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ENHANCING SYSTEM FAULT TOLERANCE THROUGH THE USE OF BLOCKCHAIN TECHNOLOGY

The paper deals with the issues of the profitability of using blockchain technology to create more enhanced fault-tolerant systems. The advantages and disadvantages of using public and private blockchain are considered, as well as the impact of this technology on distributed and centralized systems. Examples of the use of blockchain technology to increase system productivity in various spheres of human activity are given.

Keywords: blockchain, fault-tolerant systems

Relevance of the research topic. Blockchain technology, which forms the foundation of decentralized digital currencies, is becoming very popular in today's world due to qualities such as transparency, immutability, reliability, speed, and efficiency. Therefore, it's necessary to consider the use of this technology to increase the reliability and fault tolerance of systems in various spheres of life.

Target setting. The opportunity to find better ways to increase the reliability and fault tolerance of computer systems.

Actual scientific researches and issues analysis. Recent studies show that blockchain technology can be very useful for the task of increasing system reliability and fault tolerance due to decentralization, transparency in task execution, and security features such as immutability. However, there is also an opinion that for large computations, the question of energy efficiency arises, especially when performing consensus algorithms to confirm the result.

Uninvestigated parts of general matters defining. This article is dedicated to studying and analyzing approaches to optimizing the use of blockchain technology in high computational requirements and in distributed systems.

The research objective. Analyze the appropriateness of using blockchain technology to increase system fault tolerance. Consider the advantages and disadvantages of using this technology in centralized and distributed systems.

The statement of basic materials. Blockchain technology, which underlies most decentralized digital currencies such as Bitcoin, Ethereum, Binance Coin, and many others, has great potential for creating reliable and fault tolerant systems [1].

Thanks to features like decentralization, transparency, and immutability, it's possible to enhance fault tolerance and improve the security of computer systems.

Blockchain for fault tolerance. Fault tolerance is the system's ability to continue performing actions programmed into it even after the occurrence of malfunctions or the complete breakdown of some of its components [2]. Blockchain ensures fault tolerance through decentralization and consensus mechanism. As each node contains a copy of the entire blockchain, the system will continue to work even if one node fails. Thanks to the consensus mechanism, a single node failure won't disrupt the system's operation, as each node's state is agreed upon with others, and nodes with deviations will be ignored by the system. These consensus mechanisms come in various forms, including Proof of Work (PoW), Proof of Stake (PoS), and Byzantine Fault Tolerance (BFT). PoW requires significant computational effort to validate transactions, whereas PoS requires participants to have a certain number of coins. BFT, on the other hand, is designed to provide reliable consensus in systems with potentially hostile nodes.

Public and private blockchain. However, a system based on blockchain technology is not perfect and has many different usage aspects. For example, to create a fault tolerant system, we can use both a public and a private blockchain [3]. In the case of using a public blockchain, you need to pay "gas" when performing operations. Using this approach can have a very negative impact on your bank account, especially under high system load. But in this case, the fault tolerance of the system will be at its maximum, as anyone can join the computation process and for a certain fee, above-mentioned "gas", provide their computing capabilities to perform operations. Thus, we have a strongly decentralized topology in the network created around the public blockchain, in which the correctness of the program is checked using public consensus. However, this approach can have weak performance due to the same strong decentralization of the system. Another approach to creating a fault tolerant system is the use of a private blockchain. In this case, it is possible to control the entire network and set your own rules for its operation. Such a system is not decentralized, so each node must be serviced and maintained for stable task execution. This solution leads to a reduction in fault tolerance but does not require transaction fees and can be useful for organizations that want to use blockchain properties without making their network externally accessible.

Blockchain in distributed systems. The next issue may be the use of blockchain technology in distributed systems, as they are designed to maximize the division of program code into parts and parallel execution of a given task, while blockchain implies performing the same task on many nodes simultaneously. Indeed,

blockchain technology and distributed computing serve two different purposes and they solve two different types of problems. Because each blockchain transaction is verified by the entire network, operations performed with blockchain provide a high level of security and increase fault tolerance. However, this technology will perform very poorly in large computations, as each node will perform the same operation. Distributed systems are used for maximum optimization of the use of computational resources. Large tasks are divided into parts that can be executed in parallel on many nodes. This approach provides much higher execution speed, but the system is much less fault tolerant. Therefore, while it is possible to use blockchain technology for distributed computing to ensure transparency and security, such an approach will significantly reduce the execution time of a task and heavily load the system.

Other approaches to enhance fault tolerance. Now let's consider other ways to increase system fault tolerance, separately for distributed and centralized ones. For centralized systems, the following approaches can be used:

1. Redundancy - duplicating hardware, data storages, or software to ensure continuous system operation in case of one component failure.
2. Regular backup - copying system operating data to a remote storage to restore the state of system operation after a failure.
3. Disaster recovery mode - introducing some solutions into the software that allow the system to quickly recover after a failure.

For distributed systems, the following approaches can be used:

1. Replication - creating copies of data or services in different parts of the system so that if one node fails, another node can continue processing.
2. Sharding - distributing data among different nodes, allowing the system to continue working, even if one node fails.
3. Applying consensus algorithms - manage the state of the system in a distributed environment using consensus algorithms to ensure data consistency between nodes.

So, we see that in addition to blockchain technology, there are many ways to increase the fault tolerance of computer systems depending on the type and requirements. Depending on the task, you can choose which one fits best.

Application areas. Let's talk about the exact areas where blockchain technology would be useful in creating a fault tolerant system that also has a high level of security and transparency:

1. Financial sector: Blockchain technology is already widely used in cryptocurrencies to ensure fault tolerance in conditions where there is no centralized authority that would control transactions. The same solution can be useful for ensuring security in banking systems and other financial institutions.

2. Logistics sector: Blockchain can be used to create a fault tolerant supply tracking system where each stage in the supply chain can be tracked and verified, ensuring transparency, and reducing the possibility of fraud.

3. Healthcare sector: Blockchain can help create fault tolerant systems for recording and storing patient data that guarantee the integrity and privacy of patient data.

4. Legal sector: Blockchain technology can ensure fault tolerance and transparency in electronic voting systems, reducing the possibility of manipulation and fraud in elections. Also, the immutability of the blockchain would help to avoid the "disappearance" of evidence and other investigative materials from court cases, which would help eradicate corruption in the judicial system.

Implementation problems. With widespread implementation of blockchain technology, you may face the following problems:

1. Scalability: Blockchains may have problems processing many transactions per unit of time, making them less suitable for large systems.

2. Energy efficiency: Some consensus algorithms, such as Proof of Work, use a large amount of energy to confirm the correctness of execution results.

3. Implementation complexity: Blockchain is a relatively new technology, and its implementation will require specialists who will create new and adapt existing systems using blockchain technology.

4. Legal and regulatory issues: Blockchain, especially in financial sectors and those related to personal data, may face issues of compliance with existing laws and regulatory norms.

I would like to note that blockchain technology isn't always the best way to improve the fault tolerance of computer systems. However, the advantages that this technology provides can be widely used in various areas of human activity and make blockchain a standard tool for creating fault tolerant and secure systems. It's important to note that some countries are already making the first steps in using blockchain technology at the state level. For example, Estonia successfully uses the e-Estonia electronic citizenship system, which operates on the blockchain [4]. Through this system, elections are held, taxes are paid, and it helps the country save up to 2% of

GDP annually. But it's important to remember that the example of a country with a population of less than two million people cannot guarantee that a similar model will take root in other countries. However, it's impossible not to recognize that distributed digital registers are becoming increasingly popular and blockchain has the potential to radically change the world around us.

Conclusions. The potential of blockchain technology to enhance the fault tolerance of both distributed and centralized systems, including in high computational requirements, has been analyzed. Approaches and methods of using this technology in those systems where it can be most effective have been identified. Areas where the implementation of fault tolerant systems based on blockchain technology is most profitable have been identified.

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РОЗШИРЕНА АНОТАЦІЯ

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ПІДВИЩЕННЯ ВІДМОВОСТІЙКОСТІ СИСТЕМ ЗА ДОПОМОГОЮ ТЕХНОЛОГІЇ БЛОКЧЕЙН

Актуальність теми дослідження. Технологія блокчейн, яка є основою децентралізованих цифрових валют, стає дуже популярною в наш час завдяки таким якостям як прозорість, незмінність, надійність, швидкість та ефективність. Тож вважаю за потрібне розглянути використання даної технології для підвищення надійності та відмовостійкості систем у різних сферах життєдіяльності.

Постановка проблеми. Можливість відшукати кращі способи підвищення надійності та відмовостійкості комп'ютерних систем.

Аналіз останніх досліджень та публікацій. Останні дослідження показують, що технологія блокчейн може бути дуже корисною для виконання задачі підвищення надійності і відмовостійкості систем завдяки децентралізації, прозорості у виконанні задач та безпековим характеристикам, таким як незмінність. Однак також існує думка, що для великих обчислень постає питання енергоефективності, особливо при виконанні консенсусних алгоритмів для підтвердження результату.

Виділення недосліджених частин загальної проблеми. Дана стаття присвячена вивченню та аналізу підходів до оптимізації використання технології блокчейну при великих обчислювальних вимогах, а також у розподіленого системах.

Постановка завдання. Проаналізувати доцільність використання технології блокчейн для підвищення відмовостійкості систем. Розглянути переваги та недоліки використання даної технології у централізованих та розподілених системах.

Викладення основного матеріалу. Проведено аналіз різних аспектів використання технології блокчейну в розподілених та централізованих системах, включаючи безпеку, відмовостійкість, прозорість, масштабованість та вартість використання, включаючи витрати на gas при виконанні програмного коду.

Висновки. Проаналізовано потенціал технології блокчейну для підвищення відмовостійкості як розподілених так і централізованих систем, в тому числі при великих обчислювальних вимогах. Визначено підходи та способи використання даної технології у тих системах, де це може бути найбільш ефективним. Визначено напрями, де впровадження відмовостійких системи заснованих на технології блокчейн є найбільш вигідним.

Ключові слова: блокчейн, відмовостійкі системи