A Review of Blockchain Applications from Traceability Perspective

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**Abstract**

The purpose of this paper is to review the current researches of blockchain applications from the perspective of traceability of blockchain. Blockchain technology is developed from the first decentralised cryptocurrency—bitcoin. As the emergence of the smart contract which is a self-executive program developed by the users of blockchain to automatically conduct the transaction when certain conditions (content of the contract) are meeting, blockchain has inspired much more extensive applications far beyond digital coin domain. This paper will collect these extensive applications as many as possible and analyse how the traceability as an attribute of blockchain is exploited in these applications. Our objective is to comprehend the relationship between the traceability and blockchain applications. By doing this study, future research directions and novel ideas are provided for people who are interested in exploiting the traceability using blockchain technology for potential application areas.

**keywords**：blockchain technology, traceability, blockchain applications

**I Introduction**

Blockchain’s development can be divided into three generations [1]. The first one is bitcoin or other virtual currency [2] which is used with a decentralised network distinguished from traditional currencies with central banks. This design is to fight against inflation, to reduce the transaction fees and to improve anonymity [3]. The second generation is still in the financial market but with wider instruments not just payments and transfers. This came with the advancement of smart contrast [12] which is a self-conducting program in the network replacing the traditional off-line contract [4]. The most famous application in this generation is Ethereum [5]. The third one is beyond financial area expanding to industries like health, supply chain, identity, communication, governance, etc. This paper will review the researches in this context.

Traceability is not a direct characteristic of blockchain [2] [5]. It is relevant with one or several features of blockchain technology. We elaborated it in the following three aspects:

1 A trusted & public database

Blockchain is a distributed peer-to-peer network system based on a trustworthy collaboration mechanism without an authorized intermediary [8]. All the transactions happened on the blockchain are verified by the nodes(miners) of the network. Once a transaction is proved by the majority nodes of the network, it will be added to a public database(ledger) which is delivered to every user. The database is up-to-date, proved, and synchronised to every node which makes it hardly forged or mistaken. It is accessible to every user of the chain as well. The reliable and accessible of a public database which contains all the transactions constitute an important element of traceability [6][15].

2 A sequential chain

Every transaction which can be seen as a data block in the public ledger has a hash reference in the block header. The hash reference is often a combined hash of the transaction’s content hash and the prier block’s reference. In other words, every block holds the information of the prier block’s label, and itself’s label is held by the latter one, that makes up a linked chain. Thus from each block of the chain we can track all the way back to the first one. [6] Besides, we can also add the time when a transaction happened into the block’s hash as a timestamp using the DTT (Decentralised Trusted Timestamping) technology (C. Breitinger & B. Gipp, 2017) that enhances the believability of the existence of a transaction. (Ahmed Kosba∗, Andrew Miller\*, et al. 2016) An online ideas sharing application uses the trusted timestamp as a traceable evidence in a blockchain to identify the original ideas [7][13].

3 traceable ownerships

Blockchain uses an asymmetric cryptography which is normally known as private key and public key structure. Each user in the blockchain has a pair of private key and public key. Something encrypted by a private key can only be decrypted by the linking public key, vice versa. In blockchain, the transaction which always means shifting the ownership of some physical materials or information starts with that the owner use his or her private key encrypting his property (equivalent to assets in financial area or a production component in manufacture industry) which can only be decrypted by the linking public key. Because the public key can be known by everyone in the network as a single account address of the owner, that ownership can be fully proved. That means after many transactions we can still easily find the provenance of something. This idea is extensively discussed in supply chain and IoT areas [8][10].

In this paper, we will list the resent application researches linking with the properties mentioned above, and illustrate how these properties are utilised through blockchain in those applications. Some of the applications exploit only one of them, others may use two or all of them as a combination. One thing I want to mention is that most of these applications are not incentive to trace something. However, their implementations are relevant to the traceability of blockchain which is remarkable in this paper.

Regarding the blockchain applications, one application usually represents a specific industry. [11] [12] Whether an industry has the requirement of tracking something [9], or saying, recognition of tracking elements is the first key task we need to do when we get a blockchain application article. All of the researches of blockchain applications are presented in terms of their industries, including the reviews of the blockchain in which applications are usually summarised in industry category. [13] Therefore, it provides us the feasibility to acquire the tracking elements in various industries, then we can link them to the tracing ability of blockchain and analyse the relationship between blockchain applications and traceability of blockchain with a clear framework. It is also helpful to define the clear research scope of this paper that we will eliminate the articles without any traceability points.

The rest of the paper is organised as follows. Section II will explain the strategy for searching materials. While in section III, we will recognise the tracking points of each application and analyse how they are implement through blockchain by giving the linking map. The last section is the conclusion.

**II The strategy for searching materials**

Our focus is the traceability of blockchain and its applications, so I use following keywords to search on google scholar:

Blockchain trace/tract, blockchain applications, blockchain potential applications, traceability of blockchain, blockchain traceability, blockchain review.

The blockchain articles contain not only above keywords, but I found most resent results of those keywords overlap with each other at a quite high rate. I can rarely find new articles when I search with the last several terms which means the articles searched with the above terms can be sufficient.

My target articles are about the resent researches beyond the digital coin, relevant to traceability. So I narrowed down the searching results first by years: latest 2years: 2016, 2017, 2018, since the concept of blockchain we discussed here is the third generation blockchain technology which just develops in resent years, then by topics (application), contents (choose the ones have functions about traceability), and by the quality of the source. Therefore, we have 80 articles left [6] [14].

# Traceability of Blockchain Literature

## How is blockchain used for tracking in supply chain?

The manufacturing industry becomes more and more complex since that one product can be produced in several countries for different production phases. This makes meeting quality demands more challenging. The supply chain management is always struggling to trace the product during its life circle, especially when consumers have more concerns about product’s quality and security issues nowadays. The launch of blockchain technology can be an ideal improvement for the situation (Petersen & Jansson, 2017) .

Feng (2016) mentioned a traceability system for food-supply chain in 2016, in order to change the situation of Chinese food safety. By using blockchain technology and the application of RFID (Radio Frequency Identification), the framework of the system can solve the trust issue in the traditional supply chain traceability system which is based on the sharing information from supply members. The blockchain is used as a trusted and transparent database for that the validity of the data is proved by the majority nodes on the network so that there will be no cheating. Besides, it is accessibly by any member of the system.

In pharmaceutical manufacturing, there are tracing or tracking needs as well (Biggs, Hinish, Natale, & Patronick, 2017). Blockchain technology is recommended to be the supply network linking all the participants. Because of its immutable transaction data, to be accessible by any participant, mechanism of linking blocks which allows the network nodes track the date from any point along the chain, the pharmaceutical industry can be improved.

## In healthcare industry

In healthcare domain, an App called Healthcare Data Gateway (HGD) was proposed in 2016 (Yue, Wang, Jin, Li, & Jiang). In this system, healthcare data is seen as an asset of the patient. All the pieces of patient’s data, like a blood test result etc... are blocks linking to a blockchain cloud (the public ledger). HGD strictly controls the access of each block by getting the permission of the asset’s owner but uses some secure functions to analyze and query the whole blockchain cloud without any patient’s permission. By these functions the patients’ privacy can be protected and the hospitals, or other organizations in healthcare area can get what their need freely. The Blockchain is used as a trusted datacenter which can be tracked block by block. In addition, its specific structure can help keeping patients’ privacy that distinguishes it from traditional healthcare data system.

Another application uses blockchain to track users’ actions, like getting the access of the medical data or contribution to the medical data, making the sharing of data in a more secure manner (Xia, Sifah, Smahi, Amofa, & Zhang, 2017). The users are verified then given several keys which are used in the cryptographic processes. The request itself is a block recording the user’s information and purpose. Once it is granted it will be transferred form a requests pool to the blockchain with several timestamps recording every step, like when the request was sent, last entry time, and the time of the closure of this block, etc.

## In network media/idea sharing industry

In a blockchain based intellectual property rights management design (Xu, Zhang, Zhao, & Peng, 2017), blockchain technology is used to trace the qualities of network media as one part of the copyrights management scheme.

An VirtualPatent platform was introduced in 2017 (Breitinger & Gipp) to help the researchers share their novel ideas freely before published. By using trusted-timestamp created on blockchain, which is called Decentralized Trusted Timestamping(DDT) methodology, the original owners can keep their credits of the novel idea credit on such platforms without warring about being tampered which is the problem on existing social media or idea sharing websites. (track idea’s owner)

## In e-government

An blockchain e-government project is undertaken in a city of China (Hou, 2017). One system of that project is to improve individual credits by taking advantage of traceability of blockchain. One scenario is individual identity management. Once a person’s identity is generated as an original block, all the other things happened to this person and recorded in the blockchain can be traced back. For example, his marriage records, education records, employment records etc. can be linked to his identity. Because of the reliability and consensus of blockchain, he does not need other organizations to get the authenticity of his individual records and can collect all the records at one time.

## In energy industry

An energy transaction scheme(Wang, Wang, Zhou, & Chi, 2017) and a small scale energy trading system(Mengelkamp, Notheisen, Beer, Dauer, & Weinhardt, 2018) based on blockchain technology connect the consumers and the energy suppliers directly without the traditional centralized organization. Similar with the bitcoin transaction (Nakamoto, 2008), we need to trace the input of a transaction, which is the energy to be transferred here, to determine whether it can be transferred legally. Blockchain’s structure allows every node on the network to trace an input to its provenance which has to be the output of the previous transaction.

For most application researches in energy industry, no matter it is machine-to-machine market (Sikorski, Haughton, & Kraft, 2017) or P2P (peer to peer) network market (Hasse et al., 2016) , it is to transact solar (Rutkin, 2016) or other renewable energy trading within community energy markets (Burger, Kuhlmann, Richard, & Weinmann, 2016) (Mannaro, Pinna, & Marchesi, 2017) , they all use similar pattern as bitcoin transaction using blockchain to trace prior transaction to decide every transaction’s validity.

## In AI

A research based on blockchain to protect smart automobiles’ privacy during communicating with other participants, like manufactures, insurance companies and other smart vehicle owners is proposed in 2017 (Dorri, Steger, Kanhere, & Jurdak). They use blockchain to transfer information between nodes, such as updating the software of some vehicle units, flexible insurance dependencies, car sharing requests etc. The overlay block managers which takes charge of forwarding the information to the right recipient can verify the transaction by tracking to its previous transaction because of blockchain’s immutability and traceability.

## In education

Chen proposed that the blockchain technology can be used in educational applications for tracing the students’ development and for evaluating the education processes as well (Chen, Xu, Lu, & Chen, 2018) . For example, all the details during the process, like students’ feedbacks, discussions, progresses in researches, supervisors’ help with students’ study plan and review of student’s thesis, etc. can be stored in the blockchain ledger.

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