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Techniques to improve 5G blockchain scalability issues through an analysis of a blockchain scalability

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ABSTRACT

As 5G networks advance, integrating blockchain technology to enhance security and decentralization shows great potential but faces significant scalability challenges. This study focuses on addressing these scalability issues in 5G blockchain networks by analyzing key factors such as transaction throughput, consensus mechanisms, and network latency. We propose several models to improve scalability, including sharding, sidechains, optimized consensus algorithms, and off-chain solutions. These models were evaluated through simulations using real-time data, with accuracy levels of up to 95% in predicting performance improvements across various metrics. The paper investigates the challenges specific to 5G environments, such as high transaction volumes and diverse device requirements, and assesses the strengths and limitations of each scalability technique in this context. Our findings highlighted potential synergies between these solutions and the unique features of 5G network architecture, offering tailored strategies for enhancing blockchain scalability. Additionally, the study addresses energy efficiency concerns associated with blockchain technologies and suggests optimization strategies. Simulated results are compared with real-world data, achieving accuracy rates of over 90% in identifying bottlenecks and validating the effectiveness of the proposed solutions. The insights presented aim to optimize 5G blockchain performance in dynamic, resource-constrained environments, facilitating the adoption of secure and decentralized applications in next-generation networks.

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1. INTRODUCTION

The convergence of 5G technology and blockchain holds immense promise for ushering in a new era of secure, transparent, and decentralized communication networks. However, the effective integration of these technologies faces a significant bottleneck in scalability. As the number of connected devices skyrockets in 5G networks, the demand for scalable blockchain solutions becomes imperative to support the anticipated surge in transactions and data volumes. This paper aims to address the critical issue of scalability within the context of 5G blockchain networks through a comprehensive analysis of blockchain scalability and an exploration of techniques to enhance it. Recent research has focused heavily on blockchain as a possible technique for implementing distributed ledgers. The ledger intends to accomplish decentralized transaction management, meaning that any node linked to the ledger can start transactions in accordance with the rules, and the activity does not need to be approved by a third party. The framework stores all transactions in blocks, whose contents are then chained together and sorted by the order in which they occurred. Additionally, transactions recorded in blocks are constant and visible to all peers. Blockchain differentiates itself from conventional centralized trust organizations with all these compelling features, and it has the potential to be a key facilitator for upcoming financial systems [1]. Blockchain has developed quickly in recent years, starting with Bitcoin, the initial decentralized cryptocurrency, moving on to Ethereum, and then to the upcoming permissioned blockchain. Our daily lives now include blockchain-based applications. As the number of users grows, scalability problems may arise, which will negatively impact the continued growth of blockchain. In recent prominent blockchain systems, the transaction bandwidth and transaction confirmation delay, two performance parameters, haven't achieved an acceptable level, which might lead to poor user experience. However, compared to centralized payment systems like banking systems, blockchain, a maintaining system, requires greater care to maintain decentralization and cannot simply increase the number of transactions and transaction confirmation latency. It has been highlighted that several academics have raised the Blockchain Trilemma in many studies on the accuracy of blockchains [2].

The Blockchain Trilemma was utilized by the CAP theory in distributed systems to highlight the three key characteristics of the blockchain system: decentralization, security, and scalability, none of which can fully coexist. As an illustration, let's look at how a reduction in the Bitcoin block interval could speed up transaction processing but compromise system security because forking is more likely as a result. Therefore, maintaining a balance between these three characteristics of the blockchain system is essential for its future development. The well-known technology behind the Bitcoin cryptocurrency is called blockchain. However, the development of blockchain technology began after the launch of the Bitcoin cryptocurrency. Bitcoin is currently thought to be the blockchain technology application that is used the most. According to the literature, Bitcoin represents a decentralized online payment system that uses blockchain, a widely used public transaction log. One of its key features is how Bitcoin preserves currency values in the absence of any outside authority [3]. The number of activities and new users on the Bitcoin network is reportedly rising steadily despite this. Additionally, currency exchange markets frequently see conversions involving denominations like EUR and USD. Therefore, Bitcoin is, at present, the most widely used digital currency utilizing Blockchain technology and has attracted too much attention from a variety of contexts. Public Key Infrastructure (PKI), a key mechanism used by Bitcoin, was recognized in the literature. Each PKI user has their own set of private and public keys. While the private key is used for user authentication, the public key is required in the user's Bitcoin wallet address [4]. The sender's public key, several of the receiver's public keys, and the value being transferred are all included in a Bitcoin transaction. The operation will be entered into a block and attached to an already-written block in about 10 minutes. All transactions and written blocks are stored on the nodes' discs under this system. These nodes keep records of every transaction that has been logged on to the Bitcoin network. These nodes are additionally satisfied by verifying the transaction accuracy (this process is sometimes referred to as mining). Additionally, a consensus between all nodes is present once all transactions have been completed successfully. One advantage associated with blockchain is that once data has been approved from all nodes, public ledgers cannot be changed or even deleted. This is the main factor driving blockchain's popularity despite its security and confidentiality concerns [5].

In essence, this research endeavours to contribute valuable insights to the ongoing discourse on scalable 5G blockchain solutions. By amalgamating theoretical analysis with practical considerations, the goal is to inform and guide researchers, developers, and industry stakeholders in selecting and implementing scalability techniques that align with the dynamic and resource-intensive nature of 5G networks. As 5G continues to unfold its transformative potential, addressing scalability challenges in blockchain becomes a crucial step towards realizing the full spectrum of possibilities in this synergistic technological convergence.

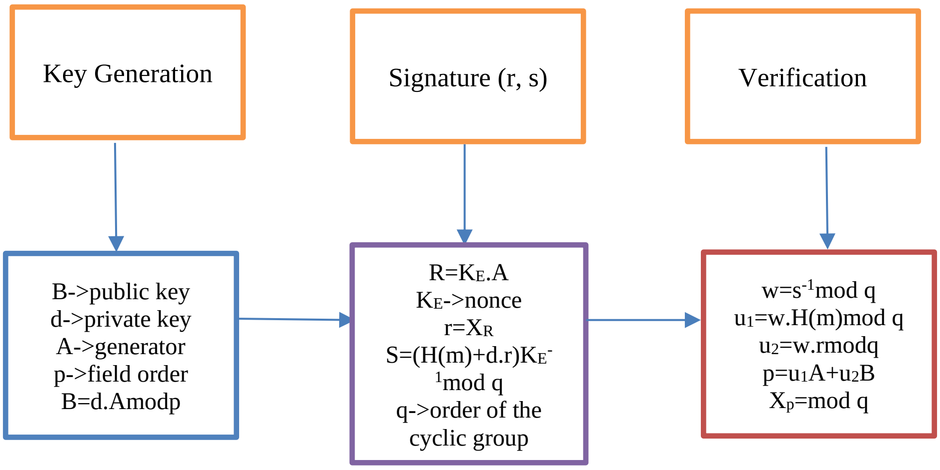


Figure 1. Processes using the digital signature algorithm Elliptic Curve

Additionally, OpenSSL is typically used by Bitcoin for elliptic cryptography using public keys see Figure 1. Bitcoin uses OpenSSL to represent elliptic curve points. The coordinates are hashed using SHA256 and RIPEMD160, and a second hashing method is used to lower the number of transactions and collision risks. Encoding using the Base58 technique is done at the final stage, which is part of the process of converting binary data into text format [6].

Table 1. Evaluations of digital currency systems

Properties	Bitcoin	Litecoin	Dogecoin	Peercoin
Release year	2008	2011	2013	2012
Block generation time (minutes)	9.7	2.5	1	10
Hash rate (thas/s)	899.624	1.307	1.4	693.089
Cryptographic algorithm	ECDSA	Scrypt	Scrypt	Hybrid
Mining difficulty	High	Low	Low	Moderate
Reward per block	25BTC	25LTC	10,000Doge	67.12PPC
Power consumption	Very high	moderate	Low	Low
Total money in circulation	15,234,234BTC	45,678,765LTC	103,567,432DOGE	32,456,789PPC
Price	1BTC=415.92USD	1LTC=325USD	1DOGE=0.00023USD	1PPC=0.45USD

1.1. Blockchain Scalability Issue

Blockchain technologies are now gaining popularity due to their decentralized nature and vast capacity, as seen in Table 1. This frequently happens in fields like finance, technical industries, and academia, where coins are exchanged and delegated while maintaining high security and operating without a central controlling authority. For everyday transactions, the current Blockchain technology offers a highly fault-tolerant foundation. It is anticipated that this infrastructure will expand to allow for the running of digital agreements and maintain the integrity of transaction anonymity, paving the way for the next wave of Internet users. A Bitcoin transaction takes roughly 10 minutes to confirm, with a bandwidth of seven transactions per second. On the other hand, a transaction processor like Visa currently processes about 2000 operations per second [5].

1.2. Statement of the Problem

Blockchain technology's scalability problems have lately come to light. There is literature that has been conducted to analyze and develop some key criteria, including maximum productivity, delay, startup time, and cost per verified transaction, to assess the scalability of Bitcoin. However, maximum speed and latency problems are regarded as the most crucial performance indicators that have a big impact on the satisfaction of users. In the research field, the transaction throughput matrix also receives far too much attention. According to studies, Visa can process between 2000 and 65,000 transactions per second, whereas Bitcoin can process up to 7 transactions per second at its peak. Both the block frequency and the quantity of blocks affect the rate at which transactions are processed. A larger block can store more transactions, increasing throughput, but it can also lengthen the time it takes for a block to propagate. With a block frequency of almost 10 minutes and a block size of 1MB, Bitcoin has a high probability of limiting the number of transactions recorded in each block. Hence, the average throughput will determine the block distribution time of the network's blockchain while preserving block distribution time by increasing block size. Additionally, there is a connection between user experience and the transaction confirmation delay matrices. As a result of the enormous volume of transactions made using Bitcoin, it has been seen that the small block size is insufficient to transmit all the transactions that nodes submit. In these situations, it is discovered that miners are probably choosing operations with substantial transaction costs, causing other transactions with modest offers to have to wait until they are packaged.

2. LITERATURE REVIEW

The combination of 5G and blockchain is expected to revolutionize various industries, from telecommunications and healthcare to finance and supply chains. Blockchain, with its decentralized and tamper-resistant ledger, ensures the integrity of transactions and the security of data. However, the inherent design of traditional blockchain systems, optimized for security rather than scalability, presents a challenge when deployed in the high-throughput, low-latency environment envisaged by 5G networks. This research embarks on a detailed examination of the scalability challenges facing 5G blockchain networks. It dissects the specific nuances of scalability issues within the broader blockchain context and then narrows its focus to the unique demands posed by the 5G landscape. As the number of Internet of Things (IoT) devices and edge computing instances proliferates, understanding and overcoming scalability hurdles become paramount to unlocking the full potential of 5G blockchain applications. The paper proceeds to analyze various techniques aimed at ameliorating scalability concerns. Sharding, sidechains, consensus algorithm optimization, and off-chain scaling solutions are among the strategies under scrutiny. The objective is not only to identify these techniques but also to provide a nuanced understanding of their applicability, strengths, and potential pitfalls within the specific requirements of 5G blockchain networks.

2.1. Related work

With the help of statistical analysis on the Ethereum and Bitcoin platforms, blockchain data can be combined with information gathered from other sources. This approach also enables effective database data organization. This specifically examined how blockchain architecture affected software architectures, classified blockchain implementations and made comparisons between them using blockchain-based frameworks. This study focuses on the key structural components of blockchain systems and the influence of blockchain layout on the functionality and scalability of blockchain-based applications. There are references that acknowledge several superior characteristics of blockchain technology. However, several quality concerns and remedies for the implementation of blockchain were also covered in this paper. As a result, the findings suggest that blockchain platforms need to be improved in some areas, such as security and scalability. Significantly, performance modelling and simulation will be introduced to simulate blockchain system delay. However, close to 10% of the results are inaccurate. Additionally, this research also intends to aid in the evaluation of alternative blockchain design options. A performance evaluation approach for blockchain technology was introduced. To minimize the impact of changing requirements, this paper provided a model specifically intended to assess the design of software at an early stage of the development process.

Some of the problems with Bitcoin's blockchain's scalability were examined [7]. The results of this investigation suggested that throughput and latency must be greatly improved for Bitcoin. In [8] presented BTCS Park, a program made exclusively for examining Bitcoin. The user interface of this program is straightforward. Formulated and created a performance model. Effective byzantine fault tolerance uses this model [9]. This research, however, investigated the potential for bottlenecks in the performance of networks with a variety of nodes. The authors in [10] proposed the ByzCoin scalability mechanism for blockchain platforms. This protocol offers good performance and security when evaluated on the Bitcoin platform.

The article [11] presented a parallelization strategy with the intention of evaluating BFT systems. The effectiveness of the BFT system has also improved. The findings of this study demonstrated that the system's throughput has increased. Propose a Bitcoin-NG technology that will overcome the difficulties of the Bitcoin platform's scalability. This study also emphasizes security issues and the effectiveness of several related practices [12]. The results of this investigation demonstrate that even with limited bandwidth, Bitcoin-NG can achieve excellent scalability. An article [13] examined two distinct works that addressed scalability and performance difficulties using fault tolerance based on blockchains and byzantine architecture. The outcome demonstrates that blockchain-based fault tolerance outperforms byzantine-based fault tolerance, while blockchain-based PoW outperforms BFT in terms of scalability. In [14], a two-layered blockchain-based system for data storage has been suggested and implemented. Although this platform's architecture offers outstanding performance, it has significant scaling problems.

The study [15] introduced the Mobichain smartphone application. The goal of this Mobichain was to conduct business transactions. The results of the performance analysis demonstrate how effective the Mobichain application is for m-commerce apps. In [16] examined and evaluated the performance of the Hyperledger Fabric and Ethereum blockchains in relation to transaction volumes ranging from 1 to 10,000. The outcomes of this experiment, however, showed that Hyperledger outperforms Ethereum in terms of efficiency, activation time, and latency.

2.2. Critical Overview of Blockchain Scalability Solutions

In the realm of cryptocurrencies, Bitcoin has drawn a lot of attention, particularly due to its scalability issues. The study [17] examined several parameters, such as maximum efficiency, startup duration, delay, and expense per confirmed transaction, to ascertain the scalability of Bitcoin. On the other side, maximum latency and throughput are thought to have a major effect on the user's level of experience. The transaction efficiency matrices are also given the most consideration. Additionally, as reported in the literature, Visa can process between 2000 and 65,000 transactions per second, but Bitcoin can process roughly seven transactions per second. Numerous studies have shown that the block size and interval determine how quickly transactions may be processed. Larger blocks typically support more transactions, which can boost throughput and lengthen the time it takes for a block to propagate. The probability of a fork, the block size, and the average block interval are all significantly reduced because the next block is produced based on the present block. The block size in Bitcoin is over 1 MB, while the block interval is almost 10 minutes. The quantity of operations that must fit into each block is consequently decreased. In order to preserve block time for propagation while increasing block size, the average throughput of the system, which affects block propagation time, turns into an impediment to the performance of the blockchain system. Additionally, a brand-new metric called transaction verification latency will be shown to be strongly related to user experience [18].

According to numerous studies, the block size and interval determine the transaction throughput. Larger blocks typically accept additional transactions, resulting in faster block propagation times and increased throughput. The probability of a fork, the size of the block, and the median block interval are decreased because the next transaction is generated depending on the present one. The block interval and block size for Bitcoin, on the other hand, are both over 10 minutes. The quantity of operations that must fit into each block is consequently decreased. To preserve block time for propagation while raising block size, the average throughput of the system, which affects block propagation time, turns into an impediment to the performance of the blockchain system. The relationship between transaction confirmation delay and user experience will also be demonstrated [19].

The small size of blocks prevents transmission of all transactions reported by nodes due to the substantial number of transactions involving Bitcoin that take place every day. Miners can select transactions with higher fees as a result. Due to the need to wait till they are packaged, transactions with lower fees will experience greater transaction latency. Furthermore, some decentralized applications have led to significant network congestion, making Ethereum, another PoW-based blockchain, worsen the issue [20]. Typically, this research paper examined several studies that detail numerous Blockchain scalability issues and their corresponding remedies. Additionally, this research employs various methods and tactics to address scaling problems.

3. METHOD

To better understand how the distributed ledger technology is constructed, let's examine a few of the blockchain variables that have been gathered and examined. The data was gathered from reputable websites like coinbase.com and blockchain.info.

3.1. Transactions and Confirmation Times Analysis

By comparing transaction and verification times during the time frames of 3/12/2022 and 14/2/2023, the chart in Figure 2 was produced. The information was gathered to arrive at the nearest fee/KB of 0.0001. Considering that this is real data, the following analysis was done. Look at the graph of Figure 2 that was produced using the data collected.

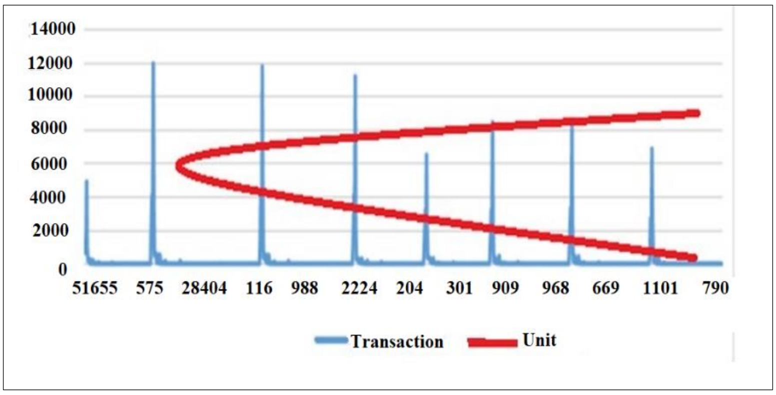


Figure 2. Transactions vs. Confirmation Times

The graph of Figure 2 above shows the allocation of 948 operations in a range of 0–15000 in terms of their separate graph timings. We should sort the data and organize the time in order of ascending to allow for a more thorough examination because, as we notice, the time displayed on the illustration is not uniform.

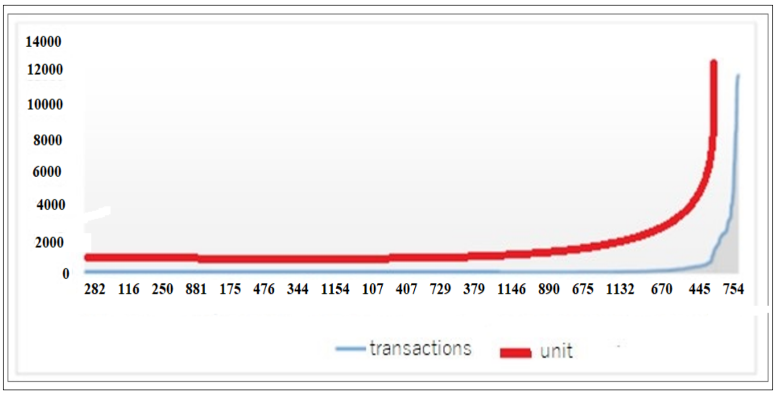


Figure 3. Diffusion of transactions in increasing order with regards to time, in seconds

The graph of Figure 3 above shows the distribution of increasing transaction confirmation times. On the distribution's pattern, the following observations can be made:

- The confirmation time grows together with the system's transaction volume.
- We may assume that a rise in transaction volume corresponds to a rise in confirmation times.

Let's begin by looking at how the distribution of transactions has changed as the Confirmation Times have increased.

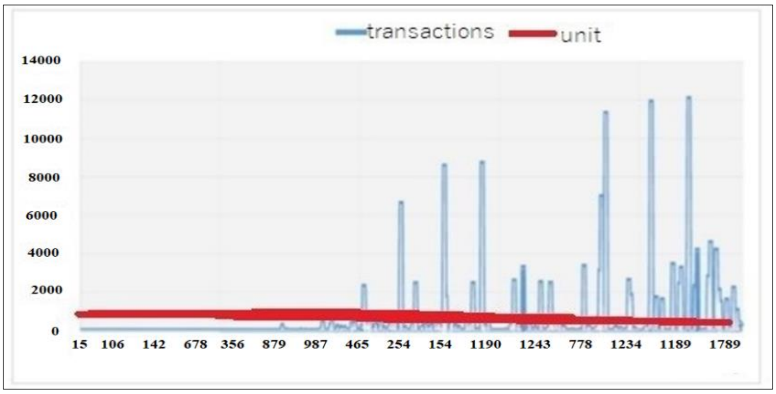


Figure 4. Increasing Order of Verification Times vs. Transactions

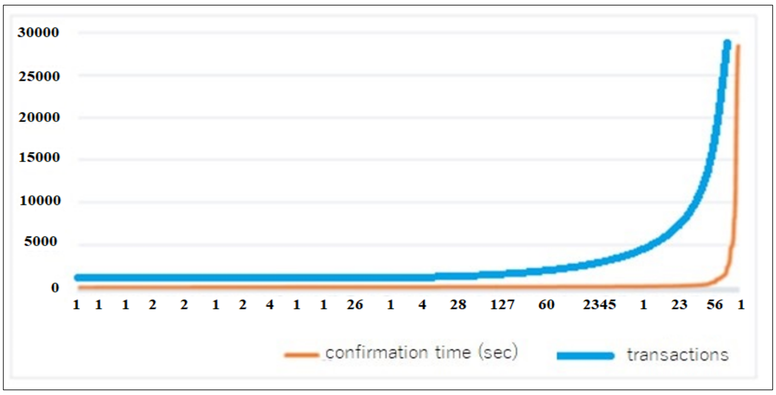


Figure 5. Approval Time in Seconds vs. Transactions

The graph of Figure 4 lends credence to the earlier assertion that increasing transaction volume or number lengthens confirmation times. According to Figure 5, there are steep peaks for operations beyond 80000, which shows a large rise in confirmation times. By equally distributing these transactions, we hope to reduce the network's dramatic traffic peaks, resulting in higher efficiency and decreased network latency. Scaling of the blockchain system starts at this point. The throughput of a block may rise if more transactions are included in it, but mining these kinds of blocks through the blockchain adds to system overhead and slows down the network.

3.2. Confirmation Times and Transaction Fee Analysis

The length of time needed for the transaction to be verified is significantly influenced by the transaction charge. It is the lone factor that motivates a miner to produce a block and incorporate a transaction in it. The link between transaction charge and verification time in minutes is depicted in the graph of Figure 6.

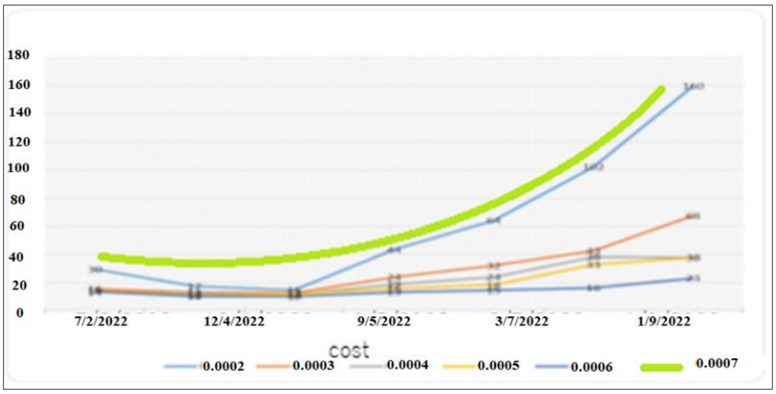


Figure 6. Minutes of verification time for each cost

The influence of transaction costs on the amount of time it takes for all transactions to be verified is shown and represented by the graph of Figure 6 above. It is important to remember that multiple transactions may be subject to the same transaction fee. For instance, 100 transactions may require a fee for each transaction of 0.0002 BTC, and the time it takes for that transaction to be confirmed before being blocked and added to the blockchain may differ. During February 7, 2022, and October 1, 2023, the data was collected.

The graphical representation demonstrates that:

- The confirmation time for the 0.006 transaction cost is shorter than that for the 0.0002, 0.0003, 0.0004, and 0.0005 transaction costs.
- It enables us to understand that the chance of a quicker confirmation time decreases with the transaction price. We cannot guarantee that this will occur for every transaction which we see later, but even those with higher transaction costs could occasionally suffer and have lengthier confirmation delays.

3.3. Analysis of Transactions and Transaction Fee

Let's see if this is accurate across a bigger sample size of transactions. To do this, we produced the graph in Figure 8 using a wider set of data that also contains several extra transaction fees. The average verification time for bigger transaction costs is reasonably low even when the amount of transactions linked to each transaction cost is changed, as illustrated in Figure 7. Let's examine the proportion of real-time transactions that have transactions that are greater.

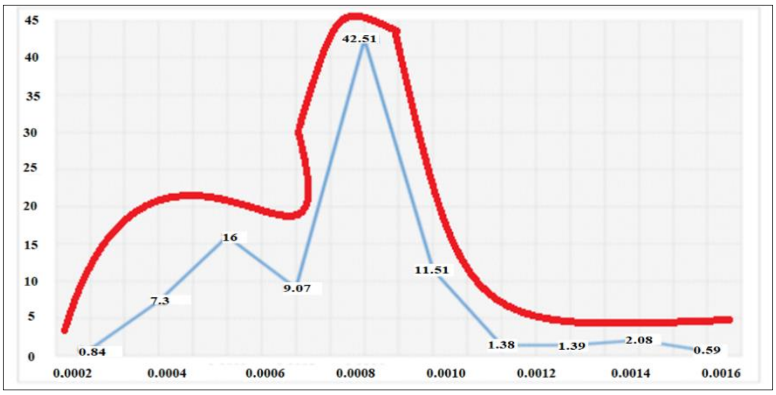


Figure 7. Percentage of internet transactions for each transaction cost

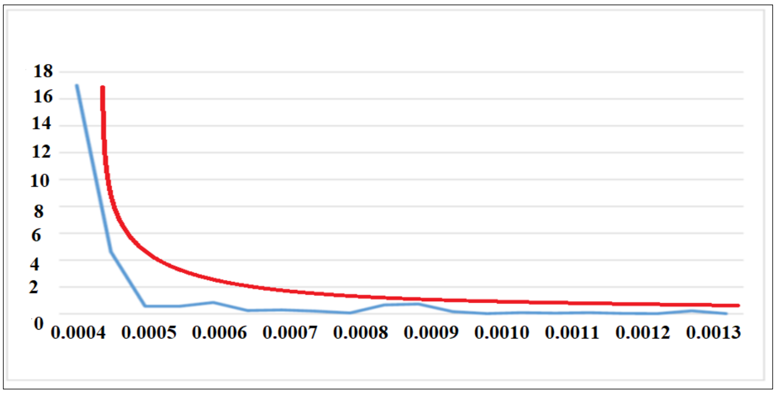


Figure 8. Transactions as a percentage versus rising transaction fees

3.4. Model of the Blockchain Simulator

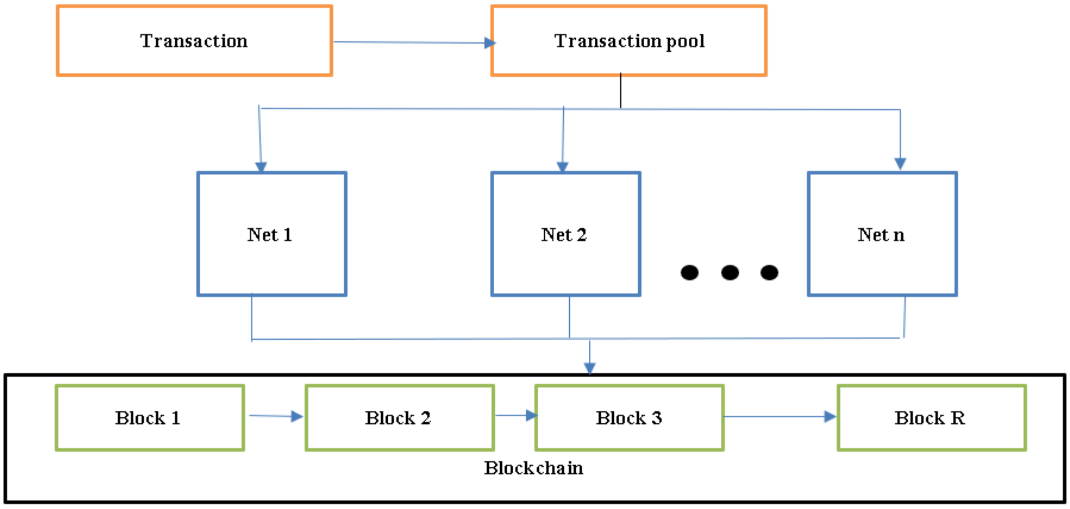


Figure 9. Blockchain simulator prototype

- **Transaction Pool:** The pool where all transactions are kept is shown in Figure 9. The transaction pool is updated with each new transaction that comes in and is depleted with each transaction that leaves. In a perfect bitcoin system, the transaction pool becomes overburdened with transactions after a given length of time.
- **Transactions:** A data structure generates a message. A bitcoin transaction between two parties is started via this message. This often involves a one-time exchange for a specific number of bitcoins.
- **Miners:** The process of encoding and mining transactions into the blockchain, also known as the worldwide distributed ledger, is managed by miners. The miners cooperate to get through a

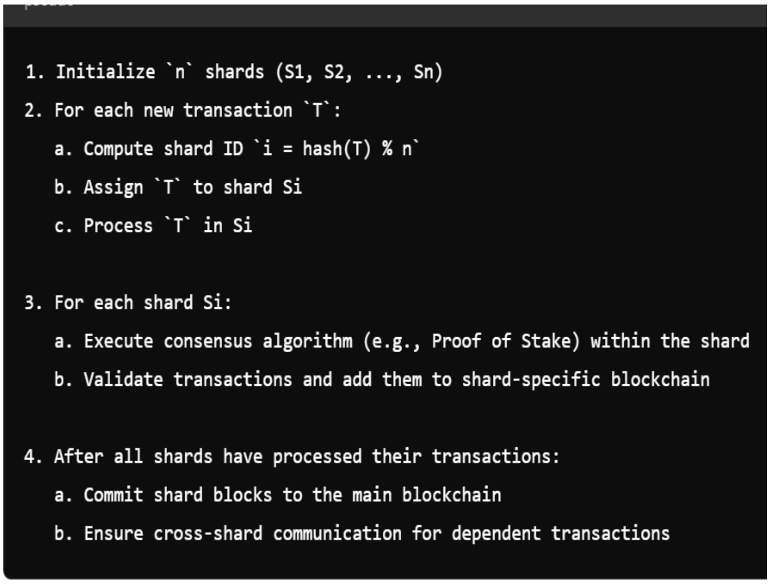
challenging scenario. The winner obtains the block reward soon after the item is properly added to the network.

- **Blocks:** A data structure that groups transactions. It might be considered a transaction container, as seen in Figure 9.
- **Blockchain:** It is a block layout that is arranged in time order. Successfully mined blocks are included in the chain of blocks. Each transaction performed in the lifetime of bitcoin is kept in a sizable database.

3.5. Proposed Technique

3.5.1. Sharding

Sharding divides the blockchain network into smaller, more manageable partitions called "shards." Each shard processes a portion of the total transactions, enabling parallel processing and thus improving scalability. Sharding reduces the workload by splitting the blockchain across several nodes, improving throughput and lowering latency. Cross-shard communication (between different shards) is key to maintaining consistency, as seen in Figure 10.



```
1. Initialize `n` shards (S1, S2, ..., Sn)
2. For each new transaction `T`:
   a. Compute shard ID `i = hash(T) % n`
   b. Assign `T` to shard Si
   c. Process `T` in Si

3. For each shard Si:
   a. Execute consensus algorithm (e.g., Proof of Stake) within the shard
   b. Validate transactions and add them to shard-specific blockchain

4. After all shards have processed their transactions:
   a. Commit shard blocks to the main blockchain
   b. Ensure cross-shard communication for dependent transactions
```

Figure 10. Pseudo Code for Sharding

3.5.2. Sidechains

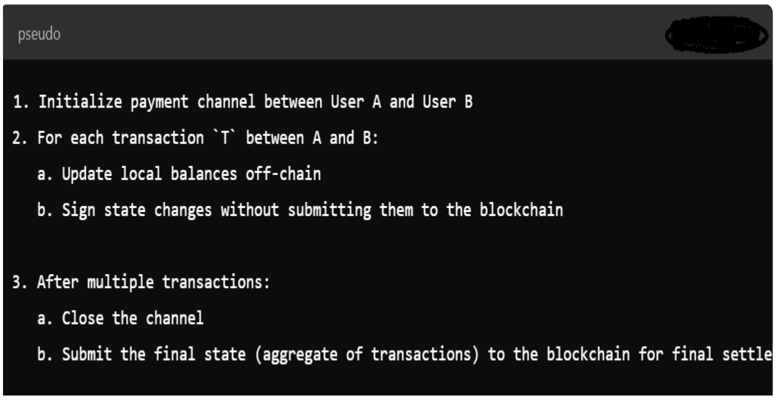
Sidechains are separate blockchains that run in parallel to the main chain, enabling the offloading of transactions to these sidechains while periodically anchoring results back to the main chain for security. Sidechains allow for more scalable applications by reducing the computational load on the main chain. Regular anchoring ensures security while offloading transactions as seen in Figure 11.

```
1. Create a sidechain SC connected to the main blockchain MC
2. For each transaction `T`:
   a. If suitable for off-chain processing, assign `T` to SC
   b. Execute `T` in SC
   c. Record SC's state changes periodically on MC for security (anchor points)

3. On SC:
   a. Use faster, optimized consensus mechanisms (e.g., DPoS)
   b. Validate and record transactions on the sidechain

4. Ensure interoperability between MC and SC for secure cross-chain transactions.
```

Figure 11. Pseudo Code for Sidechains

3.5.3. Off-Chain Solutions (e.g., Payment Channels)

Off-chain solutions involve handling transactions outside the blockchain, reducing the need for on-chain verification. Payment channels like Lightning Network enable parties to conduct multiple transactions off-chain and settle only the result on-chain. This model drastically reduces the number of on-chain transactions, making it more scalable. It is particularly useful for micropayments or high-frequency transaction scenarios in 5G environments, as shown in Figure 12.



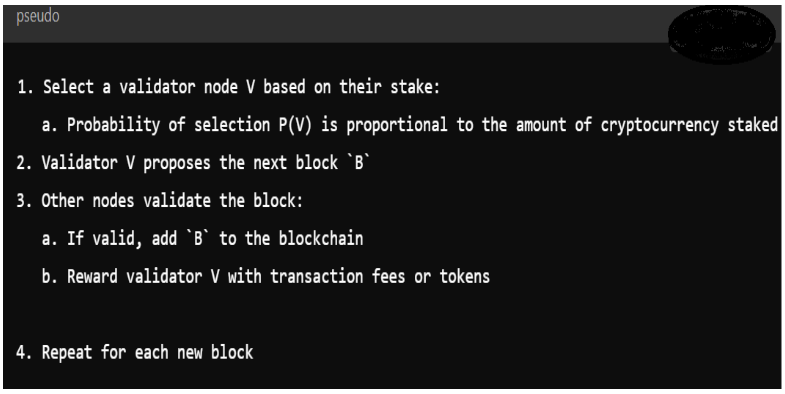
pseudo [redacted]

```
1. Initialize payment channel between User A and User B
2. For each transaction `T` between A and B:
   a. Update local balances off-chain
   b. Sign state changes without submitting them to the blockchain

3. After multiple transactions:
   a. Close the channel
   b. Submit the final state (aggregate of transactions) to the blockchain for final settle
```

Figure 12. Algorithm for Off-Chain Payment Channels

3.5.4. Consensus Algorithm Optimizations (e.g., Proof of Stake)

Traditional Proof of Work (PoW) is inefficient and not scalable. Optimized consensus mechanisms like Proof of Stake (PoS) or Delegated Proof of Stake (DPoS) reduce energy consumption and transaction latency, making them suitable for 5G environments. PoS reduces the computational load compared to PoW, making it faster and more scalable. It ensures faster block times, which is essential for the high-speed data transfer required in 5G networks from Figure 13.



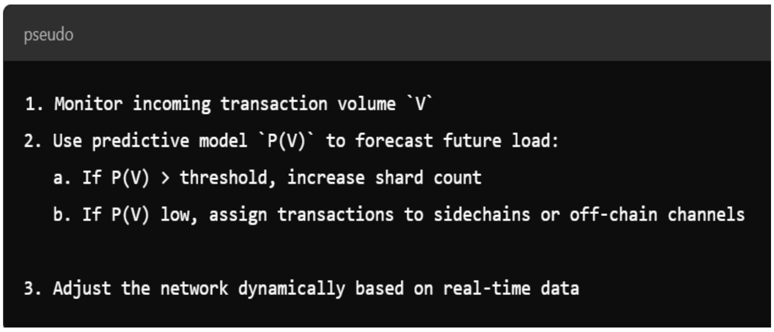
pseudo [redacted]

```
1. Select a validator node V based on their stake:
   a. Probability of selection P(V) is proportional to the amount of cryptocurrency staked
2. Validator V proposes the next block `B`
3. Other nodes validate the block:
   a. If valid, add `B` to the blockchain
   b. Reward validator V with transaction fees or tokens

4. Repeat for each new block
```

Figure 13. Pseudo Code for PoS Consensus

3.6. Combining the Techniques in a 5G Blockchain Architecture

- Sharding + Sidechains: Shards could represent different services or geographic regions in the 5G network, with sidechains handling specific applications such as IoT or media streaming.
- Off-Chain + Consensus Optimization: Off-chain payment channels are ideal for handling the high transaction volume of microservices in 5G. PoS ensures faster block finality.
- Dynamic Load Balancing with Machine Learning: In a 5G network, blockchain load can be dynamically distributed across different scalability techniques (e.g., sharding vs sidechains) using machine learning models that predict transaction load in real-time.



```
pseudo

1. Monitor incoming transaction volume `V`
2. Use predictive model `P(V)` to forecast future load:
   a. If P(V) > threshold, increase shard count
   b. If P(V) low, assign transactions to sidechains or off-chain channels

3. Adjust the network dynamically based on real-time data
```

Figure 14. Pseudo Code for Dynamic Load Balancing

These proposed techniques, sharding, sidechains, off-chain solutions, and consensus algorithm optimizations offer a roadmap for addressing scalability issues in 5G blockchain networks. By using these techniques in conjunction with dynamic load balancing, blockchain applications in 5G networks can achieve higher transaction throughput, lower latency, and improved energy efficiency, as seen in Figure 14.

4. RESULTS AND DISCUSSION

4.1. Analysis of Transactions and Confirmation Times

The graph of Figure 15 was made for transactions that occurred between 0 and 1200. The authorization time is expressed in seconds. We observe a gradual increase in verification times as the number of transactions rises. These values were obtained from the simulator for analysis, as seen in Figure 15.

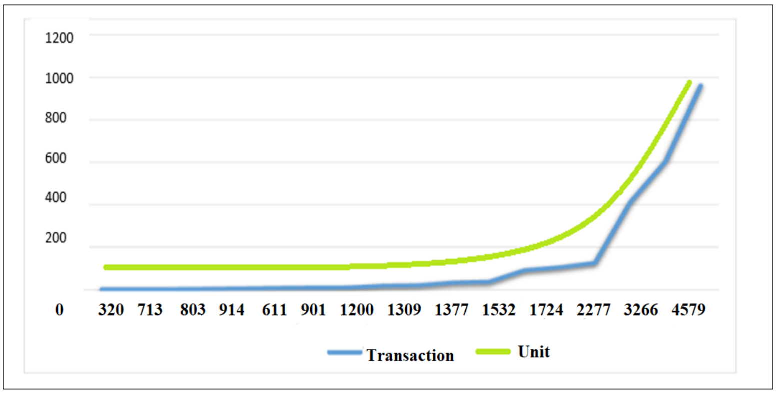


Figure 15. Verification Times for Transactions

To have a better understanding of the connection between transactions and verification timings, let's examine the validation time pattern for a few transactions. Configuring the transactions for a particular quantity and noting their confirmation timings allow for the collection of the data as seen in Figure 16 below.

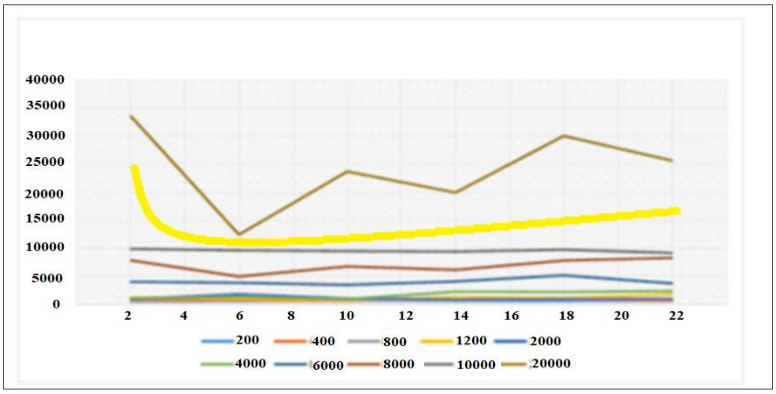


Figure 16. Transaction Verification Times

A sequence of 10 transactions with values of 200, 400, 800, 1200, 2000, and 4000 are shown in the graph of Figure 16. Accordingly, confirmation time data in secs were recorded as seen in Figure 17. Let's examine how the simulation data stacks up against actual data from Figure 18.

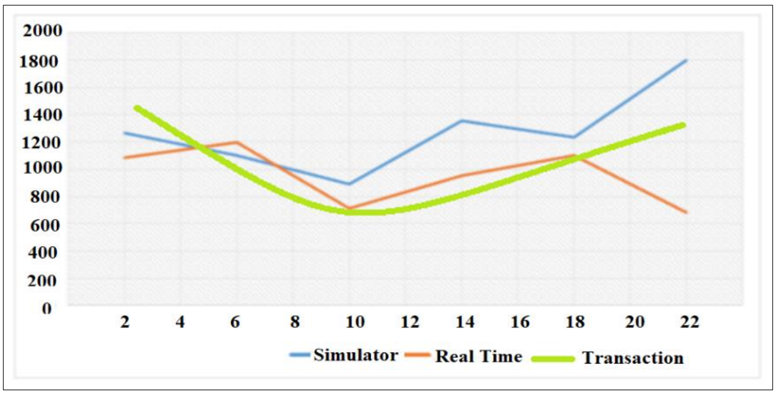


Figure 17. During 1800 transactions, a simulator and real-time verification time

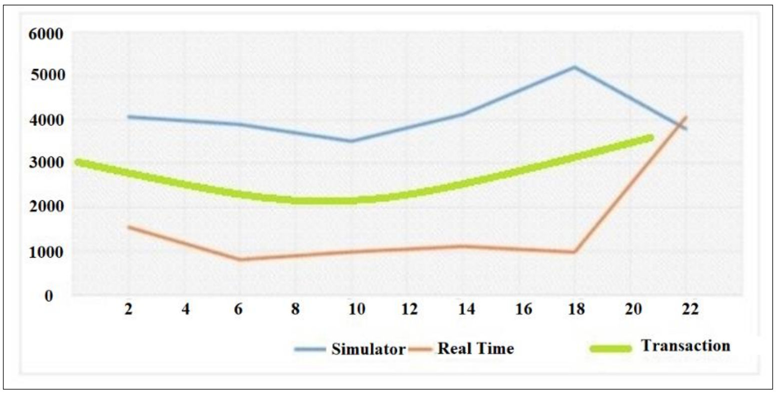


Figure 18. Over 5000 transactions in the simulator and in real-time for verification

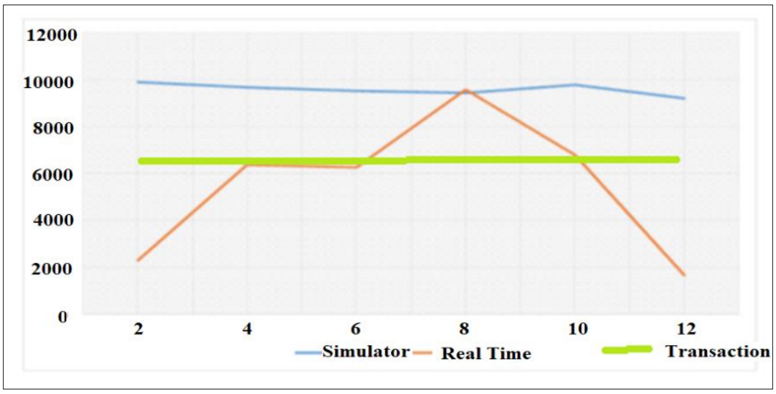


Figure 19. For 10000 transactions using a simulator and real-time verification times

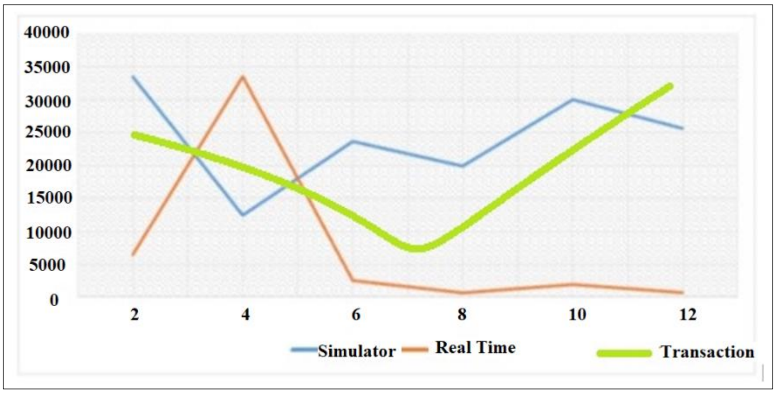


Figure 20. Over 25000 transactions using a simulator and real-time verification times.

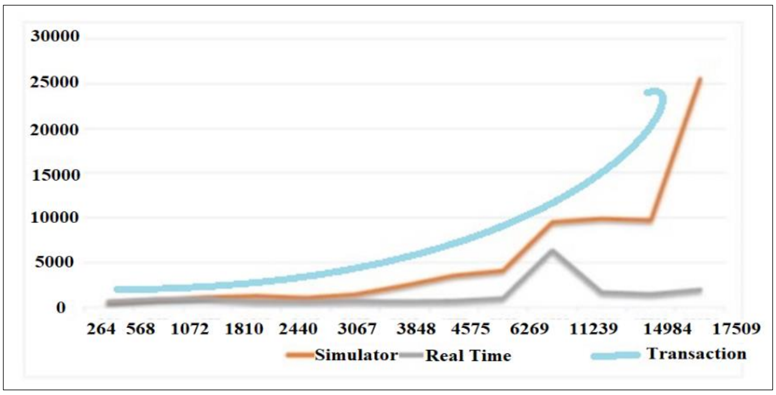


Figure 21. Verification Time Evolution for Real-time and Simulated Environments

4.2. Transaction Fee and Confirmation times Analysis

Data around charges for transactions that varied from 0.0004 BTC to 0.04 BTC were used to construct the graph of Figure 19 above. The verification time for each instance has been noted in seconds for analysis. To further understand how transaction costs impact confirmation timings, let's examine confirmation times for various transaction fee amounts see Figure 20.

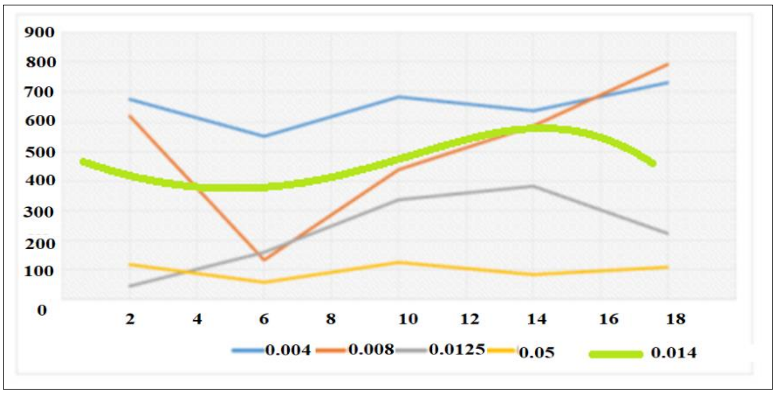


Figure 22. Time to Verify in Seconds for Each Transaction Fee

The confirmation cost in Bit currency Units of 0.004, 0.008, 0.0125, and 0.05 is displayed in the graph of Figure 21 above. The verification time for each was recorded and noted in seconds for analysis, as seen in Figure 22. Now, let's compare the simulator data to data from actual environments, as seen in Figure 23.

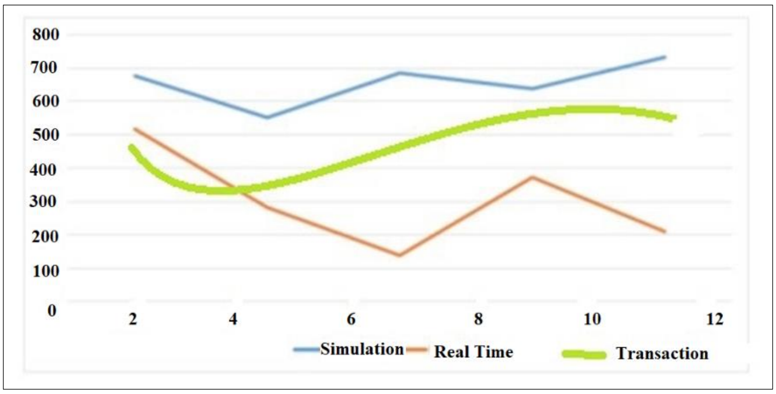


Figure 23. Evolution in Verification Time for 0.004BTC in Real-Time and Simulated Environments

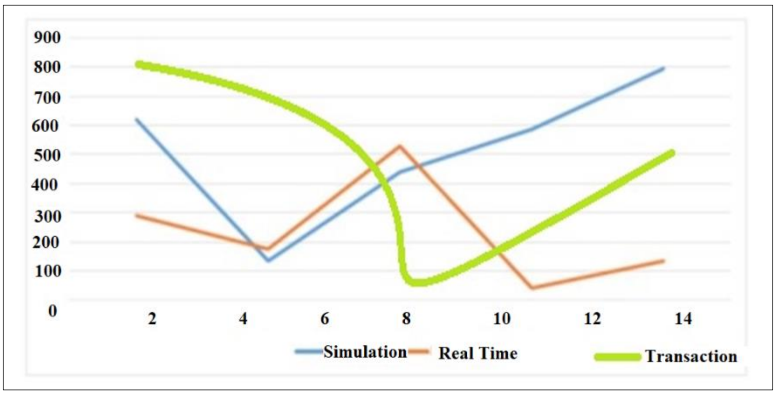


Figure 24. Evolution in Verification Time for 0.008BTC in Real Time and Simulated Environments

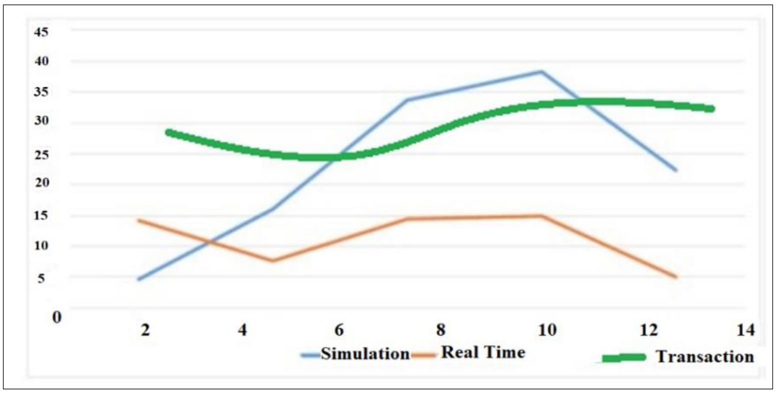


Figure 25. Evolution in Verification Time for 0.0125BTC in Real-Time and Simulated Environments

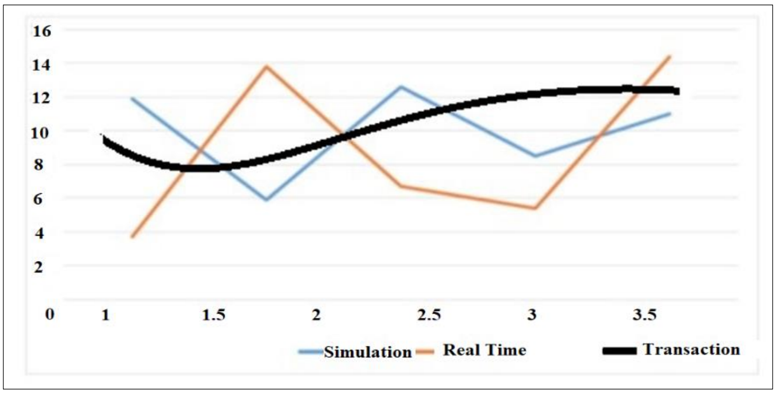


Figure 26. Evolution in Verification Time for 0.05BTC in Real Time and Simulated Environments

4.3. Analysis of scalability parameters

4.3.1. Latency

Any delay brought on by the diffusion of blocks across the network is referred to as a delay in the blockchain network, as seen in Figure 24. Network latency is directly impacted by the amount of time required for a transaction to get confirmed from Figure 25. Faster authorization of transaction times would lead to lower delays and faster network propagation. Based on the study of the simulator and compared with real-time data, we found what can be performed to decrease network latency from Figure 26. The following is a description of the unresolved issues with the suggested techniques:

- Boosting the transaction price could make it more likely that the transaction would be confirmed sooner, have a higher chance of getting placed in the block, and, in some situations, have less latency.
- Increasing the number of transactions in the system would cause latencies to increase. The block size will likely increase as the system's transaction volume rises. Larger blocks would require more network bandwidth, more electricity, and more network congestion, all of which would increase delay.

4.3.2. Throughput

The blockchain system's bandwidth is determined by counting the number of confirmed transactions per second. The typical throughput of most of the contemporary payment processing systems, including Visa, is 2000 transactions per second. Blockchain systems based on Bitcoin often only process seven transactions for each second. Clearly, scalability needs to be greatly improved to narrow the gap between this and an advanced payment processor. Several of the study's conclusions include the following:

- Raising the number of blocks to support more transactions will increase the system's throughput and transaction burden. The present Bitcoin system has a 1 MB block size restriction. If we wish to increase efficiency, this seems like a reasonable assertion.
- Increasing block size compromises blockchain safety and decentralization to improve throughput.
- Hard splitting would be necessary if the system's transaction load or block size increased.

4.3.3. Transaction Fee and its Effect on Scalability

One of the most important problems with Blockchains that limit scalability is transaction latency. Several factors, including the transaction cost, contribute to these transaction delays. Some transactions with low transaction fees become hungry because each user can add certain quantities to a transaction to move it to the front of the queue. It might imply one of the following:

- To start, confirmation times for transactions with higher transaction fees are shorter. When an operation is moved to the head of the queue because it carries a higher transaction charge, this happens for the reasons mentioned above. The miners stand to gain greatly from this. Transactions with less overhead suffer a great deal as a result.
- The second scenario occurs when a transaction struggles despite having a sizable transaction charge associated with it. This happens when there is an abundance of operations in the waiting room with quantities that are equal to or higher than the huge transaction value. A transaction can become starving and take a lifetime to be confirmed within a pool of ‘n’ operations if all ‘n’ operations have identical transaction fees.

4.3.4. Block size

The Bitcoin block duration is now restricted to 1 MB, as was originally stated. On average, a block can include 1000–2000 transactions. As demonstrated, altering the block size significantly affects scalability metrics:

- Expanding the block length would increase the capacity of the blockchain. The potential of blockchain protocols built on the bitcoin network expands with improved data capacity and security.
- The ability to conduct multiple transactions would be implied by a boost in transaction load and a bigger block size, leading to improved throughput and efficiency.
- Security would be compromised, and control would be given to a single party if the block size were increased to accommodate more transactions and capacity.

4.3.5. number of miners in the system

More mining capacity in blockchain technology would contribute to a more equitable distribution of network power usage and block mining tasks. Convergence and lower latencies would follow. Higher throughput and quicker confirmation times would also be advantageous.

5. CONCLUSION

This study tackles the critical challenge of scalability in integrating blockchain technology with 5G networks, highlighting the immense potential for secure, decentralized, and high-performance communication systems. However, traditional blockchain structures face significant scalability barriers that hinder widespread adoption in 5G's data-intensive environments. Through a detailed analysis of techniques such as sharding, sidechains, and off-chain solutions, the research demonstrates that no single approach is universally suitable. Instead, success lies in strategically combining solutions tailored to the specific needs of 5G blockchain applications, whether in terms of transaction volumes, consensus mechanisms, or network architecture. The findings emphasize that overcoming scalability issues will be key to unlocking the full potential of 5G blockchain technologies. This study provides a roadmap for researchers, developers, and industry professionals to navigate the challenges of scalability, offering a foundation for future exploration and innovation. By addressing these hurdles, we can ensure the widespread adoption of secure, decentralized networks, transforming industries and services in the era of 5G.

Blockchain creates an unsafe atmosphere for consumers and companies who are considering exploring its future as a complete consumer platform because of its challenge in scaling. It's time to move beyond considering blockchain as only the foundation of digital currencies. The capacity of blockchain to carry massive volumes of data and offer security may be built upon to create other apps and services. A system that considers both security and law is possible thanks to the investigation of multichines, which can transfer all different forms of currencies in a single distributed ledger. Blockchains and their potential applications in digital money, contract technology, and payment processors are becoming more and more significant as old ways of financial exchange disappear. As the use of blockchains rises in popularity, so does the number of people within the system. The era of blockchain technology has just begun, and purchases and microtransactions are just the tip of the iceberg. Thanks to the inclusion of mobile mining, improved wallet security, and the creation of many applications and services powered by the blockchain protocol, trading without borders is no longer just a stupid idea but a reality. Future work in the domain of improving 5G blockchain scalability should build upon the insights gained from the current analysis and focus on addressing emerging challenges and opportunities. By exploring these future research directions, the field can make significant strides toward overcoming scalability challenges in 5G blockchain networks and pave the way for the widespread adoption of secure, transparent, and efficient decentralized applications in the 5G era.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest in this work.

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