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Rafael E. Bettín Díaz

EAN University: Universidad EAN

Alix E Rojas (✉ aerojash@universidadean.edu.co)

Universidad Ean <https://orcid.org/0000-0002-0371-3925>

Camilo Mejía Moncayo

EAN University: Universidad EAN

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Rafael Bettín-Díaz¹, Alix E. Rojas^{2,*}, Camilo Mejía-Moncayo³

¹ 0000-0003-1938-190X, ² 0000-0002-0371-3925, ³ 0000-0002-3661-2231.
{rbettind4339, aerojash, cmejiam}@universidadean.edu.co

Universidad Ean, Bogota, Colombia.

Abstract

This paper examines the process of implementing a Blockchain on a supply chain study case using Hyperledger. The objective of this research is to understand how to implement Blockchain technology into a business process like the supply chain. This document explains from the study case of Colombian organic coffee to develop a proof-of-concept of the technology and how establish its feasibility, isolate technical issues, and provide feedback. With the recent interest of adopting Blockchain to leverage business process capabilities, the results of this implementation show it is possible to trace product origin using Blockchain, as well they also reveal challenges that need to be addressed. This paper analyses the process used in the coffee production supply chain, the technological architecture proposed to support this scope, and a proposal to store the data into the Blockchain.

keywords. *Blockchain; Traceability; Supply Chain; Organic Coffee; Hyperledger.*

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Code availability. Software application.

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Consent. All authors whose names appear on the submission made substantial contributions to the work, and read and approved the final manuscript.

Code availability. Data and the free software application used support the published claims.

*Corresponding author

Authors' contribution. All authors contributed to the study conception, design and analysis results. The first draft of the manuscript was written by Rafael Bettín Díaz and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Rafael Bettín-Díaz¹ · *Alix E. Rojas² · Camilo Mejía-Moncayo³

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Abstract This paper examines the process of implementing a Blockchain on a supply chain study case using Hyperledger¹. The objective of this research is to understand how to implement Blockchain technology into a business process like the supply chain. This document explains from the study case of Colombian organic coffee to develop a proof-of-concept of the technology and how establish its feasibility, isolate technical issues, and provide feedback. With the recent interest of adopting Blockchain to leverage business process capabilities, the results of this implementation show it is possible to trace product origin using Blockchain, as well they also reveal challenges that need to be addressed. This paper analyses the process used in the coffee production supply chain, the technological architecture proposed to support this scope, and a proposal to store the data into the Blockchain.

Keywords Blockchain · Traceability · Supply Chain · Organic Coffee · Hyperledger

1 Introduction

Agriculture is one of the essential economic activities in Colombia, it is a fundamental pillar to cover the food needs of the country’s inhabitants, and it is the primary source of income in non-urban areas. According to the Bank of the Republic of Colombia, the agricultural sector is the most representative in rural

Universidad Ean
Cl 79 # 11 - 45, Bogota, Colombia.
Tel.: +57-1-5936565.

*Corresponding author
¹E-mail: rbettind4339@universidadean.edu.co · ORCID: 0000-0003-1938-190X
²E-mail: arojash@universidadean.edu.co · ORCID: 0000-0002-0371-3925
³E-mail: cmejiam@universidadean.edu.co · ORCID: 0000-0002-3661-2231

¹ Hyperledger is an open source collaborative effort created to advance cross-industry blockchain technologies. It is a global collaboration including leaders in finance, banking, Internet of Things, supply chains, manufacturing and Technology. The Linux Foundation hosts Hyperledger under the foundation”. [30]

employment with at least 60% participation, and the main agricultural products of the country are coffee, cocoa, sugar cane, rice, potatoes, corn, cotton, and flowers, among others[6]. For decades, coffee has been one of the country's most consumed agricultural products in the Andes region and the most commercial in the International market. However, there is a category of coffee that has been growing in recent times as more and more consumers are willing to pay more for organic products. Organic coffee is grown and harvest without using any harmful chemicals and whose production process must protect the sustainability and conservation of natural resources.

IFOAM² is the organization that sets international standards, produces regulations, monitors and guarantees compliance for everyone who has been awarded a certificate. Likewise, it accredits certification agencies to carry out the corresponding inspections and issue the certificates in its name. Certification in organic agriculture requires initiating a process before a certification agency accredited by IFOAM, verifying compliance with regulations, and gives the certificate. In simple words, it establishes the confidence between farmer and customer[28]. However, farmers cannot guarantee an "organic" label in their product without carrying out detailed written monitoring of their agricultural work; In farms, traditional paper records and manual inspections still prevail, leading to the introduction of errors and delays in the exchange of information. These deficiencies in the process do not allow traceability of the coffee supply chain.

This paper attempts to explain how Blockchain technology can be used in business processes as complex as a supply chain traceability. And how, through a methodological framework, it is possible to build tools, with the support of technology, that allows adding value to business processes. To capture and validate insights about the application blockchain technology in the study case of the Colombian organic coffee, we developed a proof of concept using a modular blockchain framework called Hyperledger. We analyze and discuss the implementation details and security issues that need to be addressed for this application and, in general, when using blockchain technologies. Finally, we present conclusions.

2 Background

2.1 Organic Agriculture

As the author explains it well in [11], agricultural products with some certification belong to a differentiated market and are distinguished from the common ones by some particular characteristic. These coffees are demanded from buyers who pay more for a coffee if they have better qualities or characteristics than the average. The existence of varieties in the types of coffee is a trend that was consolidated in industrialized countries' markets towards the end of the 60s. It is the adoption of highly differentiated market consumption logics, in which for each type of coffee product, there is a specific type of consumer. The adoption of organic production within the coffee market was possible with the implementation of mechanisms that generated consumer confidence about the product's origin since this property is not perceptible in the product.

² <https://www.ifoam.bio/>

The certification schemes adopted consist of a regulation regulating organic production, suitable trade production, and a private body that controls the rules' follow-up and grants a seal that guarantees the consumer that the product meets the requirements to label "organic." The Research Institute of Organic Agriculture FiBL and IFOAM - Organics International [25], defines organic agriculture as a production system that sustains the health of the ecosystem as a whole, it also relies on ecological process, biodiversity and cycles adapted to local conditions; all of the above, promote a good conditions for the environment and good quality of life for all involved. Another authors cited by [27], defines organic agriculture as a production system that uses natural inputs and special practices, such as crop rotation, and prohibits the use of pesticides, synthetic fertilizers and pesticides, medicines for use in animals, genetically modified seeds, as well as preservatives and additives. For example, the U.S. Department of Agriculture sets at least 95 percent of the beans must have been grown under organic conditions for a product to be labeled "organic" and carry the seal on the packaging [21].

2.2 Supply Chain

It can be define as a set of firms that passes material forward [33]; in line with this, it can also be define as firms that brings, products or services, to the market. Another definition of supply chain, is the network of organization that are involved in the upstream and downstream process in order to add value in the form of product or services delivered to the final costumer[7]. As define by [19] is a set of entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer.

At [5], it was stated that the supply chain objective refers to "...processes and activities that produce value in the form of products and services, in the hands of the ultimate consumer", this can be used as an objective of the supply chain management, and for the purpose of this research, added value is one of the most important ingredients of the entire process. Currently, the general supply chain management process, no matter the perspective, has a lack of information for the final consumer. As was seen in the definition above, the process foundation's relays on the communication and integration of a set of actors that manufacture or produce the good or service.

This particular definitions links with the justification of this research, due to the importance of providing valuable information to the final consumer and being an important piece of the chain. Also, it's important to note the definition of [7], but mostly, this statement, Starting with unprocessed raw materials and ending with the final customer using the finished goods, the supply chain links many companies together; our focal point will be working specifically with the food industry, this is simply raw material, that needs to be transformed or processed in order to deliver a finished good to the final consumer, in between those "actors" raw material and final consumer, there are several other, some of those participants of the supply chain according to [15] are (a) Producers or manufacturers, organizations that make a product. This can include transformation of raw material or the production of finished goods (b) Distributors, are mostly known as a wholesaler, (c) Retailers, manage stock inventory and sell in smaller quantities to the general public, (d)

Customers or consumers, may be the final end user of a product who buys the product in order to consume it, (e) Service providers, these are organizations that provide services to producers, distributors, retailers, and customers.

2.3 Supply Chain in the Food Industry

Foot industry will become competitive as long it meets the demand requirements and ensure profit to companies [31]; there always a constant related to the customer, its taste will change over time, and necessary will obligate the industry to adapt faster to this changes and respond accordingly. With this research we are aiming to attack the most critical challenges that can affect the supply chain in the foot industry[14], which are, *Cold Chain*, this means to control and trace the product throughout all stages during transportation and storage in a warehouse; *Traceability*, it refers to the ability to trace the product across all stages of the production and distribution and *Quality*, this is essential in this industry due to the compliance certification that are needed for agricultural products.

2.4 Blockchain

The most common and accurate definition for Blockchain, would be the underlying technology that will allow you to trade any kind of asset, through validation and consensus of all of the nodes connected to the network, who happens to share the same ledger of transaction; this consensus needs to be reached by the majority of the network, which are all of the participants participants who validate the transaction [10], once the transaction has been validated, it goes through and it is added to the Blockchain [3].

Blockchain networks offers several characteristics, one of them is immutability, which means that this transactions can not be modified or altered by anyone[8]. The next one is traceability, due to all transactions are stored on a single ledger of transaction across the network, which is being updated anytime a transaction is valid, everybody has access to all of the transactions that have ever occurred on the network and traced back to the genesis block[12]. However, participants on the network, depending whether the Blockchain is private o public, will not be able to see one another identities', this is because all of the transactions are being encode thanks the cryptography and mathematical algorithms used to ensure the security of all the transaction on the network; at last, one of the most important characteristic, is the uses of a timestamp signature, once a transaction have being validated, it helps the network to trace the information or asset that was stored on the Blocks[34].

Based on this philosophy, a Blockchain has no need of a third party, regulatory entity or a government to make trading happen; this technology allows you to transact with anyone around the globe as long as both participants are connected to the Blockchain network[29]. As it was mention earlier, you can have both, private or public Blockchains network. A private Blockchain means, that all the participants of the network are known one another and functions can be segregated for each participant based on a given role; Despite of a public Blockchain, where participants are anonymous, and everybody is equal to the network. This last

case, can be referenced with Bitcoin, the cryptocurrency that originated all the Blockchain fuss.

3 Traceability process for organic Colombian coffee

3.1 Proposed Methodology Approach

The integration of the Blockchain with the Supply Chain, will depend on the product characteristics and the added value Blockchain will offer; in this case, will be the traceability of information to certificate the origin of a product to determinate whether is organic or not, like Colombian coffee. Once all of the product characteristics has been defined, the authors proposes to describe the processes involved in the organic coffee production, in order to understand all of the variables that may affect the process and the ones that should be taken into consideration to use for the Blockchain business network; in line with this, that article suggest to outline all of the information that goes through the entire production process. All of this information will help us to define participants, assets and how the information should flow across the business network.

As it is describes by [4] in their article, this are the steps to consider to integrate a technology like Blockchain to trace the information in a Supply Chain process;

1. Select the product, this definition will be accordingly with the main asset that will define the scope of the Blockchain architecture, it also will help us define processes, operations and components that will be a part of the product identity.
2. Product characteristics, this are attributes that make a product unique and easy to identify. This definition may be one of the most important, considering that those characteristics are the ones to trace with Blockchain to generate the origin certificate.
3. Requirements for production, technical, functional, legal and regulatory, among others; it is important to define those, taking into account that they will lead us to the process that will transform the product from raw material to finish goods.
4. Actors of the process, it will help us to identify all the participants that needed to configure Blockchain business network, their role and scope for transactions.
5. Unit operation and processes, will define the product transformation into finish goods. This will be consider, as the product itself, as assets of the Blockchain business network, will help us transact and to trace the product characteristic needed to certificate the origin of the product.
6. Business rules, are conditions to the processes that will trigger an action. In order to apply rules every time a transaction is made, this are validated by smart contract³ and, once it goes through, the transaction is added to the blockchain.
7. Digital Assets, it is the product itself that is going to be traceable and the transnational document that is going to support each transaction and have all the information across the process.

³ "Smart Contracts are computer programs that are stored in a completely distributed manner on a blockchain database"[18]

8. Information flow, using a data flow diagram will help to understand how the information, regarding the assets, will flow in the process.
9. Configure the blockchain, this means to define the type of business network that will apply to the process, select the software to create the business network and all of its components.
10. Test the new business model, a business network validation to ensure that everything is working according the objective.

Fig. 1 General Coffee Production Process

3.2 Study Case Description

Nowadays, personal care and health have become imperative among generations, this is what [23] and [24] shows in its study, We are what we eat and what's in our food and on our mind respectively. In this growing market, the proliferation of training centers, gyms, bicycle use and above all, improving eating habits; people are more concerned about knowing what kind of food they are including in their diets, what nutrients they have, where they come from, how there were cultivated, how their selection has been made, among others questions regarding its origins; but sadly, there are some questions that, in most cases, are left unanswered and there is nothing more than trust in the goodwill and response of those who place it at our disposal, whether on a shelf or in a restaurant. Being aware of what we buy and eat favors proper nutrition, as well as the care and maintenance of our health. It is very important to identify nutritional information, ingredients and other recommendations when buying packaged foods [1]. With that being said, we must point out that customers have never been able to actually know in detail

the characteristics, attributes and valuable information about the food they are purchasing. In Colombia, according to [20], the following information is currently necessary for the labeling of food:

- Name of the food
- List of ingredients
- Net content and drained weight
- Name or business name and address of the manufacturer
- Lot identification
- Date of expiration and/or date of minimum duration
- Instructions for use
- Sanitary registration

However, none of the above presented, actually provide information about the different stages and processes to which, for this case, organics food products are subjected from their harvesting throughout the supply chain to the final consumer. In an interview conducted by [17], the president of Almacenes Exito, Carlos Mario Giraldo, said that “the market for products with benefits moves about 20 percent of food consumption in the country and grows 10 percent per year, twice the industry as a whole, which evidence the potential market that is behind a good food habits. Now, lets imagine the same scenario but providing information to the customer, that never has been accessed or shared before.

According to the [32], “People are now consuming more foods high in energy, fats, free sugars or salt/sodium, and many do not eat enough fruit, vegetables and dietary fiber such as whole grains”. Just as the Blockchain technology is transforming the way we carry out transactions, it might do with many other industries, including the organic food industry, by giving people the opportunity to actually know the origin and traceability (along the process) of what they are eating. With the growing demand in the fitness market, in line with [22] and [23] “Consistent with consumers’ rating of the importance of attributes, sales of products with “natural” and “organic” claims have grown 24% and 28%, respectively, over the two-year period”. With this information, it can be appreciated how important has become for people, to change its eating habits; specifically, in Colombia, people tend to look for food with local ingredients, natural and organic alternatives¹ which makes us think about the current state of the transformation process that experience food across the value chain, since its plantation until its placement on a supermarket shelf.

3.3 Implementation

In order to validate the methodology, prior explained, it has been used the online software Hyperledger Fabric provided freely by [30].

1. Define Unit Operations and Processes: In figure 1 is shown the general process for the coffee production, as well as the main participants of the process[9].
2. Define the software architecture for the business network, see figure 2: Based on the architecture for originChain[35], this proposal is considered to used a similar one in order to accomplish the traceability of the product.
 - (a) First layer of the architecture defines the life cycle of the product, this takes into consideration upstream and downstream process of the supply chain.

Fig. 2 Business Network Architecture

- (b) Layer number two will be consider the application end for the user, this can be an ERP, a BPMN or any other software able to manage this processes.
 - (c) Then, there is a third layer, this a relational database, that will host all the information and transaction generated across the business network. It will manage the product information, the traceability database as a master for all transactions, a repository for smart contract and the control of all permissions to access the database.
 - (d) And last, The fourth layer or the Blockchain layer; this server will store all the transactions defined to safeguard the origin traceability of the product.
3. Name and describe the new business network: E.g. Organic Colombian Coffee Origin Traceability, this network tracks the supply chain from up stream to down stream processes, from raw material to finished products, which will provide the final customer with information about its origin. A regulator is able to provide oversight throughout this whole process. The business network defines:
 - (a) Participants: *Farmer, Manufacturer, Distributor, Regulator, Farm, Factory*
 - (b) Assets: *Coffee, Order*
 - (c) Transactions: *CoffeeMovements, CoffeeMovementArrival, CoffeeMovement-Departure, PlaceOrder*
 - (d) Events: *PlaceOrderEvent, UpdateOrderEvent, CoffeeMovementEvent*
 4. Deploy
 5. Connect the new business network
 - (a) Generate the model files: This will define assets, participants, transactions and events on our business network.
 - (b) Create the script to manage transactions, as they were define above.
 - (c) Create the script to manage security access to the the network

4 Results and analysis

4.1 Results

While validating the model, it was determined that the assets that travel along the productive process, in the first instance, have the information, data, technical data that should be treated in a relational database, allowing, from the user interface (UI), to generate all types of transactions. Once this information is stored in the business network (Blockchain), which is done through the use of smart contracts, which will have encoded the transactions that goes to the Blockchain (this is done from layer 2 of the architecture proposal see figure 2). Whenever these transactions, such as the generation of an order, the movement from one process to another, change of custody between the participants, among others, have been stored into the Blockchain, it generates a unique and immutable record which will be the basis to generate the product traceability of origin. Likewise, with the assets defined in the case study it guarantees, on one hand, to have control of the attributes that are part of the main asset *coffee* and, on the other hand, the control through the *order* everything that happens with the *coffee*; for example, the changes that the coffee has along the processes, the new attributes that are gained or lost, the movements that are made with it, the events that are triggered throughout the process and the custody that is generated, allowing the construction of the - coffee - traceability of origin.

Fig. 3 Data Base and Blockchain process storage

This is how the figure 3 shows that the processes and movements between them, send information to a database from which transactions are generated, and once they are validated by the smart contracts capability, they will be stored in the Blockchain. An example is shown in the following transaction *Submit a Transaction* - *Transaction Type: PlaceOrder*, in which, for the first time an order is being generated to obtain a wet benefit, which is the final product, in a series of processes, within the productive unit (farm). This order is made on a specific lot to be cultivated, identified as “5128”, whose transaction is generated by the participant - farmer - and is in turn assigned to a - regulator -, in order to validate the veracity of the information. That transaction can be observed in the ledger of transaction, see Ledger of transactions - Order Placed, with a transactionID and a specific timestamp. With these records, we generate the validation and traceability of origin of the final product that was born from lot “5128” and whose movements will be recorded as shown in figure 3; where we have the process as it happens. In this example, at the productive unit (farm); from each processes there are transaction that are stored in a Data Base. Transactions A to G..., will have information regarding process, for this example, the coffee growing process attributes such as, Farm ID, Farmer ID, Fertilized used for the process, Pest Control assignation, Seed type, Seed Color, Seed Sized, Lot Number and Order Number; this transactions will go straight to the Blockchain, as it is shown in figure 3 in the sequence of number (1 to 7...), after a smart contract has verified its validity, and it will create the following transactions, Place Order, e.g. see figure 4, this transaction will be storage on the blockchain with a transaction ID and TimeStamp as shown in figure 5, *Make wet benefit*, *Update Order Coffee Growing*, *Event Place Order make wet coffee*, *Event Update Order Coffee Growing*. This means that, for every transaction created on the business network, there will be a log on the ledger with all those records.

```
{
  "$class": "org.example.scpcoffee.farmer.placeorder",
  "orderId": "1234",
  "coffeedetails": {
    "$class": "org.example.scpcoffee.coffeedetails",
    "make": "WET_BENEFIT",
    "lotID": "5128",
  }
  "manufacturer":
  "resource": "org.example.scpcoffee.farmer.farmer#4578",
  "orderer":
  "resource": "org.example.scpcoffee.regulator#2382"
}
```

Fig. 4 Submit a Transaction, Transaction Type: PlaceOrder

```

{
  "$class": "org.example.scpcoffee.farmer.placeorder",
  "orderId": "1234",
  "coffeedetails": {
    "$class": "org.example.scpcoffee.coffeedetails",
    "make": "WET_BENEFIT",
    "lotID": "5128",
  }
  "manufacturer":
  "resource": "org.example.scpcoffee.farmer.farmer#4578",
  "orderer":
  "resource": "org.example.scpcoffee.regulator#2382"
  "transactionID": "591b6ad6-5bac-4a8d-bb29-a8e15fd774c2",
  "timestamp": "2019-02-24T17:50:59.125z"
}

```

Fig. 5 Ledger of Transactions, Transaction Type: PlaceOrder

4.2 Analysis

- It is necessary, in the architecture of the business network, to have a relational database that allows to store all the transactions in a traceability repository (as shown in figure 2), with the aim of validating the transactions against the information stored in the Blockchain.
- The check points of the model allow to generate audits by a "regulator", as it is called in this case study, because the information manipulated through the entire process must be entered by the different "participants"; even with this technology, the data it is not exempt from manipulation before its registration.
- In order to minimize the risks of altering the information, it is recommended to automate the entire process from start to finish. This will help to have the information from the original source, which can be sensors, meters or other Internet of Things[13]. (IoT) components that allow the reading of data, considering the scope of a project of this type; however is important to consider the limitations for such integration [26]. This information entry would be connected to layer 2 of the proposed architecture, replacing the manual entries of information. This would be limited only to entries that affect the administration and the traceability database.
- To guarantee the traceability of the transactions associated with a particular lot or product, it is recommended to integrate all the participants of the chain. This generates integrity in the information and greater confidence in the data. This particular is of greater impact because any participant outside of the business network, directly affects the confidence of the information and therefore, the final consumer.
- Based on the model described by [4] , the steps 1 to 6 mentioned in their methodology, are considered highly important within the definitions to be made; Knowing the product, its characteristics, the production process, the requirements of the process and its participants, these are the main inputs for

the definition of the business network. The business rules defined in the initial model, can be considered from now on the "transactions" to be carried out by the participants of the network, which are made upon assets. The latter are considered the fundamental piece that must be traceable throughout the process. For this case, the study had two main assets, the *coffee* as the protagonist of the process and the *order* that, throughout the process, information is fed to generate the traceability of the product. Finally, there is the information flow, it is an exercise that is not required for the process, it can complement the understanding of the business network; This will depend to a great extent on the transactions that are made and who makes them.

- Another important aspect to consider is security. It does not matter the type of Blockchain implemented; whether it is public, consortium, or private, the structure and functionality are the same. Data inside a Blockchain are secure from a conceptual view; however, Blockchain security depends on the whole system architecture that supports it [16]. In the Hyperledger Fabric case, security depends on the adequate configuration of Hyperledger certificate authority and key management. The system must also enable TLS client authentication on peer nodes to configure the whole network's overall trust level[2]. Another aspect to consider is that data are susceptible to being stolen by malicious actors at the host level if they are not under encryption.

5 Conclusions

Through the application and implementation of this model, for the creation of a business network based on Blockchain, it is feasible to obtain the traceability of origin for a product. Our case study refers to organic products, but, without a doubt, this same methodology can be homologated to any product, as long as the use of Blockchain technology generates value to the process.

It is important to note, that Blockchain as a technology, provides support to the process, to ensure that the information has not been altered and is trusted, with the objective of providing information to the end user of the value chain; however, these information sources cannot be susceptible to manipulation before being stored in a Blockchain. That is why, based on the validation of this model implementation, it is recommended to have a robust technological infrastructure that allows to complement and harmonize the different sources of information that, through the transactions, will take the data to the Blockchain.

In accordance with the above, for the Colombian market, in terms of production of organic coffee, this represents an important cultural challenge; initially, because the processes in coffee farms are carried out mostly manually, it must also be taken into account that automation is an important part of the adoption process of Blockchain technology; Another important point is the reference made to the integration of the participants of the chain, where currently, each of them has its own repositories of information, which can be manual or digital, their own internal information systems for the control of their processes, which makes it difficult to have information integrity and therefore carry out the origin traceability process.

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