SINGAPORE MANAGEMENT UNIVERSITY

ISFS626 Digitalized Currencies and CBDCs

Group 8

Central Bank Digital Currency

Current Architecture, Implementation and Challenges for Cross-Border Transactions

Name	Student Number
Marceline Calista	01497614
Sidra Naz D/O Arshad Zaman	01330026
Tai Wen Wei (David)	01254422
Wang Xingyun	01496991

Contents

Abstract

The purpose of this report is to explain and emphasize the current architecture, implementation, and challenges associated with Central Bank Digital Currencies (CBDCs) for cross-border transactions. The introduction provides an overview of CBDCs, including their definition, types, objectives, and examples of current live CBDC projects. It also covers cross-border payments and the limitations of existing technologies, including cyber risks.

Blockchain and Distributed Ledger Technology are currently adopted, as they are the main underlying infrastructure that helps to drive the various CBDCs project. We will be examining the latest development for blockchain, as well as the measures taken to resolve the scalability issues that are currently faced in the initial implementation of the blockchain (known as Layer 1).

The section on existing projects and progress highlights notable examples such as The Bahamas' Sand Dollar, launched in 2020, and China's e-CNY, introduced in 2019. Additionally, Singapore's exploration of CBDCs through Project Ubin and StraitsX Stablecoins, which offer XSGD, XUSD, and XIDR digital currencies, is discussed. The benefits of these projects illustrate that CBDCs offer significant advantages, including enhanced financial inclusion, reduced costs, and improved payment efficiency.

A potential challenge identified in existing CBDC projects is the use of diverse platforms and technologies by different countries, which may lead to interoperability issues and complications in system architecture, such as user privacy and offline payment features. As a proposed solution, the report recommends adopting the BIS Model 3 approach, with the Bank for International Settlements (BIS) overseeing the blockchain infrastructure and issuing its own stablecoin to manage the liquidity and integrity of blockchain-native currencies.

Introduction

Central Bank Digital Currency (CBDC) refers to the digital representation of a country’s fiat currency, issued by the central bank. Unlike physical commodities, CBDC is directly associated with the value of the nation's official currency (Seth, S., June 2024).

There are two primary types of CBDCs: retail and wholesale. Retail CBDC is utilized by individuals, commonly referred to as retail consumers, and businesses for everyday transactions and expenditures. The advantages of implementing a retail CBDC include:

1. **Increased Availability:** Digital currencies offer round-the-clock availability on mobile devices, significantly improving access for users.
2. **Streamlined Reconciliation:** The digital framework of CBDCs eliminates the need for extensive and costly reconciliation processes, streamlining financial operations.
3. **Foster Digital Innovation:** By utilizing a platform-based software model, CBDCs lower entry barriers for emerging companies in the payments industry. This foster increased competition and innovation, driving financial institutions towards a more globalized service model.

Wholesale CBDC, on the other hand, is employed by central banks as reserves for settling interbank transfers and payments. In certain situations, central banks may also use wholesale CBDC to provide temporary liquidity to banks in times of crisis. The benefits of wholesale CBDC include:

1. **Improve Interbank Payment Settlement:** CBDC facilitates decentralized transaction settlements, significantly reducing the time and complexity traditionally associated with multi-day settlement processes.

2. **Reduced Counterparty Risk:** By enabling payment-versus-payment settlements for multi-currency transactions, CBDC effectively reduces credit risk in cross-border payments.
3. **Stay Competitive:** CBDC supports an efficient banking infrastructure for end users and ensures that central banks retain their pivotal role in interbank settlements, even as stablecoin technology gains broader acceptance.

Central Bank Digital Currencies (CBDCs) serve multiple purposes that are poised to transform the landscape of financial services. Key objectives include:

1. **Payment Inclusion:** Offer a digital alternative to traditional banking services, making financial services accessible to individuals without conventional banking resources. Enable online banking through smartphones, replacing the need for traditional physical banking services.
2. **Ensuring Competition**: Government-backed CBDCs can challenge the market dominance of private banks and fintech companies, potentially leading to lower fees, enhanced services, and increased options for consumers. They also encourage innovation among key market players.
3. **Data Privacy:** CBDCs can be designed to ensure transaction anonymity while allowing central banks to monitor financial activities based on aggregated data. This approach can influence the collection and usage of data, promoting transparency.
4. **Enhancing Efficiency:** CBDCs streamline payment processes by enabling real-time processing and faster transaction turnaround. This reduces operational complexity and overhead associated with traditional financial services.
5. **System Integrity:** As a stable, government-backed digital currency, CBDCs provide a reliable and secure financial infrastructure. They enhance trust and mitigate the risk of financial instability, supported by robust security measures to prevent cyber-attacks and fraud.

Many countries worldwide have been experimenting with and developing native digital currencies to explore new methods of spending. Several nations have advanced to the stage of launching pilot Central Bank Digital Currencies (CBDCs) domestically. Notable examples include (McKinsey & Company, March 2023):

1. **Jamaica** introduced **JAM-DEX** in June 2022, marking it as the first CBDC to be formally recognized as legal tender.
2. **China** launched **e-CNY**, also known as the Digital Currency Electronic Payment (DCEP), officially in 2019 as part of a broader initiative to create a digital version of the Chinese yuan (RMB).
3. **The Bahamas** introduced **Sand Dollar** in October 2020 as the world's first fully operational central bank digital currency to enhance financial inclusion in The Bahamas by providing a digital means of payment that is accessible to all residents, including those in remote or underserved areas.

A cross-border payment refers to a transaction conducted between banks, financial institutions, businesses, or individuals located in different countries, which may or may not share a border. Such transactions are everywhere and utilized globally (Tipalti.com, July 2024). Despite their widespread use, cross-border payments face several limitations due to existing technologies (IR, n.d.):

1. **High Transaction Costs:** Cross-border transactions often incur foreign exchange markups and intermediary bank charges in addition to standard transaction processing fees for banks and their clients.

2. **Processing Delays:** Completing a cross-border transaction can take up to two days. Delays arise from time zone differences between the sending and receiving banks, multiple reconciliation processes, and compliance checks, including Anti-Money Laundering (AML) and Counter-Terrorist Financing (CTF) measures.
3. **Limited Transparency:** The multi-layered processing and clearing involved in cross-border transactions can result in a lack of transparency. Parties involved often cannot track the status or identify any delays in real time, creating challenges for both consumers and banks.
4. **Cyber Risks** (Murphy, S., March 2024):
    a. Money Laundering: Illicit funds can be disguised through complex layering and integration processes, making it difficult to trace the origins of the money. These funds may be distributed across multiple accounts and jurisdictions.
    b. Terrorist Financing: Funds can be clandestinely channeled across borders to support terrorism, making it challenging to identify and disrupt the flow of these funds.
    c. Sanctions Evasion: Entities subject to sanctions may attempt to circumvent restrictions by using non-sanctioned channels and third parties, complicating monitoring and enforcement of compliance.

These limitations highlight the need for improved technologies and processes to enhance the efficiency, transparency, and security of cross-border payments.

Blockchain Technology

Blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. (IBM, n.d.) This blockchain network can track orders, payments, accounts, production and much more; and because members share a single view of the truth, it allows members to see all details of a transaction end to end, giving the public a much greater confidence, and new efficiencies and opportunities. Figure 1 shows the overview of the process of Blockchain.

A blockchain has three central attributes.

1. **Blockchain database must be cryptographically secure.** This means that users will need two cryptographic keys to view and add data on the database. There are two types of keys: Public key is the address in the database; Private key is the individualized that must be authenticated by the network.
2. **Blockchain is a digital log** or database of transactions, meaning it happens fully online.
3. **Blockchain is a database that is shared across a public, private or consortium network**. Figure 2 shows the overview of the difference between each model implementation.

Scalability issue

Bitcoin uses peer-to-peer technology to operate with no central authority or banks; managing transactions and the issuing of bitcoins is carried out collectively by the network (bitcoin.org, n.d.). However, as the network has grown and the number of transactions increased, Bitcoin's limited blockchain capacity to process transactions rapidly and efficiently has become evident. (Crypto.com, 2023). On the other hand, Ethereum, the world's 2nd most popular cryptocurrency, had also begun to gain traction along with bitcoin. Similarly, Ethereum also could not address the scalability issue too. Figure 3 shows the overview of the number of transactions per second of selected providers. To achieve scalability, there are two primary approaches: Scaling at the base layer or outsourcing work to a new layer. However, scaling the base layer is challenging due to the blockchain trilemma, which involves balancing between Decentralization, Scalability and Security. As a result, Layer 2 solutions

provide an alternative by introducing external tools and mechanisms to enable scaling without directly affecting the underlying blockchain (Bertelsmann Investment, 2023).

Layer 2 Solution - Rollups

Rollups perform the execution of a transaction off-chain but submit the final transaction data to the main blockchain at a later point. In the case of Ethereum, it leverages the block's capacity to hold not only transactions but also data. By consolidating multiple transactions into one piece of data, it will significantly increase the number of transactions that can be processed within a block. For instance, Ethereum at its base layer can only process approximately 15 transactions per second. Polygon, a Layer 2 solution that is built on Ethereum network, has the capability to transact 65,000 transactions per second. (Bertelsmann Investment, 2023)

There are two types of rollups, namely zk-SNARKs and Optimistic Rollups.

zk-SNARKs (Zero Knowledge Succinct Non-Interactive Arguments of Knowledge)

zk-SNARKs is a cryptographic proof that allows one party to prove it possesses certain information without revealing that information. This proof is made possible using a secret key created before the transaction takes place. Figure 4 shows zk-SNARKs process.

This is how it works:

1. The prover provides a mathematical proof that only they can generate
2. The verifier uses this mathematical proof to verify the validity of the transaction
3. The information can receive validity proof without revealing the contents to the verifier

Optimistic Rollups

In optimistic rollups, transactions are valid by default to increase efficiency. To prevent compromising of security, optimistic rollups are using a fraud-proving scheme, with a dispute-resolution period known as a "challenge period" (which is typically a week). Within this timeframe, anyone monitoring the rollup can submit a challenge to verify if the transactions are valid and if it has been processed accurately through "fraud proof". If that batch is found to have errors, the rollup protocol will rectify them by re-executing the wrong transaction(s) and updating the block. Penalization will then occur on those parties who had approved the incorrect transactions. Figure 5 shows Optimistic Rollups process.

Differences between zk-SNARKs and Optimistic Rollups

While both protocols are designed to enable higher throughput and lower cost, however, there is still a significant difference between them due to its transaction validation process.

In zk-SNARKs, due to the requirement to create a complex cryptographic proof, as well as the requirement for a trusted set-up for working, zk-SNARK will generally incur higher transaction cost due to the requirement of high-end hardware for creating zk-proofs, albeit in exchange for better security and a faster transaction finality confirmation. In Optimistic Rollups, as the transactions are valid by default, it does not require to post any proof of transaction and publish the limited data. However, due to the "challenge period", the transaction finality will take much longer as compared to zk-SNARKs. Figure 6 shows a tabulated difference between each protocol.

CBDCs Existing Projects and Progress

Currently, 134 countries are exploring CBDC. This number has significantly increased from 2020, where it was only 35 countries. 3 countries including The Bahamas, Jamaica, and Nigeria have fully

launched their digital currency and 66 countries are in the advanced phase of pilot and development process.

The Bahamas Sand Dollar

In 2020, The Bahamas became the first country in the world to fully launched CDBC, which are introduced as the Sand Dollar. One of the reasons why The Bahamas introduced the Sand Dollar is to address their financial exclusion problem by eliminating barriers to financial services.

The Bahamas consists of many islands with a small population of around 400,000 people, most of their citizens lives in a remote location and the country is prone to natural disaster such as hurricane. Given this situation, bank branches have become unsustainable and it's expensive as well as inefficient to transport cash.

The Bahamas saw an opportunity in the use of CBDC to make payments services more accessible for everyone, especially with the high mobile usage in the country. The digital currency can offer inclusivity, more secure, convenience, and lower cost payment system. In 2024, four years after the launch of the Sand Dollar, $2.1 million Sand Dollar are now in circulation, with more than 120,000 registered wallets, equivalent to about 30% of the population.

The Sand Dollar transaction can be validated almost instantly with no transaction cost for the users, it has 3 wallet categories: Basic (tier 1), Premium (tier 2), and Business (tier 3). For Basic wallets, the holding limit and monthly transaction limit is $500 and $1,500 respectively and users do not need to undergo any consumer due diligence procedures. For Premium wallets, it has a $8,000 holding limit with monthly transaction limit of $10,000. For this wallet, users are required to go through risk-based identity checks. Lastly, the Business wallet is designed for businesses or merchants and the transaction limit is set on a case-by-case basis.

E-CNY

E-CNY is China's digital currency that was piloted in 2020. While the Bahamas Sand Dollar is mostly used for domestic retail CBDC, E-CNY has a groundbreaking success in the cross-border payment as well as the domestic retail payment. In June 2023, China's digital yuan transaction hit 1.8 trillion yuan or about $249.33 billion. E-CNY was initially used for domestic retail payments but has expanded its scope to cross-border payments.

In December 2023, Bank of China successfully settled a $14 million or around 100 million E-CNY transaction in gold. This transaction showcases the milestone and acceptance of CBDC transactions in international trade.

Singapore

Singapore has also begun its journey in exploring CBDC. It first started with project Ubin, this project is aimed to help MAS and the industry to better understand and explore the use of blockchain technology and Distributed Ledger Technology (DLT) for clearing and settling of payments and security.

Project Ubin started in 2016 and ends in 2020. It consists of 5 phases:

1. Tokenised SGD
2. Feasibility of DLT for real-time settlement
3. Domestic delivery vs payment on DLT
4. Cross-border payment vs payment
5. Enabling broad ecosystem collaboration.

Project Ubin has successfully carried out their evaluation of blockchain and DLT. After the successful completion of Project Ubin, in 2022 MAS announced Project Ubin+ to advance cross-border

connectivity through collaboration with international partners. This project will focus more on testing CBDC for Foreign Exchange (FX) and liquidity management, connectivity between CBDC and other digital assets networks, and explore how DLT system could interact with non-ledger payment systems.

MAS has said that Singapore is not in urgent need of retail CBDC as the current payment system is already in high quality of service. Singapore will be focusing more on their wholesale CBDC but will still explore its retail CBDC and they are planning to pilot its wholesale CDBC in 2024.

Singapore Stablecoins

In 2023, MAS has issued a new regulatory framework for stablecoins. StraitsX is one of the companies that is licensed by the MAS to issue the Singapore Stablecoins. StraitsX offers 3 stablecoins including XSGD, XUSD, and XIDR. Each of these stablecoins are pegged to their respective currencies, which always be redeemable on a 1:1 basis with the respective currencies on the StraitsX platform, this ensures StraitsX transparency and trustability. StraitsX operates in multiple chains like Ethereum, Polygon, Avalanche, Hedera, and Zilliga. This will provide faster transaction speed, scalability, and cost efficiency.

With Singapore stablecoins, XSGD can provide a near instant and low-cost transaction across the world at any time for 24/7 without the need for intermediaries or third parties. It also offers interoperability across digital asset markets, which can allow more efficiency in the transfer, spend, and receiving of XSGD. They are also supported by Decentralized Finance (DeFi) protocols allowing users to engage with a wide range of financial activities.

Benefits of Existing Projects

CBDCs are being explored and implemented by various countries to improve their financial systems. We focus on the benefits realized from three significant CBDC projects: The Bahamas' Sand Dollar, China's e-Yuan, and Singapore's Project Ubin and X-SGD.

The Bahamas Sand Dollar

This project leverages Distributed Leger Technology (DLT) and digital wallets integrated with mobile phones to offer several benefits. It significantly improves access to financial services for residents in remote and underserved areas, reducing reliance on physical cash. Residents can use mobile phones to store and transfer Sand Dollars, providing greater access to financial services. By digitizing currency, the project reduces costs associated with printing, distributing, and handling physical cash. This results in lower operational costs for the Central Bank and commercial banks, making financial services more affordable for consumers. Additionally, the digital currency enhances the resilience of the financial system, crucial for a disaster-prone country, by enabling faster and more efficient transactions and reducing the need for physical cash handling.

China E-CNY

China’s e-Yuan project utilizes the Digital Currency Electronic Payment (DCEP) system and QR code payments, yielding multiple benefits. The e-Yuan facilitates faster transaction times with widespread QR code payments, offering instant, secure, low-cost transactions both domestically and internationally. This enhances payment efficiency, making financial transactions quicker and safer. The e-Yuan also includes features for traceability and compliance with Anti-Money Laundering (AML) and Counter-Terrorism Financing (CTF) regulations. This improves the monitoring and control of illegal financial activities, ensuring a more secure financial environment. Additionally, the e-Yuan provides convenient access for foreign tourists and business travelers, boosting tourism and

international business. It offers easier and more convenient access to the local economy, enhancing financial inclusion for foreigner.

Singapore's project Ubin and X-SGD

Singapore's project Ubin and X-SGD leverage Blockchain, Distributed Ledger Technology, and smart contracts, demonstrating significant benefits. Project Ubin has shown successful cross-border transactions between Singapore, France, and Switzerland, highlighting faster and more efficient international payments. By using blockchain and smart contracts, the project reduces the need for intermediaries, lowering transaction costs, increasing transparency, and ensuring real-time settlement, which reduces the risks of errors or fraud.

The project fosters collaboration among financial institutions, technology firms, and regulatory bodies, promoting a robust ecosystem for financial innovation. Additionally, X-SGD supports near-instant, low-cost transfers of the Singapore Dollar globally, integrating with multiple blockchain networks and leveraging DeFi protocols for enhanced financial services. This enhanced digital asset integration demonstrates the potential for seamless and cost-effective global financial transactions.

Highlight key benefits of existing project

The implementation of CBDCs across various projects has demonstrated numerous benefits, as the below:

a. Financial Inclusion: CBDCs have enhanced access to financial services for residents in remote areas, tourists, and facilitated global digital asset integration.
b. Cost Reduction: The digitization of currency has led to lower costs associated with handling physical cash and reduced overall transaction costs.
c. Enhanced Efficiency and Transparency: The introduction of CBDCs has resulted in faster QR code payments and real-time settlements, improving the efficiency and transparency of financial transactions.
d. Security Compliance: Improved traceability and compliance with Anti-Money Laundering (AML) and Counter-Terrorism Financing (CTF) regulations have strengthened security and monitoring of illegal financial activities.
e. Technological Innovation: The promotion of collaboration among financial institutions, technology firms, and regulatory bodies has fostered financial innovation and the development of resilient Distributed Ledger Technology (DLT) systems.

Potential Issues and Proposed Solution

Traditional cross-border payments are still currently facing key inefficiencies, which include high costs, low speed and operational complexities. As a result, several key financial institutions and unions are working towards resolving this issue by exploring cross-border CBDCs (m-CBDC). (BIS, 2024)

Project mBridge, a wholesale cross-border CBDC project, is a collaboration starting in 2021 between the BIS Innovation Hub, the Bank of Thailand, the Central Bank of the United Arab Emirates, the Digital Currency Institute of the People's Bank of China and the Hong Kong Monetary Authority *(at present, there are more than 26 observing members).* One of the key takeaways for this project is that it only uses a single platform based on a new blockchain *(known as mBridge Ledger)*.

For retail-CBDC project, based on our group observation, we have noticed that most of the current CBDC projects are currently running on different blockchains. For instance, Project Jasper runs on Corda; Project Khokha runs on Quorum; China E-Yuan is not using blockchain. Cross-chain interoperability among different blockchains is a huge challenge for both blockchain and blockchain

based CBDC schemes (Tao & Huang, 2022). Furthermore, the difference in architecture design, such as user privacy, offline payment facilities, regulation, convenience and security may further complicate the system.

According to BIS report, there are three main types of architecture design as shown in Figure 7. To better adopt the retail-CBDC to be embedded with the cross-border CBDC projects, we believe that the participants should adopt BIS *Model 3* approach, with BIS controlling the blockchain infrastructure and issuing its own stablecoin to regulate the liquidity and validity of the blockchain-native currency. We believe that BIS will be the most suitable candidate as it has 63 central bank and monetary authorities' memberships, providing sufficient coverage and representation to the global financial market system. Figure 8 shows a high-level architecture design overview of the proposed solution. We believe that with a common blockchain, protocol and governance structure, similar to Project mBridge, will help to standardize the process and procedure by removing away the potential cross-chain interoperability issue.

Conclusion

This report examined the architecture, implementation, and challenges of Central Bank Digital Currencies (CBDCs) for cross-border transactions. CBDCs, leveraging blockchain technology, offer benefits like enhanced financial inclusion, reduced costs, and improved payment efficiency. Notable examples include The Bahamas' Sand Dollar, China's e-CNY, and Singapore's Project Ubin and StraitsX Stablecoins.

However, interoperability remains a significant challenge. Adopting the BIS Model 3 approach, where the Bank for International Settlements oversees the blockchain infrastructure, could standardize processes and enhance system integrity.

In summary, CBDCs hold great promise for transforming global financial systems, but their success depends on international cooperation, strong regulations, and technological innovation.

Appendix

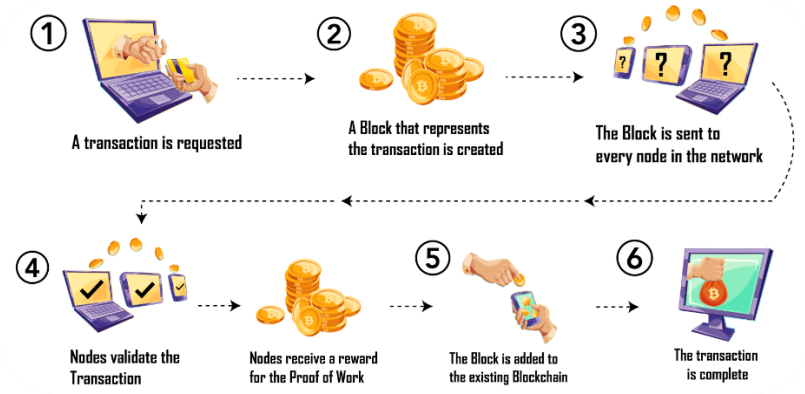

Figure 1. Overview on the process of Blockchain

Aspect	Private Blockchain	Public Blockchain	Consortium Blockchain
Access Control	Restricted access	Open to anyone	Limited access
Participants	Known and permissioned	Anonymous and open	Known and permissioned
Consensus Mechanism	Faster, less energy-intensive	Slower, energy-intensive	Variable, depends on consensus model
Decentralization	More centralized	Fully decentralized	Intermediate level
Speed and Scalability	Faster and scalable	Slower and less scalable	Moderate speed and scalability
Example	Hyperledger Fabric, Corda	Bitcoin, Ethereum	Quorum, R3 Corda

Figure 2. Difference between blockchain implementation models

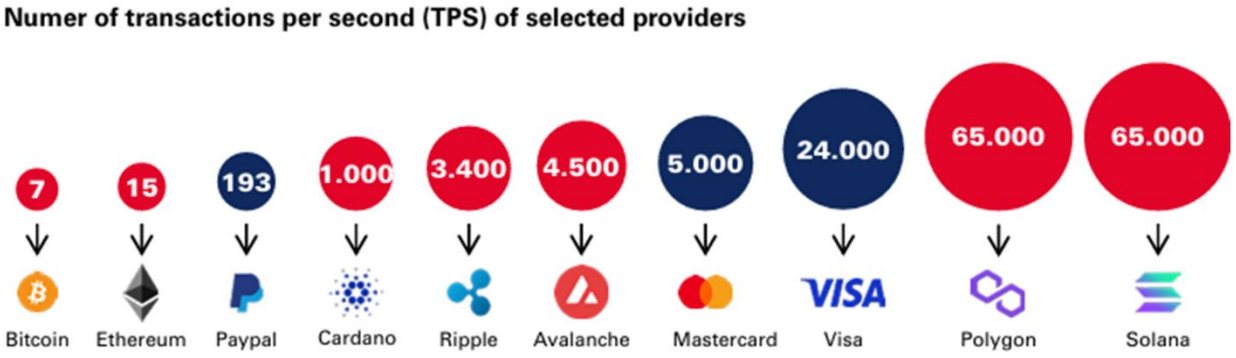

Figure 3. Number of transactions per second of selected providers

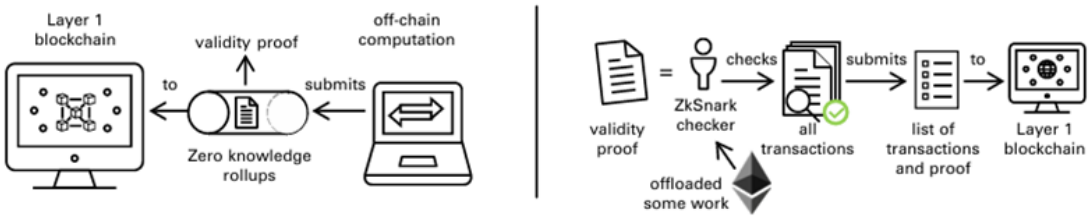

Figure 4. zk-SNARKs process overview

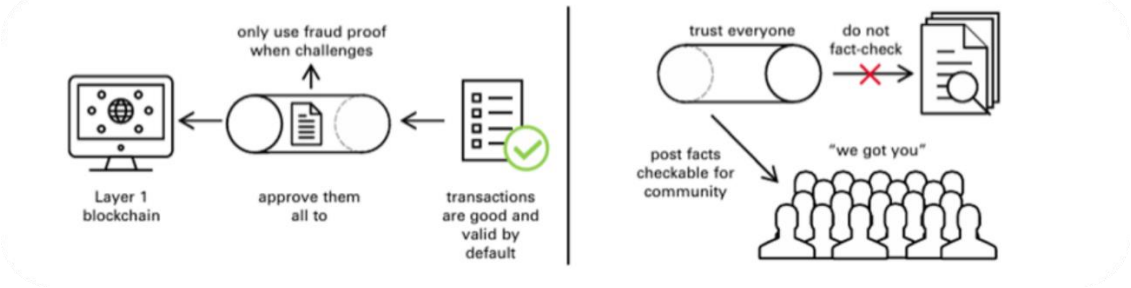

Figure 5. Optimistic Rollups process overview

Criteria	Optimistic Rollup	ZK Rollup
DeFi Readiness	Similar execution models to EVM	Lack of wide-ranging EVM support with few EVM-compatible zk rollups.
Validity Proof	Fraud proofs help in proving validity.	Zero-Knowledge Proofs or ZKPs serve as transaction validity proof.
Transaction Finality	Delay of 1 week in transaction finality for the challenge period.	No delays in transaction finality as ZK rollups feature validity proof.
Ease of Programming	Better ease of programming without need for validity computation and effective data compression.	Complicated cryptographic proofs can be difficult to design and implement with ZK rollups.
Transaction Costs	Lower transaction costs as optimistic rollups do not post the proof of transaction and publish limited data.	Higher costs due to the need for verifying proofs alongside expensive high-end hardware for creating ZK proofs.
Trust	No need for a trusted setup.	Needs a trusted setup for working.
Live Monitoring	Verifiers must maintain live tracking of actual rollup state and the reference state in the state root.	No need for monitoring the layer 2 chain for fraud detection.
Security	Emphasizes crypto-economic incentives to users for ensuring rollup security.	Cryptographic proofs can guarantee security.

Figure 6. Difference between zk-SNARKs and Optimistic Rollups

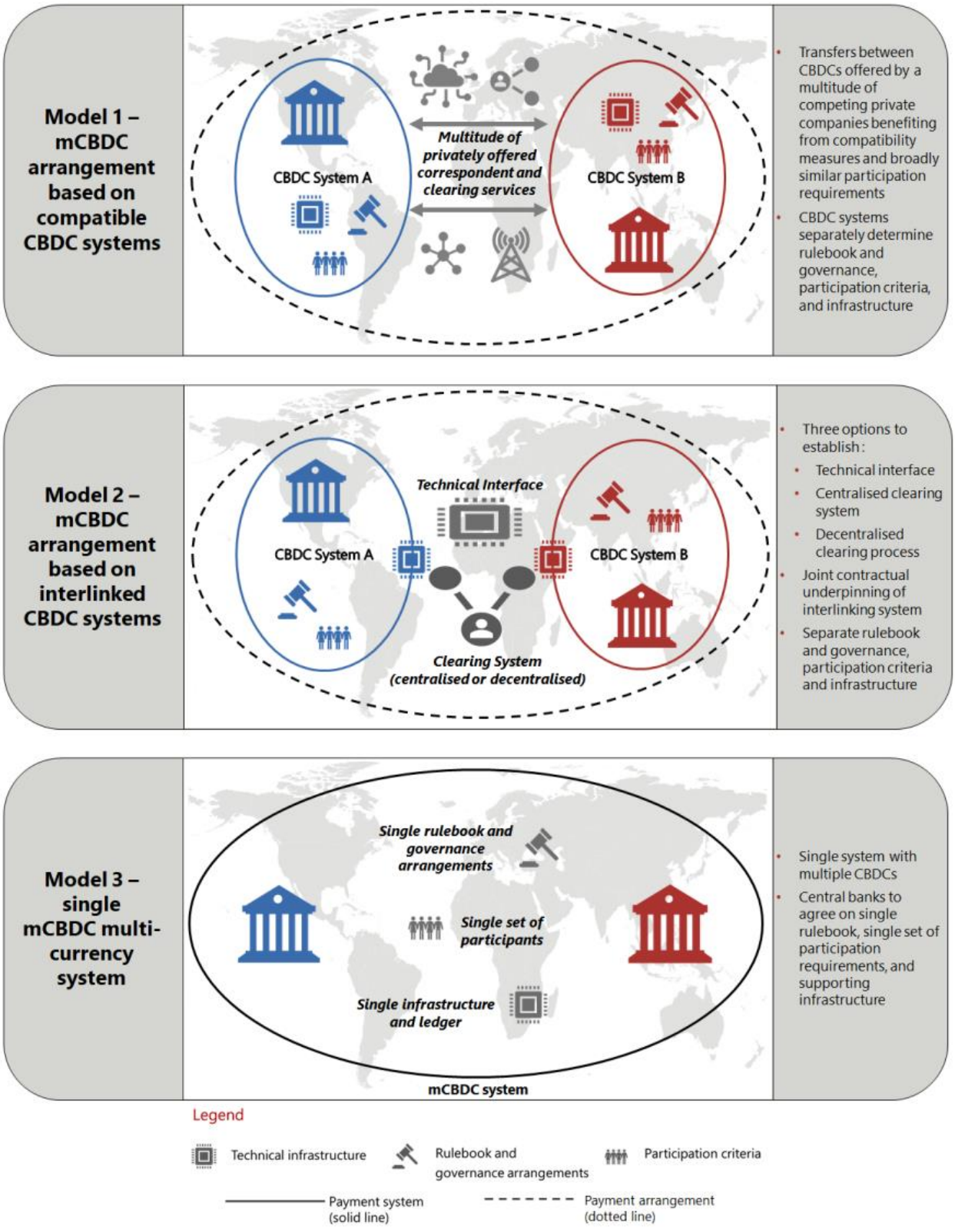

Figure 7. Different mCBDC architecture design

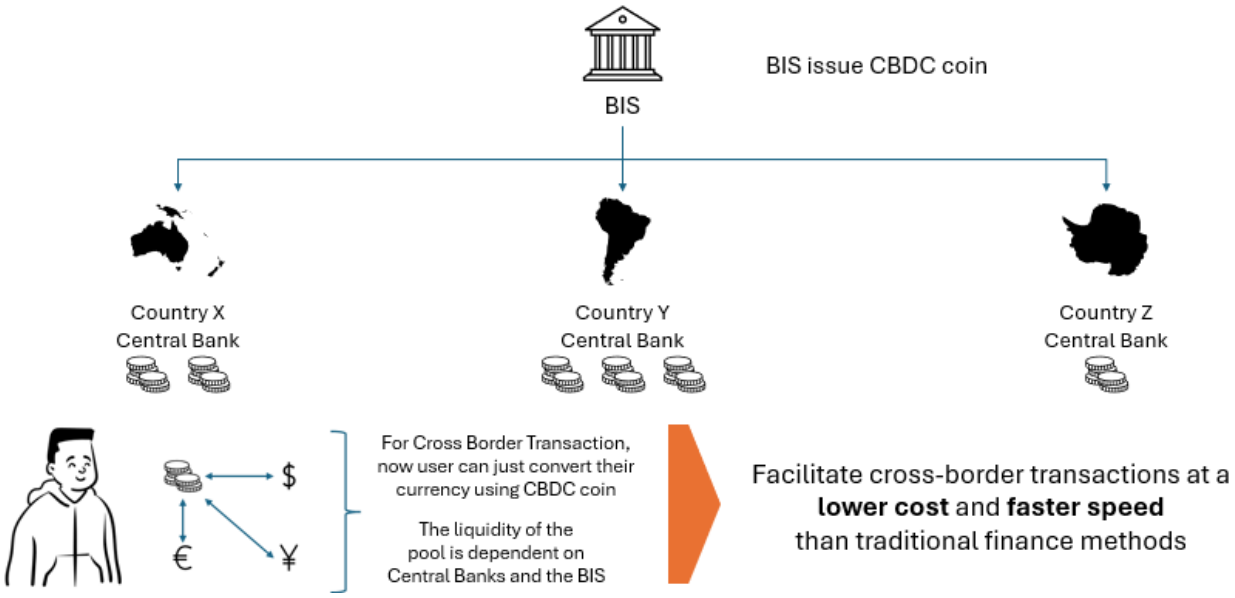

Figure 8. Proposed architecture to infuse r-CBDC and cross-border CBDC

References

AFI. (2024, 01 3). *Central bank digital currency: lessons from The Bahamas*. Retrieved from AFI: https://www.afi-global.org/newsroom/blogs/central-bank-digital-currency-lessons-from-the-bahamas/

Behamas, C. B. (December, 2019). PROJECT SANDDOLLAR: A Bahamian Payments System Modernization Initiative. *Central Bank of the Behamas*, 1. Retrieved from https://www.centralbankbahamas.com/publications/main-publications/project-sanddollar-a-bahamian-payments-system-modernization-initiative

Behamas, C. B. (2023, April). Press Release: Public Update on The Bahamas Digital Currency SandDollar. *Central Bank of the Behamas*, 1. Retrieved from https://www.centralbankbahamas.com/news/press-releases/press-release-public-update-on-the-bahamas-digital-currency-sanddollar-1

Bertelsmann Investment. (2023). *Web 3 Fundamentals*. Retrieved from https://www.bertelsmann-investments.com/fileadmin/files/B3_The_Hub/B3_Web3_Fundamentals.pdf

Binance Academy. (2023, March). *Optimistic vs. Zero-Knowledge Rollups: What's the Difference?* Retrieved from https://academy.binance.com/en/articles/optimistic-vs-zero-knowledge-rollups-what-s-the-difference

BIS. (2021). *Central bank digital currencies for cross-border payments.* BIS.

BIS. (2024, June). *Project mBridge reaches minimum viable product stage and invites further international participation*. Retrieved from https://www.bis.org/about/bisih/topics/cbdc/mcbdc_bridge.htm

BIS Innovation Hub. (2023, November). Retrieved from Project Tourbillion: Exploring privacy, security and scalability for CBDCs: https://www.bis.org/publ/othp80.pdf

bitcoin.org. (n.d.). *Bitcoin is an innovative payment network and a new kind of money.* Retrieved from https://bitcoin.org/en/

Blockchain Council. (2024, June). *Types of Blockchains Explained- Public Vs. Private Vs. Consortium*. Retrieved from https://www.blockchain-council.org/blockchain/types-of-blockchains-explained-public-vs-private-vs-consortium/

Blockchain Solutions for Central Bank Digital Currency (CBDC). (n.d.). Retrieved from Consensys: https://consensys.io/solutions/payments-and-money/cbdc

Brian Tang, C. (2020, August 20). Project Ubin Phase 5: Enabling Broad Ecosystem Opportunities. Retrieved from https://www.cartan.group/industry-insights/article/project-ubin-phase-5-enabling-broad-ecosystem-opportunities

Chan, S. (2023). China's Central Bank Digital Currency: Impact and Policy Implications. Retrieved from https://muse.jhu.edu/pub/43/article/904731/pdf

Chiang, S. (2023, 11). *Singapore to pilot use of wholesale central bank digital currencies in 2024*. Retrieved from CNBC: https://www.cnbc.com/2023/11/17/singapore-to-pilot-wholesale-central-bank-digital-currencies-in-2024.html

Company, M. &. (2023, March 01). *What is Central Bank Digital Currency (CBDC)?* Retrieved from McKinsey & Company: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-central-bank-digital-currency-cbdc

Cook, B. (2024, July 09). *The Complete Guide to Cross-Border Payments*. Retrieved from Tipalti: https://tipalti.com/mass-payments-hub/cross-border-payments-guide/

Council, A. (n.d.). *Central Bank Digital Currency Tracker*. Retrieved from Atlantic Council: https://www.atlanticcouncil.org/cbdctracker/

Crypto.com. (2023, June). *Bitcoin Scalability: Challenges and Solutions*. Retrieved from https://crypto.com/university/bitcoin-scalability

Ellis, J. A. (2023, 12). *Bank of China Achieves Groundbreaking $14 Million e-CNY CBDC Settlement in Gold*. Retrieved from https://blockchain.news/news/bank-of-china-achieves-groundbreaking-14-million-e-cny-cbdc-settlement-in-gold

Huld, A. (2022, September). China Launches Digital Yuan App – All You Need to Know. Retrieved from https://www.china-briefing.com/news/china-launches-digital-yuan-app-what-you-need-to-know/

IBM. (n.d.). *What is Blockchain?* Retrieved from https://www.ibm.com/topics/blockchain

International Monetary Fund. (2021, 03). *The Bahamas: The World's First Digital Currency*. Retrieved from https://www.imf.org/en/Videos/view?vid=6238535912001

Introducing XSGD — the Singapore Dollar-backed and Travel Rule¹ compliant stablecoin. (2020, October 5). Retrieved from https://www.straitsx.com/blog-post/introducing-xsgd-the-singapore-dollar-backed-and-travel-rule1-compliant-stablecoin

IR, T. (n.d.). *Your Guide to Secure Cross-Border Payments*. Retrieved from IR: https://www.ir.com/guides/cross-border-payments

Ledger Insights. (2024, 03 4). *Bahamas Sand Dollar CBDC has $2.1m in circulation after 3 years*. Retrieved from https://www.ledgerinsights.com/bahamas-sand-dollar-cbdc-has-2-1m-in-circulation-after-3-years/

Leong, J. (2022, 03). *What is Project Ubin?* Retrieved from https://coinpasar.sg/what-is-project-ubin/

MAS. (2022, 12). *Ubin+: Advancing Cross-Border Connectivity with Wholesale Digital Currencies*. Retrieved from https://www.mas.gov.sg/schemes-and-initiatives/ubin-plus

MAS. (n.d.). *Project Ubin: Central Bank Digital Money using Distributed Ledger Technology*. Retrieved from https://www.mas.gov.sg/schemes-and-initiatives/project-ubin

McKinsey & Company. (2024, June). *What is blockchain?* Retrieved from https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-blockchain

Mishra, P. (2022, 11). *Singapore's MAS Starts Wholesale CBDC Project Ubin+ for Cross-Border Payments*. Retrieved from https://www.coindesk.com/policy/2022/11/03/singapores-mas-starts-wholesale-cbdc-project-with-french-and-swiss-central-banks/

Murphy, S. (2024, March 17). *Cross-Border Transactions: A Hotbed for Financial Crime*. Retrieved from LinkedIn: https://www.linkedin.com/pulse/cross-border-transactions-hotbed-financial-crime-mike-murphy-w6j6c

Powell, M. (2024, March 22). Beyond Cash: Embracing China's Digital Yuan Revolution. Retrieved from https://www.cpomagazine.com/digital/beyond-cash-embracing-chinas-digital-yuan-revolution/

Progress Progress Progress Progress of Research Research Research Research & Development Development Development Development Development. (2021, July). Retrieved from http://www.pbc.gov.cn/en/3688110/3688172/4157443/4293696/2021071614584691871.pdf

Project Ubin: SGD on Distributed Ledger. (n.d.). Retrieved from https://www2.deloitte.com/content/dam/Deloitte/sg/Documents/financial-services/sg-fsi-project-ubin-report.pdf

Seth, S. (2024, June 14). *What is a Central Bank Digital Currency (CBDC)?* Retrieved from Investopedia: https://www.investopedia.com/terms/c/central-bank-digital-currency-cbdc.asp

Sharma, R. (2020, December 09). Understanding China's Digital Yuan. Retrieved from https://www.investopedia.com/understanding-chinas-digital-yuan-5090699

StraitsX. (n.d.). *Payments infrastructure for Digital Assets*. Retrieved from https://www.straitsx.com/en

Tao, Z., & Huang, Z. (2022, June). *Blockchain and central bank digital currency*. Retrieved from https://www.sciencedirect.com/science/article/pii/S2405959521001399

Wee, R. (2023, 07). *China's digital yuan transactions seeing strong momentum, says cbank gov Yi*. Retrieved from Reuters: https://www.reuters.com/markets/asia/chinas-digital-yuan-transactions-seeing-strong-momentum-says-cbank-gov-yi-2023-07-19/

What is Central Bank Digital Currency (CDBC)? (2023, March 01). Retrieved from McKinsey & Company: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-central-bank-digital-currency-cbdc