A blockchain based approach for improving transparency and traceability in silk production and marketing

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Abstract. Blockchain technology may be described as a distributed digital ledger database for transparent and immutable recording of transactions occurring between a groups of non-trusting parties. Transactions can be implemented without any intermediaries. Given this potential, it can play a great role in enhancing Supply chain management. Silk production and marketing has exponentially increased and spanned across the world in recent years. To redefine current silk production and marketing industry, there is a need to strengthen its supply chain management process. With Blockchain, government, farmers, weavers, and sellers can collaborate on a single system without any inconvenience. They create an immutable chain of transactions which can be verified by any of the parties. There is an immutable shared ledger that no one can modify. This research presents a private and permissioned application that uses Blockchain and aims to automate the shipping processes among different participants in the supply chain ecosystem. Data in this private ledger is governed with the participants' invocation of their smart contracts. The performance of the proposed work is evaluated in terms of the transaction throughput, transaction average latency, resource utilization with a fixed and variable rate of transactions.

1. Introduction

Over the last few years, Blockchain has increasingly attracted the attention of different industries and industries have already achieved significant business benefits of it. Blockchain provides transparency as each transaction is recorded on the chain chronologically. All parties involved in a business should be able to agree precisely on a successful transaction. Blockchain can substantially be used where transparent and immutable records are useful. Blockchain is a transparent and verifiable technology so one can exchange contemplating human beings approximately changing value and property, privacy facts subject imposing contracts, and sharing statistics. Blockchain came into existence with Bitcoin [1] which is a leading digital currency stored on a peer to peer blockchain. These are digital assets, meaning they are designed to use as a medium of exchange. Anyone can participate in bitcoin blockchain and ownership can be digitally transferred without the need for an intermediary. Blockchain has advantages mainly in terms of accuracy, cost reduction, transparency, secure transaction, and verification. A transaction in the Blockchain is always approved by millions of

computer. This reduces the cost of human involvement. Blockchain technology has recently received notable attention as enterprises and institutions started to invest in research and development to leverage its potential for applications beyond cryptocurrency [3]. Blockchain is characteristically known as an immutable distributed ledger of records that are shared and verified using a specific consensus [4] algorithm among participating parties. It opens the door to enhance digital transformation development without the interference of a centralized authority. Blockchain's primary characteristic is that it enables untrusted participants to securely communicate and send transactions between themselves without the need for a trusted third party. Blockchain is an ordered block list whereits cryptographic hash identifies each block. Each block refers to the block that went before it, leading to ablockchain. Once a block is created and attached to the blockchain, it is not possible to change or revertthe transactions in that block.

1.1. Basic Terminologies

Hyperledger is a global collaboration for enhancement of Blockchain technologies under The Linux Foundation. It was launched in 2016 with 30 corporate founding members. Hyperledger Fabric and Hyperledger Sawtooth Frameworks are presented by IBM and Intel's incubation group respectively for developing blockchain-based solutions. Hyperledger Composer is a set of tools based on Hyperledger Fabric. It provides easy and faster deployment of Blockchain-based business networks. It is possible for anentity to create and run a sample Blockchain and grant access to various participants. Hyperledger architecture mainly consists of following Blockchain business components [5].

- **Consensus Layer** - it is responsible for the transaction's correctness in a block and generation ofan agreement on the order.
- **Smart Contract Layer** - process transaction requests and validate those by executing functional business logic.
- **Communication Layer** - handles the transportation of messages between nodes that are part of ashared ledger.
- **Data Store Abstraction** - Stores various information for distinct modules to use.
- **Crypto Abstraction** - responsible for allowing crypto algorithm execution without affecting other modules.
- **Policy Services**- responsible for management of various policies like consensus policy, endorsement policy and group management policy.
- **APIs** – enables interface for applications and clients.

Consensus is a mechanism by which nodes decide whether to commit a transaction to a shared ledgeror not. Simultaneously, consensus does ordering of transactions as well. Currently, Hyperledger Fabric supports two types of consensus protocol: Solo and Kafka. Solo protocol is only for trial purpose. Kafka requires the odd number of nodes in order to achieve a majority. A consensus should satisfy at least the following properties:

- A consensus should ensure the validity of all the transactions in a block based on consensus and
- Agrees on sequence, accuracy, and results of execution. Consequently, it reconciles on global state.
- Employs smart contract to check the correctness of transactions in a block.

Proof of work the earliest implementation of a distributed consensus algorithm in Blockchain is Bitcoin's proof of work (PoW) algorithm [11]. Proof of work is implemented via miners. Miners are the nodes which provide huge computation power to facilitate the creation of new blocks. They are given a complex cryptographic puzzle and the one who is able to solve it, gets a chance to add new

block and rewarded too.

Proof of stake an alternative to the PoW algorithm is the proof of stake (PoS) consensus algorithm used by Ethereum which does not apply "mining" in its mechanism [12]. The main advantage of the proof of stake approach is the diminished need for computational power and hence a lower entry barrier for getting rewards for generation. As per PoS, a node can validate block transactions based on the amount of stakes (coins) it is having. However, this process includes the possibility for an attacker or malicious node to hold enough stakes and hence becomes the node with the highest decision weight which relates to achieving consensus in the network.

Practical Byzantine Fault Tolerance Byzantine Fault Tolerance (BFT) is the capacity of a distributed system to achieve an adequate consensus properly despite the existence of failed scheme malicious nodes that propagate inaccurate data to other nodes. BFT protects against system failures by reducing the effect of these malicious nodes on the correct functioning of the system. This topic, derived from the problem of the Byzantine Generals, was investigated and optimized with a variety of methods. The PBFT scheme focuses on delivering State Machine Replication (SMR) tolerating Byzantine faults by assuming independent node failures are present. The algorithm is intended to function in asynchronous systems and is developed with an overhead run-time and a slight increase in latency to be high-performing. All nodes are set in a succession with the primary node (leader) being a single node in the PBFT system. The algorithm offers integrity, consent, and security.

1.2. Challenges in silk market

India is the second most producing silk countries. Over 8.6 million people in India were employed under sericulture during 2017- 18. Exports from India of silk and its commodities reached 255,93 million dollars in 2017-18 and 123,05 million dollars between Apr-Sep 2018. The silk commodities exported include natural silk threads, textiles, readymade apparels, and rugs. Silk material buying are very selective and preferential. Limited storage and depository facilities at the grower's side impel to a reduction of the product's quality. Appropriate picking of worms for fabrication plays an important part in silk businesses. Acquiring the proper volume of worms will enlarge the likelihood of production and decreases fritter. In such conditions to satisfy customers, transparency is required and Blockchain plays an inevitable role in achieving transparent silk market.

- **Paper-based processes are inefficient** paper-based processes are long-delayed, sloppy and costly for all the parties involved in. A Blockchain-based solution can reduce processing time and cost as well.
- **Low traceability** there are a dozen of intermediaries from silkworm to silk market. Data can be lost while from one intermediary to another and no one takes the responsibility. An error can propagate through the entire chain.
- **The market is big and growing daily** after China, India produces the largest amount of silk and it is going to grow exponentially over time. The global silk market is estimated to reach USD 16.94 Billion by 2021. Further, silk is a low capital investment industry, in terms of technology and labor, which is driving the silk market globally. Business trends are always changing.
- **Black market currency exchange between locals and foreigners** locals who could use the 'foreign' currency to purchase counterfeit Western goods were part of the market's customer base from the outset. Their business depends on getting as much money out of naive, unsuspecting foreigners as possible.
- **Source invisibility** customers have become more conscious and curious. They want to know the source and transportation of the product in order to verify its originality. Customers have several questions in their mind like whether this is organic silk or not, whether this product passed quality testing or not? It is difficult to trust intermediaries in such a competitive

environment. This drawback makes the old system very weak in terms of originality and customer never get the sourcefrom where it is generated.

2. Related work

Zhang et al. [1] have proposed a technique where regular silk design is combined with the latest art. Since silk products require more professional knowledge, a Web-based knowledge system is designed. The application provides an interface where the designers can show their art to the experts directly and canseek their suggestions. This presented a way to provide different quality of silk in the market in one place using the web interface.

Gao et al. [5] have pointed out the challenges of (Distributed Ledger Technology) DLT in supply chainmanagement like heavy computation involved in proof-of-work. To overcome these challenges the paper proposes a hybrid DLT method named as (Chain of Custody) CoC. It involves two steps for blockcreation. There are three types of participants in the network: Ordinary Users, Third Party Users and Supporting entities. The proposed idea can be extended to other similar domains as well.

Min et al. [11] have presented a Permissioned Blockchain Framework (PBF) as Bitcoin-derived blockchain do not prove better e-commerce performance. For enhancing the integrity of transactions, a consensus algorithm named Permissioned Trusted Trading Network Consensus Algorithm (PTTNCA) is introduced. The central concept behind PTTNCA is to divide the network into subcommittees. The partitioning of a complex network into small subcommittees provides a better understanding of the network and simultaneously to maintain high correctness the paper introduces a Peer Inner Blockchain Protocol (PIBP).

Kravitz et al. [12] have used a permissioned blockchain technology to secure transactions. The proposed method is a combination of on-chain and off-chain technologies. Since blockchain suffers from scalability issues a prior trust relationship is developed which is used on the on-chain application. The environment is a combination of both a trusted third party and a semi-trusted environment.

Sharandavar et al. [13] have used Garrett ranking technique to reveal the issue of watering the trees during sunny days, high degrees and high-cost variation were the big limitations for a silk market and its various procedures. The optimum temperature for cocoon production is between 23-28 degree Celsius. Maintaining this particular temperature range throughout the year is a difficult job to perform. The farmersshould get trained for organic cultivation of mulberry.

Migirov et al. [17] have deployed a blockchain application which opens up a “supply circle” where manufacturer and buyer sincerely coordinate with regional associations. A smart contract-based platform is used for transferring of skills and products. The proposed method makes easy connecting with people and skills exchange. The automation provided by the program using smart contract business logic makes supply chain management in a way so that all the transaction successfully stored in the blockchain network

Wang et al. [20] also discuss the challenges of the manufacturing industry. Multiple items are bought and sold during construction of a single project. According to the proposed method, all buys and sells are recorded on a Blockchain such that each material can be traced at any time. This blockchain network provides proof of every material purchase with all the data .Applications for equipment loaning, supply chain management, and contract management are developed.

Yu Nandar Aung et. al. [21] have implemented an approach of private Blockchain for (Secure Hash Standard) SHS to cope with its privacy and security issues implemented. Ethereum blockchain bundles

for SHS as indicated by its keen contract highlights for taking care of access control strategy information stockpiling and information stream administration. Private Blockchain implementation approach presentedso that attackers cannot impersonate as an owner to steal the privacy information, important data which may be vital signs for doing a crime like life-threatening and extortion. It uses control policy smart contracts and data storage in another remote server which is honest node

Ilya Sukhodolskiy et.al [22] provided blockchain for the security of file stored in cloud servers. It usesa prototype software system implementing the access control system for the information stored in untrusted settings. Acceptable complexity, functionality, and execution complexity were chosen to execute the system algorithms. It resolves the integrity of information on all transactions, including the granting and modification of access.

Yeh et.al [23] provided that in a Bitcoin-oriented environment hierarchical deterministic (HD) wallet scheme that gives out a signature with trapdoor hash functions instead of directly giving private keys for signing. The proposed scheme can provide unlinkability between two public keys to achieve anonymity of user identities and high scalability to the derivations of huge amount of keys. In addition, the proposed scheme can prevent from privilege escalation attacks by concealing private keys from any child nodes in the hierarchical management manner

Some of the limitations in the existing work are described as follows.

- Silk market is one of the biggest markets of India and there is a lack of a single platform wherecross-organizations can participate seamlessly.
- Existing approaches are using Proof of work algorithm for consensus on a public blockchain. Itconsumes a lot of energy due to the requirement of computational power.
- There is a need of an approach which works on private blockchain using more reliable consensusalgorithms which leads to better transaction verification and privacy of data over a network.

3. Proposed methodology

This research work proposes a Blockchain based solution that offers a distributed, shared, paperless, private, and permissioned ledger that aims to automate the shipping processes among different participants in the supply chain ecosystem (e.g., sellers, buyers, providers). The primary goal is to develop a platform that can be used to exchange assets and values between untrusted members (i.e. members do not trust eachother) and thus enhance the effectiveness of present supply chain procedures by establishing a traceable and unchangeable chain of transactions and blocks. This application also has a private and permissioned ledger to secure data flow and meet common business requirements. These requirements define the data accessibility rights among different parties and thereby protect the privacy of the participant's data. Moreover, this work aims to evaluate and measure the performance of this Blockchain application in terms of different indicators (e.g., transaction throughput and transaction latency).

Fig.1 depicts the layered architecture of proposed framework. It consists of following layers- Infrastructure Layer, Platform layer, Domain layer, Service layer, and Presentation layer. Platform layer is responsible for all Hyperledger services. It starts from Fabric installation and generating all service files from network card to business network as given in Fig. 2. Domain layer handles all business logic, objects, smart contract execution, and monitoring. It also provides services in terms of certificate management and verification. Service layer in this architecture is responsible for API interface request andresponse code. Presentation layer contains front end execution of transaction and updates the blockchain automatically

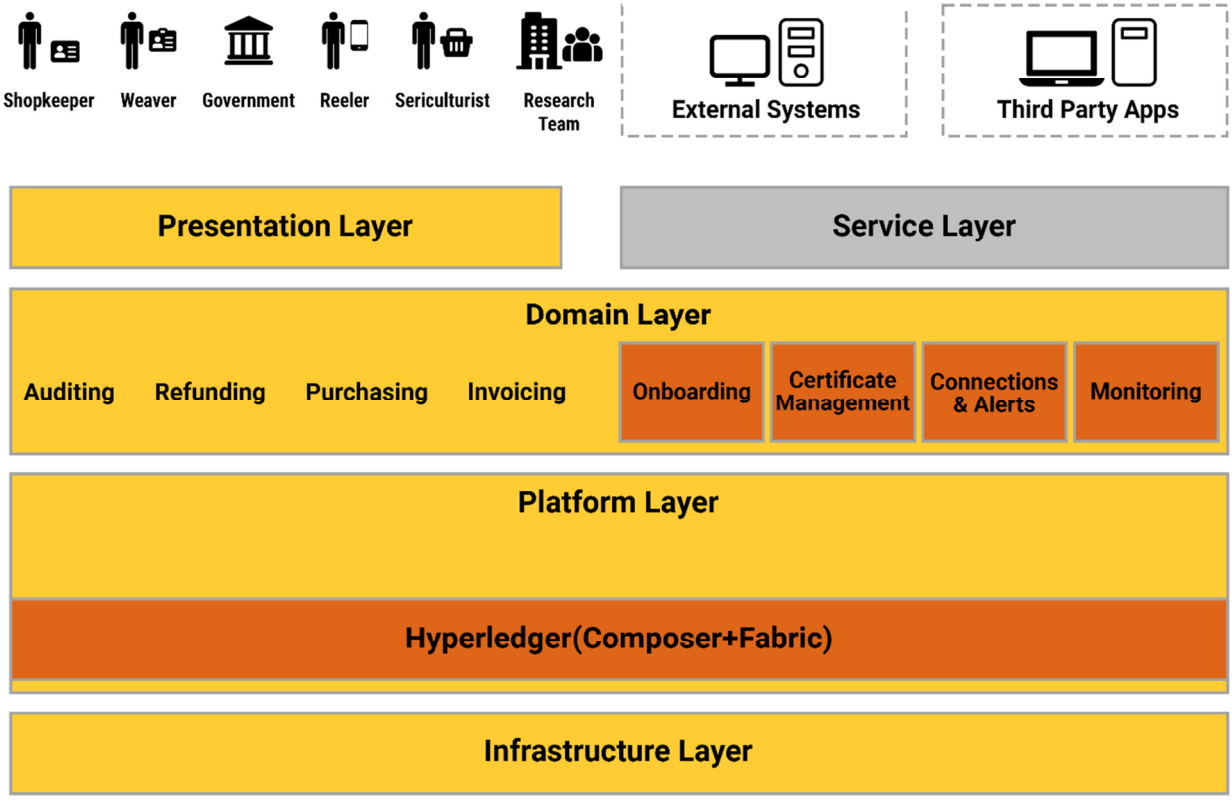

Figure 1. Implementation Framework

Fig. 2 explain the steps involves in implementing Blockchain network using Hyperledger. The flow diagram shows steps starting from Hyperledger implementation on Platform layer. Once Platform layer starts working, REST server implemented in business layer will submit transactions to the network and write data to blockchain.

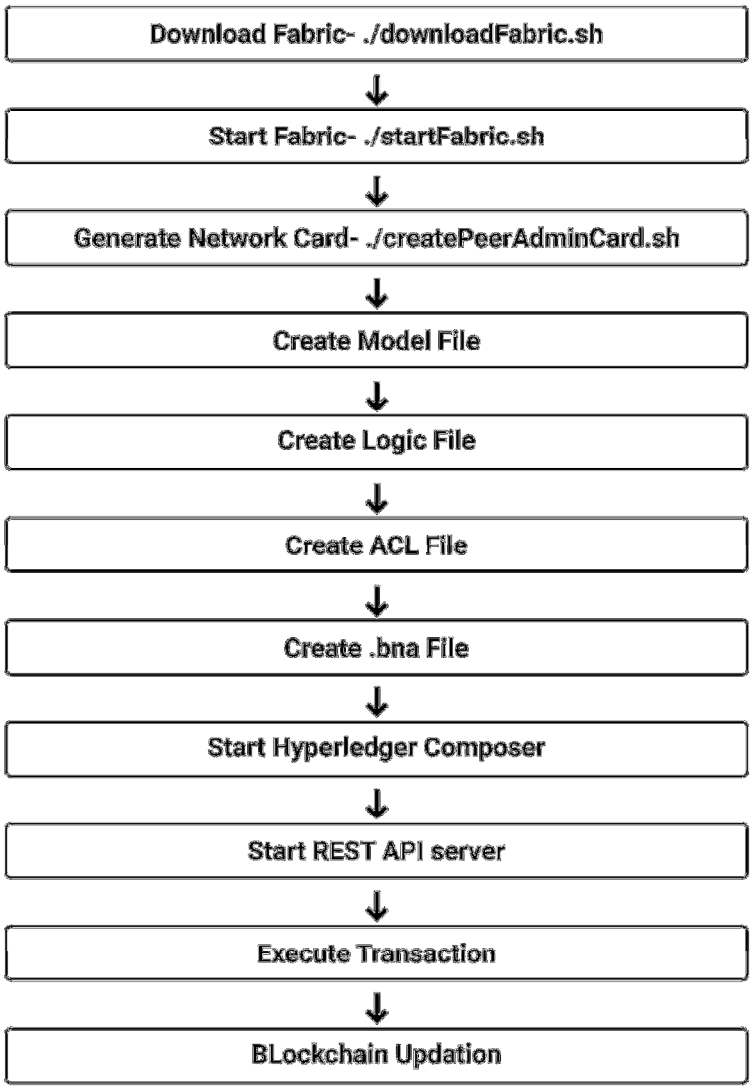

Figure 2. Flow of Proposed Work

4. Experimental setup and result analysis

Tests are performed locally using the Hyperledger Caliper tool and configuration files. To display the performance test, the test environment is set up as follows:

- The local HL Caliper platform is designed to incorporate the required development dependencies.
- Shipping request is integrated with HL Caliper by setting up JSON configuration files. These files contain the necessary information for HL Caliper to connect with the proposed architecture of the shipping application as described in Figure 3.1 and desirable testing methods.
- HL Caliper is designed to link to the HL Fabric construction scheme using configuration files.
- The results are visible on the Docker panel as well as in the form of automated reports in HTML format.

Method A Fixed Rate: This controller moves transactions over a period of time specified as TPS.

The following example is a limited-level control configuration in a TPS (Transactions per second) 10-point transmission defined within the JSON configuration file

rate:{ type : fixed rate, options : {tps : 10} }

Method B Fixed Feedback: This controller moves transactions at a fixed TPS shipping rate. Still, it works both of each client's unfinished structures as a consistent response and sleep time

rateControl : [{ type : fixed feedback, options : {unfinished_per client : 10, tps : 40, sleep_time :

2000}}]

In Table 1, Data Set I and II are given to Methods A and B. In this experiment, the transmission rate of TPS is set to 10 TPS and using the load parameters of different networks to investigate the effect of loading on network performance.

Table 1. Data set with TPS rate

Experiment I: Network Load Parameters Data Set	
Data Set 1	
Parameter	**Value**
Total Transactions	20
Send TPS Rate	10
Assets	20
Data Set II	
Parameter	**Value**
Total Transactions	40
Send TPS Rate	10
Assets	40

4.1. Performance Metrics

Following parameters are used for evaluating the performance of proposed work.

- *Transaction Latency* The time from the moment the transaction is submitted to the point that it is confirmed and committed in the Ledger of Blockchain. It is measured in Transaction per Second (TPS), is the maximum rate in which valid transactions are committed in the HL Fabric ledger:

  Transaction Throughput = Total transactions committed / total time in seconds

- *Transaction Throughput* It is time to use the impact of a transaction across the network. The measurement includes the time from the point that the transaction is submitted to the point that it is confirmed and committed in the HL Fabric ledger. This includes the time that the REST client takes to submit the transaction to the network and any assigned time due to the Hyperledger Fabric's consensus mechanism (e.g., endorsement, validation and committing time)

  Transaction Latency = Committed Transaction Time- Submit time

4.2. Results Analysis and Discussion

In Table 2, higher network load at 40 transactions, 40 assets, and fixed send TPS rate at 10 results in increase in the average latency (by nearly a factor of 2) than the lower network load in Table 3 that is 20 transactions, 20 assets, and fixed send TPS rate at 10. This is because the number of transactions pending in the orderer node grows faster than the network load of 40 transactions rather than the network load of 20 transactions. Therefore, the waiting time at the orderer node is increased and because of this the average latency too**.**

Table 2. Data set 1 with TPS rate

Experiment I Method A Fixed Rate					
Data Set 1					
Round	**TPS**	**Success**	**Fail**	**Average**	**Throughput**
1	10	20	-	2.32s	3
2	10	20	-	2.40s	3
3	10	20	-	1.86s	4

Table 3. Data set 2 with TPS rate

Experiment I Method A Fixed Rate					
Data Set 2					
Round	**TPS**	**Success**	**Fail**	**Average**	**Throughput**
1	10	40	-	5.01s	3
2	10	40	-	4.92s	3
3	10	40	-	4.19s	4

Table 4. Resource Utilization for Data set 1

Resource Utilization For Data Set I Method A				
Process	**RAM**	**CPU**	**In Traffic**	**Out Traffic**
Primary Peer 1	40.02 MB	19.01%	2.1 MB	2.4 MB
Primary Peer 2	37 MB	11.57%	1.1 MB	1.7 MB
Orderer	10.08 MB	1.78 %	204.8 KB	312.4 KB
DB	120 MB	26.86%	395.4 KB	0.813 KB
Hyperledger Peer 1	105 MB	11.55%	666.2 KB	592.5 KB
Hyperledger Peer 2	103 MB	7.24 %	311.8 KB	282.6 KB

Table 5. Resource Utilization for Data set 2

Resource Utilization For Data Set II Method A				
Process	**RAM**	**CPU**	**In Traffic**	**Out Traffic**
Primary Peer 1	42.8 MB	23.32 %	3.1 MB	3.4 MB
Primary Peer 2	39.6 MB	11.67 %	1.7 MB	2.1 MB
Orderer	12 MB	1.83 %	319.1 KB	611.9 KB
DB	100.3 MB	29.45 %	629.8 KB	1.3 MB
Hyperledger Peer 1	93.1 MB	7.52 %	534.8 KB	473.4 KB
Hyperledger Peer 2	106.2 MB	14 %	1.1 MB	964.8 KB

Comparing to Table 4, Table 5 shows Peers 1 and 2 (authoritative and verification peers) use larger CPU resources for higher network load than for lower network. The validator peer uses the computer power of the CPU to check the signature of the transaction block and verify each transaction within the block with the consent policy before performing this transaction on the log. Therefore, as more transactions need to be guaranteed at higher network load than at lower network load, CPU usage is increasing.

Table 6. Data set 1 with TPS rate (Method B)

Experiment I Method B Fixed Feedback Rate					
Data Set 1					
Round	**TPS**	**Success**	**Fail**	**Average**	**Throughput**
1	10	20	-	2.41s	4
2	10	20	-	2.74s	3
3	10	20	-	2.08s	4

In Table 7, higher network load at 40 transactions, 40 assets, and fixed send TPS rate at 10, results in an increase in the average latency than the lower network load in Table 6 at 20 transactions, 20 assets, and fixed send TPS rate at 10.

Table 7. Data set II with TPS rate (Method B)

Experiment I Method B Fixed Feedback Rate					
Data Set 2					
Round	**TPS**	**Success**	**Fail**	**Average**	**Throughput**
1	10	40	-	3.98s	4
2	10	40	-	4.34s	4
3	10	40	-	3.31s	5

Table 8. Resource utilization Data set 1 Method B

Resource Utilization For Data Set I Method B				
Process	**RAM**	**CPU**	**In Traffic**	**Out Traffic**
Primary Peer 1	40.1 MB	20.16%	1.5 MB	1.8 MB
Primary Peer 2	38.2 MB	10.86%	972.1 KB	1.2 MB
Orderer	11 MB	1.65 %	113.9 KB	237.5 KB
DB	99.6 MB	28.8 %	350.16 KB	765.3 KB
Hyperledger Peer 1	106 MB	13.48%	573.1 MB	398.7 KB
Hyperledger Peer 2	104 MB	6.88 %	292.8 KB	242.4 KB

Table 9. Resource utilization Data set 2 Method B

Resource Utilization For Data Set II Method B				
Process	**RAM**	**CPU**	**In Traffic**	**Out Traffic**
Primary Peer 1	42.32MB	22.32 %	3.1 MB	4.0 MB
Primary Peer 2	39.43MB	12.34 %	1.8 MB	2.9 MB
Orderer	11.8 MB	1.87 %	356 KB	719.3 KB
DB	101 MB	33.15%	691 KB	1.5 MB
Hyperledger Peer 1	106.9MB	14.65 %	1.2 MB	813.5 KB
Hyperledger Peer 2	104.5MB	7.79%	519.4 KB	477 KB

Table 8 and Table 9 describes the resource utilization for both data sets using fixed feedback controller. The difference in CPU usage between peers 1 and 2 in high and low network load in Method A is 4.31%, 0.13%, respectively, and in Method B it is 2.17%, 1.57%, respectively. Therefore, peers in
Method B use less CPU resources than Method A. The Fixed Feedback controller pauses to move new transactions. Therefore, the amount of transactions that need to be verified is less than the case when usingFixed Controller. Therefore, CPU usage by the author when installing Fixed Feedback Controller is less likely to occur when using Fixed Controller. The use of the Orderer CPU shifts slightly at higher network load than at lower network load.

Following are the reasons for better performance of the proposed architecture.

- The implemented work uses private blockchain with Hyperledger implemented for proof of concept ina layer architecture of algorithm
- This approach uses algorithm PBFT and blockchain model approach.
- This work implementation of architecture lead to increase in performance for transactions, validatingthe nodes with more accuracy and securing the transaction with data privacy

5. Conclusion and future scope

This paper studied the realization of a Blockchain shipping industry user story as a Proof of Concept. The privacy and validity of the data being exchanged was considered. Moreover, untrusted participants were enabled to interact through a private but shared ledger that records the transfer of each order from the point of creating the order to delivery. Furthermore, participants can only invoke the smart contract that satisfies their pre-defined role in the application (e.g., Buyer is not allowed to invoke the shipping request smart contract). Finally, the participants can only invoke the smart contract on their own asset. A performance measurement was conducted on the application to measure the transaction throughput, transaction average latency and resource utilization, focused on analyzing the effect of the network load with fixed send TPS rate Furthermore, two methods of Fixed Rate controller and Fixed Feedback controller were applied in experiment. The application achieved a transaction throughput of 5 TPS in the experimental setup and a pattern was observed in which the Fixed Feedback rate Controller achieved a better average latency performance than the Fixed Rate Controller.

In the future, an architecture with cloud infrastructure and IoT devices for block storage may be deployed with higher resources and multiple Hyperledger Fabric peers.

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