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Applied Practice on Fresh Food Cold Chain System with Blockchain Solution

Eun Choul Jang[*], Janghwan Kim[**], R. Young Chul Kim[***]

[*]PhD., Software Engineering Laboratory, Department of Software and Communication Engineering, Hongik University, Republic of Korea
[**]M.A., Software Engineering Laboratory, Department of Software and Communication Engineering, Hongik University, Republic of Korea
[***]Professor, Software Engineering Laboratory, Dept. of Software and Communication Engineering, Hongik University, Republic of Korea
E-mail: {[*]ecjang, [**]janghwan, [***]bob}@selab.hongik.ac.kr

Abstract

Informatization and digital transformation across industries are big trends in the world. However, although a few food groups are investing in informatization on a pilot basis, informatization is still delayed in related industries, such as distribution, logistics, etc. Therefore, consumers often are not able to have easy access to detailed information about products. In this paper, to improve these problems, we propose a fresh food logistics solution that adopts Proof of Nonce (PoN) consensus algorithm with Internet of Thing (IoT) technology. The recently developed PoN algorithm dramatically reduces a time for generating a block and is suitable for a platform that collects and services real-time information. We expect to improve their trust in the platform by preventing forgery/falsification of information recorded in real time through this paper.

Keywords: *Block Chain, Proof of Nonce Consensus algorithm, Cold chain logistics, Internet of Thing, Information tracking*

1. Introduction

Recently, an imbalance in the supply and demand of agricultural products continues due to global population growth and climate change. As a result, international trade and product standardization of agricultural products are expanding all over the world, requiring major changes in management systems and logistics technologies for fresh foods such as agricultural products [1]. In addition, although the world is paying great attention to digital transformation, the informatization rate of the logistics industry is still low compared to other industries [2]. This happens because industries don't invest on digital transformation. From these reasons, it causes losing the competitiveness of companies engaged in the distribution / logistics. However, as IoT technology has developed, logistics industry has also changed its data collection method. Usually, methods of collecting information about products were collected manually, usually recorded by producers. However, the development of IoT technology has created a cornerstone for automatic collection and storage of digital information from these passive records [3].

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Corresponding Author: bob@selab.hongik.ac.kr
Tel: +82-44-860-2477, Fax: +82-44-865-0460
Professor, Software Engineering Laboratory, Department of Software and Communication Engineering, Hongik University, Republic of Korea

Because reliability of these data is very important in a logistics system, many companies and research institutes are conducting research to build a blockchain-based logistics system. However, in a commercialized blockchain platform, it is difficult to quickly generate a block with the data that is newely generated. Therefore, there is a limit to processing real-time data and making blocks. Also, In the case of the logistics industry, information containing the distribution processes, such as the movement route of the product from the origin and the state of the product during movement, and the detail information of product which is created by the producer can affect the consumer's choice of product. Therefore, this information should not be allowed to be altered nor falsified.

To improve these problems, this paper proposes a fresh food logistics solution that combines PoN algorithm and IoT technology. This solution uses the PoN algorithm, a new distributed consensus algorithm, to solve the problem of generating blocks of real-time data by improving the performance (TPS) of real-time block generation for large amounts of data, and improves the reliability of the generated data. We expect that the security against forgery/falsification of the fresh logistics solution will be strengthened through the proposed method, and the efficiency of the fresh logistics platform will be improved through generating blocks in real time. Chapter 2 will introduce researches on the fresh agricultural product logistics system and PoN consensus algorithm as related works. Chapter 3 will remark the design of the proposed solution for fresh logistics platform.

2. Related Works

2.1 Research on Proof of Nonce Consensus Algorithm

Proof on Nonce consensus Algorithm is an algorithm that accomplish the decentralization of between consensus nodes. It is also a non-competitive agreement algorithm that has low message exchange complexity [4]. Other consensus algorithms, including Proof of Work (PoW), Proof of Stake (PoS), Practical Byzantine Fault Tolerance (PBFT) had several limitations such as resource consumption, decentralization, and consensus cost to overcome the trilemma of blockchain [5-7]. These limitations have become a major obstacle to the commercialization of blockchain.

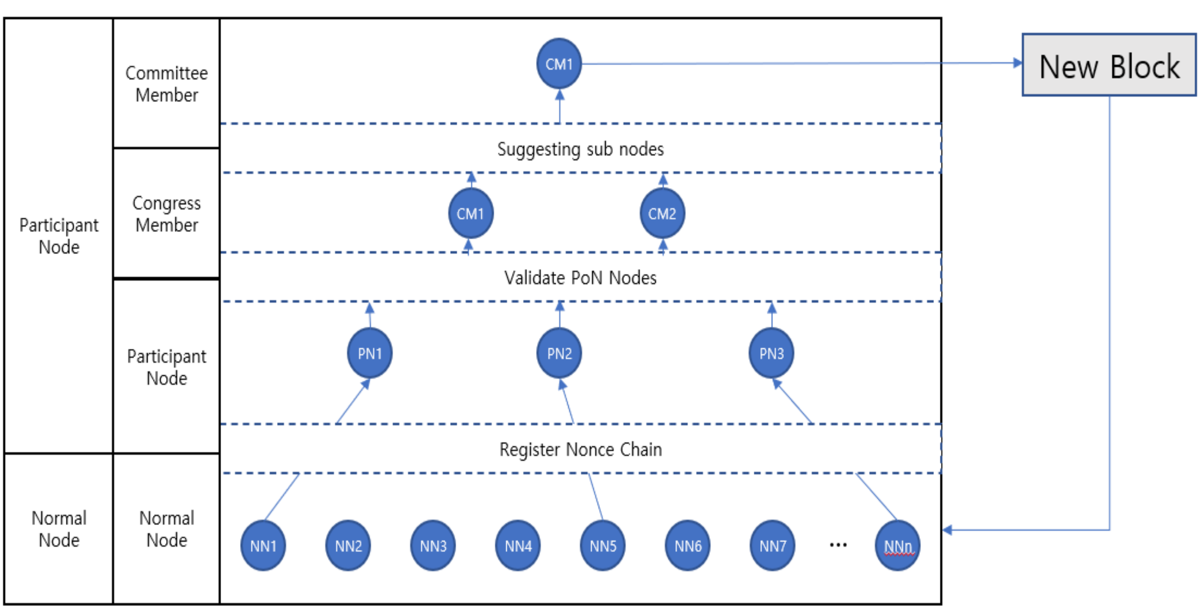

Figure 1. PoN Consensus Algorithm Node Structure

Figure 1 shows a diagram how PoN consensus algorithm works with nodes. PoN algorithm may provide all nodes with an equal opportunity to participate, secures security by randomly selecting nodes, guarantees block-level scalability, and minimizes costs by lowering message complexity. this algorithm made the node unpredictable in a random way, preventing it from being compromised in the network in advance. With this consensus algorithm, more transactions can be processed faster, more environmentally friendly, no-cost validation, and more secure decentralization.

2.2 Walmart Safety Alliance

Since the Industrial Revolution, research has continued producing products and safely reaching consumers through the distribution process. Nevertheless, there are many safety accidents with fresh food, and consumers' trust in the product is declining. Accordingly, Walmart has researched and developed a solution that provides information on the production, manufacturing process and distribution process to consumers by applying block chain technology in the distribution stage [8].

3. A Blockchain-based Fresh food Distribution Logistics Solution

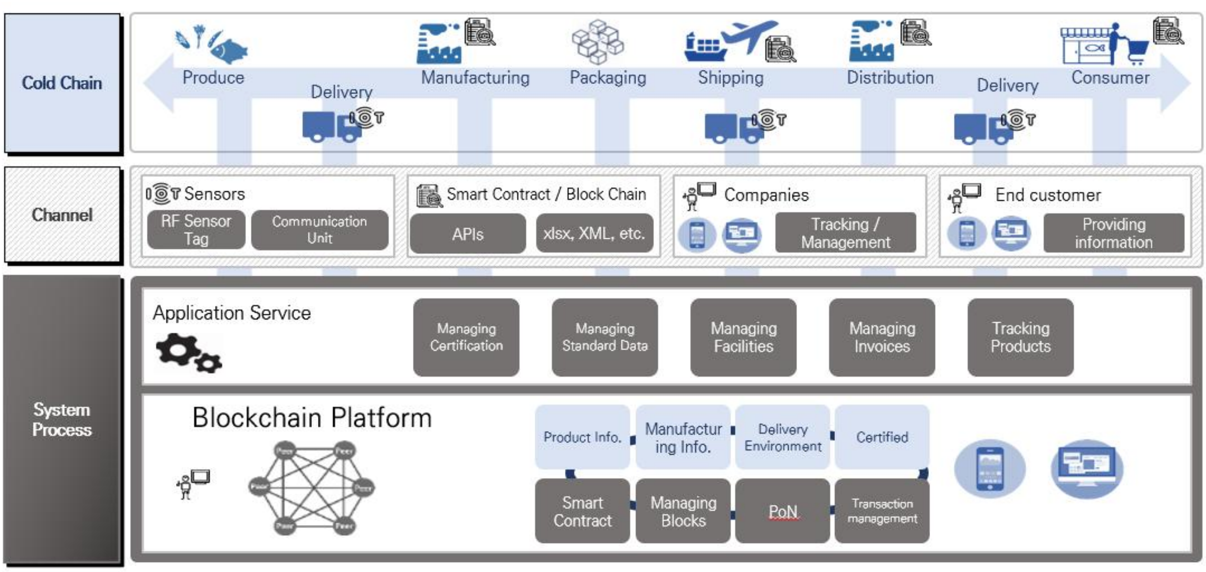

Figure 2. Design diagram of a blockchain

The solution proposed in this paper is a blockchain-based solution that enables real-time distribution history tracking. It uses the PoN consensus algorithm to record and safely store information on fresh products through the blockchain to prevent counterfeiting. This technology can process transactions at a speed equivalent to about 5,000 TPS, which is significantly improved compared to the existing blockchain platform by optimizing the message transmission/reception protocol of the consensus process between nodes. This reduces the block generation time from around 10 seconds to less than 3 seconds and creates blocks at a speed equivalent to real-time, enabling real-time monitoring of process details and real-time product tracking. One of the reasons why this is important is that due to this technology will make users to trust the product via the platform.

Product information is data collected and generated through IoT, provided by the producer, and contains product details. The producer inputs this information through the platform proposed in this paper, and the input information is verified (consent) through the platform again and stored. Not only having trust on products but also the distribution process is also recorded and managed in blocks by recording environmental information of factors (temperature, humidity, impact) that affect products using IoT technology. Then, this solution can provide end-to-end cold chain services for producers, logistics/distributors, and consumers.

Figure 2 is a design diagram that is showing the platform solution that we proposed in this paper. First, information about the product is collected from the producer. This information is input from the producer using a physical measuring tool. Then, in order to store it in the block, the detailed data of the product is collected with RFID tags, etc. The data to be created differs depending on the product, but basically, if producer enters information about the product itself, such as name, content, unit, price, and country of origin, the information is recorded in the block. Each time a record is made, each product is given a unique ID, and all information is connected to a chain created by a consensus algorithm through blocks. Then, Consumers can check the generated data by tracking products using the platform. In addition, through this stored information, the platform can prevent accidents that are related to food freshness and provide risk management services for producers, consumers, and companies engaged in logistics services. In this way, accumulating data through IoT technology and applying it to logistics makes data-based cold chain distribution history management possible more efficiently and increases the reliability of fresh logistics distribution.

The platform we propose is provided through web and mobile applications. Providing through mobile applications maximizes user convenience and increases accessibility of real-time monitoring. However, not everyone needs to see all the information all the time. Unnecessary and difficult terminology confuses consumers. Therefore, the consumer can access the basic information provided by the platform and, if desired, check the detailed records of the product. Production, processing and transport operators can also access basic information provided by the platform for the same reason. All of this through the admin mode allows consumers or companies to provide more information on their request if they so desire. Therefore, consumers and companies can access all of this information input, storage, and management using smart contract APIs and platforms [9].

The data that consumers access is data containing a large amount of distribution history (data collected from IoT) that is generated close to real-time and is processed into data needed by the consumer and shown to the consumer. The original data shown to the consumer is created in blocks, so it is very difficult to modify it. Therefore, we add an administrator mode to the platform, and the information shown to consumers using this mode provides a solution so that the processed data can be shown to help consumers understand the raw data. The next section shows the application as an example of this platform solution that we have proposed.

4. Applied Practice with Smart Cold Chain Logistics Tracking System

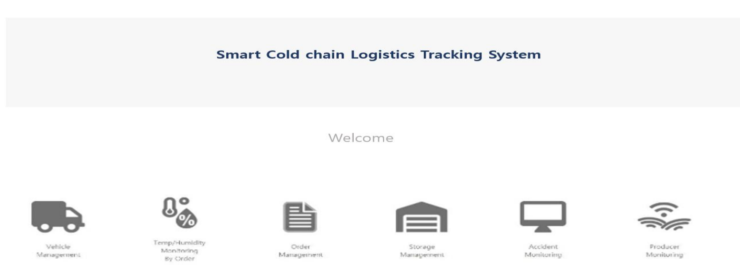

Figure 3. Smart Cold Chain Logistics Tracking System Main page

Figure 3 shows the main page of an example implementation of the design mentioned in Chapter 3. At the bottom of Figure 3, there are icons for Vehicle Management, Temp/Humidity Monitoring by Order, Order Management, Storage management, Accident Monitoring, and Producer Monitoring. Each icons link to services that this platform provides.

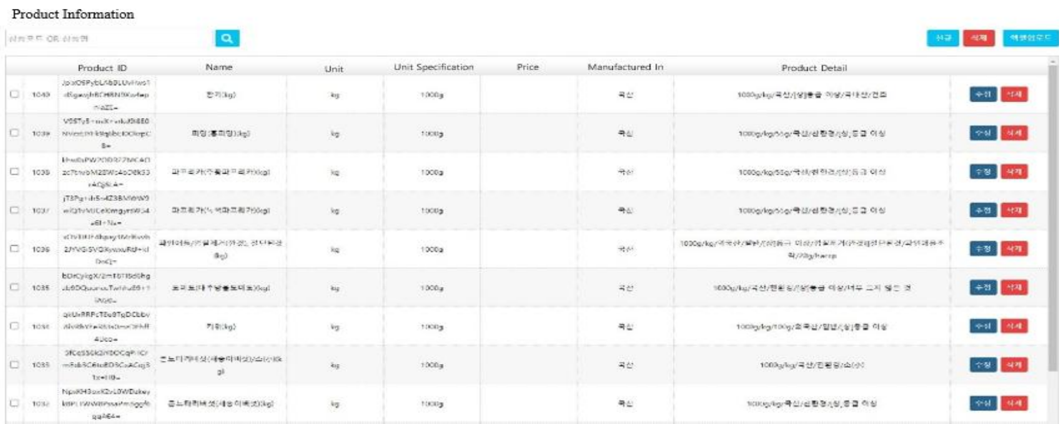

Figure 4. Product Information Page

Figure 4 is a page showing product information. At the top of the webpage, there is a search bar where user can find products and its information. Product information includes product ID, name, unit for the product, details of unit, price of the product, country of origin, and detailed description of the product. This record is information recorded when a producer registers a product in the database. Since this information is recorded in blocks through a consensus algorithm, modification (forgery/falsification) is hardly possible, but administrators can modify the categories of information that can be exposed with administrator privileges [7]. Since page in figure 4 is for administrators, all information about all products can be viewed, but consumers can only view information about the products they have purchased.

Figure 5. IoT Sensor Information, Vehicle & Facility Information Page

Figure 5 is a page showing IoT sensor information and vehicle/facility information. This page also provides a search bar for information retrieval. On this page, user can check IoT sensor device information, including installation location, serial number, sensor type, and usage history. In Vehicle Management, it is possible to grasp the status of the delivery vehicle and the location of the product. In addition, as a basis for checking the type of delivery and the state in which the product is stored, it is possible to improve the customer's trust in the product. In addition, regular inspection of the condition of the delivery vehicle can reduce the risk of logistics accidents.

In Vehicle Management, it is possible to grasp the status of the delivery vehicle and the location of the product. Using this page, the user can check information about the delivery driver, information on the delivery vehicle, and the status of the product. In addition, as a basis for checking the type of delivery and the state in which the product is stored, it is possible to improve the customer's trust in the product. In addition, regular inspection of the condition of the delivery vehicle can reduce the risk of logistics accidents.

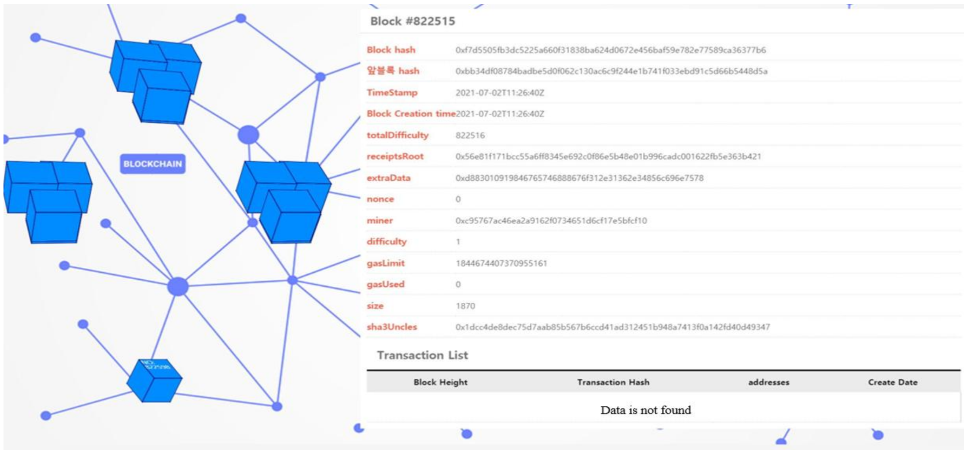

Figure 6. Real-time Monitoring Page for Blocks

Figure 6 shows the real-time monitoring page for a block. On this page the user can view information about a block. Blocks in which various types of information are recorded are managed by a blockchain through a PoN consensus algorithm [10]. This block contains information on block hash information, previous block hash, creation time, nonce, size, totalDifficaulty, etc.

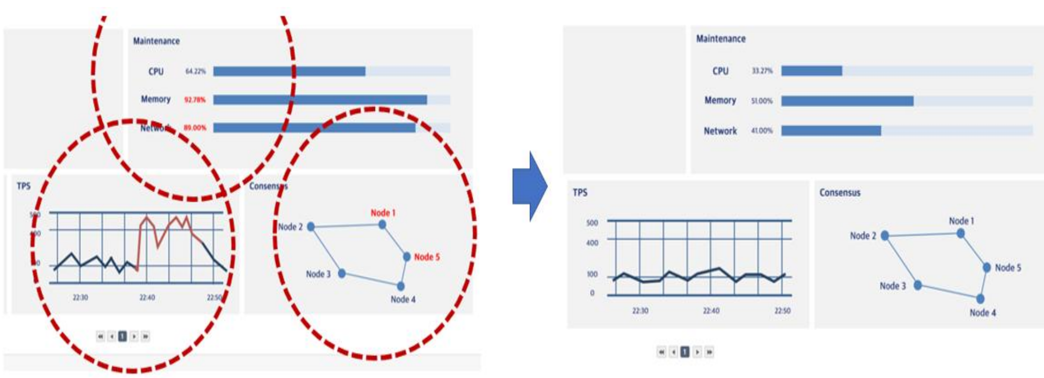

Figure 7. Benchmarking Test Results Before and After applying PoN algorithm

To show that the performance of the platform with PoN algorithm, we test two different algorithms in the same environment. Figure 7 shows the results of both tests. The first was tested by running the benchmark program using the Hyperledger fabric-based consensus algorithm, and the second was tested after replacing it with the PoN consensus algorithm. In order to have good test result, we created a specific environment for testing. This testing environment is designed to test the electricity consumption, computing power consumption, and network load usage due to the rapid increase in block generation. As a result of our tests, we confirmed that when using the Hyperledger public-based algorithm in a specific environment we set, a large load is applied on CPU, Memory, and Network.

On the other hand, in case of using the PoN consensus algorithm via benchmark program in the same situation, the CPU was reduced by about 30%, the memory by about 40%, and the network by about 40% compared to when the Hyperledger fabric-based algorithm was used. It means that the platform was stable than the other case. Therefore, we can find out that the PoN consensus algorithm is better fit for the proposed platform.

5. Conclusion

This paper is a fresh food logistics solution that combines PoN algorithm and IoT technology. This solution is a convergence solution that records state information and environmental information about products using IoT technology and records, stores, and manages them with a blockchain through a consensus algorithm with a PoN algorithm. Users have restrictions on the information that can be checked through the platform according to their authority, but they can deliver necessary information to the user without modification upon request, contributing to greatly increasing the reliability of the information provided by the platform. In addition, since the platform is well modularized according to the type of service, the platform can be further expanded without spending a lot of money.

In the future, we will conduct research to process data through data collected using IoT technology to extract meaningful information and to improve it into an intelligent blockchain platform by using A.I technology.

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