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USE OF BLOCKCHAIN FOR DATA PROTECTION AND TECHNOLOGY DRAWBACKS

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Abstract. Blockchain technology offers significant opportunities for data protection, including decentralization, immutability, and security. However, its drawbacks, such as scalability issues and high energy consumption, require careful analysis. For effective use of blockchain in the field of data protection, it is essential to consider both its advantages and limitations. In this article, we examine the drawbacks of blockchain technology, with a particular focus on the scalability issue. We will analyze various approaches to solving this problem and thoroughly discuss the proposed solutions. Additionally, attention will be given to the concept of multidimensional blockchain and its structural features. In conclusion, we will present formulas and methods aimed at increasing transaction speed, which will help to better understand how multidimensional blockchains can serve as an effective solution for scalability.

Keywords: blockchain; data protection; scalability; security; smart contract.

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ДЕРЕКТЕРДІ ҚОРҒАУДА БЛОКЧЕЙНДІ ПАЙДАЛАНУ ЖӘНЕ ТЕХНОЛОГИЯНЫҢ КЕМШІЛІКТЕРІ

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Аннотация: Блокчейн технологиясы деректерді қорғаудың маңызды мүмкіндіктері орталықсыздандыру, қолдан жасалмау және қауіпсіздендіруді ұсынады. Деректерді қорғау саласында блокчейнді тиімді пайдалану үшін оның артықшылықтары мен шектеулерін ескеру қажет. Дегенмен бұл технологияның кемшілік тұстары да бар, мысалы масштабтау мәселелері және жоғары энергия шығындары мұқият талдауды қажет етеді. Бұл мақалада біз масштабтау мәселесіне ерекше назар аудара отырып, блокчейн технологиясының кемшіліктерін қарастырамыз. Біз бұл мәселені шешудің әртүрлі тәсілдерін сонымен қатар ұсынылған әдістерді егжей-тегжейлі талдаймыз. Сонымен қатар, көп өлшемді блокчейн тұжырымдамасына және оның құрылымдық ерекшеліктеріне назар аударамыз. Нәтижесінде біз транзакция жылдамдығын арттыруға бағытталған формулалар мен әдістерді ұсынамыз, масштабтау мәселесі үшін тиімді шешім бола алатындай көп өлшемді блокчейнді қолданудады ұсынамыз

Түйін сөздер: блокчейн; мәліметтерді қорғау; масштабтау; қауіпсіздік; смарт контракт.

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ИСПОЛЬЗОВАНИЕ БЛОКЧЕЙНА ДЛЯ ЗАЩИТЫ ДАННЫХ И НЕДОСТАТКИ ТЕХНОЛОГИИ

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Аннотация: блокчейн-технология предоставляет значительные возможности для защиты данных, включая децентрализацию, неподделываемость и безопасность. Для эффективного использования блокчейна в сфере защиты данных необходимо учитывать как его преимущества, так и ограничения. Однако недостатки, такие как проблемы с масштабируемостью и высокие энергозатраты, требуют внимательного анализа. В данной статье мы рассматриваем недостатки технологии блокчейн, с особым акцентом на проблему масштабируемости. Мы проанализируем различные подходы к решению этой проблемы и подробно разберем предложенные способы. Кроме того, внимание будет уделено концепции многомерного блокчейна и его структурным особенностям. В заключение мы представим формулы и методы, направленные на увеличение скорости транзакций, что позволит лучше понять, как многомерные блокчейны могут стать эффективным решением для масштабируемости.

Ключевые слова: блокчейн, защита данных, масштабируемость, безопасность, смарт-контракт.

Introduction

In the context of modern cybersecurity threats, data protection has become a critical task for organizations. Blockchain technology, initially developed for cryptocurrencies, offers innovative solutions for ensuring information security. However, despite numerous advantages, there are also serious drawbacks that must be considered.

Blockchain is one type of a broader class of data storage and synchronization technologies known as Distributed Ledger Technology (DLT). A key feature of all distributed ledger technologies is the absence of centralized control. Each node in the distributed system (comprising accompanying software and the ledger itself) makes entries in its version of the ledger independently of other nodes and synchronizes with them within a peer-to-peer network. A distinctive feature of blockchain as a type of distributed ledger is that records are linked in an incremental chain of blocks using cryptographic algorithms, which is where its name comes from (blockchain).

Thus, blockchain is a decentralized database in which all records are collected into blocks and linked together using cryptography. In addition to the records (or transactions) and the block identifier, each block includes the hash values of the current and previous blocks. These hash values are the result of cryptographic hash function calculations. Hash functions in blockchain, combined with its distributed architecture, ensure the immutability and irreversibility of the entire chain of blocks and transactions. (Barakova, 2024)

Blockchain technology is one of the most innovative and promising technologies, but it does have some drawbacks. Nevertheless, it remains a significant and promising technology that can solve many problems and provide considerable benefits across various fields.

Main Drawbacks of Blockchain Technology

1. Scalability: Limited transaction processing speed, especially in one-dimensional blockchains.
2. Energy Consumption: High energy usage, particularly in systems with Proof of Work consensus mechanisms.
3. Development Complexity and Cost: Developing and implementing blockchain solutions can be complicated and expensive.
4. Regulatory Issues: Uncertainty in legal regulations can create risks for businesses.
5. Security: While blockchain is considered secure, it is not immune to attacks, such as the 51% attack.
6. Privacy Concerns: Public blockchains may expose users' personal data to risks.

Blockchain technology faces scalability challenges. As the network grows, the number of transactions increases, which can lead to system slowdowns. For example, the Bitcoin network can process a limited number of transactions per second, making it less efficient for mass use. Scalability issues can also result in longer transaction confirmation times and higher fees.(Cachin, 2017)

The problems of scaling and information exchange between blockchains have only been partially addressed. To scale blockchain-based solutions, sharding is proposed; however, there is no theoretical description of how to construct such a solution. The concept of sidechains is used for information exchange between blockchains, allowing only two systems to connect and requiring a complete overhaul of the underlying protocols.

Research Methodology

Drawbacks of blockchain, such as scalability and transaction speed, can be addressed through several methods:

1. Sharding: Dividing the network into smaller segments, or "shards," that can process transactions in parallel, increasing overall throughput.
2. Layered Solutions: Implementing second-layer solutions, such as the Lightning Network for Bitcoin or Plasma for Ethereum, allows transactions to be processed off the main chain, significantly speeding them up.
3. Improved Consensus Algorithms: Transitioning to more efficient consensus algorithms, such as Proof of Stake (PoS) or Delegated Proof of Stake (DPoS), which require fewer computational resources and can process transactions more quickly.
4. Smart Contract Optimization: Developing more efficient smart contracts that require less computational resources and time to execute.
5. Data Compression: Using compression methods to reduce the volume of data that needs to be stored and transmitted.
6. Block Size Increase: For some blockchains, increasing the block size can help reduce the time between transactions, although this must be approached carefully to avoid compromising decentralization.
7. Multidimensional Blockchain: Utilizing multiple parallel chains to process transactions and data. This allows different types of operations to be handled simultaneously, increasing overall performance and scalability while maintaining decentralization.

Table 1. Comparative analysis of the methods mentioned for addressing blockchain drawbacks, such as scalability and transaction speed

№	Type of methods	Advantages	Complexity
1	Data segregation (Sharding)	• Allows for parallel processing of transactions, increasing overall throughput. • Efficiently utilizes resources, as each shard can handle its portion of the data	• Complexity of implementation and the need for coordination between shards. • Security may be compromised if there is not a good data distribution scheme.
2	Layered Solutions	• Significantly speed up transactions by processing them off the main chain. • Reduce the load on the main chain, improving its performance	• Depend on the reliability of the second layer and may be vulnerable to certain attacks. • Complexity of integrating and maintaining multiple layers

3	Improved Consensus Algorithms	• More efficient algorithms, such as PoS and DPoS, can significantly reduce transaction processing times. • Lower the costs of computational resources and energy consumption.	• Transitioning to new algorithms may require significant changes in infrastructure. • Potential issues with decentralization (e.g., in PoS).
4	Smart Contract Optimization	• Efficient smart contracts can reduce resource consumption and accelerate their execution. • Improve the overall performance of the network.	• A deep understanding of programming and smart contract architecture is required. • Optimization may limit functionality.
5	Data Compression	• Reduction in data volume, which speeds up transmission and storage. • Increased network efficiency.	• Challenges in implementing compression and potential data loss. • Additional computational costs for compressing and decompressing data..
6	Increase in Block Size	• Allows for processing more transactions at once, reducing the time between them. • Ease of implementation in certain systems	• Risk of deteriorating decentralization, as larger blocks require more resources for storage and processing. • May lead to increased data transmission times.
7	Multidimensional Blockchain	• Processing different types of operations simultaneously, which increases overall performance and scalability. • Maintains decentralization while distributing the load.	• High complexity of architecture and interaction between chains. • Issues with security and data consistency between chains.

Each of these methods has its strengths and weaknesses. The choice of the appropriate solution depends on the specific requirements and goals of the system, as well as the trade-offs you are willing to accept between performance, security, and decentralization. (Garay 2015)

These methods will be used in combination to achieve the best results in addressing scalability and transaction speed issues in blockchain.

Methods for addressing blockchain scalability issues can be used either individually or in combination, depending on the specific needs and goals of the project. To achieve the best results, it is often advisable to combine several methods.

In our case, we will use a combined approach that includes increasing the block size and implementing a multidimensional blockchain. This will significantly enhance the efficiency and scalability of our system. The use of smart contracts will optimize processes and reduce computational costs, while the multidimensional blockchain will enable parallel processing of transactions and flexibility in data management. This approach will allow us to adapt to changes in requirements and workloads, ensuring high performance and reliability.

Multidimensional Blockchain

A multidimensional blockchain is an architecture that utilizes multiple parallel chains (or structures) for processing transactions and storing data. Each chain can perform its specific function, allowing for efficient load distribution and increased overall system performance. (Pass, 2017)

Key Characteristics:

1. Parallel Chains:

A multidimensional blockchain consists of several independent chains, each capable of processing transactions and performing its operations. This significantly increases the overall throughput of the network.

2. Specialization:

Each chain can be optimized for specific tasks (e.g., one for financial transactions, another for data storage, or executing smart contracts). This allows for more efficient resource utilization.

3. Cross-Chain Interaction:

Chains can interact with one another, enabling the exchange of data and transactions. This requires protocols that ensure data security and consistency.

4. Flexibility and Adaptability:

The multidimensional architecture allows for easy addition of new chains as the network grows and requirements change, providing scalability for the system.

5. Resilience and Security:

Distributing the load among various chains reduces the risk of centralization and enhances the system's resilience to attacks and failures.

Advantages

- Increased Performance: Parallel processing of transactions significantly reduces confirmation times and enhances the overall speed of the system.
- Resource Optimization: Each chain can be tailored to specific tasks, allowing for more efficient use of computational and network resources.
- Scalability: The ability to add new chains or modify existing ones provides flexibility and resilience to changing conditions.

A multidimensional blockchain is an effective solution for modern scalability and performance requirements of distributed systems. Its architecture allows for adaptation to changes and process optimization, ensuring a high degree of reliability and security.

Results and Discussion

A multidimensional blockchain consists of multiple blockchains, where all blockchains, except the first, undergo a registration procedure in one of the existing blockchains. Registration involves recording information about the genesis block (the first block of the new blockchain) and the basic properties of the blockchain in another blockchain. The concept of distributed ledger thus becomes dual: on one hand, the multidimensional blockchain implements a distributed ledger, and on the other hand, each blockchain within the multidimensional blockchain also implements its own distributed ledger.(Reid, 2013)

Depending on the architecture, there are two operational modes for the multidimensional blockchain: block mode and state mode. A generalized representation of the multidimensional blockchain is shown in Figure 1. Each blockchain within the multidimensional blockchain implements a distributed ledger. This assumption allows us to avoid delving into the specific functioning of individual blockchains.

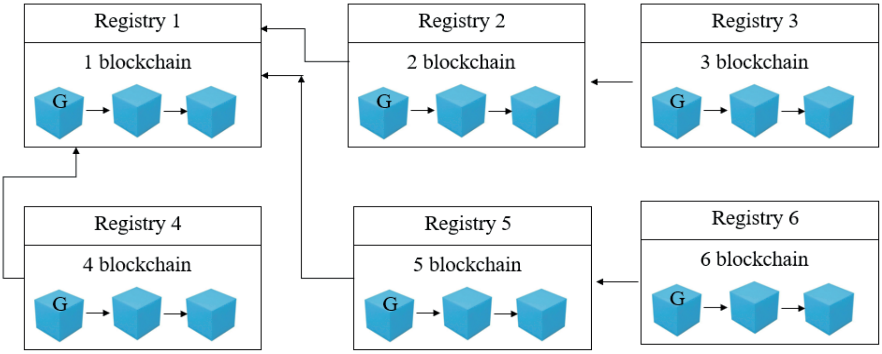

Figure 1. Structure of the Multidimensional Blockchain

In Figure 1, the overall view of a multidimensional blockchain is presented, integrating multiple blockchains into a single system. G—Genesis block, which is the first block in a blockchain. This concept is preserved for blockchains within a multidimensional blockchain. (Ben-Sasson, 2014) Genesis blocks are explicitly registered in existing blockchains. In this context, the notion of a distributed ledger can be understood in two ways:

1. Each one-dimensional blockchain within the multidimensional blockchain implements a distributed ledger.
2. The entire system collectively represents a distributed ledger (hypothesis).

There are two ways to construct a multidimensional blockchain:

1. Block mode.
2. State mode.

In the case of a multidimensional blockchain, the genesis block is of the type Registrar. Typically, it does not contain transactions, is generated by the system creator, and exists solely to initiate the system's operation. In a multidimensional blockchain, the Registrar block defines the operational characteristics of the system. The first genesis block is generated by the system creator. When it is necessary to create a new blockchain within the current blockchain, a new Registrar block is created, which is a legitimate block and can be generated by system users at any time. After this, the functioning of the old blockchain continues in standard mode. However, the generated Registrar block can now be used as the genesis block of a new blockchain. In other words, all genesis blocks, except for the very first one, must be placed into one of the existing chains of blocks. For an individual blockchain, the fact of its "registration" using Registrar block 131 in another blockchain is completely transparent since it can subsequently operate independently, without utilizing the functionality of the multidimensional blockchain.

Whenever scalability of the blockchain is discussed, the number of transactions that the network can process per second is mentioned. However, many forget that increasing throughput should not compromise network security or raise the requirements for nodes wishing to support the network. These modifications can reduce the number of independent transaction validators in the network, thereby decreasing the level of decentralization.

The transaction throughput in Bitcoin can be easily calculated using the formula:

$$Throughput = \frac{B_{size}}{T_{size} \cdot B_{time}} \quad (1)$$

where

Bsize – block size in bytes,

Tsize – average transaction record size in the block,

Btime – average time between consecutive blocks in the blockchain.

It is evident that throughput can be improved by increasing the block size, decreasing the size of the transaction record, or reducing the interval between blocks. Reducing the size of transaction records is quite challenging. It is much simpler to attempt the other two options. However, these actions will increase the time taken to propagate blocks. Thus, the security and decentralization of the network may be compromised.

To describe this, we will proceed to examine the mathematical model of a multidimensional blockchain. Since blockchains create new states at varying speeds, the following relationships assume that transactions were created during a fixed-length time interval—referred to as a slot. For the most accurate formulation of the mathematical model, the following relationships can be accepted:

$$sl \equiv GC(Time(\sigma_t \rightarrow \sigma_{t+1})) \quad (2)$$

$$(k) = (^{(k,1)}, \ldots, T^{(k,j)}) | j = [\frac{\text{Time } (\delta_t^{(\kappa)} \rightarrow \delta_{t+1}^{(\kappa)}}{sl}], T^{(k,l)} = (T_0^{(k,j)}, \ldots, T_n^{(k,j)}) \quad (3)$$

In other words, a slot is the largest time interval into which the time intervals required to transition between states in all blockchains are evenly divided. As a result, each transition between states in each blockchain occurs once every fixed (whole) number of slots. That is:

$$\Pi' (\sigma^{(k)} T^{(k,j)} = \Pi'(\sigma(k), T(k,j)) = \{ \Omega(Y(\ldots Y(Y(\sigma(k), T0\ (k,j)), \ldots)$$

$$Tn\ (k,j))) \ oth\ erwise \quad (4)$$

In general form, a multidimensional blockchain can be represented as follows:

$$\Sigma_{i+1} \equiv \Phi(\Sigma_i,T)|\Sigma_i \equiv \{\sigma^{(1)},\ldots,\sigma^{(N)}\} \wedge \Phi(\Sigma_i,T) \equiv \Psi(\mathrm{P}(\Sigma_i,T),T) \quad (5)$$

$$\mathrm{P}(\Sigma_i,T) = \mathrm{E}(\mathrm{E}(\ldots\mathrm{E}(\Sigma_i,T,1),\ldots)T,N)|\mathrm{E}(\Sigma_i,T,k) = E'(\Pi'(\sigma^{(k)},T)) \quad (6)$$

where

Ψ – creates new blockchains,

P – state transition function,

E – state transition function for the k-th blockchain within its structure.

E′ – an auxiliary function that returns a multidimensional blockchain for a one-dimensional blockchain and is used to avoid the use of the universal quantifier in mathematical notation.

The state of a multidimensional blockchain at any given moment is the set of states of all the individual blockchains within it. The state transition function **Φ** addresses two tasks: it applies transactions to the individual states of the blockchains and creates new blockchains, that is, it initializes their first state (the genesis block). Formally, it would be correct to use the addresses of the blockchains instead of their numbers, but for simplicity, integer numbering is used.(Sompolinsky, 2013)

In general, a multidimensional blockchain operates as an analogue of a one-dimensional blockchain, but it requires many independent distributed ledgers.

Conclusion

The scalability limitation in blockchain is most commonly observed in one-dimensional blockchains, such as Bitcoin and Ethereum, where transaction processing speed is constrained by a linear structure. In contrast, multidimensional blockchains offer a more scalable solution compared to traditional one-dimensional ones. Despite the complexities of implementation, multidimensional blockchains present promising solutions for the modern digital world.

How Multidimensional Blockchain Addresses Scalability:

1. Transaction Parallelization: In multidimensional blockchains, it is possible to process multiple transactions simultaneously, significantly increasing the network's throughput.

2. Flexible Data Structure: Multidimensional blocks can represent more complex relationships between data, allowing for optimized storage and processing.

3. Avoidance of Bottlenecks: By utilizing various approaches, such as Directed Acyclic Graph (DAG), bottlenecks associated with sequential transaction processing can be avoided.

4. Network Protocols: Multidimensional blockchains can implement more sophisticated network protocols, enabling better scalability based on load.

Thus, multidimensional blockchains can offer more effective solutions for scalability compared to traditional one-dimensional blockchains.

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