The State of the Art of the Electronic Bill of Lading

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ABSTRACT
The shipping industry is widely regarded as a slow adapting industry, for any innovation to be made there needs to be a real demand. One of these innovations is the electronic Bill of Lading, the need for an alternative to the expensive and slow traditional Bill of Lading has been rising since the beginning of the century. Now the digital revolution naturally introduced the electronic Bill of Lading, but its unclear legal status and different regulations in different countries make it hard to establish a worldwide solution. This paper aims to provide information about the most relevant providers of electronic bills of lading focusing on the underlying technology in order to make a grounded analysis about each solution individually and in general. Some of the challenges encountered by the electronic Bill of Lading are the lack of trust and investment in innovative technologies, such as blockchain. But, it also shows promising aspects such as increased resiliency and security along with a much faster issuance and transfer for lower direct and indirect costs.

KEYWORDS
Shipping; Electronic; Bill of Lading; Blockchain; Energy; Environment

1. Introduction

The growing need for goods around the world has demanded innovation from the shipping industry in the last centuries. The shipping industry has also been a target of the digital revolution, the Bill of Lading is naturally included. The Bill of Lading is an essential legal document to move a freight shipment, it as three main functions: a receipt, a contract between a carrier and shipper and a document of title. These functions make it challenging to digitalize it.

In the last decades several attempts were made in the digitalization of this document. None of the attempts has achieved widespread adoption, but in the last years the trust in technology and its evolution has given more confidence in these solutions.

2. Bill of Lading

The movement of goods between countries has always raised the problem of ownership: who owns the goods when they are being transported from the seller to the buyer?

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Therefore, a document that could provide evidence of ownership of goods and proof of the contract of carriage was necessary.

2.1. Brief History

The history of the Bill of Lading was "contemporaneous with that of the carrier" (Mclaughlin, 1926). There is clear evidence of the use of a similar document to a Bill of Lading in the Roman empire. But, the modern Bill of Lading, as we know it today, originated in the eleventh century with the rise of great commercial cities in the Mediterranean. With problems arising between shippers and ship masters as to what goods were delivered, the need for an unquestionable proof also started to appear. Cities started to pass statutes that required every master to take a clerk obliged to take an oath of fidelity, and to enter in a register a record of the goods received from the shipper. In the fourteenth century another statute was introduced, which stated that if the register was at some point in possession of someone but the clerk, nothing it contained should be believed.

Until this the Bill of Lading did not exist, it was a book. The bill started to appear as a result of a statute that required clerks to give a copy of their registers to those who have the right to demand them, the master or owner.

In the sixteenth century the Bill of Lading started to appear in a form similar to the existing today. Toward the end of the century the use of the Bill of Lading as widespread. In the early seventeenth century a statute passed in France defined the Bill of Lading as an acknowledgment, given by the master, of the quantity of the goods loaded and also required marks of the merchandise, condition, name of the consignee and the amount of freight. Also, three copies should be issued, one for the shipper, one for the master and one to be sent to the consignee via another ship. Later, for a bill of a lading to be accepted as evidence it would have to be executed by a public notary instead of a clerk.

There was no statute law relating to bills of lading until mid nineteenth century. In 1855 the British Parliament passed the Bill of Lading Act, and most other countries engaged in international trade later adopted similar legislation. This act established the three functions of the Bill of Lading:

- Receipt for goods: When a carrier issues a Bill of Lading, it is confirming that goods have been loaded onto the transporting vessel. The receipt covers quantity and apparent quality of the cargo.
- Evidence of Contract of Carriage: The reverse of the Bill of Lading contains evidence of a 'contract of carriage' and may contain terms and conditions which are the whole contract. It is only 'evidence' because the Bill of Lading is only issued when the goods are received by the carrier, but the agreement of the transportation of goods would be already made at that time that is the moment the contract is established.
- Document of Title: As soon as the Bill of Lading has been signed for the carrier, the consignee can claim the goods as soon as they arrive at the destination port. If the consignee so wishes, it can endorse the Bill of Lading transferring the right – the title to the goods – to another party, as stated in the Bill of Lading Act. This will transfer the rights and liabilities under the original contract of carriage to the new owner of the goods. This endorsement may occur any number of times. As a document of title, it can be used as a security of payment and it is a vital document among others required for a letter of credit.

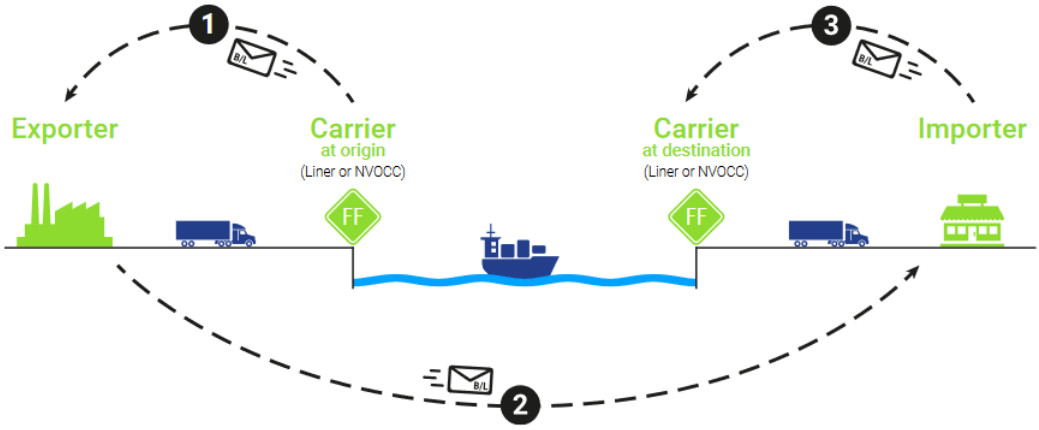

Figure 1. Typical life cycle of a Bill of Lading (CargoX Ltd, 2021)

Several international rules – not only, but also focused on the Bill of Lading– were proposed over the years, like the Hague Rules in 1924; an updated version was introduced in 1968 (UN, 1979). These rules were criticized for covering only transport by sea, ignoring multi-modal transports, and not recognizing the container revolution; other critics focus on the vulnerable law structure, arguing that it is greatly in favor of the vessels' operators when compared to the shipping companies. The Hamburg Rules (UN, 1978), provided a more modern approach and tackled the bias toward ship operators in the Hague-Visby rules.

The Rotterdam Rules, adopted in 2008, is a treaty that proposed new international rules, in contrast with the existing conventions. These rules also apply to multi-modal transports that involve an international sea-leg and also deal with issues not covered at the time in international law.

The Rotterdam Rules include a chapter dedicated to electronic records in view of the continuous development of systems and technologies that allow the replacement of paper documents – like the Bill of Lading – with electronic records. The provisions introduced aimed to regulate a possible replacement since at the time of creation there was no great success in the area (Berlingieri, 2009).

The diagram in Figure 1 shows the typical life cycle of a modern Bill of Lading.

2.1.1. Types of Bills of Lading

Bills of Lading can be described as negotiable or non-negotiable. Negotiable Bills of Lading provide clear instruction to deliver the goods to anyone in possession of the bill, which itself is a title to the goods. Non-negotiable Bills of Lading have a specific consignee to whom the goods are to be delivered; only it can claim the cargo at the destination.

Despite this, there are several other types of Bills of Lading, some negotiable, others non-negotiable:

- **Bearer Bill of Lading** A bill that states that delivery shall be made to whoever holds it. May be created explicitly or it is an order bill that failed to nominate the consignee whether in its original form or through a blank endorsement. This bill can be negotiated.
- **Order Bill of Lading** This bill uses express words to make it negotiable, this

means that delivery is made to the order of the consignee using words such as "to order". The cargo will be delivered to the bonafide holder of the Bill of Lading. As it is made "to order" of the consignee, it is a negotiable document of title. This bill is commonly used when goods have not been paid, in this case the intended consignee is identified as a notify party.

- **Straight Bill of Lading** The goods are consigned to a specific entity and it is not negotiable. This type of bill is also known as non-negotiable, and from a bank's perspective it is not safe. Because of this, it is mainly used in military cargo.
- **House Bill of Lading** A Bill of Lading created by an Ocean Transport Intermediary (OTI), for example, a freight forwarder or a non-vessel operating carrier (NVOC), that is issued to the supplier once the cargo is received. The shipper is the actual exporter of the cargo, and the consignee will be the actual importer of the cargo.
- **Master Bill of Lading** A master Bill of Lading is issued by the carrier, which is a ship owner or operator. The shipper is usually the NVOC or their agent of the freight forwarder. The consignee is usually the agent, NVOC, or freight forwarder in the port of discharge that assists with the transaction.
- **Shipped Bill of Lading** A Bill of Lading that is issued when cargo is loaded on the vessel. Sometimes referred to as "on board" bills.
- **Received for shipment Bill of Lading** This bill differs from a shipped Bill of Lading in not stating that the goods received have been loaded on to a vessel. It is only recorded that the goods were received for shipment.
- **Through Bill of Lading** It is typically used when the main carrier undertakes a portion of the carriage, for example, the sea leg, but also undertakes to arrange, as an agent, an additional leg, for example the road portion from the discharge port.
- **Combined transport Bill of Lading** The combined transport Bill of Lading evidences a contract between the cargo owner and the carrier, where the carrier agrees to arrange transport of the goods between two points, even if the route between the two points involves a series of stages of sea carriage or other means, such as road or rail.
- **Clean/Claused Bill of Lading** If the ship owner raises an objection about the condition of the cargo, they can clause the Bill of Lading along with the cargo condition, making it a claused Bill of Lading. Otherwise, it is a clean Bill of Lading.

2.2. Bill of Lading clauses

The usual items that appear on the face of normal bills of lading are:

- Name of the shipper: the first party of the contract of carriage, that is why it should be the name of the cargo owner and not of an agent
- Name of consignee or 'to order' and notify party: it can be filled with the name of the consignee or the words "to order" and the name of a "Notify party" below it. This is done when a documentary credit is used to negotiate a Bill of Lading, then it is an order Bill of Lading.
- Ship's name: the name of the carrying vessel. If another vessel is used in the transport of the goods, usually the one that carries out the deep sea or main leg voyage appears in this space.

- Place of receipt / Port of loading: Place of receipt will appear depending on the type of transport or bill, port of loading should always be present. With multimodal, combined transport bills or through bills, the place of receipt is also shown.
- Port of discharge: Port of discharge is always shown, and in the same way, in the case of multimodal, combined transport or through bills, place of delivery should also appear.
- When and where freight to be paid: "freight paid", or "payable at destination" often called "collect". The Bill of Lading is not totally a document of title until the freight is paid and the Bill of Lading is endorsed by the carrier with the words "freight paid".
- Number of original bills of lading: only one is necessary but usually two or three exist.
- Full description of the cargo: marks, which are used to identify packages in LCL (Less than Container Load), container numbers and container seal numbers appear here. Also, number and kinds of packages, for example, three containers and two cases. And weight and measurement; weight is crucial in the stowage of the ship; the measurement is more relevant in LCL cargo. It is important to describe the contents of a package in a way that satisfies the letter of credit but also avoiding including anything that might suggest value.
- Place and date of the issue of the Bill of Lading: in the case of a received bill, it is the date the goods were received for shipment; if it is a 'shipped' Bill of Lading, the date the goods were loaded
- Signed "for the carrier": the signature must identify the carrier and if the bills are signed by an agent on its behalf. This signature converts the bill into a document of title of goods.
- Printed clauses: this is the described evidence of contract; on the reverse of the bill the terms of the contract are spelled out.

3. Blockchains

Before introducing the electronic Bill of Lading, it is important to look into blockchains since they are the base technology for some of the solutions. In 2008, Satoshi Nakamoto, whose true identity is still unknown, released a whitepaper (Nakamoto, 2008) that described "a peer-to-peer electronic cash system" with the name Bitcoin, he introduced the term chain of blocks. Satoshi Nakamoto remained an active developer in the Bitcoin community until 2011, when it handed over Bitcoin development to its core developers. In the meanwhile, the expression *chain of blocks* evolved into the term blockchain. Bitcoin became the first ever conceptualized blockchain and also the biggest to this day. Blockchain has developed into one of the biggest ground-breaking technologies today, it has the potential to impact every industry from finance, supply chains to even art.

Blockchain can be seen as a large decentralized database that stores information of transactions securely and allows users to interact with others without the need of any trusted third party. Technically, the blockchain acts as a ledger that records and tracks resources without requiring a centralized trusted authority. It allows for the sharing of information between parties within a peer-to-peer network. Nowadays, the resources can material like money, houses, land, etc. Or immaterial like digital documents, digital art, intellectual property rights, etc. Blockchain provides a different way of storing data

with a "chain of blocks" using cryptography to ensure integrity of the data stored.

A Blockchain is managed by a network of nodes connected over the Internet; any device connected to the Internet with an IP address can be a node in the blockchain. Since it is a distributed network, all nodes are equally important, but may have different roles in order to make the blockchain work properly. A node can store information that is on the blockchain or a copy of all the information recorded. Nodes can also process transactions, place them in blocks, append them to the blockchain, approve them, and finally send them to the network.

3.1. Properties

A good technical definition for blockchain is that it is a "peer-to-peer, distributed ledger, that is cryptographically secure, append-only, immutable, and updateable only via consensus or agreement among peers" (Bashir, 2018). To understand this definition, it is important to understand some of its properties.

From all blockchains developed it is possible to identify common properties in most of them that make it suitable for many applications in different industries. The most important are presented below.

3.1.1. Peer-to-peer

It refers to networks that use a distributed architecture. All members of the network are referred to as peers, each peer in a peer-to-peer network is equal to other peers and each has the same rights and duties as others. Peers are both clients and servers at the same time.

3.1.2. Distributed

A distributed ledger can be described as a ledger of any transactions, maintained in a distributed form across the network among all peers in the network.

3.1.3. Decentralized and Updateable via consensus

Since in a peer-to-peer network peers are all equal to each other, there is no central authority. In a centralized transaction system, a mediator is necessary to provide the transaction services. An example of this is a bank, it acts as a central authority and everything has to go through it; this gives the central authority full control of the system. Decentralization is the transfer of control and decision-making from the central authority to a distributed network[1]. Without a central authority, it is necessary to have a consensus mechanism so different network nodes can validate transactions. Any update made to the blockchain is validated and added only after consensus is reached among all participating peers. In order to achieve this consensus, there are different consensus algorithms which ensure that all peers agree about the final state of the data.

[1]What is Decentralization in Blockchain?, `https://aws.amazon.com/blockchain/decentralization-in-blockchain` [Accessed on March 2022]

3.1.4. Cryptographically secure

A cryptographically secure ledger uses cryptography to provide security services. These services include non-repudiation, data integrity, and data origin authentication.

3.1.5. Anonymity

Any user in the network can communicate with other users using their public address, much like explained in public key cryptography, it is not possible to identify a user using its public address. Therefore, even though the system is transparent, the anonymity of the user is maintained.

3.1.6. Transparency

All transactions in a blockchain are public and visible to anyone who is a part of the network, a network participant can access holdings and transactions of public addresses, this is what makes the blockchain transparent (Jung, 2019). This type of transparency never existed in centralized systems.

3.1.7. Persistency

When validating transactions, it is possible to identify invalid transactions and stop them from being inserted into a block. Once transactions are connected to a block, it is not possible to remove or reverse them. There are some legitimate motivations to remove data once it has been added, such as the right to erasure ('right to be forgotten') defined in the General Data Protection Regulation (GDPR) (European Union (EU), 2016).

3.1.8. Append-only and Immutable

Data can only be added to the blockchain time ordered. This property implies that once the data is added to the blockchain, it is almost impossible to change it and can be practically immutable. There are rare scenarios where data can be changed, when there is collusion against the network and 51 percent of the power is obtained by an organized group.

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3.2. Blockchain types

In this section, different relevant types of blockchains will be analyzed from a technical and business perspective.

3.2.1. Distributed ledger

Before defining different types of blockchains it is important to understand the concept of distributed ledger. A distributed ledger is a broad term used to describe shared,

distributed databases, it encompasses all sorts of structures, such as the blockchain, which is just one type of distributed ledger.

Blockchains have two additional distinguishing factors from all other types of distributed ledgers. The data is organized in a block structure and it has a particular sequence. In order to keep the blockchain ledger growing, data is stored in a block and it is attached to the previous block maintaining a sequence. There are technologies using block structures that are often called blockchains due to the popularity of the term, but this is not enough to call it a blockchain, the sequence of data is also necessary. The important takeaway is that all blockchains are distributed ledgers, but not all distributed ledgers are blockchains.

3.2.2. Permissioned Blockchain

A permissioned blockchain can be seen as an additional security system, as they maintain an access control layer in order to permit only well-defined identities to transact with the distributed ledger in the network. They allow for different levels of permissions to be designated to its users, therefore, satisfying confidentiality needs. These blockchains may allow anyone to transact in the network once their identity and role are defined. Such Blockchains are better fitted for individuals who within the blockchain need to define security, identity, and role.

3.2.3. Public Blockchain

A public blockchain is a blockchain where users can join whenever they want, there are basically no restrictions when it comes to participation. Users can see the ledger and take part in the consensus process. Thus, all transactions over public blockchains are transparent. They may or may not be rewarded for their participation. They are also permissionless as anyone is allowed to maintain a copy of the ledger on their local nodes and participate in block validation.

3.2.4. Private Blockchain

A private blockchain is a permissioned blockchain, therefore participants need consent to join the network. Only those allowed to join the network can view the transactions. Private blockchains are considered more centralized than the public counterpart because the entities responsible for the blockchain have more control over the participants and governing structures, therefore are more suitable for individual enterprise solutions.

There is no transfer of currency or tokens in these blockchains, also no transaction fee is necessary since the nodes involved in the validation of the block are well known and trust each other. It is also possible to rollback in a private blockchain if necessary.

3.2.5. Consortium Blockchain

Like private blockchain, consortium blockchain, also called hybrid blockchain, also requires permission for participants to join the network. On the contrary, the network is not restricted to a single organization or enterprise, it expands to multiple organizations and provides accountability between parties involved. Transaction fee is also not necessary in consortium blockchain. It has the privacy benefits of a private blockchain while maintaining the secure and transparent nature of public blockchains.

3.2.6. Tokenized Blockchains

These are the standard blockchains, they generate cryptocurrencies as a result of the consensus process via mining or initial distribution. The main examples of this type of blockchain are Bitcoin and Ethereum.

3.2.7. Tokenless Blockchain

Tokenless blockchains are designed so that they do not have the basic unit for the transfer of value. These are still valuable when there is no need to transfer value, only sharing data among different trusted parties is required.

3.3. Smart contracts

The concept of smart contracts was first introduced by Nick Szabo (Szabo, 1994), back in 1994, long time before blockchains being defined. They are enforceable and automatically executed programs that run on top of the blockchain and have business logic to be executed in certain conditions. This feature is not available in all blockchains but has become a desirable feature, since they provide flexibility and power to the blockchain applications.

Smart contracts were popularized by Ethereum, the second biggest blockchain, smart contracts allowed decentralized applications (dApps) to be built on the network. A smart contract can be divided into a few steps. First, it needs an agreement between two or more parties. Then, conditions have to be agreed upon to know when the smart contract will be completed, this decision is then automatically written on the blockchain, becoming immutable and irreversible. Once the contract is completed, the transaction is recorded on the blockchain just like any other would.

What makes smart contracts a desirable feature is not just as a contract for a payment, there are innumerable implementations that can automate several parts of a society. Some examples of where they can be applied are, for example, real estate, insurance, supply chains, digital identity, banking, and many others.

3.4. Consensus

One of the most important aspects in a blockchain is the consensus, the choice of the consensus algorithm is highly dependent on the type of the blockchain. Some consensus algorithms are not suitable for distinct types of blockchains; therefore, it is essential to choose an appropriate algorithm for a certain blockchain.

Consensus is the process of agreement between nodes that do not trust each other on the final state of the data. In a client-server architecture it is simple to achieve consensus between client and server, but in distributed systems several nodes must agree on a single value, making it quite challenging to achieve an agreement. This process of obtaining an agreement in a common state or value between several nodes, despite failure of some of them, is known as distributed consensus.

To achieve consensus there are a few requirements that must be met. These requirements are:

- Agreement: All honest nodes, or non-malicious, should agree on the same value;
- Termination: All honest nodes must reach a decision and terminate the consensus process;

- Validity: The final value agreed upon by all the honest nodes, should be one proposed initially by at least one of those honest nodes;
- Integrity: Every node can make a decision only once in a single consensus cycle.

Consensus mechanisms can be divided differently depending on the criteria used. A reasonable categorization is presented below:

- Proof-based, or leader-election based, where a leader is elected randomly and proposes a value. It can be also referred to as fully decentralized or permissionless;
- Byzantine Fault Tolerance (BFT)-based, an approach based on rounds of votes, they are also known as consortium or permissioned mechanisms.

Typically, BFT-based consensus mechanisms perform very well when there are few nodes, contrasting with leader-election lottery-based mechanisms that performs much better with a large number of nodes. BFT-based consensus mechanisms do not scale as well as leader-election lottery-based mechanisms, but these also perform much slower than their counterparts. Therefore, when choosing consensus algorithms, it is important to keep in mind the type of the blockchain and what balance between scalability and performance is better suited.

Nowadays, there are several different consensus algorithms in the context of blockchain and others are being researched. Proof of Work is currently, the most widely used and one of the most robust mechanisms in blockchain. The so called miners compete to find a nonce that produces a hash with a value lower than or equal to that set by the network difficulty, as evidence that they have expended computational power in order to achieve consensus. This process is referred to as mining. It is extremely robust against collusion attacks, where different nodes cooperate to deceive the blockchain, if 51% of the nodes of the blockchain collude, they will effectively decide which blocks are added to the blockchain. This mechanism is used in blockchains like Bitcoin, Ethereum and others.

3.5. Relevant Blockchains

Some relevant blockchains in this study are introduced next.

3.5.1. Ethereum

Ethereum was first conceptualized in 2013 by Vitalik Buterin. In the Ethereum yellow paper (Wood, 2014), Ethereum is described as a very specialized version of a cryptographically secure, transaction-based state machine. It is an open-source platform created to enable the use of smart contracts and consequently decentralized applications with advantages inherited from the blockchain.

It distinguishes itself from the main competitor, Bitcoin, as a programmable network serving as a marketplace for several different services, such as finance, games, art, and many others. All of this can be paid in the network currency ETH[2].

Ethereum enables transfers of several types of tokens that represent diverse types of assets. Blockchain currencies, or cryptocurrencies, are called fungible tokens. These tokens are interchangeable, this means that tokens of this type are equal between each other. In the Ethereum network these are the most common and are called ERC-20 tokens[3].

[2] `https://ethereum.org/en/eth`

[3] `https://ethereum.org/en/developers/docs/standards/tokens/erc-20`

On the other hand, Non-Fungible Tokens[4] (NFTs), are not interchangeable, these tokens represent unique assets. They enable a whole new set of functionalities in a blockchain. NFTs can be used to represent ownership of unique items, these items can be almost anything, they are used in art, collectibles, real estate and in the context of this study documents of title. In the Ethereum blockchain they are usually built using the standard ERC-721[5] (Casale-Brunet et al., 2021).

3.5.2. Hyperledger Fabric

Hyperledger[6] was founded by the Linux Foundation in 2015 to advance cross-industry blockchain technologies. Instead of using a single blockchain standard, it encourages a collaborative approach to developing blockchains and open development (Dhillon et al., 2017).

Hyperledger Fabric[7] is one of the blockchains within Hyperledger. It is a private and permissioned blockchain with smart contracts (aka chaincode)(Androulaki et al., 2018a). The members need to enroll through a trusted Membership Service Provider (MSP). It has a modular and versatile design, offering pluggable options, different formats for data storage, consensus mechanisms can be swapped, and different MSPs are also supported.

Its architecture separates transaction processing into three phases: (i) distributed logic process and agreement, or chaincode; (ii) transaction ordering; and (iii) transaction validation and commitment. This division grants fewer levels of trust and verification across node types, and better network scalability and performance.

A Fabric blockchain network is comprised of orderers (ordering nodes), charged with ordering and packaging of transactions into blocks, and peers[8] (non-ordering nodes), responsible for storing and managing copies of ledgers and smart contracts.

A target peer, selected by a client application, executes transactions by invoking the chaincode, then returns the result to the client. The transaction proposal is also forwarded to the required endorsing peers (depending on the defined endorsement policies), these will also execute the transaction and return the result. If all the responses satisfy the endorsement policies, the transaction is then forwarded to the ordering service[9] in an ordering node.

The ordering service receives transactions containing signed and endorsed proposal responses, from one or more applications via the gateway service, and orders and packages the transactions into blocks. These are the blocks (which are also ordered) — consisting of endorsed and ordered transactions — that make up a Fabric blockchain ledger.

Finally the ordered blocks are sent to every peer that then validates each transaction, in the correct order, and ensures the correct endorsement. If all is well, each peer commits the received block to its local copy of the ledger. The transaction life-cycle can be observed in the Figure 2.

A group of participants have the ability to create channels that allow them to create a separate ledger of transactions (Androulaki et al., 2018b). This feature allows the existence of competitors to use the same network without having every transaction

[4] https://ethereum.org/en/nft

[5] https://ethereum.org/en/developers/docs/standards/tokens/erc-721

[6] https://www.hyperledger.org

[7] https://hyperledger-fabric.readthedocs.io/en/latest/index.html

[8] https://hyperledger-fabric.readthedocs.io/en/latest/peers/peers.html

[9] https://hyperledger-fabric.readthedocs.io/en/latest/orderer/ordering_service.html

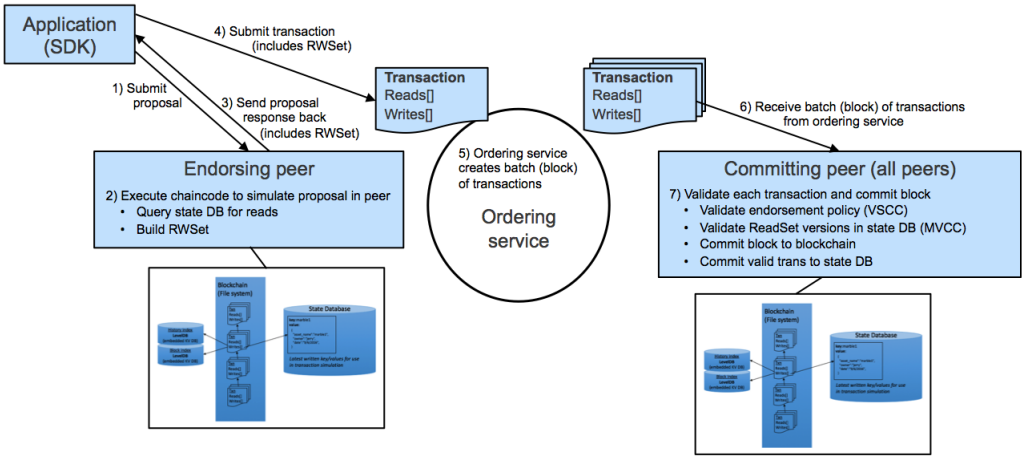

Figure 2. Transaction lifecycle in Hyperledger Fabric (Cocco and Singh, 2018)

known to each other.

3.5.3. Contour (Voltron)

It uses R3 Corda[10], another blockchain platform, as their base technology and was founded by 8 banks. Contour delivers a network for trade finance over a distributed ledger, inheriting all its benefits. Contour's initial objective was to digitally manage the issuance of letters of credit, but, even though it is still their main focus, they now also provide other electronic trade documents including documents of title such as the Bill of Lading.

Corda is not a blockchain by definition. Transactions do get cryptographically chained, however it does not have blocks to store them before confirmation, Corda confirms the transactions immediately. Corda was created as an alternative to permissionless blockchains, since it is aimed at the financial sector and banks do not want competitors to have access to their data, even encrypted. This permissioned network provides transacting parties a way to achieve a consensus without revealing sensible information, this is achieved via smart contracts.

Also, in traditional blockchains where parties are unknown, every message is broadcast to every participant. This happens because the identity of the recipient is not known and allows the network to be aware of every transaction avoiding double-spending - a phenomenon where a single unit of currency is spent simultaneously more than once. But since privacy is one of the main concerns in Corda, this solution is inadequate, all participants would see transactions from everyone else. Instead, Corda addresses each message to a specific counterparty, resulting in data being shared on a need-to-know basis only[11].

Corda reduces record-keeping and transaction costs and allows companies to streamline operations with several programs: CorDapps, Partner Connect Program, Launchpad, Venture Development, and Conclave. CorDapps (Corda Distributed Networks) are distributed applications with the goal of allowing nodes to reach agreement on updates to the ledger; some examples are applications for public or private auctions, pur-

[10] `https://www.r3.com/corda-platform`

[11] Corda open source 4.7 Development: Key concepts: Trade-offs, `https://docs.r3.com/en/platform/corda/4.7/open-source/key-concepts-tradeoffs.html`, [accessed on March 2022]

chasing wellness services, managing expiry dates on food items, approving, or denying loans based on credit agency ratings, and many more. The Partner Connect Program helps new adopters to develop innovative solutions on Corda. The Launchpad, as the name suggests, is a launchpad for new CorDapps, providing developers with a space to deploy CorDapps in their early stages. Venture Development program helps startups get to market faster, offering resources and support such as workshops and access to educational content. Finally, the Conclave enables users to verify an application's integrity to guarantee sensible data security.

4. Electronic Bill of Lading - eBL

An electronic Bill of Lading is a paperless Bill of Lading electronically issued instead of a traditional printed on paper and physically issued as a hard copy.

Independent of the technology where the electronic Bill of Lading is issued, the Bill of Lading should fulfill the same functions as its traditional paper counterpart, the functions are receipt of goods, evidence of contract of carriage and document of title of goods.

Many believe the electronic Bill of Lading to be a game changer in the shipping industry, since it is faster, more efficient, provides cost reductions with good security and small risk.

The solutions presented are most of the ones approved by the International Group of Protection and Indemnity (IGP&I) clubs. The Group is organized as an unincorporated association of the 13 member Clubs and between them provide marine liability cover (protection and indemnity) for approximately 90% of the world's ocean-going tonnage[12]. Previously, the IGP&I's rules excluded liabilities in respect of the carriage of cargo under all electronic systems. In 2010 this changed when the group changed its stance and decided to cover these liabilities, but only with systems that received approval first. Approval from the IGP&I gives the same terms of indemnity coverage as paper bills of lading. Therefore, it is essential for the technologies to be approved so they can reach the global market.

4.1. Bolero

Bolero is the oldest and the first electronic Bill of Lading solution approved by the IGP&I. The name stands for Bill of Lading Electronic Registry Organization. It also allows other documentation like purchase orders, invoices, letters of credit, and others.

Bolero International claims that the receipt and evidence of contract functions of a Bill of Lading are relatively easy to achieve in an electronic world. Also, that electronic solutions are even better than traditional paper-based bills of lading when it comes to integrity of these documents given that it is correctly implemented. But the harder function to replicate would be the ability to transfer rights and obligations while maintaining the originality of the Bill of Lading. Therefore, an electronic Bill of Lading would require two components: a legal agreement and a technology that implemented the functions of the Bill of Lading while fulfilling the legal obligations of the agreement (Bolero International Ltd, 2020).

Based on this, the Bolero electronic Bill of Lading integrates a legal solution with a technology implementation. The parts that achieve this integration are the Bolero

[12]About the International Group, `https://www.igpandi.org/about` [Accessed on Marc 2022]

Rulebook (Bolero International Ltd, 2013), the Bolero Title Registry and the Bolero Messaging platform.

The Bolero Rulebook is an agreement between all the parties involved in the Bolero system, it guarantees that all users follow the same set of rules. The existence of this Rulebook is justified by the lack of standard rules between countries, and its objective is to apply only the rules necessary for the electronic messaging to work. It covers maters related with the Bolero electronic Bill of Lading such as the creation of a Bolero Bill of Lading (Section 3.1), rights over a Bolero Bill of Lading (Section 3.3), transfer of possession of the Bolero Bill of Lading (Section 3.4); but also matters relating to the messages in the system (Section 2.2). Other rules resembling usual clauses used in bilateral agreements about electronic document communication are also present.

The Bolero Messaging platform is common for all Bolero solutions, and it is claimed that it provides two advantages over traditional databases: allows the replication of the traditional process of sending paper bills of lading supporting the sending of its electronic counterpart between parties and deliver it to the holder without the need for him to interact directly with the application.

The Bolero Title Registry is an application connected to the Bolero Messaging Platform. It records the current holder of the electronic Bill of Lading and only allows updates from him. It is a database that records the lifecycle of an electronic Bill of Lading, and ensures that it cannot be changed by anyone but the carrier and cannot be duplicated. The electronic Bill of Lading must remain unique, or original, and this is guaranteed by the title registry.

The electronic bills of lading are signed with digital certificates and the communication channels are encrypted. Bolero is audited according to auditing standard developed by the American Institute of Certified Public Accountants – SSAE16 – every year by an external auditor.

In Bolero an electronic Bill of Lading can only be created by a carrier or their explicit authority, it can be created directly in the app or by scanning a paper one. The document is uploaded into the system and attached to a Title Registry Instruction (TRI). The electronic Bill of Lading along with the TRI is digitally signed and sent to the first holder, usually the shipper. When it is surrendered, the carrier receives an email, and is then able to release the cargo at the discharge port.

Bolero is a cloud-based platform that can be accessed via a web interface, but also allows for integration with internal back-offices. Since it is a closed system, Bolero accepts members manually, requiring customers to register and wait for approval. This approval is only given after signing an agreement and receiving training. The system is free of charge for carriers, agents, forwarders, and operators.

Bolero is a Countour (formerly known as Voltron) contributing technology partner integrating its electronic Bill of Lading onto the platform[13].

4.2. CargoDocs by essDOCS

EssDOCS was founded in 2005, several years after Bolero. They offer a range of solutions to digitize trade finance and logistics documents, including the Bill of Lading via CargoDocs[14]. At first glance CargoDocs is very similar to Bolero: both have a registry to store electronic Bills of Lading, are web-based and centralized. Besides bills

[13]Our partners, `https://www.bolero.net/partners`, [accessed on Mach 2022]

[14]eletronic Bills of Lading (eB/Ls), `https://www.essdocs.com/edocs/electronic-bills-of-lading` [Accessed on March 2022]

of lading, essDOCS also allows the management of other documents like certificates of origin, commercial invoices, sales of goods contracts, and more. The CargoDocs solution is made of two major components, Assemble Cargo Docs (formerly DocHub) for creation & approval and Exchange Title Docs (formerly DocEx) for exchange & legal transfer.

Assemble Cargo Docs[15] is a document hub that allows to collaboratively create, review, and approve paper or electronic documents. Exchange Title Docs[16] is a solution that enables digital signing, exchange and legal transfer of title documents. Users can push documents directly from Assemble Cargo Docs to Exchange Title Docs.

EssDOCS also has an agreement that all users should sign, the Databridge Services & Users Agreement (DSUA); it regulates the operation of the solution and provides a legal framework. Only users that join this agreement can create legally effective eDocs, guaranteeing that all participants are committed to treat electronic documents as the equivalent of paper documents[17].

They are subject to annual audits focused on external penetration testing and internal vulnerability assessment and the data centers are ISO 27001 and ISO 27002 certified[18].

The creation and management of documents is similar to the traditional way. If another party is not in the system, the user can transition back to paper at any point. Supporting paper documents can be scanned, converting them into PDF's and signed, but this cannot be done with bills of lading since it is not a safe way of storing critical information.

Even though CargoDocs is a web-based solution, it also provides API's for integration in internal financial, operational or document creating systems.

EssDocs also announced a partnership with Voltron in 2019 in order to integrate CargoDocs into their blockchain (essDocs, 2019).

4.3. E-Title

This solution was created by ex-members of Bolero but works in a unique way than the other solutions already presented. It is a peer-to-peer network, unlike the other centralized systems. They claim that it works as well in the back-office of carriers, banks, or multinational companies as when provided by an Application Service Provider (ASP) for Small and Medium Enterprises (SMEs)[19], as shown in Figure 3.

Like the other solutions, it also has a legal framework called Electronic Title User Agreement, written in accordance with United Nations Commission On International Trade Law (UNCITRAL) Model Law. It is aimed at filling the legislative gap by providing a private agreement between the parties that use the system, that provides a legal foundation to allow the transfer of electronic bills of lading. It was based on English common Law The focus of this solution is on the electronic title creation and negotiation, enabling full electronic trading, documentary credits and collections, and release of goods.

To guarantee the secure transfer of documents during negotiations, a component called Hardware Security Module (HSMs) is used. It is a tamper-proof hardware that

[15] `https://www.essdocs.com/solutions/assemble-cargo-docs`, [Accessed on March 2022]

[16] `https://www.essdocs.com/solutions/exchange-title-docs` [Accessed om March 2022]

[17] Users Agreement (DSUA), `https://www.essdocs.com/capabilities/users-agreement-dsua` [Accessed on March 2022]

[18] Security, `https://www.essdocs.com/company/security` [Accessed on March 2022]

[19] What is e-title™?, `https://www.e-title.net/sol_what.php` [Accessed on March 2022]

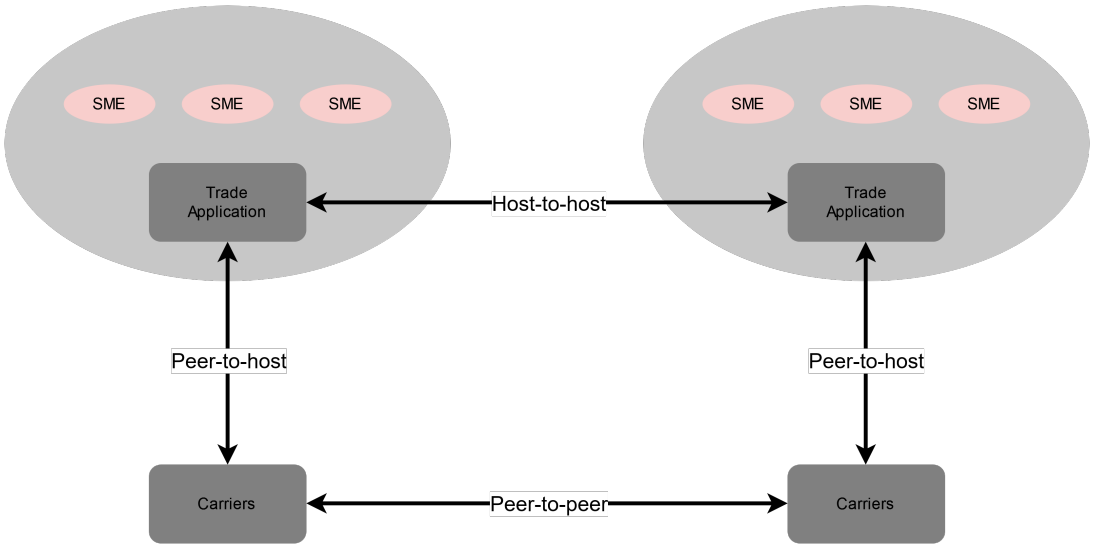

Figure 3. Example of ASP and SME organization on e-title (figure inspired in the one in `https://www.e-title.net/sol_what.php`

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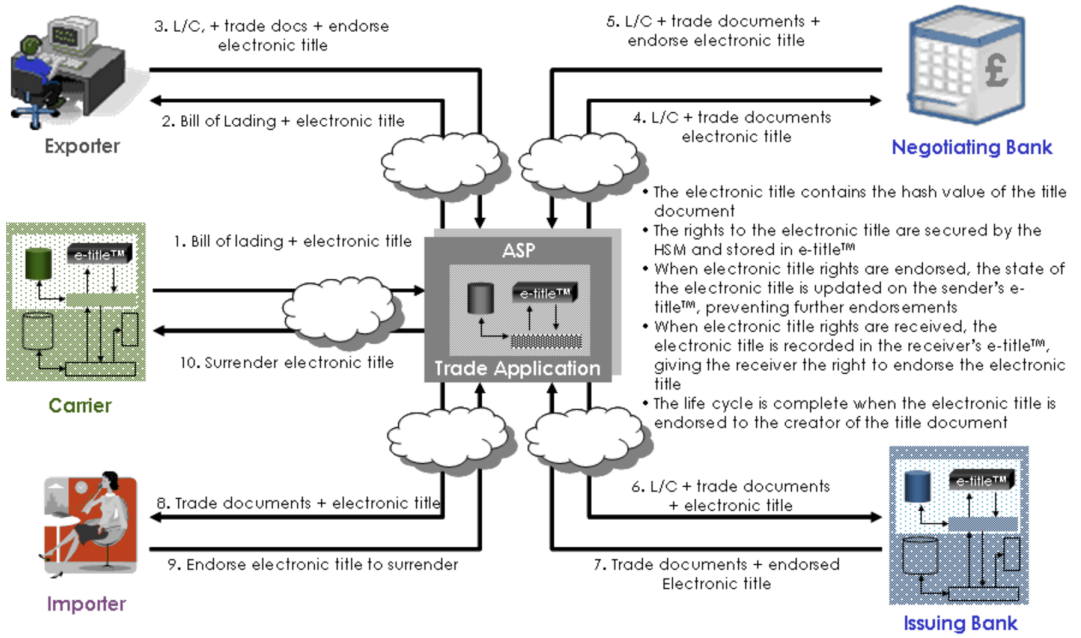

Figure 4. Generic in-depth electronic title life cycle (figure extracted from `https://www.e-title.net/sol_work.php`)

prevents alteration and forgery of title documents, it also prevents double trading (using the same electronic title more than once).

E-Title's software is connected to companies back-office or trade documentation system. A carrier can create a Bill of Lading traditionally on paper or on a document creation software and send it to e-title. There, an electronic Bill of Lading is created, signed, and registered in the HSMs. The electronic Bill of Lading is then sent back to a carrier's back office, where it can then be redirected to the shipper. Finally, the shipper can verify the signature and that the electronic Bill of Lading remains unchanged. A more in-depth generic electronic title life cycle is shown in Figure 4.

4.4. EdoxOnline

The Argentinian software provider Global Share was founded in 2007 with focus on streamlining the issuance of shipping and commercial documents. EdoxOnline[20] marked the beginning of the second generation of electronic Bill of Lading systems; the key difference from the first generation is the reliance on blockchain technology. EdoxOnline's product is based on the Ethereum blockchain, and allows users to automatically issue and manage electronic Bills of Lading in collaboration with all supply chain members.

Like Bolero and essDocs, it also uses a web platform, where the instructions for a document are inserted from the destination point and sent to the exporter's country. There, exporters coordinate with other members of the supply chain who use the system to add the corresponding information. Finally, the Bill of Lading can be saved as a PDF, printed, and signed[21].

The web platform is available to all members via a single page, but only the necessary information for each member is displayed. EdoxOnline has also integrations with other electronic Bill of Lading systems, such as Bolero and CargoDocs.

4.5. CargoX

CargoX is a crowdfunded project started in 2018 that counted with the contribution of thousands of individuals and companies in a KYC (Know Your Customer) procedure. They claim to be one of the most market-neutral companies in logistics and want to remain independent and open to everyone.

CargoX relies on the security and decentralization provided by open blockchains and smart contracts. One of the main objectives of the company is to eliminate the need for paper documents in logistics.

Currently CargoX's solutions are built over Ethereum, since it is one of the most robust blockchains in the market, with a strong developing community, along with industry support, and a roadmap filled with innovative features for the future.

To drive the core functionalities of CargoX's smart contracts and also to serve as a payment method for logistics services, the company created the ERC-20 token CXO.

CargoX uses the Ethereum public network to transfer documents of title, such as a Bill of Lading. Documents uploaded to the network are stored in a distributed file system, the InterPlanetary File System, and encrypted (Vlacic and Cekelic, 2020).

[20] `https://web.edoxonline.com`

[21] Cutting Edge Platform, `https://web.edoxonline.com/index.php/cutting-edge-platform`, accessed on March 2022

The InterPlanetary File System (IPFS[22]) is a protocol for storing and retrieving files from a peer-to-peer network; the files stored are content-addressable by a hash. Since it uses a Merkle tree like process, the Merkle Directed Acyclic Graphs (DAG), any tamper with a file will result in a change to the hash.

After being stored, the document is converted to a token, and ownership can be transferred using Ethereum's public token ownership transfer capabilities. CargoX uses ERC-721 NFTs to achieve this, transactions can be signed in the decentralized application or via an API that is available for integration with back-offices.

CargoX also has a set of rules and principles that enable the platform ecosystem and logistics services to work, it is called the CargoX Document eXchange Protocol. These rules and principles are mainly enforced by the smart contracts (CargoX, 2021).

Since the solution is built on a public blockchain, CargoX does not have the capabilities to take over ownership of any documents. Also, users can always audit the trail of title transfers and other transactions via blockchain explorers.

4.6. TradeLens

TradeLens is an open and neutral supply chain platform built over blockchain technology (TradeLens, 2020). It was developed in a collaboration between GTD Solution and IBM with support from other major players in the logistics industry.

TradeLens can be divided into three main components: the ecosystem, platform, and applications and services marketplace. The ecosystem is its business network, which involves ports or terminal operators, government authorities, shippers, financial services, carriers, intermodal operators, and freight forwarders.

The platform is the digital tools provided to the entities involved, so they can share information and collaborate securely. It is achieved with a strict permissions structure based on an organization's role; this way, only the necessary parts can access information about a shipment. The logical choice of a blockchain that can implement these strict permissions is a permissioned blockchain. TradeLens uses the blockchain Hyperledger Fabric, which is a permissioned blockchain that can provide a high degree of privacy to the users.

Another focus of TradeLens is the promotion and adoption of standards and interoperability of platforms. The platform uses the Supply Chain Reference Data Model from UN/CEFACT and shares their APIs to support interoperability.

The platform is accredited with the ISO 27001 security certification.

This solution addresses the broader supply chain processes and not just the shipping activity where the Bill of Lading is included. Exchanging the electronic Bill of Lading is a standardized process for all users and adheres to legal and regulatory frameworks. Carriers issue an electronic Bill of Lading for a shipper, the issuance is recorded, and a hash of the document is saved in the blockchain. The shipper can then view the electronic Bill of Lading on the platform, and when necessary, transfers it to the consignee. When the shipment arrives, the consignee can surrender the electronic Bill of Lading that will return to carrier for the cargo to be released.

[22] `https://ipfs.io/`

5. Discussion

5.1. General SWOT analysis

SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. Strengths and weaknesses are related to the solutions themselves, what do they do well and what needs improvements. Opportunities and threats are external, opportunities are things that solutions can take advantage of, and threats are things that they should be protected from.

In the case of the electronic Bill of Lading, there are some obvious strengths. A Bill of Lading is usually sent three times through a courier, each time costing a certain amount of money and time. As a digital alternative to traditional paper and courier services, the issuing and transfer of the Bill of Lading is almost instantaneous and costs nothing. Since there are no courier fees or insurance costs, the Digital Container Shipping Association (DCSA) estimated a total of four billion dollars annual savings at a 50% adoption rate for the container shipping industry alone (DCSA, 2020). Another important strength is that it cannot be lost, damaged or destroyed during transport, an accident such as spilling a cup of coffee on the Bill of Lading or the courier simply losing it would cause additional costs and time delays. Also, since the transfer of a Bill of Lading is almost instantaneous there is never the problem of the cargo arriving before the Bill of Lading is in possession of the importer; if this happens, the importer will not have the required document of title to present to the carrier, potentially causing more costs to place goods in storage or losses due to market fluctuations. Finally, forgery is way more difficult in electronic bills of lading when compared to paper ones. Therefore, the strengths can be summed up in cost and time savings, more reliability and more security against accidents or intentional forgeries.

The weaknesses in electronic bills of lading are common to the ones identified by CargoX in their solution, they are not about the technology itself but more about the businesses and the industry, such as the lack of funding and marketing, electronic Bill of Lading unawareness in the shipping industry, insufficient reputation, and lack of trust in innovative technologies, like blockchains and their suppliers. Most of these weaknesses will disappear as time goes on and existing solutions prove themselves in the industry by showing their strengths.

Several factors can be a great opportunity for different electronic Bill of Lading solutions. The size of the shipping industry and the possible revenue that comes from it, potential to optimize supply chains, and integration with major logistics companies. Further technology development will allow even more cost reductions and faster speeds of transfer. Governments and other entities pushing for adoption of paperless trading systems due to COVID-19. The increasing awareness of environmental issues and increased pressure from the general public to adopt eco-friendly and sustainable solutions. And finally, possible integration with banking, insurance, and other institutions.

Some existing threats to the electronic Bill of Lading are institutional adoption barriers, the characteristically slow changing or developing environment of the logistics industry, poor computer literacy among users. Lack of legislation, even though a lot has been done in this area in the past decades, and slow response from governments to international initiatives in this aspect, such as the Modern Law on Electronic Transferable Records (MLETR) formulated by UNCITRAL (United Nations Commission On International Trade Law) in 2017 (UN, 2017), resulting in an unclear legal status of electronic Bills of Lading. Lack of common standards and interoperability issues,

result in slow adoption of electronic Bills of Lading, this can be seen as an opportunity for new convenient approaches and technologies but possible integrations with different entities in different industries becomes harder; DCSA, a consortium of some of the largest carriers, has already published standards to facilitate acceptance and adoption, but only time will tell if this initiative is successful.

5.2. Individual analysis

The objective of this section is to evaluate the different electronic Bill of Lading solutions already introduced in this study focusing on several factors and specifying each solution's unique strengths and weaknesses.

5.2.1. Centralization

The first electronic Bill of Lading solutions – Bolero, CargoDocs, and e-Title – which were initially centralized, did not have much success, justifying the limited acceptance and adoption in the beginning of the century. One of the main reasons for the lack of success was the centralization aspect. In a centralized system, a single entity is responsible for the traffic and operating rules in the network. This means that this entity also has access to all business transactions from every user and can even change the rules. Even though the providers of these centralized solutions have good security and privacy measures, this centralization still requires full trust in the service provider, something that some traders do not have. As a contrast, decentralized solutions, especially blockchain-based solutions, enable parties to engage in trade issuing, exchanging, and signing the Bill of Lading and possibly other documents without needing a central authority. These platforms simply enable the trade to occur securely and efficiently.

5.2.2. Privacy

When it comes to privacy in centralized solutions, it is guaranteed as long as the central authority of the system is trusted to implement security measures, such as encryption of the communication channels from the user to the central server or registry. There is still the risk of attacks on the servers that might release sensitive user information.

On blockchains the risk of attacks is decreased substantially and the technologies behind them are well-known and documented and have been proved and continue to prove to be secure. But, this does not mean that privacy is guaranteed, as explained in the Blockchain section, in a blockchain every user has a public address and any transaction made by them is associated with that public address. Therefore, if anyone knows the public address of a company, they can associate every transaction made by that public address to the company. This problem exists in solutions that use public blockchains, CargoX and edoxOnline, which are built on the Ethereum network. This can be attenuated by using private blockchains, where the members are well-known. In the case of Hyperledger Fabric used by TradeLens, this solution even supports the creation of "channels" – explained in Hyperledger Fabric subsection – that allows segregation of groups of organizations that trust each other.

5.2.3. Scalability

With the need to save and maintain growing amounts of data, scalability plays a big part in solutions that involve thousands and even reaching millions of active users.

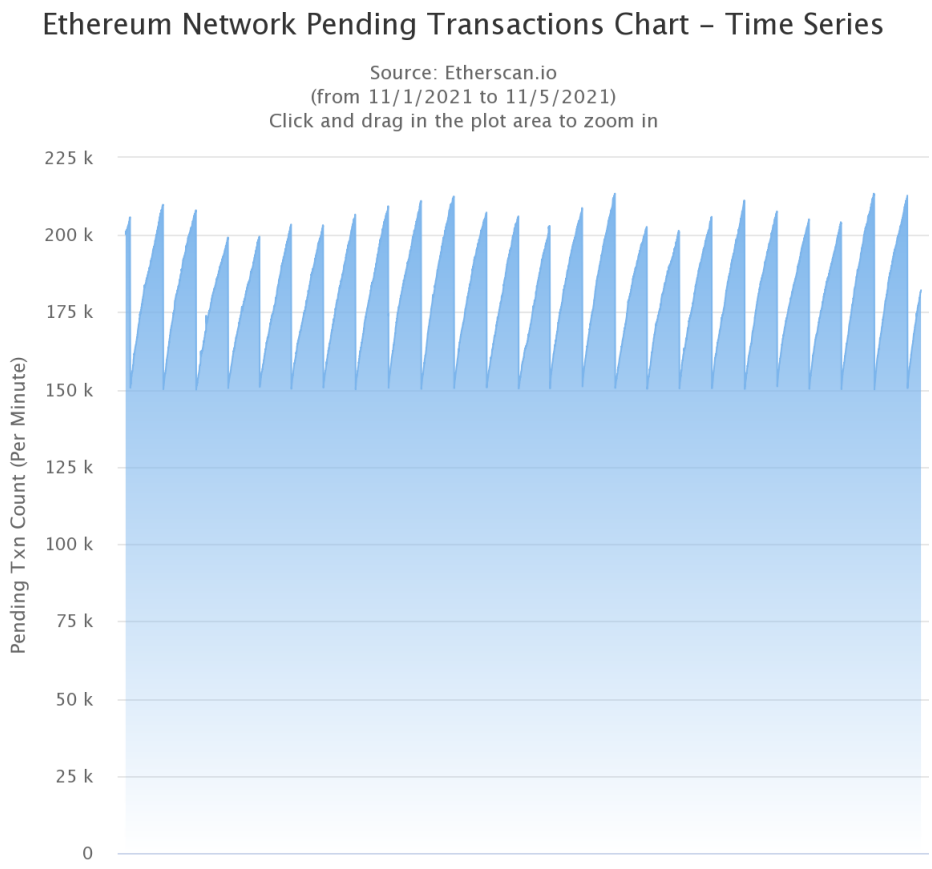

Figure 5. Ethereum pending transactions (extracted from `https://etherscan.io/chart/pendingtx` on November 4, 2021)

Scalability is the capacity of a solution to maintain a correct functioning and good user experience even if it changes in size, typically to a larger size. Centralized solutions such as Bolero and CargoDocs may or may not be built with scalability, and might require continuous investment in infrastructure; customers have to trust that the solutions will evolve with the increase of users. Blockchains do not require as much care and investment when building solutions, but some public blockchains like Bitcoin and Ethereum, also have known problems, in a publication of late 2019 about solutions to scalability of blockchains (Zhou et al., 2020), the authors reinforce the scalability issues on Ethereum and show the statistic of pending transactions per minute that went from 35 000 to almost 75 000; nowadays this number is ranging from 150 000 to 200 000 as can be seen in figure 5.

The scalability problems of Ethereum naturally impact the decentralized applications built over it, such as CargoX, not because there time constraints that the number of pending transactions will impact, but because these problems also increase transaction costs, which has been a problem for Ethereum in some occasions. To tackle this issue, CargoX uses a layer 2 solution called Polygon to increase speed and reduce costs that come from the increase in fees due to scalability issues. Layer 2 solutions help applications to scale up by handling transactions off the Ethereum main network

(aka layer 1 Mainnet[23]). Polygon[24] has a proof-of-stake commit chain – a network that operates adjacent to the main blockchain, similar to a side-chain – where transactions are bundled and confirmed together before returning them to the main chain.

Hyperledger Fabric has better scalability due to the capability to organize the blockchain in separate channels, which can be seen as independent networks.

5.2.4. Flexibility and integration

When talking about flexibility, the first that comes to mind is the TradeLens solution, built on Hyperledger Fabric, since it was built with modularity and versatility as a major priority, it can be changed to adapt to any needs that might arise. These characteristics allow Hyperledger Fabric to be used in a wide range of use cases; that is the main reason why TradeLens can be more than just an electronic Bill of Lading system, covering whole supply chains.

All solutions provide a web platform except for e-Title that requires software to be integrated in companies' back-offices. Solutions that provide the web platform also have APIs, allowing back office integration.

5.2.5. Environmentally friendly

All the solutions presented obviously have hardware and necessary amount of power to keep the systems working properly. When it comes to blockchains the consensus mechanism proof-of-work is the main point of talk on eco-friendliness. Ethereum estimated energy consumption per year reached a peak in March 2022 of 113 TWh[25] (see Figure 6), which is comparable to the power consumption of Netherlands.

Furthermore, Raynor de Best estimated that in January 10, 2022, a single Ethereum transaction consumes more power (238.22 kWh) than 100 000 transactions (148.63 kWh) in the VISA global payment network (de Best, 2022).

With these statistics, it is safe to say that Ethereum is far from being energy efficient. Applications built on Ethereum, such as CargoX and edoxOnline, are obviously responsible for some of this consumption (impossible to say how much), but they also leverage from the network's consensus mechanism. Once Ethereum completes the transition to proof-of-stake this energy consumption should reduce drastically. On May 2021, Carl Beekhuizen estimated that the proof-of-stake alternative is around 2000 times more energy efficient, resulting on a reduction in energy consumption of about 99.95% (Beekhuizen, 2021).

5.2.6. Individual Strengths and Weaknesses

From these and other factors it is possible to extract some strengths and weaknesses of each of the solutions.

Bolero and CargoDocs (initially centralized solutions), main weakness was lack of trust, since they were centralized solutions with no proven use in the real world. The partnership with Contour may solve these weaknesses and add strengths, mainly the connectivity with the banking industry, since Contour was built with the financial system in mind. Also cross-platform connectivity with other solutions also in Contour becomes easier.

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[23] `https://ethereum.org/en/developers/docs/scaling/layer-2-rollups`

[24] New to Polygon?, `https://docs.polygon.technology/docs/home/new-to-polygon` [accessed on March 2022]

[25] Ethereum Energy Consumption Index, `https://digiconomist.net/ethereum-energy-consumption` [Accessed on March 2022]

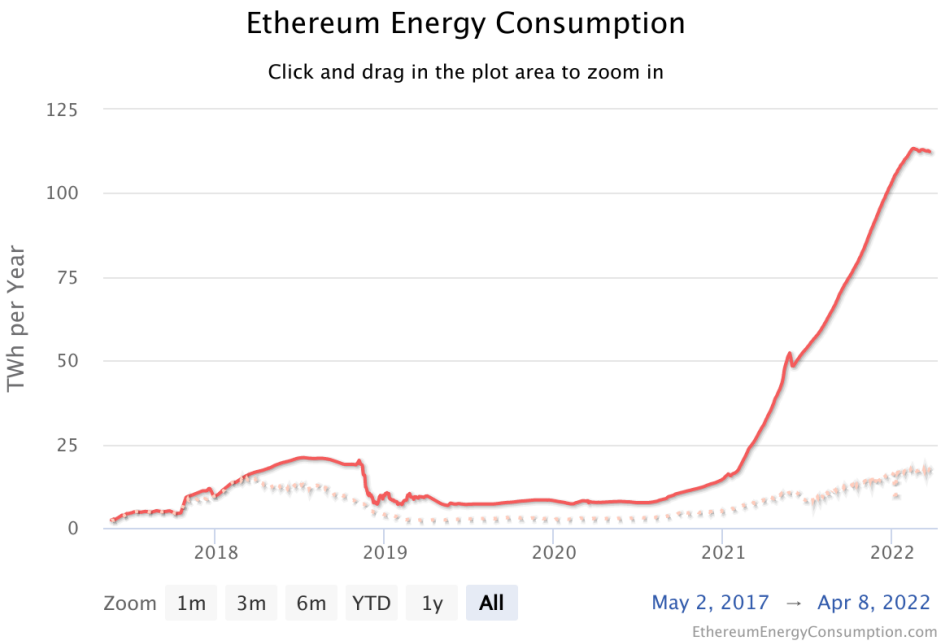

Figure 6. Ethereum estimated maximum and minimum energy consumption (extracted from `https://digiconomist.net/ethereum-energy-consumption` on March 23, 2022)

CargoX and edoxOnline share advantages and weaknesses since they are both built on Ethereum and adopt some of the advantages and weaknesses. To name a few advantages, enhanced security, trust, reliability, transparency and traceability; weaknesses are low scalability, environmental unfriendliness and possible privacy problems. CargoX distinguishes itself from edoxOnline with the layer 2 solution Polygon, which greatly increases efficiency and scalability.

TradeLens, as a solution that uses a private blockchain, will also inherit some of its characteristics. It is a partially decentralized solution with strengths like better performance and efficiency, along with the security and reliability provided by blockchains in general. Another major strength of this solution is its flexibility, that allows for many use cases in supply chains, not being limited to electronic Bills of Lading.

Related Work

Most of the existing related work about electronic Bill of Lading is focused on the legal aspects, in different countries' legislative frameworks. Even though it is an important point, the focus of this work is the technology.

The work by Kapnissis et al. (2020) also focused on the technology, along with an investigation on the willingness and main drivers of its adoption. It was the main inspiration for our study, as it was the only one that had a similar goal. Although the time difference between these two articles is relatively small, there are already some significant advances in some of the existing solutions, namely CargoX, which is now approved by the IGP&I and supports negotiable Bills of Lading, among other novelties.

With independent research, that article also proved to be vague in some areas, and completely lacking in others, such as the environmental impact of the technologies

used. Therefore, the main differences between their work and ours, here published, are the more in-depth analysis of the solutions and underlying technologies, focusing on aspects such as centralization, privacy, scalability, flexibility, integration and environmental impact.

Conclusions

This study started by giving an introduction to the Bill of Lading and to blockchains, the main technology that is being envisioned to implement its electronic counterpart. The adoption of this technology in all of the solutions, even the ones that have existed for longer than the first blockchain ever, proves how valuable it has become in the industry.

The use of smart contracts within blockchain-based solutions provides an efficient, fast, reliable and much cheaper alternative to the current paper-based approach. This will allow for significant monetary and time savings, with a relevant upgrade in reliability and security, since forgeries and accidents such as losing the document is significantly harder.

Also, it is important to note that the term blockchain encompasses many different technological solutions, with many critical differences among them (consensus algorithms, scalability, energy consumption, etc.). Consequently, they are not all suited for the problem at stake, the implementation of electronic Bills of Lading. Public blockchains that use the proof-of-work consensus, such as Ethereum have major environmental impact due to the high energy consumption, but are extremely resilient against attacks. Consortium or private blockchains, on the other hand, with less users and applications are usually more efficient and scalable but there are still concerns about privacy.

There are many challenges and obstacles for the presented solutions that have to be solved in order to achieve a widespread adoption of the electronic Bill of Lading. Nevertheless, looking at the recent investments and the interest from the major shipping companies, it is likely that it is only a matter of time.

Disclosure statement

No potential conflict of interest was reported by the author.

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