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The Coupling of Blockchain and Supply Chain

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Abstract

In today's industrial landscape, supply chain management (SCM) is pivotal in ensuring the smooth supply of products from the manufacturing house to the seller shop. However, digitizing SCM processes has brought new challenges, particularly in data security and trustability. Blockchain, a decentralized peer-to-peer network, offers enhanced security and privacy through its distributed ledger technology. By incorporating blockchain into SCM, businesses can ensure the integrity of their data, mitigate risks such as tampering and unauthorized access, and facilitate transparent and trustworthy transactions. This paper presents a case study of implementing blockchain technology in the industry's SCM. Through this case study, we demonstrate how blockchain can revolutionize traditional SCM practices, enhance quality control, and enable more accurate decision-making. Blockchain's immutability ensures that all transactions and data entries are securely recorded, giving stakeholders a transparent view of the entire supply chain process. The potential of blockchain technology is to address the challenges of SCM and explore ways to improve the quality and reliability of SCM data. By leveraging blockchain technology, businesses can improve the efficiency of their SCM operations and build trust among partners and consumers. Therefore, in this literature, a blockchain application in SCM for a case study of garment SCM, provides practical insights for businesses adopting this transformative technology.

Keywords: Internet security, blockchain, supply chain management (SCM), SCM data, transparent transactions

INTRODUCTION

The process and dimensions of supply chain management (SCM) have been changed with the exposure of globalization of the present trade of business. The diversification of policies and cultural differences across the globe puts the business trade under risk and also increases the security threats. SCM has been also suffering with the same issue of risk and threat management [1]. The existing issues of the conventional SCM (shown in Figure 1) are as follows.

- *Transaction issues:* There is a chance of hacking the transaction under the cybercrime. In case of terrorist activities of SCM there is an issue to trace the origin of the routed information [1].
- *Performance issues:* In conventional SCM, the performance is comparatively slow to address because of too many official and documentation processes, therefore the business and economic growth of the organization also comes under question.
- *Global policy difference:* Different policy of different countries and states also affect centralized SCM.
- *Fraud and hacking issues:* In case of partially automated SCM, hacking is one of the most expected external threats to the system.

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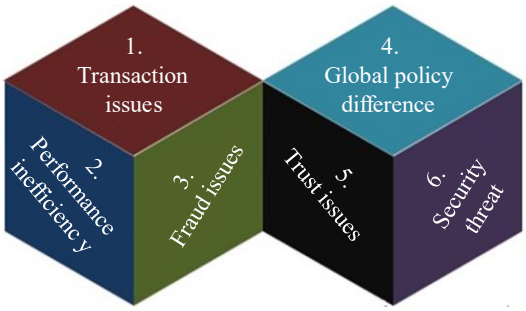

Figure 1. Important issues of supply chain management (SCM).

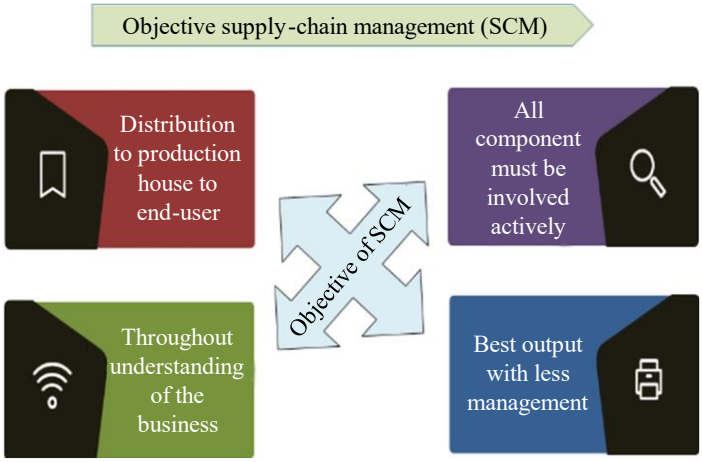

Figure 2. Objectives of supply chain management (SCM).

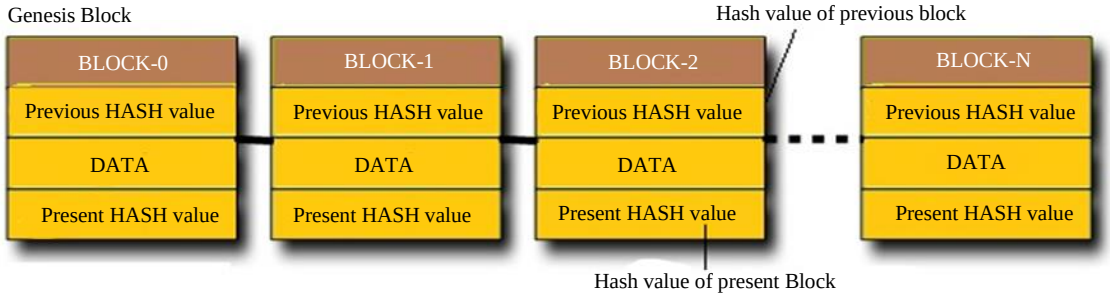

Figure 3. Structure of Blockchain.

- *Trust issues:* If the data is not secure, the tractability of the system obviously gets reduced.
- *Security threats:* Conventional SCM also suffers from spamware, DDoS (distributed denial of services), cyberattack, etc.

The existing centralized system of the SCM also contradicts to achieve the benefit of present globalized market across the world [1]. The objective of general SCM is shown in Figure 2.

Blockchain is a distributed, peer-to-peer, tamperproof, cryptography-based network that maintains a hash key for every transaction to secure data (Figure 3). Blockchain platforms like Bitcoin, Hyperledger Fabric, Ethereum, etc. are open source in nature. The application can be customized according to requirements. These must be an impact on the cost. The block structure of blockchain is shown in Figure 4. Each block contains the hash value of the previous block (except the first block called genesis block) and own transactional hash value.

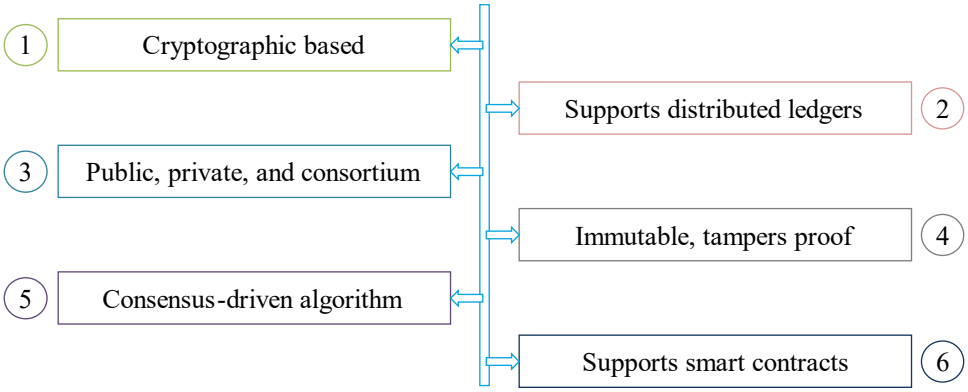

Figure 4. Advantages of blockchain coupling with supply chain management (SCM).

The introduction of blockchain in the digital market has brought an explosion not only in terms of buyer–seller business strategies but also the tracking of transportation, delivery and other series of activities even in globalized business domains. The technology was appreciated and became useful more broadly at the time of lockdown period of COVID-19 pandemic [2, 3]. The primary reasons for implementing blockchain technology in the SCM system (Figure 4) are the following:

1. The operation of blockchain framework is on the cryptographic-based application.
2. Blockchain framework also supports all transaction ledgers in the network in a distributed environment.
3. Blockchain can be implemented as a public, private, and consortium blockchain mode of operation.
4. The blockchain technology is immutable and tamperproof, which increases the robustness and trustworthiness of data.
5. Blockchain works on a consensus-driven algorithm like proof of work (PoW), proof of state (PoS), etc.
6. Blockchain framework also supports smart contracts, which is one of the document-less transactions and agreements between two parties without involving third parties.

In this article, a blockchain-based application is proposed to explore the business domain of SCM with the technological benefit in reduced time and documentary hazards.

LITERATURE REVIEW

A paper proposed by Saberi et al. [1] reports that the barrier of the limitation of centralized SCM may be overcome by the use of blockchain technology. The authors proposed a prospective research work for the future by recommending blockchain-based SCM [1]. The article by Blossey et al. [4] proposed a blockchain-based SCM by utilizing the cryptography to track and trace the product by analyzing the framework of 53 applications. The prospect of research in the operational supply chain management (OSCM) by integrating with the blockchain technology and artificial intelligence is proposed in the article [5].

An article by Wu et al. [6] proposes a blockchain-integrated SCM with a case study of food safety tracing system (FSTS) [6]. An article by Cordova et al. [7] deals with the challenges of SCM like retrieval and reuse of data for tracking of the product, and sharing of information. This article also focuses on the process that those challenges can be mitigated by integrating with the blockchain technology [7]. An article by Keresztes et al. [8] proposed the different avenue of research integrating with the blockchain and also concludes that the blockchain works efficiently in supply chain with the integration of internet of Things (IoT). Similarly, Keresztes et al. proposed the blockchain integrated SCM of 50 different companies by interviewing for collection of the data, analysis of the data in the framework of blockchain, and the advantages and the constraints of blockchain implementation in

SCM. The main purpose of the paper was the time and cost saving in case of tracking, identifying the supply of SCM [9]. Sahoo et al. [9] proposed a blockchain based sustainable SCM of different industrial sectors, including manufacturing, healthcare, and agro-food industries [10].

Kurdi et al. [11] proposed a model using statistical tool analysis of variance (ANOVA) to establish interdependency among blockchain, smart inventory system, and the supply chain performance [11]. Yontar [12] proposed an impact of blockchain technology on agri-food based SCM [12]. The PASTEL approach, analytic network process (ANP) and multi attributives ideal-real comparative analysis (MAIRCA) are taken into consideration [12]. A paper by Arkeman et al. [13] proposed a blockchain, IoT integrated SCM. The integration of artificial intelligence (AI) improves the quality of SCM [13]. An SCM with blockchain for supplementing the vaccine of COVID-19 is shown in the paper by Hasan et al. [3].

Therefore, the existing literature enlightens that the implementation of blockchain along with a existing conventional SCM is an opportunity to enhance the security of transactional data of SCM.

Finding From the Literature Review

The theoretical articles are mainly taken into the consideration in the proposal in the article [1, 4]. The application of blockchain in different domains as introduced by different countries is shown in Figure 5. The analysis of the country-wise research articles published on SCM is shown in Figure 5 It shows that most of the countries have started their research work significantly in the blockchain domain as well through different applications [5]. The paper by Cordova et al. [7] expressed the challenges of SCM and the opportunity that can be expected by integration of blockchain. The feasibility area of the blockchain in SCM can be estimated in the paper by Keresztes et al. [9]. The performance of SCM also taken into consideration and is an important parameter to integrate it with the blockchain [11].

Gap Analysis

There is an opportunity to practically implement the recommendation in the article [1, 7]. What is the change in sustainability of SCM with and without embedding with the blockchain is also a scope of explanation [9]. The source of authenticated data is not available for future research [11].

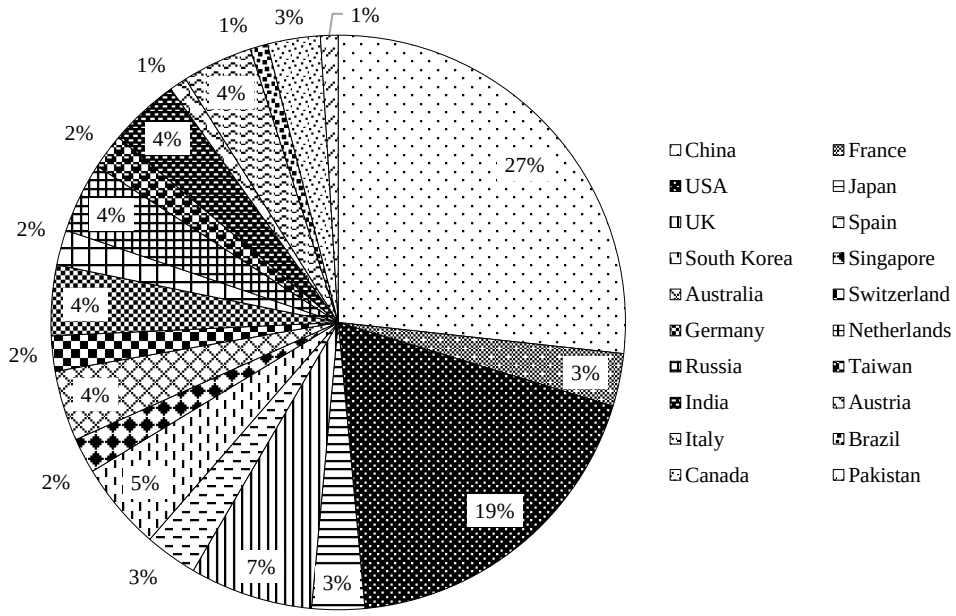

Figure 5. Countries-based blockchain research articles.

Problem Definition

The upgradation of SCM has been reflected by the development of information technology (IT) enabled applications and its operational level of SCM. However, the transactional and the stored data are always suffering the threat of external tampering, hacking, and false information.

In India, garments are used by individuals all the areas of the country. In this paper, a case study of the SCM of garments is discussed. The involvement of brokers and the third party are involved from every stage from procurement of garments, manufacturing house, distribution to the distributor, retailer, and finally, until the garments are purchased by the end-user. The cost is increased by the broker at each stage of this SCM system. Therefore, the existing system has an impact on data, and due to that

- The data of the system is not secure, and are poor quality of data, the management suffers from poor decision-making.
- The organization has always to be in alert mode to keep privacy of data from its closest rival organization.
- The trustworthiness of the end-user is lost and they purchase the garment at a high price.
- The government loses a huge amount of revenue.

In this paper, it is discussed that how blockchain can be incorporated and also provide a possible solution to the existing issues of SCM.

THE PROPOSED METHODOLOGY

The cryptographic-based blockchain technology is embedded with the IT enabled SCM to make the integrated system robust. In the proposed system data is recorded at every stage from procurement of manufacturing house, production, inventory controller, distributor, supplier, and retailer. The threat of stilling, false information, black marketing is taken part of this system to some extent.

Description of the Proposed Work

The deployment of a garment house case study of SCM, the process is initiated from the procurement of the raw materials of the garments (as shown in Table 1). The hyperledger is the famous framework of blockchain and is useful to establish a smart contract.

Algorithm of Blockchain-Coupled Supply Chain Management

The algorithm of deployment of blockchain-coupled SCM is shown in Figure 6 and the entire system is represented by Figure 7.

Description of Data Validation in Blockchain-Coupled Supply Chain Management

Each node of the entire network of Blockchain has a public key (pub.key) and a private key (pvt.key). The nodes in the Blockchain are categorized as:

1. The block generation nodes that generate the data for transactions.
2. The miner nodes that write the transactional data following some consensus algorithm.
3. The validator nodes that validate the nodes that generate the transactions and the miner nodes.

Table 1. Code of deployment.

Code	Descriptions
$GP=\{gp_1, gp_2, gp_3, \ldots.\}$	Different procurement houses and $gp_i \in GP$
$GM=\{gm_1, gm_2, gm_3\ldots.\}$	Different manufacturing factory of Garments and $gm_i \in GM$.
$GD=\{gd_1, gd_2, gd_3,\ldots\ldots\}$	Number of distributors and $gd_i \in GD$.
$GR=\{gr_1, gr_2, gr_3, \ldots.\}$	Number of retailers and $gr_i \in GR$.
$GC=\{gc_1, gc_2, gc_3, \ldots.\}$	Number of consumers and $gc_i \in GC$.
i, j, k	1, 2, 3, ……

1.
The procurement of raw material (of garments) by the procurement house gp_i where (i = 1, 2, 3).

2.
The manufacturing (gm_i...) house then use the smart contract along with the procurement unit (gp_i...) to keep the trustful transaction in between and (i = 1, 2, 3..).

3.
The distribution of garments are also done from distributer gd_i to retailer grj. The smart contract may be established between gd_i and gr_j where (i, j = 1, 2, 3..).

4.
If the manufacturing house allows, the retailer gr_t may purchase the garments direct from the manufacturing house gm_j. In that case, the retailer may purchase the garments from the manufacturing house by communicating through the smart contract where (i, j = 1, 2, 3..).

5.
The garments may be purchased by the consumer gc_i (end-user) either from the retailer gr_j or direct from the manufacturing house by executing the smart contract.

Figure 6. Blockchain coupled supply chain management (SCM) system.

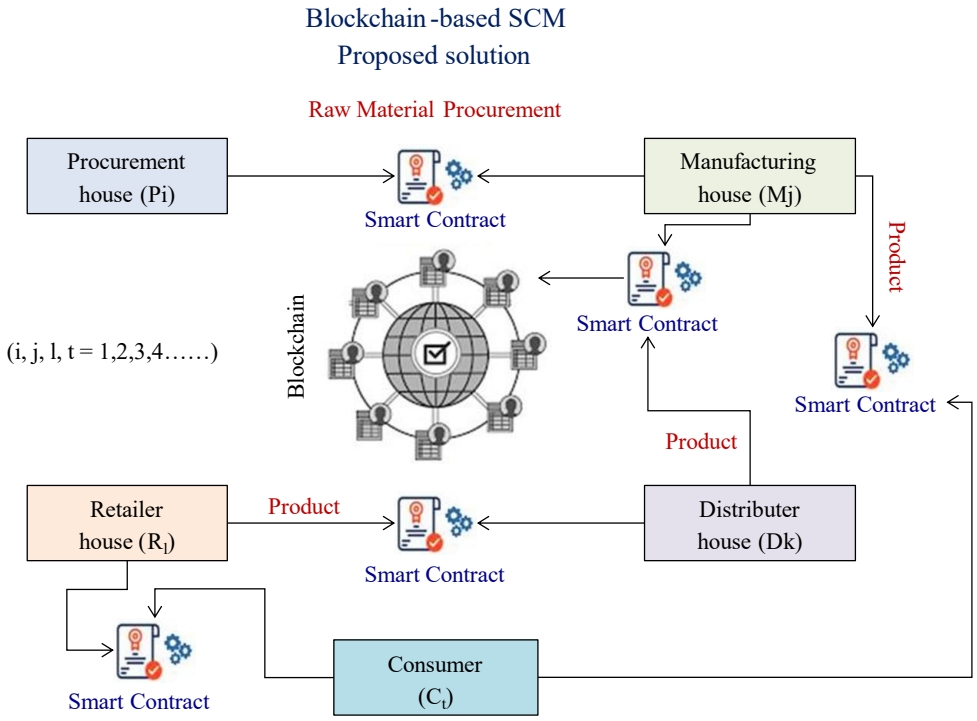

Figure 7. Blockchain-enabled supply chain management (SCM) system.

In this validation process, it is considered that the entire validation work is under the control and vigilance of administrative validator (AV). Odd number of validators are selected (the count is 3 in this case studies) for validation to authenticate the communicating nodes engaged in smart contract. The AV selects the four validator nodes from the blockchain network randomly and sends a message M_1 to all the nodes nodes (M1, M2, M3, and M4 denote some messages in the suggested algorithm).

1. M_1= hash_value (validator.pub.key + random_number)
   The validator sends the message M_2 to the communicating nodes and also requested to send the details to the validator.
2. M_2= hash_value (M_1, communicating node.pub.key)
   The communicating node returns the message M_3 to the validators.
3. M_3= hash_value (M_2, communicating_node.pvt.key, mail_ID to send acknowledgement)
   The validators returned a message M_4 and a binary value in the form true or false along with a probability of validation to the AV.
4. M_4=hash_value(validator.pvt.ky + randomnumber, M_3)
   It is expected in a true case of internal attack at least two validators would respond honestly. If the probability is $\frac{2}{3}$ then only the AV permits the communicating nodes to communicate and establish a smart contract.

Algorithm 1: Validation of communicating nodes

Input: Validator v1, v2, v2, pub.keys, pvt.keys, N

Output:Prob, validation value, message M_4

1 i=1, p=0
2 While(i≤N)
3 M_1= hash_value (validator.pub.key + random_number)
4 $AV.M_1 \leftarrow V_1$
5 M_2= hash_value (M_1, communicating node.pub.key)
6 $V_{i.}M_2 \leftarrow N_c$
7 M_3= hash_value (M_2, communicating_node.pvt.key, mail_ID to send acknowledgement)
8 $N_{c.}M_3 \leftarrow V_i$
9 M_4=hash_value(validator.pvt.ky + randomnumber, M_3)
10 $V_{i.}M_4 \leftarrow AV$
$AV \leftarrow p \pm \frac{1}{3}$
11 End while
12 End

EXPERIMENTAL SETUP

The manual setup is done using Intel (R) Core (TM)i5-5200U CPU @ 2.20 GHz, 2201 MHz, 2 Core(s), 4 logical processor(s), 16 GB RAM. Windows-7 64-bit operating system is used. The test URL used in this case is https://andersbrownworth.com/blockchain/block/.

Simulated Result

The simulated result of smart contract in between the two parties is shown in Figures 8 and 9. The smart contract may be executed between any two parties among procurement unit, manufacturing unit, distributor, retailer, and consumer.

DISCUSSION

The test result shows that the block of the blockchain uses the SHA256 encrypting hash code of 256 bit for each and every transaction. The change of data in any end change the hash code. This makes the

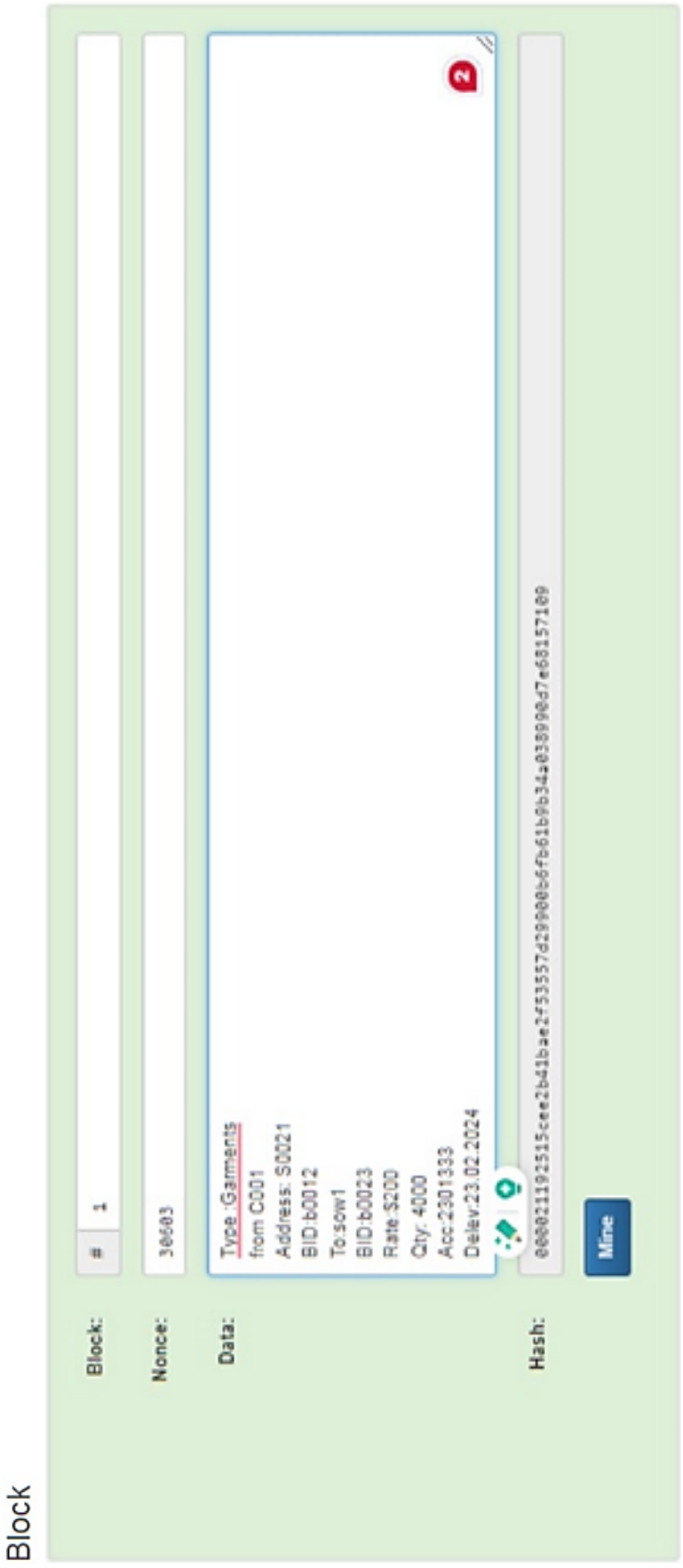

Figure 8. Blockchain Enabled SCM system Block.

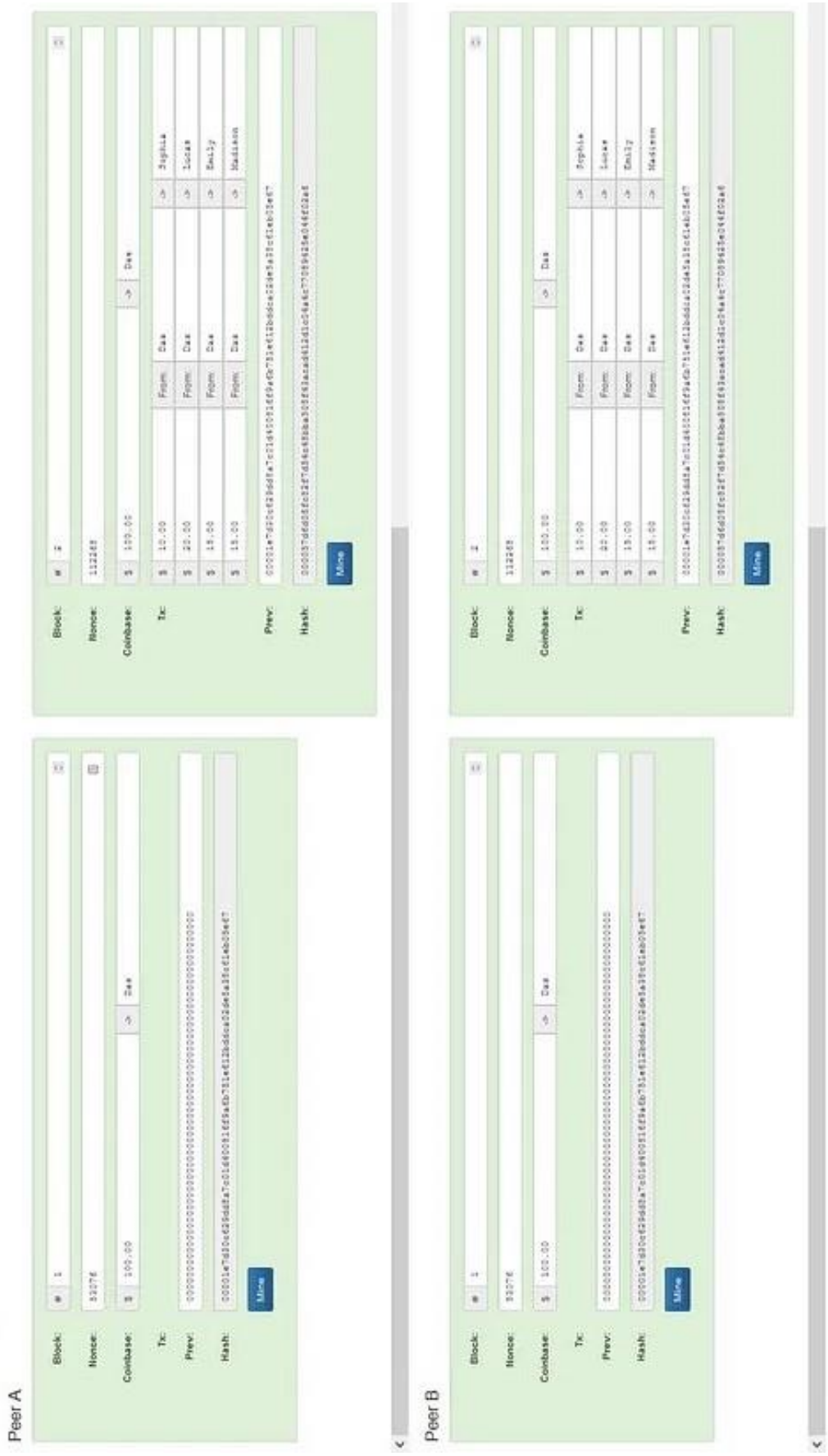

Figure 9. Blockchain enabled SCM system chain.

Table 2. A comparative analysis of conventional supply chain management (SCM) and blockchain-coupled SCM.

S.N.	Content	Conventional SCM	Blockchain-Coupled SCM
1	Setup	Setup is comparatively less complex	The configuration setup is relatively complex and the administrator has to design and implement the entire scripts.
2	Data security	The change of resources is much easier. The security is much less	The change of framework. The security of data must be enhanced.
3	Trustworthiness	The insecure data has the less trust value.	The trustability of secure data must be enhanced
4	Cost	The operational cost must be high and the security cost must be less.	The operational cost must be less due to document less system and the security cost must be high.
5	Adaptibility	The adaptation is without technology	The adaptation enhances due to technological security and business exposure.
6	Performance	Slow due to document handling process.	Comparatively fast due to no document handling process.
7	Internet bandwidth requirement	Internet connection is not mandatory.	A strong internet connection is required to operate through an online browser and also for connection through the third-party software.

data tamperproof and enhance the security of the data. The enhanced security also maintains the data privacy and explores the business opportunity due to safe transaction of data. A comparative study of existing IT-enabled SCM and blockchain-coupled SCM is given in Table 2.

CONCLUSION AND FUTURE WORK

In this paper, the different security aspects of SCM have been highlighted. The implementation of blockchain and smart contracts in practices is proposed in this paper to secure the data and function of SCM. Furthermore, an algorithm is also proposed to validate the generated block before executing the smart contract. It is encouraging to develop an application incorporating blockchain, integrating with SCM using big data services. The work can be explored in the future to evaluate the mixed framework for big data. The blockchain also suffered from different security threats. Then there is also a scope of research to mitigate the system. There is also a scope of work to mitigate security issues and other vulnerabilities problems with game theory.

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