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Is blockchain a solution for logistics and freight transportation problems?

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Abstract

Fragmented market of freight transportation impose several inefficiency costs as a result of delay, double-spending, disputes, and cancellations. While in such competitive market, every player seeks its own profit, optimization at individual level also becomes harder due to invisibility and disconnectivity. Although, tackling some of these issues are doable by synchronization, encryption and integration, it seems that blockchain not only incorporates all these solutions in a one package, but also may provide other economic benefits. This paper discusses blockchain' s potential in improving the inefficiencies in supply chain and logistics, as well as limitations and challenges.

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Keywords: Blockchain; supply chain; logistics; distributed ledger

1. Introduction

Blockchain is known as the main authentication and verification technology behind the first digital currency "Bitcoin". Blockchain is an open-source decentralized platform that allows a more efficient, transparent and trustworthy flow of transactions between companies and individuals by removing the middleman and cutting out the costs, time lapses, and inter-parties lack of trust issues, while also maintains the privacy, immutability and business data confidentiality. Blockchain characteristics can assist a business structure which involves many parties that need trust transparency, as well as efficiency in inter-party transactions, contracting, and data management.

Supply chain and international trade is one of those fragmented and complex systems that provides a great promise for blockchain adaptation. End-to-end supply chain (e.g. from row material to finished products, or from

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importer/exporter to international seller/buyer) needs track and trace that can be reengineered by the adaptation of blockchain. The use of blockchain can help particularly on shipments or commodities with digital identifiers such as container trade. It can improve the process coordination by increasing knowledge and information sharing among the stakeholders.

This technology can not only overcome international trade hurdles and disputes among agents for incurred unexpected costs by digitizing peer-to-peer collaboration tools and payments, but also widen trade possibilities by providing the easy access to the services and infrastructure for all businesses. Blockchain technology is also emerging in the logistics industry as big freight agents have already joined the blockchain (e.g. Maersk, and United Parcel Service).

With traditional supply chain and international trade, often the significant number of transactions can be impacted with data discrepancies and disputes due to lots of paperwork, multiple stakeholders, and human mistakes through passing through multiple systems. Additional costs emerge when shipments are entitled to delay in payments, and mutual contracts. Blockchain provides the smart contract without human intervention, where an encrypted, immutable and seamless transaction can be seen by everyone on the supply chain, ensuring a transparent and efficient supply chain. Moreover, the distributed and encrypted data structure of blockchain and absence of a central server increases the security of the system and eliminates the risk of cyberattack or hacking. Thus, the potential of blockchain to lower the operating costs, boost the service quality, and consequently improve the organization and the entire supply chain competitiveness, is significant.

However, it is important to consider the rationale for embracing it as there are many questions that need to be answered as this technology progresses. This paper attempt to answer two research questions:

- What kind of inefficiencies can be managed with blockchain?
- What are the barriers and challenges, and the prediction of the technology?

In the following sections, these two questions are addressed where the value propositions of blockchain in supply chain and logistics is discussed in section 2, and section 3 represents several challenges of this technology and prediction of the future. Section 4 draws the conclusion.

2. What is blockchain' s value proposition in logistics?

Efficient logistics services are a precursor for competitive domestic industries in the international market, and, accordingly, contribute to driving economic growth in a region. Improving the competitiveness of local businesses and their products within worldwide markets is a vital element for the long-term economic growth of a region. End-to-end supply chain (e.g. from row material to finished products, or from importer/exporter to international seller/buyer) needs track and trace that can be assisted by technologies such as blockchain, digital identifiers, and electronic transactions.

International trade is one example of the fragmented supply chain market where multiple parties interact with each other over a shipment as shown in Fig. 1. In such a multi-agent system, the inter-organizational transaction can take various formats, one of which is electronic data interchange (EDI). EDI permits instantaneous computer-to-computer transfer of information and is one of the most common forms applied in international trade. However EDI has not been adopted by many freight operators which rely on their traditional way of operation. It has long been understood that the traditional methods of freight transportation and logistics operations impose extra costs, delay, and inefficiencies. In such a fragmented industry where every actor seeks to do their own things while minimizing their own costs, coordination and cooperation becomes harder.

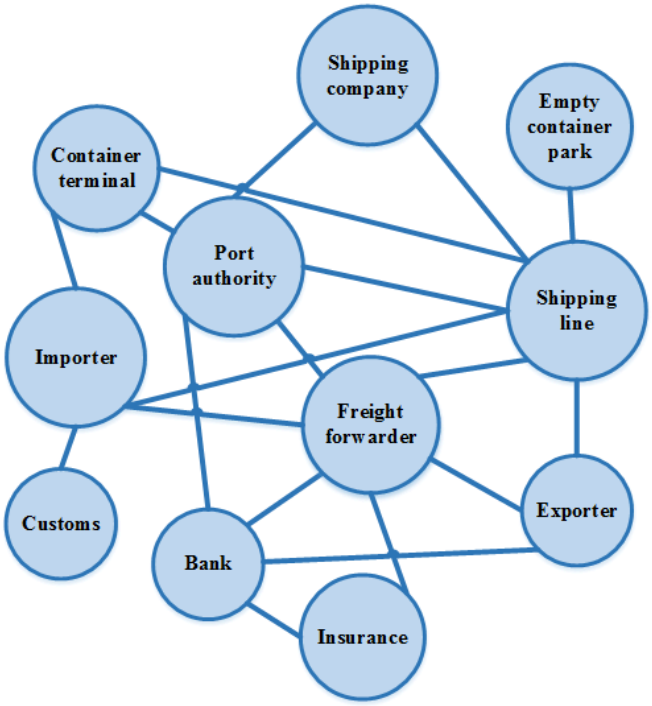

Fig.1. Fragmented market of international freight transportation

Ports and airports as the primary interface in international trade can play an important role to increase efficiency by integrating these several actors. Public ports such as the Port of Rotterdam is a good example of providing such an integrated information exchange service or so-called "Port Community System". While such a central integration model may be successfully adopted by the governmental ports, landlord ports are yet to find their central role as a trade facilitator.

Global experience of privatization of ports has shown a major improvements in increasing efficiency and market competition (Chang and Tovar, 2014, Hoffmann, 2001). However, landlord ports suffer from the lack of authority over freight operators which is a big challenge for integration or perhaps reengineering the logistics business processes. Accordingly, freight operators have no incentive or obligation in sharing information with the port authorities, and as a result there is no efficient monitoring mechanism over the whole supply chain and logistics operations. Where there is a lack of transparency, trust and coordination, inefficiencies hardly can be quantified and be highlighted to the involved parties. On the other hand, a central portal such those in governmental ports may get hacked, break down or become costly for the port authorities. Furthermore, freight operators might be afraid of revealing their business information through sharing their transaction data.

In order to illustrate the logistics operation and possible inefficiencies, let's assume an exporter "*E*" books a slot in a ship by shipping line "*S*". A cover booking sent by *E* gives the S about the potential customer demands and the type of container (22' or 44', a general, refrigerated or food licensed container) and based on the business relations *S* prioritize the requests among various customers and assigns a slot for a booking. A major issue for the shipping lines are the hardship of container managements since there is a lack of information about where its containers are. Some containers are detained by importers outside of the booking time-windows for several reasons, and some are on the way into empty container parks. However, *S* assumes there will be a stock of the requested empty containers available for the booking date and announce a release number to both *E* and empty container park "*P*". E arranges a transport service by trucking company "*T*" to pick up the empty container from *P* and deliver it to the packers location to be loaded, while both *T* and *P* has no information about the booking details and the type of requested container. In the optimum situation, the requested container is available and *T* picks up a right box. However, due to lack of information

exchange extra trips are more likely happens by *T* to *P* to check the availability and even a wrong box is delivered to the packers afterward. Unexpected costs are borne by *E* due to unloading the wrong box and loading another box, amendment fees, and extra trips by *T*. A double-spending, double-booking, and forgotten bookings are other common mistake attributing to inefficiencies and extra costs in the international trade.

Furthermore, it is likely that shipment arrives late at the wharf and misses the ship, and accordingly imposes extra costs due to late delivery to the overseas buyer. On the other hand, the costs associated with idle drivers and fleets are borne by *T* while *S* also suffers from booking cancellation, empty ship slots, and hardship of container management.

Lastly, most of these transactions are done manually either by email or phone calls, and are not in an electronic version such as electronic data interchange (EDI). Every operator has its own management platforms and dataset, with minimum interconnection between other platforms. Lack of transparency adds complexity to the management where no party has the monitoring power over its resources when they are outside their yard. Lack of a trustable and unique source of proof may lead to disputes over unexpected costs and who should pay for that. There might also be several middlemen (e.g. custom broker and freight forwarding company) involved in the process which imposes extra costs.

This is where blockchain can help to increase the transparency, connectivity, and efficiency. One may claim that this is also doable by digitizing the transactions and an integrated database. However, what makes blockchain different from a database, which has existed for a while, is its assured immutability/irreversibility of the imputed original content due to its complex cryptographic verification, making it nearly impossible to alter fraudulently the state of the ledger. While a centralized systems is vulnerable against cyberattacks, and possibly untrustworthy by freight operators, blockchain provides privacy by hiding the information in the blocks. The sender can only send the information to the recipient may wish to know to finalize the transaction. The immutability aspect of blockchains and the fact that they are distributed among multiple nodes (computers) means that it is extremely hard for a hacker to tamper with them and as a result it is not hackable. Accordingly, sharing, updating and reacting on information types of activities can be almost instantly automated with a high degree of security which correlates directly to the efficiency. Using hashing system and a distributed database can also protect the malware attack by issuing a new hash, while also many copies of the transaction is stored in other nodes of the network that are immutable.

Accordingly, ledgers are defined as the encrypted transactions which can be shared with the freight agents to whom it is relevant, and be hided from others. In logistics, ledgers may represents the movements of cargo, information, or currency. While, transactions are encrypted, a kind of unique fingerprint is assigned to that transaction block which in this process is called hashing or cryptography. While everyone can see the transactions are taking place, the detailed information is encrypted inside every block, and it is immutable and will be there forever. Only the mutual freight operators that hold the signature on the transaction will have a copy of the ledger through interfaces such as a mobile application, web-based service or computer-based. The link between proceeding and previous transactions (blocks) is specified through this hashing as shown in Fig. 2.

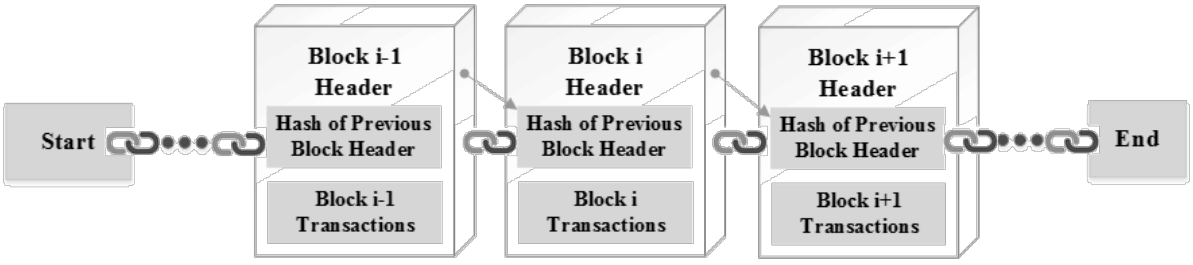

Fig. 2. Ledger architecture

Blockchains attain immutability from the hashing algorithm and creating a block of ledgers. Hashing means taking an input string of any length and giving out an output of a fixed length (e.g. 256 bit in Bitcoin). There are certain properties that a cryptographic hash function needs to have in order to be considered secure which “avalanche effect” is one of the most important ones. Avalanche effect means even a small change in the input, will be reflected in the hash drastically. The chain of blocks also means that any slight changes made in one block, will change the hash which is stored in all the previous blocks, and as a result will completely change the chain, which is impossible.

In a peer-to-peer network where no single authority can shut down the system or cut off an individual or a group of users, everyone can participate in the system without any favoritism. The consensus algorithm is defined as a set of rules and procedures to maintain the coherency between multiple participating nodes which is based on a notion that a majority (or in some cases all) of network validators should come to agreement on the state of a ledger. Several consensus algorithms have been developed such as Proof of Work, Proof of Stake, and Proof of Authority, Proof of Devotion, and Proof of Importance, Byzantine Fault Tolerance, RAFT, and hybrid forms of the aforementioned algorithms.

Double-spending and double-booking problem can also be easily solved by the consensus algorithm applied in blockchain, since there will be only one transaction linked to the previous and proceeding block in the chain that can be approved.

Blockchain also enable smart contracts. Smart contract is an automatic and self-executing contracting application which automatically triggers actions or payments once conditions are met. The idea of smart contracts was first proposed by Szabo (1997) which combined computer protocols with user interfaces to execute the terms of a contract. Technologies such as Blockchain and Internet of things (IoT) provide a platform to utilize the smart contract easily by enabling a better integration of supply chain flows including information, physical, and financial flows on a global scale. Reduced payment reconciliation time and cost are the most important advantageous of smart contracts in supply chain use-cases.

The smart contract has a few specifications which is useful for the supply chain application. First, transactions can be executed automatically if prespecified conditions met. Second, transactions which are sent from unauthorized agents, or in a wrong point of the process are automatically rejected (Staples et al., 2017).

Not only smart contract can solve the inter-agent lack of trust, but also reduces human error. Accordingly, operators see the advantages of an integrated marketplace, compared with dealing with multiple parties with different platforms and business structures. It removes the dependency to the other authorities and middlemen by the disintermediation of intermediaries. Fig. 3 represents several beneficial characteristics of blockchain.

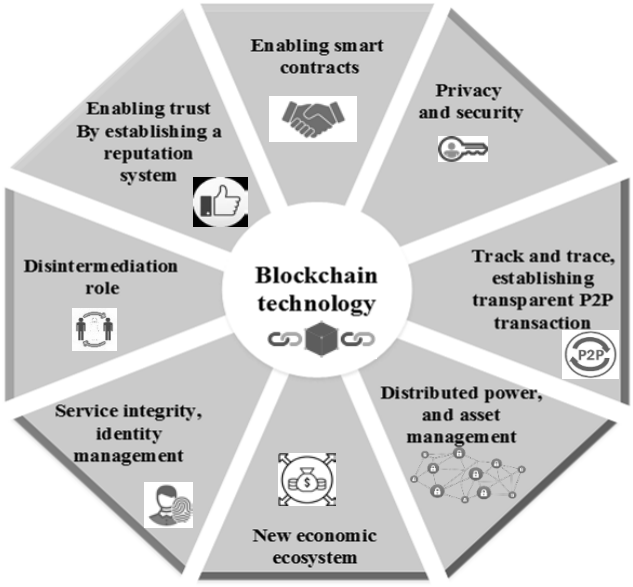

Fig. 3. Blockchain characteristics

3. Challenges and the road ahead

Despite all the aforementioned benefits to reap, blockchain has several challenges and unpredictable changes. While blockchain makes bold promises, it is unclear when it will be ready for a real-world applications and commercially be viable. Consistent with up and down evidences, Gartner Hype Cycle (Fig. 4) suggests that we are in

the disillusionment period of blockchain technology where it is likely that in the next5 to ten years it will reach to the plateau of productivity.

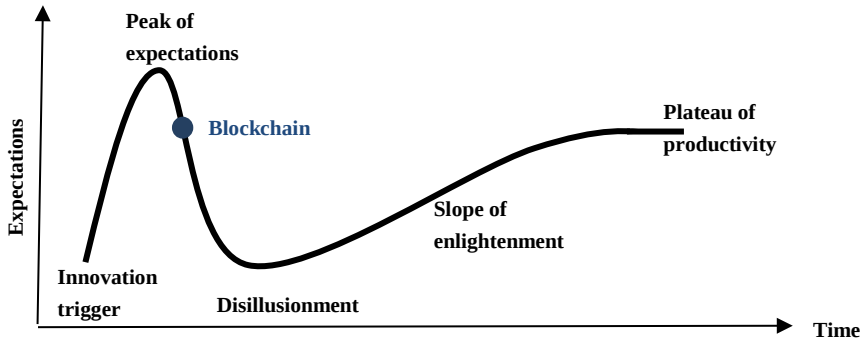

Fig. 4. Gartner Hype Cycle Model †

Blockchain is susceptible to capacity problems, system failures, unanticipated bugs, and perhaps the huge disappointment of technically unsophisticated users. Blockchain currently faces several challenges namely throughput (i.e. how fast the nodes can replicate a transaction), scalability, interoperability, usability, lack of standards and regulations, and unpredictable future of cryptocurrencies. In this paper, we do not discuss the various challenges that cryptocurrency faces, but it should be noted that decentralized consensus is hard to achieve without economic incentive. The key question remains - who will build, maintain, and improve the platforms especially if no value can be harvested for their creation. What hidden costs are there? However, if blockchain can reduce the inefficiency costs may still provide enough incentive for the freight transport actors to participate. In this case, a blockchain without a cryptocurrency falls into a distributed ledger technology.

Scalability can be defined as a blockchain's ability to accommodate as many users as possible on the chain while still retaining low transaction fees and fast consensus. This massive amount of unsustainable energy consumed to reach the Proof of Work consensus (i.e., the process of running pending transactions and solving a block in Bitcoin or Ethereum) is one of the big challenges. Considering such a consensus algorithm for a real-size logistics operations, will result in an extreme carbon footprint.

Furthermore, the stakeholders in supply chain should have the capacity to embrace and foster this new technology. Usability means that platform should be easily usable by end-users as well as by developers. A user-friendly interface will not be enough for both users and validators. It should be noted that smart contracts are coded in programing languages where many lawyers, judges, and also users might not be able to interpret and check the validity of these codes.

Currently, blockchain suffers from the lack of standard protocols to link different blockchains, instead of creating a new larger blockchain. Creating a new blockchain would be like a large intranet that all the other intranets would have to trust. It would be way more difficult to convince everyone to have that trust than it is to leave everyone on their Blockchain and just connect them to the rest of the ecosystem. This is where interoperability and cross-chain blockchains become vital. Interoperability can be defined as a capacity to interact and cooperate with different blockchains, and to facilitate smart contracts between one protocol and another.

However, standards, regulations, and usage should be balanced, because there should be enough users to comply with. Considering the global inter-connected blockchains (e.g. various freight and supply chain markets), it is also important to answer whether governments can be aligned to force and control the regulations and legislations over such global systems.

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† https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/

Regarding multiple actors and different roles, from risk assessment perspective the whole chain is only as strong as the weakest link (Parent and Reich, 2009). Mitigating the risk is an important decision.

Another important decision that organizations are facing with is either develop a new blockchain network (become both blockchain application provider and service provider for the owned blockchain application), or join an existing blockchain network that is run by others (become only blockchain application provider). Economic incentives (needs a proper business plan) and maintenance and changes in future (needs proper governance) are important factors affecting this decision. However, they need to establish a trust on the existing platforms, while there is not information about the business model or governance of many of them(Deventer et al., 2017).

Furthermore, supply chain and international trade are multi stakeholder tasks. However, the stakeholders are pre-identified and not subject to varying degrees. The decision whether blockchain should be operated publicly where everyone can participate and be involved, or it would operate better if a private consortium is made among the existing stakeholders is another research question.

4. Conclusion

This paper attempts to clarify the opportunities and challenges of the blockchain technology in logistics and transportation. Currently the information systems supporting supply chains reside at the individual supply chain participants, and are subject to varying degrees, for example various barcodes or tracking IDs. However, blockchain can bring the integrated system where every kind of transactions be digitized uniformly in order to facilitate accessibility and readability. The use of blockchain can help particularly on shipments or commodities with digital identifiers such as container trade. It not only improves the process coordination by increasing knowledge and mutual information sharing among the stakeholders, but also increases the security of physical flows by encryption of transactions. Enabling smart contract increases the gains from contractual trade, reducing the size of companies, paper-based and manual works, and increasing economic outputs through a more efficient system.

This technology can overcome international trade hurdles and disputes among agents for incurred unexpected costs by digitizing peer-to-peer collaboration tools and payments. Although, track and traceability can be provided by digital identifiers and universal product codes, immutability of blockchain plays an important role in ensuring all parties about the validity of those identifiers. This characteristic of blockchain is particularly useful for luxury goods (e.g. blood diamond, fine wines, jewellery and antiques), and fresh food products (e.g. meat, sea food and organic products).

However, considering several freight actors interacting in a dynamic freight transportation market introduces several unexpected transactions and uncommon contracts where makes it difficult for the blockchain adaptation. It is of high importance that instead of digitizing the old process, re-thinking and re-engineering should be tackled, where all processes including contracting and is required to be redesigned to tick the blockchain characteristics. Some of these processes are done by private stakeholders where organizations such as landlord ports do not hold any responsibility of the legal. Obviously, it is a hassle that organizations are not willing to take without enough economic gains and other motivation such as increasing the security and facilitating the international trade.

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