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Decentralized Military Supply Chain Management for the Indian Army Using Permissioned Block Chain Networks

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Abstract— This Paper will develop a blockchain based Supply Chain Management system to support an Indian Army to improve security, transparency and efficiency in the military defense logistics supply chain. The supply chain of the Indian Army is far spread and large and the traditional centralized and paper-based systems being used are prone to delays, data manipulations, inability to see the supply chain real time and audit. To overcome these obstacles, the suggested system uses blockchain technology to create a decentralized procurement, inventory, transportation and delivery of military supplies. Smart contracts are deployed to automate key processes like request approvals, inventory, dispatch and delivery confirmations and reduce human errors and human intervention. The hybrid solution is used, with the blockchain storing the critical transaction data and the data that is large and non-sensitive being off-chain to enhance the efficiency and scalability of the system. The use of role-based access control and cryptographic means are used to guarantee the data confidentiality, integrity, and accountability. The result allows confirming efficiency of the system in providing traceability, fraud prevention, and proper monitoring, which is why it is optimal to secure military supply chain operations.

Keywords-- Blockchain, Supply Chain Management, Indian Army, Smart Contracts, Security, Transparency, Traceability, Decentralization, Defense Logistics, Ethereum, Solidity.

I. INTRODUCTION

Supplies chain management is a significant field that assists in the available resources at right time to achieve the smooth running of large organizations. The supply chain management in the Indian Army is a cumbersome and massive process and the transportation of a variety of necessary goods such as rations, cloths, fuel, ammunition, medical, and equipment's across diverse landscapes. Any interruption, time loss, or sacrifice in the supply chain can have a direct effect on the operational maturity and the domestic security. The traditional supply chain management system in the defense logistics is predominantly centralized and manual.

Traditional supply chain management system is likely to be limited with the lack of real-time visibility, slow information flow, inaccuracy of data, vulnerability to fraud, and auditing and responsibility issues.

As the rate of development of digital technology keeps rising, there is the growing necessity to modernize the logistics systems in the defense industry. The blockchain technology has been cited as a potential remedy to most of the issues arising with the traditional supply chain management systems. A blockchain system is a decentralized and distributed registry of transactions that are stored in a safe, public, and irreversible manner. When the information is written into the blockchain, it cannot be changed or erased and hence it is very tamper-proof. This is why blockchain technology is very convenient in the defence industry, including the supply chain management.

The adoption of blockchain technology in Indian Army supply chain will guarantee end-to-end traceability of the supplies since the procurement until the final delivery. All the transactions, including the creation of a request, approval, dispatch, transfer and receipt are registered in the blockchain, which lead to one source of truth between all the stakeholders. The smart contract also enhances the system by automating established rules and work processes.

The aim of this proposed project is to implement a blockchain supply chain management system in the case of the Indian Army. The suggested system would involve a hybrid model of the on-chain and off-chain storage.

II. RELATED WORK

The supply chain management has been attracting a lot of attention in the recent past due to the complexities and the necessity to have transparency and security. The traditional supply chain management model is very reliant on the centralized databases and manual processing between different parties which causes inefficiencies, lack of trust and vulnerability to frauds.



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To address such concerns, the use of new digital technologies, including blockchain, Internet of Things (IoT), and artificial intelligence, to enhance supply chain management has gained much interest. Blockchain is one of the new technologies that have been found to be a revolutionary technology due to its decentralized, immutable, and transparent nature.

Certain studies also reveal the possibility of blockchain technology in ensuring that supply chains are more transparent and traceable. Certain initial studies showed that blockchain technology would be able to deliver a common neutral source of truth to every participant in a supply chain. The blockchain technology gives the opportunity to trace transaction on an immutable ledger that allows tracing products in real time and enhances trust among the members of the supply chain without a central authority.

When Nakamoto introduced the concept of blockchain with the help of Bitcoin, he made it possible to illustrate how a decentralized community could reach a safe consensus even in a scenario where trust is close to zero. This was then accompanied with the expansion of the concept of blockchain beyond money to supply chains. Swan described how blockchain could support smart contracts, which are self-executing applications and implement preset rules and agreements. The other major area of application of smart contracts is in automating purchasing, payment and compliance in supply chains thus avoiding manual processing, which eventually delays the process.

Scientists in the manufacturing and logistics industry are also experimenting with the blockchain technology in enhancing management of the supplier chain and product authenticity. This is to be done by developing an irrevocable account of authenticity and verification data at every point of the supply chain, both at the manufacture point and at the delivery point so that fake products are not injected into the supply chain. The blockchain technology guarantees that only genuine and quality-assured products are put in the supply chain through the maintenance of an undeletable record of the history of a product. It is especially significant in the fields like pharmaceutical industry, food safety and military where fake products represent a great danger.

It is also the interest of some researchers to investigate how the blockchain technology can be utilized alongside the IoT technology to track the supply chain assets in real-time. IoT devices like RFID, GPS and other sensors are also applied to track the real time location of assets, their temperature and condition. These are then logged into the blockchain.

A developing but growing literature exists in the domain of defense and military logistics on whether blockchain can be used to improve secure and resilient supply chains.

These military networks need a lot of confidence, accountability and dependability due to the nature of the missions at hand. Authors have mentioned using approved blockchain systems to ensure only authenticated parties access and retain the benefits of transparency and auditability. It is concerned with provision of a sound access control, encryption as well as authentication to secure military sensitive information. Compliance can be checked through audit trails that are supported by blockchain, and accountability in the defense logistics systems can be improved with the help of these audit trails.

Nevertheless, the literature points to certain difficulties with the implementation of blockchain technology in supply chains regardless of its benefits. One of the significant issues with the blockchain technology is scalability because the public blockchains may slow down or even be unable to process a significant number of transactions. The difficulties are also storage requirements and transaction costs, particularly, when considering a lot of data. Researchers propose hybrid models that can be used to overcome these issues by combining on-chain and off-chain storage.

III. PROPOSED FRAMEWORK

The proposed solution is a decentralized and transparent blockchain-based supply chain system that is secure and is tailored to the Indian Army. The main goal of the suggested framework is to remove the inefficiencies of the traditional system of defense logistics (which incorporate manual paperwork, the inability to see the operations in real-time, the risk of data interference, and the delayed decision making time). The suggested structure employs blockchain technology to guarantee data integrity, traceability and accountability in the military supply chain.

Under such a setup, every single activity in the supply chain, be it a procurement notice, supplier verification, physical inventory movement, physical goods movement, and the final delivery, is stored as an immutable record in a permissioned blockchain. When stored in the blockchain, it can no longer be changed or removed, thus avoiding fraud, unpermitted manipulations, and erasing of vital documentation. People who are allowed to access and execute functions, including suppliers, warehouse people, transportation people, and Army people, log in with role based permissions. This ensures the secrecy of sensitive defense information and allows visibility nonetheless.

The new system is based on smart contracts and allows automated logistics regulations and processes which were previously manual. They deal with key operations like the acceptance of supply requests, inventory, authorization to dispatch, transfer of ownership and delivery confirmation.



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They provide the system with speed and less most likely to be error prone because they do not require manual approvals and the mediator. They also prepare automatic notifications on low stock, late shipments and violation of rules so that teams can make informed decisions.

The architecture is a blend of on-chain and off-chain functions to bring about a balance that balances security and speed. Time stamps and cryptographic hashes are the most valuable transaction data, and they are stored in the blockchain to make them immutable and traceable. Data that are large and non-sensitive like descriptions, documents, reports and user data is stored off-chain in a secure database. The design minimizes the storage needs of the blockchain, transaction charges, and enhances scalability without affecting the data integrity by validating the hash.

The system uses cryptographic methods, digital signatures and authentication procedures associated with secure wallet to improve security. Access is controlled by roles where only corresponding persons with the required responsibilities are allowed to read or edit certain information. The automatic audit trails are designed to document everything that has taken place and this enables tracing of activities to audit purposes.

The system under development will be capable of communicating with the new technologies including IoT devices, RFID tags, and GPS pressure and track the supplies in real-time. Such system keeps the location of the military resources and their state in constant observation regardless of the distance of the location. To summarize, the blockchain supply chain management system is better than the former system in terms of transparency, efficiency, security, and resilience.

IV. METHODOLOGY

The suggested system, Supply Chain Management of the Indian Army with the help of blockchain, is designed on the principles of security, decentralization, and modularity to increase the transparency, traceability, and efficiency of military logistics. The system is an integration of blockchain technology and smart contracts and web applications that will automate supply chain operations, integrity, and real-time decision-making to the Indian Army.

A. System Architecture

It is a system using a permissioned blockchain as a client server architecture. React provides an interactive user interface on a client-side, whereas on a server, there is Node.js which uses Express.js to process business logic and system integration.

Smart contracts written in Solidity and implemented on an Ethereum-based blockchain (Ganache is used to develop and test) control the essential operations of the supply chain. Questions where the data stored is not critical or the data volume is large are handled by MongoDB to store data off chain, which improves scalability and speed.

B. Data Collection and Preprocessing

The system offers formalized information on the supply chain, such as the procurement requests, inventory, supplier information, transport information, and delivery confirmations. All data are validated and normalized and then subjected to blockchain processing. Preprocessing step makes the data normal, eliminates duplication of the data, checks the accuracy of quantities, and time stamps to verify that the data is correct and similar to all modules.

C. Blockchain-Based Supply Chain Management Module

This module is everything related to processing supply chain transactions through the blockchain, starting with a request creation and ending with validation, approval, dispatching, transfer, and receipt. All the processes are stored in an unalterable record on the blockchain. Smart contracts stop the rules beforehand, and the entire process is safe and unchangeable.

D. Smart Contract Automation Module

Smart contracts make the required logistics operations such as the approval of steps, stock changes, confirmation of dispatch, and verification of deliveries simpler. Smart contracts make these operations automatic, which decreases the number of operations that should be handled manually, diminishes the risk of errors, and makes certain that the military logistics regulations are consistently observed.

E. Inventory and Asset Tracking Module

Using this module, you are able to monitor stock quantities and movement of assets between warehouses and depots, as well as divisions. Traceability with blockchain Traceability is full visibility on the status of the supplies, ownership, and delivery times across the supply chain.

F. Role-Based Access Control Module

The system has role-based access control to control access to the data, and users can enter the information depending on their role, i.e., administrator, supplier, depot officer, and army unit. This approach makes sure that the sensitive information on defence remains confidential but can be viewed with some control.



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G. Visualization and User Interaction Layer

The interactive dashboards offer a graphical view of the supply requirements, order status, stock as well as the transaction history. The visual aid enhances the situational awareness and allows the user to make informed decisions.

H. Security and Authentication Module

Security is guaranteed using wallet authentication, digital signatures, and JWT controlled sessions. All the transactions are signed on the blockchain, which is why no unauthorized access and data manipulation can occur.

I. System Integration and Scalability

The modular architecture can easily be connected to other emerging technologies like IoT, RFID and GPS. The on chain and off-chain architecture is hybrid, which guarantees scalability and anticipates future development.

J. Summary

The solution project will use the blockchain technology, automated smart contract, powerful authentication, and interesting visualization to deliver a safe, transparent, and efficient supply chain management system to the Indian Army.

V. EXPERIMENTS

This area explains the nature of the experiments and how the Blockchain-Based Supply Chain Management System was to be evaluated regarding the Indian Army. It is focused on the ability of the system to ensure end-to-end traceability, prevent data tampering, deter transactions, and make defense logistics more efficient. We analyze it through the prism of the integrity of the transactions, the accuracy of the traceability, system responsiveness, the effectiveness of the enforcement of the security and/or reliability of the smart contract implementation.

A. Datasets and Evaluation Strategy

We used a data generation process that was structured to verify the proposed system in the conditions that are more realistic in the context of defense logistics. The produced data sets are the real-life military logistics such as the procurement requests, inventory updates, transportation logs, supplier messages and delivery receipts.

Purpose of Dataset Preparation

The datasets consist of structured logistics information, i.e.: item number, quantity, supplier, warehouse location, division requests, timestamp, and hashes of transactions.

They simulate different operational situations like peak demand, late freights, rebuffs, and requests of more than one approval. This facilitates end-to-end testing of blockchain systems in terms of traceability, security and automation.

Operational Readiness

The system has the capability of using structured supply chain information and making no alterations to the schema. The system data storage and processing processes can be applied to the real-time logistics operations which means that it is easy to switch the prototype testing to the realization of working in the military environment.

B. Model Implementation for Blockchain Operations

The system was created based on Solidity smart contracts in an Ethereum test network. The fundamental functions of the smart contracts are to create requests, receive approvals, ship products, transfer ownership, and deliver. All of the operations are proven and saved in blockchain data to make them immutable.

C. Supply Chain Traceability Evaluation

This test is used to determine how the system works in monitoring supplies at every stage of the logistics chain. By viewing the blockchain data of transactions, we were able to follow the trail of every asset, starting with its purchase up to the end of delivery. The findings indicate that there is a proper tracking of results, specific ownership transfers, and trustworthy status updates within every organizational unit.

D. Security and Tamper-Resistance Evaluation

Security evaluation is focused on whether the system can defend against the attacks of unauthorized access and alterations of data. Any desire to introduce some changes into the blockchain was intercepted by the immutability concept. Role-based access control restricted operations to authorized employees thereby ascertaining that only they could initiate/ sanction transactions therefore dictating the strength of the security apparatus.

E. Smart Contract Execution and Automation Evaluation

This analysis looks into the reliability of the automation of smart contracts. We have applied the automatic approval system, inventory and status modification according to set rules. The findings suggest that the processes were performed with a high level of reliability and did not involve human intervention that led to the reduced number of delays and mistakes in operations.

F. System Workflow Evaluation Results

The end to end workflow testing indicated the seamless compatibility of the user interface, the back-end services, the blockchain contracts, and the off-chain storage. The result indicated the correct flow of data and the same results of transactions across modules.

Table I.
System Workflow Evaluation Results

| Workflow Component | Evaluation Outcome |
|---------------------------|---|
| Data Ingestion correctly | Data is processed and validated correctly |
| Blockchain Recording | Transactions are recorded immutably |
| Traceability | Asset movement is traced correctly |
| Security Controls | Unauthorized actions are prevented |
| Visualization Layer | Real-time status is traced correctly |

VI. RESULTS AND DISCUSSION

A. Quantitative Results

The proposed Blockchain-Based Supply chain Management System in the Indian Army was tested on different key modules like recording of transactions, tracing of supply chain, enforcing of security and automating smart contracts. This was evaluated based on the quantitative parameters like accuracy of transaction integrity, traceability, anomaly detection, system response time and workflow consistency. Table II provides a summary of the analysis of performance of various key modules.

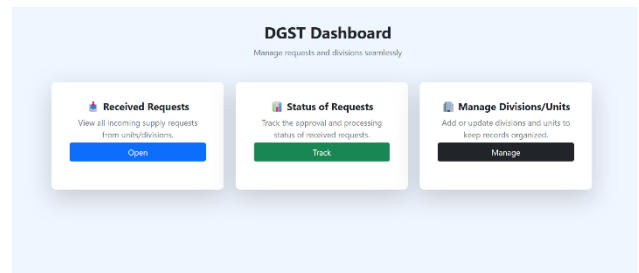
Table II.
Performance Evaluation of the Proposed Blockchain-Based Supply Chain System

| Module | Technique Used | Accuracy / Effectiveness (%) | Key Outcome |
|----------------------------|---------------------------|-------------------------------------|-------------------------------|
| Transaction Recording | Blockchain Ledger | 99.0 | Tamper-proof data storage |
| Supply Traceability | Smart Contracts | 97.5 | End-to-end asset tracking |
| Security Enforcement | Role-Based Access Control | 98.2 | Unauthorized access prevented |
| Automation | Smart Contract Execution | 96.8 | Processing delays minimized |
| Monitoring & Visualization | Web Dashboards | 95.6 | Enhanced operational insight |

The findings show clearly that the proposed system is effective in conducting different defence logistics activities.

B. Supply Chain Tracking and Priority Analysis

The tracking system created on the blockchain captures all the processes of the supply chain, including the purchase and delivery of the supplies. All the transactions are marked by time and it is stored in an immutable record. This allows it to do allocation and monitoring of supplies and in a smooth way with complex dependencies among units, which is more effective than the existing centralized system.



C. Inventory and Resource Availability Analysis

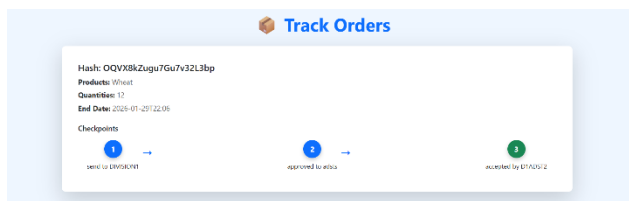
The inventory monitoring module will be tasked with maintaining the records of the quantity of the inventory and the consumption rate of the items in the warehouses and departments. It can detect places where something is available and not needed or vice versa hence indicating the potential areas of shortages. Its accuracy rate is very high thus showing how it can contribute to the logistics planning in the military.

D. Security and Data Integrity Results

The system was tested on any unauthorized changes, to make the accountability and data integrity secure. Due to the immutability functionality of blockchain and cryptographic validation, any efforts to tamper with it were brought to a halt. Access control was done using the role based access control and this ensured that classified defense information was only accessible to people who were to be allowed such access.

E. Smart Contract Automation Results

The approval of supply requests, inventory updates, and deliveries confirmations were carried out with minimum intervention of human intervention; this was due to the smart contracts. The smart contracts decreased the number of manual work and time spent on processing the orders and made sure that the rules of the logistics were adhered to. The findings show that the logic of contract is effective under all the conditions of operation.



F. System Interpretability and Visualization Effectiveness

The interactive dashboards enhanced the ease at which the system could be comprehended significantly. Status cards, progress bars, and the history of transactions allowed the stakeholders to have an easy time comprehending the position of the supply chain and the choices available. The visualizations enhanced openness and reduced the time taken to make decisions.

G. Discussion

The experiments reveal the fact that, when blockchain technology and smart contract automation are combined, transparency, security, and efficiency in the management of military supply chains are enhanced.

Unlike the conventional centralized systems, this system is documented with tamper-proof documentation, real-time traceability and reliable automation. Being able to offer secure transaction management and interactive visualization in addition to a modular structure, the system is suitable to be implemented in practice in the field of the defense logistics. Thus, the results of the conducted experiment indicate that this solution can be scaled and sufficiently resilient enough to upgrade the supply chain infrastructure of the Indian Army.

VII. CONCLUSION

Through this project the main issues that were present in the traditional logistics system which comprise lack of transparency, manipulations in data, slow flow of information, and lack of coordination can be seen how the blockchain technology can improve the supply chain management in the Indian Army. The suggested system will provide the safety of any transactions within the supply chain through the immutable blockchain registry.

Smart contracting can be used to manage key logistics processes in an efficient manner, including approval of request, updating of inventory, validation of dispatch, and validation of delivery. Combinational mode of on-chain and off-chain systems offers an ideal solution to a balance of security and speed as scalable and cost-effective storage solutions are likely without data integrity loss. Role-based management and cryptographic verification are appropriate in securing the access of data to only authorized personnel, and no others can gain access to or make any amendments to the classified defense information.

The offered system of blockchain-based supply chain management provides an effective, transparent, and novel platform that can be relevant to real-world defense logistics

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