RESEARCH ARTICLE
Vol.11.Issue.4: 2024
Oct-Dec.

INTERNATIONAL JOURNAL OF BUSINESS, MANAGEMENT AND ALLIED SCIENCES (IJBMAS)
A Peer Reviewed and Refereed Journal

Implementation of Blockchain-Based Supply Chain Management (SCM) In Manufacturing Companies

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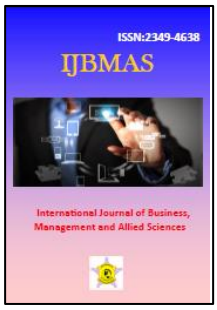
DOI: 10.33329/ijbmas.11.4.37



ABSTRACT

Contemporary supply chain management (SCM) is intricate and consists of several resources, rendering traceability, transparency, and security significant difficulties for various stakeholders. The utilization of blockchain technology is highly beneficial for manufacturing organizations in supply chain management. Blockchain utilization can reduce employee fraud. This study seeks to implement blockchain supply chain management technologies in industrial enterprises. Blockchain has evolved to enhance supply chain processes by integrating all participants in a decentralized, transparent, immutable, and secure manner. Despite being a young technology, it offers numerous applications within the supply chain, owing to its flow properties and the prevailing demands. This work aims to develop a blockchain proof of concept based on the SCOR model for the import-export process of a manufacturing company by developing a Hyperledger fabric network prototype illustrating the advantages of this technology in enhancing the safety, reliability, and transparency of information flow from the initiation of the purchase order to its delivery at the specified location. This study will demonstrate a proof of concept for the application of blockchain in the import process, identifying the opportunities this technology may provide. This study primarily addresses the critical subject of how to implement blockchain technology in the international supply chain, tailored to the infrastructural requirements of foreign commerce within a Libyan manufacturing enterprise.

Keywords: Supply Chain Management, Blockchain, Libyan manufacturing company, SCOR Model, Hyperledger Fabric network

1. Introduction

Regarding blockchain articulated to supply chain processes, previous systematic reviews have been developed focused on traceability, development and effects on sustainable manufacturing and supply chain management, analysis of the advantages and disadvantages of its adaptation; and its contribution to supply chains, finance, logistics and security; these articles, related to this field of study, serve as a reference for the present research [1]. Due to the relevance of the application of blockchain in supply chain operations, it is considered necessary to carry out a bibliometric analysis of research trends in this topic, based on the review of the original and structural studies in the area, which have contributed to the development of this technology in logistics processes [2].

This research explores the relevance of using blockchain in the supply chain and manufacturing companies, intending to identify the benefits and challenges of its implementation in these areas, by studying the trends in this field. Blockchain has established itself as a promising technology in various activities, and its application in manufacturing could have a significant impact on the efficiency, transparency and security of processes.

The original documents resulting from the identification of the Indegree indicators allowed the categorization of the publications, which become the supporting research to be referenced, as they are the basis of the field of study between blockchain and supply chains. Below, the most relevant publications are analysed according to their citation level [3].

The application of blockchain as a data manager has been represented in the decentralized environment of cryptocurrencies such as Bitcoin and applications such as the Internet of Things. As a tool to minimize operation times, it has presented benefits in terms of access to information, facilitating the development of service markets between devices, such as cryptocurrency automation and workflow tracking [4].

In relation to supply chains, blockchain has participated in areas of traceability, supporting the agri-food industry to increase the safety and quality of products and reduce losses associated with logistics processes [5]. As a result, the information, in addition to being reliable, guarantees safety and quality in food with the collection of real data in the production, storage, processing, distribution and sale of products. In terms of efficiency, blockchain has demonstrated favourable productivity results in processes associated with the supply chain. Likewise, transparency stands out as an attribute of this technology by providing stable and non-modifiable access to information, characteristics that support secure trade and the legality of the origin of products [6]. Regarding the structural documents obtained from the betweenness indicator, the articulation of the blockchain and the supply chain is identified from the usefulness it provides to business processes, especially in the possibility of reducing intermediaries in negotiation operations between third parties and the traceability of related information in negotiation support documents [8]. In turn, the blockchain favourably impacts factors such as quality, costs, time and transparency of all processes along the supply chain, according to the dynamism and flexibility required by the market to mitigate risks. Another of the blockchain's capabilities has been to manage the consistency and integrity of the data involved in a negotiation process, which is essential for decision-making by actors in the supply chain, because it facilitates transactions and the exchange of information, resources or products, without the need for intermediaries or third parties to validate the operation. In this sense, among the researchers, the application of blockchain in smart contracts stands out, as a useful tool in the negotiation processes of the supply chain through the development of shared accounting books, digital contracts and secure networks [8]. This facilitates the direct relationship of transactions between the parties and the reduction of the role of intermediaries. Studies in India and the United States stand out, where the usefulness of blockchain and its progressive implementation in the supply chain are reinforced. Blockchain is therefore presented as an emerging technology with the ability to provide a solution to the problems of exchange and transparency of information from end to end in the supply chain, critical

situations that concern the parties involved, in terms of traceability and security [9]. Although it is a recent technology, there are many possibilities for its application in the supply chain due to its flow characteristics and the current needs that are being presented. Currently, there are implemented examples, such as in Walmart and Tradelens, but this technology is still in its initial stages. This study will present a proof of concept of the application of blockchain in an import process and thus find the opportunities that this tool can offer [10].

The objective of the supply chain is to maximize the overall added value, which is called supply chain surplus (Chopra & Meindl, 2016), which consists of the difference between the consumer value and the supply chain cost. This can be measured as the value that a customer is willing to pay against the efforts to fulfill the requirement.

International trade is a part of the international supply chain, which consists of the commercialization of goods across borders [11]. The most common method of entry for this activity corresponds to the import and export of goods, therefore, international trade management encompasses the administration of all risks, operations, obligations, duties, among other activities of the import and export process [11].

Based on the above discussion we formulate the question for the current research work i.e., How to apply blockchain technology in the international supply chain adapted to the needs, and infrastructure of foreign trade in Libya for a manufacturing company. Hence this work is developed to assess, through a proof of concept, the application of blockchain technology in the international supply chain process, from the moment of the purchase order until it arrives at the destination, considering the physical, financial and documentary processes in a manufacturing company.

2. Methodology

2.1 SCOR model for international supply chain management

The SCOR model stands for "Supply Chain Operations Reference" and aims to provide uniform definitions, concepts, processes and metrics for managing the supply chain. It facilitates communication and allows performance to be evaluated and compared between companies or industries [12, 17].

According to Hammadi et al, (2018) [13], the SCOR model has three levels: Supply chain network structure, supply chain pillar configuration, and process configuration. These are composed of 5 processes which correspond to planning, procurement, manufacturing, distribution, and return. Planning includes supply planning and resource management, procurement considers the supply infrastructure, manufacturing manages the manufacturing process, distribution covers orders, storage and transportation, and returns include business rules, change inventory, and product returns etc.,

Figure 2 describes the SCOR model adapted to the international supply chain of Mitsubishi Electric de Colombia. At level 1, the scope and content of the SCOR are defined, where the competitive performance objectives of the supply chain are visualized globally. At level 2, the planning, procurement, manufacturing and return processes are configured, where the interaction flow between all parties is shown so that the flow can function between all participants, which is illustrated in Table 1 [13]. Level 3 generates a detailed breakdown of the activities of each link; These are generally referred to as inputs, outputs, and information and materials.

Table 1. Participants in the SCOR model

Category	Interest groups
Commercial Organization	Importer and exporter
	Forwarders, shipping line agent, logistics service providers
Physical	Port terminal operator, shipping company, airline, carriers, container depot operator
Authorization	Customs, customs authorities, port police, inspection authorities
Financial	Bank, insurance company

For proper management of the SCOR model, the company's strategic vision must be subsequently involved, since it only analyzes the details of the supply chain, but not other points such as sales, finances, human resources, among others.

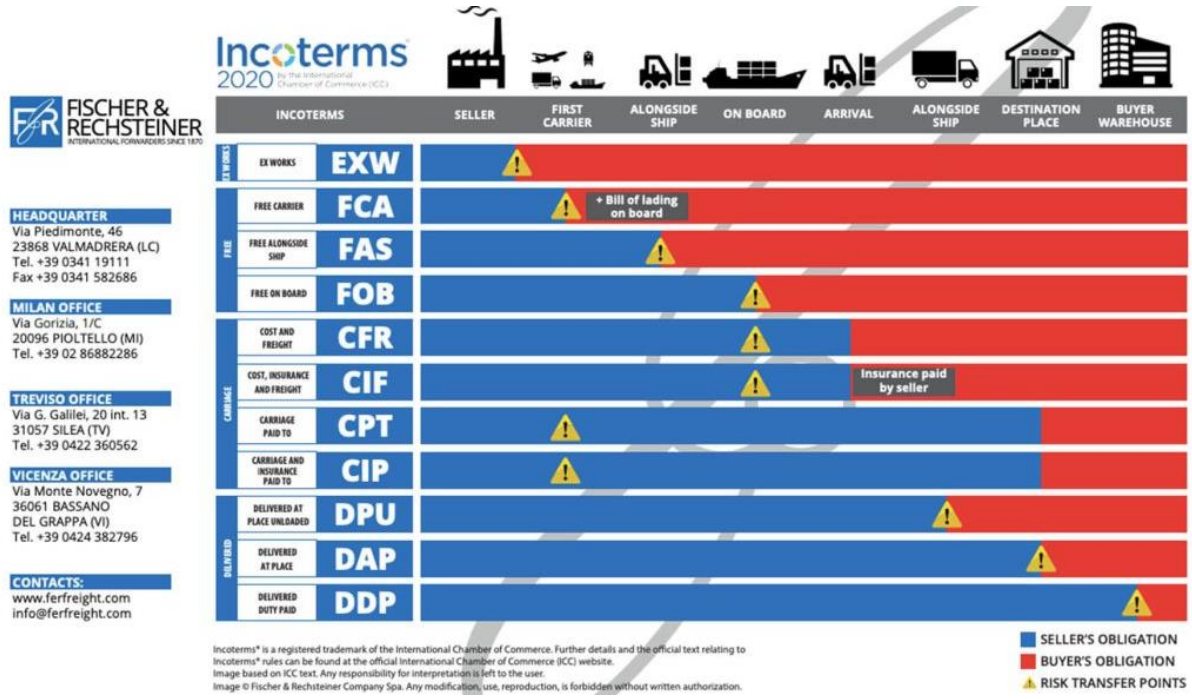


Figure 1: INCOTERMS 2020

Figure 1 shows the costs, obligations, risks and insurance that both sellers and buyers must consider when using Incoterms as a means of negotiating the international supply chain (International Chamber of Commerce, 2020).

It should be noted that Incoterms cannot replace a sales contract, therefore, the specifications of the products sold, the time, place, currency, sanctions, taxes, tariffs or intellectual property rights are not part of the function of Incoterms. All of these are agreed between the parties in their contractual agreements.

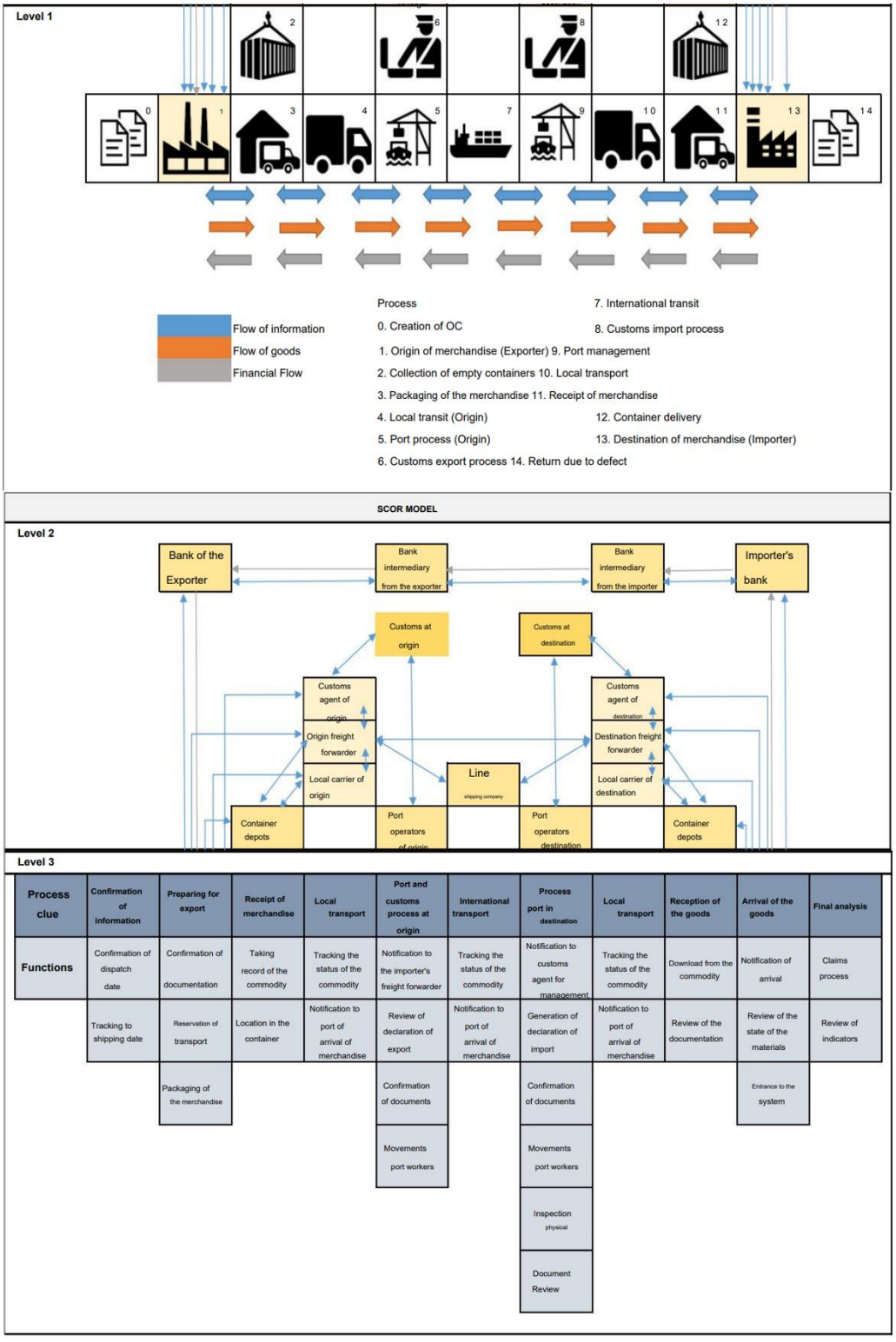


Figure 2: SCOR model inspired by Hammadi, et al, 2018 [13]

2.2 Cybersecurity in the Supply Chain

Based on Ajagbe et al (2023) [14], cybersecurity throughout the supply chain is defined as a holistic system that identifies technologies, procedures, and people to protect the network, devices, and all digital assets that may be affected by damage, attacks, or unauthorized access to affect the supply chain.

Currently, some of the methodologies to protect systems from cyber-attacks within the supply chain consist of the installation of firewalls, virus detection programs, and malware etc.,. Additionally,

activities within the organization such as employee training, hiring cybersecurity experts, collaboration with suppliers, and contingency plans within the business continuity plan protocols.

2.3 Blockchain

Blockchain is an immutable and shared ledger that facilitates the process of recording transactions and tracking assets in a business network [15]. This methodology allows both tangible and intangible valuables to be managed less riskily and reduces costs for all involved [16]. This ledger does not respond to a central authority, but rather each person included in the community can view the information. Once a transaction is made, a block is created which is verified by the network participants to determine whether it is valid or not .

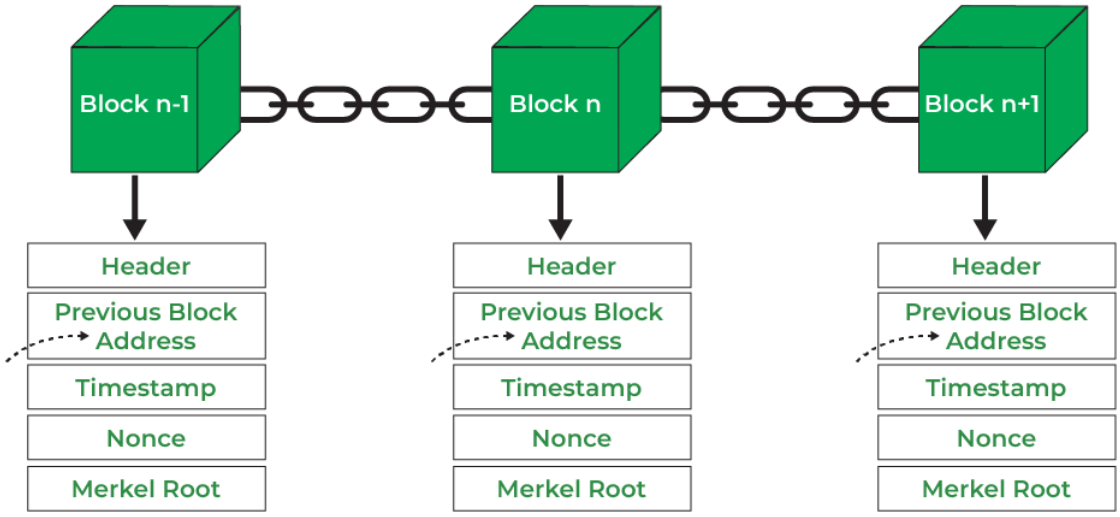


Figure 3: Blockchain Flow [16]

According to Gupta (2020)[15], the characteristics of the blockchain are the following:-Consensus, Provenance, Immutability, and Purpose

Several consensus mechanisms can be considered and these will depend on the type of network being used. Some of them are: Proof of work, Proof of stake, and Byzantine fault tolerance.

3. Prototype

3.1. Description of the prototype

The proof of concept consists of creating a blockchain environment, which is carried out through the instructions given by Hyperledger Foundation in its Blockchain development course, so that several organizations, within the supply chain, can access and transact the tracking information of an international purchase order, from the approval of the purchase order for 12mm traction cable from South Korea until its arrival at the warehouse in Medellín, Colombia. This will consider the factors of merchandise movement, documentation and financial data to cover the 3 main dimensions of the supply chain according to the SCOR model.

3.2. Considerations for the prototype to be made for the Hyperledger Fabric network

Below are the considerations necessary to be able to carry out the network of this proof of concept.

- An infrastructure must be installed on the computer that allows the deployment of a Hyperledger fabric network. For this case, you must have Docker, WSL2 (Windows Subsystem for Linux version 2), Git, cURL, Go, JQ and Fabric samples, docker samples and binaries installed. This network will run on a computer with a Windows operating system, but it will work under the Ubuntu network.

Additionally, Visual Studio Code will be used for code development due to its ease of code management.

-The domain test.com will be chosen to group a set of network participants. For ease and understanding of the exercise, only 3 organizations will be analyzed:

- Organization 1 (Buyer): org1.test.com
- Organization 2 (Government): org2.test.com
- Organization 3 (Logistics Agent): org3.test.com

-For Hyperledger Fabric to work, the network ordering service is needed, which helps to carry out transactions and order the requests, petitions or transactions that the organizations generate.

- A Hyperledger Fabric channel will be created that allows a private secure channel to be set up where only the 3 organizations will be able to see and generate the information that occurs in the channel.
- Each organization will have only one node.
- Only one certification authority will be used for organization 1.
- There will be a distributed ledger that is present for each of the nodes.
- The Go programming language will be used to create the smart contract.
- For the transaction backup policies, it will be indicated that only the first and third organizations will be able to approve transactions. The second organization will only have viewing and not writing.
- Containerization: Each component is dockerized, the ordering service will be a docker service

3.3. Steps

3.3.1. Step 1: Creating cryptographic material

Before starting, you must create a folder where all the codes will be stored. For this exercise, it will be called "proof of concept".

The first step is to create the cryptographic material that contains all the certificates, private keys and users. For this to work, you must have the program called "Cryptogen" installed.

A file called crypto-config.yaml is created, which contains the definitions of the cryptographic material, in other words the identifications of the high-level components of the network.

Step 1.1: Create crypto-config.yaml file

First section: Defines the main ordering service of the OrdererOrgs consortium:

- Name: Orderer -> Defines the Name

Domain: test.com -> Defines the main domain of the consortium

EnableNodeOUs: true -> Enables the NodeOUs

Specs:

- Hostname: orderer

SANS:

- localhost -> The local host is defined to be able to operate on a local network for the proof of concept, however, for the productive area the name of the server corresponding to the company must be entered.

Second section

In the second section, the peers that will be part of the blockchain network are defined.

The information is similar to the first section.

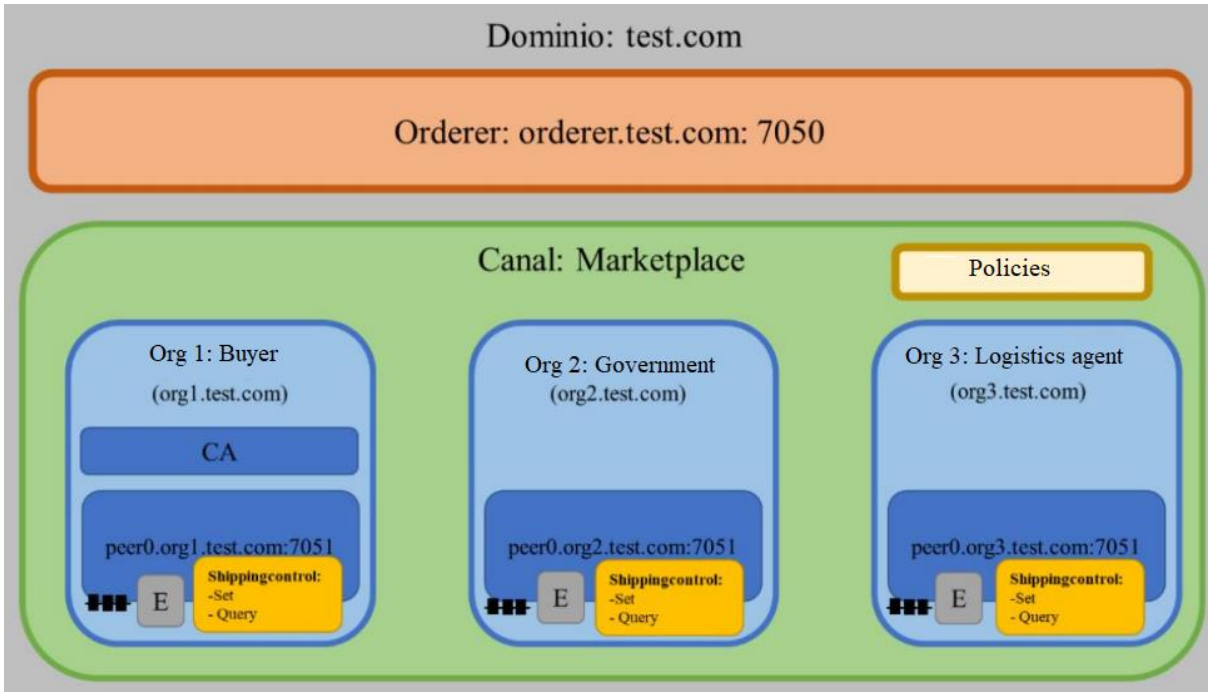


Figure 4: Proof of concept design (Hyperledger Foundation, 2020)

To add more organizations, you simply need to generate the information for each organization, similar to what was explained above. In this way, you can add the number of organizations, nodes and users you want.

Step 1.2: Using the Cryptogen program

In the location where you are working "~/proof-of-concept/proof-of-concept-network" you run the cryptogen command to create the organizations according to the configuration defined in crypto-config.yaml,

Once the command is executed correctly, a folder called crypto-config will be created containing all the certificates and private keys of the orderer and the peers with their respective certificates for the certification authorities (CA), membership service providers (MSP), and secure communication (TLS), as you can see in the attached image (Figure 5).

Step 1.3: Create the configuration transactions in the configtx.yaml file

The configtx.yaml file is intended to configure, organize, define compatibility, policies, ordering services, and manage channel attributes to generate the initial block or genesis block.

Section 2: Capabilities: This section defines the capabilities of the network, so that compatibility is guaranteed

for nodes running different versions of the network. It defines the characteristics of each of the layers that are part of a Hyperledger network.

Channel: &ChannelCapabilities

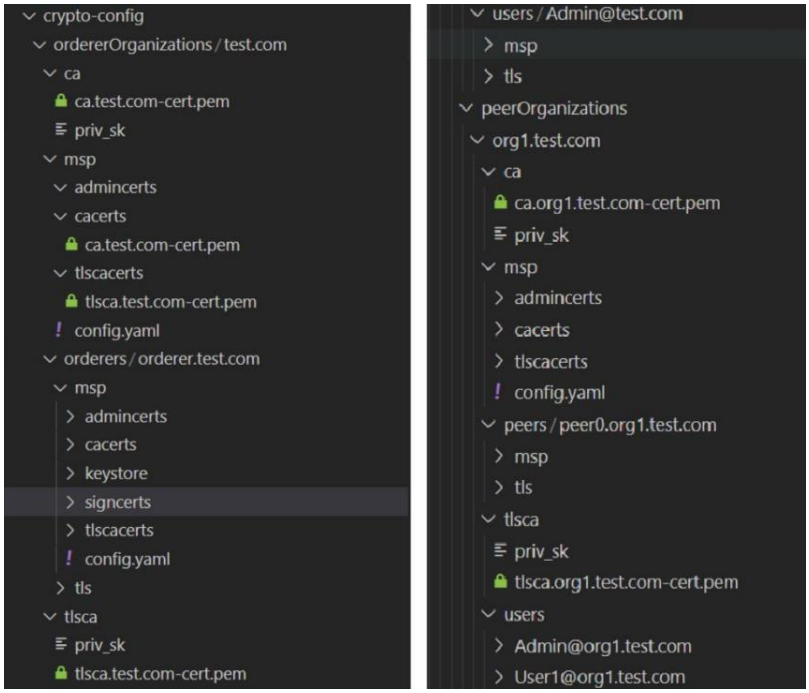


Figure 5: Cryptogen result

Section 3: Application: This section defines the configuration policies for this network.

Application: &ApplicationDefaults

Section 4: Orderer: This section basically defines the implementation of the ordering service that will be used to start the network. It should be noted that there are 3 types of ordering service: Solo, which is used for testing, Kafka, which corresponded to the version prior to version 2, and etc draft, which corresponds to production areas. For the proof of concept, the "Solo" version will be used as follows:

Orderer: &OrdererDefaults

Section 5: Channel: This section defines the policies that govern the highest level of channel configuration.

Section 6: Profile: In this section, you need to define 2 profiles: The first profile defines the genesis block of the channel and the second profile defines how the channel is going to be created for transactions. In other words, how the operation of the Hyperledger Fabric network channel is configured.

Step 1.4: Create genesis block

A folder called "channel-artifacts" is created and the program "configtxgen" is used to create the initial block (genesis) and the channel:

Transaction 1: configtxgen -profile ThreeOrgsOrdererGenesis -channelID system-channel -outputBlock ./channel-artifacts/genesis.block

Explanation of transaction 1: create the initial block

configtxgen -profile ThreeOrgsOrdererGenesis (Indicate which profile I am going to use) -channelID (Indicate the default channel called system channel) system-channel -outputBlock (Indicate where you want to store the information)./channel-artifacts/genesis.block

Step 1.5: Create and configure the transaction channel

For this step, proceed with the following command:

Step 1.6: Create anchor peer files

Few commands must be used for each of the organizations to create the anchors that allow peers to have access to advanced features such as private information and service discovery.

After completing steps 1.4, 1.5 and 1.6, the following files will have been created in the "channel-artifacts" folder: channel.tx, genesis.block, Org1MSPanchors.tx, Org2MSPanchors.tx and Org3MSPanchors.tx as can be seen in the image below. This is proof that the cryptographic materials and channels were successfully created.

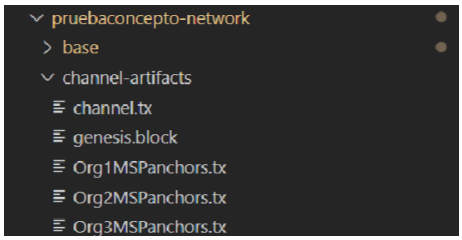


Figure 6: Result of Configtxgen

Once all these steps are completed, the first step of generating cryptographic material is finished.

3.3.2. Step 2: Network design

The next step is to design the network and define the Docker services that will be set up. Docker is a containerization service [18] that facilitates the implementation of the system in any computing environment. For this part, Docker compose will be used to run all the services of this application.

Step 2.1: Creation of the "base" folder and peer-base.yaml file.

This step defines the main behavior of the peers so that, based on the definitions placed in this file, the services to be offered can be extended.

In the exercise folder, the folder with the necessary files is created as illustrated in the image below

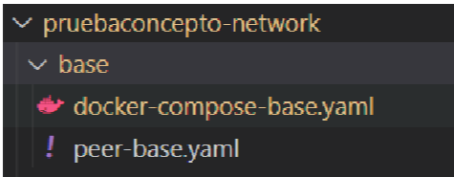


Figure 7: Contents of the "Base" folder

Step 2.2: Create Docker-compose-base.yaml file

This file helps define a generic blockchain network, in other words, it is the high-level definitions of how you want to build the blockchain network.

version: '2'

Section 1: Activating services, environment, TLS and Volumes for the orderer

In this part, the orderer service is defined. For the exercise, only one room will be activated, however, it should be noted that in a production environment, several rooms must be activated so that it can work on the different machines and guarantee the availability of the network.

Section 5: Peer Configuration

For this section, the necessary configuration is done for each of the peers.

3.3.3. Step 3: Docker Containers

The following parameters must be taken into account in order to correctly operate:

-Three (3) containers will be activated within the computer's host machine. Later, a program, written in the "Go" programming language, called peer, will be activated. This program contains the logic and configuration to be able to perform transactions. For this exercise, all peers will be on one machine, although for a production scenario, they should be on different machines.

- In order for containers to communicate, a docker network is needed. A driver is used that allows the creation of a network that will be called testnetwork_basic.

- The Docker network must be defined in the docker-compose-cli file so that it can be created.

- Each container will have its own IP address (internet protocol). Containers must always perform transactions using the Docker network. In this case, they will be used on port 7051.

Step 3.1: Define couchdb by creating the docker-composecli-couchdb.yaml file

Section 1: Services

Section 2: Peers: In this peers section, it is explicitly indicated that the Couchdb database will be used for the peer states. Couchdb is an open source, NoSQL database developed by the Apache Foundation and used as the database in this proof of concept.

Section 3: Environment: This section defines the environment variables used.

Section 4: Volumes: The volumes section identifies a directory where the chaincode will be generated, located in the "chaincode" folder, so everything that is mounted locally will be mounted in the assigned folder. Chaincode is code that runs on the blockchain and is responsible for initializing and managing the state of the ledger as applications perform transactions.

Step 3.2 Generate deployment through Portainer to manage Docker

Portainer is an application that provides a graphical interface (GUI) for managing different containers, including Kubernetes and docker. To generate the deployment, use the following command: docker volume create portainer_data

Answer: portainer_data

Step 3.3: Activate Docker compose

In the exercise folder, some variables will be defined that will help to correctly activate the network:

```
darroya8@Daniel:~/pruebaconcepto/pruebaconcepto-network$ CHANNEL_NAME=$CHANNEL_NAME docker-compose -f docker-compose-cli-couchdb.yaml
 up -d

Starting orderer.test.com ... done
Starting couchdb2         ... done
Starting couchdb1         ... done
Starting couchdb0         ... done
Starting ca.org1.test.com    ... done
Starting peer0.org3.test.com ... done
Starting peer0.org1.test.com ... done
Starting peer0.org2.test.com ... done
Starting cli                 ... done
```

Figure 8: Docker-compose trigger response

Step 3.4: Enter portainer

Click on the containers tab and you will be able to see the containers that were lifted.

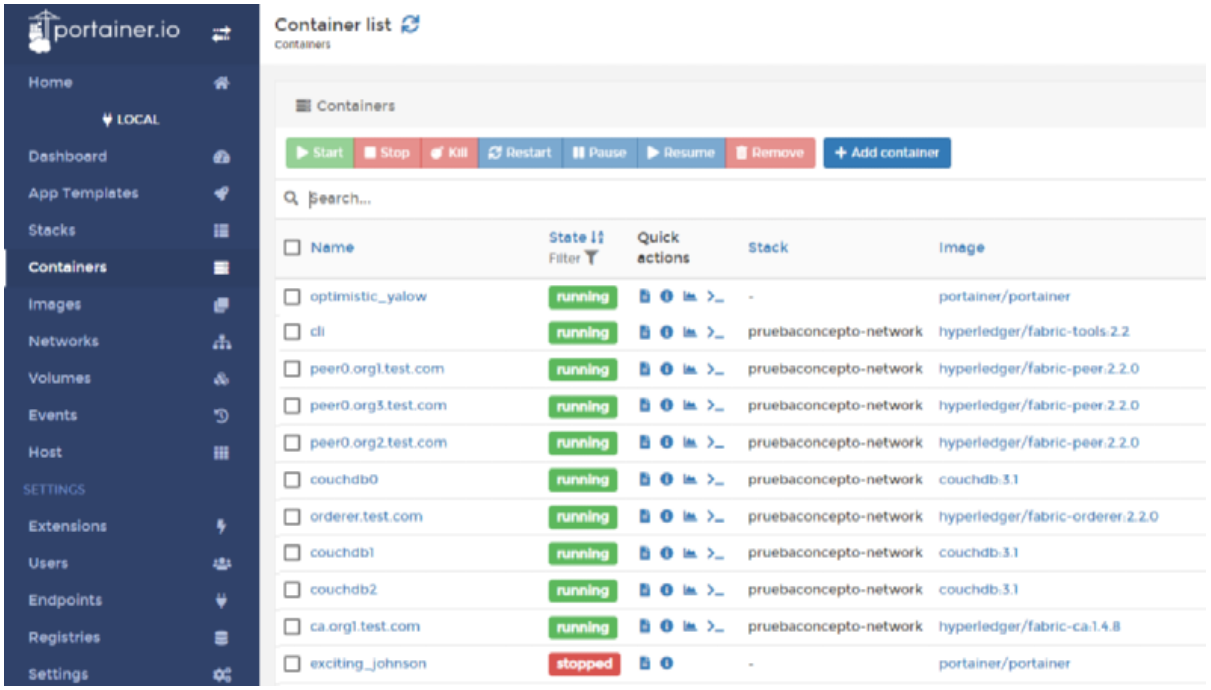


Figure 9: Portainer cover

Step 3.5: Command line operations (CLI)

You must go to the cli command and click on the icon shown in the image. Once clicked, the following console will open:

In this section, the channel will be created using the configuration defined in channel.tx. This file has the necessary settings to configure the channel.

The following commands are executed:

- export CHANNEL_NAME=marketplace
- Peer command
- Explanation
- Answer:
- Explanation
- Commands:

At this point, the configuration of the different components of the blockchain network using Docker is finished and, therefore, the network is ready to deploy smart contracts.

Step 4: Smart Contracts

Section 1: Generating the Smart Contract code

In this section, the smart contract is created, which will be programmed in the "Go" programming language. In Go, it is essential to define a base structure on which one will provide control and functions. Additionally, a structure that implements the "Contractapi" and all the functions that compose it must be defined.

To begin, a subfolder called "shipping" is created and then, in this folder, a file called "shipping.go" is created.

The scope of the smart contract will be one that allows the creation and consultation of the blockchain file. The "shipping.go" file is explained step by step below.

package main -> A package is defined

With the “import” value, some libraries necessary to execute the Smart

contract are defined. import (

"encoding/json" -> library 1

"fmt" -> Library 2

"github.com/hyperledger/fabric-contract-api-go/contractapi"

->Library 3: API control module to create the smart contract. It abstracts the use and implementation of “init” and “invoke”, additionally, it offers the possibility of implementing as many functions as we want and these functions are exposed directly.

Other important data:

It is necessary to have a file called "go.mod", which indicates which versions of the modules are being used within the project and defines the go version.

Likewise, you must have a file called "go.sum", which is created within the subsequent transactions and this indicates that exactly the same libraries and compilations of this network will be used.

Section 2: Deployment of the smart contract

To deploy the smart contract, you must return to the online command interface

CLI.

The first step is to generate the following environment variables:

export CHANNEL_NAME=marketplace -> channel name

export CHAINCODE_NAME=shipping -> chaincode name

When all the steps above are completed with their respective messages, it can be confirmed that the contract is now installed. The next step is to set the approval policies that have been defined for the chaincode. For this chaincode, Org 1 and Org 3 are able to approve transactions, sign transactions.

The following must be executed:

Organization 1

export CHAINCODE_VERSION=1 -> version name

export CC_RUNTIME_LANGUAGE=golang -> smart contract execution language

Step 5: Creating transactions on the blockchain network in Hyperledger Fabric

For this exercise, a series of 6 transactions related to the traceability of the cargo from the starting point to its arrival will be made to comply with resolution 67 of 2022 of the DIAN, point 6.3, which must be met to obtain the AEO certification: “Have tools that allow you to guarantee the traceability of the cargo, from the filling point abroad to the headquarters of the importer or the distribution point.” The image below illustrates each of the stages that will be included within this network for the import of a 20-foot container of 12-millimeter traction cable from the port of Busan, South Korea until the arrival of the merchandise at the facilities of a factory located in the city of Port of Tripoli, Libya.

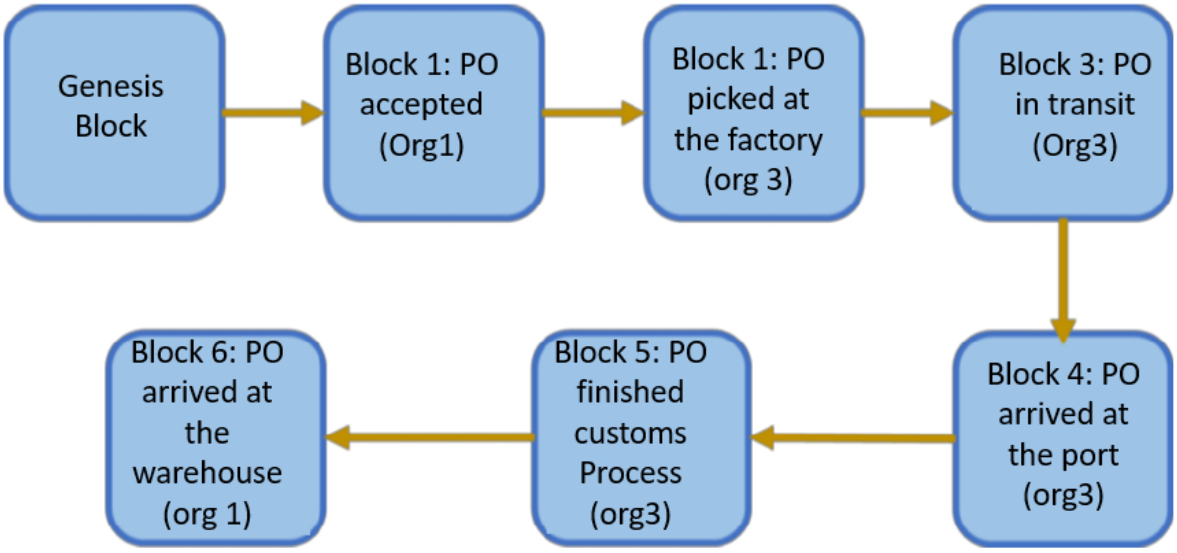


Figure 10: Proof of concept transactions Own creation

Below is the detail of each of the blocks

Table 2: Transaction details

Function	Definition	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
	Organization that created the bloc	Org1	Org3	Org3	Org3	Org3	Org1
Date	Date of execution	22-11-2021	21-01-2022	30-01-2022	05-03-2022	25-03-2022	28-06-2022
Xbuyer	Buyer name	XYZ company	XYZ company	XYZ company	XYZ company	XYZ company	XYZ company
Seller	Name of seller	ABC company	ABC company	ABC company	ABC company	ABC company	ABC company
etc.,							

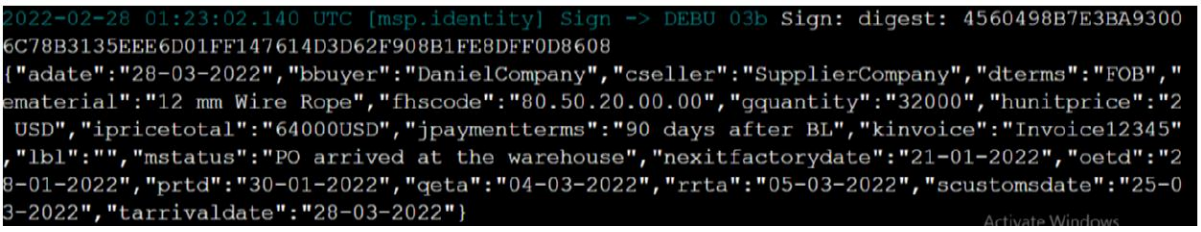


Figure 11: Tracking response

Step 5.1: Invoke transactions

Transaction 1: peer chaincode invoke -o orderer.test.com:

Step 5.2: Check tracking

From the command line interface – CLI –, proceed to use the second function included in the smart contract called "query", which allows viewing the status of the purchase order. In this case, it is shown that the import process has already finished since

Step 5.3: Others - Check if Organization 2 can generate changes.

Based on the policies established in the smart contract, organization 2 could not write. To check this policy, proceed with the given command:

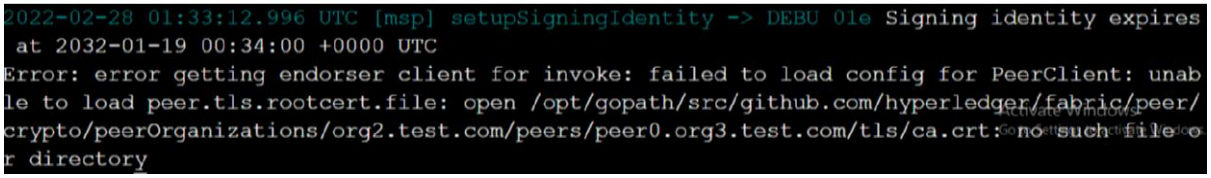


Figure 12: Response to error

4. Conclusions and final assessments

The application of Blockchain in the supply chain is a valuable opportunity to be applied for the following reasons:

- -As can be seen from the proof of concept, the application of private Blockchain guarantees that only the actors that are indicated can approve and carry out transactions within the network.
- -The application of Blockchain would allow Colombian companies wishing to be certified as Authorized Economic Operators to guarantee that the law is applied by guaranteeing all computer traceability from the beginning of the purchase order, to the payment and arrival of the merchandise.
    - The application of this technology will allow external auditors to verify the veracity of the information in a more agile way.
    - To apply private Blockchain technology, an agreement is needed between all parties that wish to view and participate in the transactions so that this can be applied in the business field.

Since the scope of this project consists of carrying out a proof of concept to demonstrate its applicability within the supply chain, the following scenarios could be considered for future studies:

- -Generate a code that considers user experience so that the impact that this type of technology could provide can be observed within a business environment.
- -Analyze the economic and financial variables that justify the investment of this type of technology in an organization.

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