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Systematic Analysis of Blockchain Technology for Supply Chain and Logistics - Background, Implications, Emerging Trends and Future Directions

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Abstract - *A systematic review of the literature is presented related to the usage of Blockchain technology for supply chain and logistics. Blockchain technology is a revolution to the digital world by offering a new perspective to the industry. Improved security, traceability, flexibility, controllability of data is some of the best benefits of using Blockchain. Blockchain provides a safe way to exchange any kind of data, service, or transaction. A supply chain is a system amongst a business to provide a specific product or service by involving it in the production and distribution (1). Blockchain is a Decentralized and Distributed Ledger Technology (DLT), that records transactions and allows users to connect with one another. Blockchain consists of fundamental attributes such as recorded, transparent, and decentralized. Blockchain technology was created by combining various technologies such as algorithms, cryptography, mathematics etc* (2)*. Blockchain-based applications are emerging day by day, covering numerous fields such as the Internet of Things (IoT), financial services, medical sectors, cryptocurrency exchange, and so on. However, there are many challenges of Blockchain technology such as low scalability, high energy consumption, lack of privacy, security problems waiting to be overcome (3). This paper presents a broad overview of Blockchain technology. Firstly, an overview of Blockchain architecture. Furthermore, technical challenges, recent advances, and emerging trends in Blockchain technology for the supply chain industry are briefly listed.*

Key words: Blockchain; Supply Chain; Decentralized; Internet of Things (IoT); Cryptocurrency;

1. Introduction

In 2008, *Satoshi Nakamoto* created the first-ever Blockchain-based network called Bitcoin. (4) Bitcoin became the major virtual currency after the Blockchain was invented. Originally, Bitcoin turned into supposed to offer an opportunity to the banking industry, now we can see the Blockchain era being carried out to remedy all the complex problems. Blockchain is a decentralized database of statistics for all transactions that have been completed and shared among associated events. Blockchain technology records transactions in an incorruptible digital ledger that is sent across the network (4). Whatever the price inclusive of Assets, Land, Vehicles, etc. can be documented and stored on the Blockchain as a transaction. In most cases, today's supply chains are large enough that Blockchain technology isn't required. However, technology has caught on with the IT and supply chain world. It has also inspired numerous articles and inspired established IT players start-ups to launch promising pilot projects such as:

- $800,000 has been raised by a UK-based start-up company named Provenance to adapt Blockchain technology for food tracking.
- Maersk and IBM are working in collaboration to improve process efficiency through cross-border and inter-party transactions using Blockchain technology.
- BHP presents a Blockchain-based solution that replaces spreadsheets for tracking samples from a variety of vendors both internally and externally.
- Walmart tested an app that tracks pork in China and the information is sent to the United States, to authenticate the transactions and maintain the accuracy of the product more efficiently.

Blockchain's goal is to allow digital data to be recorded and distributed. However, that is not edited. Thus, a Blockchain is the source of transaction records and fixed ledgers that cannot be altered, erased, or destroyed. This is the reason Blockchains are acknowledged as Distributed Ledger Technology (DLT). One of the well-known uses of Blockchain is Bitcoin. Bitcoin is a cryptocurrency, and it's far used to substitute virtual property online. Bitcoin makes use of cryptographic evidence instead of third-party trust for two events to execute transactions over the internet. Each transaction protects through a virtual signature (2).

1.1. How do Blockchain Technology work?

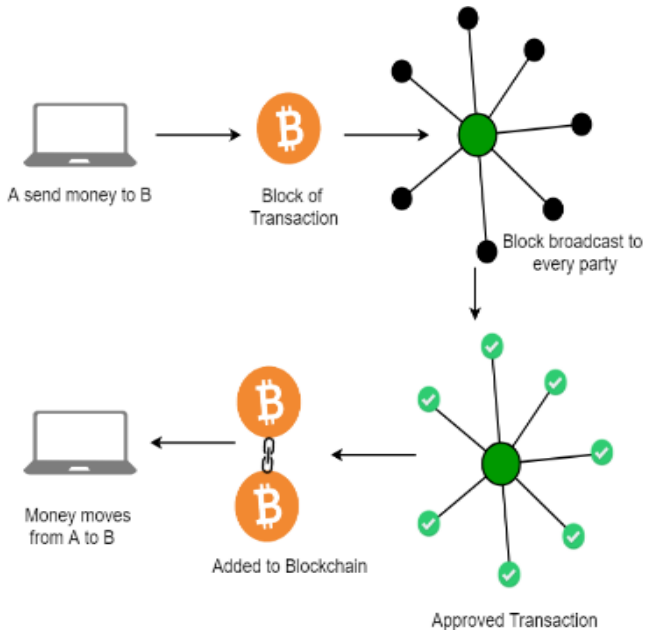

Figure – 1: Process of a Blockchain Transaction

What a Blockchain makes sure of is, allowing the data in the database to be distributed among different network nodes in several locations**.** This not only creates redundancy but also preserves the accuracy of the data stored in there, if somebody tries to adjust or modify a record of the database in one instance, the other nodes cannot be modified and therefore preventing the attacker from manipulating it (6). In case of an exploiter tampers with Bitcoin's transaction records**,** the other nodes will change the paths and easily identify the node with the incorrect information**.** This approach ensures that no single node in the network could alter the data contained within it. As a result, each block of the Bitcoin Blockchain's transaction history is unchangeable.

Because of the Blockchain's decentralized structure, all the transactions can be viewed in real-time by hosting a personal node or utilizing Blockchain explorers, which let anybody view live transactions. Each node has its own copy of the chain, which is updated as new blocks are added. The users can track the live transactions. For this reason, the information and the history are irreversible (7). This record might be a list of transactions (as with cryptocurrencies), but it's also feasible that a Blockchain contains additional data such as legal contracts, corporate shares, etc.

Blockchain is a blend of three popular technologies.:

a. Cryptographic keys.
b. A peer-to-peer network that includes a shared ledger.
c. A means of computing, to store the network transactions and records.

Cryptographic keys are of two types, Private keys, and public keys. These keys support executing successful transactions between two participants. These two keys are held by each participant and are used to generate a secure digital identity position. The most crucial feature of Blockchain technology is its ability to provide secure identities (7). This is often referred to as a 'digital signature,' and it is used to control and authorize transactions.

The digital signature is associated with the peer-to-peer network, and a huge number of people acting as authorities use it to obtain approval on those transactions. When customers authorize a transaction, it is mathematically verified, resulting in a safe transaction between two network-connected participants. In summary, Blockchain users perform many forms of digital interactions on the peer-to-peer network using cryptography keys. (8).

2. Background

In this section, basic background, fundamentals of Blockchain technology, the architecture of Blockchain technology, and Blockchain's value in supply chains were briefly described. also, comparisons and clarifications are given to facilitate the understanding.

2.1. Fundamentals of Blockchain

A Blockchain is a collection of cryptographically connected records that form a chain. There are two sorts of Blockchains: public chains and permissioned chains. A public chain, on the one hand, is similar to the Internet. Individual users of this record system can quickly locate and access this chain. A permissioned chain, on the other hand, permits only legitimate entities to view and update the data. Furthermore, a consortium Blockchain is a blend among both public and permissioned chains, yet it operates more like a private chain. A specified group of entities authorises and supervises it. Blockchain records are guaranteed to be immutable according to the chain design. If a block exists in this chain, nothing in the preceding blocks can be changed.

For example, when we transfer money from our bank account to friends or family, we first login to the banking application and transfer the money to the other person using the bank account number. After the transaction is finished, the bank updates the transaction history. Although it looks to be a simple procedure, it contains a probable flaw. This transaction is readily modified or interfered with. Blockchain technology was developed to address this problem.

2.2. Blockchain Architecture

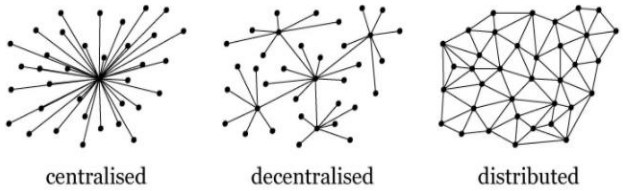

Figure – 2: Architecture of a Blockchain

The Blockchain architecture provides a growing list of ordered records called blocks. Each block preserves a timestamp and a connection to the previous block.

The main components of a Blockchain architecture are:

- *Node*: In a Blockchain network, nodes are electronic devices with an IP address that are linked to the network. Nodes, in general, are communication endpoints that may communicate with any user or application(3). There are several roles depending on specific tasks, such as accepting or rejecting transactions, monitoring transactions and their validity, storing cryptographically linked blocks, as well as functioning as a contact point.

- *Block:* The block comprises a timestamp, digital signature, and other pertinent information. It should be highlighted that the block does not include the identity of the transaction's participants. The transaction is completed properly when the correct user uses their private key and matches it with the block, which is broadcasted to all of the network's nodes.

- *Chain:* An ordered series of blocks. A Blockchain accumulates information in groupings known as blocks that retain units of facts. Blocks have unique storage capacity and, once full, are closed and connected to the previously populated block, resulting in the Blockchain, a data chain.

- *Miners:* When a transaction has been modified on a Blockchain, the transaction records must be recorded and are therefore placed on a block. This block seeks protection, confidentiality and encryption, and it is open to all miners that are members of the network (3). To encrypt this block, miners must solve a cryptographic challenge using a guess-and-check procedure to obtain the right cryptographic hash. If a miner successfully authenticates and secures a block, he or she is rewarded with newly created currency.

- *Consensus:* is an algorithm that transforms a decentralized database into a centralized database. It's an automated method that ensures that just one valid copy of the record is shared among all nodes.

2.3. Blockchain's value in the Supply Chain Industry

Traditional supply chains were slow and manual processes, to overcome this, Blockchain technology is one the better solution. Here are some of the areas where Blockchain technology can add value to the supply chain world:

- *Sluggish and laborious procedures should be replaced.* Although supply chains can now handle massive, complex data sets, many of their procedures, particularly those from the lowest supply tiers, are slow and rely entirely on paper, which is still true in the delivery sector. Taking over slow and manual procedures should be an advantage by using Blockchain technology.

- *Improving traceability*. Change is already being driven by increased regulatory and customer demand for provenance information. Furthermore, improving traceability provides value by reducing the high expenses of quality issues, such as recalls, reputational harm, and the loss of revenues from black or grey market goods. Simplifying a complex supplier base provides comparable cost-cutting benefits.

- *Reducing supply-chain IT transaction expenses*. at this point, this advantage is more theoretical than the real one. Bitcoin pays individuals to validate each block or transaction, and anybody proposing a new block must include a commission in their proposal. In addition, all these transactions would significantly increase the data storage demand, an essential component of the distributed-ledger approach. Also, creating and maintaining many copies of records in the supply chain environment would be impractical.

A corporation must first select what sort of Blockchain it should develop before implementing Blockchain technology in its supply chain. Considering that the bitcoin method is a permissionless Blockchain filled by unknown or untrustworthy people. It is free to use and relies on a consent verification process to create confidence in each block. In these Blockchains, there is no central database or authority. In contrast, most supply networks have recognised and trusted stakeholders. Furthermore, the supply chain industry is unlikely to adopt open access since its users do not want to divulge private data such as demand, capacity, orders, pricing, and margins to unknown actors at all points in the value chain. This approach, in principle, allows for either public or private validation of each block. However, it is doubtful that a public audit of prospective supply chain shutdowns will be faced when all stakeholders are aware. In the shipping industry, for example, just a few recognised players in the chain, such as carriers, ports, customs, and shipping corporations, are responsible for confirming each block. When the number of trustworthy individuals is small, there is less

need to separately check the consent methods employed in the public domain.

3. Emerging Trends and Visions

In this section, Firstly, to give readers a basic idea, Blockchain-based IoT technologies are specified. Formerly, the use cases of Blockchain technology, supply chain use cases in the industry are briefly described. Finally, a summary and illustration of different trends are specified to facilitate the understanding.

3.1. Blockchain-based IoT technologies

- *5G:* Lately we have been experiencing the growing trend of Blockchain being integrated into technologies such as Artificial Intelligence and Big Data amongst others. Also, the use of Blockchain for IoT applications growing the attention of corporates. Blockchain technology seems to be potentially the most suitable and effective way to meet the various 5G IoT challenges. This can potentially help solve many security and scalability issues due to the encrypted and immutable automated nature of Blockchain. More use cases in this field are expected in late 2022. Furthermore, Blockchain is helpful to the future directions for IoT communication in 6G systems.
- *Edge Computing:* A significant challenge for edge computing is balancing limited resources with the required latency for computing. The connection of edge and cloud might be the solution to this situation. An effective and energy-efficient IoT offloading technique for Blockchain-enabled edge computing. The implementation of Blockchain ensures the integrity of data passed via levels. To establish a solid computing channel, the system checks the identification of the IoT device using smart contracts and accurate data from the Blockchain database at the business solution layer.
- *Automotive Industry:* Digitization is currently a realistic and competing requirement. The automobile industry is developing fully autonomous cars using IoT-enabled sensors. Integrating the Industrial IoT solutions in the automobile sector to a decentralised network enables many users to simply and rapidly share critical information. The automotive industry is an excellent Blockchain IoT use case, since shared technology may aid in the development of cutting-edge technologies like driverless vehicles, automated fuel payments, smart parking, automated traffic control etc.

3.2 Blockchain-based Supply Chain industry

One of the most prominent instances of organisations with prospective IoT Blockchain initiatives is supply chain management. Various stakeholders, such as brokers and raw material suppliers, are part of the global supply chain network. As a result, it may be to blame for causing issues in the supply chain's end-to-end visibility. (9) Surprisingly, the supply chain could also include a variety of payments and invoices, perhaps adding several months to the lead time. Furthermore, the participation of multiple stakeholders causes delivery delays. Companies are collaborating on IoT and Blockchain applications, such as having IoT-enabled trucks track shipments. The marriage of Blockchain and IoT technology has the potential to increase network dependability and traceability. (9) IoT sensors may also be able to offer critical shipping status information. Motion sensors, GPS, temperature sensors, connected gadgets, and vehicle information are examples of notable IoT sensors. Here are some supply chain use cases that make use of Blockchain technology:

- *Supply chain logistics:* Because of the numerous middlemen and the repetitive back and forth between partners, logistics suffers from major operational tension. Transactions may be confirmed, recorded, and coordinated autonomously with the use of Blockchain technology. This absolutely removes a layer of complication.
- *Supply Chain Finance:* Since Blockchain is very effective and efficient in the billing process, as well as more transparent and secure transactions, it is becoming increasingly prevalent and common in supply chain finance. Additionally, Blockchain technology allows for the deployment of smart contracts, which trigger quick payments when the goods have been delivered.
- *Food Safety:* It's difficult to track and isolate cross-contamination in complex supply chains. Interruptions and delays might result in considerable reputational harm and refund costs. Nestlé, Walmart, and Unilever, among others, are utilising Blockchain to pinpoint the source of food contamination in the supply chain.
- *Cold Chain Traceability:* Blockchain benefits very vital and critical substances such as food products and pharmaceuticals since it allows for the secure recording of data from IoT sensors such as temperature, vibration, humidity, and other environmental variables. For example, Walmart employs Blockchain technology to track the origin and quality of its beef items imported from China. (10).
- *Supplier Payments:* Best360, a firm that creates technology to improve crucial supply chains in emerging economies, has opened the world's first Blockchain-traceable café. Bext360 employs Blockchain technology to improve tracking of all parts of the global coffee trade, from production to consumption, hence enhancing the production and productivity of the supply chain. Using bitcoins, this Blockchain application ensures direct payment to farmers immediately following the sale of their crops. By utilising encrypted distributed ledgers that provide verified real-time transaction verification without the need for intermediaries such as banks, Blockchain technology promises to enable faster, secure, and low-cost international payment processing services.

4. Future Directions - Open Issues and Discussions

As per this study, the utilization of Blockchain technology would be a reliable alternative for controlling the supply chain business, but it is not yet ready for widespread usage. Before deciding on Blockchain technology as the prime option to traditional supply chain management, consider the following challenges. Blockchain technology will offer security, transparency, and traceability to supply chains wherein players aren't verified or trusted. These supply chains are complicated, multi-tiered, include numerous partners, and operate in highly regulated environments that necessitate a greater level of traceability. However, for supply chains with known and confidential participants, a centralised database method is usually sufficient. In many situations, supply chains are now exchanging billions of information and data, typically in real-time. (11). Many supply chains have challenges with data that is preserved, independently structured, hard to access, view, or analyse in the context of big data because the tools are not adequate. Blockchain technology isn't yet ready to gather data from a large number of untrustworthy parties. Similarly, it is too early to evaluate and compare the costs of managing and operating Blockchain technology in the supply-chain environment with other technologies. Some of the few other factors include initial costs, permissioned Blockchains, scalability, adaption, and human error.

- *The Initial costs* of implementing Blockchain technology would be expensive. Employing Blockchain developers involves more expenses, which tend to be more than hiring ordinary developers due to their field of expertise. Also, planning costs, licensing costs, developing costs, and maintenance costs add up to a hefty price tag.
- *Permissioned Blockchains.* Because supply chain information could be confidential and crucial, a licenced Blockchain is usually the best option. However, a permission system is less secure since there are fewer nodes to form the Blockchain, which makes the blocks more vulnerable to modification.
- *Scalability*. Blockchain is comparatively slower than the standard database transactions as the transactions need to be validated on several different servers and computers. Moreover, due to the higher number of transactions in the supply chain, it is more likely to have a permissionless approach. having permissionless aspects would be costly as the transaction fees need to be paid for the job executed by the nodes to create the blocks. Given that supply chains process millions of transactions every day, the means through which Blockchain technology is deployed must be carefully considered in terms of scalability.
- *Adaption and human error.* While understanding that data on the Blockchain cannot be modified once it is created is valuable to all parties of a supply chain, there may still be a human mistake or wilful malfeasance in inserting preliminary data onto the Blockchain. As a result, Blockchain data is not original information; it may be forged or even false. For example, instead of filling a container with auto parts, a bad actor may fill it with stones and record it on the Blockchain. Blockchain technology may have made it simpler to determine where in the supply chain the container contained rocks, (12) but it would not have prevented counterfeit data from entering the Blockchain in the first place. In essence, Blockchain technology does not prohibit inaccurate data from being added to the chain; rather, it allows each Blockchain user to authenticate that the data on the Blockchain has so far not been updated for a certain period of time. Because Blockchain technology is usually fixed, fraudulent data inserted onto the chain is a problem to be aware of.

Conclusions

In this review, thorough literature research on Blockchain technology for the supply chain industry has been specified. To help readers understand this area, first some basic knowledge about Blockchain, fundamentals, architecture is briefly discussed. Furthermore, emerging trends in IoT are mentioned. Finally, Blockchain's value in the supply chain and future directions are briefly discussed.

The supply chain and logistics industries are among the most potential Blockchain applications. The adoption of Blockchain technology for supply chain management is growing by the day. Blockchain technology has entered the sector of the supply chain to make way for better and more secure transactions. Contracts and documents from different companies can be digitized with smart contracts. As a result, the process will be considerably more efficient, with fewer costs and more customer satisfaction.

To conclude, no technology is perfect, neither is Blockchain. while Blockchain technology can potentially provide cutting edge use cases and huge advantages, there are also a few disadvantages as well such as human errors, high costs, and scalability. a decentralized network Blockchain will have several advantages for a supply chain network.

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