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Application of Blockchain in Supply Chain Management

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Abstract:
In the rapidly evolving environment of the international supply chain, the traditional network of manufacturers and suppliers has grown into a vast ecosystem made of various products that move through multiple parties and require cooperation among stakeholders. Additionally, the demand for improved product visibility and source-to-store traceability has never been higher. However, traditional data sharing procedures in today's supply chain are inefficient, costly, and unadaptable as compared to new and innovative technology. Blockchain technology has shown promising results for improving supply chain networks in recent applications and has already impacted our society and lifestyle by reshaping many business and industry processes. In an effort to understand the integration of blockchain technology in the supply chain, the proposed work consists of novel approach to improve the traceability in supply chain through the blockchain technology.

Keywords: Blockchain, Supply Chain, Traceability.

I. INTRODUCTION

The emergence of blockchain technology introduces a new way of thinking on supply chain management. The recent development of e-commerce platforms brings plenty of data related to consumers, products and suppliers. The techniques on data storage, management and analysis have greatly evolved. The ecommerce platform has the natural advantage to integrate data from upstream manufacturers or suppliers, intermediary service providers and downstream consumers. There are still several open issues on the integration between blockchain technology and supply chain management. Achieving product information traceability in decentralized blockchain system requests a new system design, which requires the domain knowledge on supply chain management. The great amount of data generated from supply chain requires a more efficient structure model in the blockchain. The security problem in the blockchain-based open access system is also important. New information encryption algorithms and key management methods that protect data security in supply chain management should be developed [1]. A block chain is a chain of blocks of information that registers Bitcoin transactions; of course, there is a stringent set of rules that govern how to verify the validity of the block and make certain that the block will not be altered or disappear. The algorithms and the computational infrastructure of creating, inserting, and using the blocks are considered as the blockchain technology. Many people believe that blockchain could revolu tionize many fields, such as finance, accounting, management, and law leading to three generations of blockchains, namly, Blockchain 1.0 for digital currency, Blockchain 2.0 for digital finance, and Blockchain 3.0 for digital society [2].With the implementation of blockchain trustless networks appeared. This is possible because in networks that use

blockchain we can make transfers with no need to trust other users. The most significant difference between the transaction structure based on block chain and the traditional transaction structure is that all participants share a common ledger, and all participants have a complete general ledger. The original application of the blockchain was to build a system for payment. The issuer and receiver do not need the central transaction party during the payment process. It is necessary to firstly explain how the current payment system works to demonstrate the potential value of blockchain for financial institutions [3]. A blockchain is a distributed data structure that is replicated and shared among the members of a network. It was introduced with Bitcoin to solve the double-spending problem. As a result of how the nodes in Bitcoin (the so-called miners) mutually validate the agreed transactions, Bitcoin blockchain establishes the owners and states what they own. A blockchain is built using cryptography. Each block is identified by its own cryptographic hash and each block refers to the hash of the previous block. This establishes a link between the blocks, forming a blockchain [4]. Figure 1[5] depicts the main elements of blockchain technology in a schematic form. The blocks are linked in a chain (blockchain) in which each block has a hash of the previous blocks and a record of all transactions. Furthermore, because the block has a copy of all transactions and it cannot be modified, the technology ensures transparency and enhances trust over the network. Thus, in Figure 1, each block has the hash of the prior block, for instance, block n+3 has the hash of the block n+ 2 and so on, ensuring traceability. Consequently, this process validates the preceding blocks' information back to the first block that started a process. Blockchains, applied in a SCM context, will likely lead to disrupting transformations in all types of industries. Hence, traditional relationship models are already being reconfigured, mainly because of the disintermediation of the transactions.

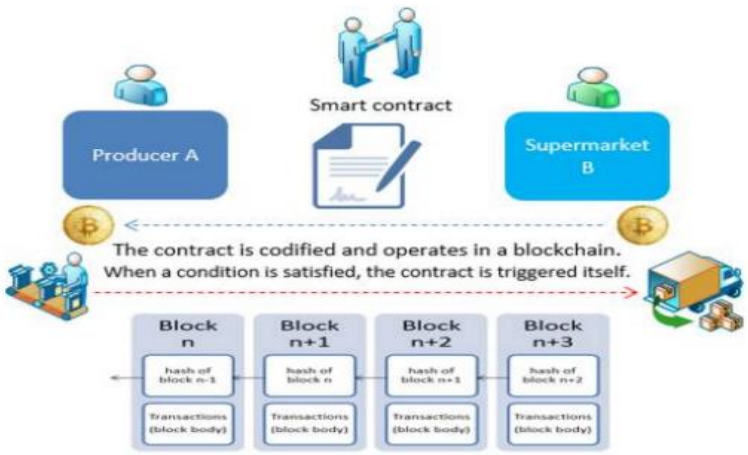

Fig. 1. Blockchain Architecture

Blockchain technology provides us a new tool to solve the product traceability problem in supply chain management. The emergence of blockchain technology introduces a new way of thinking on supply chain management. There are still several open issues on the integration between blockchain technology and supply chain management. Achieving product information traceability in decentralized blockchain system requests a new system design, which requires the domain knowledge on supply chain management. The great amount of data generated from supply chain requires a more efficient structure model in the blockchain. The security problem in the blockchain-based open access system is also important [6]. In a blockchain model, there is no need to store information with third parties. The records are on many interlocked computers that hold identical information. If one computer's blockchain updates

are breached, the system rejects it. In addition, multi-signature (multisig) protection or the requirements of more than one key to authorize a transaction processes can further improve security and privacy [7]. Blockchain is a kind of new Information Technologies (IT) used in supply chain quality management. It solves the issues of distrust on the basis of unchanged information and traceable records through standardized norms and agreements. By setting up automatic executions of quality management contracts, it is possible to develop an auto-run intelligent system. Secondly, blockchain has brought a new mechanism and ways of thinking to supply chain quality management. Blockchain technology adopts the governance model of human society in IT systems, and further develops the traditional centralized system to a multi-centered or decentralized system that enables different interest groups to share power in the same IT system. This system also improves the qualities of products and services in supply chains by contracts [8].

Supply chains can span from over hundreds of stages and multiple geographical locations which makes it complex to trace events in the supply chain and investigate any issues. To date, customers have no reliable way to validate the true value and authenticity of a product purchased due to the lack of transparency, tracking, recording and sharing of information. The lack of transparency causes an absence of information from being shared about the manufacturing process of goods, assembly, delivery and certification of materials used that might pose risks and issues in the supply chain. This also poses a risk to fraud occurring in the supply chain such as counterfeiting of products, and the accountability of any illicit activities that may occur [9]. The blockchain network can be categorized as permission-less or as permissioned network. Permission-less blockchain, is an open distributed ledger where any node can join the network and where any two peers can conduct transactions without any authentication from the central agency. A permissioned blockchain is a controlled distributed ledger, where the decision making and the validation process are kept to one organization. A Certificate Authority determines who can join the network. All nodes are authenticated, and their identity is known to other nodes [10].

The rest of this paper is summarized as follows: in section 2 related works are displayed; section 3 gives insights about Blockchain technology; section 4 features about the Blockchain in supply chain; section 5 concerns about Challenges; and finally concludes the papers in section 6.

II. RELATED WORKS

In 2017, Chen et al. [12] proposed a supply chain quality management framework based on blockchain technology. Apart from enterprises on the supply chain, this framework consists of blockchain, smart contracts and various IoT sensors. The framework and the corresponding system architecture are composed of four layers based on different functions, the bottom layer is IoT Sensor Layer. In this layer, GPS is used to locate the products in logistics process.

In 2018, Caro et al. [13] proposed a Blockchain-based Traceability framework in Agri-Food Supply Chain Management. It is a layered architecture able to rely on the Blockchain and the IoT technologies to achieve transparency, auditability and immutability of the stored records in a trustless environment. It considers the blockchain as a layer of our system allowing AgriBlockIoT to be blockchainin dependent, while it can be integrated into existing traditional software systems (ERP, CRM, etc.).

In 2019, Azzi et al. [14] describes how the blockchain can be integrated into the supply chain

architecture to create a reliable, transparent, authentic and secure system. The Ambrosus network uses tags, tracers and sensors to track products throughout their lifecycles. In the Ambrosus network, all tracking devices are authenticated by a public-private key cryptography. The sensors and the QR code sign the collected data before sending it to the edge gateway using RFID technology.

In 2020, Wamba et al. [15] examine the potential influence of blockchain on supply chain performance. The results support the model and indicate that blockchain applications can improve supply chain performance. The primary objective of this study was to show strong empirical evidence of the relationship between blockchain and supply chain performance in two selected countries, with the hope that the results obtained may serve as a catalyst for further research and be generalized.

In 2021, Vadgama et al. [16] emphasis on Blockchain adoption in supply chain between 2010 and 2020. In this research, the evolution of blockchain applied to supply chains has been mapped from the inception of the technology until June 2020. It has analyzed 271 blockchain projects on parameters such as their inception dates, types of blockchain, status, sectors applied to and type of organization that founded the project.

In 2021, Durach et al. [17] clarifies the discussion about blockchain application areas (BAAs) in SC transactions and their relevance for businesses. This study contributes to the few studies in the literature that exist at the intersection of blockchain technology and SC management. This study combines the findings from three methodological approaches: an extant literature review, a Delphi study, and a survey of 151 German machinery and equipment sector business managers.
In 2022, Omar et al. [18] develop a Blockchain-based Supply Chain Traceability for COVID-19 personal protective equipment. It consist a blockchain-based approach using smart contracts to transform PPE supply chain operations. Author propose a generic framework using Ethereum smart contracts and decentralized storage systems to automate the processes and information exchange and present detailed algorithms that capture the interactions among supply chain stakeholders.
In 2022, Agi et al. [19] develop a comprehensive framework for blockchain adoption in the supply chain by identifying the enablers and empirically evaluating their interdependencies and impact on adoption. This study makes a significant contribution to extant literature on blockchain adoption in the supply chain. Indeed, this work is one of the first empirical studies that attempt to analyze and understand blockchain adoption in the supply chain. The findings allowed to uncover the role of 20 enablers of blockchain adoption in the supply chain with regard to the adoption decision and to establish a series of insights on how to encourage such decision.

III. BLOCKCHAIN TECHNOLOGY

Blockchain can be described as a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, a car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved". The term blockchain is derived from the way it stored the transactional data. It consists of a sequence of blocks that are linked in the form of a chain, as shown in Fig. 2 [11]. Each block holds a set/batch of the transactions arranged in Merkle tree form (represented by Tx_Root in Fig. 3 [11]) where the

cryptographic hashes of the transactions are stored as header for a quick and easy verification of individual transactions in the block. In addition, each block contains a timestamp indicating when the block is formed, the hash of previous block (represented by Prev_Hash in Fig. 3[11]), a block ID/Number and a proof from the consensus algorithm (represented by Nonce in Fig. 3 [11]). The blocks are logged into a distributed ledger based on the consensus rules agreed upon by the network partners. A ledger is simply a record of transactions. It has been used in double entry book-keeping since ages. In blockchain, a common, shared ledgers that record all the transactions taking place between all the multiple authorized partners of the blockchain network and thus terming it as a distributed ledger. Additionally, the ledger is made immutable by binding the transactions with cryptographic hash. A hash is a combination of random digits generated by passing the block information (transaction detail and a hash of the previous block) in a cryptographic hash function (e.g. SHA-256) which produces a new hash of a desired length (e.g. 256 bit for SHA-256) for the current block. The cryptographic functions uniquely map the input data with output hash, and slight variation in input generates a different hash with no apparent pattern. Thus, due to the pseudo-random nature of calculated hash value, it is extremely difficult to compute the input information using the resulting hash value. Hence, it is also known as one-way encryption. In blockchain, as each block consists of the hash of a previous block as shown in Fig. 2, any modification in the transactions of a previously registered block would alter the hashes of all subsequent blocks. Therefore, it makes it quite easy and quick to identify any tampering done with a block in the distributed ledger. Additionally, on a distributed ledger, each transaction is recorded only once, thus eliminating the risk of duplicate entry. The ledger holds the current state of the network (record and track of all tangible and intangible assets that are being traded since the installation of blockchain) and chain of transactions. As the blockchain ledger is an append-only system, it serves as a single source of truth for all associated parties. Therefore, the shared ledger is one of the most important blockchain components that facilitates traceability of assets and information, and creates a technology-based trust among a group of parties interacting on the blockchain network without centralized authority.

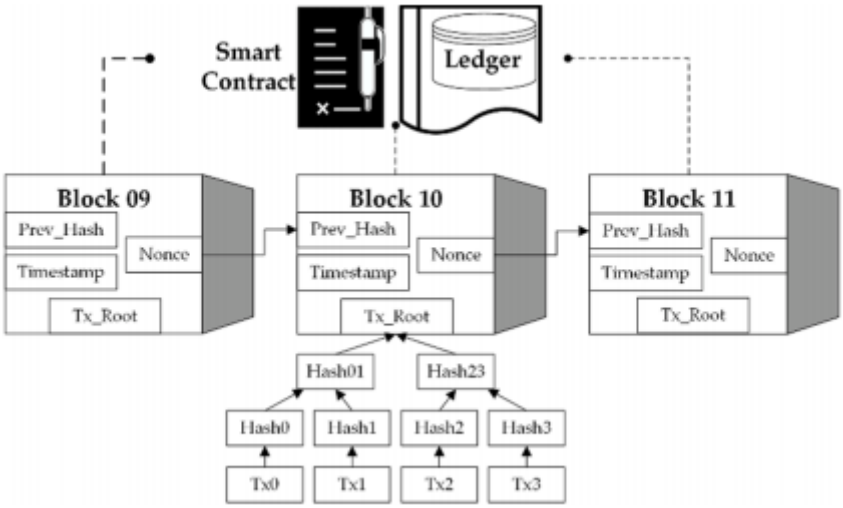

Fig. 2. Blockchain Architecture

In blockchain smart contracts set the rules for the game that governs business transactions. In blockchain, smart contracts are hardcore programmable logics or rules with strict implementation conditions. Each transaction is verified against the rules before recording on the shared ledger.

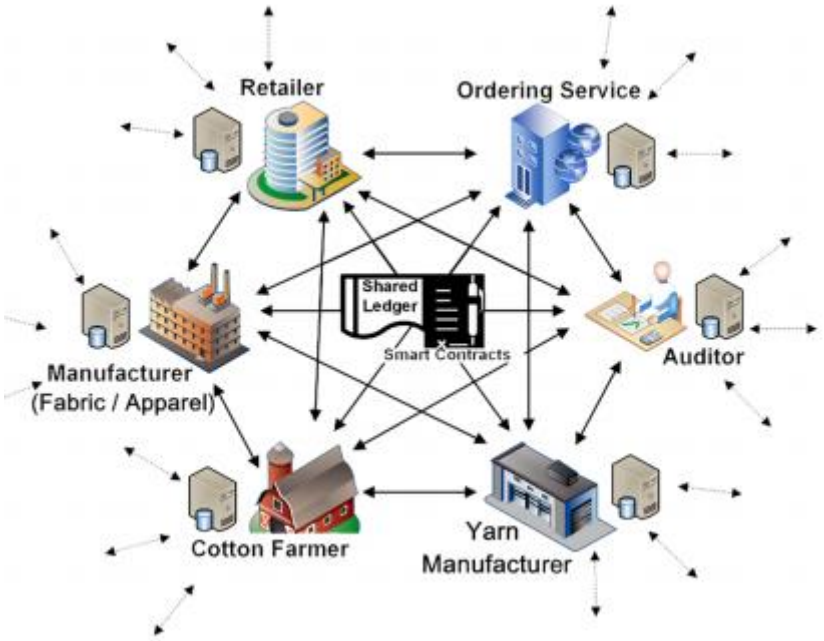

Fig.3. Blockchain-based decentralized network

While dealing with a shared ledger, it is important to have a mechanism to avoid what is called the Byzantine fault. In simple terms, it is a wrong ledger entry, done by mistake or deliberately. Therefore, each transaction is verified against the current state of the shared ledger before recording it in a block. This validation can be done by single peer (validating peer) on the blockchain that can be randomly selected when a new block is formed. This safeguards the ledger from a wrong entry. The address of the validating peer is also saved on each block along with the transactions data and other information. Public blockchain like, Bitcoin uses a proof-of-work (PoW) consensus mechanism that makes bitcoin blockchain highly secured from attacks. In PoW, the miners (pool of processing nodes) compete with each other to find appropriate hash of the new block and earn a reward in the form of bitcoins. The appropriate hash is obtained by calculating a number referred as nonce (number only used once). Greater the diffiulty level, harder it is to create a hash lesser than the target. In a private blockchain, apart from PoW, mechanisms such as Proof-of-Elapsed Time, Byzantine fault tolerance, etc. can also be used where the validating miner is chosen randomly based on a set mechanism.

IV. Blockchain in Supply Chain

Many supply chain processes, especially at lower levels of the supply chain, are slow and almost entirely paper-based. Blockchain technology in the supply chain can replace these manual processes with continuous digital processes that provide new levels of visibility and transparency.

The following are the application of blockchain in supply chain.

1. **Improving Traceability:** Regulatory and growing consumer demand for paternity is already driving change. For this reason, companies are already turning to blockchain for supply chain transparency by applying blockchain tracking and tracking styles to the supply chain is one of the most popular. Supply Chain Transparency increases the transparency of supply chain operations to increase inventory utilization, shorten delivery times, increase quality, and reduce lost revenue from black or gray market products.

2. **Transactional Cost Reduction:** At a basic level, the ability of blockchain-based cryptocurrencies to enable cross-border transfers of funds without banks and clearing means that blockchain technology in the supply chain can speed up payments while lowering the fees incurred. However, developing smart contracts via the Ethereum platform, for example, means that many supply chain tasks can be executed automatically via smart contracts. For example, a smart contract could define the agreed delivery of a product and what happens if delivery is delayed or missed. Contracts can track shipments and automatically initiate action in case of violations. This saves a lot of money, especially if a third party was previously used to perform part of the process.

3. **Accelerating Process:** In theory, blockchain technology protects the integrity of information and transactions. Fewer mistakes and disputes. The need to recall products or refill missing orders is reduced, speeding up the entire process. In addition, the use of smart contracts reduces the need for intermediaries or third parties, as mentioned above. For example, blockchain in the supply chain can reduce the need for a bank or clearinghouse in the payment process.

4. **Making Supply Chain Ethical:** Consumers demand a deeper understanding of the origin of their products and the activities of the companies that manufacture them. This has sparked the momentum to build an ethical supply chain.

There are various branches of supply chain where we can use supply chain efficiently. The following are the different branches of supply chain.

1. **Food and Agriculture:** Improved traceability is a large opportunity in the food and agriculture industry. The Food Safety Modernization Act (FSMA) currently requires food companies to know “one up and one back,” where the product came from and where it is going next.

2. **Pharmaceuticals:** With blockchain, pharmaceutical companies can closely track medications throughout the entire supply chain by individual serial numbers. The network ledger records production updates by serial number, and serves as a tamper-proof source of truth that eliminates opportunity for nefarious actors.

3. **Manufacturing:** shoe companies have intricate multinational supply chains that transform raw materials into wearable finished products. Clothing items and shoes have short product life cycles that quickly pass through several manufacturing sites and processors before arriving to retailers.

4. **Automotive Manufacturing:** Auto manufacturers lose billions annually due to damaged, lost, stolen,

and counterfeit car parts. With complete visibility on a blockchain network, auto companies can trace spare parts to their original manufacturer and query exactly where they were lost or damaged. Blockchain solutions can address the infiltration of poorly made counterfeit spare parts that put consumers at risk while costing auto companies money and customer satisfaction.

5. **Mining:** The diamond industry suffers from supply chain inefficiency that makes it difficult to ensure stones are conflict free and authentic. Laboratory grown diamonds are sold as natural ones, and diamond qualities can be fabricated or exaggerated. With the current state of supply chain management in the diamond industry, consumers can't be certain of the origin and quality of their diamonds. Diamond companies have adopted blockchain to track diamond provenance and ensure they are compliant in only selling authentic and conflict free diamonds. Blockchain also makes it possible to track diamonds individually instead of by the case, which means being able to record individual level details of the stone's condition for customers.

V. Challenges

There are many limitations and challenges in its adoption in applications. Considering the length of the article, a short but comprehensive discussion is made on non-technical and technical challenges Blockchain Adoption in Supply Chain. Even now, many warehouses still operate with paper at the integral points, although RFID chips and scanners are now conveniently available, in reach and access [20]. Understanding of Blockchain among business leaders, the view that it is a fad, and waiting for wider adoption before committing. Even those business leaders who realize the potential of Blockchain are hesitant to invest money and time into it, keeping in view the lack of industry-wide standards and practices. Hence, for Blockchain to be successful everyone in a typical supply chain industry needs to be convinced of its benefits; the key stakeholders should be on-board and be able to see the benefits in introducing Blockchain. Hence, market acceptability is a key challenge to face. There is also a lack of enterprise resource planning (ERP) tools and support within existing systems. Typical ERP systems used in many organizations do not support Blockchain. Hence, a bold step is required to either outsource the application development for its particular supply chain or set up in-house development. In the former case, apart from other risks, privacy leakage can be a major concern, as an organization has to hire the services of the third party who must be trusted with the organization's data. In the latter case, privacy risks are lower, but significant investment is required for the long term. Either existing staff requires training or existing professionals with these skills must be employed. This may be difficult, since the development requires a range of software skills, as well as requiring an understanding of the economic and business issues and of the underlying supply chain setup. Data entered to a Blockchain must be correct; the immutable and transparent attribute of Blockchain technology means the user cannot easily update or modify the entered record. If a supply chain partner is using an unreliable system to record information, then the addition of Blockchain technology can become more detrimental rather than facilitating the user. The immutability of the Blockchain does not guarantee the quality of the data. Compared to a traditional database, Blockchain is significantly slower in retrieving and committing records. It also requires significantly more computing resources, and the scalability of these resources is a significant concern. Moreover, interoperability between all systems interacting with the Blockchain is needed. Scalability is the ability of a system to continue to respond and function after increasing the size of the input to fulfill user demand.

Conclusion

This paper presents the application of using blockchain technology in supply chain management. It also presents possible opportunities that the whole supply chain will benefit from such technology. It may include companies or organizations that have existing ERP systems or for companies that are planning to implement directly blockchain without existing ERP systems. The technology is still at an early stage but the potential benefits are enormous, once it is fully implemented in various areas of the supply chain, a lot of industries may benefit with the functionalities that the blockchain technology will provide. The blockchain technology is rapidly expanding and a lot of companies are doing their best to take advantage of this new technology. It will enable their companies or organizations to have efficient business process that may open the doors to facilitate effective system models and innovative business processes. For future work, we will try to work on real-world examples where blockchain technology is being implemented. Successful use cases will be investigated to have a clearer picture of how blockchain is being utilized by companies or enterprises for the improvement of their current digital systems.

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