Design Document

BLOCKCHAIN-BASED SUPPLY CHAIN OPTIMIZATION

Revision Number: 3.0

Last Date of Revision: 29/11/2021

SYED MOHAMMAD YAMAAN (B2020059)

NINAD MUZUMDAR (B2020028)

SHREY SAKLANI (B2020053)

ROHAN TANDEL (B2020041)

ABHISHEK UPDADHYAY (B2020004)

Document Version Control

Date Issued	Version	Description	Author
03/11/2021	1	Initial Draft	Abhishek
20/11/2021	2	1st round of Changes	Yamaan, Rohan
29/11/2021	3	2nd round of Changes	Ninad, Shrey

Table of Contents

Abstract

Blockchains are attracting interest from stakeholders in a variety of industries, including logistics and supply chain management. Blockchain technology can help to record every single asset as it moves through the supply chain, track orders, receipts, and payments, and track digital assets like warranties and licences in a centralised and transparent manner. The methodology used in the paper provides a detailed analysis of how blockchain fits into the supply chain industry. It details the impact that blockchains will have on the supply chain industry, including scalability, performance, consensus mechanism, privacy considerations, location proof, and cost, as well as the impact that blockchains will have on the supply chain industry. It starts with a discussion of the tradeoff between consensus cost, throughput, and validation time, then moves on to a suggested high-level architectural approach, and concludes with a discussion of the changes required and challenges faced for in-vivo blockchain deployment in the supply chain industry. While the technological features of modern blockchains can effectively facilitate supply chain use cases, the numerous challenges that remain place a large number of changes and additional research efforts in front of us in order to achieve a global, production-level blockchain for the supply chain industry.

1. Introduction

1.1 Why this Design Document?

This Design Document contains both the components

- High-Level Design (HLD)
- Low-Level Design (LLD)

The goal of the High-Level Design Document (HLD) is to supplement the current project description with the essential details and to serve as a reference manual for how modules interact at a high level. We hope to provide a bird' eye view of the architecture and design of the solution we're giving for e-voting system traceability difficulties in this document.

The HLD will:

- Describe the project's constraints and assumptions
- Present all design aspects and characterize them in depth
- Present the process flow
- Describe the asset tracker's performance and reusability

The purpose of the Low-Level Design Document (LLD) is to provide the internal logical design of the actual program code for the aupply chain blockchain solution. LLD describes class diagrams, including methods and relationships between classes, as well as program specifications. It explains the modules in such a way that the programmer can code the program directly from the document.

1.2 Scope

This article aims to outline in as much detail as possible the High-Level features (HLD) of an FMCG Visibility supply chain visibility project The paper combines information from previous discussions, blockchain lectures, and IT skills to create a strategy for a blockchain-enabled supply chain procedure.

The Low-level design (LLD) is a component-level design approach that is refined in a step-by-step manner. This method can be applied to the creation of data structures, software architecture, source code, and, eventually, performance algorithms. Overall, data organization can be determined at the requirement analysis phase and then refined throughout the data design phase.

2. General Description

2.1 Product Perspective

At its core, blockchain technology is exciting because it has the potential to increase trust, transparency, and collaboration across a wide range of business requirements in almost all verticals. Otherwise, it would aid in the struggle to achieve as much as before. Furthermore, blockchain's use of "smart contracts" provides an impossible (i.e., never-before-seen) method of automating and examining transactions. These benefits can be earned in retailing by vendors, employees, and then customers.

Features of Blockchain

- Blockchain maintains a record of all data transaction and exchanges that is referred as a 'ledger'.
- All information that is transferred or exchanged called a 'transaction'. Once the transaction is made and analysed, it is combined to the ledger as a 'block'.
- In order to verify each transaction, blockchain uses a distributed system i.e. a peer-to-peer network of nodes.
- It is impossible to change a transaction once it has been signed, analysed, verified, and added to the blockchain.
- All data stored in blockchain cannot be changed or tracked by third parties, making it incredibly secure.

2.2 Business Challenges in FMCG

Traditionally, the FMCG industry has been a fiercely competitive industry. It is not an easy task for many consumer-packaged goods (CPG) companies to implement the following issues in order to survive in the digital innovation world. It complicates the expansion of current data streams such as sales, finance, promotions, supply chain, and social media, among others. To address these issues,

- CPG companies must manage, streamline, and sort all of this data in real time, making the data more instinctive and insightful.
- Identifying what to sell based on the needs of customers at their preferred point of purchase
- Optimizing warehouse management, increasing inventory levels, and delivering compelling value across the entire supply chain
- Increasing profitability and revenue across all channels in the customer decision-making process announcing personalised promotions and making changes to the marketing contribution
- All of these challenges in the FMCG industry can be overcome by utilising blockchain technology and its benefits.

2.3 Benefits of Integrating Blockchain in FMCG

To be sure, the success of an FMCG company is heavily reliant on two key factors. The first is speed, and the second is accuracy.

Whether it's running precise sales promotions, selecting the best marketing campaign, or securing the most cost-effective supply chain, overall success is determined by:

- The accuracy with which decisions are made in every situation
- The speed with which decisions are implemented

There are still more tangible benefits of consumer goods industries that can be obtained by utilising blockchain technology. Before diving into blockchain integration for the FMCG industry, it's important to understand the real-world benefits of blockchain in consumer goods and retail.

2.4 Conceptual Diagram:

A diagram combining blockchain technology with supply chain functionalities is described and analysed in the figure below. Figure below depicts how the various actors in a supply chain can collaborate and interact using a blockchain network. Depending on the completed activity, each participant submits transactions to the blockchain network in a specific way. The suppliers who pre-process natural resources submit transactions on the ledger for that initial process in the raw materials step. Tags such as raw material name, quantity, quality, origin geo-location, and others are included in these transactions. The appropriate transactions are submitted as soon as the raw materials begin their journey to the manufacturer. Every network party can then double-check important details about the specific raw material they received or from which their product is made.

By reading and verifying all of the tags that the manufacturer includes in their transactions, the manufacturer is able to validate crucial information about the natural resources they collected, and then proceed to the proper execution of the manufacturing step. Following the completion of the stage, new transactions with new information tags, such as manufacturer name, field experience, and others, are submitted.

The products are then handed over to the distributors. The products are sold to wholesalers and retailers by the distributors. This is represented by blockchain transactions, which show important data tags like the merchant and customer addresses, the exchange amount, the quality of the product raw materials, and so on. The distributor's job description is to sell products to middlemen, not end users. The distributor (generally every stage party) can check valuable tag information about the product progress route until that stage at this point, as they can at every step of the supply chain; information such as the raw material origin geolocation, the manufacturer company popularity, the distributor name, and others.

For example, before selling a product to a consumer, a retailer can conduct an immediate audit of the product's natural resource quality and obtain appropriate feedback. Following that, when a distributor delivers a product to a wholesaler and submits a corresponding transaction, the latter behaves similarly. They look for extra data on the transaction tags before selling to the next wholesaler or retailer and submitting a new transaction. The same can be said for retail companies. Finally, the end user receives the final product, along with a completed transaction (complete with appropriate tags), and is able to inspect and verify every aspect of it from the start of its supply chain journey until that point. The table below (Table 1) summarises the current limitations that supply chain actors face, as well as the benefits that blockchain adoption can bring.

Table 1. Supply Chain actors, current limitations faced and blockchain impact.

Supply chain actor	Current limitations	Blockchain impact
Raw material/Producer	Ability to prove in a global and transparent way the origin and quality metrics of products.	Benefits from increased trust of keep track of the production raw material and value chain from the raw material to the end consumer.
Manufacturer	Limited ability to monitor the product to the final destination. Limited capabilities of checking quality measured from raw material.	Added value from shared information system with raw material suppliers and distribution networks.
Distributor	Custom tracking systems with poor collaboration capabilities. Limited certification ability and trust issues.	Ability to have proof-of-location and conditions certifications registered in the ledger.
Wholesaler	Lack of trust and certification of the products' path.	Ability to check the origin of the goods and the transformation/transportation conditions.
Retailer	Lack of trust and certification of the products' path.	Track of each individual product between the end consumer and the wholesaler. Ability to handle effectively return of malfunctioning products.
End user/Consumer	Lack of trust regarding the compliance of the product with respect to origin, quality and compliance of the product to the specified standards and origin.	Full and transparent view on the product origin and its whole journey from raw material to final, purchased product.

2.5 Problem Statement

Due to the increasing complexity of supply chains in recent years, a number of issues have played a major role in diminishing supply chain performance. One of the issues is poor visibility which majorly impacts the supply chain efficiency performance. Moreover, the problem is quite critical for food supply chain where demand uncertainties and long lead times of food supplies could result in huge loss of time and money to a retail store.

2.6 Traditional Solution

Earlier, all the data related to purchased order and shipment status used to be done manually. Due to large amount of data, retail companies were facing problem while tracking their goods. For instance, the recall of a batch of pork in China. The firm loss was over $60 million for recalling the supplier where that infected batch came from.

2.7 Proposed Solution

Walmart and other large retailers could use Blockchain technology to improve their business operations, including velocity, throughput, latency, compliance, cost-effectiveness, provenance awareness, and trust building. It's been used to make supply chain transactions more cost-effective and secure. This will result in solving the core problems in supply chain like transparency, order traceability and improve inventory visibility.

2.8 Elements that Affect the Supply Chain:

Security is one of the cornerstone aspects that must be addressed because supply chains typically raise a variety of issues that are highly dependent on freight failure, human error, intended fraud, and other factors. All circulated data in a supply chain takes on different forms and must meet different needs, resulting in a much more demanding and complex course of controlling and ensuring immutability and secure transparency between transactions and their data, which is rarely guaranteed. A malicious party in the supply chain, for example, could tamper with invoice information and erroneously change paid or due values.

As a result, support for a mechanism that improves immutability and ensures transaction confidentiality in supply chain use cases is critical. Blockchain technology offers a viable solution to the security issues that arise along the supply chain, ensuring product integrity and transparency. Different aspects of blockchain technology that affect the supply chain, explicitly or implicitly, are presented and analysed in the subsections that follow.

Table 2. Blockchain Elements that affect Supply Chain Logistics with Roles Scope.

	Relation and impact to the Supply Chain roles
Scalability	Scalability is improved since the suppliers are participating in a general system of the supply chain (not different ones depending on the different companies as in traditional supply chain architecture). The Peer-to-Peer nature of blockchains is by design more robust and scalable given the fact that the there is no single point of interaction (as compared to centralized solutions). Distributors scalability is improved since in a common ledger all their customers (wholesalers, retailers) can be effortlessly accessed (no need for different supply chains for different customers). Blockchain scalability improves consumers experience since they are more aware of the supply chain size and functionalities through transaction tag information and their trust towards the system increases.
Performance	Blockchain performance enhances this step since transaction submission and verification high speed (comparing to traditional bank methods) provides quick and trustful liquidity of payments. Recent blockchain implementations are being designed as to facilitate a high throughput of transactions per second.
Consensus	Blockchain consensus offers trust to the whole supply chain system. Country origin, quality and other details are recorded as tags on the ledger, adding value to the final product. It benefits the Distributors stage since the raw materials are validated and the manufacturer signature is checked, which all together add value to the final product. It also helps vitally this stage since the retailers are assured that the final product which is about to be sold to the end users has all the exact natural resources and passed through all the manufacturers, distributors and wholesalers that the ledger confirms. Consumers are confident that the product quality and general characteristics are the ones that the blockchain ledger confirms they are; value is added to the product.
Privacy	Although blockchains are considered public ledger, privacy can be engineered in a way to facilitate access control to who is going to have access to the information contained in the blocks. Blockchain provides privacy in the sense that private transactions are not visible (but are legitimately verified) by parties that transaction issuers might not want to display. It also helps keep identity of users private when it is needed, but still verifying values that are essential for the consistency of a products journey, such as raw material quality, distributor geolocation and others.
Location	Supply chain dependency on location becomes flexible. Raw materials are transferred around the world while transactions are not dependent on country regulations and laws; with rapid submission and validation rates. Manufacturers are cooperating with different supplier and distribution companies around the world while transactions are country regulation and law independent with rapid submission and validation rates. Distributors are cooperating with different wholesale and retail companies around the world while transactions do not depend on country regulations and laws and are accomplished with rapid submission and validation rates. Additional measures and methods for proof-of-location mechanisms are being considered these days as a way to prove the location through its registration to a blockchain that cannot be disputed.
Cost	Blockchain transaction costs can be significantly reduced comparing to traditional payments with banks. In contrast with banks, crypto-payment fees are negligible, especially when transferring funds between countries with different regulations and economy laws. Suppliers are paid faster for the natural resources that the sell to manufacturers, while the later are charged subtly on their purchase. Distributors are compensated quicker for their offered products, while the wholesalers or retailers benefit from the low fees. The final product overall value is increased while at the same time its price is substantially decreased which both leave the consumer happier than in the traditional supply chain system in terms of quality and price.

2.9 Data Requirements

This blockchain system uses data about the orders recorded by the user along with its location details. The timestamp data showing the date when order was placed. Other data requirements are unique ID number, User name and location for which the approval is required to send the product.

2.10 Programming Used

Python Programming is used with the Hashlib module which is used to implement a common interface to message-digest algorithm and different secure hash. SHA 256 cryptographic algorithm is used in this to add blocks we will also need to flesh out methods for the new_block(), add_new_transaction(), and hash() in the blockchain system for this improving supply chain visibility.

2.11 Constraints

Blockchain technology has a lot of potential for creating decentralised, trustless applications. However, it is not without flaws. Due to a number of impediments, blockchain technology is deemed unsuitable for mainstream applications. The following image depicts the limitations of blockchain technology.

- Lack of Awareness:
  There is a lot of talk about blockchain these days, but few people understand its true value or how to use it in different situations.

- Limited availability of technical talent:
  In the field of blockchain technology, there aren't many developers with specialised knowledge of the technology. As a result, a scarcity of developers makes it difficult to develop anything on the blockchain.

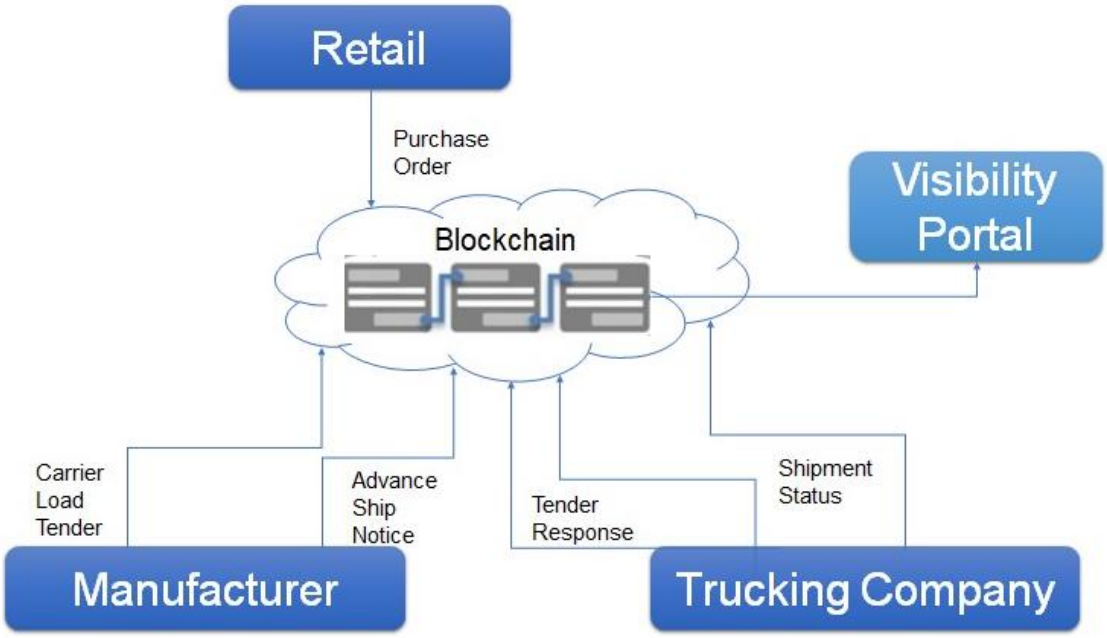
- Immutable:
  We are unable to make any changes to any of the records in immutable. There is a disadvantage to immutability. When you want to make any changes or reversals, this is the case. For example, suppose you've already processed a payment and now need to make a change to it.

- Key Management:
  There are several types of keys, including public and private keys. When dealing with a private key, you also run the risk of someone else gaining access to it. It happened a lot in the early days of bitcoin, when the currency wasn't worth much. People would simply accumulate a large amount of bitcoin and then forget the key, which could be worth millions of dollars today.

- Consensus Mechanism:
  In the blockchain, Depending on the network size and the number of blocks or nodes involved in a blockchain, the back-and-forth communications involved to attain a consensus can consume a considerable amount of time and resources.

3. Design Details

3.1 Architecture

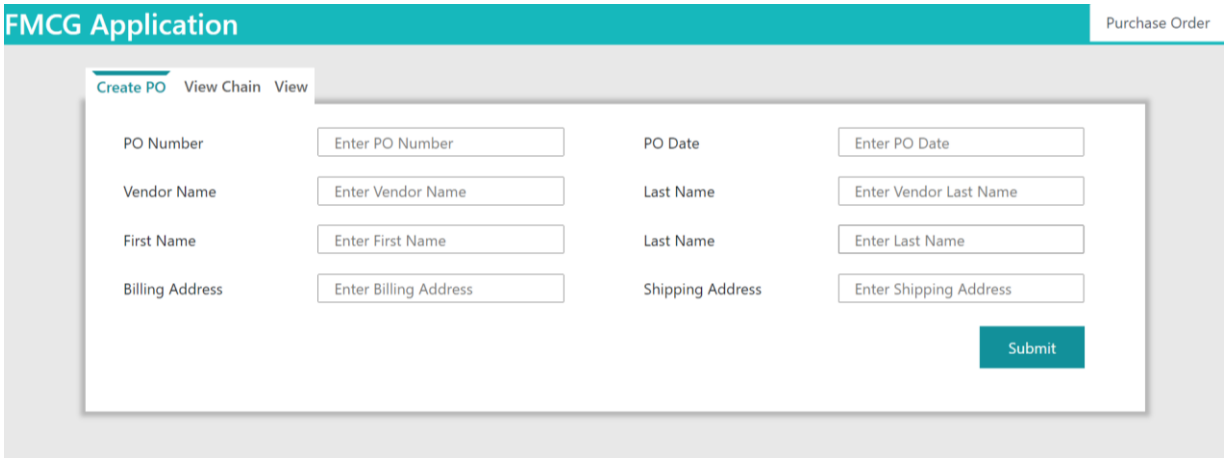


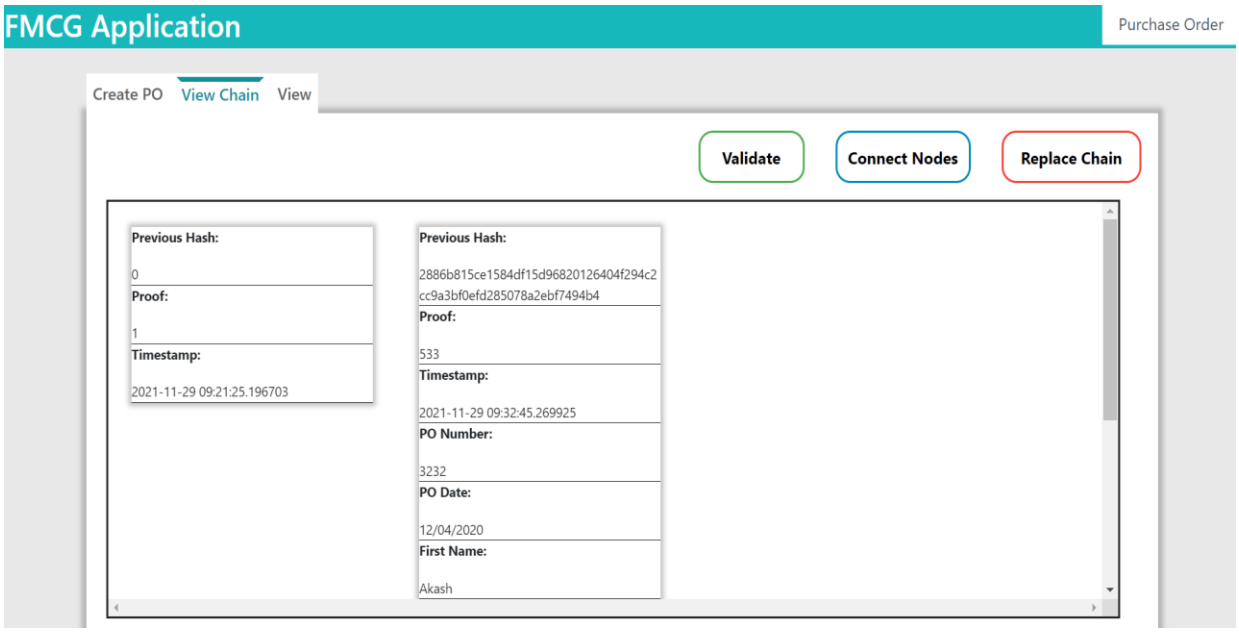
3.2 Process Flow

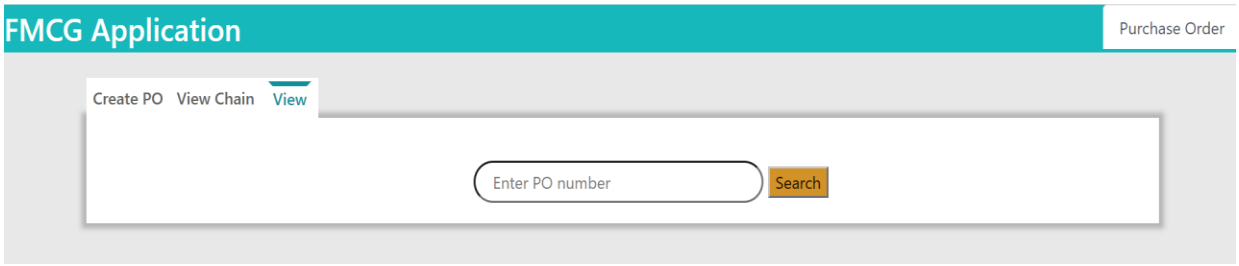
The platform designed enables employess of FMCG companies to login to the platform in order to track the purchase order and the shipment details. The platform also provides a facility to authorised users to login to the platform to track complete end-to-end blockchain process and ensure that there is no interference with the system.

There is a provision to create a purchase order which encompasses all the purchase related and shipment related details. On submission of the purchase order, a purchase order transaction is created and stored within a block. Subsequently, the block is mined on submission itself. In a similar fashion, multiple blocks can be created by creating purchase orders and every block is mined on its creation. The multiple blocks created form a ledger. There is a provision on the platform to check the validity of each blockchain ledger. After verifying the blockchain on one particular node, multiple nodes are created. All the nodes are connected to each other to replicate the blockchain on each node which helps in ensuring that there is no interference and no blockchain ledger on any node is altered. This complete functionality is for authorised users to facilitate the tracking of blockchain and ensure its integrity.

For employees of FMCG companies, there is a separate section to fetch the details pertaining to the purchase orders created, on just inputting the Purchase Order Id. This can also help the employees in tracking the shipment status in a similar way by just entering the Shipment Id. The platform offers and plans to offer a secure visibility portal with various functionalities which would help users in tracking the supply chain process including manufacturing, retail and logistics.




FMCG Application
Purchase Order
Create PO
View Chain
View
Validate
Connect Nodes
Replace Chain
Previous Hash:
0
Proof:
1
Timestamp:
2021-11-29 09:21:25.196703
Previous Hash:
2886b815ce1584df15d96820126404f294c2cc9a3bf0efd285078a2ebf7494b4
Proof:
533
Timestamp:
2021-11-29 09:32:45.269925
PO Number:
3232
PO Date:
12/04/2020
First Name:
Akash


FMCG Application
Purchase Order
Create PO
View Chain
View
Enter PO number
Search

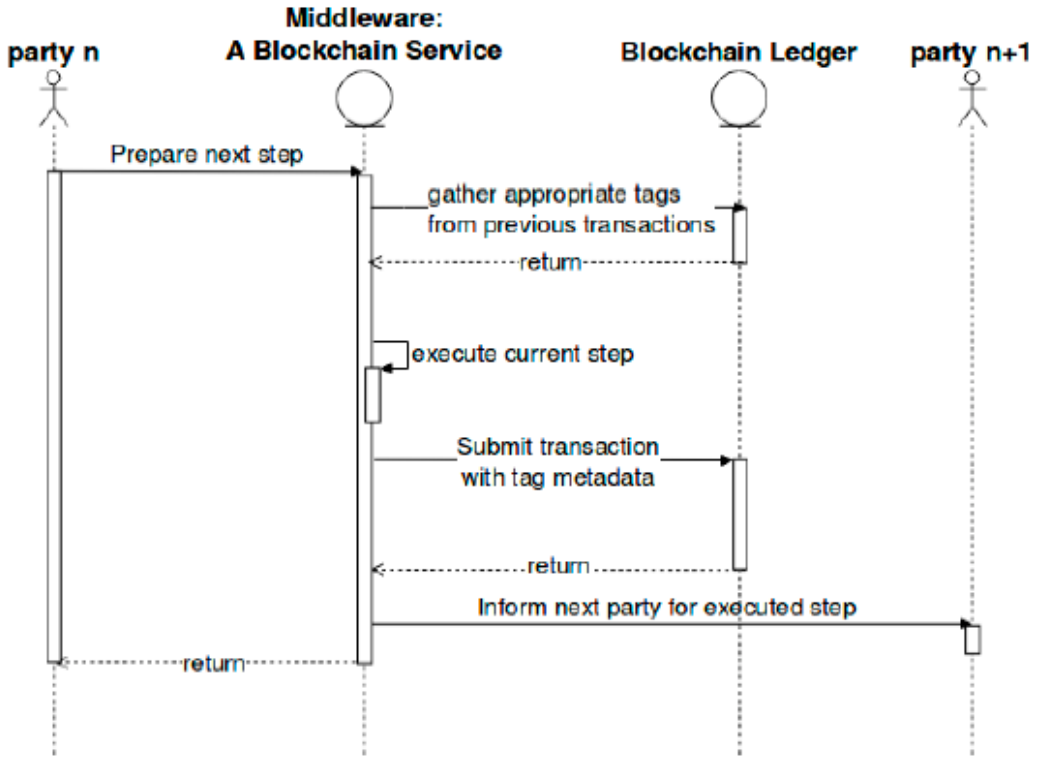


Figure 2. One supply chain freight stage (***stage number n+1***) as a blockchain transaction. Every stage's functionality is automated by the "Middleware", and thus, the parties that participate in each stage (a single one in the input and another one in the output) have a small interaction with it; for instance, the driver confirms that the transportation was completed by receiving the appropriate transaction hash, or the employee confirms that certain materials were kept refrigerated, as expected, by collecting the corresponding transaction hashes and others. Here, ***party n*** participates in ***stage n+1*** input (and already in stage n output) while ***party n+1*** participates on ***stage n+1*** output (and stage n+2 input).

3.3 Error Handling

The different types of errors in blockchain development.

1. Network-based Errors
   One of the easiest methods to avoid this is by ensuring the proper installation and starting of the network. You will have to take all the steps according to the network we have.

2. Database Errors
   During each line of code, data from different databases may be pulled and put to use. If we encounter database errors while coding for blockchain, we should be much alarmed. The first step is to make sure that there are no corruptions in the database set. Next step, you need to ensure the proper connection between the system and the data.

3. HTTP/API Errors
   Depending on the type of error that occurs, certain codes are given for each type. In the world of the world wide web, for instance, HTTP Error 404 means that the page has not been found. Similarly, it is possible to find other types of errors in blockchain development as well.

4. Runtime Errors
   We would also have come across runtime errors while dealing with Hyperledger or other types of blockchain development tech. If we see one of these errors, it means that there is something wrong with the process of runtime.

3.4 Reusability

The code written and the components used for the project can be reused and with appropriate changes, we can scale up to meet new requirements as well. The code is written can be further scaled up by importing real-time data into the system.

3.5 Application Compatibility

We have designed a webpage that is integrated with the block chain technology that can be accessed on various platforms ranging from smartphones to laptops and computers

3.6 Deployment

The Visibilty portal created is using blockchain and has been deployed on Python flask framework, where all stakeholders with valid credentials can access it to add and view new and current logs such as Purchase Orders and Shipment Status.

4. Conclusion

The path to a global supply chain management framework based on blockchains is long and winding, with many obstacles to overcome. While a discussion on features such as scalability, performance, consensus mechanisms, and public vs. permissioned blockchain cannot be exhaustively covered in a single study, more research on topics that will pave the way for blockchain adoption in the supply chain industry is required. A starting point for tackling the research challenges and facilitating the necessary changes based on controlled private ledger environments, where such blockchain features can be managed effectively, is to have consortium-based, permissioned ledgers, which can be applied on specific cross-organizational domains. Permissioned blockchains present a number of challenges, including energy efficiency, transaction costs, total confirmation time, and security and privacy concerns. However, such approaches cannot be considered completely decentralised because they still rely on central trusted parties to validate the identities of participating actors and assign the blockchain's necessary credentials. As inter-domain and inter-chain blockchain implementation research advances, the road to public blockchains will be paved with more concrete ideas, and implementation will be facilitated by more concreted design principles and adoption maturity from the supply chain industry's various stakeholders.

The specific paper included an analysis of blockchain adoption for a large-scale deployment in the supply chain management industry, among other things. The team has therefore created a small working of the visibility portal using blockchain to show a prototype of this near future implementation.