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A Preliminary Approach of Blockchain Technology in Supply Chain System

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***Abstract*—Blockchain technology combined with IoT to improve the reliability of the supply chain system is one of the topics in great demand lately. Due to the nature of blockchain, it is suitable to be applied in the supply chain to improve the level of service with security guarantees. In this paper, we present a preliminary study of blockchain in the supply chain using Ethereum smart contract to maintain ownership of digital assets and to track the origin of a product. By leveraging the proposed model, the user can be protected by minimizing the fake online trading activity because product assets that have been recorded by blockchain can be guaranteed since the data cannot be changed by anyone (tamper-proof). Further research needs to be developed, especially the connection between IoT devices and the blockchain network to improve the reliability and effectiveness of the decentralized supply chain system.**

***Index Terms*—Blockchain, digital asset, Ethereum, smart contract, supply chain**

Fig. 1. Blockchain enabled supply chain, adapted [5].

I. Introduction

Blockchain technology is currently one of the most research topics conducted by researchers. Since its emergence, blockchain has been developed in various disciplines such as supply chain [1], decentralized energy trading, and healthcare area [2]. One of the advantages of the decentralized blockchain model is the absence of third parties involved in the system, thereby reducing transaction costs and remove the single point of failure. Therefore, blockchain in the supply chain area is carried out with the aim of increasing effectiveness and credibility. For instance, blockchain in the pharma supply chain [3] is implemented with the aim of ensuring all processes run according to standards such as the new EU (European Union) regulation Good Distribution Practice of medicinal products (GDP 2013/C 343/01) [4].

Blockchain with various advantages is very suitable to be applied in the supply chain area. Blockchain in the supply chain can be used to maintain digital assets, assembly and maintenance tracking, integrated financial transactions and to name a few. In terms of digital ownership certificates, the blockchain permits to securely store the ownership of the asset by storing the physical properties as shown in Figure 1. Due to the nature of blockchain, this cannot be manipulated, altered or duplicated by the attacker. Therefore, blockchain indirectly maintains the integrity of a data, considering that data integrity is a fundamental component in information security [6].

By looking at these opportunities, we propose a system model by relying on the blockchain technology to maintain ownership of digital assets which provides traceability of the goods using the Ethereum smart contract. It makes it possible for users to avoid fake online trading and increase the visibility of the transaction due to the ownership of the asset in the Ethereum network cannot be manipulated. The information data of the asset is distributed to each node on the Ethereum network without interference from third parties. This research is a preliminary idea and an early stage in the sense that it is still under development.

Related Work. Recently, research on blockchain in supply chain management has been conducted by researchers. An Ontology-driven blockchain in the supply chain has been proposed by Kim et al. [1] which analyzes the traceability ontology in a supply chain system using Ethereum smart contract. The authors design a case why ontologies can contribute to the blockchain and supply chain design. TOVE traceability ontology is used in order to construct a quality control application of the system. Bocek et al. [3] propose blockchain technology for pharma supply chain which uses modum.io as a start-up that uses the Internet of Things sensor devices in order to get the data needed. All temperature data

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needs to be recorded and monitored to always meet GDP regulations, and then the data is sent by relying on blockchain technology.

An agri-food supply chain system based on RFID and blockchain technology has been conducted by Tian [7]. The system is developed to track the agri-food process with a combination of RFID and blockchain technology. The author claims the proposed scheme effectively improves the quality of agri-food products. Similar work is proposed by Toyoda et al. [8] which presented a blockchain-based product ownership management system (POMS) that every parties allow checking the proof of possession of balance. RFID is also used as an additional component in the system.

The structure of the paper is organized as follows. Section II presents the overview of blockchain in general and the prominent of cryptocurrencies. Whilst, system design and discussions are drawn in section III. Finally, section IV concludes the paper.

II. Blockchain in Supply Chain

In this section, we briefly present the essential information of blockchain in general and blockchain in supply chain management that uses the traceability ontology data model.

A. Essential of Blockchain

A blockchain technology (or distributed ledger) has the potential to lead the innovation across a range of commerce and industries. Blockchain offers a radically transform the way parties access the digital asset securely without the third party involvement [9]. One of the advantages of decentralized systems is that data is not controlled by anyone, and each node in the network has the same data version so that the tamper proof from the attacker.

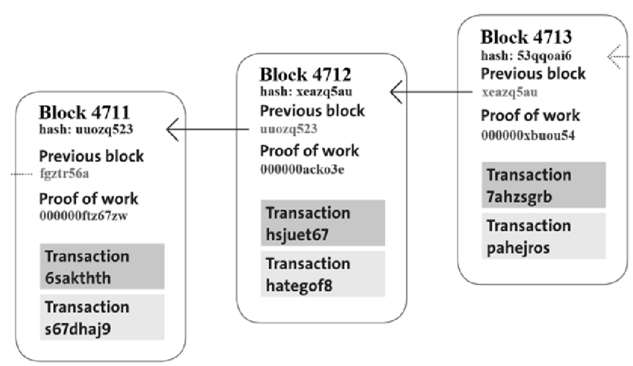

Fig. 2. Blockchain transaction in general.

Every valid transaction in an activity will be made into a block so that it becomes a block chain as shown in Figure 2. Once a new block has been verified by the miners, it will be permanently stored in the blockchain unless the attacker network can control more than 51% of the pool in the blockchain network which is very difficult to reach this condition in the real blockchain network.

Bitcoin is considered the first cryptocurrency (virtual currency) using the decentralized ledger as the core of the system which is developed by Nakamoto in 2008 [10]. Since its first appearance as the open-source software in 2009, Bitcoin blockchain has attracted the attention of various researchers and software developers to improve its reliability. Bitcoin uses proof-of-work (PoW) as a consensus algorithm in blockchain network. By leveraging the PoW, the miners rely on their mining power (resources) to solve the cryptographic puzzle by finding 256 bits of the target value for every transaction.

TABLE I
The Basic Comparison of Bitcoin and Ethereum

No.	Bitcoin vs Ethereum		
B/E	***Parameter***	***Bitcoin***	***Ethereum***
1	Release Method	Genesis block mined	Presale
2	Block Time	Average 10 min.	Average 15 sec.
3	Consensus	Proof-of-Work	PoW, PoS
4	Scalability	3 Tx/s	15 Tx/s
5	Algorithm	SHA-256	Ethash
6	Crytpcurrency used	Bitcoin (Satoshi)	Ether
7	Mining	ASIC miners	GPUs

PoS: Proof-of-Stake, ASIC: Application-Specific Integrated Circuit

Ethereum is one of the most well-known and widely used decentralized platforms besides Bitcoin. Ethereum allows the developer to run the decentralized applications on top of it. These decentralized applications are written using a smart contract [11]. The main advantage of using Ethereum smart contracts is the ease of interacting with each other. The users do not have to worry about how to integrate the consensus protocol in the network instead, the user just need to write the correct logic in the smart contract. The Ethereum transaction is confirmed in seconds compared to around 10 minutes for Bitcoin.

B. Blockchain in the Supply Chain Management

At present, food safety has drawn growth of academic and commercial concerns. Transparency and traceability are essential as a foundation in the supply chain system. The combination of the Internet of Things and blockchain technology give a positive impact on the supply chain system so that it becomes better in various aspects. Several studies have been conducted to increase the reliability of supply chains such as Digital Supply Chain toward blockchain integration [12]. The information of product and service needs to be shared effectively, transparent, and easy to be tracked in order to provide visibility in the supply chain system. Simply, by using blockchain for supply chain management, it allows the user to record the price, location, quality of product, certification [13], and other information to effectively manage the system as follows:

- Improve traceability for material supply chain and to ensure all processes meet the standards.
- It is possible to avoid fake online trading i.e gray market trading.
- Increase the visibility over several outsourced contract.

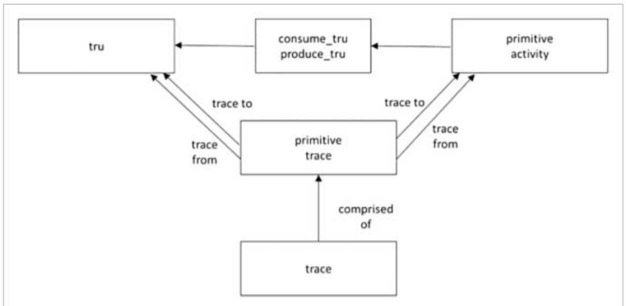

Fig. 3. Traceability ontology data model [1].

- Reduce the administrative cost and paperless.
- Increase the credibility of data sharing among the parties.

One of the most widely used methods for supply chain management is TOVE Quality Ontology, which was first introduced by Kim in 1995 [14] and then remodeled by the same main author in 2018 [1] (see Figure 3) which combines blockchain technology for supply chain provenance. The main keys of TOVE are as follows:

- It is possible to trace from one point to another, and the object is not an abstract object.
- Traceable resource unit (TRU) must be traceable and information for each change must be clearly known.
- The primitive activity must be traceable.

A good traceability system helps to minimize the production and distribution of unsafe or poor quality products, thereby minimizing the potential for bad publicity, liability, and recalls. The Global Food Traceability Center is intended to assist companies to better understand and implement ways to track and trace the paths of products through the food chain, to improve food safety and security and to avoid or mitigate devastating public health and economic impacts. However, we want to emphasize that food traceability is about more than recalls.

III. System Design and Discussions

The previous chapter supplied us with the fundamental information of blockchain in the supply chain. In this section, we present the traceability supply chain model of our system, Ethereum smart contract, and several key points of the model.

A. The Traceability Model

The data information such as the original data source, batch numbers, factory and processing data, expiration dates, storage temperatures and shipping detail are digitally linked to the physical (product) items as it moves from source to destination as shown in Figure 4. Traceability (see Figure 6) indicates that a product can be traced to the original source that was executed using the Ethereum smart contract. Once the data is added to the new block, it remains unchangeable in the blockchain for all time.

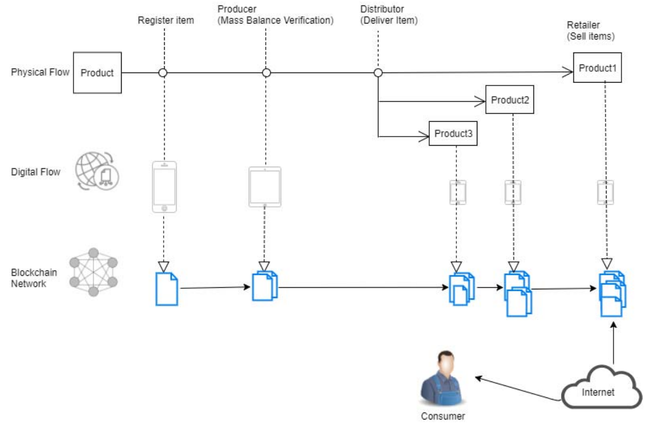

Fig. 4. Traceability for supply chains.

The information captured during each transaction is validated by businesses within the network (farms, transport companies, packaging companies, warehouses, and stores) forming a consensus. After each block (record of each transaction) is validated, it is added to a chain of transactions, becoming a permanent record of the entire process. Each product item received at the store is verified as authentic, whilst the digital record can also help retailers better manage the shelf-life of products in individual stores.

In the supply chain area, due to the rapid growth of internet technologies, a lot of emerging technologies have been applied in traceability systems. In order to build a supply chain traceability system based on HACCP (Hazard Analysis and Critical Control Points) as shown in Figure 5, blockchain and internet of things are needed as a solution to provide the information with transparency and reliability.

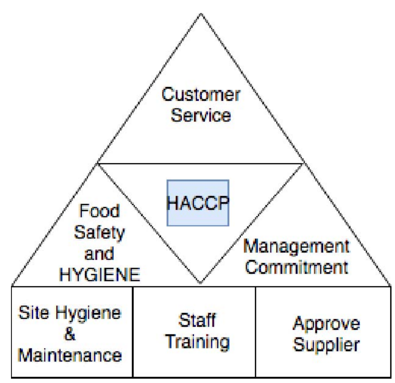

Fig. 5. HACCP system model.

HACCP system could make food traceability from farm to fork become a reality and rebuild public confidence in the food supply chain. In order for HACCP to be effective, it must be simple, manageable and specific to each establishment. HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling to manufacturing, distribution, and consumption of the finished product [7]. HACCP is a preventive food safety system that tries to reduce the risk of hazards getting into food products to an acceptable level. It focused on risk management and prevention was considered to be synonymous with food safety. It can be a feasible strategy for dairy supply chain safety. Imported food benefits both the consumer and the food processor. Sourcing products or ingredients internationally provides cost savings and the ability to source products all year long.

While companies can often make a case for improving product traceability using the blockchain, this technology will not magically solve all problems. For instance, leveraging it does not mean that everyone will enter the right data. Depending on the level of automation, there may still be humans involved in data entry. On the other hand, the data can be corrected and there is always a record of it in the immutable ledger.

B. System Components

To support a system in order to run properly, it requires several additional components that are connected to each other. The system model is briefly described as follows:

- **Ethereum Blockchain Network.** The Ethereum network is run on a virtual machine commonly called the Ethereum Virtual Machine (EVM). To run the Ethereum blockchain, a network consisting of several related parties and miners is needed to verify each transaction [15].

```
contract Trace{
        struct trace {
            bool consumed;
            bool used;
            bool created;
            uint id;
            uint producedBy;
            uint consumedBy;
        }
        struct activity{
            bool created;
            string name;
            uint id;
        }
        mapping(uint => trace) lookup;
        mapping(uint => activity) activityLookup;

        uint orders;
        function trace(){

            orders = 0;
        }
        event ActivityCreated(uint orders, uint activityId, string description,
            uint consumedtraceId, uint producetraceId);
        event traceCreated(uint orders, uint traceId);
}
```

Fig. 6. Smart contract.

- **Ethereum Smart Contract.** A Ethereum smart contract runs definitely as programmed without any possibility downtime, fraud, censorship, and middleman interference [16]. In order to deploy smart contracts (see Fig. 6) or execute the functions, the internal Ethereum currency called ether is needed.
- **Peer Discovery.** A node that is part of the Ethereum network needs to connect with other nodes so that transactions can be made. In the node discovery protocol of Ethereum, Bootstrap nodes which are responsible for maintaining a list of all nodes that have and will be connected to the Ethereum network.
- **Server.** It is a communication device between the Ethereum blockchain network and front-end users.
- **Database.** For a blockchain database, every party maintains, calculate and updates new entries into the database. The node works together to ensure they have the same conclusions, providing inbuilt security in the blockchain database.
- **Mobile Device.** The devices are used by users to be able to interact with the Ethereum network, knowing the status of the data and to name a few.

Algorithm 1: AddUser

Input: addNewUser
Output: bool
if *msg.sender not the owner of the contract* **then**
    throw;
    end
else
if *addNewUser exist* **then**
    return false;
else
    authorizeUsers[addNewUser] = true;
    return false;
End

Algorithm 2: CreateItem

Input: item[Id], producedBy[id], consumedBy[id], productDescription, enum ItemNames, timestamp (date)
Output: Added items with timestamp captured
if *msg.sender not the owner of the contract* **then**
    throw;
else
    mapping CreateItem to (id) and add it to Index variable collection of data
return true;

The contract consists of three functions, **Adduser (Algorithm 1), createItem (2), and searchItem (Aglorithm 3)**.

- **AddUser** this function can only be executed by the owner of the contract. It is embedded by his account address which will be used to authenticate each time the the user invoke the function within the contract.
- **CreateItem** this function invoked only with the owner of contract allowed to add the items listed in the algorithm such *item, product*. The first argument is to validate the owner address if indeed exist, if not reject and last argument is to add data into the blockchain, using mapping that will allow us to look up a specific item and retrieve necessary information.

Algorithm 3: SearchItem

```
Input: itemId
Output: searchResult
if msg.sender not the owner of the contract then
    throw;
else
searchResult ⇐ Index[itemId] ;
get Index[itemId] array's length len;
for uint i=0; i¡ itemId; i++ do
    return itemId;
return searchResult;
```

- **SearchItem** also this function as it stated, allow to search stored items. The first argument checked user validity address, then do the looping of all records by using Ids created in the second function and returns the searched results.

This paper is the preliminary stage of developing a decentralized supply chain system that will be connected to the IoT devices. The proposed system makes it possible for the user to know the source of a product where every data update is distributed to the Ethereum network. Meanwhile, the digital ownership provided by the Ethereum network gives users the confidence to trust ownership of digital assets from producers. The architectural system of the database is also mandatory in the decentralized supply chain. For instance, the CHAINSQL [17] which is an open-source system developed to integrates the blockchain and database architecture. It also supports the consistent multi-active database which is tamper-resistant.

IV. Conclusion

Blockchain in the supply chain area has been implemented using the Ethereum platform to increase the credibility of data sharing, trace the origin of a product, and ensure that all processes run according to established standards. The parties allow tracking the source of products managed by nodes on the Ethereum network thus it increases the visibility of the system. As well as typical of a decentralized system, the model reduces administrative costs and gets rid of the complicated administrative procedures. For future work, this design needs to be developed further as it is connected to IoT systems in order to improve the reliability of the supply chain system.

Acknowledgment

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