Blockchain Blended Supply Chain for Improved Operational Management

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Abstract:
The supply chain is the most used in the business and the industrial logistic domain. The activities in the domain include procurement and production to distribution the goods to the consumer. It is the normal practice of the Industrial house to distribute their product through Supply Chain Management (SCM).

The entire information of the SCM is tried to be stored and maintained as data for the generation of the customized report and future decision making. The database-enabled SCM provides better control of the system by the management. However, this digitization introduced some new kinds of threats on the data like document tampering, data tampering, stealing, improper decision making, manipulation of the decision to some extent, etc. The quality and trust ability of the data are get deteriorated. Therefore, the quality of data and proper decision-making are under question. Blockchain is one of the evolving technology for the last five years. The technology is a pear-to pear network and shares the information through distributed ledger within the network. The privacy and security of data and transactions can be maintained to large extent through the use of a private blockchain network. The objective of this paper, to incorporate blockchain technology in supply chain management and try to validate it with a case study of blockchain implementation of SCM of Rice. The immutative technology shall keep the quality of data for maintaining the transparency and help the business houses for decision making with more accuracy and enhance the quality control.

Keywords: *Blockchain, Data Security, Supply-Chain, Smart Contract*

1. Introduction:

The logistic requirement and the corresponding logistic support were introduced in the early primitive age of human civilization. The civil globalized world then nomenclature the process with an ornamental term as "Supply Chain Management (SCM)". The management has to be deeply involved in SCM to satisfy the customer expectation within the market of global competitions of the same trade. Therefore, all of the business houses try to provide an uninterrupted effort to develop their system to maintain the SCM most effectively and efficiently *(Casado-Vara et al. 2018)*[1]**.** The management gives the administrative vigilance of the following primary concepts of SCM

[1] https://www.sciencedirect.com/science/article/pii/S187705091831158X

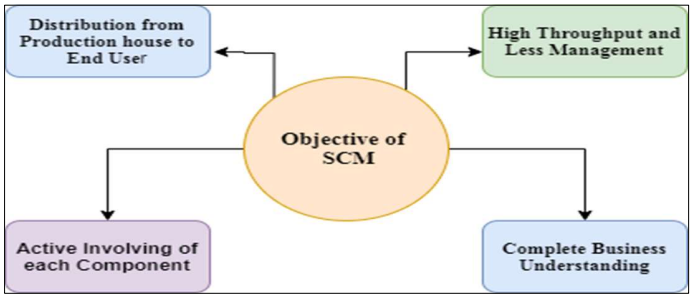

Figure 1: Objective of Supply chain management

i) The supply of the product from the manufacturer's house to the end-user.
ii) There may be involved different sub-organizations, distributors, retailers.
iii) Every component, from the production house to the retailer must be active to complete the chain.
iv) The high throughput with a less managed system.
v) A complete business understanding at each level for future decision-making.

In the second stage, the industrial approach was to develop the respective application software along with the integration of a strong database to overcome the primary limitation of SCM. The relation database incorporation has given temporary relief to the industrial administrator by monitoring the entire system virtually, and instant report generation on existing data which helps for immediate or future decision making *(Amr et al. 2019)*[2]. However, the further research and quality control process identified some of the new threats on the SCM like-

i) The accuracy and trustworthiness of data.
ii) The maintaining of privacy and confidentiality of data.
iii) If the data tampering at any stage how it would be identified.

How the decision-making based on this data would be accurate and appropriate for this real-life system. Further research introduces blockchain technology to mitigate the issues of SCM to some large extent. Blockchain technology shares the information in a distributed way among all the users of the network after proper authorizations and authentications. Each block in the blockchain contain its block header, data, the

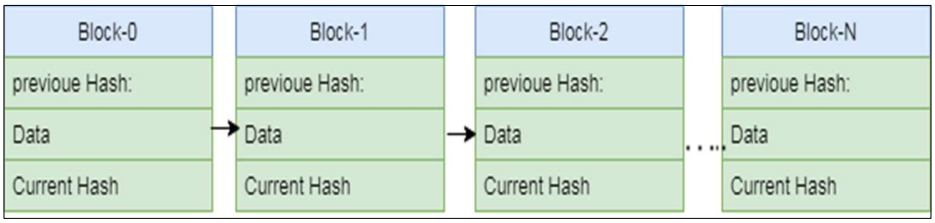

Figure 2: Blocks in blockchain technology

[2] https://www.researchgate.net/publication/332571505_Merging_Supply_Chain_and_Blockchain_Technologies

reference the previous block and the block identity (hash value) in encoded form (Figure 2). The incorporation of blockchain technology secured the transactional data of SCM to large extent. Smart contract blockchain application provides the flexibility of communication and transactions between the two parties or agencies without involving third parties. The blockchain is designed as a public, private, consortium network depending on a specific application area. Bitcoin, Ethereum, Hyperledger are the popular important framework are used to develop the blockchain network.

Table 1: Different Types of Access Controlled Blockchain

Private Blockchain	Public Blockchain	Consortium Blockchain
To become a member, to access the database, to make any transaction permission is required *(Ismail and Materwala 2019)*.	These networks allow anyone to participate in the network. The database is open to access, no permission is required to join the network *(Ismail and Materwala 2019)*.	To join this BC must have some common objective with some mutual agreements *(Ismail and Materwala 2019)*.

The Blockchain user different consensus protocols to maintain the agreement policy of the nodes of the blockchain network. The important consensus algorithm is used in a blockchain network, is shown in Table 2.

Table 2: Consensus Protocols are used in Blockchain

Sl. No.	Name of the Algorithm	Description
1	Proof of Work (PoW)	The PoW consensus algorithm is used by Bitcoin to identify a miner for the next block generation or to write the transaction *(Gao, Hatcher, and Yu 2018)*.
2	Proof of Stake (PoS)	In PoS the block validators are selected based on the number of coins they are staking. The validators can only participate in the process of producing new blocks in the case of locking their coins *(Gao, Hatcher, and Yu 2018)*.
3	PBFT (Practical Byzantine Fault Tolerance)	The three phases (prepare, broadcast, and commit phase) consensus algorithm secures the inclusion of the block into the blockchain *(Gao, Hatcher, and Yu 2018)*.

In this paper, an effort has been given to identifying the issue of existing SCM and also analyze how the issue is mitigated after deployment of blockchain technology and validate it with a case study of supply chain management of rice.

2. Literature Review:

In the paper by (Casado-Vara et al. 2018)[3], the author proposed a model to circulate the economy by minimizing the issues of supply chain management and incorporated the blockchain over supply chain management. The blockchain was and proposed for the agricultural product to

[3] https://www.sciencedirect.com/science/article/pii/S187705091831158X

maintain the security of data. In a paper by (Amr et al. 2019)[4], the author proposed blockchain technology to mitigate the three issues of the supply chain like increasing competition, deficiency of knowledge, and traceability of assets. The authors of the paper (Kawaguchi 2019, Cole, Stevenson, and Aitken 2019)[5], proposed to integrate the distribution storage process of the supply chain with the smart contract, blockchain technology. The requisite files along with the transactional records of the supply chain are stored as a block. The paper (Kumar and Tripathi 2019)[6], addressed the "issues like drug safety" of medicine. The author proposed a model to keep the data and trace the manufacturing ingredients of the medicine to reach the end-user (patient). An analytic hierarchy process (AHP) is done among the various method that enhances the quality of the process of the supply chain of agricultural food production in the paper by (Balakrishna Reddy and Ratna Kumar 2020)[7]. The author then recommends that blockchain technology to incorporate into the supply chain among all existing systems. In the paper by (Azzi, Chamoun, and Sokhn 2019, Ozdemir, Ar, and Erol 2020)[8], the security features and immutability properties of blockchain have been incorporated into the supply chain management to get a "reliable, transparent, authentic and secure system". The security features of the blockchain have been incorporated to mitigate the "corruption, fraud, and tampering" type of issues of the supply chain.

The implementation of blockchain operational mechanism in the supply chain by using some consensus protocol of data authentications in the paper by (Fu and Zhu 2019)[9]. The authors proposed the external data storage blockchain technology to avoid the arising complicacy after the implementation of blockchain technology. In the paper (ElMessiry and ElMessiry 2018)[10], the author proposed that blockchain technology has been implemented in the supply chain management of textile product. The paper also states that the sharing of information sharing to improves the textile quality and also the identification with proper authentication to address the defective products.

All the described works are encouraging the incorporation of blockchain to overcome the limitation of the centralized system of SCM. The primary objective is to bring transparency in SCM to gain the satisfaction of end-user and to expand the business domain by value and variety.

[4]Ibid; See Footnote- 2
[5] https://www.sciencedirect.com/science/article/pii/S1877050919322057
[6] https://ieeexplore.ieee.org/document/8711418
[7]www.researchgate.net/publication/339919174_Quality_Improvement_in_Organic_Food_Supply_Chain_Using_Blockchain_Technology
[8] https://www.sciencedirect.com/science/article/abs/pii/S0360835219303729
[9] https://ieeexplore.ieee.org/document/8626088
[10]https://www.researchgate.net/publication/325899719_Blockchain_Framework_for_Textile_Supply_Chain_Management

2.1 Finding and Gap Analysis:

Most of the work discussed above uses the security features of the blockchain to enhance data security. In most of the cases where the SCM fails to achieve better throughput, the blockchain provides the throw understanding and strategical efficiency to everyone related to the SCM. The use of smart contracts makes the system more efficient by eliminating the third party from interfering with the intention of extra gain which may affect the cost as well. Therefore, the new technology has given a better understanding of the benefits of introducing the technology.

Most of the industrial application does not facilitate with the maximum utility of blockchain and what are the internal rectification needs to be done to achieved complete administrative support. The cost and complexity need to be highlighted. The cost is one of the major issues that the adoption of new technology will effect on the cost (increase or reduction) in compared to security and performance. The adoption of new technology always gives birth to some new kinds of threats. The new threats also are taken to consider before the implementation of these blockchain technologies.

2.2 The Problem Definition and the Existing System:

The number of applications has been developed for SCM which are Information Technology (IT) enabled as well. However, the stored data are always under the threat of external hacking, tampering, and false information.

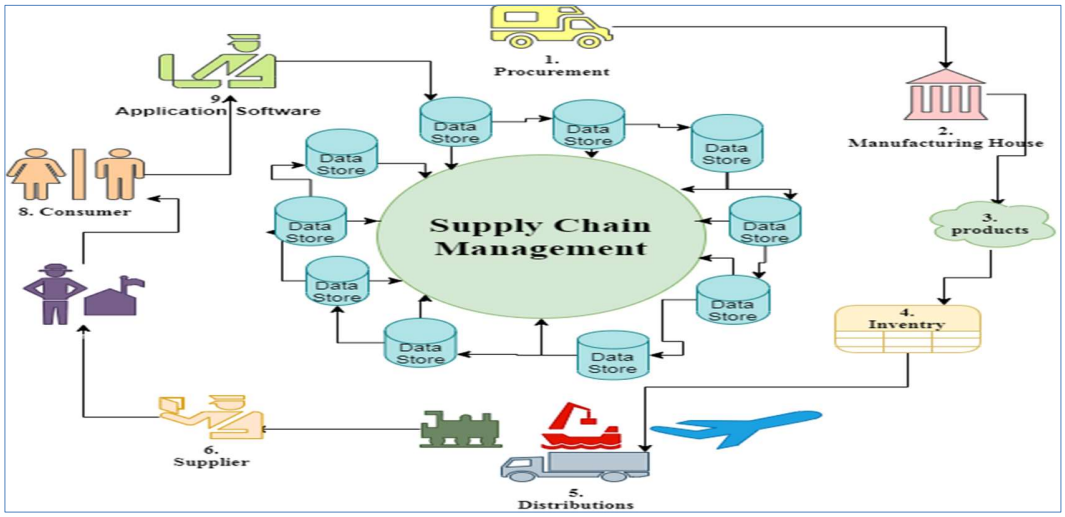

Figure 3: The Existing System IT Enabled SCM System of Rice

However, under this situation, the security of data is much essential. The centralized system of the data model is always at a high risk of system failure. The recovery of data is much complicated and sometimes is impossible.

In India rice is consumed by individuals in most of the areas of the country. In this paper, a case study of the SCM of rice is discussed (Figure 3). The involvement of third party or brokers are involved from every stage from procurement of paddy (raw material), manufacturing house, distribution to the distributor, retailer and till the rice is purchased by an individual (end-user). The cost is increased by the broker at each stage of this system. In the existing system (Figure 3) data is recorded at every stage from procurement of manufacturing house, production, inventory controller, distributor, supplier, and retailer. The threat of stelling, false information, black marketing is taken part of this system to some extent. Therefore, it gives an impact on data, and due to that

i) The management suffers from poor decision-making from poor quality of data.
ii) The organization's privacy of data can be maintained from its closest rival organization.
iii) The trustworthiness of the end-user losses and purchase the rice at a high price.
iv) The Government loses a huge amount of revenue.

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

2.3 The Proposed Solutions:

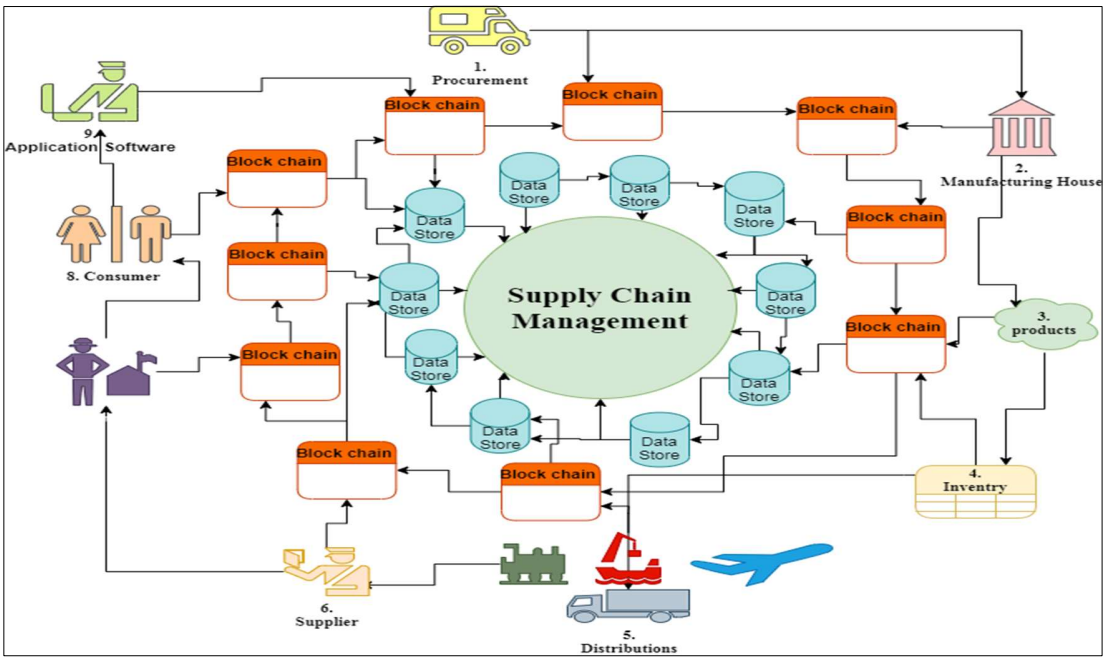

Figure 4: The Blockchain-Enabled SCM System of Rice

With the implementation of blockchain in the SCM, the security of data must be enhanced. In case of internal tampering of data or false information, the source must be traceable. The data in the blockchain are distributed among the nodes within the network. The distribution of data in the blockchain reduces the risk of the system or loss of data as it highly faults tolerance and

increased the availability of data. The implementation of blockchain is shown in figure 4. Every component of SCM is configured as a node within the chain. The individual component can communicate with each other using the smart contract technology of the blockchain.

3. Methodology and Analysis:

The deployment of the case study of SCM of Rice, let N= {n_1, n_2, n_3, ….} be the number of procurement houses of paddy. M= {m_1, m_2, m_3……..} is the number of manufacturing units of rice. C= {c_1,c_2,c_3,…….} means of communication of distribution of rice. D= {d_1, d_2, d_3,……}are the number of distributors and R={r_1, r_2, r_3, ….} number of retailers. Where n_1, n_2, n_3, …≥ 1 and m_1, m_2, m_3…≥ 1 and c_1, c_2, c_3 ,… ≥ 1 and d_1, d_2, d_3, …≥ 1 and r_1, r_2, r_3, …≥ 1. It is also assumed that each of $n_i \in N$, $m_i \in M$, $c_i \in C$, $d_i \in D$, and $r_i \in R$ have their individual authorized and authenticated accounts in the blockchain applications i= 1,2,3…. The Ethereum and Hyperledger fiber is the famous framework of blockchain and is useful to establish a smart contract.

3.1 Algorithm of Blockchain-Based SCM:

- ***Step 1***: Procurement of raw material (paddy) by the procurement house n_i.
- **Step 2**: The smart contract can be executed between ni and m_j (j=1,2,3…). If $n_i = m_j$ then the manufacturing house and the procurement hose are the same units and no smart contract is required only the inventory is maintained.
- ***Step 3***: The product (Rice) is distributed through c_k (k=1,2,3..) and the smart contract may be established between c_k and m_j.
- ***Step 4***: The Rice is distributed to the distributer d_p (p=1,2,3..) through c_k (k=1,2,3..) and the smart contract may be established between c_k and d_p or in between d_p and m_j.
- ***Step 5***: The distribution of Rice is done from distributer d_p to retailer r_t (t=1,2,3..). The smart contract may be established between d_p and r_t.
- ***Step 6***: In the online system, if the production house allows, the retailer r_t may purchase the rise from the production house m_j. In that case, the retailer may procure the Rice from the production house by communicating through the smart contract.
- ***Step 7***: The Rice is purchased by the consumer (end-user) from the retailer r_t.
- ***Step 8***: End

3.2 Algorithm of Smart Contract of SCM:

- ***Step 1:*** The participant S_i (seller) is created with the details of the Si as developed in the application along with the bank details and price details of the product where i= 1,2,3…..

- ***Step 2****:* The participant B_j (Buyer) is created with the details of the Bj as developed in the application along with the bank details and the deposit amount where j= 1,2,3….. and $S_i \neq B_j$. The deposit amount must be higher than that of the total price of the product to be purchased.
- ***Step 3****:* The Asset or details of the product would be created with its quality details.
- ***Step 4****:* The access control of the transaction needs to be declared for each participant.
- ***Step 5***: The transactions are executed with the detailed object code of asset, and participants (buyers and sellers).
- ***Step 6***: The hash key of 256 characters is generated and the price amount is automatically updated (price amount is added in seller account and is reduced from buyer account) in both the account of seller and buyer.
- ***Sept 7***: End.

3.3 Simulated Result:

The simulated result is shown with the help of the testing link (test URL)11 of the blockchain shown in figure 5. The generated block is the genesis block of the procurement. The 256 characters encrypted hash value has been generated considering all the data into the data block. Any change in the data or tamper the single character of data would change the hash value instantly. The smart contract data is shown in figure 6, where the two persons are involved in a digital contract. The block of the other participant involved in the smart contract of SCM is similar to that of figure 5, the only difference is the "business type" fields for distributor, retailer, etc.

Figure 5: Block of Procurement of Paddy on Blockchain Implementation (SCM)[12]

The transactions block of the smart contract of SCM is shown in figure 6. The prev field has taken the hash value of the previous block and the present hash value of the block contains the encrypted accumulated values of all the data contained in the block. Figure 7 represents the smart contract implemented SCM.

[11] https://andersbrownworth.com/blockchain/block

[12] Ibid; See Footnote- 11

Figure 6: Transaction of Smart Contract of SCM[13]

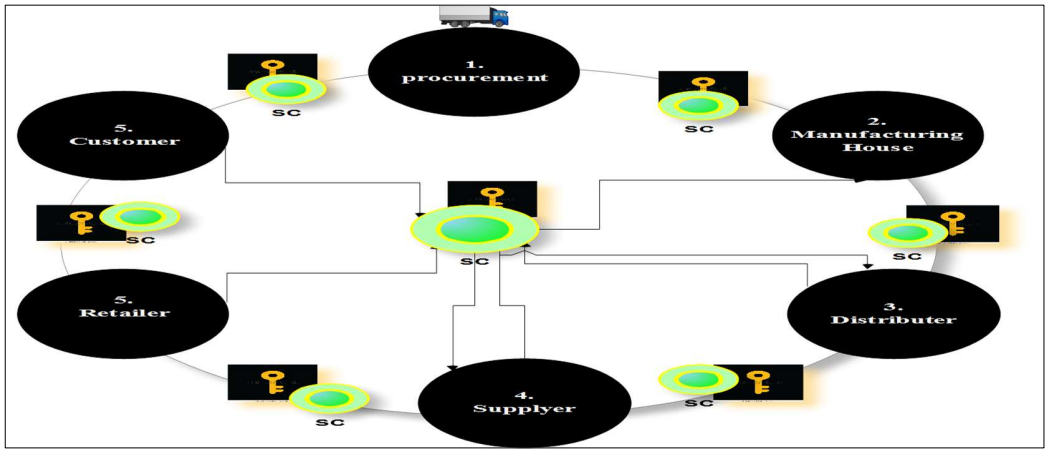

Figure 7: Blockchain Smart Contract (SC) of SCM

3.4 Analysis and Discussion:

The deployment methodology of the blockchain in SCM of rice provides the solutions to different issues and helps the management to take a trustful decision. The merits of the incorporation of blockchain in SCM are discussed in section 3.3.1 (Figure:7) and the newly generated threats due to new technology are also discussed in section 3.3.2 (Figure:8).

[13] Ibid; See Footnote- 11

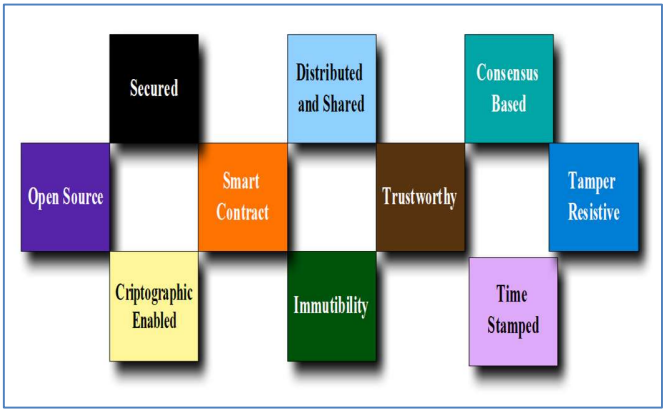

Figure 8A: Merits of Blockchain Implementation in SCM System of Rice

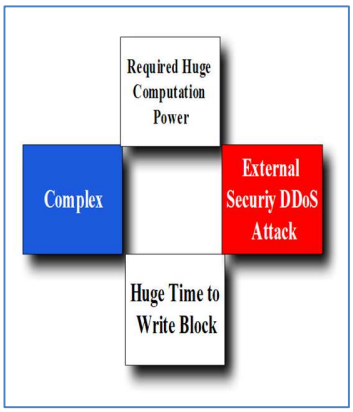

Figure 8B: De-Merits of Blockchain Implementation in SCM System of Rice

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3.4.1 Merits of Blockchain Implementation in SCM System of Rice:

Open Source: Most of the blockchain platforms like Bitcoin, Hyperledger Fabric, Ethereum, etc. are open source in nature. The application can be customized according to requirements. These must be left an impact on the cost.

- **Cryptographic Enable:** The blockchain technology generates a cryptographic-enabled encoded hash-key of 256 bits. The hash key is the key-security feature of the blockchain. That makes the SCM more secure and trustworthy.
- **Secured the Application:** Each block in the blockchain (except the first block) contains the hash value of the previous block and also has its hash key. In the case of any change of data, the hash value of the blocks changed and the rest of the blocks in the chain are mismatched. Therefore, in case of any tampering in the system would be traceable which make the system more secure.
- **Smart Contract:** The smart contract is one of the best properties of the blockchain by which the SCM would be more wanted due to the elimination of the third party in between.
- **Distributed and Shared:** The distributed and shared ledger of the blockchain would capable the SCM more fault tolerance and data would be available easily.
- **Immutability:** The tamperproof property of the blockchain makes the data of SCM immutable without proper verification and authorization.
- **Trustworthy:** The security, immutability, and distributed nature of blockchain makes the information of SCM more trustworthy.
- **Consensus Algorithm:** Different consensus algorithms like Pow, PoS, etc. make the SCM more requirement-specific with the proper interfacing of blockchain.

- **Time Stamped:** The transactions of blockchain are save with the proper timestamp within the block. That makes the understanding of the supply chain business much transparent and also better understanding.

3.4.2 De-Merits of Blockchain Implementation in SCM System of Rice:

- **Complex:** The blockchain process is complex to some extent and its implementation also required some expertise to implement and adopt the system.
- **Huge Computational Power:** The huge power is also consumed to run all of the nodes and keep the network active.
- **Huge Time of Writing:** The famous consensus protocol PoW requires huge computational power to write the block. In the case of the bitcoin framework, it requires more than 10 minutes to write a block.
- **External Security Threats:** The new technology also invited new security threats like Distributed Denial of Service Attacks (DDoS), 51% vulnerability attack, double spending attack, mining pool attack, etc.

4 Conclusion and Future Work:

Blockchain technology is implemented in several domains of applications in the industrial sector. Since BC technology is still in its early research stage, it is very early to say that at what extent the technology provides the solution of the Supply Chain. It is encouraging of developing an application incorporating blockchain, integrating with big-data services. In this paper, the different issues of the existing conventional SCM have been highlighted. It is also discussed the implementation of blockchain is one of the best solutions and its methodology of implementation has also been discussed. The merits and demerits of the proposed solution have been analyzed thoroughly. In the future, there is ample scope to explore and extend this research work to mitigate the security threats, due to the implementation of this new blockchain technology.

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