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Blockchain Technology

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Abstract: This article discusses the historical development of blockchain technology, its applications in various fields, and its future prospects. The blockchain concept, which was first introduced in 1991, was widely implemented in 2008 with Bitcoin, and is currently used in areas such as finance, healthcare, government, and supply chains. It also provides information on platforms such as Ethereum, Hyperledger, and Multichain. The main challenges of blockchain are energy consumption, hardware requirements, and system scalability.

Key words: Blockchain technology, History of cryptocurrency, Bitcoin, Ethereum, Smart contracts, Decentralized systems.

Introduction. Blockchain is a promising and revolutionary technology that helps reduce security risks, eliminate fraud, and bring transparency to an unprecedented level. Initially associated with cryptocurrencies and NFTs in the 2010s, blockchain technology has since evolved into a management solution for virtually every global industry. With blockchain, it is possible to ensure transparency in food supply chains, securely store healthcare data, innovate gaming, and fundamentally transform systems of data and ownership management. Blockchain technology, also known as distributed ledger technology (DLT), enables the free transfer of information from one person to another without the involvement of a third party, using cryptocurrencies (such as Bitcoin) and other digital data. Through blockchain, multiple nodes in the network simultaneously verify a transaction. Anyone with a computer can join the network and participate in the verification process. The transaction is stored as a block of code on multiple devices. Each subsequent transaction is added to the blockchain based on DLT, preserving a historical record, which makes tampering nearly impossible. This secure method of data exchange without third-party involvement makes blockchain highly attractive. Beyond financial operations, blockchain can be used for other types of transactions as well. In addition to security and transparency, the technology is versatile and not limited to a single field of expertise, making it applicable across various industries. Developed countries are using blockchain technology in a wide range of industries, including energy, logistics, education, and others.

Literature Review. In recent years, blockchain technology has become one of the fundamental pillars of the digital economy. Krdzalic [2021] outlines the core concepts, operating mechanisms, and advantages of blockchain. Hayes [2019] and Harvey [2014] explore the social and economic challenges surrounding Bitcoin and other crypto-assets, offering analytical perspectives on the myths and realities associated with them. The development of blockchain technology has led to the evolution of digital currencies [Rose, 2015; Burniske & White, 2017]. Mougayar [2016] and DuPont [2019] provide an in-depth analysis of the significance and practical applications of this technology within the business environment. In particular, the emergence of NFTs [Notaro, 2022] and a new range of digital assets highlight the role of blockchain in the fields of culture and art.

Franch [2022] demonstrates blockchain's impact on supply chain reliability, while Jabbar et al. [2022] analyze its application in intelligent transportation systems.

Research Methodology. This study explores the modern applications, advantages, and challenges of blockchain technology. Data was primarily gathered from scientific articles, analytical reports, and online sources. Using methods such as comparison, analysis, and content analysis, the role of blockchain in finance, healthcare, public administration, and other sectors was examined. In addition, advanced practices regarding the integration of blockchain and cloud computing technologies were analyzed.

Evolution of Blockchain. Although blockchain is a relatively new technology, it already has a rich and fascinating history. This section highlights the most significant and noteworthy events in the development of blockchain technology. The origins of blockchain date back to 1991, when Stuart Haber and W. Scott Stornetta introduced the concept of a cryptographically secured chain of records. Over the following two decades, the technology gained popularity and began to be widely applied.

In 2008, Satoshi Nakamoto (an individual or group) integrated the model and applications built on blockchain technology. In 2009, the first blockchain and cryptocurrency were launched, marking the birth of Bitcoin. This event signaled the beginning of blockchain's impact on the tech sector.

In 2010, a programmer from Florida named Laszlo Hanyecz purchased two Papa John's pizzas using Bitcoin. He transferred 10,000 BTC—worth around $60 at the time—for the pizzas. Today, Bitcoin's market value exceeds $1.9 trillion. By 2011, the value of 1 BTC equaled 1 US dollar, making it the most valuable cryptocurrency in the world. Organizations like Wikileaks and the Electronic Frontier Foundation began accepting donations in Bitcoin.

In 2012, blockchain and cryptocurrency began receiving broad media coverage. Shows like "The Good Wife" referred to blockchain as a future technology. The Bitcoin Magazine was also launched by Bitcoin developer Vitalik Buterin.

By 2013, Bitcoin's market value exceeded $1 billion, and its price reached $100 for the first time. Ethereum entered the market, signaling the emergence of cryptocurrencies beyond Bitcoin.

In 2014, several companies, including Zynga, The D Las Vegas Hotel, and Overstock.com, began accepting Bitcoin as a payment method. Buterin's Ethereum project raised over $518 million through an Initial Coin Offering (ICO), paving the way for new blockchain developments. More than 200 companies formed the R3 consortium to explore blockchain usage. PayPal also announced Bitcoin integration. That same year, the first non-fungible token (NFT) was created.

By 2015, it was estimated that over 100,000 merchants accepted Bitcoin. NASDAQ partnered with the blockchain company Chain in San Francisco to test share trading technology for private companies.

In 2016, IBM announced its blockchain strategy for cloud-based business solutions. Several government agencies in Japan recognized the legality of blockchain and cryptocurrencies.

In 2017, Bitcoin's price hit $51,000 for the first time, and the total market value of cryptocurrencies reached $150 billion. Despite skepticism on Wall Street, JPMorgan CEO Jamie Dimon expressed his belief in the technology. Dubai launched a blockchain-powered government project.

In 2018, Facebook initiated the creation of a blockchain group and revealed plans to develop its own cryptocurrency. Major banks such as Citi and Barclays registered to use IBM's blockchain-based banking platform.

In 2019, Chinese President Xi Jinping publicly endorsed blockchain technology. The People's Bank of China announced its own cryptocurrency. Twitter CEO Jack Dorsey announced hiring blockchain engineers at Square as part of crypto expansion plans. Bakkt, a digital wallet company offering crypto trading on the New York Stock Exchange (NYSE), was launched.

By the end of 2020, Bitcoin's price was projected to reach $30,000. PayPal enabled its users to buy, sell, and store Bitcoin and other cryptocurrencies. The Bahamas became the first country to launch a central bank digital currency with its "Sand Dollar" initiative. During the fight against COVID-19, blockchain technology played a vital role in securely storing medical researchers' and patients' data. Bitcoin reached a new all-time high in market value.

Blockchain is currently one of the most widely discussed innovations and has gained popularity as a technology applied across numerous sectors. Many consider blockchain as a digital distributed ledger or accounting book. Since its launch in 2008, it has continued to evolve as a disruptive technology capable of transforming interpersonal relations, automating expenses, and revolutionizing transaction transfer and tracking processes.

Blockchain can help prevent corruption and embezzlement of budget funds among various authorities. Today, Bitcoin blockchain is one of the largest and most popular public blockchains. Satoshi Nakamoto introduced it in 2008 as an alternative to the traditional banking system. The main goal was to decentralize the banking industry and issue a digital currency called Bitcoin. It uses cryptographic methods to manage cryptocurrency, which includes verifying transactions and creating a long-term chain of transaction history. The key elements of a Bitcoin transaction are the private key, Bitcoin software, and wallet application. Unlike traditional currencies, it is entirely virtual. Bitcoin users have keys that represent ownership within the network. Private keys are used to unlock and sign transactions, and value is transferred by sending it to another key holder. These keys are often stored in digital wallets on user terminals. The Bitcoin network relies on a computational process called "mining" to verify and approve transactions. On average, miners are rewarded every 10 minutes.

Ethereum is another public blockchain platform developed by programmer Vitalik Buterin in late 2013. It features an operating system called the Ethereum Virtual Machine (EVM) to execute smart contracts across participant nodes. Ethereum is an open-source, decentralized public platform that allows anyone to develop and deploy decentralized applications. It supports a consensus mechanism called Proof of Work (PoW), specifically the Dagger-Hashimoto algorithm. Ether (ETH) is the native cryptocurrency of the Ethereum platform and can be transferred between Ethereum accounts. It also includes a data structure known as the Merkle tree, which stores transactions within blocks and forms a hierarchical structure from the bottom up.

Launched in 2016, Hyperledger is an open-source, enterprise-grade platform designed for developing blockchain solutions. It is an active platform, with several projects still in the incubation stage. Hyperledger is a distributed ledger technology (DLT) that supports smart contract functionality. Its consensus mechanisms can include PBFT, Kafka, Solo, and others. It also provides membership service functions to develop permissioned blockchains.

Multichain is another platform designed for the creation and deployment of private blockchains. It is used as a DIY (Do It Yourself) platform for banks looking to develop decentralized financial applications. Unlike other platforms, Multichain does not use the Proof of Work (PoW) consensus model. Instead, miners are selected in a round-robin fashion from a permitted pool. There are no transaction fees or mining rewards in Multichain, which differentiates it from other blockchain platforms.

Each of these platforms has its own characteristics and areas of application, created to meet specific needs. The adaptability of blockchain technology enables it to enter not only the financial sector but also education, healthcare, and logistics, paving the way for broader integration across industries.

Blockchain technology can reduce the risk of data breaches for organizations. By preventing breaches, companies can avoid costs associated with lawsuits, losses, compromised data, and system downtime. Organizations allocate more than 20% of their IT budgets to security and data protection. Most of these expenses are caused by malicious software, averaging $2.4 million per year. Furthermore, it often takes several months to restore affected systems. According to IBM's

latest report, data breaches currently cost $3.2 million annually—a 12% increase over the last five years.

Blockchain technology helps speed up cross-border money transfers and reduce transaction costs. The main challenge facing banks and other financial institutions is the high cost and lengthy processing time of international operations. In traditional systems, such transactions can take three or more days. Cryptocurrencies and blockchain technologies—such as those used by companies like Ripple—are being implemented to overcome these barriers. Today, Ripple's network spans six continents and includes over 40 countries. Blockchain allows cross-border transactions to be completed in near real-time and at a fraction of the usual cost.

Blockchain can also eliminate inefficient supply chains and reduce associated costs. Currently, it can take several days to complete supply chain and trade finance operations after documents are verified, mainly due to manual documentation processes. Key shortcomings include inefficiency, fraud risk, and high costs. Various blockchain platforms are being used to address these problems, such as IBM's Batavia, R3's Marco Polo, the Digital Trade Chain, and the Hong Kong Trade Finance Platform. These operations can now be completed in minutes at a fraction of the cost.

Governments are using blockchain technology to protect national identity data. It is also employed in the management of digital identities. For example, Estonia uses a blockchain-based digital identity system to digitize national ID records, protect citizens' data, and overcome the inefficiencies and high costs of legacy digital ID management platforms.

Blockchain is also an effective solution for protecting copyright and intellectual property. Several startups use blockchain to safeguard their clients' IP rights. After registering, users can protect their artwork on the platform from unauthorized use. For instance, companies like Blockai and Copyrobo enable artists to secure their work online within seconds. With blockchain and artificial intelligence, users can prove ownership through copyright certificates, timestamps, or digital fingerprints.

In healthcare, blockchain is used to track pharmaceuticals through the supply chain and protect sensitive data. In pharmaceutical supply chains, blockchain is utilized to monitor prescription medications. Under the U.S. Drug Supply Chain Security Act, blockchain helps prevent and control the distribution of counterfeit drugs, and enables the quick and efficient recall of ineffective or harmful medicines.

Blockchain also holds great potential in cybersecurity. It can enhance the security of 5G applications and mitigate cyberattacks. Among various types of blockchains, public blockchains are generally more secure than consortium or private blockchains due to their open membership and consensus mechanisms. Public blockchains allow members to remain anonymous. In contrast, only trusted nodes can participate in consortium and private blockchains. Public blockchains typically use the Proof of Work (PoW) consensus mechanism, while consortium blockchains rely on multi-party voting, and private blockchains use strictly pre-approved nodes for consensus.

One of the main issues facing blockchain applications is hardware and energy consumption. Blockchain is widely used across the internet for various purposes. Due to its decentralized nature, it is considered a viable alternative to many traditional transaction systems. To ensure scalability, interoperability, and stability, blockchain systems must be supported by acceleration mechanisms. Operations involving public keys, such as signature generation and verification, are one solution that can serve as a secure public key infrastructure mechanism.

Researchers have designed a blockchain hardware accelerator by integrating a load dispatcher with a public-key crypto engine (BA414EP). Since the transaction load is distributed across multiple components, overall transaction speed and output accuracy increase.

On average, a single Bitcoin transaction consumes 707 kilowatt-hours of energy, which is 11 times more than that of Ethereum. Bitcoin requires computers to solve complex mathematical problems to verify transactions. The miner who solves the equation the fastest confirms the

transaction and receives a small Bitcoin reward in return. The Proof of Work (PoW) consensus mechanism consumes more energy than many assume. According to Paul Brody, EY Global Blockchain Leader, it resembles a race where many competitors rush to solve a small math problem as quickly as possible to collect transactions.

Additionally, Bitcoin transactions take more than 10 minutes to complete — the time required to mine a new block. When compared with digital transactions managed by Visa, Visa operates much faster and requires less energy. Bitcoin can handle only 4 transactions per second, while Visa is capable of processing up to 1,700 transactions per second.

Conclusion. Blockchain technology is not limited to cryptocurrencies; it is successfully applied across numerous sectors. Its development and widespread adoption offer innovative approaches not only in finance but also in healthcare, public administration, intellectual property protection, and other fields. The main advantages of blockchain lie in its decentralized structure, enhanced security, transparency, and the ability to perform transactions quickly and efficiently. Moreover, it contributes to improvements in data protection, cybersecurity, and cross-border payments.

However, the widespread adoption of blockchain technology still faces several challenges. The most significant issue is hardware and energy consumption. Executing operations on Bitcoin and other blockchain networks requires high energy usage, which may lead to environmental concerns. Additionally, transaction speed and scalability — especially compared to traditional systems — remain limited.

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