

Blockchain Ecosystem Meet Supply Chain Ecosystem and an Application to Dairy Product Provenance

Pengdi Zhao¹, Ashley Jensen² and Tim Johnsen³

¹Griffith University, Gold Coast, Queensland, Australia

²SmartIndustrial Pty Ltd, Brisbane, Queensland

³BluLogistics PL, Queensland

The demand from consumers about information transparency in raw materials, production, and manufacturing processes of the products they purchase is increasing in recent markets. The traceability and provenance of information across all stakeholders on the supply chain is becoming an essential requirement. In this paper, we design a model for a blockchain ecosystem to meet the supply chain ecosystem and an application for dairy farm product provenance. This model aims to provide a reliable provenance of dairy products for consumers based on the requirements and regulations. By adopting this model, consumers can receive all information from the public blockchain by scanning the QR code on the package of products. The overall benefits of this proposed model are discussed along with further applications in Australian Dairy exportation trade.

Keywords: Supply Chain Ecosystem, Blockchain Ecosystem, Dairy Product, Provenance, Traceability

1. INTRODUCTION

The establishment of a reliable and traceable system for agricultural products is of great importance since it can collect, store, and transmit the full information related to raw materials, processing methods, and production. The provision of transparent information throughout the supply chain can guarantee the quality and safety of agri-products [1], and consumers can track the information, when necessary, to improve their trust and expand the sales market. To expand the market share of Australian agricultural exports [2], and improve the safety of agri-food, this work aims to build up a conceptual model of a data-led traceability ecosystem using blockchain. The provision of such information can achieve full tracking and traceability regarding the provenance of agricultural food products.

2. PROVANCE IN SUPPLY CHAIN

The traditional tracing system for agricultural products focused on the construction of a centralized database [3]. Once it got attacked or distorted, the information may be released and therefore lack credibility. Also, the supply chain of agri-food generally involves different stakeholders, such as farmers, logistics, processing companies, retailers, and customers [4]. The adaption of different platforms led to the difficulty in sharing information among different shareholders and the lack of uniform standards and formats for data exchange [5]. Therefore, the promotion and application of the agri-food tracing system are hindered. To address this problem, this work adapts the blockchain technology, which has the properties of traceable, decentralized, and unchangeable [6], thus sharing full data and improving



Figure 1 Traditional Supply Chain Ecosystems.

the trust level among different parties in the supply chain. For example, Bumblauskas et al. applied the blockchain technique to construct the tracing system of eggs with the “farm to table” production mode, to solve the fraud issue in the traditional agricultural industry [7]. Hao et al. proposed the quantitative method to estimate the safety risk level of Agri-food based on the data management in the supply chain with an embedded blockchain technique [8].

The idea of the provenance of agricultural products starts by European Union in 2000, by combining the Hazard Analysis Critical Control Points (HACCP) and tracing and tracking technology together to control the food safety issues such as the spreading of Bovine Spongiform Encephalopathy (BSE) [1]. In 2011, the Food and Drug Administration (FDA) published Food Safety Modernization Act (FSMA) to reinforce the control of the traceability of the food supply chain [9]. Food Standards Australia New Zealand (FSANZ) is a statutory authority in the Australian Government’s health portfolio, and it develops food standards and regulatory frames for Australia and New Zealand [10]. In 2001, the FSANZ established a national livestock identification system (NLIS) to track the whole process of domestic cattle from birth to death. In addition, the Meat Standards Australia (MSA) has been implemented to strengthen the supervision of the intermediate links of the supply chain [11].

Considering the type and growth cycle of certain agricultural products (such as Australian exports: milk), this work aims to develop a blockchain-based supply chain ecosystem for tracing the information on milk production, properties (protein concentration, sterilization methods, storage temperature, processing procedures: lactose-free, low fat or full fat, cows living environment: free-range or pasture-raised), logistics, retailers and so on. This provenance of dairy product ecosystem enables export target countries and customers to get access to information related to food sources, thus improving the quality of agri-food and increasing the sales market.

3. SUPPLY CHAIN ECOSYSTEM

3.1 The Supply Chain Ecosystem

Supply chain ecosystem is gradually evolved by business ecosystem. In the development of supply chain ecosystem, Papert and Pflaum considered stakeholders, business, government regulations, research institutions, and consumers as main elements in ecosystem [12]. Gupta et al. mentioned

that the supply chain ecosystem can be regarded as the greater connectivity and information flow that enabled through information technology for example, IoT [13]. It can be generally shown in Figure 1.

The advanced blockchain integrated supply chain ecosystem aims to achieve information traceability and improve data transparency, thus enhancing the public recognition and trust confidence for customers towards dairy products. Compared with the traditional paper certificate and labeling system or the separated databases for different users, the introduction of blockchain technology enables the decentralized processing of data, therefore achieving the governance and management of data from each link in the system.

While the Dairy agri-food traceability and supply chain operations part can upload all the information of raw materials and manufacturing and transporting processes onto the blockchain database, consumers and international trade have the right to access and trace the information. The standards and regulators will get into this chain and investigate information when issues happened. The supply chain operation history, including the production, storage, transportation, and distribution steps within the system that can be recorded and uploaded to the each of the blockchain node, and generate a traceable and untampered record of dairy products for customers to refer to. The immutable data stored in the blockchain enables consumers or international trade partners to track the records and relevant food safety information within the supply chain system in the dairy industry. This can improve the confidence and trust from customers and further increase the international trade parties, due to the authentic and trustworthy data sharing. Furthermore, the standards and regulators play an important role in monitoring the authenticity of the data and information.

The scheme of a typical dairy supply chain with traceable information sources is proposed and illustrated in Figure 2. Before reaching the consumers part, the dairy related information is well recorded and stored, to be generated into a QR-code that customers can get access to the dairy data and report at both the production and processing stages. Starting from the first node of this supply chain – Dairy Farm, each cow comes with a RFID tag and NLIS accredited tag which monitor the health condition, including the age, vaccination history, body temperature, meadow locations and the related farmer ID. This information is uploaded frequently to monitor the well-being of cows’ while being stored into the local database and running out a report as a reference, for data traceability and to reduce the congestion in the supply chain database. Then, the fresh milk is stored in the milk vat before sending

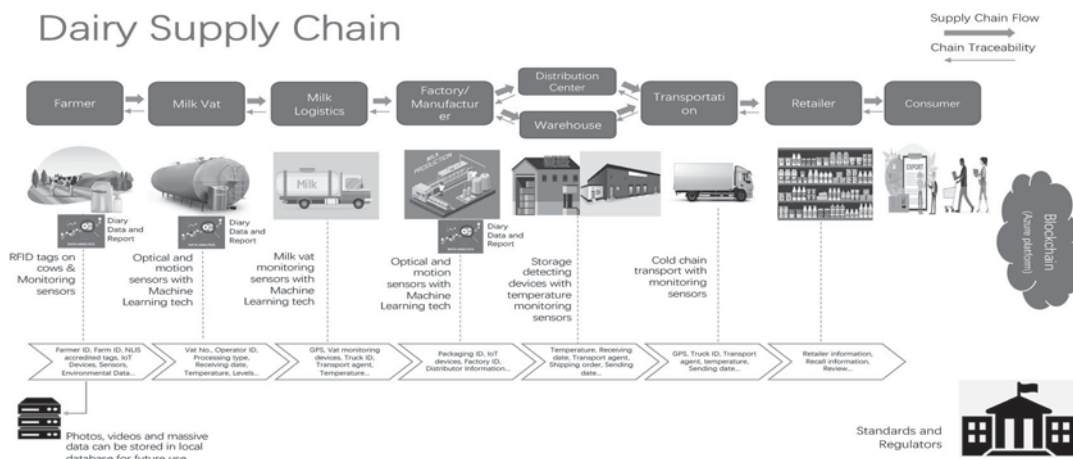


Figure 2 Dairy Supply Chain Ecosystem and Flow Map.

for processing. The dairy data and reports should be uploaded to the database with the quantity, storage temperature and time periods.

In the dairy processing stage, the dairy production factories (such as milk or cheese industries) are responsible for documenting the process and quality parameters (sanitation temperature, processing methods and nutrition concentrations) of dairy products. To ensure the authenticity of information, optical and motion sensors with the machine learning technology are implemented to automatically upload the monitored processing methods and product quality, where the dairy industry only has the right to read the data without altering rights.

In order to provide additional evidence to trace the quality of the raw milk and products, samples will be collected and analyzed by stakeholders (Farmer, Milk Vat and Manufacturers) at their own stage and then upload the reports to the database. Also, the regulators have the right to check the reports and records that uploaded from any step of the supply chain. When there is a quality issue, the regulators have the privilege to take samples from the processing factories to conduct quality check and to compare with the dairy quality report from the factories. The certificate from the regulators can further improve the data reliability of dairy qualities.

Finally, the distribution center or warehouses stage apply the cold chain transportation to ensure the freshness of dairy products and the data including GPS positions, vehicle ID, freezer temperatures and delivery periods are automatically uploaded to the system to achieve data traceability along the process. When it comes to the retailer part, they can recall the information uploaded to the database and review the quality of products.

3.2 Blockchain Ecosystem Meets Supply Chain Ecosystem

The smart contract can authorize the access of users in each step and offers information interaction among different layers [14]. For example, it can either achieve the backward tracing of customer orders or the forward tracing of different batches

of agri-products [15]. Therefore, the products can be labeled at each stage in this supply chain, to simplify the inquiry procedures for information [16].

Due to the complexity of stakeholders and participants (farmers, logistic companies, food production companies, retailers, customers, governments, and so on) in this blockchain database, the management of authority and access to different parties will be managed by the blockchain ecosystem. In particular, a consortium blockchain, which constitutes the channels that reflect the operation dynamics, can be introduced in this system to enable flexibility for data management [17]. Each participant in this channel will be responsible to maintain the sharing database that guarantees the transparency of shared data.

The structure of the blockchain integrated into the dairy supply chain system is demonstrated in Figure 3. The private chain within the blockchain layer includes the text information uploaded from the business layer which corresponds to the supply chain users as illustrated in Figure 2. The end users in the business layer represent the key steps within the supply chain of dairy products, starting from cows to the final retailers. The information, such as the details of farmers/breeders, milk vat, logistics companies, dairy processing factories and manufacturers, product distribution systems and retailers, will be firstly stored in the local database of the business layer users. When it becomes to the confidential commercial information, the dairy report and essential text information can be uploaded to the database in the private chain, as requested by the smart contract. That is to say, the local database of the supply chain users works together with the private chain to store the source information from each link of the business layer. Due to the supreme independency of this job and the followed connection with the public chain, Azure Authenticator (Microsoft) is recommended in uploading the data into the local database and private chain layer and connect with the web page for integrating information. It should be noted that each link only has the right in accessing the private chain to upload and traceable data rather than altering the uploaded information, thus realizing data authenticity. The introduction of regulators in the system can further increase the data reliability of the public chain. In another word, the connection between the

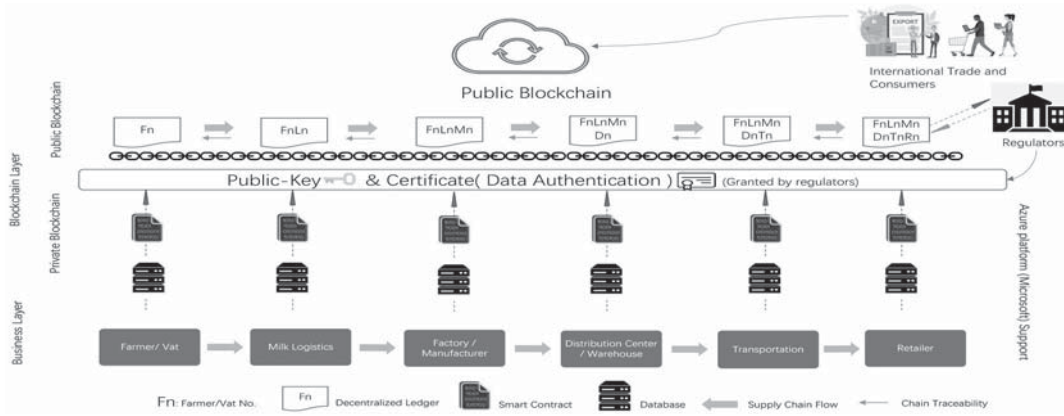


Figure 3 Blockchain Ecosystems Design for Supply Chain (Model design on Microsoft Azure).

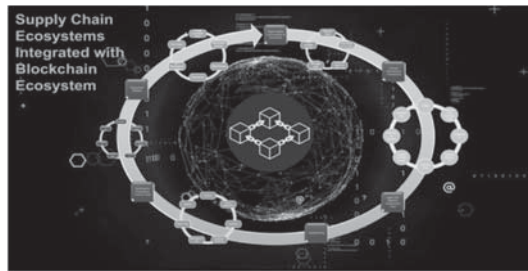


Figure 4 Proposed Supply Chain Ecosystems Integrated with Blockchain Ecosystem.

public chain and private chain is achieved by the public key and certificates which are granted by the regulators, and this system can be treated as a consortium. Regarding the issue that many small or medium sized farms, manufacturing, and logistics companies may exist in the supply chain system, this scheme only allows each link within the business layer to access and upload information towards the public chain when they are granted the permission from external regulators. The authentication of the public key can significantly improve the data capacity in the public chain and achieve the data traceability once receiving the access request from end users in the public chain. Within the public chain, the uploaded information is stored by the decentralized ledger from the authorized node in the private chain. When customers and international trade customs scan the QR code from the product packages, the request for accessing the public chain is initialized and sent to the system. A web page including the information of dairy products, such as farm location, processing methods, production dates will be shown on the smart devices that they have used for scan.

4. CONCLUSIONS

An advanced agri-food supply chain ecosystem has been proposed and designed in this work. The realization methods of whole process recording and traceability management of quality information in the links of grazing, warehousing, transportation, consumption, and supervision are expounded. This ecosystem achieves the feasibility of visibility and traceability by introducing blockchain platform and a set of smart contracts across agricultural industries, supply

chains, and commodities. The using of smart contracts and Azure Authenticator highly increased the security and protection of all information that recorded and uploaded on blockchain.

However, here are still some future works that can be discussed to optimize this proposed ecosystem. Firstly, we can do a review on the regulations and policies of Australian and international agri-product logistics and transportations, import and export. To optimize the regulator part of framework and the relationship between supply chain and regulators. Secondly, we can do some real- world experiments or demonstrations in an industrial complex. Also, we can test and design the consumer interface from front and back end to complete the whole ecosystem.

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