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Decentralized Supply-Chain Application using Blockchain Technology

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Abstract

Blockchain technology offers a promising solution to build trust between parties by ensuring data integrity and immutability. Its inherent properties make it suitable for optimizing transformation models in various fields, including healthcare , commercial supply chains and food safety. This document provides a comprehensive overview of the application of blockchain technology in international trade supply chains, focusing on classifying proposals according to their target application scenarios. The goal is to highlight the benefits of blockchain technology in the business world while addressing the challenges associated with its implementation. This includes identifying issues that arise when designing blockchain solutions to optimize international trade supply chains.

Key Words: *Blockchain Technology, Data Integrity , immutability , and optimization*

1. Introduction and Background

A supply chain is a network of organizations that create value by producing products and services for customers. Global supply chains are complex, with many participants and processes[[1]. Global trade is worth trillions of dollars, and the supply chain ownership of products changes hands several times before reaching the end consumer. Agricultural and mining commodities are supplied by small-scale producers to larger supply chain partners for further processing.

Traditional supply chain models limit data sharing between participants, making it difficult to verify the origin of products. Blockchain technology, popularized by Nakamoto's (2008) article on Bitcoin, offers a solution to these problems. By integrating blockchain into supply chains, data can be shared between participants, increasing transparency and traceability. The participants and their roles in a typical blockchain-integrated supply chain process are shown in Figure 1. Adoption of blockchain technology is expected to reach a tipping point soon.

2. Blockchain Background

Blockchain technology has its roots in crypto money and can be traced back to the 1980s, but it gained popularity in 2008 with the publication of the article "Bitcoin: A Peer-to-peer Electronic [4] Cash System" by an author using the pseudonym Satoshi Nakamoto. It is a disruptive technology that combines mathematics, cryptography,
computer science, and monetary science.[1] The architecture of blockchain technology is parallel and distributed, allowing for the elimination of central servers or trusted authorities in digital interactions. Ledger copies are stored on multiple computers, and changes to the data are made through consensus. All changes to data are recorded with a timestamp for transparency, and the trust among the stakeholders of the system is ensured through specific rules and cryptographic techniques. The changes are kept in a transparently open ledger that can be audited, and all parties have access to a copy of this chain. This technology allows digital data to change ownership like assets in the physical world.
who are granted permission to participate. Private blockchains are often used din enterprise settings where participants are known and trusted, and where privacy
and control over data is important. Public blockchains, on the other hand, are completely open and permissionless, allowing anyone to join and participate in the network. Bitcoin and Ethereum are examples of public blockchain networks,while Hyperledger Fabric and Corda are examples of private blockchain networks.Overall, blockchain technology has the potential to transform various industries
by providing a secure, transparent, and decentralized platform for digital transactions and interactions.

3. Impact of Blockchain on Automotive Industry and Microfactory Concept

The [1] automotive industry has played a pivotal role in the global supply chain, and blockchain technology has the potential to transform supply chain operations in this sector. As shown in Figure 2, blockchain technology can be applied in various ways in the automotive industry.

This paper proposes the concept of microfactories as a new production facility for manufacturing next-generation electric vehicles. These smart factories can be quickly reconfigured to produce customized[1] products for local needs. Local Motors has already established microfactories for building automobiles in Phoenix, Las Vegas, and Knoxville, and it has an open library of vehicle designs to encourage collaboration among designers, engineers, manufacturers, and car enthusiasts.

While microfactories have the potential to democratize manufacturing by making it more accessible to distributed networks of people, they require secure supply chain infrastructure to reduce distribution costs. To replicate microfactories globally and establish a network of collaborating local brands compatible with the existing automotive industry, a proposed network model is needed. However, a central authority is required to succeed in such a highly distributed network, which is not defined in the sharing economy concept for microfactories.

By implementing blockchain technology, it is possible to distribute data securely across the network without the need for intermediaries. All transactions can occur directly between related microfactories and suppliers without a central authority to control or manage the system. Data from all microfactories can be stored in a global ledger, secured with high-level cryptography, making it almost impossible to hack a blockchain network. This microfactory network can be established using a smart contract that defines the rules and steps to be performed automatically whenever a specific event occurs.

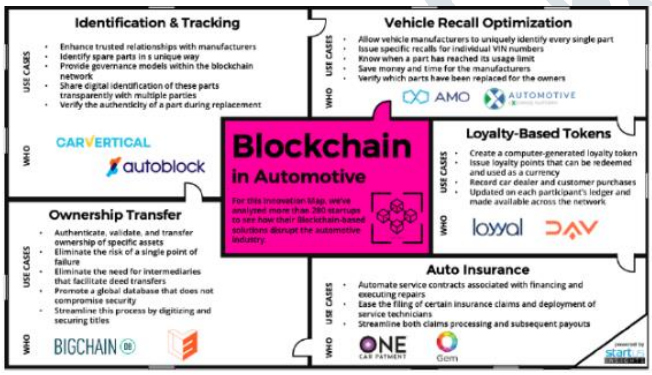

Fig1. Implementation of Blockchain Technology in Supply-chain - network

4. Impact of Blockchain on Logistics Industry

These are just a few examples of the many blockchain-based supply chain projects that are currently underway. By leveraging the benefits of blockchain technology, such as improved transparency, security, and immutability, supply chain actors and startups are able to create innovative solutions that can transform the industry. In addition to the examples mentioned above, other blockchain-based supply chain projects include Provenance, which tracks the origin and journey of food products, and Ambrosius, which uses IoT devices and blockchain to monitor the quality and safety of pharmaceutical products.[5] The potential benefits of blockchain in supply chain are vast, including reduced fraud and counterfeiting, improved traceability and accountability, and increased efficiency and cost savings.

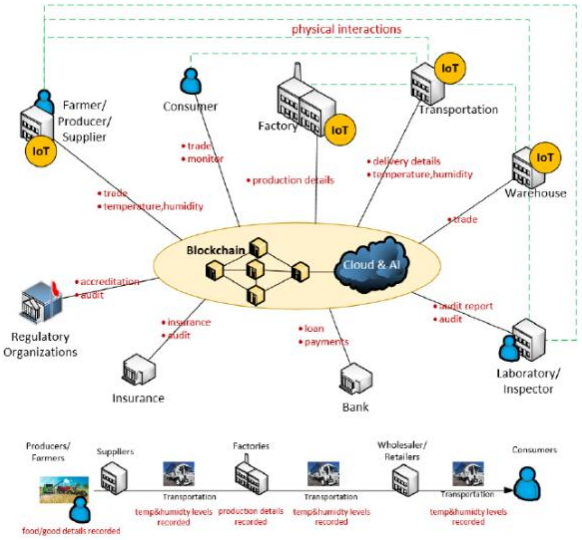

Fig2 Participants and their roles in a typical blockchain integrated supply chain flow

Table 1. Blockchain on Logistics Industry

Name	Description	Partners
VeChain	To track inventory	BMW, Haier, BIOS
WaltonChain	RFID technology	fashion chain, MoneyNet
Ambrosius	Proprietary IoT devices	BioFirm, Nestle
Modum	IoT devices	Swiss Commission
CargoCoin	Secured Storage	NoBar, CargoLine

4. Transparency and Traceability

This paper presents a system for establishing a supply chain with traceability using various technologies. The proposed system involves collecting and managing data from every node of information, enabling tracking and tracing using IoT devices. The devices used in the system update the movement of the product, allowing for enhanced transparency and trust. As technology advances, the decentralized system will continue to develop and become even more reliable. The use of QR codes and RFID tags in the future will result in lower costs and increased tracking and tracing capabilities, leading to an improvement in the overall supply chain management system.

Fig 3 Transparency and Traceability

4.1.Certificate Authentication with Secure QR Codes

Inventory management is a crucial part of the supply chain process as it involves tracking inventory and stock quantities in and out of the stockroom. Quick and accurate inventory management is necessary for successful supply chain management in any organization. QR codes can improve inventory management by enabling fast information transfer and reducing errors in inventory records. However, relying solely on QR codes for inventory management could result in a centralized database. By using blockchain, manufacturers can connect all parties involved in the supply chain, creating a permanent record of each exchange that occurs. These records are decentralized, transparent, and available to all parties involved. Blockchain's transparency

and permanency are particularly useful for managing product origins and traceability. Smart contracts, a feature of blockchain, can automate transaction management, further enhancing the efficiency of inventory management. In this paper, the combination of QR codes and blockchain technology is proposed as a solution for transparent, distributed, and reliable inventory management.

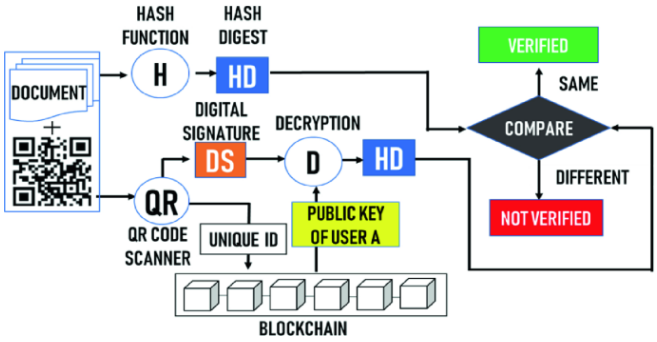

Fig4 Authentication with Secure QR Codes

5. System Architecture

In this project, a smart contract is being developed using Solidity, which is then compiled, migrated, and deployed using Truffle.js on a local blockchain network created using Ganache-cli. The frontend of the application uses Web3.js to communicate with the smart contract and the local blockchain network. The frontend is developed using the React.js framework, which offers better component and state lifecycle management. User requests are directed to the frontend through Nginx (load balancer) and Express.js for dynamic routing. This architecture ensures that the application is scalable, reliable, and responsive to user requests.

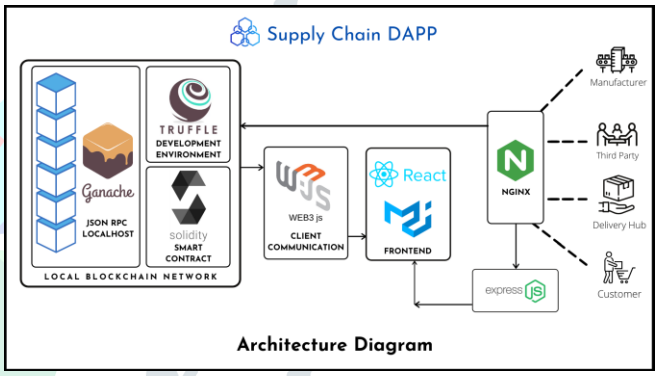

Fig5. Architecture Diagram

6. Working

[4]The process of tracking a product's lifecycle starts with the manufactureProduct() function. This function creates an entry in the blockchain with details of the product and the manufacturer. At this stage, the productHistory[] array is initialized, and the current product data is stored with the manufacturer as the owner. The product is then put up for sale by a Third Party seller.\par

When a Third Party seller purchases the product, the purchasedByThirdParty() function is called, which updates the owner to the Third Party seller and adds the current data to the productHistory[]. The manufacturer then ships the product to the Third Party seller using the shipToThirdParty() function, and upon receipt, receivedByThirdParty() is called to update the product history with the Third Party seller's details.\par

Once the product is sold online to a customer, the Third Party seller ships the product to the delivery hub using the shipByThirdParty() function. When the delivery hub receives the product, the receivedByDeliveryHub() function is called to update the details of the delivery hub as the new owner of the product, and the customer's address is stored. The current data state is then pushed to the productHistory[] array. Finally, the delivery hub ships the product to the customer using the shipByDeliveryHub() function, and the receivedByCustomer() function is called to update the product's final state in the productHistory[].\par

It's important to note that each checkpoint function can only be called after verifying the product and productHistory[] details. Various functions such as fetchProductPart1(), fetchProductPart2(),fetchProductPart3(),fetchProductHistoryLength(), fetchProductCount(), and fetchProductState() can be used to retrieve data of a queried product with UID and data type as product (current state).In this supply chain setup, certificates are generated at each stage of the product's shipping to record critical information such as its location, condition, and ownership. The keccak256() cryptographic function is used to generate these certificates, ensuring their security and immutability on the blockchain. This approach makes it extremely difficult for anyone to tamper with the information without getting detected, guaranteeing the integrity and trustworthiness of the supply chain data.

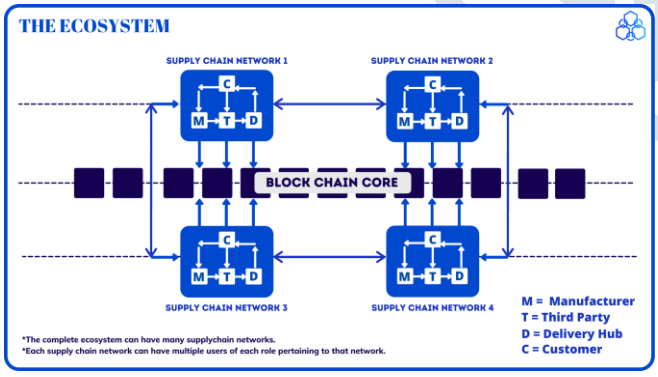

fig 4 The Ecosystem

7. Benefits of implementing of Blockchain on Supply Chain management

A. Reduction in development costs

Blockchain technology can potentially reduce development costs in supply chain management in several ways:

- **Elimination of intermediaries:** Blockchain technology enables direct communication and transactions between parties involved in the supply chain without the need for intermediaries such as brokers, clearinghouses, and banks. This can result in significant cost savings.
- **Increased transparency and efficiency:** The use of blockchain technology can increase transparency and efficiency in supply chain management by providing real-time information and reducing the need for manual data entry and verification. This can result in reduced errors, faster decision-making, and lower costs associated with delays and inefficiencies.
- **Improved security and fraud prevention:** The secure and decentralized nature of blockchain technology can help prevent fraud and reduce costs associated with fraud detection and recovery.

B. Logistics system efficiency improvements

Implementing blockchain in the supply chain can lead to several efficiency improvements in the logistics system

- **Faster processing and settlement:** Blockchain technology can streamline and automate many of the manual processes involved in logistics. This can lead to faster processing times, which in turn reduces delays and improves delivery times. Smart contracts can also automate payment processing, making settlement faster and more accurate.
- **Improved inventory management:** Blockchain can provide real-time visibility of inventory levels and movement, enabling logistics managers to optimize inventory levels and reduce waste. With better inventory management, logistics managers can reduce costs and improve the overall efficiency of the supply chain
- **Reduced paperwork and administrative burdens:** Blockchain technology can automate many of the manual paperwork and administrative tasks involved in logistics. This can free up logistics managers to focus on more value-adding activities and reduce administrative costs.
- **Enhanced security:** Blockchain technology provides a high level of security by design, making it difficult for cybercriminals to tamper with the

data. This reduces the risk of theft, fraud, and other security breaches in the supply chain

C. Increased efficiency and processing speed

Blockchain technology can increase the efficiency and processing speed of a supply chain .

- **Automated processes**: Smart contracts, a key feature of blockchain, can automate many of the processes involved in supply chain management, such as payments, quality checks, and documentation. This reduces the need for manual intervention and speeds up the overall process.
- **Real-time tracking and monitoring:** Blockchain provides real-time tracking and monitoring of products and goods as they move through the supply chain. This enables businesses to quickly identify any delays or bottlenecks in the system and take corrective action.
- **Transparency and visibility:**Blockchain provides a transparent and auditable record of all transactions in the supply chain. This enables businesses to quickly identify any errors or discrepancies and take corrective action. Additionally, this transparency allows businesses to build trust with their customers by providing them with visibility into the entire supply chain
- **Reduced paperwork:** Blockchain eliminates the need for paper-based documentation, which can be time-consuming and error-prone. Instead, all documentation is stored digitally on the blockchain, making it easily accessible and searchable.

D. Automation of tasks

Automation is a key benefit of blockchain in the supply chain. Smart contracts, which are self-executing digital contracts with the terms of the agreement between buyer and seller being directly written into lines of code, allow for automation of various tasks in the supply chain.

With the help of smart contracts, the manual process of verifying and executing contracts can be eliminated. This results in faster and more efficient processing of transactions. Smart contracts can automate the verification of product origin, quality control checks, and payment processing.

In addition, blockchain technology can automate the tracking and tracing of products as they move through the

supply chain. By using RFID tags, IoT devices, and other sensors, real-time data can be collected and recorded on the blockchain. This allows for automated monitoring of inventory levels, temperature control, and shipment status. Overall, automation in the blockchain supply chain can reduce costs, improve processing speed, and increase accuracy and efficiency**.**

E. Quality control and quality assurance

Blockchain technology has the potential to improve quality control and assurance in supply chains by creating an immutable and transparent record of every step in the production process. With blockchain, manufacturers can track the origin and movement of raw materials and finished goods in real-time, which enables them to identify any quality issues and take corrective action quickly.

Smart contracts can also automate quality control and assurance tasks by setting quality standards, and if the quality criteria are not met, the contract can trigger actions such as rejecting the product, notifying the supplier or initiating a recall process. This can lead to a reduction in errors, delays, and waste, and increase the efficiency and accuracy of quality control and assurance.

Additionally, blockchain can enable the creation of decentralized quality assurance networks, where manufacturers, suppliers, and other parties can collaborate and share quality data in real-time. This can lead to better communication, collaboration, and trust among supply chain partners, and enable them to quickly identify and address any quality issues that arise.

Overall, blockchain technology has the potential to improve the quality control and assurance in supply chains by providing a secure, transparent, and decentralized platform for tracking and managing quality data, which can lead to improved product quality and customer satisfaction.

F. Reduced transit and shipping times

One of the key advantages of implementing blockchain technology in the supply chain is the potential for reduced transit and shipping times. With the use of blockchain, the

entire supply chain can be streamlined and made more efficient, allowing for faster processing and delivery times.

This is due to several factors, including increased transparency and traceability, automated processes, and real-time data sharing. For example, blockchain can provide real-time tracking and monitoring of shipments, allowing for more accurate delivery estimates and proactive problem-solving in case of any delays or issues.

In addition, smart contracts can be used to automate tasks such as payment processing, customs clearance, and documentation, which can significantly reduce processing times and minimize human errors. This automation can also help to reduce delays and increase efficiency throughout the entire supply chain.

Furthermore, blockchain can also facilitate collaboration between different parties in the supply chain, such as manufacturers, shippers, and distributors, allowing for faster communication and decision-making. This can help to identify and address issues more quickly, ultimately leading to faster delivery times and improved customer satisfaction.

8. Conclusion

Businesses face a significant challenge in grasping the fundamental concepts of blockchain technology and understanding its potential to benefit supply chain management. To promote and expedite the integration of blockchain technology in logistics and supply chain operations, it is vital to engage with stakeholders and conduct further empirical research by analyzing supply chain data and simulations. This paper describes an ongoing research project aimed at developing an innovative learning model for academics, students, and business professionals involved in the digital transformation of the supply chain. The educational tool discussed in this paper is intended to be used alongside traditional learning methods, such as classroom or online training, to enhance knowledge acquisition and increase the value of the interactive game. By introducing the blockchain game to universities and companies, the authors aim to close the existing knowledge gap that currently hinders the mainstream adoption of blockchain technology. Furthermore, the authors intend to contribute to the emergence of new supply chain practices and advance engineering process modeling by implementing technologies like blockchain.

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