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How blockchain improves the supply chain: case study alimentary supply chain

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Abstract

Current supply chain is a linear economy model that directly or indirectly fulfills supply needs. But this model has some disadvantages, such as the relationships between the members of the supply chain or the lack of information for the consumer about the origin of the products. In this paper we propose a new model of supply chain via blockchain. This new model enables the concept of circular economy and eliminates many of the disadvantages of the current supply chain. In order to coordinate all the transactions that take place in the supply chain a multi-agent system is created for this paper.

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1. Introduction

Blockchain is currently gaining the interest of a wide variety of industries: from finance [1][2], health-care [5], other sectors [37], utilities and the government sector. The reason for this growing interest: With a blockchain, applications that worked only through a trusted intermediary. Now they can operate in a decentralized way, without the need for a verification system and achieve the same functionality with the same amount of reliability. This was not possible until the blockchain was created. With the implementation of blockchain trustless networks appeared. This is possible because in networks that use blockchain you can make transfers with no need to trust other users [8]. With the lack of intermediaries, transactions become faster between users. In addition, the use of cryptography in the blockchain ensures that the information is secure[20]. Blockchain is a large accounting ledger that records all transactions made by users. This makes researchers and developers on the Internet of Things (IoT) look for

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ways to link IoT with blockchain[23][29]. Nowadays supply chain is a core area for companies which is concerned with transporting products between parties. However, the problem of this sector is that its scale may lead to delays and defaults in the delivery of goods as well as other issues. In addition, large distributors need a large volume of workers to meet all the demands of stores. All this may contribute to big delays in order processing and increases the possibility of losing orders [20]. In an attempt to solve this problem, companies have automated all their processes, contributing to a significant increase in the number of businesses and distributors in the supply chain. However, an increase in the amount of digitized data and the expansion of Internet companies means that the risk of attacks on their databases is also greater. Hackers may intend to modify, steal or delete data[7][36].

We suggest an alternative way of solving this problem. In our case study (i.e., agriculture supply chain), we are going to consider two different scenarios[21].Firstly, we provide security to the data of the companies involved in the supply chain with the inclusion of blockchain. Secondly, multi-agent systems will be used for the organization's problem[22]. It has been proven that multi-agent systems provide efficient solutions to a huge variety of problems [39]. These include, but are not limited to, the use of agents for image classification [16][14], decentralized network control [27], real-time problems [6] and Internet of Things applications [15]. In this paper we propose a new model of supply chain. This new model enables the use of circular economy in supply chains. In addition, to coordinate everything that happens in the supply chain a MAS is created. In each of the members of the supply chain, agents are defined to coordinate all the operations and transactions carried out by that member of the supply chain.

2. Related work

A blockchain is a distributed data structure that is replicated and shared among the members of a network[26]. It was introduced with Bitcoin [28] to solve the double-spending problem [12]. As a result of how the nodes in Bitcoin (the so-called miners) mutually validate the agreed transactions, Bitcoin blockchain establishes the owners and states what they own [13]. A blockchain is built using cryptography. Each block is identified by its own cryptographic hash and each block refers to the hash of the previous block. This establishes a link between the blocks, forming a blockchain [2][7]. For this reason, users can interact with a blockchain by using a pair of public and private keys. Miners in a blockchain need to agree on the transactions and the order in which they have occurred. Otherwise the individual copies of this blockchain can diverge producing a fork; miners then have a different view of how the transactions have occurred, and it will not be possible to keep a single blockchain until the fork is not solved [30][32]. To address this a distributed consensus mechanism is required in every blockchain network [37]. Blockchain's way to solve the fork problem is that each blockchain node can link next block. Just a correct random number with SHA-256 has to be found [1][8], [19] so you have number of zeros that the blockchain expects. Any node that can solve this puzzle has generated the so-called proof-of-work (pow) and gets to shape the chain's next block [10]. Since a one-way cryptographic hash function is involved, any other node can easily verify that the given answer satisfies the requirement. Notice that a fork may still occur in the network, when two competing nodes mine blocks almost simultaneously. Such forks are usually resolved automatically by the next block[31][4]. With the implementation of blockchain, smart contracts are included to make transactions between different users faster and more effective[17]. Nick Szabo introduced this concept in 1994 and defined a smart contract as "a computerized transaction protocol that executes the terms of a contract" [34]. Szabo suggested that the clauses of contracts could be transferred to code, thus reducing the need for intermediaries in transactions between parties. In the blockchain context a smart contract is a script that is stored on a blockchain [35]. Smart contracts have a unique address in a blockchain (i. e., they are in a block with a hash that identifies it). We can trigger a smart contract in a transaction by indicating the address on the blockchain. It is executed independently and automatically in a prescribed manner on every node in the network, according to the data contained in the triggered transaction.

A multi-agent system is a computerized system composed of multiple intelligent agents that interact with each other. Multi-agent systems are used to solve complex problems with very good results. Multi-agent systems are used in a wide range of applications. In [33] authors presents a multi-agent system for the intelligent use of electricity in a Smart home and thus, an increase in its energy efficiency. Another problem that multi-agent systems have solved effectively is the monitoring of sound in a variety of situations [24]. The application of a multi-agent system

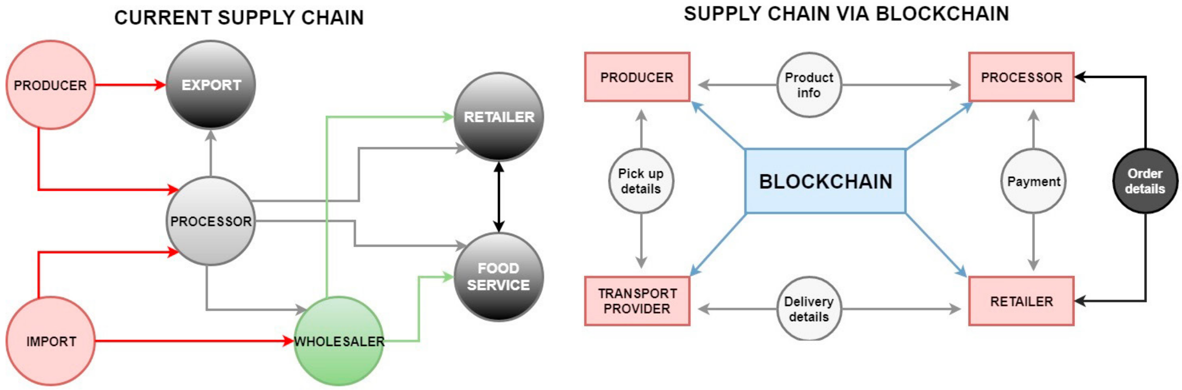

Fig. 1. Current agriculture supply chain model. This is a linear model from producers and imports to retailer and food service. Through the inclusion of blockchain, supplies chains are now decentralized and all the transactions are placed in blockchain. Each member of the supply chain is able to write their transactions on the blockchain. However, members of the supply chain can only read those blocks of the blockchain that have a direct connection with them.

to logistics is not a new problem, in [25] a multi-agent system is proposed to provide a solution to the logistical problem. In addition, another successful application of multi-agent systems is the problem of distributed computing [3]. Therefore, some of the proposals that we find in the literature combine the advantages of blockchain and multi-agent systems. From a range of systems that integrate blockchain and multi-agent systems the work of [40] is worthy of mention. This work proposes to use both technologies to increase security and privacy in decentralised energy networks. In [38] authors propose a model that employs agents and blockchain for a ride-sharing system. In addition, there are other applications of blockchain and multi-agent systems. In [11] the authors propose an innovative blockchain model for IoT. However, after looking at the state of the art, we believe that the current blockchain and multi-agent system models have some shortcomings. We propose a new model that leverages smart contracts and multi-agent systems, it is aimed at increasing efficiency in the logistics system management. This paper describes a case study which verified the proposed model, it focused specifically on agriculture supply chain sector[9].

3. Methodology and case study

A new model for agriculture tracking is presented in this paper. The proposed model involves blockchain, smart contract and a MAS to coordinate the tracking of food in the agriculture supply chain. Through the implementation of this new model, the current agriculture supply chain has an improvement based on the addition of blockchain. In Fig.1 are the current supply chain and supply chain architectures via blockchain. Both models are described below, including the advantages provided by the new supply chain model. 1) Current supply chain: The current model begins with the producer and the import. These two supply chain members send their products and data to the next layer of the supply chain. At this next layer are the export, the processor and the wholesaler. This is the middle layer that processes the basic products received by the supply chain. Finally, in the final layer are the retailer and the food service who sell the products. The main disadvantage of this model is that the data is centralized in each of the elements of the supply chain and the remaining elements cannot see the transactions. The main implication of this disadvantage is that the consumer has no way of verifying the source of the food to be purchased. In addition, there is no way to ensure that the consumer's data is reliable. 2) Supply chain via blockchain: With the addition of blockchain to the agriculture supply chain the model changes. Now all members of the supply chain save all their transactions in the blockchain. This enables a higher security in the transactions. In addition, this new model corrects the disadvantages of the current supply chain. The data is decentralized and each member can read important data for its operations in the blockchain. For instance, the producer can view the product info of the processor and the pick up details of the transport provider.

This new model is available via blockchain. In order to coordinate all the members of the supply chain a

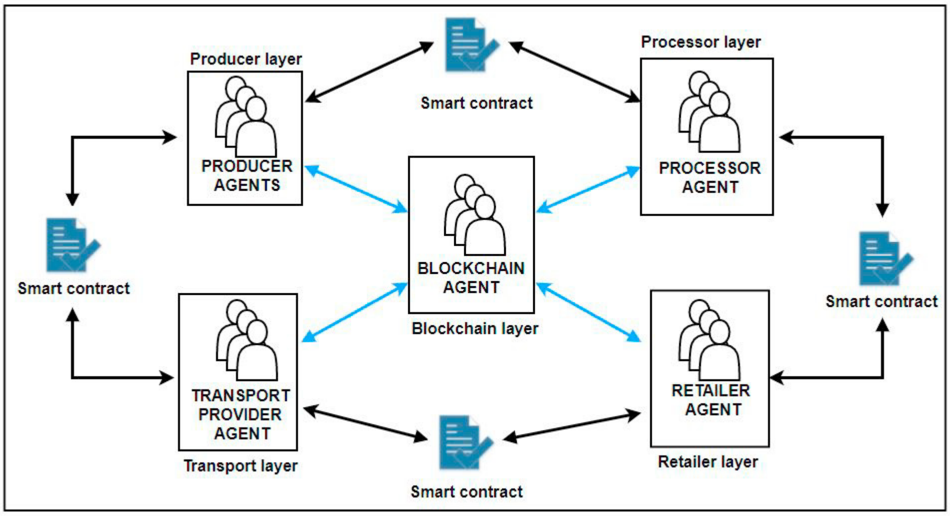

Fig. 2. Supply chain via blockchain MAS architecture. Each layer sends data from its transactions to the blockchain. In addition, the layers that manage the articles communicate with each other with smart contract. These smart contracts are for buying and selling items.

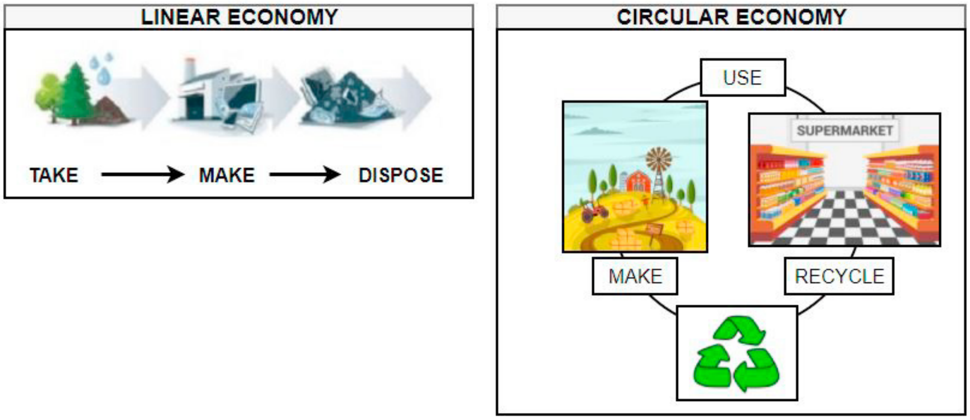

Fig. 3. The figure shows the concept of linear and circular economy. This change of market model is made possible by the inclusion of blockchain..

MAS is created (see Fig.2). The MAS has 5 layers: 1) In the producer layer is the producer agent. This agent coordinates all the operations that the producer has to do (e.g., buying materials, selling products, etc.). 2) In the processor layer is the processor agent. This agent coordinates all tasks that are performed in this layer (e.g., buying primary materials, selling products, contracting transport providers, etc.). 3) In the transport layer is the transport provider agent. This agent coordinates all transport between the other members of the supply chain. 4) In the retailer layer is the retailer agent. This agent coordinates the purchases of materials from the processor and the sale to the consumer. Finally, 5) in the blockchain layer is the blockchain agent. This agent is synchronized with the agents of the other layers so that all the data of all the transactions is correctly stored in the blockchain.

This new supply chain via blockchain enables the new market model called circular economy. You can find the change in the market model in the fig.3. While the current supply chain follows the Take - Make - Dispose model. With the supply chain via blockchain, the circular economy model is enabled. This new market model follows the Make - Use - Recycle model. This new model allows the economy to be self-sufficient. With the use of blockchain, all products can be traced from their origin to their sale and subsequent recycling. The advantage of this model over the linear economy is that all the products are tracked with blockchain and with this traceability it is possible to give confidence to the final consumers about the origin of the products, whether they are recycled, whether they are first use, etc.

4. Discussion and future work

This paper presents a new blockchain approach to improving the current supply chain. The novelty of this paper lies in a blockchain to store all transaction information in the supply chain of the proposed case study. In addition, the multi-agent system uses smart contracts to manage the entire supply chain process more efficiently, this is because smart contracts remove intermediaries and enables the circular economy market.

Our model can be used to improve any supply chain. The case study conducted in this proposal focuses on the agriculture sector. Our model has improved security and efficiency as it is automated by the agent system. By incorporating blockchain we provide the agricuture system with solid security features. Shipments can be tracked, origin and destinations authenticated, and proof of all transactions can be stored and unmanipulated.

Another novelty of this paper are agents who verify that both parties abide to the terms of a smart contract. If the agents detect that either of the parties is not fulfilling the established conditions, a penalty is imposed and the agents keep money in the control entity until the conditions agreed upon are met. This makes our model more efficient than current models. Moreover, it is able to track and authenticate orders. In addition, a ranking and award system is introduced in the supply chain via blockchain to acknowledge and reward members who most closely fulfill this new supply chain model.

Future lines of research include improving the multi-agent system by introducing new agents for the monitoring of procedures. In addition, our model could be enhanced by integrating a case-based reasoning system (CBR).

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