Blockchain implementation in supply chain management systems: a survey on methodologies and challenges

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Abstract- ***Block chain technologies have the potential to transform the way supply chain management systems operate by providing increased transparency, traceability and security. This survey paper aims to provide a detailed overview of the current state of applicability and advancements in the implementation of blockchain technology in supply chain management. We will examine the various types of blockchain platforms and their potential applications in supply chain operations, such as tracking the movement of goods and preventing fraud and propose a system to functionally achieve the same. Additionally, this paper will delve into the challenges and limitations faced during the implementation of blockchain technologies in supply chain management systems, such as scalability and regulatory compliance. Furthermore, we will also highlight future research directions and identify potential opportunities for innovation in this field. Overall, this survey paper aims to provide a comprehensive understanding of the current state of blockchain implementation for product delivery in supply chain management and its potential impact on the industry.***

Keywords—Blockchain, smart contracts, supply chain, product delivery, smart contracts.

I. INTRODUCTION

Blockchain technology has emerged as a promising solution for supply chain management, with the potential to disrupt traditional supply chain processes and improve transparency, traceability, and security. A blockchain is a decentralized and distributed ledger system that facilitates the secure and efficient tracking of goods and services as they move across the supply chain. This shared ledger technology can be used for various applications in supply chain, such as tracking inventory, managing logistics, and monitoring compliance. By using blockchain, supply chain participants can share information and collaborate more effectively, reducing costs and increasing trust among all parties involved. In this paper, we will provide an overview of the current state of research on blockchain implementation for product delivery in supply chain management, discussing its potential use cases, challenges and limitations, and future directions for research and innovation.

Blockchain technology provides efficient customer confidence by letting customers verify the full trail of the asset through the supply chain.

The blockchain system facilitates the identification of any tampering traces across the product and fake transactions over the supply chain by making use of a traceability mechanism due to which the supply chain can have efficient cost reduction and productivity. The key characteristics of the blockchain include being digital, distributed, decentralized, immutable, having consensus, anonymous and traceable. Digitalization eliminates the need for manual documents, while the distributed and decentralized nature of the blockchain eliminates the need for a central authority. The immutability of the blockchain ensures that once a data transaction is entered, it cannot be deleted or rolled back. The consensus mechanism ensures that fraud transactions are kept out of the system, and the anonymity and traceability of the blockchain allows for easy traceability and verification of transactions

II. MOTIVATION

There's a glaring need for the utilisation of blockchain technologies to optimise and enable supply chain management systems for effective product tracking. Some of the crucial points that prove the same are:

1. Transparency: Blockchain enables all parties in the supply chain to access and view the same information, leading to more efficient and accurate tracking of products. This can help to increase transparency and trust between different actors in the supply chain, such as suppliers, manufacturers, and retailers.
2. Immutability: Once data is added to a blockchain, it cannot be altered, deleted or tampered with. This ensures that the entire supply chain history can be tracked and audited, and that data is tamper-proof.
3. Security: Blockchain uses advanced cryptography to secure data and transactions, making it virtually impossible for hackers to alter or tamper with data. This can help to protect sensitive information such as trade secrets and financial data.

4. Automation: Smart contracts will be used to automate processes which reduces the need for intermediaries. This can lead to faster and more efficient execution of transactions, and can help to reduce costs for all parties involved.
5. Traceability: Blockchain technology allows for all parties in the supply chain to track the entire journey of a given product from the source to the end consumer, enabling product traceability and transparency in the supply chain.
6. Cost reduction: By reducing intermediaries and automating processes, blockchain can help to reduce costs for all parties involved in the various components of a supply chain. Additionally, by elevating transparency and trust, blockchain can help to reduce the need for costly inspections and certifications.

III. LITERATURE SURVEY

REQUIREMENTS FOR BLOCK CHAIN IMPLEMENTATION IN PRODUCT DELIVERY:

A study by [1] Helo, Petri, and A. H. M. Shamsuzzoha examines the supply networks within a Finnish energy company that specializes in project-based work. The research team designed a data collection process to meet their objectives and gathered information from a variety of sources within the company, including executives, business managers, IT experts, product designers and engineers, and project managers. The data collected was used to identify various functional and non-functional requirements for the company's supply chain and logistics operations.

Client Requirements:
• Client application’s purpose is to facilitate a secure, decentralized methodology to create and update package tracking information.
• Linking of the transaction events to their respective tracking numbers in the supply chain is done using a safe method.
• Barcode or RFID tags must be used to take in input of the reference number.
• Updated information can be obtained by utilising the given reference number.
• Creation of tracking data is enabled through a decentralised data system which is a crucial client end requirement.

Integration Requirements:
• External data elements that are to be linked with the tracking numbers generated include shipment number, purchase order number and sales order number.
• Integration of external data sources as transaction event sources such as the given transportation company
• A system of external iot devices that can track the efficacy of the product as well as link the real time data to the interface must be provided

Portal Requirements:
• The portal collects data from the different decentralised transaction data available on a given product across different warehouses and links it to the central data storage.
• The portal must provide a search view for multiple constraints to be tracked in the form of project shipments, tracking numbers, purchase orders, delivery IDs and project name.
• The portal shall help connect the necessary supply chain key performance metrics within the data view.

Non-functional requirements:
As per the analysis phase of the none functional requirement collection, the given real-time supply chain management system must be able to cater to the manufacturers as well as their respective suppliers in the project or product supply networks. Each actor involved must have a lucid idea of the material flow across the different checkpoints of the SC. The proposed system aims to accommodate a scenario with the following characteristics:

- Over 4000 vendors utilising the system for shipment creation, including both occasional and frequent suppliers;
- Over 100 projects that can operate simultaneously.
- Average shipping whose duration may extend from 8 to 30 days between the distribution centres and active project site locations.
- Project materials dispatched in 1 to 4 instalments during the project phase;
- Each project having 50-200 material handling units with every unit of a container holding up to a hundred components.

[1] Helo, Petri, and A. H. M. Shamsuzzoha suggests implementing a cloud-based pilot system for real-time tracking and tracing in logistics and supply chains. The system leverages Iot, RFID, and blockchain technology to provide a unified, live view of the supply chain. IoT and RFID provide live data, while blockchain technology ensures a secure chain of unalterable transactions. The proposed system will connect transport companies, tracking and tracing devices, consolidation networks, and suppliers within its architecture.

CLOUD BASED SCM USING BLOCKCHAIN:

In [2] Karumanchi, Mani Deep, J. I. Sheeba, and S. Pradeep Devaneyan propose a model for development of an efficient system of supply chain technology through integration of block chain technology processes that involve digital ledgers along with the strategy of elevating the performance by supply chain partner collaboration. A supply chain network entails a roadmap of the processes which are crucial in selling the manufactured product to the customer. The challenges involved are deduced to be in terms of payments that are to be handled with respect to the vendors, suppliers, and customers which take a lot of time to rectify and later transfer of the manufactured product across the varied locations that the supply chain includes. This challenge is resolved through the integration of blockchain ledger technologies and smart contracts with supply chain management systems. Blockchain ledger technology consists of protocols developed by its entities to facilitate validation and authentications of all updates made to a shared ledger on a regular basis. Individual transactions in the SC are recorded in an online register, and several transactions are carried out via the development of an immutable block. Once the specified quantity of each immutable block has been updated and registered to the digital register, a blockchain is formed by the collection of several blocks in the supply chain.

[2] Karumanchi, Mani Deep, J. I. Sheeba, and S. Pradeep Devaneyan propose a novel approach to rectify on the network that stores the registered public keys, peer info and digital signatures within a given encrypted database that relate to the different participants taking part in the SCM. By letting each component to be registered, the network shall validate the information about neighbor node in the block

chain authentication and trust module (BATM) specified in the paper.

AMBROSUS: A BLOCKCHAIN INTEGRATION CASE STUDY

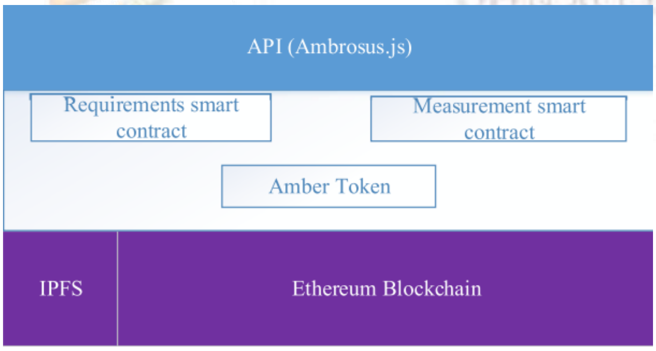
[4] Azzi, Rita, Rima Kilany Chamoun, and Maria Sokhn, as part of their case study on blockchain integration in SCMs selected Ambrosus and Modum, two Swiss start-ups, since they could obtain the required information and as they are related to the management of food and pharmaceutical supply chains that utilize the integration of iot devices and blockchain ledgers to ensure product efficacy.

The Ambrosus network implements a tracking system that follows products from start to finish using tags, tracers, and sensors. Their aim is to link the product and its efficacy with its packaging and the respective mode of transportation used on dispatch, and to alert the blockchain in case of any potential tampering.

The tracking components can be customized based on the specific needs of each product and client.

All the tracking devices are secured through an asynchronous cryptography that involves public and private keeys, and the sensors and QR codes imprint their signature on the collected data which is then transmitted to the edge gateway through RFID technology. Customers can access information about their purchased product through the application which utilises an API gateway to service its user requests.

The Ambrosus network incorporates the use of Ethereum blockchain to ensure the authenticity and quality of products based on set standards. The Ethereum blockchain and distributed storage serve as the foundation of the Ambrosus system and are positioned at the bottommost layer of the Ambrosus layered architecture. Smart contracts on the Ethereum blockchain are developed using the Parity programming language, but due to the high cost of running transactions on Ethereum, the Ambrosus blockchain was adopted as the primary network for transactions.
The Ambrosus blockchain is written in solidity and built based on the Ethereum blockchain. The architecture specified is illustrated in the figure below.



The Ambrosus protocol's related smart contracts will operate on their own customised blockchain, which is later replicated onto the Ethereum network for additional verification. Above the protocol layer exists the API, also referred to as the JavaScript layer. This layer enables developers to conjure and execute Ambrosus specific contracts and objects on the Ambrosus platform without the need for knowledge related to blockchain technologies. Developers can utilize NodeJS, JavaScript or HTML to bridge their hardware to the Ambrosus-specific network.

BLOCKCHAIN-AS-A-SERVICE PLATFORMS:

Blockchain-as-a-Service (BaaS) platforms are a type of cloud-based service that allows businesses to use blockchain technology without the need for in-house infrastructure or expertise. BaaS platforms provide customers with the necessary infrastructure, tools, and support to create, deploy, and manage blockchain-based applications and networks. These are crucial in deploying managed blockchain networks that maintain the distributed ledgers which supply chain management systems need to keep track of their products. Some of the key features of BaaS platforms include:

- Easy deployment: BaaS platforms typically provide a user-friendly interface for creating and deploying blockchain networks, which can be beneficial for businesses that do not have in-house blockchain expertise.
- Scalability: BaaS platforms provide the necessary infrastructure to support large amounts of data and high levels of traffic, which can be beneficial for businesses that expect to see a lot of usage of their blockchain-based applications.
- Security: BaaS platforms typically have advanced security measures in place to protect data, and they can also provide regular backups to ensure that data is not lost in case of a disaster.
- Integration: BaaS platforms can integrate with other systems, such as ERP and CRM systems, which can help to streamline processes and improve efficiency.
- Support: BaaS platforms typically provide customer support and technical assistance to help customers with any issues or questions that may arise.
- Blockchain Platforms support: BaaS platforms can support a variety of blockchain platforms like Ethereum, Hyperledger, Corda, Quorum, and more.

BENEFITS OF AWS AS A BLOCKCHAIN AS A SERVICE PLATFORM:

[3] Mukherjee, Sourav. Elucidates the various advantages of using aws over its competitor services such as azure blockchain and Alibaba blockchain, google cloud and IBM cloud.

Customers can join either private Hyperledger Fabric networks or the Public Ethereum network using Amazon Managed Blockchain. You are freed from the undifferentiated heavy lifting related to building, setting up, and maintaining the underpinning infrastructure for a Hyperledger Fabric network when using Managed Blockchain. You may instead concentrate your efforts on use case-specific components development or consortium creation, both of which are mission-critical value generators. Multiple businesses can join a scalable Hyperledger Fabric network created and managed in this way using their AWS accounts.

Many blockchain protocols included in the AWS dashboard can run programmable logic written as code in a decentralised manner in addition to offering an immutable system of record. This computer code, which allows multi-party business logic to operate on the blockchain, is frequently referred to as a "smart contract." This means that putting your supply chain on a blockchain enables network users (such suppliers, merchants, etc.) to perform transactions that are only allowed to be processed by those users.

SMART CONTRACTS TO TRACK PRODUCT CONSTRAINTS:

Initialization: The smart contract is initialized when the product is first created, and the initial details of the product (such as the manufacturer, batch number, and expiration date) are recorded on the blockchain.

Tracking: As the product moves through the supply chain, each transaction (such as a shipment or a sale) is recorded on the blockchain using the smart contract. This creates a digital trail that can be used to track the product from the manufacturer to the end consumer.

Verification: Smart contracts can be programmed to include specific rules and conditions that must be met before a transaction can be recorded on the blockchain. This ensures that only valid transactions are recorded, which can help to prevent fraud and errors.

Traceability: The digital trail of transactions recorded on the blockchain can be used to trace the product's journey through the supply chain, which can be useful for identifying the source of any problems or issues that may arise.

Automation: Smart contracts can be programmed to automatically trigger actions based on specific conditions, such as releasing payment to a supplier when a shipment is received or triggering a recall when a product is found to be defective.

IV. PROPOSED SYSTEM

An innovative method for monitoring supply chain events is provided by blockchain technology. Block chains are immutable ledgers which let you cryptographically ensure in a verifiable manner that each entry made to the ledger has remained unchanged after it was recorded. This immutability is a major advantage for a supply chain network from a procedural perspective. When you are positive that no one has tampered with the production, transit, storage and usage history of a specific part or the entire efficacy of a product in the time after an issue occurred, auditing the varied components of the supply chain network becomes significantly easier.

Our decentralized application will facilitate the management of a track-and-trace supply chain. This supply chain has two different members:

- The **retailer** who labels products and sells them to consumers.
- The **supplier** who manufactures, warehouses, and ships the products to retailers.

The next step involves creating a cloud9 environment which is done using AWS management console selecting instance and launch environment.

IAM policies and configurations are set up to establish the respective retailer and manufacturer nodes on the management console. This will provide the necessary privileges needed for our Cloud9 environment that is used to access our block chain network.

Assign an IAM machine role to your Cloud9 environment.

Next part is creating the network, The Fabric ordering service ensures that transactions have been validated properly by the responsible member peer nodes and produces new blocks of transactions in a settled, pre-defined order, broadcasting them to every peer node for it to be recorded and updated on distributed ledgers.

Each member in the consortium has their respective certificate authority that enable them in managing the identities of users who are authorized and authenticated to access the managed blockchain network, as well as the respective retailer and manufacturer peer nodes, which endorse transactions and store blockchain data.

The peer nodes are situated in different availability zones to ensure high availability and for failover and disaster recovery purposes. This Infrastructure is managed by AWS and accessed by each member over a VPC endpoint using AWS private link.

Members and networks can be deployed onto the system. After the network and member creation is complete after which we create a peer node for the Retailer as per the hyper fabric ledger architecture illustrated in Fig 2. This is the component that validates the blockchain transactions and stores the block details in a blockchain ledger.

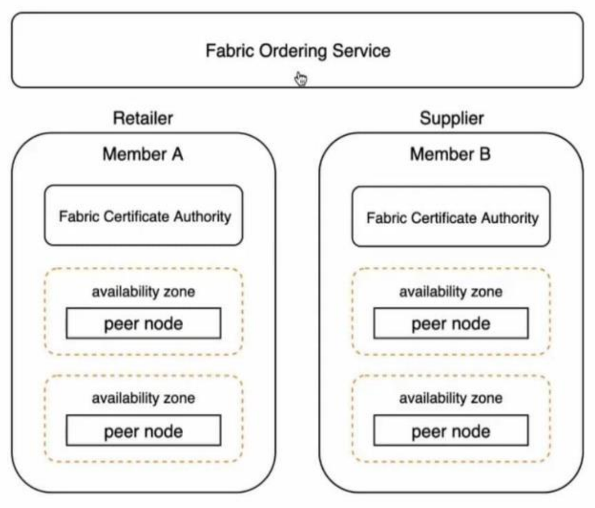
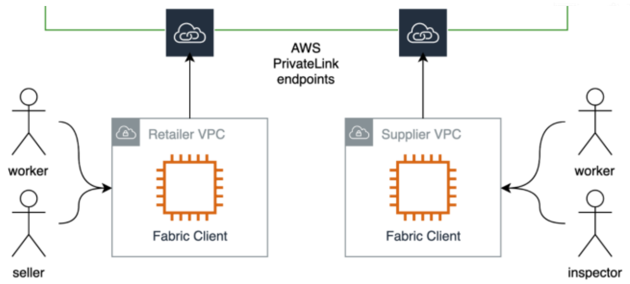


Fig 2. Hyper-ledger fabric architecture

All interaction with the blockchain network stems from a Fabric client. This client node shall have the Fabric SDK which after being installed within it will let us generate digital certificates that represent the end users authenticated to carry out operations on the network as well as to oversee deployment and supplicate chain code within the given established network.

Network security groups are then created for the Fabric client instance. All communication between member peer nodes and Fabric client instances must occur through a VPC endpoint using AWS private link. Our Cloud9 environment will be used as the Fabric Client. In order for it to communicate with the blockchain network over the VPC endpoint, it needs to be in the same security group. After the client instance is created we configure it to communicate with our managed blockchain network.



We now deploy the chain code and create a new channel for it to execute in, have each network member join the channel, and then we deploy the chain code to the channel.

The above diagram depicts the blockchain network that was set up previously, with chain code installed on the peer nodes. It also shows that each blockchain member has users that interact with the chain code based on their permissions.

The chain code is written using node.JS to accommodate its peers. It is then instantiated on the channel, at which point all members will use their different user identities to invoke the chain code, in order to update the current state of an arbitrary product whose efficacy is to be tracked, in the supply chain via the interaction of the chain code with the AWS lambda function. This will lessen the amount of infrastructure required to enable and aid our decentralized application, and shall also help it to scale and balance varying loads to handle heavier volumes of transaction data. The Lambda function trusts that the registered names of the end users that are streamlined from AppSync have been authenticated, and are thus authorized to access secrets that belong to the user in AWS manager. These secrets contain the keys which are used to sign Fabric transactions in the user's stead. These secrets are used by the lambda function in order to query and invoke the chain code in the blockchain ledger as from the calling user's side.

A frontend interface lets the companies register for our blockchain network with their products and their product constraints that are to be tracked in real time using the hyper ledger maintained at aws.

V. CONCLUSION

In conclusion, blockchain distributed ledger technologies has the potential to transform supply chain management by upgrading traceability, transparency, and security. This technology is based on a decentralized, distributed ledger that lets the stakeholder access and update information in real-time that can be used to track supply chain management systems. The literature review conducted for this survey paper on implementation of blockchain in supply chain management has shown that blockchain technology has the potential to significantly improve supply chain efficiency, reduce costs, and increase trust among supply chain partners.

The literature review also highlighted several challenges and limitations as well as the applicability of implementing blockchain technology in supply chain management, such as scalability, regulatory compliance, and data privacy concerns. Therefore, it is crucial that organizations carefully evaluate the latent benefits and drawbacks of blockchain technology before a viable implementation.

The literature review also revealed that blockchain adoption in SCMs is still in its initial stages, with most of the current use cases being pilot projects and proof of concepts. The most common use cases for blockchain technologies and smart contracts in supply chain management are for tracking and traceability of goods, digital identity management and smart contract automation.

The future research in this area should focus on addressing the challenges of scalability and regulatory compliance, as well as exploring the potential of blockchain technology to improve other aspects of supply chain management, such as inventory management and logistics. Additionally, more research is needed to explore the potential of blockchain technology that facilitates and improves on the productivity and sustainability of supply chains.

Overall, the specified blockchain technologies have the capacity to transform the way supply chains operate, but further research is needed to fully realize its potential and address the challenges of implementation.

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