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| RESEARCH ARTICLE

A Survey of Blockchain-Powered Digital Payment Systems and Their Influence on Global Financial Inclusion

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| ABSTRACT

The blockchain technology has adhered to becoming a radical innovation in the area of digital finance, in which it has delivered secure, decentralized and transparent methods of transacting business. This paper examines the application of digital payment systems based on blockchain and how it enhances financial inclusion in the world. It describes the fundamental concepts of blockchain, such as transaction formats, block architecture, and digital signatures, as well as how cryptocurrencies can support peer-to-peer digital payments. Payments and settlements, smart contracts, asset tokenization, trade financing, and other notable applications of blockchain technology in the financial sector are included in the study. Furthermore, the paper examines the concepts of financial inclusion and the applicability of digital payments to the magnitude of supplying underserved groups with formal financial services. It is assessed that digital finance that utilizes blockchain technology might offer a viable alternative.to several prominent financial inclusion challenges, including high transaction costs, a lack of digital identity, and mistrust of financial institutions. Lastly, the study concludes blockchain technology's impact on financial inclusion globally by discussing how it improves financial system accessibility, efficiency, and transparency while also addressing new challenges in infrastructure, cybersecurity, and regulation.

| KEYWORDS

Blockchain Technology, Digital Payment Systems, Financial Inclusion, Cryptocurrencies, Decentralized Finance (DeFi), and Digital Finance.

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I. Introduction

With the rapid advancement of digital technologies and information and communication technology (ICT), the financial ecosystem has been modernized, which has a significant impact on the world's financial system. The use of the internet, mobile phones and electronic commerce has increased the adoption of electronic payment systems as opposed to cash-based transactions[1]. Digital payment technologies allow individuals and businesses to transact financial transactions effectively online and eliminate reliance on physical currency, increasing the effectiveness, practicality, and openness of financial transactions. The realm of digital financial services has seen blockchain technology's dramatic rise in the past few years[2]. Cryptocurrencies like Bitcoin are built on top of blockchain technology, which has evolved into a secure, decentralized ledger system with several financial applications. Minimal middlemen and counterparty risks in financial transactions are made possible by the technology's decentralization, transparency, immutability, and cryptographic security [3] . Because of these features, the blockchain technology has become a subject of extraordinary attention from financial institutions, technology companies, policymakers, and those who desire safer and more effective financial systems.

The application of blockchain on digital payment systems can transform the financial services industry as it allows quick, safe, and inexpensive transactions[4]. Banks and globally, central banks are progressively thinking about implementing blockchain-based solutions as ways of enhancing payment infrastructures, increasing data security, and simplifying financial processes[5]. Moreover,

blockchain is already implemented in different sectors of supply chain management, cybersecurity, insurance, and digital identity management, and these examples suggest its wide potential to transform the traditional business model.

Financial inclusion has gained a high priority among most developing economies. People and businesses are considered financially included when they have access to reliable and reasonably priced banking, payment, credit, and savings services. Despite developments in financial technology, a large segment of the global population, particularly in developing countries, does not have access to formal financial services [6][7]. The lack of access to banking facilities, excessive transaction prices and financial illiteracy are the biggest obstacles in ensuring that the underserved people can access the formal financial system. Digital payment systems based on blockchain can be promising solutions to these problems because they provide the use of decentralized and transparent financial services that are cost-effective[8]. Blockchain, with its recent innovations such as cryptocurrencies, smart contracts, and decentralized finance platforms, has the potential to increase access to finance and offer new opportunities to unbanked and underbanked groups[9]. The blockchain-based payment systems are able to make financial accessibility and economic involvement more widespread by lowering operational expenses and removing intermediaries.

A. Organization of the Paper

The following sections are included in the paper: Section II delves into the fundamentals of blockchain technology and digital payment systems. An overview of the design and execution of the financial payment system based on blockchain would be included in Section III. Section IV examines how blockchain technology can improve access to global financial services. The review of recent works is in Section V. The conclusion and suggestions for future research are presented in Section VI.

II. Blockchain-Based Systems for Digital Payments

The blockchain-based digital payment systems incorporate digital signatures, block components, and transaction structures. It goes on to say that among blockchain's main uses—along with smart contracts, financial processing, and fraud mitigation—is the importance of cryptocurrencies and trade finance.

A. Fundamentals of Blockchain

The term "blockchain" refers to a distributed ledger system that uses a peer-to-peer network to record and update transactions across several computers. Blockchain was first created for Bitcoin, a cryptocurrency. A central authority is no longer necessary thanks to blockchain technology, which records and verifies transactions for almost everything of value[10]. Blockchain is special because it establishes confidence in the data prior to a block array being added to the chain. Blockchain technology is such a game-changer; no more intermediaries. Today, while doing business with one another, it doesn't display the other person's personal financial and commercial records. To see records and maintain the privacy of this information, they rely on reliable middlemen like banks or lawyers. These middlemen enable verification and foster confidence between the parties. Blockchain technology may be applied in a number of methods and is not restricted to a certain network[11]. It can be restricted to a certain set of authorized users, such as a group of banks or government organizations, but it is fully public and accessible to anyone. Blockchain is safe and tamper-proof, and it decreases risk and cost.

A state shift that modifies the value of data on the blockchain is implied by a transaction. Cryptocurrency, smart contracts, records, and data storage are all possible components of a blockchain transaction. The blockchain has three types of transaction categories shown below:

- **On-chain transactions:** These are accessible on any network participant can view the distributed ledger. Since the transaction's numerous details are stored on the block and distributed across the blockchain, it cannot be undone. An agreed-upon number of miners must confirm the transaction for it to be finalized.
- **Off-chain transactions:** These are not recorded on the network and occur outside of a main blockchain. The parties can decide to forego the blockchain and reach an agreement elsewhere. There may also be a guarantor, who is in charge of attesting to the transaction's completion and the agreement's adherence. Once it has been accepted by the people involved outside of it, the actual transaction is carried out on the blockchain. Various techniques, incorporating credit-based solutions and multi-signature technologies, can be used to complete the e-commerce transactions. While on-chain transactions take time to complete, off-chain transactions are completed rapidly.
- **Hybrid transactions:** The transactions incorporate components of both on-chain and off-chain transactions. The differentiation between on-chain and off-chain operations is established based on many variables, including cost, decentralization, storage, and privacy.

B. Architecture of Blockchain Payment Systems

A blockchain, which resembles a digital public ledger, is a set of blocks that includes an extensive transaction record. A cryptographic hash is used to connect each block to the previous block. and comprises a collection of validated transactions, creating a continuous and safe sequence. Every block has a single parent block that is referenced in its header via the hash of the preceding

block, as shown in Figure 1. The genesis block, the initial block on a blockchain, has no parent block[12] . In some blockchain platforms, such as Ethereum, additional block references (called uncle blocks) may also be stored to improve network efficiency and security. This structured architecture ensures transparency, including the transaction's date and time.

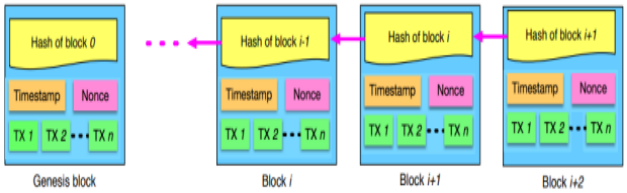

Fig. 1. Sequence of Blocks in Blockchain

A block

Information such as the amount transferred between the two parties involved, the time and date of the transaction, and other pertinent details is included. The two primary parts of a block are its content and header, as seen in Figure 2.

- **Block version:** The rules for block validity are specified here:
- **Merkle tree root hash:** Each transaction has a unique code that distinguishes it from the others. In essence, it distinguishes each transaction from the others, facilitating the identification of the specific transaction at the moment of inquiry. The distinct code is referred to as "Hash."
- **Timestamp:** This is the current time in Coordinated Universal Time (UTC) expressed in seconds.
- **nBits:** Minimum required hash value for a legitimate block.
- **Nonce:** An initial value of 0 is used to increment the size of this 4-byte field with each hash calculation.
- **Parent block hash:** For the purpose of validating the preceding block in the blockchain, hash is a 256-bit integer.
- **Block Body:** A block's body is made up of transactions and their corresponding counters. The maximum number of transactions that can fit inside a block is determined by its size and the size of each transaction. To verify the authenticity of transactions, blockchain employs asymmetric cryptography [13]. In a dynamic environment, asymmetric cryptography-based digital signatures can be helpful.

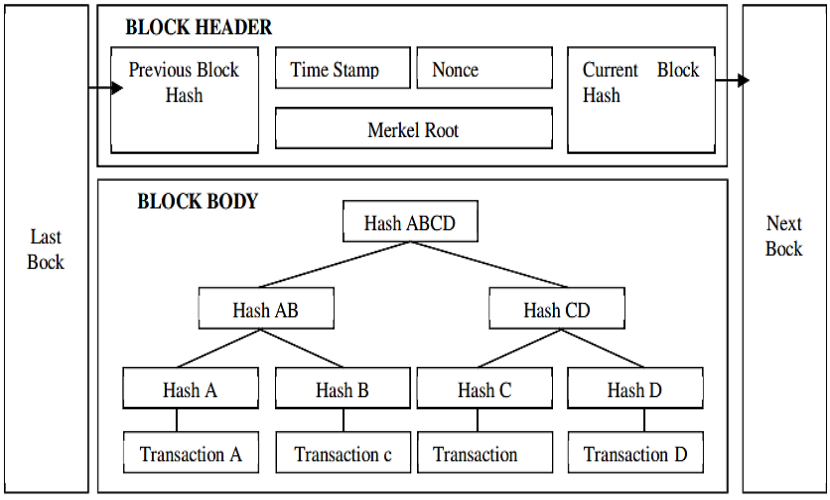

Fig. 2. Block Structure

Digital Signature

It includes a distinct digital signature assigned to each member of the whole network. At the moment of the transaction, all parties involved are identified using this digital signature. With a capacity of about 1 MB, each block may accommodate thousands of transactions.

C. Cryptocurrencies and Digital Tokens in Payments

Cryptocurrencies and digital tokens are crucial in payment systems based on blockchains because they function as a medium of exchange when carrying out digital transactions[14]. These are stored on blockchain, an intercomputer distributed system spread (distributed) over computers all over the world, which means that such transactions are transparent, secure, and immutable. Cryptocurrencies are decentralized and provide individuals with the opportunity to transfer value directly between each other using

blockchain networks. The users in blockchain networks carry out transactions through public addresses, which act like email addresses and enable the transfer of funds without loss of user anonymity. The sender needs to be aware of the public address of the recipient to make a transaction, but it is typically distributed to the customer by use of QR codes or alphanumeric wallet addresses. The sender signs the transaction digitally with the help of his/her own key and informs the blockchain network, where it is verified[15]. Once the transaction has been verified by network nodes or miners, the blockchain registry stores the transaction indefinitely once it has been assembled into a block. Moreover, cryptocurrencies are usually bought and sold in cryptocurrency exchanges, just as is the case with traditional currencies or assets in financial markets. This is a decentralized and secure system with the capacity to facilitate quicker, transparent and efficient digital payments across all financial systems in the world.

D. Applications of Blockchain in Finance

In several financial services industries, the blockchain technology has significantly advanced, specifically in the digital payment systems[16]. It has a decentralized and secure structure that enables money to be transferred effectively, enhances transparency and reduces the complications of operations. The most prominent uses of blockchain in finance and electronic payments may be outlined as follows:

- **Payments and Settlements:** Blockchain allows faster, safer, and less expensive international payments. Blockchain helps to reduce transaction costs and settlement time since it removes intermediaries and makes verification processes simpler, thus enhancing the efficiency of financial systems in general.
- **Smart Contracts:** Smart contracts are self-executing agreements that record trade conditions in a blockchain. They improve the transparency of lending, insurance, and compliance procedures and lessen the number of mistakes and sluggish commercial operations.
- **Trade Finance:** The use of blockchain-based systems is revolutionizing the finance of trade by computerizing documentation and automating supply chain interactions. This minimizes the risk of fraud, shortens processing time, and enhances confidence and cooperation among the participating entities.
- **Asset Tokenization and Securities Trading:** Blockchain has enabled tokenization of real-world assets that can be fractionally owned and have finer access to the investments. It can also help achieve faster settlement of securities trades and improve the liquidity and efficiency of the market.
- **Fraud Prevention and Compliance:** Blockchain is decentralized and immutable, which enhances fraud detection and regulatory compliance. It enforces secure identity verification and improves its services, such as Know Your Customer (KYC) and Anti-Money laundering (AML), that ensure the financial transactions are safer and more transparent.

III. Financial Inclusion and Digital Payments

Blockchain technology has rapidly evolved into a revolutionary platform for financial services, but it was initially developed as a basis for cryptocurrencies such as Bitcoin. Its decentralization, immutability, and transparency in distributed ledgers help address most inefficiencies in conventional financial systems. Furthermore, financial inclusion is enabled through the integration of digital finance and blockchain technologies to enhance access to digital payment services for underserved groups and to identify novel solutions that can help address the main financial challenges.

A. Concept of Financial Inclusion and Digital Payment

The continuous supply of effective and reasonably priced financial services is known as financial inclusion, which can enable individuals, especially those with low income, to access the formal financial system. Access to and usage of formal financial services include banking, credit, savings accounts, and payment facilities. Financial inclusion initiatives will provide access to these services for more people, particularly those who did not have access to them earlier and are now actively involved in such systems [17]. A wider range of financial services makes it easier for individuals to put money down, put it toward education, start their own businesses, and deal with financial risks. As a result, making sure that everyone has equal access to financial opportunities is essential for financial inclusion to promote economic development and reduce poverty.

Digital payment is a process that involves the electronic transfer of money using digital systems without using physical cash. It allows people and companies to transact their financial transactions through mobile phones, computers, and payment cards. The provision of digital services to underprivileged people is known as "digital financial inclusion" and marginalized populations that enable them to conduct simple financial services including payments and transfers, as well as, saving remotely using formal financial services[18]. As financial technologies rapidly evolve, new digital financial services have appeared in most countries, with their mobile applications, digital wallets, and online banking. These services encourage consumers to abandon offline modes of payment for online modes of payment that are safe and efficient.

B. Digital Finance Framework for Financial Inclusion

One tactic to eradicate or lessen poverty is financial inclusion. Through enhanced financial inclusion, the public sector, the business sector, or a combination of the two may take the initiative to reduce poverty. In order to increase financial inclusion, the

private sector offers digital financing. Fintech and financial services firms are examples of private sector participants may encourage disadvantaged and marginalized populations to interact with the formal financial sector through mobile channels by providing them with services and solutions related to digital finance[19]. With digital banking credentials, such as passwords for online banking or other forms of digital access, the excluded group can connect their bank accounts to digital payment channels and do basic financial tasks. Further, financial inclusion will improve if low-income and disadvantaged people can afford to use the digital financial system. Figure 3 illustrates the government's efforts to alleviate poverty and increase access to financial services by highlighting the role of technology and banks.

In contrast, financial data inclusion seeks to expand access to legal financial services, primarily bank accounts, by linking biometric data for the entire population with their financial accounts. The target audience in this case is low-income individuals. From a policy standpoint, including financial data is more feasible than including financial inclusion [20]. Integrating biometric data with bank accounts can accomplish two things: first, it can help with tracking the demographics and income levels of people who use digital financial services, and second, it can enable digital financial transactions that can be validated and linked to specific individuals or businesses.

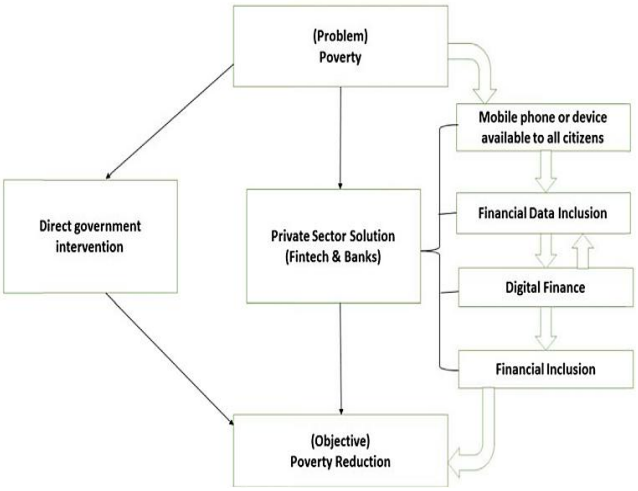

Fig. 3. Framework for Digital Financial Inclusion

The success of digital finance, however, hinges on people's willingness to interact with digital systems using digital access tools and credentials for online banking. People can access a range of financial services from anywhere when they use digital financial platforms. Governments, financial institutions, and technology suppliers must collaborate actively with users to accomplish digital finance systems' long-term goal of enabling financial inclusion.

C. Digital Payment Adoption and the Growth of Financial Inclusion

As real-time digital connectivity is rapidly becoming a reality, financial services have become more accessible to individuals in most regions. Previously, the Business Correspondent (BC) model was used to expand the banking services to rural and remote locations with the help of trained representatives providing simple financial services. Even though this model was significant in enhancing access, it was usually sluggish and resource-intensive. With the introduction of new online payment platforms, the provision of financial services has greatly changed[21]. For Digital Financial Inclusion (DFI), the National Payments Corporation of India (NPCI) developed services including the Unified Payments Interface (UPI), the Aadhaar Enabled Payment System (AePS), and the Immediate Payment Service (IMPS).

These are technologies that provide immediate transfer of funds, authenticated digital identities and accessible financial services using mobile devices. More recently, blockchain technology has also been used to improve digital payment systems through decentralized, transparent, and secure forms of transactions. The systems based on blockchain help to minimize the transaction costs, enhance transparency, and boost trust in digital financial services. Consequently, blockchain and digital payments are increasingly becoming important in increasing financial access, especially to underserved and rural communities.

D. Blockchain-Based Solutions to Financial Inclusion Challenges

To address the problems of financial inclusion, blockchain technology has arisen as a disruptive factor. Blockchain's decentralized, safe, and transparent financial systems have the ability to lower the majority of the obstacles faced by underbanked and unbanked people.

- **Reducing Transaction Costs:** The ability to reduce transaction costs is one of blockchain technology's biggest advantages. Due to the large number of middlemen in traditional banking structures, the costs are high and disproportionately impact those with low incomes[22]. Blockchain technology can simplify decentralized systems, lower transaction costs, and foster distributed trust. Financial services can be more affordable for disadvantaged communities when blockchain technology is used to eliminate intermediaries and enable direct peer-to-peer transactions.
- **Digital Identity Verification:** A significant portion of the population lacks the official identifying documents necessary to obtain banking services. The creation of secure digital identities is one way that blockchain technology might help solve this issue. To help more individuals gain access to financial services, which are often inaccessible due to a lack of proper documents, this is crucial.
- **Decentralized Finance (DeFi) Solutions:** Increasing access to financial services is the goal of a recent invention called decentralized finance systems. Using blockchain technology, DeFi creates a decentralized financial infrastructure that eliminates middlemen in lending, trading, and borrowing, and it may help more consumers acquire, use, and receive better financial products, according to the Aspen Institute.
- **Smart Contracts for Financial Services:** Financial procedures can be automated by using code-coded terms and conditions in self-executing smart contracts. They reduce the need for middlemen in transactions and promote transparency. Smart contracts are used to increase the effectiveness of current procedures and enable faster, more reliable transactions for those who might otherwise be delayed by bureaucracy.
- **Addressing Trust Issues:** Users who might not feel at ease with the current traditional financial institutions are encouraged to trust blockchain because of its decentralized nature. It is feasible to validate every transaction without relying on a central authority since blockchain records are unchangeable and transparent. Trust concerns are resolved in the absence of a central authority, which is essential for building confidence among those who were previously shut out of traditional financial institutions.

IV. Impact of Blockchain on Global Financial Inclusion

Blockchain technology is also a crucial part of advancing global financial inclusion since it makes financial services more accessible, transparent, and efficient. New financial ecosystems, cryptocurrencies, and decentralization offer secure, cheap transactions, and this enhances financial accessibility to underserved populations in all parts of the world. The financial system of the world is being changed and blockchain technology can possibly render financial services less demanding to a non-bank world population of about 1.4 billion adults[23]. Blockchain assists in minimizing the use of the traditional banking system and enhances accessibility to financial services, opening them up and making them cheaper by means of decentralized and secure financial operations. The evolution of digital technologies has made blockchain-based solutions crucial to the definition of financial inclusion, a factor that many governments, financial institutions, and technology providers are now considering. Figure 4 shows financial inclusion and blockchain technology, as it enables solutions that encompass cryptocurrencies, smart contracts, and DeFi, which increase access to financial services. It also shows the benefits like transparency, low transaction costs and efficiency and describes the challenges like regulatory issues, infrastructure limitations and cybersecurity risks.

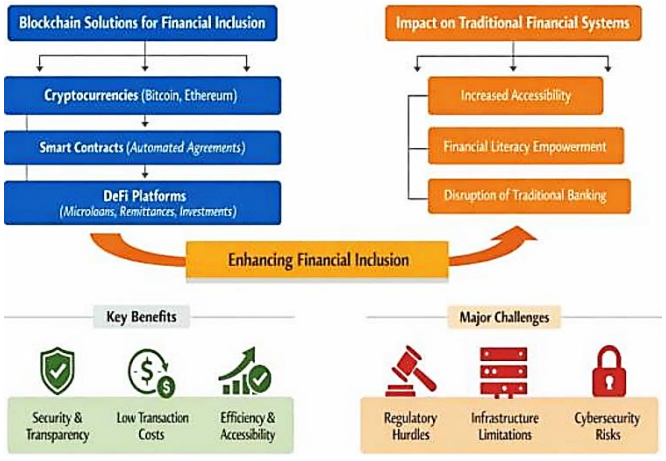

Fig. 4. Impacts of Blockchain On Financial Inclusion

A. Decentralized and Transparency

Blockchain technology records transactions using a distributed ledger system that is spread out among many nodes in the network, as opposed to previous centralized systems. This system enhances transparency, stability and responsibility in the financial dealings. Users now have significantly greater control over their financial and personal data, with less reliance on intermediaries.

Even the financial institutions have started exploring the opportunities of blockchain to streamline their businesses and allow them to be more efficient.

B. Transformation of the Business Landscape

Blockchain is also changing the global business environment and introducing new models of finance and digital asset systems. New technologies such as tokenization, a real or virtual asset on a blockchain system, and Initial Coin Offering (ICOs) as alternative sources of funding have also increased. Most enterprise technology companies are also deploying the blockchain to enhance transparency, offer better data security, and enable organizations to share information efficiently.

C. Growth of Cryptocurrencies

Blockchain technology has given rise to numerous cryptocurrencies, enabling decentralized digital transactions between users without the need for a central authority. These digital currencies enable people to move value across the world but with some degree of anonymity and security. Though the traditional fiat currencies are still predominant, the trend of growing popularity of cryptocurrencies proves the rising demand for decentralized financial systems.

D. Emergence of New Financial Ecosystems

Occurrences of new financial services and digital ecosystems have been borne by blockchain technology, such as cryptocurrency exchanges, digital wallets, decentralized finance (DeFi) platforms, and blockchain-based financial applications[24]. The innovations are generating new business opportunities for businesses and individuals and fostering technological leadership between countries that invest in blockchain development.

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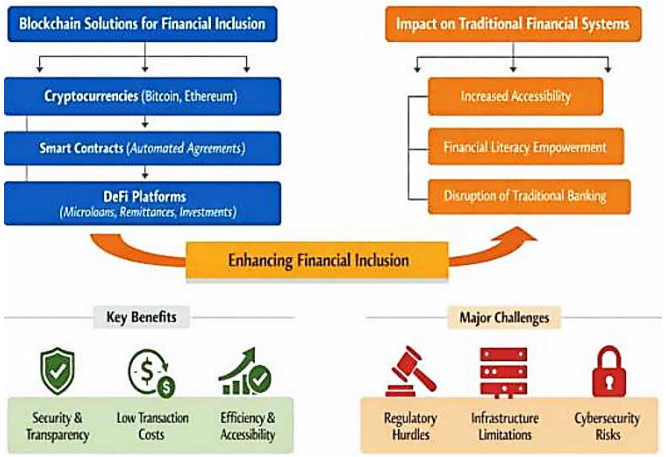

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Blockchain solutions can reduce the cost of transactions, enhance security and give confidence to financial systems, and then enable new financial systems such as the idea of decentralized finance. Generally, digitally financed blockchain can create a more open, effective, and transparent world financial infrastructure, although regulation, technology, and adoption challenges need to be resolved. Future research can focus on developing scalable blockchain systems that can operate large-scale digital payment systems, mitigate security breaches, and operate efficiently. Further studies on regulatory frameworks can also be conducted, and financial inclusion programs can be strengthened by combining blockchain systems with emerging technologies like AI and IoT.

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