Integration Of Blockchain and Edge Computing to Improve The Scalability and Latency

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ABSTRACT: - The core technology of cryptocurrency is blockchain which has attracted a lot of attention. This technology has been adopted in many real-time applications. Still, there is an expandable scalability barrier to the blockchain, that bounds its capability to support amenities with recurring transactions. Edge Computing, on the other hand, has expanded to distribute cloud resources and services across the network, however at this time facing challenges in the management of distributed environment and security. The combination of blockchain with EDGE computing solves such type of problems and gives secure reliable access, improving scalability by reducing the latency time, data storage, and control of decentralized networks. In this study, we describe and discuss the research challenges and combination of edge computing and blockchain system. We find some key features of the incorporation of blockchain and edge computing with some broad theories explored.
Keywords: Blockchain Computing, Scalability, Latency, Integration of Blockchain and Edge Computing, Distributed Environment

1. Introduction

The first blockchain article entitled "Bitcoin: A Democratizer-to-Peer Electronic Cash System" was published in October 2018, by Satoshi Nakamoto. Blockchain has numerous characteristics, for example, trust-free, decentralized, transparent, democratic, automated, anonymous, and secure11]. Despite these characteristics, scalability is as yet a basic boundary when blockchain innovation is broadly utilized in a real-time environment for business conditions. In this paper, we discuss what is scalability the issues related to scalability, what is performance, and how to measure and effect of scalability on latency and give a concise review of ongoing examinations on adaptable blockchain frameworks. The scalability issues are discussed from the perceptive of latency. Although researchers are considering powerful empowering innovations to acknowledge adaptable blockchain frameworks. However, most existing empowering advancements just spotlight improving scalability yet give up other significant characteristics, for example, distributed environment, security, or invariability [12]. Further, there exists a gap and existing technologies do have not all the characteristics of blockchain. This recommends while implementing these tools, we should choose the most reasonable one as indicated by the necessities of uses and the requirement framework conditions [12]. The performance of the blockchain is based on different parameters like Block size, block time, no of transactions, and throughput performance. In the following section scalability issues are discussed, the relationship between scalability and latency, how latency affects the scalability, and then enabling technologies for scalable blockchain systems are discussed.

1.1 Scalability Issues

While applying blockchain technology in real-time environment scalability is the obstruction and important metric. This section mainly focused on the issues related to scalability from the points of view of latency, throughput, networking, and storage. Latency alludes to the wait time which is required till the transaction is processed. For the consensus of a transaction verification a vast number of nodes need to reach in distributed decentralized public ledger and for the consensus to proceed with the transaction every node in the ledger requires access to the whole blockchain. This would mean a huge database is required after some time. Giving access to the whole blockchain to many nodes create a delay time and the system performance affects the number of transactions increases the latency decreases which affects the scalability. Blockchain structure throughput is related to the number of exchanges in each endless block time. Bitcoin blockchain makes some square memories outline around 10 minutes, and the number of exchanges is reliant upon the size of each square, which is normally one megabyte (1MB). In the run of the mill blockchain structures, each hub should process and store them all out exchanges. In this way, the execution of the blockchain continuous climate is confined by limited and restricted processing assets, likewise in the blockchain framework, each hub has relied upon all exchanges. The method of information transmission can't be increased to manage a tremendous measure of exchanges on the grounds that the constraint of the data transfer capacity assets of the organization and furthermore improve the square engendering delay.

2. Background

For scalability and latency issues different studies have been done and some researchers provide solutions to these problems. PBFT consensus algorithm assumes that below one-third of nodes are harmful. A leader selects the order of the transactions for each node that is added to the chain. For such type of a selection, at least 2/3 of all the nodes must be supported, which must be identified through the network. Delegated Proof-of-Stake (DPoS) has a little bit different from PoS as it selects specific delegates for the creation and validation of blocks rather than being the one generation and validation of blocks. All the nodes contribute to Transactions as Proof-of-Stake (TaPOS) to make transactions for the safety of the network. Proof-of-Stake Velocity (PoSV) concept is based on the velocity of money in a certain period. In Delegated BFT (DBFT) certain nodes are selected to be the ones creating and authenticating blocks. As of now, the scalability issues, particularly the constraints of high latency, low throughput, and asset depletion spoil the practicality of any blockchain-based systems. For this, different studies have been done to tackle these issues some researchers provide the solutions like Practical Byzantine Fault Tolerance and different variants like DPoS, TaPoS, PoSV, DBFT, and Bitcoin-NG, choose some ones to make and authenticate blocks to enhance the scalability, throughput, and latency [16].

2.1 Existing Technologies for Blockchain Scalability

This section represents the existing technologies that are designed for scalable blockchain systems which are built on the study in the earlier section. Latency is related to the transmission medium, propagation, and storage delays. High latency can bottleneck a system diminishing its performance.

2.1.1 Increase the size of the Block.

Throughput increases as the block size increase because many transactions include in every block but at the same time propagation delay occurs because nodes require more time to spend on each block for the confirmation and process of transactions.

2.1.2 Reduce the Size of Transactions

Another solution for the scalable blockchain system is to increase the transactions in every block by keeping the chunk of information in each transaction to reduce the size of the transaction. As digital signatures are used for the validation and verification of transactions, SegWit separates out the signature and data of each transaction and moves the digital signatures, to reduce the size of the block. Through this block can maintain additional transactions.

2.1.3 Reduce the Number of Transactions Processed by Nodes

To improve the blockchain performance and make it stable by decreasing the number of transactions that are handled by different nodes for this Off-chain, Sharding, and Decoupling management used.

2.1.4 Off-Chain Transactions

This concept is based on frequent transactions made by nodes. In between nodes, the micropayment channels are generated to quickly control the chain multi-signature transactions and just final agreement, or approved transactions are passed on the blockchain. Lightning Network [17] and Duplex Micropayment Channels [18] are two executions of off-chain transactions. An important distinction exists in between which is Lightning Network has requirements to submit some data to the blockchain network for the updating of each micropayment channel. Interestingly, Duplex Micropayment Channels bolster the updating of micropayment channels atomic and empower the allocation of beginning assets over the diverts off the blockchain commonly.

2.1.5 Sharding

Sharding is a powerful procedure to increase the level of scalability of blockchain. With sharding, peers are divided into various shards and each shard processed a chunk of data from all transactions. Through this, the processes of transactions are in parallel. In shard, the consensus algorithm is based on Byzantine consensus algorithms for transition approval. For cross-shard transactions, the protocol should be designed for the process that is inter-shard communication. In this system, as the nodes are added to the framework the throughput increases directly. The sharding blockchain frameworks two examples are Elastico [19] and Omni Ledger [20]. The essential qualification in the middle is that in Elastico between shard convention exchanges can't be made do, while they can be taken care of microscopically by Omni Ledger using an Atomic Commit Protocol.

2.1.6 Decoupling Management/Control from Execution

Virtualization for Distributed Ledger Technology (vDLT) [21] explicitly reviews the QOS necessities of different conveniences and applications by decoupling the administration/control and execution of brilliant agreements. The decoupling of the administration/control from execution should be conceivable through virtualization, with that different basic DLT structures with changing characteristics can be effectively made on a comparative substrate DLT system to oblige assorted QOS necessities.

Most of the attention has been directed to the production of systems that are both safe and intelligent, and that is able to identify and respond to a broad variety of problems. A few of the research approaches are Deep Learning Approach [23], An Adaptive Approach [24], Hybrid Computational Approach [25], a Supervised Machine Learning Algorithm [26], a Deep Extreme Learning Machine [27,28,29], Machine Learning Techniques [30,31], Bio-inspired Neuro-Fuzzy [32], Fuzzy Inference System [33,34], and Attention Mechanism [35] which opened a new era for the researchers.

3. Problem Statement

In a real-time environment, the implementation of the blockchain-based system becomes problematic because the performance of the blockchain is affected by scalability which is the key hurdle. In this paper, we discuss what scalability the issues related to scalability are, what is performance, and how to measure and effect of scalability on latency and give a concise review of ongoing examinations on adaptable blockchain frameworks. The scalability issues are discussed from the perceptive of latency. Further, the study is dependent on how the application is developed. What type of hardware, network configuration, languages, etc., are required to build the application?

3.1 Research Questions

What are the ways to reduce the latency in blockchain technology to increase scalability?

What are the factors that affect latency and scalability?

4. Methodology

For the enhancement of scalability and latency, the incorporation of blockchain and edge computing trend is increasing [13-15]. Edge computing helps the consumer by giving calculation control, and data storage, keeping up low latency, holding on to diversity, and increasing the Quality of Service (QoS) of the applications, particularly the compute-intensive and delay-sensitive ones. By integrating blockchain and edge computing network, the structure can offer consistent approach and control, storage and computation on huge amount of edge nodes. This combination offers the system with effectively computational and storage resources disseminated at the network edge, that proficiently get rid of the blockchain storing and mining computation from the power-limited devices. Moreover, the off-chain storage and computation at the edges permit the scalable storage and computation on the blockchain.

4.1 Edge Computing Architecture

The configuration of edge computing is distributed into different levels like end device, edge server, and core cloud. This grading signifies the computational capacity of edge computing components and their features. End devices deliver extra cooperative and improved responsiveness for customers. Nevertheless, because of restricted capacity, source requests need to send to their servers. Edge servers can maintain maximum traffic flows in networks along with many source requests, for example processing of data in real time environment, caching of data, and offloading computation. Consequently, edge servers deliver improved performance for consumers with a little bit increase of latency. Cloud servers offer extra powerful computing and additional storage of data with latency transmission. The aim of proposed design is to implement the compute intensive and delay-sensitive part of an application in the edge network, and there are few applications in the edge server which interact to the main cloud for data management.

4.2 Specification of Edge Computing

4.1.1 Low latency

Edge computing keeps communication and data information in efficiently manners in both senses physically and logically. It regularly has several meters broadcast distances for the peer-to-peer transmission or small networks and is liberated from unnecessary wait in backhaul system and Internet broadcast. Edge processing has the capability of acknowledging tangible level latency for some critical latency-based applications which might need tangible speediness with 1ms approaching latency.

4.1.2 Scalability

Edge computing balances to an enormous collection of sites, also it is a less expensive approach to accomplish scalability rather than strengthening servers in the corporate focus.

4.1.3 Design of the System

Proposed design has three layers named as blockchain based distributed cloud layer, peer-to-peer edge layer and local network (device layer) which is shown in Fig. 1 below. The proposed design implements the similar layers of architecture of edge computing however upgraded with a Peer-2-Peer availability of devices for every layer to give extra storing capability and calculation ability. The device layer consists of peer-to-peer connection of end-users' devices where data originates. They use these resources in the P2P edge network. The middle layer that is edge layer consists of edge servers and storing facility which are linked in peer-to-peer mode. This way provides the extra storage, establish robust network and keep-away the system from point of failure. Further, it is responsible for temporary storing of data, real time processing of data, data analytics, communication handling which are performed in individual nodes. The blockchain based cloud layer consists of robust solutions to give continuous analysis of data, storage, communication and well reporting. The resources which are used in cloud configured as nodes on blockchain for the confirmation of data integrity and privacy in the system.

4.1.4 Local Network or Device Layer

The end layer which is also known as device layer which is consists of peer-to-peer connection of end user devices that can contribution in blockchain system. These devices exchange the information among each other as a sources or consumer of devices data. The device layer constitutes of smart devices with data sensors and actuators for data gathering and data sharing with other nodes or to process data to upper layer. Communication mechanisms can be done by edge servers or peer-to-peer decentralized network.

4.1.5 Peer-to-Peer Edge Server

Edge layer encompasses cloud to fetch facilities quicker to destination devices for the improvement of performance, scalability, and low latency. The edge servers spread the messages or information among different devices for the use of preferred sources to smart devices for the creation of multiple copies of information and synchronized processing of information. In this layer blockchain is used in edge server for the distributed environment for secure data transmission through the network. Alongside message passing in the system, the edge nodes are used for the achievement of self-organization. The edge nodes investigate the other peers themselves in dynamically adding and removing of nodes. They additionally process the information and forward that information to storage it long-lasting in distributed cloud or they can throw back data to end nodes according to the requirements. In this layer the peer-to-peer design makes a pool of sources for temporary storage, faster communication and data analytics. For the consensus protocol which is used to authenticate the devices requirements to computation and storing purpose. Smart contracts are used for this purpose and in a public blockchain Ethereum is highly suitable for lower latency and high throughput for large range of peer to-peer networked edge servers and distributed sources on the cloud.

4.1.6 Blockchain based Cloud.

The cloud layer is principally intended to give "services" for storing purpose or data computation however in this structure, it could likewise be handled as a peer in blockchain network equipped for the contribution in the mining procedure. Facilitating gigantic repository and calculation, consensus mechanism in disseminated blockchain considered essential for cloud layer to give safe, cheap and convenient approach to give good quality services. In cloud layer peers are not dependent on data and by using blockchain technology all the records and duplication of records are maintained can be shared among them.

4.1.7 Justification

For the improvement of scalability and latency the combination of blockchain and edge computing is the best solution. Edge computing helps user by given computation power, data storage, keep up low latency, maintain diversity, and increase QoS of applications, particularly the compute-intensive and delay-sensitive ones. However, already proposed solutions like Shardinig, Bitcoin-NG etc. have their own limitations like in Sharding the two problems are still unsolved placement of transactions into different shards and how to make it efficient for cross-shard transactions. As multiple shards are involved in the crosssharding transactions that consumes extra bandwidth and extensive confirmation delay time that's why an efficient protocol is required to decrease the latency confirmation [22]. Further, Bitcoin-NG scales optimally, however it is restricted by bandwidth of the peers and the latency associated to the propagation time of the network [16].

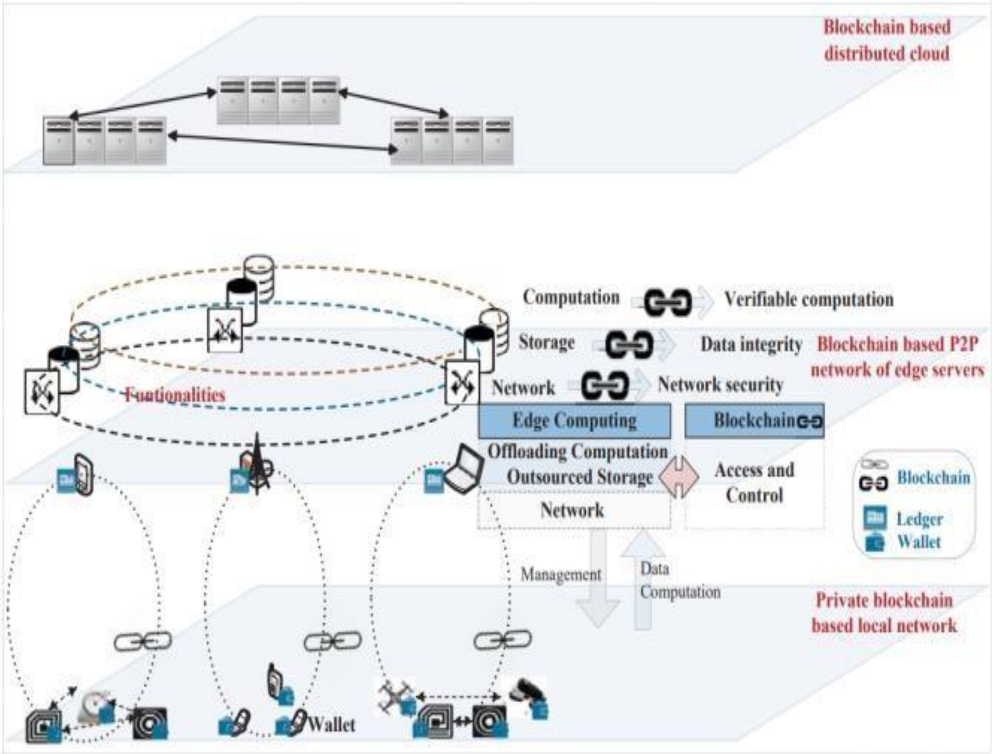

FIGURE 1. Blockchain and Edge-Computing based Systems

TABLE I
SYSTEMATIC LITERATURE REVIEW

Date	Paper Name	Year	Methodology	Used Gap	Outcomes
May 2017	(Spasovski & Eklund, 2017)	2017	For the performance evaluation of private blockchain systems like Hyperledger, Ethereum and Parity BLOCKBENCH framework is used	The given results demonstrated that on the large-scale processing of data workloads theses blockchains are not appropriate.	It evaluates the performance in terms of latency, throughput, scalability, and fault tolerance.
November 2017	(Spasovski & Eklund, 2017)	2017	The combination of blockchain and non-block chain technologies to evaluate the web-based application performance and scalability	The performance of blockchain especially inadequate for heavy load of traffic through single users.	If sufficient servers are set up, then high throughput and low response time will be achieved.

23 July 2018	(Rüsch et al., 2018)	2018	RUBIN framework is used to handle BFT-SMART and Upright	The performance evaluation of RUBIN in not investigated by using different optimization features of RDMA	By using RUBIN if the size of message is 1KB its latency is 19% lower than that of TCP and for 100KB size message it is 20% lower.
October 1519, 2018,	(Zamani et al., 2018)	2018	Rapid Chain public blockchain protocol	The author did not discuss the protocol scalability on medium or small networks. Further, the accuracy measures greater than 4000 nodes did not discussed.	It significantly shows higher throughput in a network with a size of 4000 nodes with lower latency
08 November 2018	(Thakkar et al., 2018)	2018	To evaluate throughput and latency for Fabric in WAN, Benchmark Framework is used	Fabric scalability and fault tolerance for different blockchain topologies, the impact of different consensus algorithm for different workloads are not evaluated.	Three optimization techniques are introduced to enhance the performance of single channel that are MSP store, VSCC equal approval and mass read/compose
11 February 2019	(Sanka & Cheung, 2019)	2019	NoSQL Caching mechanism which is based on proficient high-performance FPGA is used for the improvement of scalability and throughput for Blockchain system	The performance of scalability and throughput in this system is significantly improved for the lightweight nodes but not appropriate for the heavy weight nodes.	The performance of the throughput is increased by 103 times when cache hit.
July1, 1 2020	(Alrubei et al., 2020)	2020	IoT Blockchain Application which calculate the stability and latency of the network	As the number of nodes increases to make more synchronized testing the wait time and network	The block period implementation for a 3G cellular network is not

				latency increases	recommended it is better in 4G and 5G networks because the latency is better in these networks.
02 January 2020	(Kuzlu et al., 2019)	2019	Performance evaluation of Hyperledger Fabric Blockchain in terms of Throughput, Latency and Scalability	The outcomes showed Hyperledger Fabric being applied can uphold up to 100,000 members on the AWS EC2 instance with transaction rate 200 TPS and network latency approximately fraction of second	The blockchain factors like scalability, throughput, and latency are dependent on configuration of hardware, its design and complexity of smart contracts.
19 May 2020	(Sohrabi & Tari, 2020)	2020	For the scalability enhancement HTNZ protocol is used which is based on side Block and helper components.	The extension of model is required to make scalable for larger scope	It evaluates the throughput impact on scalability by using different block size. With HTNZ protocol the throughput factor of 5 for 2000 transactions.
1 July, 2020	(Meeuw et al., 2020)	2020	Implementing real-world blockchain to manage Wallerstedt microgrid for the better communication and scalability.	Tests did not cover the behavior of the system with reference to the authenticators and agents' failure. Also did not cover system stability and reliability throughout time-to-time communication.	Blockchain for smart meter offers max throughput 10 transactions/s. If validators are more than 40 then throughput halts.

5 Conclusions

This study explained the combination of blockchain and edge processing, which is turning into a significant idea that use their distributed administration and decentralized service to achieve the improved scalability, low latency time, security and performance of the systems based on this technology. Our conversation started with a review of blockchain and edge computation, in which the fundamental theory and current improvements of both of these were concisely presented. Further we introduced the inspirations and prerequisites of the incorporation of blockchain and edge computation. Then, we examined the structures of synchronized framework dependent on three-layer design of edge processing and put eyes on the private blockchain which is based on peer-to-peer local network and servers. Then talked about the organization control, scalability, low latency and calculation at the organization edges and the acknowledgment of the organization security, improved scalability and low latency check through the combination of blockchain into the edge processing.

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