A survey on the available blockchain platforms and protocols for Supply Chain Management

Michael Xevgenis[1][0000−0002−4630−1082], Dimitrios G. Kogias[3][0000−0001−8985−6136], Helen C. Leligou[1][0000−0002−1489−1495], Christos Chatzigeorgiou[2][0000−0003−2486−9897], Michalis Feidakis[2][0000−0002−6412−8420], and Charalampos Z. Patrikakis[2][0000−0003−1921−4466]

[1] Department of Industrial Design and Production Engineering, University of West Attica, Egaleo, Greece
{mxevgenis, e.leligkou}@uniwa.gr
[2] Department of Electrical and Electronics Engineering, University of West Attica, Egaleo, Greece
{chrihatz, m.feidakis, bpatr}@uniwa.gr
[3] Technical Department, iTrack Services Ltd., Piraeus, Greece
dimikog@itrack.gr

Abstract. Capabilities of the blockchain technology are beginning to be explored, beyond their use in cryptocurrencies. Recently large companies, like IBM and Walmart, are collaborating on creating blockchain solutions that will be implemented on various use cases of Supply Chain Management, to increase the system's credibility and ease the tracking of the products in the chain, introducing a level of transparency that is desired by the involved parties. This paper presents existing applications of blockchain in Supply Chain Management and assesses on the design criteria that should be considered by any interested party that wants to develop and apply a blockchain-based solution.

Keywords: Blockchain · Supply chain · platform · Distributed protocol · public · private.

1 Introduction

With the hype around the use of crypto-currencies slowly transforming from enthusiasm for the "new-kid in town" to common use and reality, the underlying blockchain technology gains the attention of both industry and academic communities to leverage its great potential. To this end, efforts take place to discover novel applications for the, still evolving, blockchain technology in various areas of interest, most of which affect the daily humans lives e.g., on public services, supply chain and many more.

Supply Chain Management (SCM), particularly, is one of the areas whose performance will be substantially affected by applying blockchain technology [1], [2], [3], as this be explored and justified in this paper. At the same time, blockchain is not a panacea nor should it be applied to all domains just because it is at a

hype. The authors in [4] propose a flow chart to help people/organisations decide whether a blockchain-enabled solution should be considered for implementation, anticipating a substantial boost in their use case and, also, guide them to define the kind of solution that could be applied (e.g., private vs. public Blockchain). This chart, in line with others [5], [6], suggests that SCM is such a case where blockchain technology can offer a significant boost. For SCM, we consider multiple organisations maintaining and processing information currently in isolated data silos which are difficult to interconnect due to multiple reasons from lack of trust among the involved parties, implementation of heterogeneous proprietary solutions to vulnerability to attacks (e.g. attack the database of a product provider).

Blockchain is expected to offer a unified framework, to be used by all the many participants in different stages of the SCM (as described later) [7], [8], [9], with many possibilities and numerous benefits including, but not limited to:

- The creation of an immutable system where information is stored and protected by cryptography, consensus and timestamps. As a result, this immutable nature of the SCM ledger enhances the willingness of the suppliers to participate in the process and add their data to the Blockchain.
- The introduced transparency across all the stages of the SCM system increases the level of trust in its performance which leads to increased trust both between the partners and between partners and end users/consumers.
- The use of the ledger for detection and tracking of any token/asset (i.e., packet or animal in the Blockchain) along with detection of any anomalies or gaps in the management process throughout its life-circle. Origin verification can, also, be applied in the chain since the trace can be followed back to its roots from any user in the Blockchain. An example where such an approach is needed is for tracing the farm where specific animals have been affected by a virus that has, also, harmed humans.
- The use of Internet of Things (IoT) devices that connect and fuel the Blockchain directly with data, without any human intervention in the process increasing the integrity of the process.
- Increased system security since any device can enter the system, encouraged to follow the rules, because there will be no gain going against them, while strengthening the overall system defense. The latter is enforced by the number of participating nodes due to its decentralized nature and the need to control over 50% of the nodes in case of an attack [10], for it to be able to succeed a breach in the system.
- Smart contracts implementation to trigger actions based on the data that are stored in the Blockchain. Usually, those contracts apply to initiate instant payments or/and alerts, supporting the automation in the system based on secured and processed data in it.
- New digital experience and services for the products and SCM with the end-user's role and control over the process being enhanced significantly.

At the same time, in order to use blockchain to address SCM's (or, otherwise, *asset chain's*) operations, a process that represents any asset to the digital

world, as a token that can be stored, processed and transferred on a Blockchain is needed. This process, also known as tokenization [11], is of fundamental importance for all the solutions that deal with SCM. Keeping in mind that SC includes various smaller stages ranging from raw materials, suppliers, manufacturers, distributors, retailers to end-user/ customers, a Blockchain platform might be designed to cover the whole process, at least for a specific use case scenario. Otherwise, co-operation between different blockchain implementations is needed to provide for a complete solution for SCM, as this will be further discussed in later sections. Figure 1 illustrates the stages that are included in SCM, along with possibilities/benefits that are born from the use of blockchain.

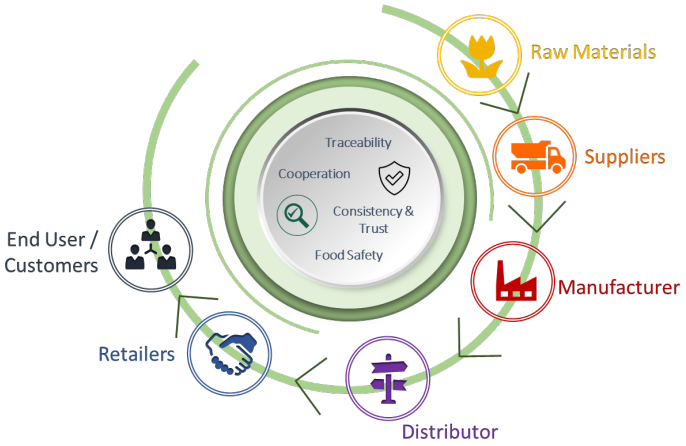

Fig. 1. SCM's circle with stages and benefits/possibilities from using blockchain

The contribution of this article is to survey the available blockchain platforms and protocols that can be used to develop blockchain-enabled solutions for SCM which is included in section 2 and their evaluation, classification and discussion of the way they address diverse SCM requirements in section 3. Finally, in section 4 conclusions are drawn.

2 Blockchain Platforms and Protocols used in SCM: Characteristics and Applied Use Cases

With the number of available solutions for SCM rising quickly, several ones are attempting to cover a specific use-case all over the SC while others to propose a common framework and bridge the gap to create a common understanding, blockchain-based "language". While a blockchain platform consists of all the software and hardware required to deploy the distributed ledger, a blockchain

protocol is any tool enriching the functionality of the blockchain platform (e.g., Ambrosus protocol).

To this end, the methodology followed in the current survey is described as:

1. The collection and examination of the most popular blockchain solutions used for SCM took place and those that provided the most promising technical results were selected.
2. The selected solutions were divided in two categories: platforms and protocols and a detailed analysis of their functionality took place where their key characteristics and their use in different SC sectors was highlighted.
3. Finally, an assessment is generated for the solution to be selected based on three key characteristics: the type of Blockchain, the support of an IoT ecosystem and the use of a Single Ledger for the data of the full SC cycle or use of individual ledgers for parts of it.

2.1 Platforms

CargoX

CargoX [12] kicked off in January 2018 and has already over 10.000 individuals and companies from 95 declaring their interest in contributing to the project. CargoX refers mostly to the *shipping industry* and focuses on the *Bill of Landing (B/L)* creation, distribution and management. The goal of CargoX solution is to digitize the B/L and distribute it with a secure manner in order to guarantee the integrity of the information.

CargoX is based on the Ethereum public Blockchain to benefit by the vast processing power which secures the consensus mechanism of one of the largest public Blockchains. CargoX transactions, which are transfers of B/L, are stored in Ethereum where users' identities are obfuscated by their blockchain addresses. The partners which share the same B/L know the real identity of the involved partner, while the content of the B/L document is visible only to them. Partners who are not involved cannot access the information regarding the B/L document, as it is securely encrypted.

In order to provide extra motivation for interactions between partners, CargoX provides: a governing body comprised of industry leaders, *CargoX B/L eXchange Protocol* for the exchange of B/L documents and *CargoX dApp*, a web-based decentralized application allowing customers to interact with Smart B/L digital document. Addons and functional enhancements of the Smart B/L from third parties is, also, allowed. Finally, CargoX Credits are used as cryptocurrency for performing the desired transactions.

IBM Food Trust

IBM Food Trust is a blockchain solution developed by IBM and its main application area is the food chain. The development of this solution aims to solve traceability and management problems by introducing the use of blockchain technology for the food chain.

IBM Food Trust provides participants with a permission-based, shared view of food ecosystem information, allowing convenient data publishing and controlled sharing of information. To achieve this goal, IBM Food Trust solution enables participants to enter and control access to their encrypted blockchain data. However, transaction partners can only access the data they can view. ***Access controls mechanisms*** embedded into the solution, ensure that the organization that owns the data maintains full control over who can access it on the network. IBM Food Trust solution users can quickly locate items at the SC, in real time, by *querying food product* identifiers such as Global Trade Item Number (GTIN) or Universal Product Code (UPC), using the product name, and filtering on dates. Finally, it is based on the HLF platform, which is a permissioned Blockchain developed by IBM. A solution that does not use cryptocurrency.

Modum

Modum [13] is a start-up founded in 2016 in Switzerland which offers blockchain-enabled SC solutions. It initially used Ethereum's public Blockchain for its pilots, however Modum is open to cooperate with other blockchain platforms which can be permissioned and free of transaction fees. This makes it perfect candidate for liaising with other Blockchain implementation along the SCM. Considering that Ethereum platform was used at the initial release phase, Modum uses the *Proof of Stake (PoS)* consensus.

Additionally, Modum uses a temperature monitoring component called MODsense that is placed in sensitive shipments. This module is connected to the MODsense web application which offers instant notifications for temperature excursions. Customers do not need to install extra hardware in order to use the solution because they only need to download the mobile application. Finally, Modum uses MOD Tokens for providing extra motivation to developers in order to join the community and increase its power. Modum is mainly used in cold chain but it can also support vaccines' distribution and food chain use cases.

Tradelens (IBM Maersk)

Tradelens was launched in 2018 and it is the result of the collaboration between IBM and Maersk, in order to create a blockchain based SC platform. It is based on the IBM's project called *Hyperledger Fabric OASIS*, which is a private Blockchain that does not use any form of cryptocurrency. The goal of this solution is to *empower businesses and authorities along the SC with a single, secure source of shipping data, enabling more efficient global trade*. The presented solution consists of three layers:

- Network layer: that consists of network shippers, forwarders, ports and terminals that together bring a wealth of information that can be tracked, stored and shared across the ecosystem.
- Platform layer: that is located above of the network's data and manifests itself into a dynamic, functional medium. This open platform is underpinned by HLF Blockchain, creating an end-to-end audit trail of important shipment information and a secure vehicle to share critical documentation.

- Application and services layer: which leverage the network and capabilities of the platform. As a result, a new marketplace is born that will serve the needs of the whole TradeLens ecosystem by offering an open medium where anyone can build, use and sell applications to their own customers to fit the ecosystem's needs, now and into the future.

Tradelens follows the consensus of Hyperledger Fabric and is designed to satisfy the requirements of the most demanding SCM applications, as Maersk is one of the global shipping leaders.

Waltonchain (WTC)
Waltonchain project was kicked off in 2016 in China and its name derived from the inventor of RFID technology, Charlie Walton. This project combines two trend technologies: blockchain and IoT, in order to develop solutions for SCM applications. Waltonchain solution consists of two major components:

- the Hardware component (an RFID chip) and
- the Blockchain network, divided in the parent chain and the child chains.

The RFID chips gather and upload data to the Blockchain and, also, perform hash-and-signature-based data self-verification for authenticity and reliability of the data sources. Moreover, the RFID device has independent intellectual property rights and can collect data, process it and upload to Blockchain automatically.Waltonchain has its own parent Blockchain which is an Ethereum Blockchain that uses the Waltonchain Proof-of-Contribution (WPoC), component that uses three consensus mechanisms: Proof of Work (PoW), Proof of Stake (PoS), Proof of Labor (PoL).

The PoS and PoW are used on the parent chain and ensure that parent chain blocks are unique and secure. PoW offers reliable data protection through hashing power but is does not prevent the risk of 51% attacks and lacks environmental protection and energy saving. Therefore, the use of PoS is introduced in order to reduce wasting of calculation resources and the risk of 51% attacks. The PoL is a new consensus mechanism introduced for the data transmission and token exchange among various parent chain, child chain and cross-child-chain nodes on Waltonchain network.

Furthermore, the Waltonchain supports smart contracts running on popular Blockchains, such as the HLF and Ethereum. As a result, child chains with different architectures are offered to cover many different scenarios. The Waltonchain project uses the WTC as its cryptocurrency, following a very similar logic to Ethereum and Gas. Finally, Waltonchain is used at tracking and managing food products and in clothing traceability.

2.2 Protocols

Ambrosus
Ambrosus protocol [14] was initiated in 2017 in Switzerland and its goal is to

offer a blockchain-based ecosystem for SCM in order to ensure the origin, quality, compliance and proper handling of items tracked by the platform. Ambrosus is an end-to-end solution which includes hardware, software, a protocol layer and development tools. Ambrosus protocol and its software run on top of Ethereum and adopts the PoS consensus algorithm, inherited by Ethereum. Ambrosus solution consists by three main components:

- The AMB-NET, which is the combination of Blockchain and Ambrosus software,
- The hardware, that consists of plug-and-play sensors and IoT devices which transmits data to AMB-NET, and
- The Amber (AMB) which is a token.

The AMB token is used as a payment for transactions in the AMB-NET, but also accompanying an asset from the beginning of its journey to the arrival on its destination representing it, therefore, on the Blockchain. Transactions based on fundamental usage of the system incentivize people to acquire tokens and give the network value. A certain portion of Amber must be pinned to an item, and then, as that item moves through the SC, information about how that item is handled and where it has been attached as metadata on that token. The token cannot be traded or exchanged so long as it is tied to a product. Although, Ambrosus can be used in many SCM use cases, however it is designed to cover the most fundamental sectors such as food chain.

OriginTrail(TRAC)
OriginTrail [15] is a protocol that was initiated in 2013 at Serbia, and its goal is to allow providers in SCM to set up blockchain-supported data-sharing. In contrast to other solutions, OriginTrail emphasizes on using common data standards for the exchange of data between the involved partners, while using the *blockchain as a platform* to ensure data integrity. In addition, an off-chain, decentralized peer to peer (P2P) network, called the *OriginTrail Decentralized Network (ODN)* is created. ODN enables peers to negotiate services, to transfer, process and retrieve data, to verify its integrity and availability and reimburse provider nodes. As a result, the size of the data stored in the Blockchain is reduced in order to minimize cost and inefficiency. The system data correspond to a cryptographic hash that is generated and stored on the Blockchain at the time of arrival. This hash is used to prove the integrity of the data by comparing it to the newly generated hash from the same data in ODN.

OriginTrail uses the Ethereum Blockchain, but it is designed to provide interfaces to many other Blockchain platforms. The ODN uses a consensus "check" procedure that consists of three steps:

- Each stakeholder gets approved by the previous and the following one,
- The information regarding the batch is verified (i.e., identifiers, timestamps and transaction data).
- The organizations confirm the data verifying their validity.

TRAC solution uses the Trace token as a cryptocurrency needed for the execution of ODN's functions and its maintenance. However, OriginTrail runs also on additional blockchain platforms such as Ethereum, where an extra cost is added, and Ether cryptocurrency is used. Finally, OriginTrail is mostly used in food chain industry, but it is also designed for many logistic use cases.

3 Assessment

Blockchain can be used in SCM to satisfy diverse purposes. Each purpose imposes different challenges and requirements which can be met by blockchain technology. To guide the prospective designer of a Blockchain select the appropriate basis for his/her solution, we have tabulated their different characteristics in Table 1. Three main characteristics of the presented platforms and protocols need to be carefully addressed based on the intended use:

- the right to access the Blockchain,
- the support for an IoT ecosystem, and
- the support for a unifying Blockchain.

Design choice 1: Private vs. Public and its business - economy relevant challenge. To decide between a private or public Blockchain platform, the solution designer has to answer the question: "Is there a single organisation that is responsible for the operation of the Blockchain and for authenticating the nodes? Who owns and operates the nodes?".

When a Private solution is implemented every member of the Blockchain is authorized to join the network and is permitted to read the ledger, transact and participate to the consensus procedure. The capabilities of a member are restricted by the rules that have been set by the system. On the other hand, in Public Blockchains, everyone can join and participate in the network without needing for a permission. Public Blockchains have also the advantage of being popular solutions due to the presence of Bitcoin and Ethereum. However, the interest regarding the design and implementation of Private blockchain platforms, such as HLF, currently presents a significant growth.

While a public Blockchain should cover all the stages of the SCM with basic details, private Blockchains seem appropriate to be used in a single-stage of the SCM, focusing on more performance-specific data of the involved actors of that stage that could be used for improving their performance and, therefore, the system's. Both Blockchains need to work supplementary with primary focus given in the public implementation to be able to satisfy the needs of all the actors in the SCM. Table 1 shows that both private and public Blockchains have been developed and proposed worldwide.

Design choice 2: IoT-generated information in the SC relevant to elaborate tracking and food security. To decide whether an IoT-capable Blockchain must be implemented, the prospective designer must answer the question - "are IoT

–generated information automatically stored in the ledger?". A positive answer is more likely in the food and pharmaceutical SCs and mandate that large amounts of "transactions" must be supported, which challenges the scalability and energy efficiency aspects of the blockchain technology. This has fueled efforts for developing Blockchains (e.g., Ambrosus) that store the data captured by sensing/actuating devices combining IoT systems with blockchain. However, the designer must be careful as many of them support proprietary IoT devices which currently impede their wide deployment. The challenge thus moves in the interconnection of IoT-fueled ecosystems with Blockchains to serve SCM requirements and operations.

Design Choice 3: Need for communication between different Blockchains, supporting various use cases of SCM or not. Most of the solutions found in Table 1 can support a reported use case throughout the life cycle of the asset on demand. Even though different kinds of data are appended at each stage on the Blockchain, interoperation actions are offered from many solutions in Table1. Furthermore, the need to interconnect two (or more) discrete Blockchains, covering different use cases of SCM, is starting to arise and Blockchains that play the role of a middleware are being studied and developed. While one could think of the challenge to be already solved with the InterLedger Protocol, this is not the case because current implementations of ILP focus on transactions which are much simpler to handle (i.e., the transaction type remains the same and thus it is a transformation of currency) while in SCM more complex information management is needed. On the contrary, Waltonchain offers a parent Blockchain (public) and child chains that interoperate through the parent one.

Table 1 summarizes the basic characteristics of all the platforms and protocols that have been presented in Section 2, while providing added information that could enhance the design choices presented above. It is easy to understand that a one-solution-to-fit-all approach cannot be expected, but there are options that provide increased possibilities and benefits, depending on the case.

4 Conclusions

The use of blockchain technology for SCM has been studied in this paper, by presenting existing, well-known platforms and protocols, emphasizing on the design criteria and requirements that each one meets. The scope of the survey is to help those that decide to trust blockchain for their work and who believe on the benefits that this technology will have on it to make critical decisions regarding the form and functionality of the Blockchain that they should implement. Table 1 summarizes the main characteristics that each of the solutions discussed here possesses, and it can be used, additionally, to help on deciding the Blockchain to be implemented in each use case.

Table 1. Summary of the characteristics of the presented blockchain Platforms and Protocols

Name	Platform/ Protocol	Private/ Public	Consensus	Crypto currency	Proprietary Hardware	Clients/ Partners	Use cases (SCM related)	Other Use cases (No SCM related)
Ambrosus	Prot.	Pub	PoS	Yes	Yes	EIT Food, Sustainable Food Systems Program	Food chain	Pharmaceuticals
CargoX	Plat.	Pub	PoS	Yes	No	MAKER, OCEAN, MILSPED GROUP	Sea shipping industry and B/L	-
IBM Food Trust	Plat.	Priv	Hyperledger Fabric	No	No	Carrefour, Walmart, Nestle	Food chain	-
Modum	Plat.	Pub	PoS	Yes	Yes	SAP, AWS	Cold chain	Food chain
OriginTrail	Prot.	Pub	Own consensus	Yes	No	Natureta, BTC Logistics Center, Perutnina	Food chain	Logistic applications
TradeLens	Plat.	Priv	Hyperledger Fabric	No	No	Modern Terminals, Port of Halifa, Seabord Marine	Most SC use cases	-
Waltonchain	Plat.	Pub	PoW, PoS, PoL	Yes	Yes	Silitec, LALABOBO	Food chain	Clothing

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