Towards Blockchain-based Stainless Steel Tracking

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***Abstract*— Supply chain is an entire network of producing and delivering a specific product to a final consumer. Stainless steel is a specific product being delivered on a supply chain. It is not easy to manage and monitor the entire supply chain because a supply chain has high complexity, including various organizations and activities. Due to this difficulty, several issues occur in the process of supplying stainless steel, such as forgery and alteration. Blockchain is a decentralized and distributed ledger technology that specializes in transparency and immutability. Many companies try to introduce this blockchain technology into supply chain management to conveniently monitor their supply chain. Accordingly, the blockchain technology can make steel companies be able to investigate and protect high-quality products from counterfeited low quality products. This paper proposes a design of a blockchain-based stainless steel tracking system to thoroughly track the entire process involved in supplies from stainless steel mills to the final customers. This proposed design is based on the hyperledger fabric which is one of the most popular private blockchain platforms.**

***Index Terms*—Blockchain, Tracking system, Supply chain management, Stainless steel**

I. Introduction

Supply chain [1] is an entire system of activities, entities, resources, and information involved in supplying a product to a consumer. Activities of a supply chain involves the all transformations from resources into a final product and its delivery reaching to the end consumer. Entities represents all participants in the supply chain, such as factories, manufacturers, transport companies, distribution centers and any consumer. Information is communicated between participants in the supply chain. Nowadays, the concept of supply chain is used in many areas including foods, drugs, cars and so on. Supply chain management (SCM) [2] is a essential function of managing the flow of goods and services involved in the movement and storage from point of origin to point of consumption. It optimizes overall process among participants in the supply chain. However, it is not easy to manage and monitor the entire supply chain when a supply chain complexly consists of a lot of entities and activities.

Blockchain [3] is a decentralized and distributed ledger technology that all participants in a blockchain network maintain the same data by connecting blocks as the form of a chain. The blockchain network is a peer-to-peer overlay network and every peer in this network receives data in a peer-to-peer manner and verifies the data without any trusted party. Anyone can see everything that happens on the blockchain network, but cannot tamper the data with malicious intention because all peers store the same data. Accordingly, the key features of blockchain technology are transparency, immutability, and security. Nowadays, people try to introduce this blockchain technology into supply chain management in order to utilize its features. There have been various researches applying blockchain technology to supply chain [4–6]

Stainless steel (STS) [4] is a family of iron-based alloys that prevents the iron from rusting as well as providing heat-resistant properties. STS is one of products on the supply chain from the stainless steel mill to the consumer. In the STS supply chain, entities include stainless steel mills, processing & distribution centers, customers and so on. Currently, there are critical issues in the STS supply chain, such as forgery and alteration because the supply chain management does not completely work in this supply chain. Steel Alliance Against Counterfeiting (SAAC) [5] is a non-profit industry initiative that mentions that the market of counterfeit steel products is more growing and poses considerable safety, legal, and financial risks. Because blockchain technology can give the traceability through its transparency and guarantee that any data is not tampered by its immutability, it can solve this type of issues in the STS supply chain. In addition, the Canadian government is interested in the blockchain technology to trace steel and establish the responsible steel [9,10]. Therefore, this work applies the blockchain technology to the STS supply chain in order to make it become fully traceable. Hence, the proposed blockchain-based STS tracking system can protect the high-quality STS product from being forged by the low-quality STS product and other types of steel.

The rest of the paper is organized as follows. Section II and III describes the background of private blockchain and related studies to apply blockchain technology to metal and other fields. Section IV covers the requirement analysis of tracking stainless steel and a design of blockchain-based stainless steel tracking system. Finally, the conclusion with contributions and our future work are presented in section V.

II. Background

Blockchain became widely known after the emergence of Bitcoin, the first cryptocurrency based on blockchain. Bitcoin is a fully open network that anyone can participate in, but because of the needs of privacy and so on, people are starting to study different ways of blockchains that allow access only to authorized participants. Regarding the accessibility of users into a blockchain, blockchain can be divided into two types: public and private. [6]

In the public blockchain, anyone can join the blockchain network and interact with other participants. Thus, everybody in the public blockchain can view and write data (e.g. reading and sending transactions). However, because the identity among participants is either pseudonymous or anonymous, it is hard to reach a consensus (e.g. recording data into an immutable blockchain ledger) from all participants. Hence, this type of blockchain normally requires a considerable amount of computational power or stake of its cryptocurrency to maintain a distributed ledger. There are many examples of public blockchain such as Bitcoin [7], Litecoin [8], Ethereum [9], and so on.

In the private blockchain, only pre-validated individuals or groups of individuals can participate in the blockchain network. This type of blockchain maintains a shared record of transactions accessible to only pre-validated entities. Thus, only those who have validated for access to a blockchain ledger can read and write data from/on a blockchain ledger. Besides, in contrast to the public blockchain, the identities of all participants are known because the private blockchain does not allow anonymity. The way to grant new participants permission to access to the blockchain varies by the form of authorization scheme to identity: Existing participants can decide on future participants, a single authority can grant new users the right to participate, or a consortium can make decisions. As a result, private blockchain is more centralized than public blockchain, showing that a small group controls the network. Therefore, entities would need trust to use this type of blockchain. Without trust among the participants, the private blockchain does not work. There are several examples of private blockchain such as hyperledger fabric [10], Quroum [11] , corda [12], and so on.

III. Related Work

Abeyratne and Monfared [13] review the current status of the blockchain technology and applications based on this technology. The authors discuss that the potential advantage of the blockchain technology in manufacturing supply, and then have proposed a vision for the future blockchain ready manufacturing supply chain. In addition, they present the requirements and challenges to adopt this technology in the future manufacturing systems.

In [14], Feng Tian mentions that a lot of emerging technologies have been applied in traceability systems in the supply chain area. However, nearly all of these systems are centralized and it could result in the trust problem and be vulnerable to a single point failure. To solve this problem, the author considers applying the blockchain technology to the supply chain. The author has proposed a food supply chain traceability system for real-time food tracing using on HACCP, Internet of things, and blockchain in order to provide all the supply chain members with openness, transparency, neutrality, reliability, and security.

IV. System Design

A. Stainless Steel Supply Chain

STS supply chain includes Stainless Steel mill, 1st Tier Processing & Distribution Center, 2nd Tier Processing & Distribution Center (Retail) and Customer. A simple flow process of the STS supply chain is presented in Fig. 1. This flow process contains the workflow in each entity and links for the transfer between the entities.

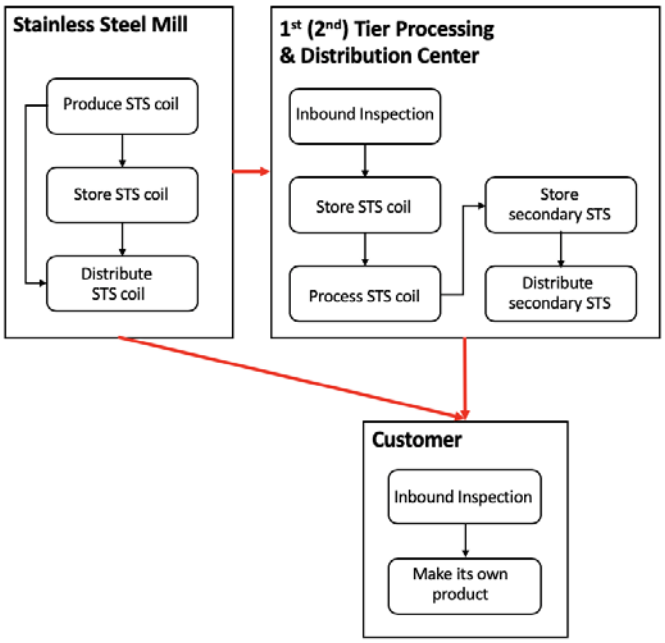

Fig. 1. Flow process of stainless steel in its supply chain

Stainless Steel Mill produces stainless steel products in coil form, using raw materials. A label containing information such as product number and date is attached to a produced STS coil and then this STS coil is stored in the warehouse inside and outside the mill. The STS coils that are stored will be inspected later and distributed. These STS coils are usually delivered to the 1st and 2nd Tier Processing & Distribution Center which apply additional processing to the STS coils in order to customize the desired thickness and size of customers. The processed STS products are stored in the warehouse and attached with a new label created by the 1st and 2nd Tier Processing & Distribution Centers. Then, they distribute the customized STS products to the customers. Customer makes its own products such as pipes, spoons, etc. after examining the STS products that have been received.

The final STS products may be accidentally or purposely replaced with counterfeit products in the flow process shown in

1. For example, mistakes may occur during product inspection and when a new label is attached by the processing & distribution centers. In addition, because the processing & distribution centers attach a new label to the processed STS product, high-quality STS products can be forged by low-quality STS ones. In a consumer's view, there is no way to verify if the delivered STS products are genuine or not. Besides, it is very difficult to track the history of each STS product because the label information changes in the middle, and also there are several stainless steel mills, 1st tier processing & distribution centers, 2nd tier processing & distribution centers, and consumers in the STS supply chain.

B. Requirement Analysis

The STS supply chain tracking system should by default be able to track STS in the flow process shown in fig. 1 and should prevent data from being altered. Because the blockchain technology has transparency and immutability as its characteristics, it can provide traceability of the STS supply chain. In addition, the STS supply chain must only allow authorized participants (stainless steel mill, 1st tier processing & distribution center, 2nd tier processing & distribution center, customer) to access to the blockchain. In addition, because flow processes occur in a sequence, the preceding data must be processed and included in the blockchain ledger in order to proceed with the next process. Therefore, high transaction per second (TPS) is needed to update the state of the blockchain ledger without long latency. In summary, private Blockchain is more suitable for organizing the STS supply chain than the Public Blockchain.

Functional requirements include:

1) Participants must update the status of the product whenever they receive/release the STS product and be able to view the status of the product through the Front-end the proposed system provides. This function can be implemented by the logic of a smart contract [15].

2) Because there can be multiple participants (companies) in one kind of entity, it should be possible to isolate the sub-supply chains which comprise of the multiple combinations of entities. This means that the entities included in the other sub-supply chain should not access to the ledger of others.

3) Because, within a sub-supply chain, there may be private data that need to be hidden among participants in the same supply chain, it should be possible to maintain private data that must be disclosed only to specific participants.

C. Overall Architecture

The overall architecture of the STS supply chain tracking system is shown in Fig. 2. The icons shown at the top represent participants in the STS supply chain (stainless steel mill, 1st tier processing & distribution center, 2nd tier processing & distribution center, customer). These participants are certified by the Membership Service Provider (MSP) and can access the blockchain network, each participating as a peer.

Each peer has a ledger and smart contract. Ledger manages three types of databases. First, the blockchain stores transactions created by requests from participants. Second, the world state stores the state information changed by transactions included in the blockchain. For example, it contains the latest information such as the weight and status of STS in the STS supply chain. Third, the private state that is shared only among special participants in a single sub-supply chain, and may include a selling price, etc.

Smart contract executes logic of update/query by transactions generated from the request of participants and returns the response which is about endorsing the transaction execution. Participants can interact with the blockchain network through the application. To the right of Fig. 2 is a list of functions (e.g. send a transaction for the actions) that can be performed through the application. Once a transaction is made through the function of this application, participants get endorsed by executing the transaction through the smart contract.

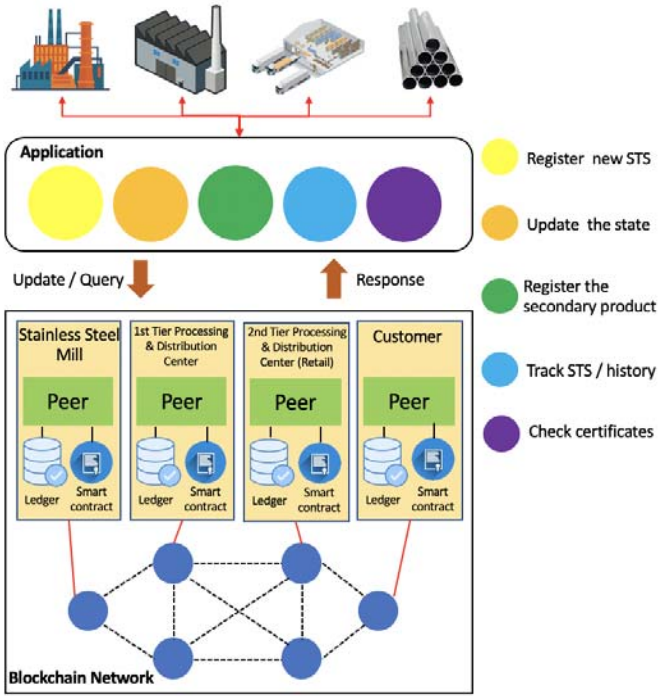

Fig. 2. Architecture of blockchain-based stainless steel tracking system

D. Blockchain network for Stainless Steel Tracking System

The proposed STS supply chain tracking system is designed based on a private blockchain called Hyperledger fabric. Fig. 3 shows the network design of the blockchain-based STS supply chain tracking system built with hyperledger fabric. The following is about introducing each component and notation shown in Fig. 3.

R* represents each organization that participates in the blockchain network for the STS supply chain, and they set up and use the network. For example, R1-1 can be a steel company that runs steel mills. CA* means each certificate authority and issues a certificate that proves that a client belongs to an organization and also is used to sign transactions.

P* represents each node (peer) running on the blockchain network. Each peer has L (Ledger) and S (Smart contact). L* is the ledger, each of which consists of a blockchain, a world (public) state, and private states. S* is the smart contact and has a logic that handles the flow of data in the STS tracking system.

The thick dashed line connecting between the peers represents the channel. Channel is the mechanism for communication between the members of each consortium (e.g. combination of participants) in the blockchain network. Members define a consortium and create a channel, which is controlled through Channel Configuration. It is possible for multiple channels to simultaneously exist on the same network, and channel provides complete isolation so that other participants, except for its members, cannot access data maintained by the channel. This means that each channel has a distinct ledger and smart contract.

A* is a client program that allows each participant to access the blockchain network of the STS tracking system. The application performs access control based on certificates and sends transactions (e.g. update or read data) to the blockchain through the channel to which each participant belongs.

Additionally, O5 is a special node that connects with the channels and proceeds with sequencing the transactions received through each channel. The entire network and its ordering node are governed through the Network Configuration, which is set when the network is first set up.

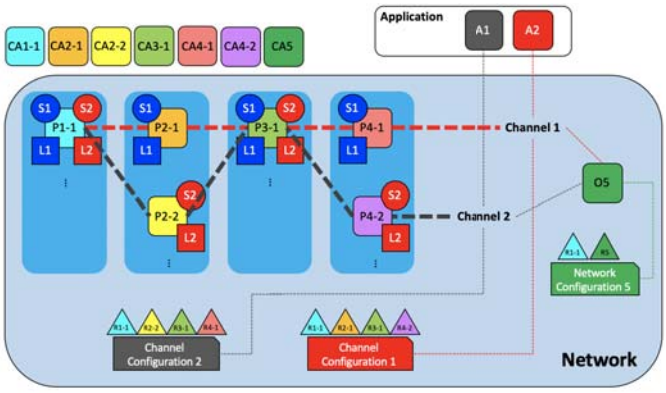

Fig. 3. The network design of blockchain-based stainless steel tracking system

In Fig. 3, P1-* represents each stainless steel mill and P2-* is a peer of each 1st tier processing & distribution center. Then, P3-* means each 2nd tier processing & distribution center and P4-* is a peer of each consumer who wants to need stainless steel products. These peers can be extended as much as participants increase. The advantages of this design are as follow. First, this design is very flexible, allowing various combinations of members in a channel and multiple channels. It matches well to the STS supply chain which has many paths from the mill to the customer. Second, the private state of the ledger allows certain members to share private data with each other, except for other members in a channel. It is good for scaling because it removes the need to create another channel that certain members belong to.

V. Conclusion

This paper proposes a novel design of a blockchain-based stainless steel tracking system in order to prevent the stainless steel in the supply chain from being counterfeited. The contribution of this work is to apply the blockchain technology into the system tracing the stainless steel supply chain. Prior to design, through the analysis of the flow process of the stainless steel supply chain and functional requirement, we selected a blockchain platform suitable for this supply chain and designed the blockchain network based on analysis results. The proposed stainless steel tracking system is based on the hyperledger fabric which is the most popular private blockchain.

A future study involves implementing the proposed design and adding an incentive mechanism to make participants be honest. Additionally, we plan to devise the policies for orders in more detail.

Acknowledgment

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