Global Journal of Computer and Engineering Technology (GJCET)

Vol. 1, No. 2, July, 2021 ISSN: 2767-1933

DAIRY LOGISTICS SUPPLY CHAIN USING BLOCKCHIAN TECHNOLOGY

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ABSTRACT

With the rapid increase in global annual consumption of fluid cow milk worldwide, serious problems including food fraud, illegal production, foodborne illness, and food recalls have kept being critical, through great efforts have been made for dealing with those food safety problems. Blockchain technology, because of Bitcoin, is becoming a popular Front-age technology in finance, business, logistics, insurance, and many other fields. This paper uses blockchain technology to redesign a new Dairy Logistic Supply System. Decentralized, Security and Eco-society, these three unique advantages can provide an eco-system have completely solved the problems of traditional or central dairy supply systems. The new system guarantees to provide customers with fresh and safe dairy products at fair prices. Consensus and real-time transaction data and information will be stored in local blockchain adapted on the Ethereum platform and shared among involved participants. The Internet of things (IoT) lowers labor and decreases errors. The most important attribute is its smart contract with a crowdfunding function, which can provide customers a brand-new market platform that is collectively owned by all the participants who can observe the entire state of the market at any time. Our research offers a viable option to solve food safety problems in a decentralized, security, immutability, transparency manner.

Keywords: Blockchain, Dairy logistics, Food safety, Smart contract, Crowdfunding.

1. INTRODUCTION

Due to the Bitcoin, the blockchain technology, has been known by the public since 2008. Compared with traditional networks, Blockchain is a distributed peer-to-peer network, each node can directly interact with other nodes without a trusted third party involved (Nakamoto, 2008; Duan et al., 2020). Its applications have been successfully introduced into the logistics supply system, voting mechanism, medical area, and financial market (Duan et al., 2020; Yiannas, 2018; Vadgama, et al., 2021). A blockchain-based ledger is elucidated as "a decentralized, security, and eco-society ledger used to permanently keep the digital records of transactions".

Unlike other traditional transactions that need to be processed and verified by central architectures or trusted third parties, decentralization can minimize intermediate waiting time and operating costs. Using the blockchain-based ledger, all users can more efficiently communicate with the other participants within the network, which speeds up the process of transactions. Information asymmetry and information fraud is the major reason to delay the transaction flow, to break trust among collaborations, to increase consuming time of products recall, and to hurt customers' confidence (Nakamoto, 2008; Duan et al., 2020; Yiannas, 2018; Wan, Huang et al., 2020; Casino et al., 2019). To avoid these issues, information sharing is regarded as one practical approach. A decentralized environment makes fair and transparent information sharing become possible. All users have the equal power to make decisions and the equal right to access all information and transactions shared among the network anytime (Duan et al., 2020; Rejeb et al., 2020). Decentralization promotes more accurate, timely information sharing, removes information inequality and builds up more trust.

In addition to information sharing, blockchain technology also ensures the originality and authenticity of all recorded information (Duan et al., 2020). With cryptographic hash algorithms, any data will be written onto a special hash and be stored in the blockchain. If any values, for example to add one space or delete one comma, got altered, the whole hash value would be totally different. Therefore, it's easy for every participant to detect the altered behaviors even one single point of failure (Duan et al., 2020; Yiannas, 2018). Hacking behaviors can only happen when at least 51% of users are replaced, which leads to one complicated blockchain network with a large number of users is very safe (Nakamoto, 2008; Duan et al., 2020).

In blockchain's decentralized network, any exchange of information, every single transaction needs to be verified by the rest of the users and then stored in one block permanently (Duan et al., 2020; Wan et al., 2020; Rejeb et al., 2020). Each user has a full copy of all transaction data that fed into the blockchain network, all transactions and data information are shared equality to each user, meanwhile, each user has the responsibility to remain the information secure and unchanged (Yiannas, 2018; Casino et al., 2018). This consensus and distributed data storage are able to prevent the usual problems in a centralized network including fraud or alteration, and more eliminate the risk of the whole centralized system failed if one single point breakdowns (Gandhi et al., 2021). Each new block is related to a prior block, the rest blocks will be broken down due to one block failed. All users can quickly and easily notice the breakdowns from the data tampering or hack behaviors. The consensus and distributed data storage guarantee transparency and immutability of information sharing to all participants within the blockchain network, which makes it more secure and has a lower probability of being hacked.

Smart contract is an account governed by code and stored on a blockchain that runs when predetermined conditions and service terms are fulfilled (Duan et al., 2020; Wan et al., 2020; IBM, 2021; Ashari, 2020). Smart contract wipes out the need for a centralized organization or trusted third party, the code will self-execute to manage, verify and store the real-time information, and more the code allows automatically flow of work and provoke the next action when the conditions are met (Wan et al., 2020; IBM, 2021; Ashari, 2020). All participants do not need to pay for the extra fee and time for any intermediary intervention. The transactions data, account balance, and capital flow stored in smart contract is transparent and visible to all participants, like theft, fraud and tampering these behaviors have no possibility to happen since smart contracts based on the agreement of all partners. The implement of smart contract can significantly speed up the transaction, reduce unnecessary cost, protect the benefit of a wild range of stakeholders, and build more trust among the participants and ecosystems (Duan et al., 2020; Yiannas, 2018).

Crowdfunding provides a practical and fast method to collect cash for innovative project ideas and emergency assistance (Ashari, 2020; Alexandria, 2021). The past 2020 has caused a lot of challenging economic times worldwide due to Covid-19 plague, many organizations like Oxford, European Institute of Innovation and Technology (EIT) were raising funding to help local governments to deal with economic and medical problems. In general, a trusted intermediary is needed to manage the planning, broadcasting, raising funds, running project, tracking funds and other complete actions. However, crowdfunding supported with smart contract can eliminate the waiting time and extra charge fee from the intermediary. Crowdfunding can be automatically delivered to start the project when the money meets the unchanged protocol and rules including necessary financial requirements and other prerequisites. Every donates can track the capital flow, funding balance and process of the projects on a consensus, transparency, and shared data information (Alexandria, 2021). Autonomy and self-execute properties reduce the intermedia charge and energy resources wastes, lead to a rapid activation, information sharing achieving a trust relationship among trustless individuals.

Internet of things, or IoT, is an intelligent, reliable, and high-speed information collecting and sharing network that connects billions of physical devices including RFID (Radio-Frequency Identification), Barcode, GPS (Global Positioning system), WSN (Wireless sensor network), etc. (Duan et al., 2020; Ranger, 2021). Blockchain system linked with IoT technology can enhance security and accuracy of automatically captured real-time information which improves transaction efficiency information transparency, supply chain traceability, enable the rapid identification of the products origination, movement and qualities (Duan et al., 2020; Wan et al., 2020; Rejeb et al., 2020).

Blockchain is a multilateral resource value model that serves the electronic ecology which including all those functions. Immediate recalling action and reduction of consumers' concerns will reduce food loss and waste globally. A safe, adequate food, trust, healthy and eco society is every human being's desire. No single company, regardless of size, can achieve all of these features alone. Blockchain provides a fair, visibility, trust, eco-society for all human beings. Everyone can work together to minimize duplication efforts, unnecessary cost, processing time, and to promote more effective and interoperable solutions for a better life, a better world, and better earth.

The purpose of this research is to develop an eco-system using blockchain technology to improve dairy food and other food safety. It is decentralized, efficient, traceable, versatile, practical. The running of smart contracts supports a more trust, and efficient high-quality dairy supply system. The implement of crowdfunding function provides customers more choice and right to direct the customization and diversify dairy market. Equal and transparent

information sharing enhances the trust among all participants. More visible and authentic tracking data will eliminate the fear of customers and build up their confidence in dairy and other food products.

We set up the following four specific aims:

I. Decentralized and Consensus data storage.
II. Real-time and Efficient traceability.
III. All information is open to customers
IV. Safer dairy logistics supply chain

Successful completion of these specific aims was expected to establish a framework for a practical solution to solve the current dairy food safety problems including illegal production, fraud milk, food illness and food recall.

2. CURRENT DAIRY FOOD SYSTEM

Food is essential to support the function, growth, and development of the human body, hence, to ensure food safety is to ensure the basic human right (Fung et al., 2018)). A rapidly increasing and complex global food supply system starts from origins to consumers is coming with a series of continuous and daunting challenges in the form of food fraud, illegal production, foodborne illness, and food recall (dlesBlockchain, 2021). World Health Organization stated that. Microbial agents, chemicals, and other contaminations are the major hazards in unsafe food, which can cause over 200 diseases like diarrhea, cramps, typhoid, etc. (Duan et al., 2020; Fung et al., 2021; Food Safety, 2021). Every year, there were 600 million people fall ill after eating contaminated food in the world, over 420,000 people included 125,000 children die annually due to foodborne diseases (Food Safety, 2021).

Dairy Food safety problems

Milk, a highly nutritious food, contains proteins, vitamins, minerals, carbohydrates, and other various essential components (Tan, 2020). Around the world, over 6 billion people are consuming it and its products, 150 million households are engaged in milk production (Dairy production and products: Processing, 2021). However, milk is required to be handled carefully because it's an excellent medium for the growth of microorganisms. Short shelf-life and greater perishability make the current dairy food supply system face more safety problems and challenges during processing, handling, and transportation (Kamath, 2018; Dairy production and products: Processing, 2021). Milk-related scandals have not waned from this earth. In 2005, contaminated baby milk resulted in 146 children's illnesses in France (Hamaide, 2021). In 2008, fraud milk caused over 300,000 victims included 54,000 babies in China (Chinese milk scandal, 2021). In 2013, Fonterra, a global dairy nutrition company, recalled 1000 tons of contaminated whey and related products across 7 countries (Fonterra recall, 2021). In 2019, Walmart, an American multinational retail company, recalled 23,388 containers contaminated infant formula globally (Levenson, 2021).

The slow and complicated transaction information track system suffered from identifying and verify the origin of dairy products and transport information by shifting from hundreds or even thousands of documents (Yiannas, 2018; Dujak, Sajter, 2019). Complex and diverse dairy food process-range from pasteurization to product labeling, and globalization markets make tracking more difficult (Duan et al., 2020). The increase of scandals of dairy food and the lack of information sharing has hurt customer's confidence in the products they got from the different retails. Recalls and customers' concerns of contaminated dairy products have brought about 29 million tons of dairy products were lost or wasted in Europe, $27 billion in dairy products waste in the United States (Food loss and waste facts, 2021).

All these serious food safety problems have already impacted customers' trust, company's brand, human health, social economy, and our ecosystem. There is a pressing need for the development of an efficient and traceability food supply system.

Current solutions for food safety problems

The global food traceability market size was valued at $14 billion by 2019 and is expected to reach $22.274 billion by 2025 (Fung et al., 2021). Most of the research and related work efforts over the past several decades focused on three approaches to achieve a better food supply system.

Traditional food supply system

In a traditional food supply system, all transaction data is stored disparately. Figure 1 shown that product information visibility is only one step ahead and one step behind (Yiannas, 2018), each stakeholder in this supply system must work with the next one in the system to identify the provenance of the product. Traditionally, the transaction information is largely stored on paper or digital methods (Duan et al., 2020; Yiannas, 2018). Each participant in this system cannot communicate efficiently with others due to the disparate and multiples transaction information. During a foodborne outbreak, one by one checking from hundreds or even thousands of documents will heavily extend the time for identifying the problems (Yiannas, 2018). And customers who want to purchase this product only get the information from the product package, the information that the producers want to tell you. Because of this pathetic traceability capability, Walmart, famous American multinational retail company, still needed to spend at least 6 days, 18hours, 14 mins to track the original grower of a package of sliced mango a few years ago (Yiannas, 2018; Kamath, 2018).

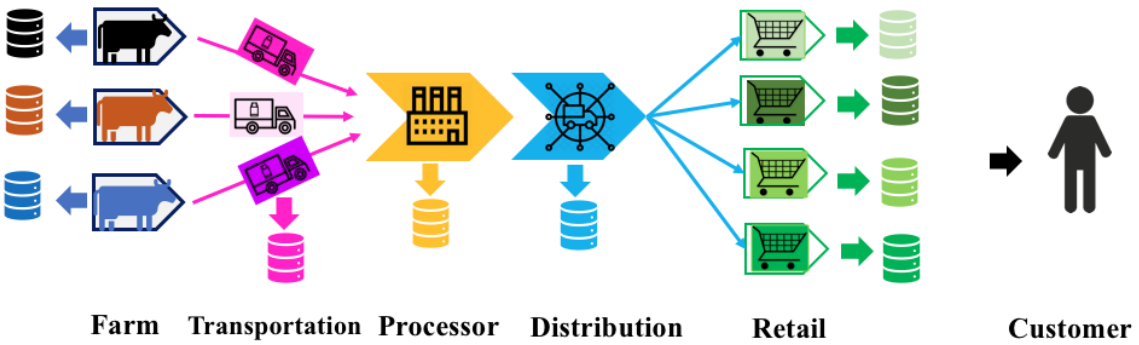


Figure 1: Traditional dairy food supply system

Centralized Service System

A lot of modern companies like Sysco, Blue Apron, Hello Fresh, are utilizing the centralized service system. A centralized supply chain must follow the central power's governance rules and mechanism (Rejeb et al., 2020), all transaction information must be depended on the central organization to collect, check, maintain (Duan et al., 2020). For example, Blue Apron, one new meal's ingredients delivery service company, will provide customers the different recipes based on the seasonal food every week. Blue Apron will buy all ingredients in the recipes from their trusted local grocery stores, and then deliver them to the customers on time after repacking (Figure 2). Each meal service has a higher price-range from $7.49 to $9.99 for each customer (Blue Apron, 2021). All the transaction data, ingredient's quality, customers' account information is stored and controlled by the 'Blue Apron', this central power. The customers have only shared the limited information provided from Blue Apron's website and the ingredients' package. For a centralized service system, inequality power enhances the more limited information sharing, all sensitive transaction information and customers' privacy would be at risk if the central organization got hacked.

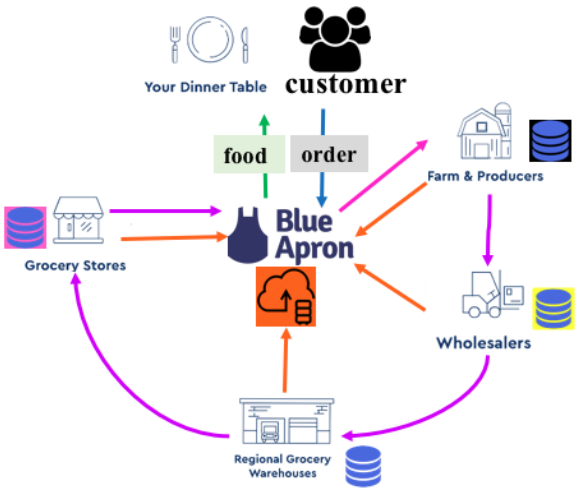


Figure 2: Blue Apron service system

Food supply system with IBM Hyperledger

In 2016, Walmart began to cooperate with IBM, the newly introduced Hyperledger technology has provided an efficient and secure digital tracking system for Walmart (Figure 3). With this new tracking system, the time needed to trace mangoes' provenance from 7 days dropped to 2.2 seconds (Duan et al., 2020; Yiannas,2018; Kamath, 2018). Walmart controls the whole supply data on the network and has the power to determine the sharing of data elements. Nowadays, customers will not only be satisfied with purchasing the food to feed their stomach, but customers will wonder whether the products they purchased have as same quality, safety, and nutrition as described. According to current market situation, customers obviously still do not have enough confidence in Walmart's new Hyperledger technology because of limited information sharing.

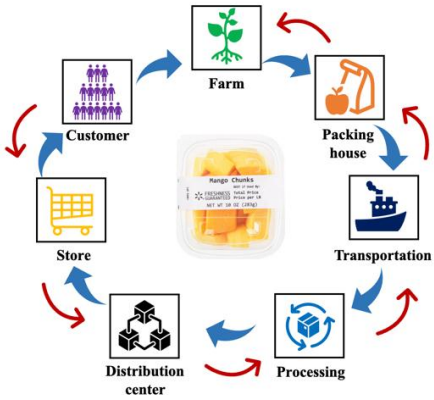


Figure 3: Walmart track mangoes system with IBM Hyperledger

For the current existed supply system, disparate and complicated one by one traditional inefficient tracking system could not provide immediate and accurate gangrened tracking information, it's not practical to ensure the food especially the fresh argi products and dairy food safety. Although a centralized service system can query transaction information in time and make better and quick responses for foodborne problems compared with the traditional ones, inequality information sharing will provide the chances for fraud and other immoral behaviors. A centralized system may put all transaction data and customers' privacy information at risk if the system got hacked. Walmart's mango tracking system with Hyperledger provided product visibility from farm to store, the database stored in the blockchain is authentic and efficient for major participants, especially for Walmart. However, the limited information shared with customers is still a challenger to solve customers' fear of food safety problems.

3. RESEARCH DESIGN

We design a brand-new dairy supply system which will provide customers with fresh, organic dairy products at fair prices. It is decentralized and the data is open to everyone in a real-time.

3.1 Create customize dairy supply chain

Smart contract is the future of crowdfunding. For traditional crowdfunding, contributors must pay for the intermediary fee and processing time, and worse, contributors do not know that whether the inventors put their money into some actual and feasible activities. The possibility of fraud issues will increase contributors' fear. However, contributing the money to a crowdfunding campaign supported by smart contract is secured and only after the campaign is successful (so when the agreement meets the predetermined conditions) the funds are given to the creators for concept realization. In case the concept fails to meet its objective-the funds will be automatically given back to the contributors immediately without third-party's time waste and extra money charged.

This new crowdfunding idea supports a more customize, diversify high-quality dairy supply system. For example, building up a new dairy supply chain needs a lot of money and not every enterprise wants to take this risk. But a crowdfunding application enables that more mid-class families living in Arlington, VA (a second headquarter of Amazon) donate a small amount of money to make a new organic goat milk supply chain become successful. Enterprises will be so willing to provide their sources to build up this new diary supply chain after they see so huge customers' demand and especially enough funding support. ~~I~~We believe that customers will be the future's major productivity leaders.

3.2 Record dairy logistics supply data

Blockchain technology works with IoT will make all the participants can easily track whether the store temperature meets the required store temperature and date conditions during the whole supply chain. Like the process shown in Figure 4, milk must be finished transporting, checking, processing, and going to the store after milking at below 40 Fahrenheit within 48 hours. To make the dairy food reliable and safer, the real-time data will get recorded when sensors scanning with FRID on the milk cooling tanks, milk transport trucks, QR code and expiration date on the products package. Each block contains a Unix timestamp which will make global participants involved in this system can check and get the actual timestamp. The decentralized attribute allows each one involving the system to enter and attach the necessary information and certifications. Real-time and efficient track and trace capability makes recalling action become more effective and improves dairy food safety.

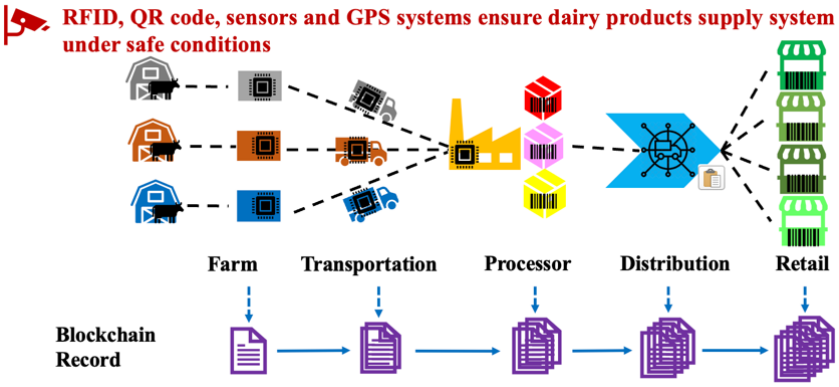


Figure 4: Record dairy logistics supply data using Blockchain

This proposed idea will be adapted to the Ethereum platform. The token wallet, MetaMask, makes participants worldwide make instant, easy payments with Ether is possible. A decentralized application was built with the Next.JS framework allows each participant can enter and attach some necessary information and certifications like farm needs to provide an FDA Dairy farm inspection report, dairy transportation company needs to provide FDA-approved inhibition test result and certificate of shippers. At the same time, IoT will record milking, transporting,

processing, distributing participants' transportation data for each participant and finally be stored into the Ganache local blockchain (Figure 5). All predetermined conditions including special service requirements, payment details and other agreements needed to be written into Smart contract (Figure 6).

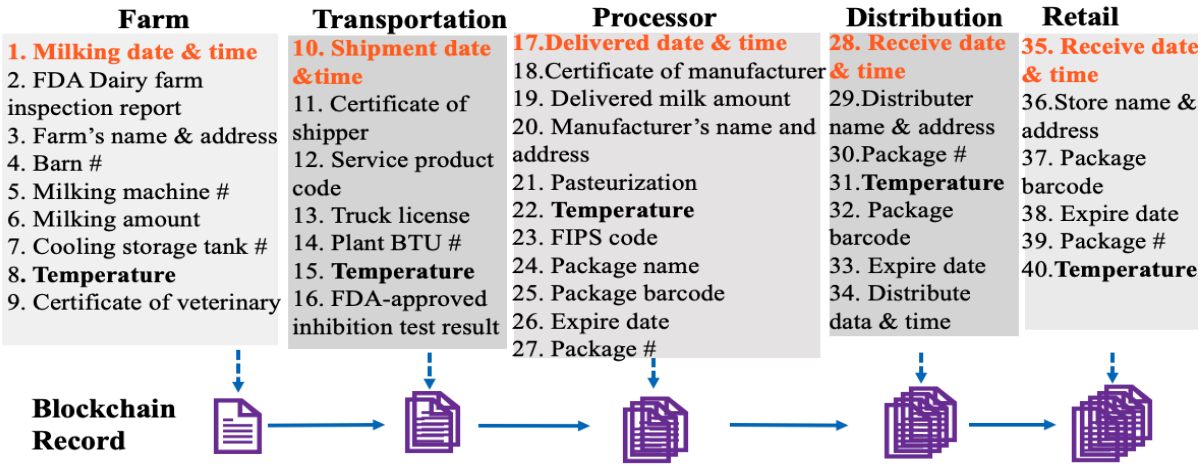


Figure 5: Transaction data for different participants

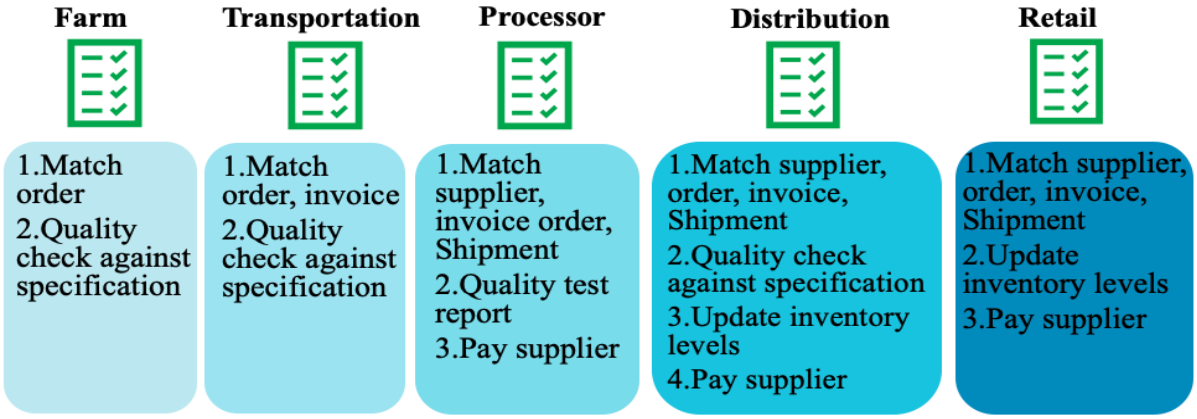


Figure 6: Predetermined conditions for different participants

3.3 Local Blockchain Network

Unlike Bitcoin, this dairy logistics supply system will be going to use a local blockchain, Ganache, instead of a public test one for the development purpose. This dairy supply system is more economic and environment friendly because less CPU space and electricity running is needed. All participants involved in this system have the same responsibility to check and maintain the data and transaction due to this system is governed by them rather than the single entity.

3.4 All information is open to Customers

As an import role in the food supply system, customers have the right to know whether the food they purchased is still in good quality, matches the products' description, meets the food safety requirements, or an organic food. After scanning the QR code and entering the expiry date on the product's package, customers can access the permission part of the blockchain record with a special App. More visible and authentic tracking data and information can reduce customers' fear to some extent. Reduction of the total food wasted in the world will contribute to the less squandering of resources including water, land, energy, labor, and capital.

4. RESULTS

4.1 Records of Dairy Logistics Data

Code in Smart contract will determine how this contract behaviors, how it handles the money. Set up different Smart contract according to each participant's special service conditions, payment details and agreements.

Smart contract for each participant

As shown from Figure 7 to Figure 11, we set up different smart contract to achieve different functions for each participant.

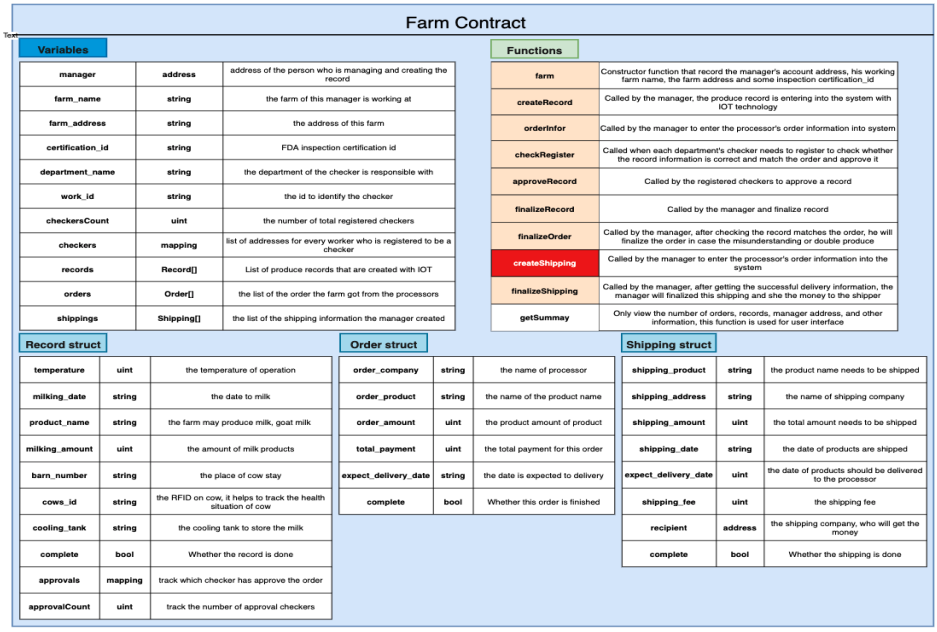


Figure 7: The variables and functions for Farm Smart Contract

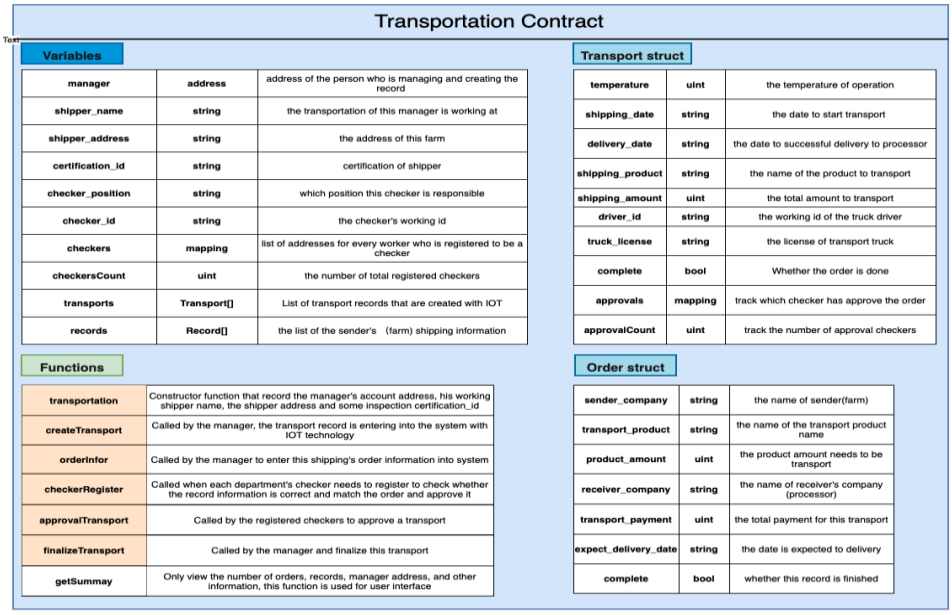


Figure 8: The variables and functions for Transportation Smart Contract

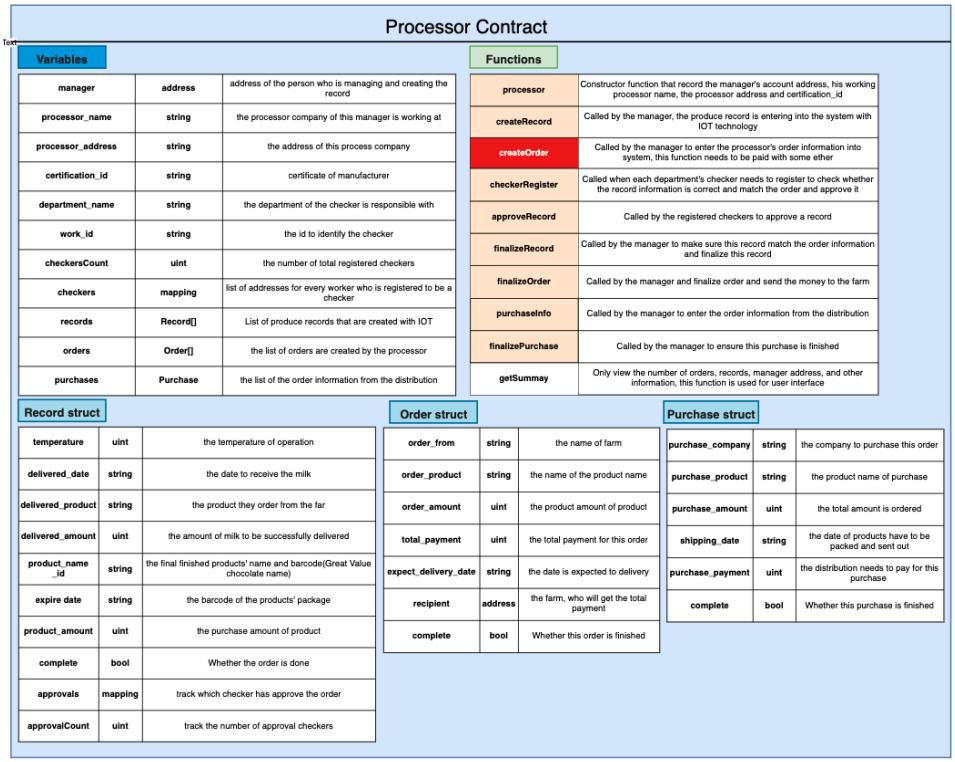


Figure 9: The variables and functions for Processor Smart Contract

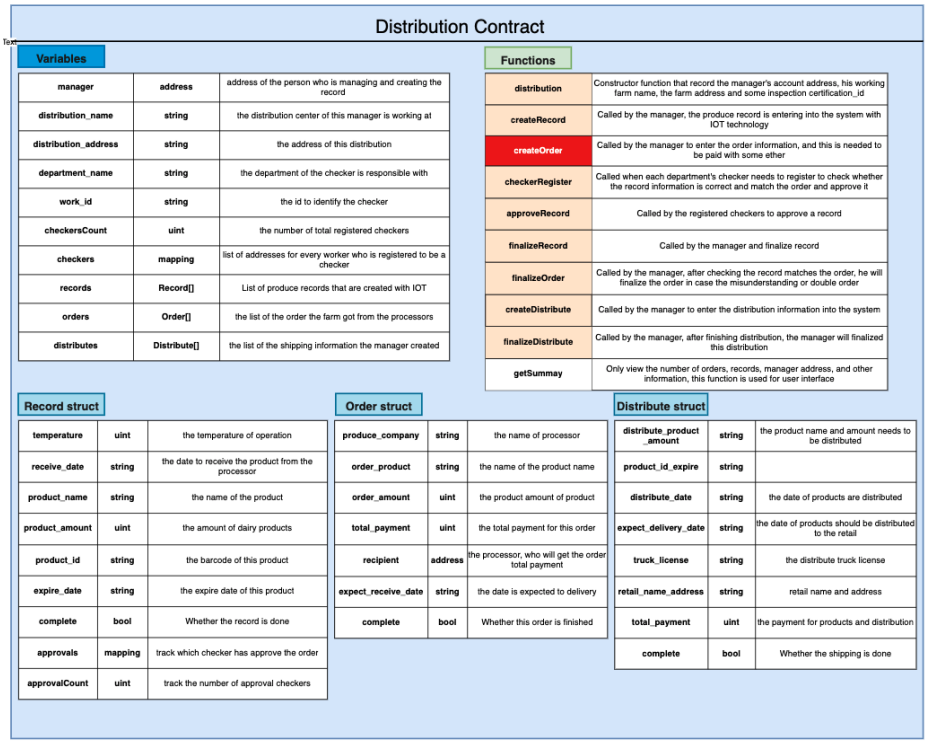


Figure 10: The variables and functions for Distribution Smart Contract

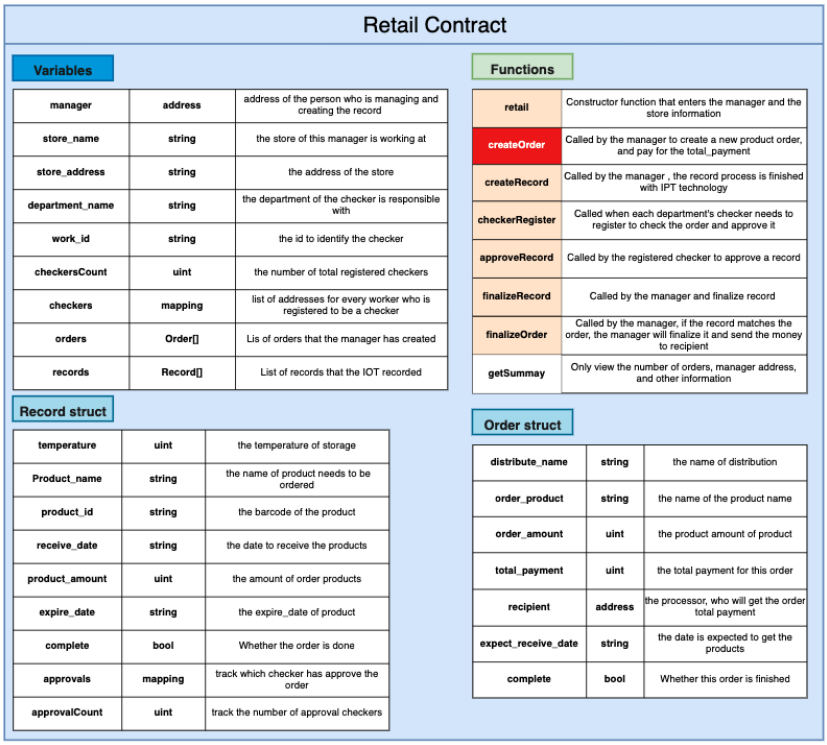
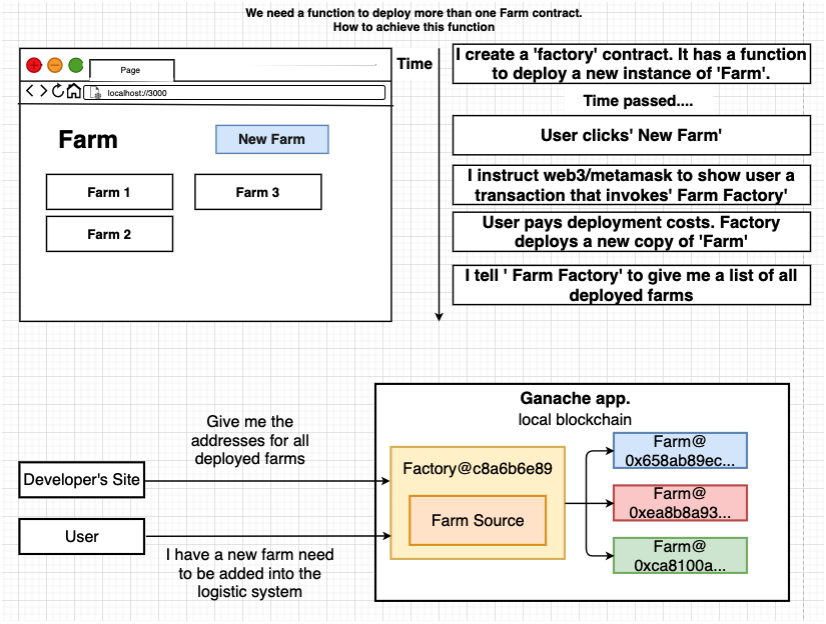


Figure 11: The variables and functions for Retail Smart Contract

Factory contract to deploy more contract instance

In a real practical logistics supply system, there will be more than one participant who needs to be added to the supply chain to record their transaction data. There is more than one solution can achieve this function. We designed my solution satisfied with two basic principles: to keep all source code security and immutability, to allow an eco-society developing environment. As Figure 12 shown the example of factory contract for Farm participant, other participants use the same solutions.



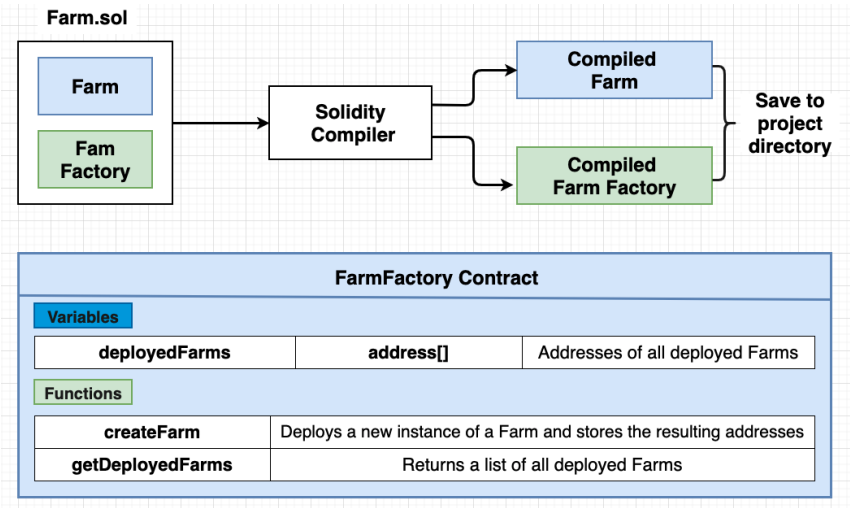


Figure 12: The method to deploy more than one Farm Smart Contract

4.2 Create a Campaign

More transparent and clear revenue and expenditure details help donors better understand the dynamics of the proposed concept and their investment income and can provide timely support or question the implementation expenditure requirements. Each contributor needs to be responsible for their money to the crowdfunding. In Figure 13 shown the details variables and functions for crowdfunding Smart contract.

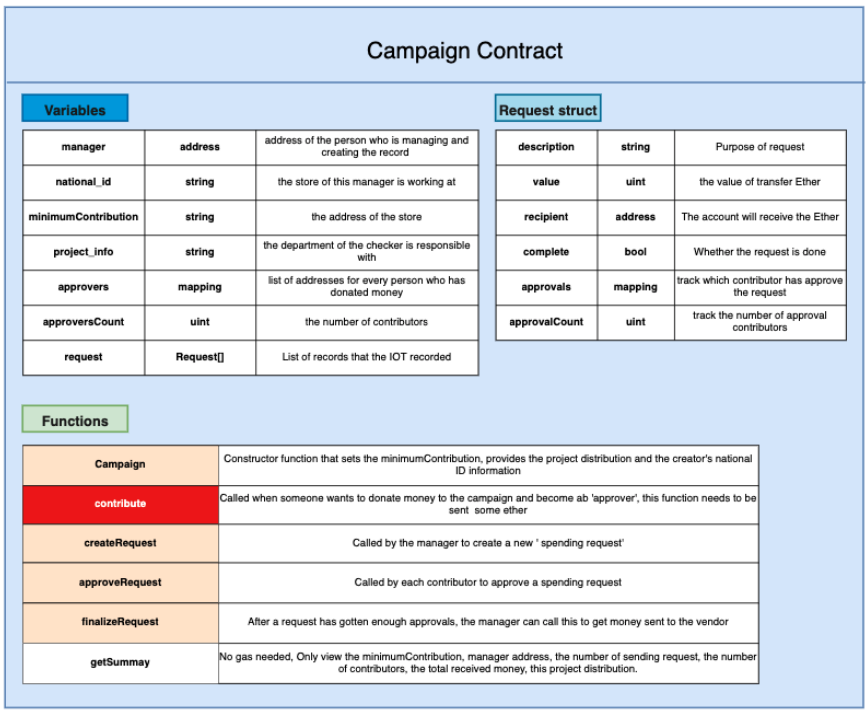


Figure 13: The variables and functions for Campaign Smart Contract

4.3. User Interface for Decentralized Application

Figure 14 demonstrated that how Next.js framework handles smart contract code, contacts with Ethereum network and shows the user interface to each participants and customers.

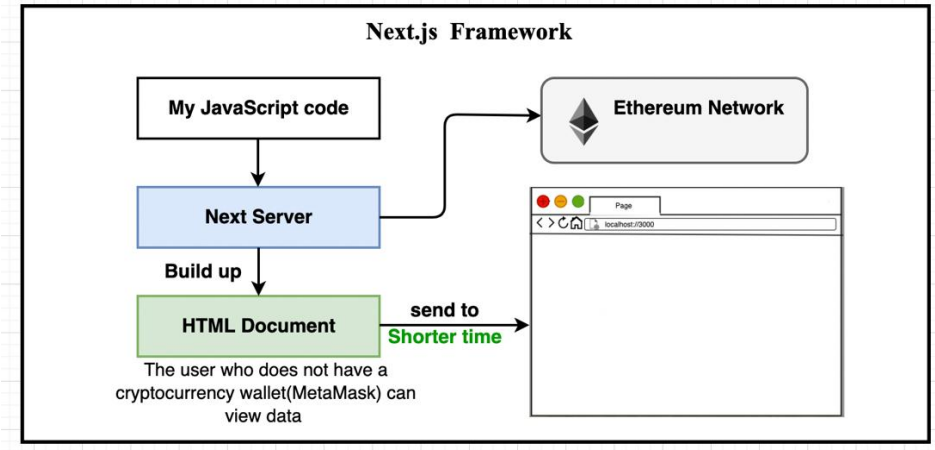


Figure 14: The working principle of Next.js framework

5. CONCLUSION

This is a better efficient and traceability dairy logistics supply system using Blockchain technology to identify and validate various stages of the food chain from farm to table or plates. This system can avoid the central authority involved, disparate and consensus data storage allows the data is visible and impossible to be altered without detection. Real-time and efficient track and trace capability make recalling action become more effective and improve dairy food safety.

More trust and security will be built up among the whole transaction system and this is crucial in the global food trade due to multi-ingredient food includes materials from a variety of food chains & countries. Crowdfunding supported by the Smart contract makes it impossible to have the chance to be possible. Customers will have the ability to lead the new direction of productivity in the future.

The successful execution of this research makes a positive impact on all the three sustainability parameters:

Environmental:

This proposal undertakes an approach to develop a better efficient and traceability dairy food supply system with Blockchain to improve dairy food safety. Immediate recalling action when a foodborne happens and reduction of consumer concerns can partly reduce food loss and waste globally. Reduction of the total food wasted in the world will avoid the needlessly produce, the less greenhouse gas emissions will contribute the global warming and climate change problems. The application of local blockchain is more environmentally friendly because of the less squandering of resources including electricity, land, and other energies.

Social:

Without safe, adequate food, trust, and a healthy environment, a society cannot flourish. This research contributes to preventing the public from suffering from hazardous to serious food safety problems through various means. Thus, the improvement of food safety will make a positive impact on the health of the current population and future generations. More trust and security will be built up among the whole supply system including customers. As a very important part of consumption, customers can guide the direction of production and create their customized supply system.

Economic:

The success of this proposal will support a sustainable economy by three means: a) it reduces the risk posed by food safety problems on the public; b) it allows reduction of the total food wasted in the world will contribute to the less

squandering of resources including water, land, energy, labor, and capital; c) it clarifies the consumption interest, direction, and quantity of consumer groups, and avoids waste caused by mistakes or overproduction.

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