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An Approach to Improvise Blockchain Scalability Using Sharding and PBFT

Murthy D. H. R.[1*], Dr. K. G. Mohan[2], Dr. Jacob Augustine[3], Dr. G. K. Patra[4]

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Abstract: IoT is mainly used to forward the data to blockchain enabled networks to avert the tampering of sensitive data. This enhances the reliability and scalability of the IoT based services. Meanwhile, the advancement of technologies might affect the blockcahin system and hence the transaction rate per second and the scalability got reduced. In concern with this, we propose a novel Shard technology along with PBFT Blockchain. This enhances the throughput along with mitigated latency. In addition to this we have developed decentralized student database using the IPFS and estimated the transaction time and compared those results with the deployment of Sharding technique and PBFT technique. The Black Hole Optimization (BHO) algorithm improves the throughput per second and thus improvize the scalability and also reduces the tradeoff between the scalability and delay. Simulation outcomes outlined the system that deployed with the sharding and PBFT techniques improvise the scalability and reliability of the system.

Keywords: *Blockchain, IoT, Scalability, Deep Adversarial Neural Network, Shard, and PBFT.*

1. Introduction:

The ability to modify a blockchain [1] is shared among the servers, either people who participate or a communal along with an internal internet connection. It is a form of decentralized record or ledger, one of the contemporary leading technological developments. These sections are connected by means of cryptography [2], every file includes financial data, a date, along with an encrypted copy of the one before it. A blockchain is an autonomous, shared, and open ledger of information that can be utilized to log activities through many devices in a way that prevents the information from being changed subsequently despite modifying all succeeding blocks and obtaining a network of things agreement. Financial services [3] payment processing costs may be reduced (or eliminated) in addition operations handled across a blockchain can be completed in just a couple of moments.

Organizations might employ blockchain to swiftly recognize bottlenecks in their distribution networks [4], identify goods during an actual moment, and monitor the nutritional value of merchandise as they move from suppliers to dealers. Microsoft [5] is trying its hands with the decentralized ledger technology in order to give individuals ownership of who is able to view their data and to assist them in managing their internet-based IDs. It might serve as a middleman to transfer and keep corporate information discreetly between sectors. It has the potential to be utilized in creating a decentralized ledger that guarantees the preservation of audio recordings and offers performers accurate and immediate time royalties; it might also benefit free-of-charge programmers in a similar way. In order to recognize electronics that are linked to an internet connection, observe individuals devices' movement, and evaluate what kind of reliable the gadgets are," and additionally to "automatically examine the dependability of freshly manufactured systems that are introduced to the system, such as motor vehicles and smartphones," blockchain may become an oversight organization of connected devices. An append-only spread data capture that is accessible through a corporate network is known as a shared ledger [6].

[1]Assistant Professor & Research Scholar School of Computer Science and Information Science Presidency University, Bangalore, India.*
[2]Professor, Department of Computer Science & Engineering, GITAM School Technology, Bengaluru, India
[3]Professor, School of Computer Science and Information Science, Presidency University, Bangalore, India
[4]Chief Scientist, CSIR Fourth Paradigm Institute, Bangalore, India

Interactions are documented solely with a common ledger, eradicating the repetition of endeavor that is distinctive of conventional enterprise connections. By limiting network involvement, organizations can effortlessly adhere to privacy legislation because authorization guarantees that interactions are protected, confirmed, and transparent. There are multiple kinds of protection [7] available with each of the two initial varieties of blockchain, both private and public. In order to authenticate payments and group the resulting blocks for addition to the record, public blockchains "use processors linked to the general web. Contrarily, only publicly accessible organizations are usually allowed to participate in private blockchains.

Public blockchains [8] may not represent the best choice if organizations are who fret over the anonymity of the data that enters the system due to any organization is able to participate in them. Communication delays on the blockchain are reduced from instances to within moments. Since official authentication is not essential, trade closure is quicker. Transactions require less supervision. Direct trade of valuables is allowed between participants. It prevents attempt duplication because users have access to a shared ledger. The security [9] aspects of blockchain guard against deception, manipulation, and hacking. Data that has already been logged using the distributed ledger system cannot be easily changed; to do so, all of the transactions' data must be rewritten, which takes a lot of cash and time. The drawback entails that it is challenging to fix errors or implement required modifications. The major contribution of this study is explained as follows;

- The IPFS develop the decentralized student database thereby calculating the transaction time.
- The latency minimization and throughput improvement is performed by using Shard technology along with PBFT Blockchain.
- Further, tradeoff between the scalability and delay are minimized via Black Hole Optimization (BHO) algorithm.

Rest of the article is arranged as; Section 2 reviews the related works followed by the proposed methodology is delineated in section 3. Section 4 discusses the experimental outcomes and the paper is concluded in section 5.

2. Literature Survey:

Cai et al. [10] have presented a many-objective optimization algorithm based on the dynamic reward and penalty mechanism (MaOEA-DRP)for fragment assurance reliability simulation optimization. The sample size is brought more connected to the true optimal margin by the continually changing incentive and consequence system which constantly combines the merging operations and the variability activity. Applicants possessing various abilities will gradually develop as a result when the measures of each of the tasks are flexibly determined to group members of a sample concurrently. The performance of the method remains strong and the efficacy of the suggested model. Thus, the issue of constantly changing connections shall be addressed.

Chen et al. [11] have modified SSChainto allow state and transaction sharding from the non-reshuffled framework. The root chain will have an important share of the network's processing power owing to its competitive stimulus process. Although attackers gain control of a particular shard, a root chain system is capable of stopping simultaneous expenditure attacks from authenticating all of the blocks created by the course partition. Shard networks make up the subsequent layer; each shard keeps its own database and handles a separate subset of deals on its own. It can successfully lower the per-node demand for storage. However, these techniques operate inadequately or are only occasionally used.

Feng et al. [12] have implemented the pruneable sharding-based blockchain protocol through the use of the sharding method. To establish in place an innovative agreement method, this is then used in the upgraded system to create the power source protocol. Additionally, every router merely stores data and fresh terminals receive the block header sequence and a few structures, maintaining the system's integrity. It is scalable and gradual development in defined units over a period of duration. Moreover, it is expensive and complicated.

Asheralieva et al. [13] have described a self-organized shard formation algorithm wherein each peer behaves as a logical player seeking to maximize the image of the cooperation. As a direct consequence, each successive fragment framework created as expected of such a consortium creation performs greater compared to its predecessor before it in regards to overall speed and coalitional credibility, or the reliability of transaction validation. The performance gets better in terms of protection and system capacity. Thus, rules out the use of these techniques in massive blockchains.

Liu et al. [14] have identified a secure and scalable hybrid consensus (SSHC) confirming individual records and gathering procedures by an intermediary group. The chosen new nodes must be allocated at unrelated to various panels depending on variance. The authentic nodes share within completely unfamiliar points prior to utilization must have a value in excess of the ratio in order to confirm that the realistic nodes portion within every group subsequent to the distribution is at least comparable to the maximum comfortable percentage. It has demonstrated stability and the existence of life. There was insufficient storage for overall transactions.

Du et al. [15] have determined mixed Byzantine fault tolerance (MBFT) to simultaneously guarantee the blockchain's durability. To differentiate between the tasks of points, utilize stratification. By distributing the complete decompression and testing functions among different points. The framework can constantly boost the number of servers and segments whenever the volume of transfers expands considerably, enhancing the ability to process and reducing latency. It is scalable and efficient. Thus, increasing the expense of a harmful node targeting the entire network.

Huang et al. [16] highlighted RepChain, fragmenting to create a reputation-based, quick, and safe blockchain network. Regarding the method used, reputation ratings are derived from validators' actions, which reflect the competence and dependability of verified users. Three key functions are served by the credibility index. It can improve the speed and degree of integrity of a distributed ledger platform built on sharding. However, it is difficult to model the shattering situation.

Kwak et al. [17] suggested the service-zone-based hierarchical consensus mechanism (SZHBFT), a protected consistency subsection directly processes a distinct collection of interactions, or accordance segments perform it generally. The essential concept is to effectively organize numerous unanimity divisions to analyze a distinct set of agreements, document committed interactions, maintain records of their legitimacy, and handle entity status in order to instantly optimize the computational strength that is possible. It has the ability to identify and eliminate bad validators. Hence, in the large-scale domain, it limits the growth of the system.

3. Proposed Methodology:

An IoT network supported sharded blockchain structure is delineated in this section. Figure 1 demonstrates the entire architecture of system model. The IoT devices are applied to various field such as smart vehicles, homes, smart grid, smart watches and so on.

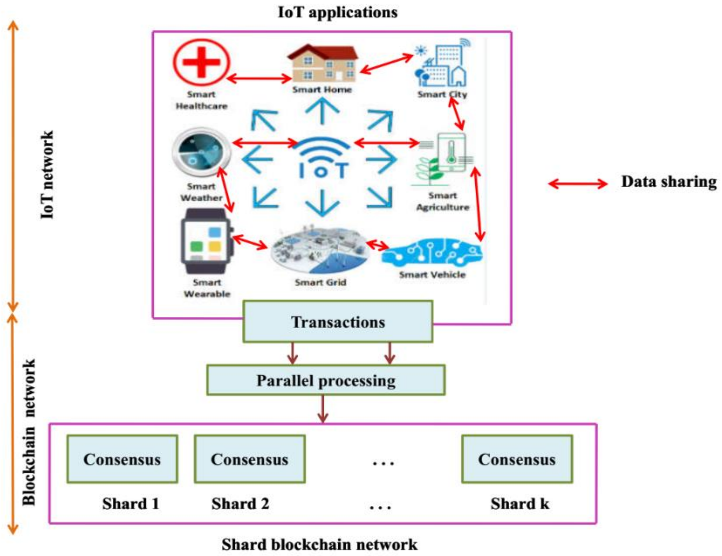

Fig 1: Entire architecture of system model

3.1.1 An IoT network supported sharded blockchain

The various application sections of IoT such as monitoring systems, robotics, smart factory, smart vehicle, and smart home and so on generate the transactions as shown in Figure 1. Various domains process or share the data [18]. Various domains examine the generated transaction data like home information, smart vehicles based on GPS information, monitoring data and etc in which these databases are shared via the infrastructure of blockchain. From the IoT network, the transactions are received via blockchain network in which the data management is ensured via distributed ledgers and recorded. From the IoT network, huge number of data is effectively handled. In a parallel manner, huge numbers of transactions are processed with the help of shard blockchain network [19]. The transaction request completion required the upcoming steps in the presence of shard based blockchain.

- Various shard groups cluster the blockchain validators. Independently create blocks via various shards and intra shard consensus surrounded by the shards verifies the blocks integrity.
- Final consensus verifies and merges the created blocks in every shard and the blockchain chain the new block.

3.1.2 Architecture of sharded blockchain

(i) PBFT consensus model

The PBFT consensus model gives details the full configuration of sharded blockchain and also it provides the assumptions of consensus model and clustering shards [20]. Many blockchain systems like EOS popularly used distributed consensus algorithm called PBF, which consist of three steps such as Commit, Prepare and Pre-prepare. Figure 2 shows the PBFT consensus model.

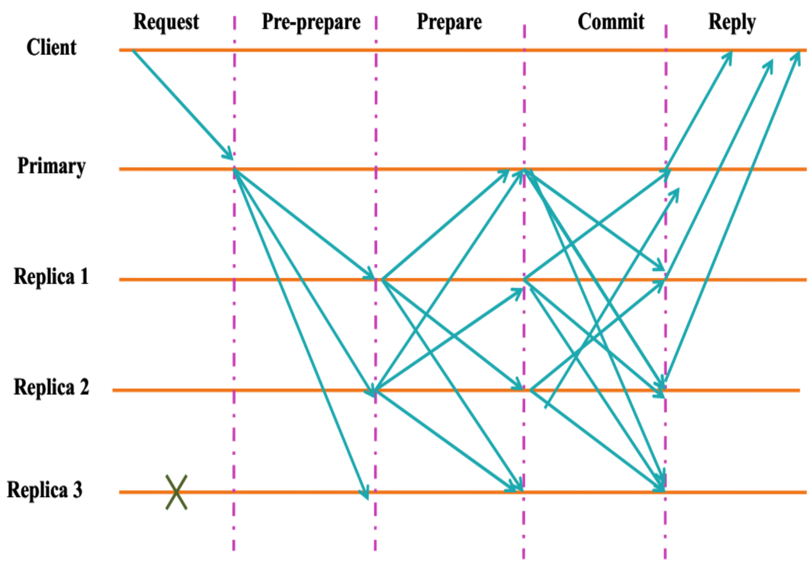

Fig 2: The PBFT consensus model

From the transaction pool, a transactions are collected using primary node in pre-prepare step in which the block created and the block to the other nodes are broadcasted. From an identical primary node, receive the blocks and compare with all replicas in the prepare phase. The primary node selective forwarding is prevented [21]. Message is validated the commit step in which the same message is received via replica. From the nodes consent participation, if an additional two-thirds of the votes process all process successfully in each PBFT procedure. The PBFT consensus bound requires that the node failure ratio allowed in a PBFT agreement not surpass one among the entirety of the nodes participating in the consensus process. To reach a consensus, PBFT generates huge messages that can be lengthy, with the time consumption increasing exponentially.

(ii) Architecture of two step consensus and shard clustering

Various shard groups cluster all blockchain validators. In a decentralized way, shard numbers to every validator are allocated by adopting the architecture of shard clustering. The two-step consensus process such as final consensus and intra shard consensus stages are processed and distribute every transaction to the shards next to the distribution of shards [22]. Perform each local block validation based on final consensus after completing the intra shard consensus. While using simple PoW, the PBFT conducts all consensus procedures. All blockchain nodes are distributed and merge all local blocks when is no faultiness in the local block. The following section describes each process details.

(i) Shard Clustering and setup identification:

The simple PoW is generated to solve the participation of nodes in the network form their ID.

$$ID = G(epoch\ rand\ IP \| KP \| nonce) < d \tag{1}$$

The node *ID* us computed using nonce, *IP* and *KP* (public key). The hash operator and the PoW algorithm complex level is *G* and *d*. The final L-bits determine the shard number assignment. Non directory committee nodes required to report the information ID. The network throughput broadcasting is the list after the collection of directory committee ID from each other nodes.

(ii) Consensus based on intra-shard

An own transaction pool is received with each node after the shard configuration. An account-based sharding decides transaction. The transactions are generated by preventing a double expenditure of malicious [23]. The local PBFT consensus process is performed and the local blocks are created. The local block header consists of local transaction hash, data size, timestamp, shard index and block producer's ID. The consensus determines the local block.

(iii) Last Consensus

From each shard, each local block is received with directory committee node in the last consensus procedure. From each shard, the local block set is received by each directory committee node by the process of intra shard consensus. An ascending order of shard number in all local blocks is merged with final block that is generated by directory committee primary node [24]. The consensus trust, transmission hash, data size, time stamp and block producer is included in the final block. During each shard of PBFT, the variation of consensus opinions between nodes calculates the consensus trust.

The PBFT consensus is proceeded by designate the block producer in each shard. The consensus procedure makes many assumptions.

- ❖ Configure maximal waiting time bound in order to unresponsiveness message exchange waiting time. The round robin fashion process the message task [25].
- ❖ During the pre-defined period *P*, perform block consensus after the process of shard clustering and set the epoch as 1. For longer time period, a validated to participate in a specific shard is prevented via reshuffled each epoch as shard.
- ❖ Verify the process and exchange message included in the process of block consensus.

3.1.3 Scalability improvement using Black Hole Optimization (BHO) algorithm:

To analyze the scalability of the blockchain it is necessity to analyze the Throughput per second (TPS). To increase the TPS the shards number should be increase, however, it might pushes the transaction time to the highest during the consensus process. Meanwhile the trade-off might have occurs and for this we introduced the Black Hole Optimization (BHO) algorithm which increases the scalability by tuning the block size and number of shard number [26]. The brief of the BHO algorithm is as follows,

The black hole thing mimicked the BHO method produced by the enormous dimensions and stars that had greater gravitational power. The equation listed below computes the Schwarzschild black hole radius and shape.

$$PB = {2NC}/{h^2} \qquad (2)$$

Where, h, C and N are the speed of light, black hole mass and gravitational constant. Here, black hole greater than PB to describe the distance between any proceedings transactions. The current state of a black hole is calculated using the formula below. The radius of Schwarzschild

$$PB = \frac{f_{HB}}{\sum_{K=1}^{m} f_K} \qquad (3)$$

The fitness price alongside everyone in the population is displayed as *m*. Use equation (3) to update the black hole's new position, which results in the star motion.

$$Z_j(t+1) = Z_j(t) \times Random \times \left(Z_{HB}(t) - Z_j(t)\right) \qquad (4)$$

Each iteration in which the absorption phases indicates this, update the position in search space. During star motion, certain stars may achieve an improved spot than the current best location. When the Schwarzschild radius is changed, BHO chooses the most powerful appear to operate as a new black hole, and the remaining stars begin to orbit the new black hole. The BHO algorithm is used to accomplish the investigation feature. By achieving the exploitation characteristic, every star attracts them in the search space for the current black hole. This algorithm improves the TPS and thus improvize the scalability and also reduces the tradeoff between the scalability and delay.

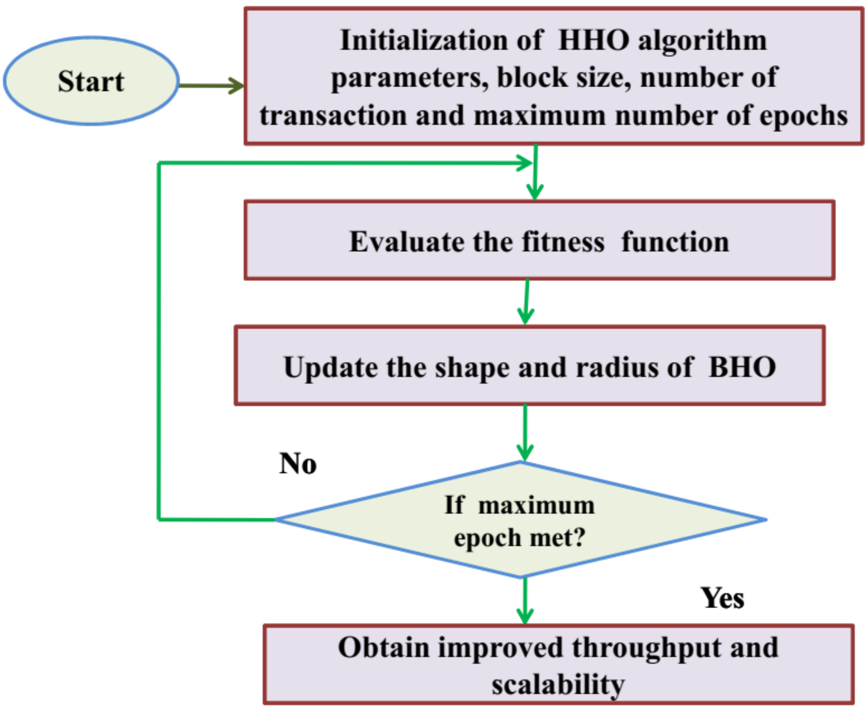

Fig 3: The BHO algorithm for scalability improvement

4. Experimental Analysis

The experimental analysis of our proposed work is elaborated in this section. The simulations are executed in MATLAB under windows 10 OS with the 16GB RAM, with the Intel core processor. Table 1 describes the parameter configuration.

Table 1: Parametric configuration

Parameters	**Ranges**
Average transaction size	100 bits
Maximal every shard block size	8.2 MB
Maximal block interval	1.5 s
Header size of the block	80 bytes
Population size of HHO algorithm	10
Number of epochs based on HHO	50
Number shard maximum allowable	8

4.2 Database

The data of 1026 students are collected and stored in decentralized Inter Planetary File System (IPFS). IPFS is a peer-to-peer communication system protocol used in network for the purpose of storing, sharing and retrieving the data via a distributed file system. The utilization of IPFS helps to avert the duplication of data, persist the clustering, and better performance. The data that are stored using the IPFS decentralized techniques is used in the analysis of Blockchain transaction. The performance of Blockchain without any improvised technology is analyzed and compared the study with utilizing the Shared technology, and PBFT technology. The outcomes are analyzed individually also.

4.3 Performance analysis

Figure 4 delineate the evaluation analysis of transaction size Vs transaction time. The average transaction size varied from 100 to 700 bytes, which is evaluated with respect to the transaction time in seconds. By this study, the blockchain, Shard and PBFT performances are changed with respect to the average transaction size and transaction time. By this plot, we analyzed that the PBFT model outperformed minimum transaction time in each transaction size compared to the blockchain as well as PBFT.

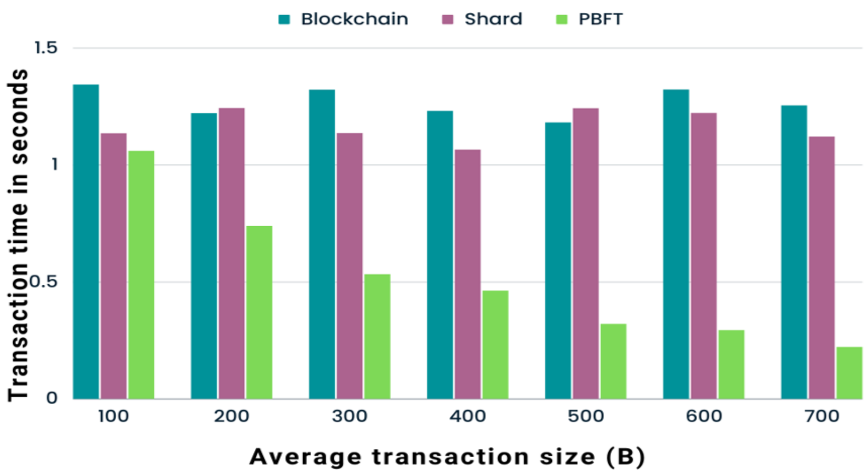

Fig 4: Performance analysis of transaction size Vs transaction time

The evaluation of transaction size Vs throughput is plotted in Figure 5. The throughput per seconds varied when measured against the transaction size. This study changes the performance of blockchain, Shard, and PBFT in terms of average transaction size and TPS. We discovered that the PBFT model outperformed superior throughput per seconds results then the blockchain and PBFT in terms of each transaction size.

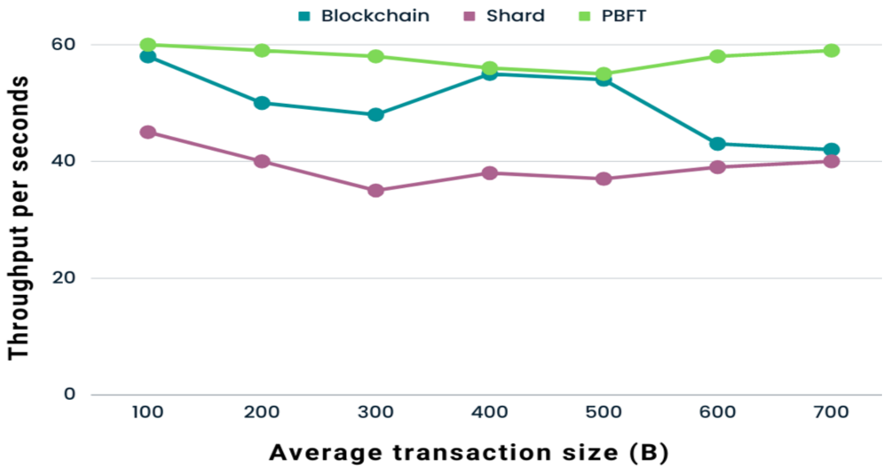

Fig 5: Performance analysis of transaction size Vs throughput

The performance analysis of throughput is compared in Figure 6. This comparative study is analyzed in the presence of existing Cuckoo Search Algorithm (CSA) and Ant Colony Optimization (ACO) algorithm with proposed Black Hole Optimization (BHO) algorithm. There are 50 epochs selected to analyze the throughput. The rate of proposed throughput is slightly increased to determine the best blockchain parameters than the previous approaches such as ACO and CSA. Based on the comparative investigation, the speed of convergence is faster to previous methods like CSA and ACO algorithm.

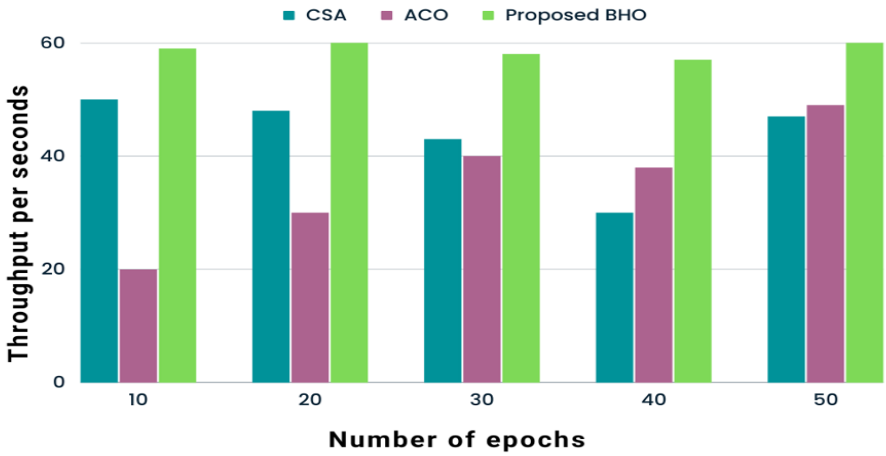

Fig 6: Performance analysis of throughput Vs number of epochs

5. Conclusion:

This work presented Shard technology along with PBFT Blockchain to mitigate the latency and improve throughput. The tradeoff between the scalability and delay are minimized as well as throughput per second is improved with the help of Black Hole Optimization (BHO) algorithm. The simulations are run in MATLAB under Windows 10 with 16GB RAM and an Intel core processor. Data from 1026 students is collected and stored in the decentralized Inter Planetary File System. IPFS is a peer-to-peer communication system protocol that is used in networks for data storage, sharing, and retrieval via a distributed file system. We discovered that the PBFT model outperformed the blockchain and PBFT in terms of minimum transaction time in each transaction size. The throughput of proposed method is superior to the previous methods like ACO and CSA models.

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