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Interoperability of Blockchain Systems in Banking: Assessing the Role of Cross-Chain Technologies in Facilitating Seamless Global Transactions

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***Abstract*: The growing usage of blockchain technology in the banking industry has brought attention to how important it is for various blockchain systems to be interoperable to facilitate smooth international transactions. To enable communication and data transfer between various blockchain platforms, cross-chain technologies present a variety of opportunities and obstacles. This study explores these issues in depth. In the context of global banking, the study attempts to evaluate how well these technologies work to address fragmentation problems that impede transactional fluidity and scalability. Through an examination of novel cross-chain structures such as atomic swaps, relays, and hash-lock time contracts, this study assesses how well they can improve operational effectiveness, shorten settlement times, and lower counterparty risk. Additionally, the study looks into how these technologies may affect data privacy, security procedures, and regulatory compliance in international financial transactions. In the end, this paper aims to further the conversation on blockchain interoperability by highlighting the main facilitators and obstacles to global banking transactions that are frictionless, emphasizing the need of cross-chain solutions for the development of decentralized financial systems.**

***Keywords*: blockchain, cross borders payments, cross-chain technology.**

1. Introduction

In recent years, banks have been threatened within the cross-border payment segment. By facilitating more effective cross-border payment processing, blockchain technology presents a game-changing opportunity for financial organizations. Since currency conversions and different regulatory frameworks cause delays, high transaction costs, and complexity, international transactions have historically relied on a network of correspondent banks, clearing houses, and intermediaries. Blockchain, also referred to as digital ledger technology (DLT), simultaneously makes users accountable for their transactions and permits untraceable or fictitious financial operations without central control.

Companies such as PayPal, Western Union and Transferwise are gaining market share as they provide customers with enhanced value propositions. Blockchain technology has unveiled yet another facet of decentralization's power (Käll, J. 2018). In the process of cross-border transactions, the credit rating of cross-border e-commerce enterprises is different due to the differences in economy, culture, and system between different countries. The mutually exclusive nature of the systems is one aspect of the issue. Without blockchain, money transfer companies, correspondent banks, and financial institutions all along the value chain have pieced together a patchwork of financial interoperability throughout the years in order to transport money to various parts of the world. Interconnecting these dissimilar systems has caused friction that leads to lengthy delays and expensive costs at each step in the chain, especially in underserved countries where the local currency is not traded internationally.

At present, there is no open enterprise credit sharing platform between countries, which makes it difficult for enterprises of different countries to evaluate each other's credit effectively in the process of cross border transactions, which makes it difficult for enterprises of both sides of the transaction to trust each other, so that enterprises have adverse selection consequences, and then affect the overall development of cross-border e-commerce. Different blockchain features and capabilities are needed to serve different use cases and stakeholders (WEF. 2020). One of the driving forces behind the creation of distinct blockchains and a heterogeneous ecosystem is the necessity for adaptation. Selecting new blockchains enables developers and researchers to stay up to date with fresh initiatives and apply new use case scenarios. However, because the technology is still developing, there are security flaws, a small user population (compared to the internet or databases, for example), and security laws, each blockchain has some dangers associated with it. Developers and researchers must therefore decide between originality and stability, which results in a wide range of options. The result of this diversity is fragmentation: a lot of blockchain solutions are immature (e.g., not thoroughly tested). Prior to recently, blockchains ignored the requirement for interoperability because they were all focused on finding solutions to certain problems, which resulted

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in data and value segregation (H. Jin and X. Dai. 2018, Tasca, P., & Tessone, C. J. (2017). Despite differences in data structures, digital signature schemes, transmission protocols, verification mechanisms, consensus mechanisms, token issue mechanisms, and smart contract language, connecting blockchains ultimately proves to be a manageable approach, despite the complexity of blockchain interoperability technology. Therefore, assessing how crosschain technology can enhance blockchain interoperability is crucial.

A. Important Terms

1) Blockchain

As per Kosba et al. 2016; Bonneau et al. 2016: Blockchain can be compared to a database or data structure. Broadly speaking, blockchain is a decentralized network or system that integrates specific technologies to provide its users with an exchange environment.

2) Cross- borders payments

Transactions that take place between two parties in separate nations and are made possible by blockchain technology are known as blockchain cross-border payments. The goal of blockchain-based cross-border payments is to speed up financial transactions, cut expenses, and do away with middlemen.

3) Cross-chain technology

The term "cross-chain technology" describes the capacity to transfer coins and data between several blockchains.

B. Research Objectives

1) To evaluate how cross-chain technology can improve blockchain systems interoperability in the banking industry.
2) To assess the opportunities and difficulties involved in putting cross-chain technologies into practice.

2. Interoperability of Blockchains

Interoperability serves more than just making applications portable and flexible among themselves. Because systems can manage higher volumes of transactions or data exchanges across different platforms, it also helps to improve scalability. Through process simplification, the elimination of redundancies, and speedier system communication, interoperability increases efficiency. Furthermore, it can improve privacy through the facilitation of safe data sharing while preserving control over sensitive data across several networks or platforms, especially in industries such as banking where data confidentiality is crucial. The main topic of blockchain interoperability is how we can combine several blockchains and get them to communicate with one another in ways that will be advantageous to us. Due to the complexity, technical, and semantic interoperability is primarily the focus. However, the explanation can be compared to how the internet operates on several layers, only this is less diverse and more specific on how malleable the integration is between the different layers. The two main types of interoperability are:

1) *Technical interoperability:* This describes the processes and tools that make it possible to integrate several blockchain systems together technically. It focuses on how several blockchains interact with one another, share information, and carry out cross-platform transactions in a seamless manner while maintaining system functionality.
2) *Semantic Interoperability:* When data moves between blockchain networks, this layer makes sure that its original state and integrity are maintained. Its fundamental objective is to ensure that data is accurately interpreted across systems, preserving its consistency and meaning even when it is moved between different blockchains.

Core Elements of Financial System:

- *Banking Sector:* The banking sector is a crucial part of financial system. It consists of a diverse range of banks, including commercial, international, and specialty banks. The country's central bank, creates monetary policy and oversees the banking industry to maintain stability and efficacy.
- *Microfinance Institutions:* Due to its ability to offer low-income people and small business owners who do not have access to traditional banking services with financial support, microfinance organizations have grown in popularity, especially in the country's rural areas.
- *Capital Market:* The nation's capital marketplace consists of the stock exchanges where businesses trade bonds and stocks to raise capital.

3. Literature Review

Duan et. al. (2023) suggested that improving smart contract standards may be able to help with standardization issues. Financial institutions can create more complicated financial instruments that function across several blockchain ecosystems and promote smoother cross-chain transactions by implementing interoperable smart contract frameworks. cross-chain protocol governance and compliance concerns might be addressed, preserving the security, openness, and compliance of financial services with international legal standards.

Sharma et.al. (2023) focused on the real-time transfer of digital assets across several blockchain networks is made possible by cross-chain technology, which helps banks manage liquidity more effectively. Large reserves in individual jurisdictions are no longer necessary since banks can hold liquidity reserves in many currencies and assets on separate chains and rapidly move them to the network where they are needed. For international banking operations to retain liquidity and manage cross-border transactions, flexibility is essential.

Zhu, L., Wang, C., & Ni, X. (2023) examined cross-chain frameworks and examines how cross-chain technologies are resolving the main issues with banking's disjointed blockchain ecosystems. It focuses on hash-locking methods and multi-signature systems used in atomic cross-chain transactions.

Sousa and Rodrigues (2022) emphasized that by allowing real-time payment settlement across several blockchain networks, cross-chain protocols enable smooth interbank transactions. Cross-chain solutions guarantee that value can be

transferred securely between banks without the need for middlemen, for example, if one bank runs on Ethereum and another on a private blockchain. By doing this, cross-border transactions become much faster, more secure, and more efficient while relying less on antiquated systems like SWIFT.

Wang, Xu, and Li (2022) studied how cross-chain technologies can be used to solve the persistent problems associated with international banking. By enabling direct asset transfers between banks using various blockchain platforms, interoperable blockchains might lessen the need for middlemen like correspondent banks. This not only expedites transaction times but also considerably lowers the expenses associated with international banking—a critical benefit for sectors such as international trade and remittances.

Natarajan, Krause, and Gradstein (2021) emphasizes that increasing blockchain interoperability requires dApps. Users can smoothly engage with many networks as they operate as bridges connecting various blockchain ecosystems. The fragmentation in the blockchain environment can be addressed by dApps by utilizing cross-chain protocols to enable transactions, data sharing, and asset transfers across many platforms. Cross-chain technology-based successful dApp case stories are included in the study. They talk about systems like Chainlink, for instance, which offers decentralized oracles that let smart contracts safely access off-chain data. For a number of financial applications, such as trading in derivatives and insurance, this capacity is essential.

Chen et.al. (2021) identified the security of cross-chain transactions in the study. Transferring assets and data between several blockchain networks is necessary for cross-chain technology, which entails hazards including potential cyberattacks, data breaches, and double-spending. The study highlights that even with the abundance of security methods available, a major obstacle to blockchain integration in banking is maintaining a reliable, unhackable system.

Weber et al. (2019) suggested a multi-tenant system's platform architecture. Every tenant will possess a distinct private network, all of which are linked to a primary public blockchain. Data integrity is achieved by the system by anchoring the tenant chains' data to the public chain. Such an architecture is better suited for a single blockchain every year or a long- and short-lived blockchain for varying business demands.

A. Revolutionizing Banking through Blockchain: Unveiling Opportunities and Navigating Emerging Challenges

Blockchain technology has been a game-changer across several industries, but finance is one that has seen the most transformation. The banking industry has a lot of opportunity because of its decentralized and unchangeable character, but it also brings with it issues that call for careful navigation. This is a thorough description of how blockchain is changing banking, along with the potential and difficulties it presents.

- *Decentralized and Transparency:* It is distributed and decentralized digital ledger used to record transactions across multiple computers, ensuring that the record cannot be changed backward without changing every block that comes after it and the network as a whole cooperating." It is made up of linked blocks, each of which has many transactions. Blocks are added to the blockchains to create a complete ledger, which is an exhaustive record of all transactions. By cutting out middlemen, increased transparency lowers operating costs and speeds up transaction procedures. Banks can use blockchain technology to give customers real-time transaction visibility and foster client trust.
- *Enhanced Security and Data Integrity:* Many experts even predict that blockchain technology will be the one to start the next wave of disruptive revolutions. Blockchain technology can address the trust mechanism issue. An essential component of blockchain technology is trust. It resembles a public accounting book that is accessible to everybody for recording, viewing, and upkeep. Every record has an unchangeable permanent time stamp. The trust dilemma plaguing the modern economy has been partially resolved in part because blockchain technology has disrupted the centralized features of the traditional Internet. The parties simply need to trust the blockchain itself to accomplish this when the transaction is carried out and settled on the ledger; they are not required to build a relationship of trust between themselves. Blockchain technology can address the issue of data authenticity. Blockchain can efficiently encourage the exchange and circulation of data. Convergence of data production can be efficiently promoted by blockchain. The "value Internet" is now possible thanks to the blockchain. Because of blockchain's cryptographic techniques, everything on the ledger is safe and unchangeable, making it very difficult to change past transactions without the approval of the entire network.
- *Cost Efficiency in Transactions:* Blockchain technology has the potential to significantly improve a number of financial services operations, including regulatory compliance, trade finance, payments, and securities settlement. Additionally, they might help eliminate some of the inefficiencies associated with traditional banking, like the prices and delays associated with foreign exchange (FX) transfers. Regular financial procedures have a high transaction cost because they require several middlemen and external validation mechanisms. Blockchain enables peer-to-peer transfers, which significantly reduces these costs. In particular, cross-border transfers, which frequently entail expensive fees and lengthy processing periods, can be made more affordable for banks by utilizing blockchain technology. Blockchain allows for almost instantaneous, affordable international transactions.
- *Smart Contracts and Automation:* A shared agreement between two or more parties is called a smart contract. Its pre-defined functions allow it to write outputs, process inputs, and store information. As an example, the constructor function that permits the formation of smart contracts can be defined by the smart contract. Invoking

the constructor function through a transaction, whose sender becomes the smart contract owner, enables hosting a new smart contract in the blockchain. One more function that may be defined in a smart contract is a self-destruct function. By using this function, a smart contract can typically only be destroyed by its owner. With smart contracts, banks may save time and money by automating repetitive procedures and decreasing paperwork in areas like lending, mortgage approvals, and regulatory compliance.

- *Cross-Border Transactions:* By discarding conventional banking middlemen, blockchain enables smooth cross-border payments, resulting in faster and more inexpensive transactions. Banks can use blockchain technology to offer low-cost, real-time cross-border transactions. This could offer them a competitive advantage in international marketplaces, particularly in areas where remittances are important. The full potential of blockchain in cross-border banking may be impeded by regulatory concerns and disparate foreign regulations around it. Developing a worldwide regulatory framework is still a significant obstacle to widespread blockchain adoption.
- *Challenges of Scalability:* The growing number of blockchain nodes and transactions causes a scalability problem. Major public blockchain technologies like Bitcoin and Ethereum do indeed have this problem since each node must store and carry out a computational task in order to validate each transaction. Processing a lot of transactions rapidly might be challenging because most blockchain systems use consensus procedures.The goal of ongoing blockchain advancements like sharding and Layer 2 solutions is to increase scalability, which will eventually enable faster transaction processing on a bigger scale.Banks may find it difficult to use blockchain for high-frequency, high-volume transactions until scaling solutions are completely developed and integrated, particularly for retail banking services.
- *Regulatory and Compliance Issues:* Banks must abide by various laws in many nations since blockchain facilitates international transactions. For instance, although China has implemented stringent rules or outright banned certain components of blockchain technology (such as cryptocurrencies), other nations, like Switzerland and Singapore, have taken a pro-blockchain position. The absence of standardization poses a challenge for banks looking to implement blockchain technology globally. Know-your-customer laws mandate that banks confirm the identity of their clients in order to stop fraud and other illegal activities. However, the decentralized structure of blockchain might make the KYC process more difficult, especially when it comes to bitcoin transactions. In order to adhere to KYC laws, banks that utilize blockchain technology must establish a means of connecting blockchain wallets and accounts to authenticated customer identities. This may necessitate cooperation among regulators, blockchain developers, and banks to establish identity verification systems that meet regulatory requirements.

B. Future Prospects of Interoperability of Block Chain

A digital representation of domestic currency having an analogous unit of account to that of its home currency is called Central Bank Digital Currency (CBDC). Peer-to-peer transactions can be executed and settled using CBDC through the usage of Distributed Ledger technology (DLT) or blockchain. The development of digital payments to slow the spread of the global pandemic and the rise of private money like stablecoins and cryptocurrencies have made central banks throughout the world actively researching the topic of CBDC. Building DLT proofs of concept (PoCs) allowed some central banks to begin their CBDC projects. These PoCs allowed them to mimic wholesale payment systems and further explore various use cases, like delivery versus Payment (DvP) and cross-border remittance. There are initiatives investigating CBDC in numerous developed economies, including the US. The China Central Bank, the People's Bank of China (PBoC), has already begun a trial program for its digital retail currency.

- Underprivileged groups will have greater access to financial services as blockchain interoperability facilitates seamless global connectivity. Blockchain-based payment and remittance solutions, which do not rely on conventional banking networks, can be advantageous for those living in areas with restricted access to banking infrastructure. This could have a significant impact on financial inclusion in the future, especially in developing nations where many households depend on cross-border remittances for survival.
- By facilitating smooth communication between various blockchain systems and cutting down on the time and expense involved with traditional remittance services, interoperability would greatly improve cross-border payments. Cross-border transactions today sometimes need several days and entail a number of intermediaries. Interoperable blockchain systems enable these transactions to happen in real-time or almost real-time, greatly increasing transaction speed. In the future, these systems will enable quick, safe, and affordable transfers across several currencies and countries. Cross-chain protocols are already building the groundwork for smooth international transactions.
- Blockchain interoperability will eventually allow banks to effectively manage liquidity across various markets and blockchain ecosystems. Because separate blockchain networks are walled, liquidity management is complicated at the moment. However, interoperable solutions will enable banks to transfer assets between blockchains smoothly in response to market demands. As a result, banks may be able to optimize their capital usage and liquidity risk may be reduced via the development of real-time liquidity hubs spanning several financial markets.
- Banks face significant challenges in adhering to Know Your Customer (KYC) and Anti-Money Laundering

(AML) rules, particularly when conducting overseas transactions. A unified, cross-border KYC/AML platform that safely validates identities and transaction histories across numerous jurisdictions might be created using interoperable blockchain systems, offering a potential answer. This would increase security, simplify compliance procedures, lessen the administrative load on institutions, and promote transparency throughout the world financial system.

4. Conclusion

Cross-chain technology ability to make blockchain systems interoperable is a significant development for the global financial industry, with unheard-of possibilities for smoothing cross-border transactions. Cross-chain technologies like atomic swaps and relays, which overcome the fundamental limits of isolated blockchain networks, have the potential to completely transform financial processes by improving transaction speed, security, and transparency. Realizing this promise, though, will involve overcoming a number of formidable obstacles, such as the difficulties in standardizing protocols, guaranteeing regulatory compliance across many jurisdictions, and protecting data privacy.

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