Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 1, 2018, vol. LXIV
article No. 2042

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RFID TECHNOLOGY AND BLOCKCHAIN IN SUPPLY CHAIN

TECHNOLOGIE RFID A BLOCHKCHAIN V DODAVATELSKÉM ŘETĚZCI

Abstract

The paper discusses the possibility of combining RFID and Blockchain technology to more effectively prevent counterfeiting of products or raw materials, and to solve problems related to production, logistics and storage. Linking these technologies can lead to better planning by increasing the transparency and traceability of industrial or logistical processes or such as efficient detection of critical chain sites.

Abstrakt

Příspěvek se zabývá možností kombinace technologií RFID a Blockchain pro účinnější zabránění padělání výrobků či surovin a řešení problémů spojených s výrobou, logistikou a skladováním. Spojení těchto technologií může vést k lepšímu plánování díky vyšší transparentnosti a sledovatelnosti průmyslových nebo logistických procesů, nebo například k efektivnímu zjišťování kritických míst řetězce.

Keywords

RFID, Blockchain, logistic, supply chain, peer-to-peer (P2P).

1 INTRODUCTION

Nowadays, almost none of the fields of human activity can do without supply chain management. Many of the risks in the logistics industry are coming from the lack of information reliability, centralized systems do not ensure the provision of complete or accurate information. Transition to decentralized services and implementing smart contract and Blockchain technologies will ensure a proper level of transparency and credibility in the logistics. The formation of costs, including commissions, will become transparent, which will enable the more efficient supply chain management. The introduction of a global decentralized system will allow significant increase in the efficiency of participants' work in the supply chain, removing unnecessary links, reduce negative consequences from the human factor influence. Besides, the control over the movement of goods will become simpler.

In the current business relationships, a significant part of the cost savings depends on the possibility and ability of the customer to manage supplies. The application of the main methods of supply logistics, allows to reduce the financial losses and, consequently, to increase the profit. Minimization (optimization) of expenses is an indispensable condition for organizing the management of the construction process and is important for creating a competitive price of the final product. Losses arise due to the downtime caused by the lack of necessary building materials, equipment or components at a certain point or vice versa due to the long-term storage of materials,

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that are not currently needed, at the company warehouses [1], [2]. On the other hand, losses can arise due to overcharged delivery, that results from illiterate supply logistics, or failure to choose the right carrier. Competent supply chain management consists in reliable and high-quality provision of production units with the material resources that are necessary to fulfill a given production plan.

Similar to supply chain traceability, the supply chain concept of transparency embodies information readily available to end-users and firms in a supply chain. There are varying degrees of supply chain information sharing (also referred to as "visibility") within the supply chain. Supply chains need to transparently supply all actors with knowledge, normalizing information leverage during negotiations and providing more information about component origins and processes. Blockchain technology provides the different supply chain partners with the technical basis for trust.

2 RFID TECHNOLOGY

The Radio Frequency Identification (RFID) technology is a communication technology that can identify specific targets and read and write relevant data through the radio signals without building a mechanical or optical contact between the recognition system and specific targets. RFID provides appealing opportunities to improve the management of information flow within the supply chain and security, because allows traceability of goods through all steps of production and supply chain.

The popularization and versatility of RFID technology will bring revolutionary changes to industry retail and logistics, eventually replacing the ubiquitous Universal Product Code (UPC) identification, mostly known as "bar code" [3,4,5]. Compared with the presently still popular bar code and QR-code technologies (similar to bar codes, readable by a QR code reader), RFID tagging has many advantages that can help enterprises to increase the speed of the flowing information, incrementing the exchange quantity per relative displacement time needed and saving of production and distribution costs. There are a series of advantages in using RFID in relation to the more traditional barcode one since an increased automatism in tagging and reading will allow users to:

- reduce stock and the sales personnel costs (e.g., reduced labour cost of products identification);
- increment efficiency in stock turnover
- reduced larceny occurrence.

RFID technology uses a few simple and inexpensive components, which in the past decade progressively gained importance in the traceability technological scenario, since it omitting the manual control, increasing versatility of operational contexts (e.g., being water-proof, antimagnetic, supporting a wide range of temperatures), versatility of logistic context (permitting a very different range of reading distances), long service life and miniaturization to a certain extent [6]. RFID architecture is composed by the following components [7](See Fig. 1):

- an RFID tag, which can be directly applied on the displacing good,
- an interrogator (or antenna), as a device (i.e., the reader) that gathers information from the tag (ID or data stored), and
- a database system used to store the information gained through the interrogation routines carried out by the antenna. An RFID interrogator (either defined by the synonymous "reader" or "antenna") is a device that recognizes the ID information of the tag upon backscattered communication.

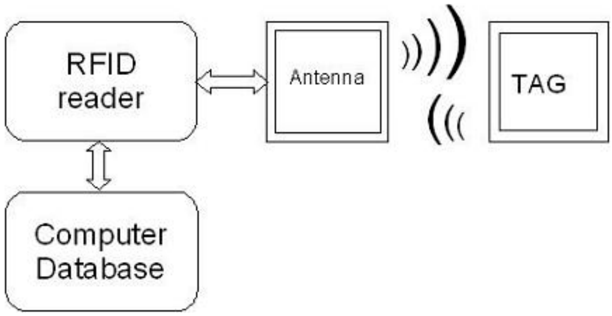

Fig. 1 Equation sizes [8]

Readers can either be portable on handheld terminals or fixed as devices that can be positioned in different strategic places of the supply chain. RFID tags, also known as transponders, are usually small pieces of material, typically comprising three components: an antenna, a microchip unit containing memory storage and an encapsulating material of different shapes and sizes. The tags have an identification code (i.e., the Electronic Product Code - EPC) commonly of 96 bits recorded at the time of manufacture. Tags can be classified in terms of data access in read-only or read–write tags. These terms refer to whether or not the information stored in the tag can be changed or erased.

In a read-only tag the data cannot be modified or appended but it may be read multiple times and they are often used in simple tracking applications. Differently, in a read–write tag the stored information can be modified or written several times but also can be write-protected. Tags of this latter category usually offer greater functionality, as they are can be reused several times or used for applications where data regarding production, manipulation and traceability of the good are required [9]. Because of this, read–write tags are usually more expensive than read-only tags. Memory capacity varies from few dozen of bits to 32 KB, usually enough in the vast majority of applications. There is no existing standardized format of data, so the final user can use the outline and data structure suitable for their applications (these could be product or environmental measurements, time-stamps and locations of the good in the supply chain and so on) or include cryptographic methods to restrict their access and improve safety [10] - in our case the connection to Blockchain. Ideally, the tag itself should carry minimal valuable data, or else include a trusted security mechanism for data protection. Other specifications of the tag are related to their activity or passivity when transmitting the information. Passive tags emit their information only when powered by the energizing field of the interrogator (i.e., the antenna; see below). This means that the tag is only powered when the bearing object enters in the range of action of the interrogator as well as using this radio wave to carry the data, and the tag is able to convert it into power. The tag then uses a technique called backscatter to reply to the interrogator. This does not involve a transmitter on the tag, but is a means of "reflecting" the carrier wave and putting a signal into that reflection.

Conversely, active tags are those which bear a battery and are able to transmit independently form the powering field of interrogators. These tags are just like passive tags since they use backscatter principle to convey their ID information but they have a battery assisted so they can provide the power source to operate the chip in an autonomous fashion. Transmitting autonomy conveys great advantages to RFID technology, because transmission can cover greater distances from the interrogator greater than several tens of meters. Active tags have not only a battery, but also some form of transmitter on the tag. The antenna in a tag is the physical interface for the RF to be received and transmitted. Its construction varies depending on the tag itself and the frequency it operates on. Low frequency tags often use coils of wire, whereas high frequency tags are usually printed with conducting inks. Depending on environmental conditions and maintenance, barcode read rates often decline to less than 90 % over time. In most environments, RFID can achieve 99.5 % to 100 % first-pass read rates [11]. RFID does not require line-of-sight with the reader, so tags can be located inside the products or inside containers.

RFID falls within the category of smart tags in relation to their capacity of data storage and real-time traceability. In relation to the technical specification of RFID tagging technology as described above, some evident operative advantage can be listed in relation to the already well-established bar code identification procedures. First of all, an elevated number of tags can be contemporarily read in an independent fashion, form the same interrogator. Each tag can uniquely identify the object to which it is attached, even if that object is one of a multitude of identical items. In second instance, tags do not require a direct line of sight for reading and may be read not only trough air cut also through hard material (e.g., book covers or packaging layers) including water [12]. Tag ID information is encoded under according to frequency specifications, the data bit/transfer rate, the method of encoding and any other parameters that may be needed.

RFID technology is not only based on the presence of tags and readers but it requires other software and hardware specifications in order to manage the information load through space and time. The most important component is the development of specific RFID management software that translates the raw ID data from the tag into information to be related to other parameters of importance associated to the tag bearer, being this a good or a live stock. This information can then be fed into other databases and applications (e.g., inventory management) for further processing. In the case of read– write tags, specific software is also required in order to manage data writing on the tag itself, containing this latter specification to initiate the process of adding or removing data.

The RFID system can be integrated into the WSN (Wireless Sensor Network) by connecting the tag readers to an RF transceiver, which has routing function and can forward information to and from other readers. An Internet application can be used to detect and monitor changes of the physical status of connected objects through sensors and RFID in real time. WSN can be based on a wide variety of different monitoring sensors which cannot identify single objects, a potentiality introduced by the RFID itself.

The integration of innovative systems such as RFID tracking with geostatistics for optimizing supply chain and logistics decisions may offer competitive great opportunities for the entire supply chain. In order to allow the maximum level of management in the flow of information trough that chain, the focus becomes the traceability of products that are based on innovative web-based systems. Web-based tracing system aims to improve products quality by increasing the level of information transparency for the consumer. This objective occurs by collecting a set of scientific and productive information which follow the product shelf life from producer to consumer, providing a specific web-based tool for each category. The subject categories involved are divided into manufacturers, wholesalers, resellers, retailers and finally the consumers. The implemented web software is structured to provide various services to all the categories thanks to the Application

Programming Interface (API), which allows the different subjects of the supply chain to implement the acquisition and/or writing system following their needs and available technologies and ensuring uniformity of data to consult or send. Infotracking systems can also provide a reference web interface to access the product info card displaying all information and data released as feedback by the manufacturer, wholesaler, reseller, retailer and consumer [13]. Each element contributes separately, according to a certain level of membership to the data collection in relation to the product at each stage of the production/supply chain. All the collected data can be entered into a decentralized database, thus into the Blockchain.

4 BLOCKCHAIN TECHNOLOGY

Blockchain is an invariable, highly available and distributed database in which all data written in to it is tamper-proof and can be protected against unwanted access via encryption. It is like a database in which, similar to in a normal ledger, all transactions are entered chronologically. In order to prevent manipulation, blocks are formed and then closed with a checksum. The blocks are then arranged one after the other, each block containing the checksum of the previous block. Thus, a type of chain is created, hence "Blockchain." Many copies of this chain are created and distributed. There is therefore no central unit that has control over the chain. The Blockchain ensures that all participants have the same copy of the Blockchain, making it easy to detect and subsequently exclude altered versions. In essence, the Blockchain is a public ledger containing information on every transaction made within a peer-to-peer (P2P) system.

Peer-to-peer (P2P) is a decentralized communications model in which each party has the same capabilities and either party can initiate a communication session. Unlike the client/server model, in which the client makes a service request and the server fulfills the request, the P2P network model allows each node to function as both a client and server [14].

The data in the Blockchain (e.g transactions) is divided into blocks. Each block is dependant on the previous one. The system in which a Blockchain serves as the database comprises of nodes or workers. These workers are responsible for appending new blocks to the Blockchain. A new block can only be appended after all nodes in the system reach a consensus, i.e all agree that this block is legit and contains only valid transactions. How the validity of transactions is determined and how the nodes compute new blocks, is regulated by the protocol. Blockchain is shared among all nodes in the system, it is monitored by every node and at the same time controlled by none. The protocol itself is responsible to keep the Blockchain valid. Each block of the Blockchain contains: Data (time stamp and transaction information), Hash (encrypted mathematical transaction imprint, Hash is a unique block identifier), and Hash of the previous block (Fig. 2).

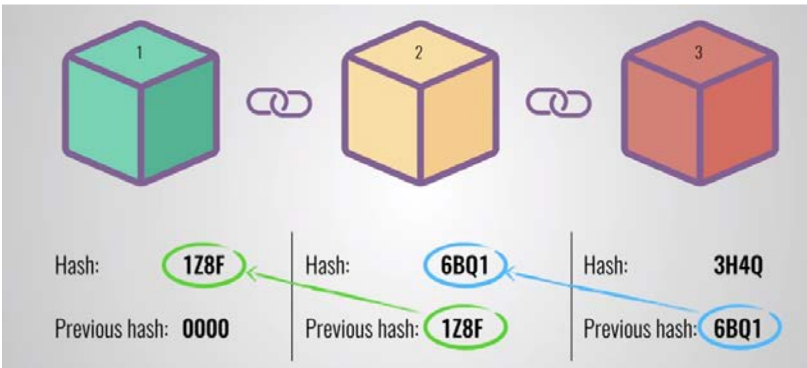

Fig. 2 Connecting blocks and checking hash function [15]

As an ICT technology, a Blockchain is driven by fundamental principles of data decentralisation, transparency, security and privacy [16].

Decentralisation of consensus - The distributed nature of the network requires untrusted participants to reach a consensus. In Blockchain, consensus can be on "rules" (that determine e.g., which transactions are allowed and which are not, the amount of Bitcoins included in the block reward, the mining difficulty, etc.) or on the history of "transactions" (that allows to determine who own what). The decentralised consensus on transactions govern the update of the ledger by transferring the responsibilities to local nodes which independently verify the transactions and add them to the most cumulative computation throughput (longest chain rule). There is no integration point or central authority required to approve transactions and set rules. No single point of trust and no single point of failure.

Transparency - Records are auditable by a predefined set of participants, albeit the set can be more or less open. For example, in public blockchains everyone with an Internet connection to the network hold equal rights and ability to access the ledger. The records are thus transparent and traceable. Moreover, every participants to the network can exercise their individual (weighted) rights (e.g. measured in CPU computing power) to update the ledger. Participants have also the option to pool together their individual weighted rights.

Security and immutability - Blockhains function under the principle of non-repudiation and irreversibility of records. Blockchain is a shared, tamper-proof replicated ledger where records are irreversible and cannot be forged thanks to one-way cryptographic hash functions and community consensus. Immutability eliminates the need for reconciliations providing a historical, unique reconciliated version of the truth. Non-repudiation, non-forgeability and immutability of the records generate trust in the historic transaction flow. History is thus recorded in perpetuity. Indeed, it becomes very difficult for an individual or any group of individuals to tamper with the ledger, unless these individuals control the majority of "voters".

Other non fundamental properties of blockchain include data automation and data storage capacity

Automation and smart contracts - Without the need for human interaction, verification or arbitration, the software is written so that conflicting or double transactions are not permanently written in the blockchain. Any conflict is automatically reconcile and each valid transaction is added only once (no double entries). Moreover, automation regards also the development and deployment of smart legal contracts (or smart contract codes) whith payoff depending on algorithms which are self-executable, self-enforceable, self-verifiable and self-constraint.

A smart contract is a computer code running on top of a blockchain containing a set of rules under which the parties to that smart contract agree to interact with each other. If and when the pre-defined rules are met, the agreement is automatically enforced. The smart contract code facilitates, verifies, and enforces the negotiation or performance of an agreement or transaction. It is the simplest form of decentralized automation. It is a mechanism involving digital assets and two or more parties, where some or all of the parties deposit assets into the smart contract and the assets automatically get redistributed among those parties according to a formula based on certain data, which is not known at the time of contract initiation.

Storage - The storage space available on the blockchain networks can be used for the storage and exchange of arbitrary data structures. The storage of the data can have some size limitations placed to avoid the blockchain bloat problem

Key features of blockchain for a supply chain:

- Consensus -All the entities in the chain agree that each transaction is valid. For supply chain, it could be payment, warehousing, transport or delivery.
- Provenance - The entities in the chain know where each asset came from. They also know who owned it before and at what time. For supply chain, assets can be anything from iron ore and wheat to money, machines and copyrights.
- Immutability - No entity can tamper with an entry in the distributed ledger. None transactions cannot be erased. Only a new transaction can reverse the effect of a previous one. Supply chain payments cannot be falsified. Neither can records of inventory, warehousing conditions, delivery times and dates, and so on.
- Finality - The copies of the shared ledger all hold the same version of the truth.

A Blockchain is more a paradigm shift in the way applications and solutions will be built, deployed, operated, consumed and marketed in the near future, than just a technology. Blockchain is secure by design and relies on well-known cryptographic tools and distributed consensus mechanisms to provide key characteristics, such as persistence, anonymity, fault-tolerance, auditability and resilience. Indeed, each record in the chain is verified by consensus of a majority of the Blockchain's participants, and once committed on the ledger, cannot be easily tampered with.

However, several challenges will need to be addressed to unlock the tremendous potential of Blockchains, especially before this paradigm shift becomes technically, economically and legally viable in business environments. Blockchain is currently under extensive research and development from both the academia and the industry, however, there are still major challenges to be overcome before mass market penetration and adoption. In this section, we highlight major research directions and opportunities that are important to investigate, including the issues related to governance, audit, scalability, incentives, data privacy, security and data analytics.

5 COMBINATION OF RFID AND BLOCKCHAIN

RFID tag with Blockchain can completely replace the supporting documents, which are almost impossible to forge. A record about the production is made on the RFID tag (the first transaction is made). In this case, as mentioned above, a number of product information can be included in the transaction. The volume of necessary data is determined by the manufacturer and depends on the necessary accuracy of accounting. The data entered into the transaction will enable fast identifying the place and time of a flaw, prevent various fraudulent fraud related to the substitution or theft of products. If necessary, a function of multi-signature can be added. The meaning of a multi-signature is that one person can not independently make a record in a Blockchain. This allows the possibility of recording false information by one of the employees is excluded. After the preparation of the parcel for dispatch, a smart contract is made for delivery, which makes accountance automatically between the parties to the transaction when certain events occur in it. Smart contracts are recorded on existing RFID tags.

The first effect from the introduction of RFID tag technologies is a significant acceleration of workflow. Filling and reading of documents can take place in automatic and semiautomatic modes. Such data as the time of production, exit from the territory of the concrete plant, entry to the site of the customer can be recorded in automatic mode saving time significantly. Automatic or semi-automatic completion of accompanying documents, besides saving time will also reduce the number of employees involved in the process of processing and control. The recoupment from the introduction of this technology in this aspect is calculated individually and depends on the volume of turnover and the corresponding reduction in downtime. By combining RFID and GPS technology, it will be possible to track the delivery in real time, which will allow accurately predicting the time of delivery of the products to the customer and optimizing process as much as possible, and minimizing losses from delays in delivery.

Goods provided with an RFID tag with Blockchain which will help the purchaser of this product to obtain comprehensive data on the purchased products:

- time and place of production, conditions of delivery, monitoring the route of the vehicle through the satellite;
- reliable composition of Goods (e.g. foods);
- suppliers of all components, the date of their production, the conditions for their storage and transportation;
- pricing of the whole production chain.

This transparency will help avoiding the use of poor-quality or counterfeit products.

The highest possible effect of the introduction of Blockchain technology using RFID tags will be observed when creating a single database (exchange) where suppliers and customers can receive actual and reliable data on turnover, place offers and find customers, optimizing the production.

The combination of RFID and Blockchain technologies will significantly reduce losses from the influence of the human factor and intentionally false information, eliminate the problem of trust between the participants in the turnover. Manufacturers that have introduced this technologies will be more trusted by the customer, and therefore will have competitive strengths.

The valuable opportunities to couple cloud computing to RFID and Blockchain tracking are a reduction in the costs of industrial monitoring technology, informative integration and optimization of intra- and inter-company logistics (best efficiencies and cost reductions) in relation to quality preservation and safety implementation. Conversely, the constraints to the widening use of RFID and Blockchain technology seems to reside in the adaptation of its designs to the elevated complexity and plurality of different supply chains, managed by professionals from very different backgrounds, which prevents the organic structuring of this technology.

RFID tools are advanced technological devices which allow the following: improvement of the vertical traceability of products and the monitoring of the status of their processing conditions at each stage of the production/distribution chain; efficiency enhancement of processes; strict quality monitoring, giving handlers the opportunity to assess the precise permanence of goods at each stage of the supply chain, which in turn may cause important issues in e.g. relation to public health when goods are highly prone to decay; improvement on information accuracy for government agencies and consumers/customs officers, which can track in real-time backward the provenience and conditions of acquired goods.

However, real applications of RFID technologies and Blockchain are still limited because of various technical and economical obstacles. From a management point of view, for example, there are applications on infotracking systems including the possibilities to explore web-based Cloud Computing, which refers to the capability to upload data (i.e.,. tag readings) into web applications that are delivered as services over the Internet and in which managing hardware and systems software are located in different data centers (i.e., the Cloud) that deliver those services worldwide.

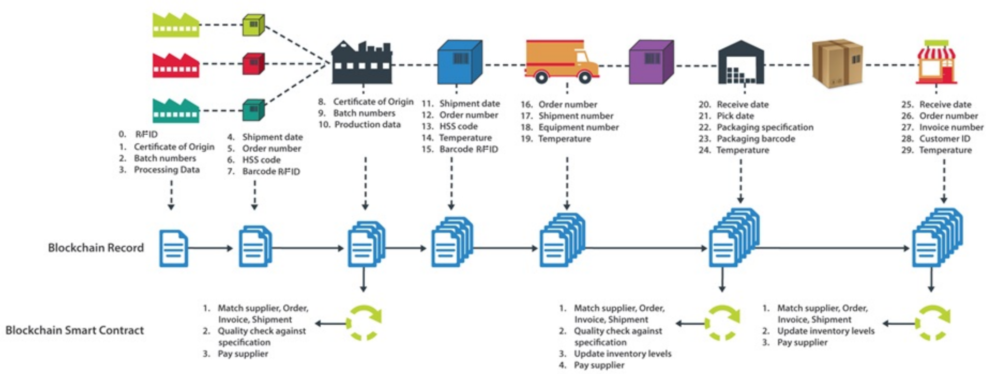

Fig. 3 A general example of using RFID and Blockchain with a Smart Contract [17]

6 CONCLUSIONS

Blockchain technology, popularized by Bitcoin cryptocurrency, is characterized as an open-source, decentralized, distributed database for storing transaction information. Rather than relying on centralized intermediaries (e.g., banks) this technology allows two parties to transact directly using duplicate, linked ledgers called Blockchains. This makes transactions considerably more transparent than those provided by centralized systems. As a result, transactions are executed without relying on explicit trust [of a third party], but on the distributed trust based on the consensus of the network (i.e., other Blockchain users). Applying this technology to improve supply chain transparency has many possibilities. Every product has a long and storied history. However, much of this history is presently obscured. Blockchain may bring the concept of technology innovation adoption as a foundational framework for supply chain traceability and transparency to a new level.

Consumers are demanding supply chain transparency. They often want guarantees that goods is authentic and genuine and that its origin is not illegal. These concerns are exacerbated when supply chains are multi-tiered and increasingly global in scope. Blockchain technology promises to dramatically change transaction methods by providing a transparent and immutable record for inspection. Currently Blockchain applications are primarily being used and developed within the finance sector, but supply chain managers have taken notice and are quickly planing the technology to customer service.

The transition of the supply chain to the Blockchain system allows making a technological breakthrough in the logistics by creating a transparent system of interaction between all participants. A decentralized logistics system based on smart contracts will help all participants to gain measurable benefits and a unique transparent economic environment, as well as it will ensure complete security of the entire supply chain. The functionality of the system allows to protect cargo owners and carriers, eliminate problems of trust between participants, remove information barriers and avoid suit costs.

Switching supply chains, as well as of logistics systems in general, to decentralized accounting seems inevitable due to certain advantages described in the article. It will certainly take a lot of time to create a unified legitimate system based on Blockchain (or a similar technology). However, the foundation is laid: successful test models between individual corporations have been created. Specialists in the field of logistics coming from different countries actively enter upon exploring the benefits and opportunities of Blockchain in logistics and using them, which offers hope for the successful development and widespread implementation of this technology.

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