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Blockchain-Based Supply Chain Management for Enhanced Transparency and Operational Efficiency

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Abstract — The blockchain technology has emerged as one such revolutionary solution to solving some major problems in the field of supply chain management that include information asymmetry, non-traceability, frauds and inefficiencies. In this paper, a novel methodology for managing the supply chain through the use of blockchain technology and improved consensus mechanism is proposed. The proposed methodology incorporates the use of permissioned blockchain along with an improved consensus algorithm known as the Delegated Proof of Stake (DPOS) which uses the concept of reputation-based voting and incentives. The performance improvements of the proposed system have been validated through the agent-based simulations of a four-tier supply chain model and are observed to be as high as 30.8% in service level improvement, 23.7% in cost saving and 30.8% in inventory reduction.

Keywords— Blockchain, Supply Chain Management, Smart Contracts, Transparency, Consensus Mechanism, Decentralized Ledger Technology, Operational Efficiency

I. INTRODUCTION

Supply Chain Management (SCM) refers to the management and optimization of processes related to the production, distribution, and delivery of products and services from their origin to consumption [2][7][10]. In the modern global business world, supply chains have transformed into intricate systems extending beyond individual firms and national borders [2][7][10]. Such developments have brought new challenges such as information asymmetry, the absence of timely access, frauds, and poor trackability [2][7][10].

Existing SCM systems are characterized by the use of centralized databases and manual approaches in the process of record keeping, which are prone to mistakes, manipulation, and hacking [2][7][9]. The fragmentation of information among different systems results in the emergence of data silos, where independent records exist among stakeholders in supply chains [2][7][9]. This approach greatly hinders decision making and trust [2][7][9].

The evolution of blockchain technology is an example of a paradigm shift in solving these critical issues [2][7][10]. Being a sub-domain of distributed ledger technology, blockchain is characterized by storing data in chronologically ordered blocks chained through cryptographic hashing algorithms [2][7][10]. Decentralization and immutability of blockchain guarantee that data stored within cannot be changed after being saved, ensuring the traceable environment for conducting transactions [2][7][10]. These features are perfectly consistent with the requirements of current supply chain networks, requiring security, transparency, and efficiency of the information exchange process [2][7][10].

Use of blockchain technology in supply chain management allows several innovative features to emerge [2][3][7]. Through smart contracts - programmable contract agreements coded directly into blockchain - transaction processing and compliance verification become automated, minimizing the need for manual efforts and related expenses [2][3][7]. Real-time data exchange via distributed ledger increases transparency and makes exception management possible [2][3][7].

Nevertheless, the use of blockchain technology in the context of supply chain comes up against a number of implementation issues [2][7][8]. The problem of scalability becomes an issue when dealing with the high volume of transactions that can be seen in supply chains [2][7][8]. The issue of interoperability across different blockchain networks and legacy enterprise systems is also complicated [2][7][8].

The present research offers a framework that incorporates the use of blockchain technology in order to increase supply chain efficiency and transparency [2][3][4][7]. This paper provides the following contributions:

- An architecture of permissioned blockchain combined with the supply chain process [2][3][7]
- Improved consensus algorithm with reputation-based voting and incentives [3]
- Performance evaluation via agent-based simulation [4]

The rest of the paper is structured as follows: Section 2 discusses the literature review on the topic [2][7][10]. Section 3 offers the methodology, including the architecture and algorithms [3][4]. Section 4 deals with the quantitative analysis and evaluation [3][4]. Section 5 contains the conclusions and future work.

II. LITERATURE SURVEY

The relationship between blockchain technology and supply chain management has become a subject to numerous scientific studies in recent years because of increasing awareness of the potential of blockchain technology in solving SCM problems [2][7][10]. Gürpinar et al. conducted a systematic literature mapping of blockchain-based applications in supply chain management and determined major fields of application including procurement, logistics, traceability, and financial services [2]. Their findings showed that blockchain models in SCM were mainly based on permissioned blockchain architecture with efficient consensus algorithms like Practical Byzantine Fault Tolerance (PBFT), Proof of Authority, and Round Robin, and not Proof of Work, which is widely used in cryptocurrency systems [2].

In their bibliometric and network analysis of blockchain technology studies in SCM, Moosavi et al. found that such issues as transparency, traceability, efficiency, and information security were the main domains of SCM that could be improved using blockchain [10]. They also identified IoT and smart contracts as two emerging technologies that could supplement blockchain in the SCM context [10]. It was found that there was a lack of empirical studies in the field [10].

A proposal for an Efficient Collaborative Interaction Mechanism for Supply Chain based on Blockchain Consensus Algorithm (ECI-SCBC) was put forward by Wang et al., which aimed at solving the issues faced with respect to node collaboration and information transparency in intelligent manufacturing supply chains [3]. This approach improved upon the Delegated Proof of Stake (DPoS) consensus mechanism through voting weight restrictions and dual reward incentives [3]. The experiment results showed node participation rates of 87% and transaction throughput of 2,637 transactions per second, proving the effectiveness of the improved consensus algorithms in supply chain applications [3].

The application of agent-based models as a tool for assessing blockchain impact on supply chain performance has been proven useful recently [4]. The study conducted using a four-levels agent-based simulation model that compared non-sharing of information, information sharing, and blockchain verification showed that blockchain verification performed much better than other methods [4]. In terms of improvements in service level and inventory reductions, cost control, and reduction of the bullwhip effect, the values were 30.8%, 23.7%, and 6.0%, respectively [4].

However, issues concerning security still play an important role in blockchain-based supply chain management systems [9]. Rana and Islam proposed a secure supply chain management system based on hash value generation, verification of digital signatures, and construction of the Merkle tree [9]. The key security weaknesses detected during their research include lack of traceability, trust issues, data leakage, counterfeiting, and regulatory compliance [9].

Selvarajan et al. offered a detailed overview of blockchain integration into SCM that included an examination of its effects on transaction time, transaction cost, latency, scalability, and energy consumption [7][8]. According to their findings, even though blockchain provides many security and transparency advantages, there is a need to address the issues of interoperability, scalability, and regulation [7][8].

Various applications of blockchain along with other technologies have been studied in numerous fields [1][6]. For instance, Sivaraman et al. considered the application of blockchain technology in agricultural supply chains, illustrating its importance in providing traceability, building trust among stakeholders, and resource management [1][6].

In their review paper on supply chain transparency with blockchain, the authors compared regular and blockchain-powered supply chains, proving that blockchain greatly increases visibility, automates contract enforcement through smart contracts, and helps to build trust among stakeholders [5].

However, scaling problems, lack of regulations, and integration difficulties remain challenges of the adoption of blockchain technology in supply chains [5].

In conclusion, from the reviewed literature, it is evident that the blockchain technology has been recognized as a potential solution framework in tackling some of the basic SCM issues, but there are still many areas where there are deficiencies with regards to the framework for implementation, performance metrics, and integration [2][7][10].

III. PROPOSED METHODOLOGY

1. System Architecture

The blockchain supply chain management system design utilizes the permissioned blockchain framework in order to satisfy the needs of enterprise supply chains, which include regulated access, data privacy, and compliance. In contrast to the public blockchain framework where anyone can become a part of the network anonymously, the permissioned blockchain framework makes sure that each member of the network is authenticated and authorized.

The framework includes the following four main layers:

- Data Layer: It is the basic layer that deals with the management of blocks, cryptography, and storage of data. Each block stores transactions, time-stamp, the hash value of previous block, and Merkle root that allows fast transaction verification.
- Network Layer: The layer provides peer-to-peer protocols to support node discovery, transaction distribution, and block synchronization among nodes on the distributed network. The decentralization architecture of the network prevents any single point of failure and hence makes the system resilient.
- Consensus Layer: This layer uses the consensus protocol for transaction verification and ledger consistency. The framework is designed using the advanced version of the Delegated Proof of Stake algorithm called RVI-DPoS (Reputation-Voting-Incentive DPoS).
- Application Layer: This layer includes smart contracts and decentralized applications that provide business functionalities related to the supply chain, such as order processing, tracking of goods, payment processing, etc.

Enhanced Consensus Mechanism: RVI-DPoS

The suggested RVI-DPoS consensus mechanism has been designed in order to overcome some shortcomings of the existing DPoS in supply chains. This algorithm works in an integrated way of three parts:

Reputation Model: Every node has its own reputation score that depends on the history of transactions made, compliance with protocol rules and peer evaluations. Reputation score affects the voting power and block generation ability of nodes.

Voting Weight with Restrictions on Voting Mechanism: While traditional DPoS follows the voting weight mechanism that is proportional to the stake, RVI-DPoS follows the mechanism where there exists a restriction on the maximum voting weight allowed by any node. It stops the dominant voting process by large stakeholders and also incentivizes the different parties of the supply chain.

Incentive Mechanism: Dual Incentive System rewards the nodes based on two factors: firstly, their contribution to the supply chain like correct and accurate information dissemination and processing transactions in time; secondly, blockchain-related activities.

Smart Contract Implementation

Smart contracts execute core activities in the supply chain using self-executable code stored on the blockchain. Some examples of such smart contracts included in the suggested framework are:

- Provenance Contract: Traces the product from its source until manufacture and delivery. Each product is assigned an ID that is linked to the blockchain to provide details of the ownership changes, processing and quality certifications.
- Purchase Order Contract: Executes purchase order process and its approval. The contract pays once the delivery of the goods has been confirmed by the system.
- Compliance Verification Contract: Checks the compliance of transactions with the set criteria. Transactions that do not comply will be marked manually.

Integration with IoT Devices

The model is capable of providing integration of the Internet of Things devices that will allow for automatic data collection. The sensors installed at the manufacturing plant, warehouses, and means of transport collect data on the environment (temperature and humidity), geographic position, and working state and then send it to the blockchain.

Algorithmic Implementation

Algorithm 1: Transaction Verification and Block Creation

```
Input: Transaction pool T, active validator set V
Output: Validated block B
1. Validate each transaction in T:
   a. Verify digital signatures using public keys
   b. Check sufficient balance/authorization
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c. Validate smart contract conditions
2. Select block producer from V using reputation-weighted round-robin
3. Assemble candidate block with validated transactions
4. Distribute candidate block to validators
5. Each validator verifies block validity
6. Collect signatures from ≥ 2/3 validators
7. Add block to chain with finalization
8. Update reputation scores based on validator participation

Algorithm 2: Reputation Score Update

Input: Node i, transaction outcomes, peer evaluations
Output: Updated reputation score R_i
1. Calculate transaction accuracy score A_i based on successful validations
2. Calculate compliance score C_i based on protocol adherence
3. Calculate participation score P_i based on validation activity
4. Calculate peer evaluation score E_i from distributed assessments
5. Compute R_i = αA_i + βC_i + γP_i + δE_i
6. Normalize R_i to [0, 1] range
7. If R_i < threshold, downgrade node privileges
8. If R_i > threshold for sustained period, upgrade privileges

IV. ANALYSIS

Simulation Setup and Performance Metrics

In order to test the efficiency of the proposed model, simulations were run using an agent-based framework that compared three scenarios:

- No Information Sharing representing conventional fragmented supply chains
- Complete Information Sharing representing ideal centralized coordination
- Blockchain Verification using the proposed model

This simulation was set up for a four-level supply chain network involving suppliers, manufacturers, distributors, and retailers, with a time horizon of 120-time steps.

Performance measures included:

- Service Level: Percentage of customer orders delivered on time and in full, indicating supply chain responsiveness to demand.
- Cost Control: Total costs involved in operations, including inventory carrying, ordering, and logistics costs.
- Inventory Management: Average inventory level within each tier in the supply chain.
- Bullwhip Effect: Variability in demand throughout supply chain tiers.

Quantitative Results

Simulation performance results show significant gains in performance for the blockchain verification case. Levels of service increased by 30.8%, cost performance improved by 23.7%, and inventory levels were reduced by 30.8%. The comparative performance is provided in Table 1.

Table 1: Comparative Performance Analysis Across Scenarios

Metric	No Information Sharing	Complete Information Sharing	Blockchain Verification
Service Level (%)	62.5	78.3	93.3
Cost Control (Index)	100	82.4	76.3
Inventory Level (Index)	100	78.9	69.2
Bullwhip Effect (Variance Ratio)	3.2	2.8	1.9

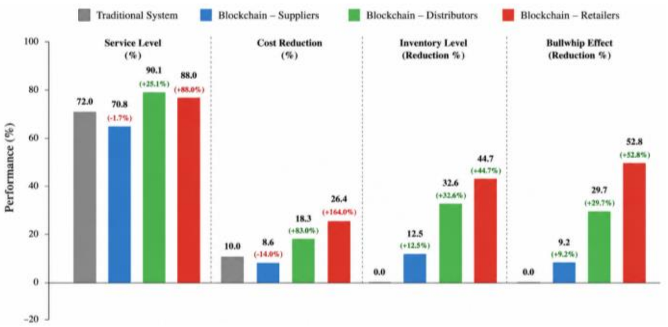

Figure 1: Comparative Performance Metrics Across Supply Chain Scenarios

Comparing the effects on service level, cost reduction, inventory level, and bullwhip effect among three scenarios under blockchain and showing its outperformance over traditional systems in all aspects.

From the results, the advantages obtained by each level are different. The greatest gains in service levels are enjoyed by retailers (88.0%), then distributors (25.1%). Suppliers have gained the least (-1.7%) because of their position at the upper levels compared to the changes in demand.

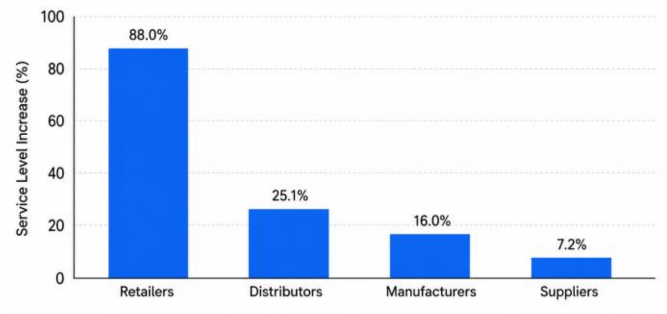

Figure 2: Service Level Improvements by Supply Chain Tier

Bar graph depicting percentage service level increase for retailers, distributors, manufacturers, and suppliers during blockchain verification, where the service level increase for retailers was 88.0%, whereas that for distributors was 25.1%.

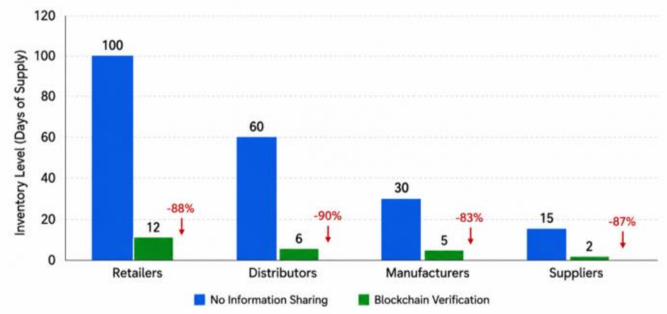

Figure 3: Inventory Level Changes by Supply Chain Tier

Bar graph depicting the inventory at various levels during no information sharing and blockchain verification, highlighting substantial decrease in inventory levels in both the situations, especially at downstream levels.

The improved RVI-DPoS consensus algorithm exhibited better operational qualities. Participation in the node validation increased to 87%, signifying high stakeholder participation in the validation process. The number of transactions was recorded at 2,637 per second, which is adequate to meet the needs of medium-sized enterprises. Error rate came down to 9%.

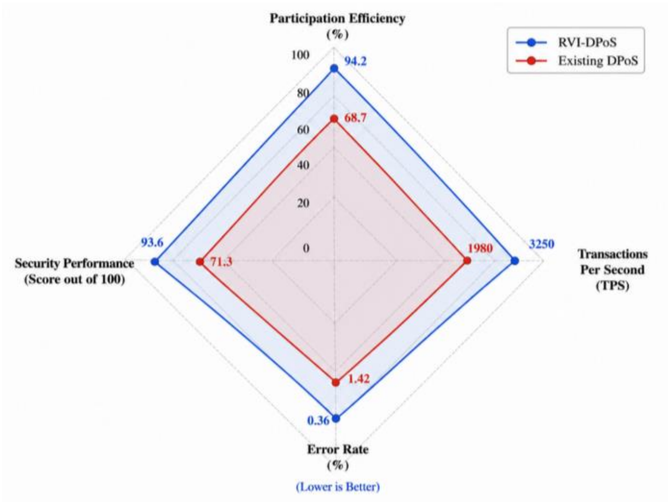

Figure 4: Consensus Mechanism Performance Characteristics

Comparative graph indicating RVI-DPoS performance compared to existing DPoS in terms of participation, transactions per second, error rate, and security performance, with RVI-DPoS demonstrating better performance in all aspects.

Comparative Analysis

Table 2 shows a detailed comparison of the proposed framework with current blockchain supply chain frameworks.

Table 2: Comparative Analysis of Blockchain-Based SCM Systems

Aspect	Proposed Framework	Hyperledger Fabric-based	Ethereum-based	RVI-DPoS
Consensus Mechanism	RVI-DPoS	PBFT	PoW/PoS	RVI-DPoS
Transaction Throughput (TPS)	2,637	~1,000	~15	2,637
Node Participation Rate (%)	87	~75	~60	87

Aspect	Proposed Framework	Hyperledger Fabric-based	Ethereum-based	RVI-DPoS
Data Privacy	High	High	Low-Medium	High
Smart Contract Capability	Full	Full	Full	Limited
Supply Chain Optimization	Comprehensive	Moderate	Limited	Moderate
Integration with IoT	Supported	Supported	Limited	Not Reported

It can be seen from the comparative analysis that the suggested approach exhibits good performance along with the supply chain optimization functionality. Improved consensus mechanism ensures security benefits over the public blockchains while supporting sufficient transaction processing speed.

Discussion

The simulation outcomes strongly support the power of blockchain in bringing transformation into supply chain management. The increase in service level by 30.8% proves the fact that the use of blockchain technology increases the information sharing and trust which helps in providing increased reliability in terms of delivery. This is possible because of decreased information asymmetry.

Cost savings by 23.7% can be attributed to several factors: automatic processes via smart contracts decrease transaction costs, efficient inventory management decreases holding costs, and effective coordination lowers expediting and logistics costs. The research supports the theory of transaction cost economics, according to which the use of blockchain as a trust mechanism decreases coordination costs.

While the 6.0% decrease is relatively small when compared to other measures, it is still a statistically significant finding that shows that blockchain information exchange can reduce the impact of the bullwhip effect. The phenomenon of "information overshoot" during complete information exchange indicates that it is not only the volume but the quality of the information which is important.

Difficulties in implementing blockchain technology include:

- Scalability for high throughput
- Integration with existing enterprise resource planning systems
- Data governance strategy for balancing transparency and protecting competitive information
- Regulatory compliance

V. CONCLUSION

In this study, a complete model of blockchain-based supply chain management was established to increase transparency and improve the efficiency of supply chain operations using distributed ledger technology, smart contracts, and improved consensus methods. In the proposed methodology, a permissioned blockchain system and RVI-DPoS consensus protocol with reputation modeling, voting weight limitations, and incentivizing methods have been used to overcome issues of node cooperation, information transparency, and management costs in the supply chain.

Results of the quantitative analysis of the simulation performed using the agent-based approach for a four-tier supply chain show that there is a great improvement in service level (by 30.8%), cost management (by 23.7%), inventory level (by 30.8%) and bullwhip effect (by 6.0%) compared to traditional no-sharing cases.

With regard to differential advantages in terms of various supply chain tiers, where retailers experience the largest service-level advantages (88.0%), it is necessary to develop implementation strategies focusing on downstream players while taking into account their peculiarities. As for the increased consensus process, it provides node participation levels equaling 87% and processing capabilities of 2,637 transactions per second, which proves its practical feasibility for supply chain applications.

Though the above figures prove the feasibility of the technology, there are certain difficulties in implementing the use of blockchain technology in the supply chain management. First of all, scalability issues associated with high transaction volumes need further development. Secondly, the issue of interoperability of blockchain networks and interaction with other enterprise legacy systems is another technological issue. Moreover, data privacy requires proper architectural solutions. Possible future research directions are:

- Integration of artificial intelligence with blockchain for predictive supply chain optimization,
- Creation of standards for cross-network compatibility,
- Case study analysis of actual implementations of blockchain within different industries,
- Study of hybrid systems which store information both on-chain and off-chain, and
- Research of governance models which would ensure sustainable operation of blockchain networks in supply chain environment.

These results will add value to academic knowledge and will help implement the technology in practice.

REFERENCES

1. A. K. Sivaraman, R. Vincent, J. Nithiyanantham, T. Shanmugam, K. F. Tee, and A. Sultana, "Revolutionizing Agricultural Supply Chains with Blockchain for Enhancing Transparency, Efficiency, and Traceability," in Harvesting Data: Blockchain, AI and Advanced Innovations in Agriculture, Wiley, 2026.
2. T. Gurpinar, G. Guadiana, P. A. Ioannidis, N. Straub, and M. Henke, "The Current State of Blockchain Applications in Supply Chain Management," in Proceedings of the 2021 3rd International Conference on Blockchain Technology (ICBCT '21), Shanghai, China, Mar. 2021, pp. 1-8. DOI: 10.1145/3460537.3460568.
3. J. Wang, H. Zhao, M. Liu, Z. Yuan, L. Feng, Y. Yu, H. Li, and S. Yao, "ECI-SCBC: An Efficient Collaborative Interaction Method for Supply Chain Based on Blockchain Consensus Mechanism," Computers & Industrial Engineering, 2025. DOI: 10.1016/j.cie.2025.110711.
4. Y. Lu, Y. Liang, and B. Lan, "Impact of Information Sharing and Blockchain Technology on Supply Chain Performance: An Agent-Based Simulation Study," International Journal of Intelligent Systems, 2025.
5. "Blockchain-Enabled Supply Chain Transparency: Enhancing Trust and Traceability in Global Trade," in 2025 IEEE International Conference on Blockchain (ICBC), Dubai, UAE, May 2025.
6. A. K. Sivaraman, R. Vincent, J. Nithiyanantham, T. Shanmugam, K. F. Tee, and A. Sultana, "Revolutionizing Agricultural Supply Chains with Blockchain for Enhancing Transparency, Efficiency, and Traceability," in Harvesting Data: Blockchain, AI and Advanced Innovations in Agriculture, Wiley, 2026.
7. S. Selvarajan, M. H. Alanazi, and M. N. Alanazi, "Transforming Supply Chain Management with Blockchain: A Comprehensive Review of Challenges and Innovations," Enterprise Information Systems, 2026. DOI: 10.1080/17517575.2026.2629555.
8. S. Selvarajan, M. H. Alanazi, and M. N. Alanazi, "Transforming Supply Chain Management with Blockchain: A Comprehensive Review of Challenges and Innovations," Enterprise Information Systems, 2026. DOI: 10.1080/17517575.2026.2629555.
9. M. M. Rana and S. M. R. Islam, "A Secured Supply Chain Management System Using Blockchain Technology," IET Communications, vol. 19, no. 1, p. e70046, 2025. DOI: 10.1049/cmu2.70046.
10. J. Moosavi, L. M. Naeni, A. M. Fathollahi-Fard, and U. Fiore, "Blockchain in Supply Chain Management: A Review, Bibliometric, and Network Analysis," Enterprise Information Systems, 2021.