactions, tracking assets and building trust".

An agri-Food Supply Chain method has been developed to improve the efficiency and reliability of agri-Food Supply Chain management and significantly strengthen the quality and safety of agri-food products, especially in China's markets. Thanks to RFlD & blockchain technology, this traceability system could realize the information identification, inquiry, tracking, monitoring and tracing for the whole supply chain, and it could also be a secure, transparent and traceable platform for all members of the agri-Food Supply Chain.

Tian F. 2017 also built a Food Supply Chain tracking and tracing system based on HACCP (Hazard Analysis and Critical Control Points), blockchain and IoT which showed that implementation of HACCP can provide a secure and reliable information platform for all of the Food Supply Chain members. Blockchain also, however, has some disadvantages, it lacks scalability when data increases to a certain level. In this regard, BigChainDB is used to fill the gap which provides a scalable solution. The proposed solution is then applied to an example scenario to show the significant transparency and efficiency and how it favours HACCP regulations [i.30].

Tse & Zhang2017 developed a simulation model for supply chain, which used the (Political Economic Social Technological) PEST analysis to analyze, contrast and demonstrate studying the application of Blockchain in the Food Supply Chain. PEST is an analytical model which analyzes the macro-environment location of the industry [i.31]. All parts of the PEST are the external environment of the industry which cannot be controlled by themselves, it also carries the demand analysis of the Blockchain system platform of the Food Supply Chain.

The document qualitatively analyzes the current situation of food security, including the demand analysis of the Food Supply Chain traceability system platform, and can trace the Food Supply Chain back to the root causes and the need for development. It also analyzes the traditional traceability system of Food Supply Chain. applies block chain technology to build a supply chain system platform for production processors, brokers and consumers.

Caro & Ali 2018 explored the use of the Blockchain technology in Agriculture and Food (Agri-Food) supply chains to build a system AgriBlockIoT, a fully decentralized, blockchain-based traceability solution for Agri-Food supply chain management that seamlessly integrates IoT devices producing and consuming digital data along the chain [i.32].

7.5 Cloud Computing technologies

Food supply chains are challenged by their increasing complexity and the need for higher flexibility to meeting individual customer requirements (e.g. automotive, electronics, engineering, construction). Where suppliers or customers on one hand break away (Food Supply Chain disintegration, disinter mediation), on the other hand new partners offering value-added services for OEMs and customers need to be integrated. Business relations change as well: from long-term contracts (static Food Supply Chain systems) to small short-term contracts and even to event-driven management for dynamically creating and delivering individualized products.

At the same time, recent developments in software technology address a very similar problem in computing: how to fulfil individual and complex user requirements by effectively and efficiently using distributed resources?

This question led to the idea of Cloud Computing. A Cloud is a pool of shared resources. Users do not need to have detailed knowledge about available resources and their properties, but search for services, consume resources as a service, and then pay only for the services used. A middleware provides respective functionality for matching demand and supply.

Table 5: Cloud perspective on food supply chain systems

Element	Cloud Computing	Food Supply Chain Tracking and Tracing Systems
Resource type	Hardware, machines, software applications	Physical and human resources in Food Supply Chain systems
Service type	Infrastructure (IaaS), Platform (PaaS), and Software as a Service (SaaS)	Food Supply Chain as a Service
Number and specificity of resources	High number; specificity relatively low due to IT standardization	High number; specificity low due to commoditization, but also high due to differentiation as strategic alternatives
Reconfiguration	Adding/removing resources results in high scalability; quick adaptation to demand volatility (e.g. within seconds)	Physical, technical and organizational constraints limit and slow down adding/removing resources.
Pay-per-use model	Based on standard measurements such as processing time, data volume	Supported by commoditization; most often based on actual load combined with performance metrics
Infrastructure Provider (IP)	Provides actual resources	Represents upstream tier of any supply chain participant
Service Provider (SP)	Provides services to the final customer by contracting Ips	Represents downstream tier, ultimately the one serving the final customer
Service Level Agreements	Exist between IP and SP only	Exist for any contractual relationship in the Food Supply Chain system, including the final customer

Most elements can be mapped to a respective phenomenon. Literature yields evidence of properties such as commoditization and customer-orientation that support this perspective. However, the analysis also points to a greater diversity and richness of resources which has to be addressed in service description and composition; this increases the interoperability problem in the Cloud. Additionally, Food Supply Chain systems are made of autonomous entities which aim at different, overarching and conflicting goals. Considering this characteristic, coordination mechanisms for supply chain services need to be carefully selected and designed.

Cloud Computing Technology (CCT) is also used to integrate the segregated segments of a particular industry using minimum resources. It has given excellent results and has wide range of applications in various industries like banking, manufacturing, IT, etc. It makes the information visible to all segments of an industry by deploying its service delivery models like Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as s Service (IaaS). Keeping these attributes in mind, CCT is deployed here to minimize carbon footprint of entire beef supply chain. The retailer, being a key stakeholder is going to maintain a private Cloud, which will map the entire Food Supply Chain. The information related to carbon footprint associated with every stakeholder will be available on the Cloud. This information will be accessible to all of them by using basic computing and Internet equipment.

8 Conclusion

With the growing complexity of the food supply chain and the proliferation of data within the industry there is greater optionality and accessibility. At the same time, with the spread of COVID-19, many food supply chains have been disrupted, so there is an urgent need for a resilient and unified food supply chain tracking architecture to restore order to the disrupted food supply chains.

FSCTT combines the concept of data sovereignty, incorporating IoT network technology and Data Block Matrix data structure to refine the overall process of Food Supply Chain data collection, processing and storage, providing complete visibility of data from farmers, retailers to consumers, which can effectively control and maintain the quality of food throughout the supply chain. Through IoT sensing devices and technologies, FSCTT can accurately acquire all kinds of information data of the whole process of products from production, transportation to sales, control the whole process status of products from production, transportation to sales, and provide data support for the overall system.

Combining the concept of data sovereignty with the use of trust to establish transparency, allowing a "trusted ecosystem" of multiple participants in the supply chain to securely exchange sovereignty and data, build more flexible and innovative ways to serve and collaborate on data, and improve overall supply chain efficiency through data collaboration and sharing.

By analyzing and comparing blockchain and Data Block Matrix in terms of integrity protection, flexibility and transparency, the solution of using Data Block Matrix instead of blockchain in the Food Supply Chain effectively solves the problem that any change in the blockchain will invalidate the subsequent hash in the subsequent block. As a result, the issue of integrity protection is addressed, thus ensuring that all information related to individuals can be deleted, which is compliant with GDPR requirements. By enabling faster traceability and more transparent and open data storage, a unified and efficient Food Supply Chain Traceability architecture can be established by enabling consumers to meet new standards of transparency and trust.

For future work, FSCTT can reduce carbon emissions in Food Supply Chain generation process and can protect environmental sustainability, so the traceability process can also be extended to monitor environmental sustainability aspects, for example, supply chain data can also include carbon footprint information from production to consumption, which will provide a complete life cycle assessment of a specific food product and can be used as an additional competitive or regulatory tool.

History

Document history		
V1.1.1	November 2022	Publication