Inventory Management in Supply Chain using Blockchain technology

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Abstract

Inventory management is a part of the supply chain where inventory and quantities of stock are tracked in and out of the stockroom. Proper handling of inventory will lead to successful supply chain management in any organization. QR codes make this inventory management speedy. This fast information transfer will also reduce the number of errors in inventory records and also gives accurate results to make informed decisions during frequent reviews. But based on Quick Response (QR) code for inventory management will become a centralized database. Blockchain facilitates manufacturers to connect each party from distribution centers and retail partners, to suppliers and production sites - with an abiding record of each, single exchange that occurred. These put away records are available to everybody inside the P2P organize and gives decentralization. The degree of straightforwardness and permanency gave in blockchain are frequently useful for manufacturers to oversee item roots and traceability. Smart contracts, one of the features of blockchain, have built-in automation, which makes a lot of sense for transaction management. In this paper, we are using both the features of QR code and blockchain for transparent, distributed, and reliable inventory management.

1. Introduction

1.1 Why this High-Level Design Document?

The purpose of this High-Level Design (HLD) Document is to add the necessary detail to the current project description to represent a suitable model for coding. This document is also intended to help detect contradictions prior to coding, and can be used as a reference manual for how the modules interact at a high level.

The HLD will:

- Present all of the design aspects and define them in detail
- Describe the user interface being implemented
- Describe the hardware and software interfaces
- Describe the performance requirements
- Include design features and the architecture of the project
- List and describe the non-functional attributes like:
    - Security
    - Reliability
    - Maintainability
    - Portability
    - Reusability
    - Application compatibility
    - Resource utilization
    - Serviceability

1.2 Scope

The HLD documentation presents the structure of the system, such as the database architecture, application architecture (layers), application flow (Navigation), and technology architecture. The HLD uses non-technical to mildly-technical terms which should be understandable to the administrators of the system.

1.3 What is Blockchain?

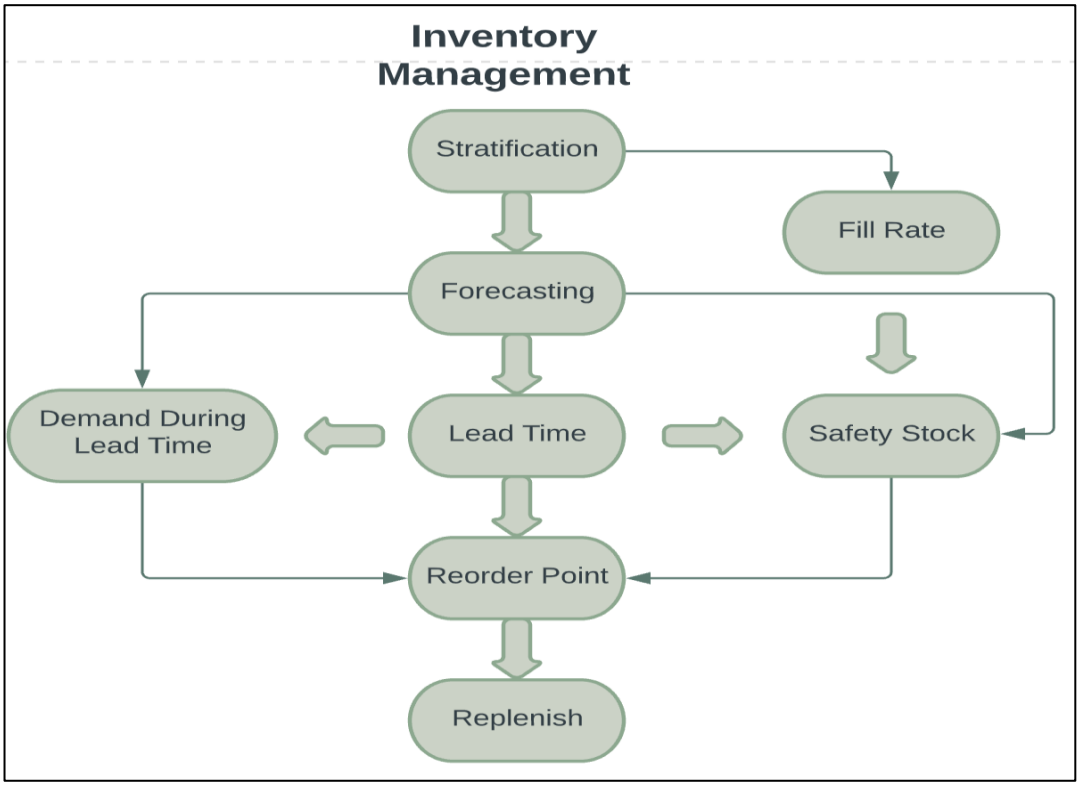
Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved.

1.4 Why it is important?

Business runs on information. The faster it's received and the more accurate it is, the better. Blockchain is ideal for delivering that information because it provides immediate, shared and completely transparent information stored on an immutable ledger that can be accessed only by permissioned network members. A blockchain network can track orders, payments, accounts, production and much more. And because members share a single view of the truth, you can see all details of a transaction end-to-end, giving you greater confidence, as well as new efficiencies and opportunities.

2. Current Problems in Inventory Management

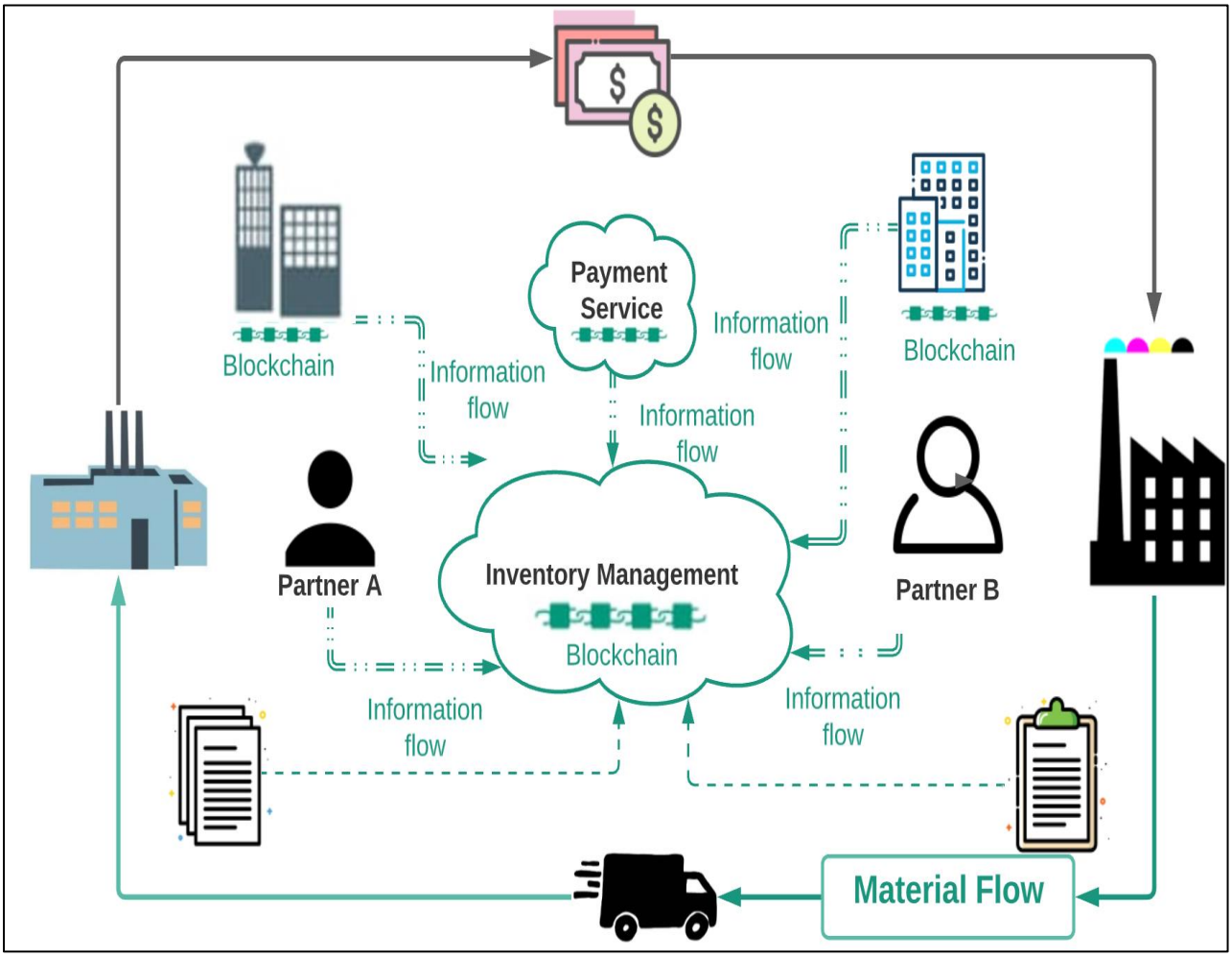
The current inventory management is based on the supply-and-demand methodology. Companies face a huge challenge in managing their supply chain network with this technique. There is a lack of visibility down the supply chain which hinders the assessment of customer demand. These supply chains comprise multiple partners like suppliers, distribution centers, and retail partners. Each of these parties uses their own methods and systems for managing transactions and the movement of goods. This practice is highly inefficient as companies are always a step behind the market needs. There is always a possibility of delay in meeting the market needs, which leads to financial losses. Companies can face losses if they understock or overstock goods while anticipating market trends. Also, a lot of time and human resources are wasted if there occurs any miscommunication or error in the supply management system. Data manipulation and unethical practices followed by employees is also a serious issue faced by companies. Blockchain helps connect all the parties involved in a unified, fixed, transparent, and decentralized record. This helps minimize discrepancies and helps companies stay ahead of the curve. Also, most of the Inventory management systems run an age-old DBMS and linear data entry in quantitative aspect.



3. Proposed Solution

Supply chain industry being a pivotal entity in the world goods movement is striving to implement new technology that can overcome these flaws. Especially with the Inventory management system business look to streamline the work flow and maintain a hassle free and accurate record keeping system. Blockchain bridges the chasm in this sector and additionally offers something that businesses have never bargained for.

Blockchain being a distributed ledger makes absolutely sure of the security and transparency; it promises to resolve the existing problems in the inventory management part of the supply chain sector. By implementing the blockchain methods and solutions, supply chain inherits the following attributes of blockchain and evolves for the better. Inventory management system with Blockchain would offer.



4. Technical Understanding

Some of the basic technical requirements are as follows:

- **Distributed systems and Networking**

  Blockchain is a distributed ledger that works across the network, and all the connected computers are used for processing in the Blockchain.

- **Cryptography**

  To understand the conversion from the plain text to the cipher text.

- **Decentralization in blockchain**

  In blockchain, decentralization refers to the transfer of control and decision-making from a centralized entity (individual, organization, or group thereof) to a distributed network.

- **Smart Contracts**

  The smart contracts are the programs which help in automating the transactions. It helps in increasing the capabilities of Blockchain without any need of middlemen or lawyers to settle the deal. The smarts contracts are made with specific conditions or in particular situations.

5. Constraints of traditional system:

1) Traceability

Traditional systems have poor capability to monitor events and metadata associated with a product. Blockchain provides full audit trail of data creating an everlasting means of record keeping along a supply chain.

2) Compliance

Standards and controls to provide evidence that regulatory conditions are not met by traditional system. All blockchain transactions are timestamped and temper-proof, providing a single source and data integrity.

3) Flexibility

Traditional systems lack the ability to adapt rapidly to events or issues, and run various scenarios, without significantly increasing operational costs. Continuous real-time tracking of data is facilitated through the use of smart contracts across the supply-chain.

4) Stakeholder management

Effective governance in place communication, risk reduction and trust among the involved parties is not present in traditional systems. Blockchain enables peer-to-peer interpretations which can be trusted based on the digital signature.

6. Assumptions

Overview and Assumptions Due to the high number of stakeholders involved in large scale supply chains of global range, the relationships between them end up to be complex. Modern supply chain management carries many trust-based concerns that constitute the main cause why a blockchain solution is essential and seems mandatory. First of all, there exists a lack of trust among the participants of a supply chain. Every party needs to trust that true data is issued and exchanged by another party in their intercommunication. Unfortunately, this does not occur in contemporary supply chains where freight failure, human error, or intended fraud prospers. Furthermore, it is essential that such systems need to effectively gather valid data, record it securely and provide exact information to several other systems. Failures on these processes occur frequently and, as a result, a global end-to-end supply chain system depends highly on its fragile links that slow down, alter or impede information flow. In addition, lack of both high standards and end-to-end integration leads to information inconsistency among stakeholders. Each party needs to collect and confirm the data validity in order to ensure integrity and effectiveness that decreases system performance. Additionally, limitations on the efficient information flow manipulation exist due to the current supply chain system structure. Due to the complex architecture, the system is additionally changed with hard tasks such as product traceability and monitoring that crucially impair performance and efficiency. For example, tracking the complete system starting from raw material extraction to factory-produced ware ready to be purchased has become a significantly complex procedure in modern supply chains. Supply chains will benefit from blockchain innovative science through numerous ways. Blockchain will essentially contribute to transparency and auditability that will support large extent freight conditions violations and human error and fraud detection (the cost of global fraud was evidenced in a report by PwC , where it is indicated that 49% of organizations globally said they have been a victim of fraud and economic crime). Product conditions will be controlled and reported on the ledger when they overcome the proper thresholds, as well as any human error that could damage the goods of the chain’s procedures. In order to reduce reputation risks, human rights, and conduct codes will be respected along the chain by being recorded on the ledger. Intended fraud will be detected and reported on the

blockchain as a transaction as well, while notifications and messages could be broadcasted inside the blockchain network in order to inform other parties about the participant that tried to commit fraud. Additionally, blockchain will provide continuity of information through its well-known properties of immutability and irrevocability. Secure sharing of data between different stakeholders that participate in a global supply chain will be essential in order to guarantee freight traceability and reduce the risk of errors or frauds and will easily be implemented inside a public or permissioned blockchain network that ensures trust less party intercommunication and tamperproof data. Further, properly authorized accessibility to information will be achieved with important benefits for future references. Agile and transparent blockchains will offer access to ledger data retrospectively in order to benefit from the massive volume of the information produced.

7. Possible Approach/Design/Deployment Process

1) Blockchain Ledger Layer

The Blockchain Layer of the architecture describes its core low-level blockchain network functionalities. The modules that constitute this layer are mainly for achieving consensus among the peers and manage the transactions that are going to be registered in the ledger. The Consensus Module confirms data authenticity and the proper execution of operations inside the blockchain network. It is responsible for transactions validation and verification and the overall agreement on current ledger state among different nodes that participate in the blockchain network. This module is directly connected with the Transactions Handling module of the Blockchain Layer and they all together form the blockchain data structure. Permissioned blockchain platforms utilize new consensus protocols in contrast with public blockchains that use traditional ones. Algorithms for permissioned blockchains tend to reach consensus faster and more efficiently in a private environment. In order for the different peers of a blockchain network to co-operate and agree on the validity of the transaction data, a protocol needs to be adopted. This is the responsibility of a consensus algorithm that offers trust-less node interaction and decentralized applications implementation inside a blockchain network. The Transactions Handling Module is another core blockchain network module. Its main responsibility is to store the transaction data on the blockchain ledger. It is directly connected with the previously mentioned Consensus Module of the Blockchain Layer together forming the blockchain data structure. The two modules interact with each other and together communicate with the Middleware Layer as a whole blockchain scheme. When a transaction is being submitted to the blockchain network, all of its information is recorded on the ledger. Data such as the transaction hash, the address of the sender, the address of the receiver, the timestamp, the value of the transaction and other information are grouped and committed on the ledger. The Transactions Module is absolutely necessary in order to properly handle and forward this information of any happening transaction inside the blockchain network.

2) Middleware Layer

The “Middleware Layer” is the core layer of the infrastructure since it is the substantial connecting tier between the Blockchain Layer and the top layers that are closer to the supply chain management such as Enterprise Resource Planning (ERPs) and other related software packages. The Middleware Layer each consists of the following modules: Upload Handler: The “Upload Handler” regulates document uploading such as e-invoices, receipts or other official documents associated with every step of the value chain. When a new document (e.g., e-invoice) needs to enter the infrastructure, certain operations need to be followed in order to handle it and guide it through the architecture. The Upload Handler module interacts with the top layers (Application Layer) through appropriate APIs for controlling and managing the initial uploading of information. For instance in order to upload an e-invoice a smart contract is created and deployed through the “Smart Contract Manager” module. After that, the e-invoice is stored on the corresponding distributed data storage, as described on the “Data Orchestrator” module below. Data Orchestrator: The “Data Orchestrator” Module is responsible for storing efficiently an e-invoice in a secure distributed manner with low latency. Highly distributed storage and file systems are very suitable for such implementations and approaches such as the InterPlanetary File System (IPFS). This module retrieves and stores securely the e-invoice, either ‘Required’ or ‘Paid’, provided from the Upload Handler module. Smart Contract Manager: The Smart Contract Manager is a crucial module of the Middleware Layer since most operations go through its functionalities and approval mechanisms. The automatic creation, deployment, and triggering of smart contracts constitute its main responsibility. It is a module with core functionalities that interacts with the Upload Handler and the Transactions Handler. When a merchant or customer is uploading an e-invoice, either ‘Required’ or ‘Paid’, the Smart Contract Manager processes the respective inputs collected from the Upload Handler (sender and receiver Logistics 2019, 3, 5 12 of 17 addresses, e-invoice due date and value, and other e-invoice information) and creates a new smart contract. After that, the module deploys it to the blockchain network through the Transactions Handler. If a ‘Required’ e-invoice is uploaded, this new smart contract emits an event inside the blockchain network in order to trigger a customer’s smart contract that eventually informs their ERP that they need to pay this ‘Required Invoice’. Application-level Transactions Handler:

This module regulates transactions managing inside the supply chain management infrastructure of the participating actors and is responsible for all the interactions between the Application level and Middleware Layer. It can be regarded as the external Application Programming Interface (API) with the middleware services that need to further process this request to the blockchain ledger. Interacting with the Smart Contract Manager module is also foreseen as many times the different transactions are going to be bound to specific conditions imposed by the smart contract upon which they are based. As clearly explained previously in the Smart Contract Manager, every smart contract related functionality creates a new transaction that is controlled by the Transactions Handler and forwarded to the Blockchain Layer. Figure 2 illustrates information about the integration of blockchain technology and supply chain by introducing a blockchain architecture scheme which handles each product stage with similar respect. As can be seen from the figure, every supply chain stage is approached as a step of the freight journey which is recorded thoroughly on the blockchain ledger. On each step, two parties are engaging together with the blockchain service which automates the procedures of the step, such as submitting any necessary transactions on the ledger. More specifically, on stage n+1 there exists a party that inputs data (party n) and a party that receives the step's output information (party n+1). This procedure is completely automated through the Middleware Blockchain Service which handles data properly and submits the necessary step transactions on the blockchain ledger. For instance, at the end of the legitimate completion of a particular step, special smart contracts would be triggered in order to distribute payments to custom parties. On the proposed schema of Figure 2, each party prepares the next step (stage) of the supply chain by confirming the previous one. In particular, the confirmation takes place by inputting the proper hashes and other proof material output from the previous step. After that, custom smart contracts could be triggered depending on the step, and then, the Middleware confirms the validity of the input and initiates next stage's procedures. Such procedures would be to gather appropriate transaction hashes, tags or electronic seals, and other ledger information of previous steps, as shown in the figure. The Middleware interacts directly with the blockchain ledger and its blocks that include transactions and all the important tamperproof data. Following this, the supply chain step is eventually executed through the Middleware in an environment that ensures a continuous data validation.

After the stage completion, the actions are reported by submitting one or more new transactions on the ledger that includes the appropriate product tags or electronic seals. The new transactions prove in the legitimate circumstances under which the supply chain stage was finished and allow the next stage to be initiated. The possible case of any product failure, human error or intended fraud will immediately be detected since the appropriate hashes and other crypto material will not match for the next step to get started. Since all values are reported on the blockchain ledger, any mismatch would trigger smart contracts that encounter matters of such kind and would inform both step parties as well as other participants of the whole chain if necessary for the error. For instance, cold medical bottles' temperature on a specific truck raised about 40% above the threshold during the transportation, and thus, they are currently useless since they are able to cause serious problems to patients.