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PERSPECTIVES OF BLOCKCHAIN TECHNOLOGY IN BUSINESS AND MANAGEMENT: ADVANTAGES AND CHALLENGES

Blockchain is a decentralized and distributed digital ledger technology that records transactions across multiple computers. The key idea is that once information is recorded on a blockchain, it is extremely difficult to alter or tamper with because each block in the chain contains a cryptographic hash of the previous block, a timestamp, and transaction data. This creates a secure, transparent, and immutable system. In this paper, we review the key features of blockchain and examples of its particular application in business and management. In Ukraine, while blockchain technology has a huge potential to change many business sectors, providing security, transparency and efficiency of processes, it is necessary to solve the issues of scalability, regulatory barriers, as well as optimize energy consumption for full implementation. The future of blockchain in business and management looks promising, especially given the opportunities offered by smart contracts, decentralized finance, and asset tokenization. The today's leading trend is energy trading whose blockchains have been increasingly used to record and publish local and regional electricity market data. This is believed to produce a significant impact on establishing and solidifying transparency of pricing and investing in energy sector. Solving current problems will allow blockchain technology to become the main tool for creating transparent and reliable business processes. However, scalability still remains the most serious and pressing problem in blockchain implementation. While significant advancements are being made to address it, the unsolved balance between scalability, security, and decentralization (the blockchain trilemma) presents ongoing technical, economic, and environmental challenges.

Key words: *blockchain, business, management, smart contracts, tokenization of assets, decentralized finance.*

Мерінова С. В., Романюк В. В. Перспективи технології блокчейн у бізнесі та менеджменті: переваги та виклики

Блокчейн – це децентралізована та розподілена технологія цифрової книги, яка записує транзакції на кількох комп'ютерах. Ключова ідея полягає в тому, що коли інформацію записано в блокчейн, її надзвичайно важко змінити або підробити, оскільки кожен блок у ланцюжку містить криптографічний хеш попереднього блоку, мітку часу та дані транзакції. Це створює безпечну, прозору та незмінну систему. У цій статті ми розглядаємо ключові особливості блокчейну та приклади його конкретного застосування в бізнесі та управлінні. В Україні, хоча технологія блокчейн має величезний потенціал змінити багато секторів бізнесу, забезпечуючи безпеку, прозорість та ефективність процесів, для повноцінного впровадження необхідно вирішити питання масштабованості, регуляторних бар'єрів, а також оптимізувати енергоспоживання. Майбутнє блокчейну в бізнесі та управлінні виглядає багатообіцяючим, особливо враховуючи можливості, які пропонують смарт-контракти, децентралізоване фінансування та токенізація активів. Провідною тенденцією сьогодні є торгівля енергією, блокчейни якої все частіше використовуються для запису та публікації даних місцевого та регіонального ринку електроенергії. Вважається, що це матиме значний вплив на встановлення та зміцнення прозорості ціноутворення та інвестування в енергетичний сектор. Вирішення актуальних проблем дозволить технології блокчейн стати основним інструментом створення прозорих і надійних бізнес-процесів. Однак масштабованість все ще залишається найсерйознішою та актуальною проблемою впровадження блокчейна.

Незважаючи на значні успіхи, щоб вирішити цю проблему, невирішений баланс між масштабованістю, безпекою та децентралізацією (трилема блокчейну) створює постійні технічні, економічні та екологічні проблеми.

Ключові слова: *блокчейн, бізнес, менеджмент, смарт-контракти, токенізація активів, децентралізовані фінанси.*

Problem statement. Blockchain technology is one of the most revolutionary innovations of contemporary era, which has the potential to fundamentally change the approach to doing business in various industries [1]. The ability of blockchain technology to provide transparency, security, and decentralization of processes makes this technology indispensable in areas such as finance, logistics, healthcare, and commerce [2]. In today's business environment, where digitization is becoming a key factor in competitiveness, blockchain is a tool that can considerably improve efficiency and significantly reduce fraud risks [3].

Despite its great potential, blockchain technology faces several unsolved challenges [4]. Blockchain systems often have limited bandwidth, which makes them difficult to deploy on a large scale. Insufficient legal regulation and legal uncertainty in many countries limit the implementation of blockchain in business processes. The technology, especially in Proof-of-Work algorithms, consumes significant amounts of energy, which raises environmental and economic issues. Implementing blockchain solutions into existing systems is often technically complex and requires significant investment.

Implementing a blockchain requires specific equipment and computational resources depending on the type of blockchain (public, private, or consortium) and its intended use (e. g., cryptocurrency, smart contracts, supply chain management). The essential equipment and computational resources needed are nodes, mining equipment, blockchain client software and platforms, cloud-based solutions, networking infrastructure, power and cooling, blockchain developers and engineers, system administrators, network engineers, and security experts [1], [2]. Implementing a blockchain involves a combination of computing hardware (nodes, storage, processors), software (blockchain clients, smart contract platforms), networking equipment, and significant power and cooling resources. The choice of equipment and resources depends on whether the blockchain is public (requiring more decentralized and secure setups) or private/consortium (where the setup can be more centralized and managed).

State-of-the-art motivation and purpose. As in many countries, the study of blockchain technology is a topical field of computer science in Ukraine. Many scientists from various scientific institutions and fields are engaged in this topic, attempting to cover a specific domain of knowledge in building distributed ledgers with growing lists of records that are securely linked together via cryptographic hashes. As of 2024, there are a lot of open questions still being studied. Among them: the use of blockchain in economics and financial technologies [5], the implementation of blockchain in business processes and decentralized financial systems [6], data security and algorithms for decentralized networks [7], the use of blockchain in public administration [8], decentralized financial systems based on the blockchain [9], the impact of blockchain on digital economies [10], the impact of blockchain on international financial systems and smart contracts [11], etc. Many scientists and international research groups are actively working on the development and improvement of blockchain technology in various fields, including economics, logistics, finance, and public administration.

The most serious problem in blockchain implementation is the scalability issue. Scalability refers to a blockchain's ability to handle a growing number of transactions and nodes without compromising speed, efficiency, or security. As blockchain networks expand and the number of transactions increases, achieving scalability while maintaining decentralization and security (the so called blockchain trilemma) becomes a significant challenge [12], [13].

The purpose of this study is to analyze the prospects for the development of blockchain technology in business and management, to identify the main problems that prevent their full implementation, and to find ways to solve them. Special attention is paid to the analysis of the impact of blockchain on various business sectors and the possibilities of its application to increase efficiency.

Analysis. Blockchain technology gained wide popularity with the appearance of the first cryptocurrency, Bitcoin, in 2009. Its creator, known under the pseudonym Satoshi Nakamoto, presented the blockchain as the basis for a digital currency that does not require the involvement of banks or governments to carry out transactions. This decentralized approach to data storage and record keeping was a breakthrough in the financial field. In subsequent years, blockchain began to be actively used in various industries: finance, logistics, health care, and others.

In Ukraine, blockchain technology is at an early stage of implementation, but it has a huge potential for development in various sectors of the economy. One of the most promising areas for the application of blockchain is public administration. Thanks to decentralized systems, Ukraine can significantly increase the transparency of government processes, including land registration, state registers and public procurement. For example, there are already projects using blockchain for electronic voting, which can reduce the risks of fraud and make the process more accessible to citizens.

Blockchain has great potential to transform business processes. First of all, this applies to the financial sector, where blockchain allows you to speed up transactions, reduce fees and increase data security. Smart contracts are one of the key features of the blockchain, which can automate and simplify transactions, reducing the need for intermediaries [11].

The most striking example is cryptocurrencies (Bitcoin, Ethereum). In addition, blockchain is used for international transfers, providing instant transactions without intermediaries and reducing fees (for example, the Ripple system).

In logistics, blockchain helps ensure full transparency of supply chains. The technology allows you to track every step of the movement of goods, which reduces opportunities for counterfeiting and ensures faster and more efficient delivery. Maersk together with IBM introduced a blockchain platform for tracking container shipments. This made it possible to automate the accounting of goods and significantly increase the transparency of supply chains.

In healthcare, blockchain can be used to ensure the safety and security of patient medical data. This allows for the creation of reliable decentralized data storage systems, which reduces the risk of loss or unauthorized access to information [7].

However, scaling blockchain technology remains a key challenge. To achieve mass adoption, solutions are needed that will increase the bandwidth of blockchain networks without increasing energy consumption and transaction costs.

Blockchain technology is rapidly developing and becoming increasingly attractive to businesses due to their ability to optimize processes, increase transparency and data security. The main prospects of blockchain are its applications for transparent transactions, asset management and automation of operations. It is expected that in the coming years, more and more companies will use blockchain to optimize business processes.

The key aspects of blockchain technology in business and management, their advantages, development prospects and challenges that blockchain implementation may face are presented in Table 1.

Table 1

Prospects of blockchain technology in business and management

Field	Blockchain application	Advantages	Prospects for development	Future challenges
Financial sector	Decentralized finance (DeFi), cryptocurrencies, smart contracts	Elimination of intermediaries, automation of deals, faster transactions	Development of DeFi, integration of cryptocurrencies into traditional systems	Scalability, regulation
Logistics and supply chains	Supply transparency, process automation, product tracking	Transparency, resource savings, real-time tracking	Full supply chain automation, customer transparency	Integration into existing systems
State services	Electronic registers, transparency of government processes, e-voting	Minimization of corruption risks, speed of processes, accessibility	Transparency of state processes, simplification of bureaucratic procedures	Legal aspects, legal regulation
Healthcare	Protection of medical data, exchange of information between institutions	Protection of personal data, secure exchange of information	Creation of secure platforms for data exchange between doctors and patients	Protection of privacy, compatibility of systems
Property registration and accounting	Tokenization of assets, registration of ownership	Transparency of registration processes, increase in liquidity of assets	Faster registration, transparency in the field of real estate and other assets	Legal regulation of tokenization of assets
Industry 4.0	Internet of Things (IoT), industrial systems	Automation, transparency of production processes	Use of blockchain for the development of IoT and industrial automation	Energy efficiency, scalability of systems

Currently in Ukraine, blockchain technology is relevantly used for the following aspects and processes in business:

1. Smart contracts.
2. Tokenization of assets.
3. Decentralized finance.

Smart contracts are one of the most promising areas of blockchain application. A smart contract is a program that automatically executes the terms of the agreement when all its conditions are met. This eliminates the need for intermediaries (such as lawyers or notaries), which reduces the time and costs of concluding transactions.

For example, in real estate, smart contracts can be used to automate sales. In this case, the money is transferred automatically after fulfilling all the conditions of the agreement, such as proof of ownership and payment. This not only simplifies the process, but also significantly reduces the risk of fraud.

With the help of this perspective, companies can save up to 10 to 15% of costs that previously went to legal services and drafting agreements. Automating transactions can reduce the time it takes to execute them from days or weeks to minutes. Automatic execution of transactions reduces the risk of errors or manipulation.

The next perspective is tokenization of assets.

Asset tokenization refers to the conversion of real assets (such as real estate, securities, commodities) into digital tokens on a blockchain platform. This allows assets to become more liquid and traded on digital platforms.

For example, instead of selling an entire building, an owner can issue tokens, each representing a portion of the property. These tokens can be sold to investors, allowing you to raise capital faster and more efficiently.

Asset owners can quickly sell ownership shares, which increases their liquidity by 20 to 30%. Tokenization allows you to reduce the costs of IPOs or attracting investments through stock markets by 10 to 20%. With the help of asset tokenization, companies can attract investors from all over the world.

As for decentralized finance, these are financial instruments that use the blockchain to provide services such as credits, loans and currency exchange without the need for intermediaries (banks, credit institutions). DeFi allows users to directly interact with each other through smart contracts.

This significantly reduces the costs of financial services and increases the speed of transactions. For example, a user can take out a loan on a blockchain platform, where the terms of the loan are regulated by smart contracts, without the involvement of the bank.

With the help of DeFi platforms, interest rates on loans can be 2 to 5% lower compared to traditional banks. Blockchain transactions can be carried out instantly, reducing waiting time, allowing transactions to be completed faster. DeFi opens up financial services to millions of people in the world who do not have access to traditional banking systems.

Therefore, the introduction of blockchain for business in Ukraine will allow:

1. Implementation of blockchain in public services to increase transparency and reduce bureaucracy.
2. Growth of investments in blockchain startups in the field of financial services, agriculture and IT.
3. Use of smart contracts to automate business processes in large and medium-sized companies.
4. The possibility of blockchain integration in the field of energy for transparent accounting of consumption and sale of energy resources.

On a global level, blockchain is already impacting industries such as finance, logistics, healthcare and digital identity. A special part takes game industry (Fig. 1), which is at the top along with financial sector. The latter, nevertheless, is the leader continuing to make significant progress since 2010s. One of the loudest trends in recent years is the development of decentralized finance (DeFi), which enables users to receive credits, loans and other financial services without the involvement of traditional banks. Many companies, such as Walmart and Maersk, are already using blockchain to track the supply of goods in real time, which can reduce losses and increase the transparency of supply chains [10], [13].

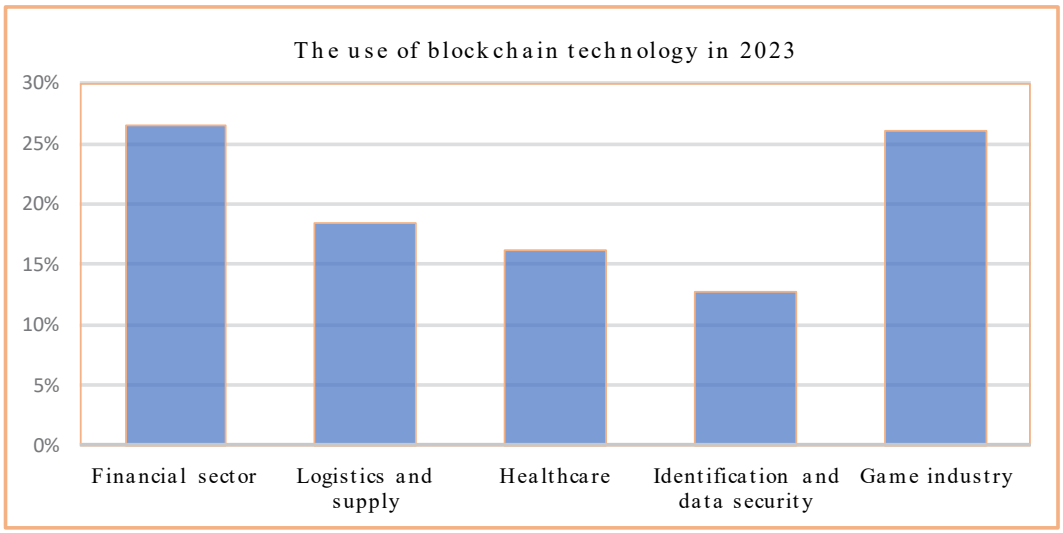

Fig. 1. Impact of blockchain technology on top-5 industries

Another comprehensive analysis carried out on reviews of the current state of blockchain in business and management has shown that supply chain models lead. For instance, Fig. 2 presents a word cloud of bigrams in recent scientific publications devoted to the use of blockchain in business and management. Apart from bigram “blockchain technology”, whose highly-rated appearance is quite obvious, other frequently appearing bigrams are “supply chain”, “smart contract(s)” (the Porter stemmer has not been applied here to normalize the words usage), “chain management”, and “energy trading”. Fields of big data, data management, and access control appear to have impressive interest from researchers.

A word cloud of trigrams in the same scientific publications is presented in Fig. 3. Supply chain management is the leading trigram, but it is not really informative. Food supply chain management is next by its frequency. Application of a latent Dirichlet allocation model discovers three underlying topics in the collection of scientific documents, from which common phrases relating to blockchain technology, smart contract, and supply chain management are deliberately excluded (Fig. 4). This model further supplements the inferences from Fig. 2 and Fig. 3, where business models and supply chain management with blockchain technology implementation are thoroughly discussed. The topic with energy trading is dominating (the cloud on the left). Information sharing and hyperledger fabric have a slightly lower weight (the cloud in the center). It is worth noting that bigram "energy trading" is present in both topics with high rates. The third topic is mainly based on business processes and models with big data. Such results are quite reproducible by dropping up to 50 % of the analyzed scientific texts. The presented visualizations remain almost the same by adding newly published reviews and original research papers.

It is interesting to remark that mentioning blockchain challenges with using word "challenge" is popular as well, although word "challenge" does not have frequent usage in bigrams and trigrams. This is particularly explained with that there are a lot of words associated with word "challenge", and thus fewer bigrams and trigrams with word "challenge" have significant frequencies. This means, in fact, that there remain many challenges to overcome.

Fig. 2. Word cloud of bigrams in recent scientific publications (years 2024 and 2023) devoted to the use of blockchain in business and management

Another interesting fact is that the blockchain trilemma is mentioned rarely in the recent scientific publications. This is a complex challenge, tackling which requires adopting advanced computational technologies and resources. Similarly to cryptocurrency transactions consuming incomparably enormous amounts of electrical energy, finding an eventual solution to the blockchain trilemma is likely to consume gigantic amounts of electrical energy, as well as a large number of scientific attempts to substantiate and implement it.

Fig. 3. Word cloud of trigrams in the recent scientific publications with bigrams in Fig. 2

Fig. 4. Three underlying topics in the recent scientific publications devoted to the use of blockchain in business and management

Obviously, blockchain is not just a fashionable technology, but a tool capable of fundamentally changing many sectors of the economy, both in Ukraine and worldwide. Its implementation will contribute to the transparency of business processes, automation of operations and increased data security. In Ukraine, blockchain can become an important factor in fighting corruption, developing financial technologies and improving business efficiency. Another perspective is the use of smart contracting in ensuring local and global safety, whose violations being properly registered would automatically impose restrictions and fining on violators and their accomplices.

Conclusion. Blockchain technology has a huge potential to change many business sectors, providing security, transparency and efficiency of processes. However, for their full implementation, it is necessary to solve the issues of scalability, regulatory barriers, as well as optimize energy consumption. The future of blockchain in business looks promising, especially given the opportunities offered by smart contracts, decentralized finance, and asset tokenization. The today's leading trend is energy trading whose blockchains have been increasingly used to record and publish local and regional electricity market data. This is believed to produce a significant impact on establishing and solidifying transparency of pricing and investing in energy sector.

Solving current problems will allow blockchain technology to become the main tool for creating transparent and reliable business processes. However, scalability still remains the most serious and pressing problem in blockchain implementation. While significant advancements are being made to address it, the unsolved balance between scalability, security, and decentralization (the blockchain trilemma) presents ongoing technical, economic, and environmental challenges. Solving these problems is crucial for blockchain technology to achieve mass adoption in business and management and, in general, to implement it across industries and applications. In particular, approaches to overcoming the blockchain trilemma, where it is extremely challenging for a blockchain network to achieve three key properties of decentralization, security, and scalability simultaneously, are actively developed. Innovative technologies and consensus models continue to evolve, potentially bringing us closer to overcoming the trilemma.

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