Global CBDC Challenge

SAFE, SUSTAINABLE, AND INCLUSIVE FINANCE

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Monetary Authority of Singapore

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Foreword

"To know what you know, and what you do not know, that is true knowledge." — Analects of Confucius: On Government

History has shown that currency is a protean concept. From livestock around 9000 BC, to the introduction of paper money around AD800, credit cards in the 1960s, and virtual currencies like Bitcoin in 2009, the medium of exchange has evolved across the ages.

Today, much has been written and continues to be, as International Organisations, Central Banks, and academics discuss the merits, challenges and potential of introducing Central Bank Digital Currencies ("CBDCs") to meet the payment needs of a digital economy, and shape next generation payment rails.

The recent report – "G7 Public Policy Principles for Retail CBDC", divides the issues coherently into two categories; (i) foundational issues, covering matters that include monetary and financial stability, and (ii) opportunities, covering matters such as financial inclusion, cross-border functionality and international development.

The motivations for this Challenge is firmly founded in the second category, albeit with references to the foundational issues in acknowledgement of the tight connection between the categories. The globla community continue to develop a deeper understanding of the foundational issues with each new study. However, it is not unreasonable to state that we only have a theoretical understanding of how to realise the opportunities before us. Notwithstanding the rich and growing literature, a degree of imagination is still needed to grasp the innovations being narrated.

For this reason, the Monetary Authority of Singapore ("MAS"), in collaboration with our international partners organised a Challenge to realise the practical implementation of the opportunities. Through 12 novel problem statements – highlighting opportunities as well as trade-offs, we sought out innovative solutions with a singular goal: How can we realise the potential of a retail CBDC, without making significant compromises to other principles that we value including security, privacy, financial inclusion, efficient cross-border flow of funds with stringent safeguards, speed, finality, among others?

More than 300 submissions later, we have 15 finalists from 8 countries, presenting solutions that, taken together, represents a body of practical knowledge on implementing a retail CBDC in any jurisdiction. This report presents, for the first time, unique solutions, for the global Central Banking community – to decide what the future of money could look like, from a technological lens.

While rich in information, this report will not provide us with all the answers. As the Analects of Confucius remind us, true knowledge includes knowing what you do not know. We can only hope that central banks and private sector stakeholders will continue to push the boundaries with better solutions to address complex challenges in this field.

We congratulate the winners of the Challenge, and the other finalists that soldiered on under tight timelines to develop the prototypes. We also commend the high quality of the submissions that we received for the competition. Finally, we would like to thank the judges of the Challenge, the partners and the technology service providers that made this Challenge possible. It has been a display of public-private partnership at its finest.

Sopnendu Mohanty
Chief Fintech Officer
Monetary Authority of Singapore

Overview

A retail Central Bank Digital Currency (CBDC) is a digital form of the currencies issued by central banks today. Digital cash, supported by next-generation financial rails built on the latest innovations, is an opportunity for central banks to provide firms and households with better, cheaper and faster ways of making payments that are compatible with the digital economies of today and tomorrow.

As state-issued digital money must be designed with society's interest foremost in mind, a retail CBDC has some unique challenges. For widespread acceptance and adoption, retail CBDCs must be designed to meet both current and anticipated future payment needs, such as micropayments, privacy and programmability. To create new pathways to broader financial access, the retail CBDC system needs to be more open and inclusive than current arrangements, allowing a broader set of firms and individuals to directly access and offer services on its financial rails. These improvements to the payment system will need to be achieved without compromising resilience and security, integrity and performance, as well as the economy's monetary and financial stability, among others. Indeed, one of the most promising avenues for welfare gains in the deployment of retail CBDCs is the use of innovative technology to overcome the trade-offs.

Today, there do not appear to be off-the-shelf or existing systems that satisfy these and other requirements. The creation of new solutions requires fundamental research and joint exploration by both policymakers and technologists.

To catalyse development of a set of technologies to enable issuance of retail CBDC, we established a global challenge:

- In partnership with the International Monetary Fund, World Bank, Asian Development Bank, United Nations Capital Development Fund, United Nations High Commission for Refugees, United Nations Development Programme, and the Organisation for Economic Co-operation and Development;
- Supported by Amazon Web Services, Mastercard, Partior, R3 and open source software foundations, Hyperledger and the Mojaloop Foundation; and
- Managed by the API Exchange (APIX) and Tribe Accelerator.

Instrument
Improving and expanding the accessibility and utility of digital payments

Distribution
Mitigating risks associated with payment transfers and market

Infrastructure
Provisioning a viable CBDC infrastructure that is low- cost, efficient and robust

OVERVIEW: PROBLEM STATEMENTS

Instrument

A retail CBDC should improve upon, and expand the accessibility and utility of digital payments. The technology must enable the issuance of a retail CBDC which supports these features and constraints.

01

New Functionalities vs Inclusivity

Can a retail CBDC system be embedded with additional functionalities beyond a basic transfer of value without requiring users to use smartphones (or other expensive/complex hardware)? How might this improve the efficiency and effectiveness of Government-to-Person payment programmes in the context of an economy with low levels of digital penetration?

02

Security vs Accessibility

Can the design of a retail CBDC system be highly secure for users (e.g. one that prevents unauthorised uses and illicit transactions) without compromising the ease of use? Would such a system be able to cater to the varied needs of the elderly, minors, and those with disabilities?

03

Availability vs Risk of Disputes

Can offline transactions be enabled in areas with no or limited internet connectivity? What safeguards against double-spending and counterfeit can be embedded to minimise disputes related to offline payments?

04

Recoverability vs Anonymity

In the event of theft, damage or loss of a wallet, card, or instrument, can a retail CBDC system adequately trace transactions, limit the loss or support the recovery of lost funds without compromising the identity of a user?

Distribution

To maximise the net benefits of a retail CBDC, the technology should include features aimed at mitigating risks related to payment transfers and market infrastructure.

05

Widespread Frictionless Use vs Control

Are there technological features that can be incorporated into a retail CBDC solution to minimise the risk of significant and abrupt outflows from bank deposits to the CBDC, while ensuring that the use of the CBDC is as seamless as possible? Are there technical designs that would allow a retail CBDC to be used for cheaper and faster cross-border payments, and yet mitigate the risk of generating more volatile and de-stabilising capital flows between countries?

06

Personal Data Protection vs System Integrity

Can the retail CBDC solution protect personal and consumer transactions data, while allowing for monitoring, detection, and prevention of illicit activities on the network (e.g. money laundering /terrorism financing, fraud, scams and corruption)?

07

Expanding Access to Financial Services vs Guarding against Data Monopolies

How can the design of a retail CBDC solution allow participating firms to harness payment data to enable the offering, customising, or improving the pricing of financial services (e.g. credit, insurance) to users, while avoiding the undesirable effects of data monopolies on consumer welfare over time? How might users retain control over use of their data?

08

Coexistence vs Integration Complexity

How can a retail CBDC solution allow financial institutions to distribute CBDCs to the end user in a manner that leverages existing national payment rails such as a country's payment systems, while keeping participation cost competitive at minimal disruption? How can it process payments between users on different payment systems without introducing the need to involve additional intermediaries, or needing custom integration for onboarding?

OVERVIEW: PROBLEM STATEMENTS

Infrastructure

A viable retail CBDC infrastructure must be low-cost, efficient and robust. It also needs to enable trusted settlement of payment transactions among participants and provide for easy integration with not just existing payment systems and solutions, but also emerging ones.

09

Decentralisation vs Accountability

How can a retail CBDC infrastructure be made more resilient to single points of failure? Can concentration risks be minimised through decentralisation? How can we develop a safe, stable and sustainable governance model for such decentralised infrastructure with clear lines of responsibility and accountability? How can the interests of citizens and market participants as well as financial stability be safeguarded in the event of a failure of such an infrastructure?

10

Extensibility vs Operational Resilience

How can a retail CBDC infrastructure be made more resilient to single points of failure? Can concentration risks be minimised through decentralisation? How can we develop a safe, stable and sustainable governance model for such decentralised infrastructure with clear lines of responsibility and accountability? How can the interests of citizens and market participants as well as financial stability be safeguarded in the event of a failure of such an infrastructure?

11

Privacy vs Performance

Can a retail CBDC infrastructure incorporate privacy preserving capabilities while remaining high performing, with fast response time, low latency, and scalability to support large deployment?

12

Interoperability vs Standardisation

Standardisation reduces overhead and integration cost. However, international standardisation will require significant coordination. How can interoperability be achieved across different instruments of digital money and across different technologies without a commonly accepted standard? Retail CBDCs in different jurisdictions would need to be interoperable with each other, as well as with non-CBDC systems and non-CBDC forms of digital money to enable better, cheaper, faster payments both cross-border and domestically.

OVERVIEW

Timeline

The Global CBDC Challenge ran for a total of 20 weeks, commencing on 28 June 2021 and ending on 11 November 2021. The diagram below summarises the chronology of the challenge.

28 June 2021
Launch of the Global CBDC Challenge

2 August 2021
Round 1 judging & selection of 15 finalists

30 August 2021
Announcement of 15 finalists and launch of Acceleration Phase

6 September 2021
Masterclass series commences

9 September 2021 | Masterclass #1
Retail CBDCs: Global Landscape

16 September 2021 | Masterclass #2
Interoperability and co-existence of retail CBDCs with existing payment ecosystems

23 September 2021 | Masterclass #3
Financial Health and Inclusion

7 October 2021 | Masterclass #4
AML/CFT risks and implications of retail CBDCs

14 October 2021 | Masterclass #5
Legal aspects of retail CBDCs

24 October 2021 | Masterclass #6
The implications of retail CBDCs for monetary policy

9 November 2021
Finals and Demo Day judging

11 November 2021
Top 3 Winners announced

OVERVIEW

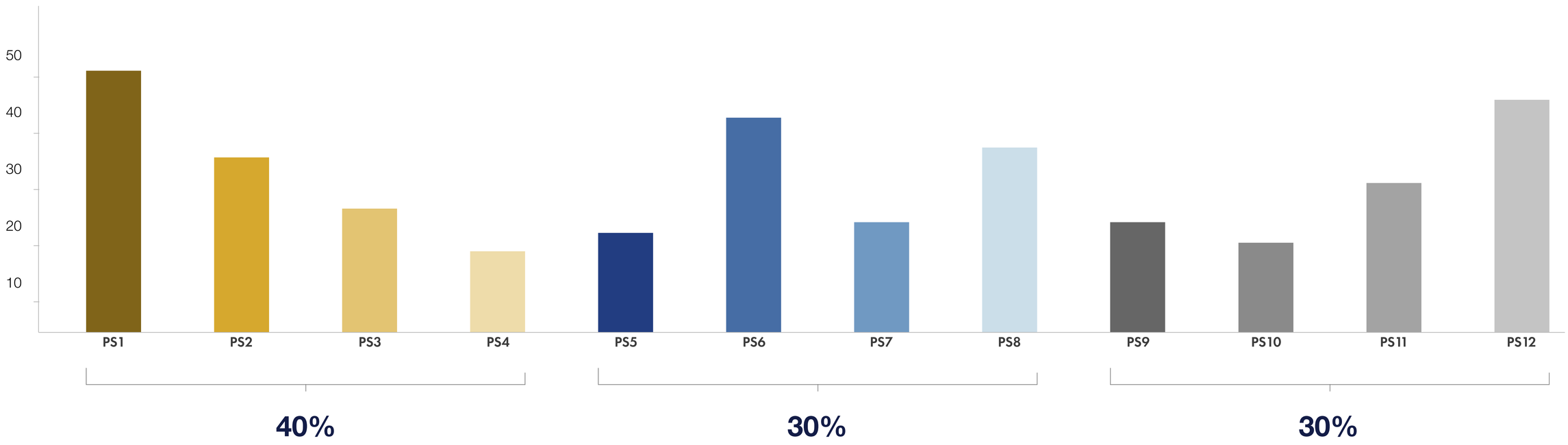
Insights to proposals & solutions

The 300 proposals received as part of the Global CBDC Challenge, were diverse in terms of the profile of participants, the experience, skills, readiness, and technology approaches. The proposals demonstrated the dedication and commitment by the industry across geographies to improve current financial infrastructures.

12
Problem Statements

300+
Proposals Submitted

50+
Countries Participated



Consortium Based

1 in 4 are consortium based.

28% of proposals came in with a consortium made up of established Financial Institutions, FinTechs, and Solution Providers, but a majority of finalists submitted entries on their own.

Experience

1 in 4 had experience deploying related solutions in production.

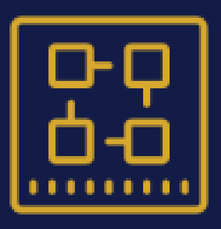
25% had experience deploying CBDC related solutions in production at a national level, while the majority of participants have vast experience with existing payment instructures.

Content

Most of the proposals provided a good holistic coverage of multiple problem statements, while there were some proposals that focused on specific problem statements. **10%** of the proposals were unique with no known competitors in their area and several of the solutions envisaged challenges in meeting regulatory requirements as the proposed solutions were still nascent.

Technology

A significant number of proposals referenced blockchain heavily or were based on distributed ledger techologies. These included private permissioned blockchain as well as private, permissionless chains. Digital identity played a big part in most of the proposals. Both hardware and software-based solutions were proposed, with hardware-based solutions addressing most of the financial inclusion problems.



Many proposals included asset tokenisation capabilities, which described how they would support the digitalisation of real-world assets and how it can interoperate with existing payment rails, and existing blockchain networks. There were several differing views on the form of a retail CBDC, some proposed the use of virtual banknotes/coins to represent CBDC, as opposed to tokenisation of Fiat.

Readiness

23% of the proposals indicated that their solutions were production ready or already running live networks, while 27% stated that their solution was in Proof of Concept (POC) or Pilot stage. Meanwhile, the rest of the proposals indicated that they were still in the ideation, development, or prototyping stages.

Multi-disciplinary

50% of the submissions had diverse multi discipline.

50% of the submissions had diverse multi-disciplinary teams, such as ex-policymakers, legal, bankers, and technologists. Many of the teams had deep understanding of CBDCs and the fundamentals behind it.

Finalist Introductions

GLOBAL CBDC CHALLENGE WINNER: ConsenSys, Visa

CBDCgo: Digital Currency, Seamless Acceptance

ConsenSys is a blockchain technology company, building Ethereum-based infrastructure for more open, efficient, and secure economic systems.

Visa, a leading, global payment network with over 70 million merchants, is becoming the network of networks - a single point of connection for any transaction, whether on the Visa payments network or beyond.

For the Global CBDC Challenge, Visa and ConsenSys developed a proof of concept retail solution, CBDCgo, with the goal of driving early CBDC adoption for everyone, everywhere. With CBDCgo, central banks and financial intermediaries can easily manage CBDC networks and instantly issue CBDC-linked payment credentials through a streamlined API gateway.

The underlying CBDC Blockchain infrastructure relies on ConsenSys Quorum: an open source version of Ethereum protocol optimised for enterprise applications. ConsenSys Codefi Payments easily connects Quorum nodes, enabling financial Institutions to create and manage digital currencies at scale through APIs. Plugging into this CBDC infrastructure, Visa's CBDC Retail Payment Module can provide a seamless on-ramp to Visa's network of over 70 million merchants globally.

When paying with CBDC in a store through CBDCgo, cards may be used. Under the hood, however, there is an asynchrony between instant real-time VisaNet authentication that happens in milliseconds, and pending block confirmations over the Quorum network that takes around 10 seconds.

For the proof of concept, the team designed a double-spend prevention mechanism to link a payment network's authentication process natively to a blockchain through the Retail Payment Module before authorising a transaction. This design balances both security and performance.

This proof of concept also conceptualised a government stimulus package which can be programmed with attributes such as time expiration and restricted merchant categories. CBDCgo is designed to be forwards-compatible with potential future use cases including programmable government benefits, streaming employee payroll, worker on-demand payouts, and loyalty systems. Concurrently, Visa is also exploring CBDCs as a bearer instrument to be used offline to increase overall accessibility.

Visa and ConsenSys have also been actively collecting insights from over 27 central banks globally. Based on those insights, the team prioritised 4 key problem statements for CBDCgo: integration and interoperability with existing systems, security, accessibility and consumer trust, as prerequisites for adoption.

Specifically:

- CBDCgo can provide a low-friction solution for existing financial institutions and payment processors to onboard CBDCs to their platforms without needing any custom blockchain plumbing:
- Integrate with standard REST APIs to:
  - Setup a blockchain node using Quorum Blockchain Service to deploy Quorum networks in Azure with financial institution-specific abstraction layer

- Build CBDC wallet interfaces for end users leveraging existing solutions that work well (for example, KYC) through banking mobile applications;
- Issue instant CBDC-linked cards using Visa capabilities, including Debit Processing Solutions (DPS) Forward and Account Device Management.

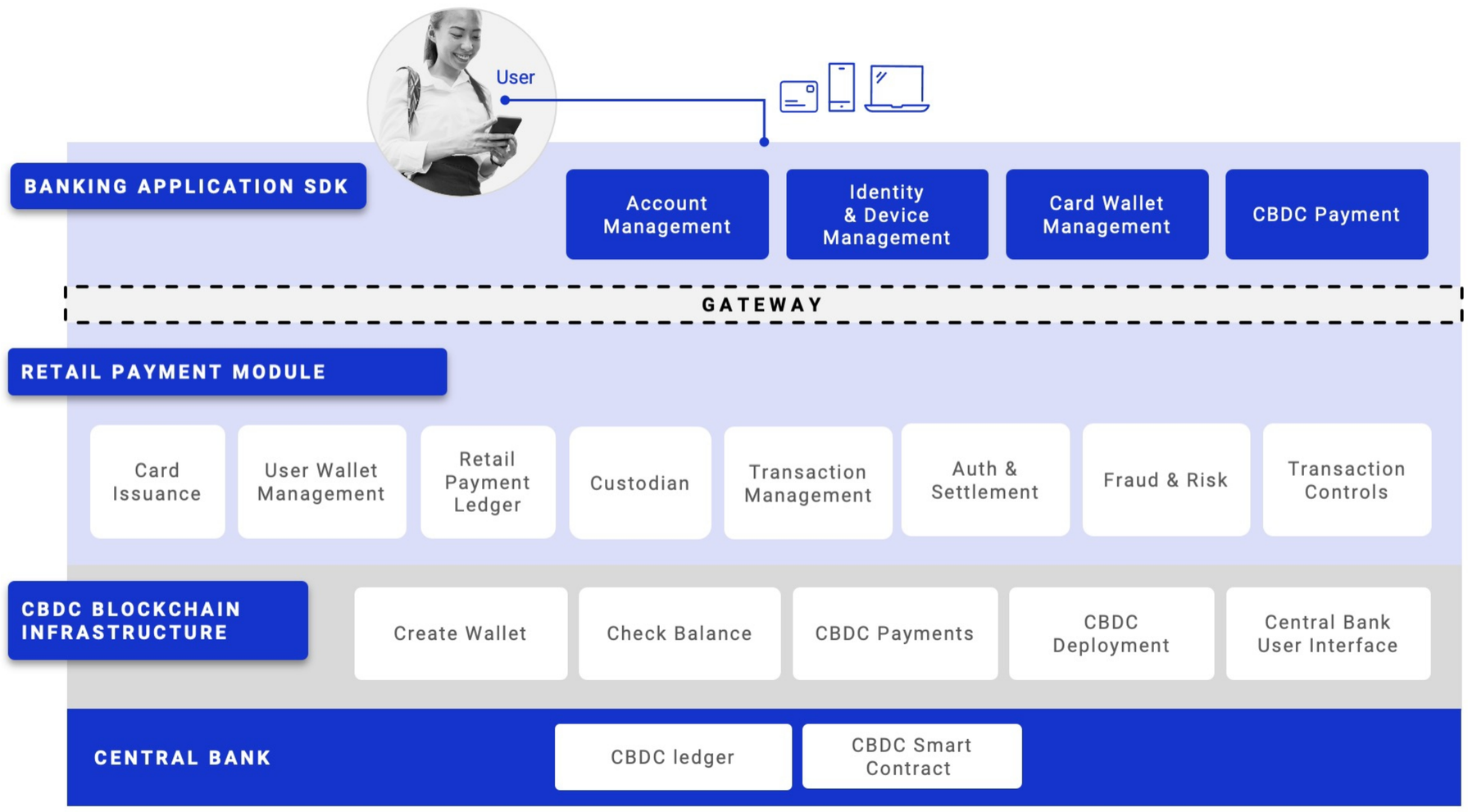
- Minimal disruption across the ecosystem
  - Banks continue as intermediaries to provide CBDC funding account and CBDC card issuance through existing banking applications;
  - Merchants accept CBDC using current point-of-sale terminals;
  - Consumers spend CBDC through familiar ways to pay, e.g.: tap-to-pay, click-to pay, scan-to-pay.

- CBDCgo will bring web3 assets into a web2 user experience that is familiar, convenient, and intuitive.

- The proof of concept will create security management via:
  - Real-time account management compatible with custodial key management;
  - Protection against on-chain double-spend attacks;
  - Security verification, alert system and application provisioning through existing Visa authentication technology;
  - Additional Visa in-network services, including fraud-risk management, data protection and dispute resolution.

The proof of concept conceptualises blockchain middleware for Central Banks and financial institutions to manage the core operations of CBDC, with a retail payment module as an on-ramp to existing payment network. This involves three major components:

1. An omni-channel user touchpoint including **Web UI, CBDC Mobile SDK, Physical Card.**
2. **Retail Payment Module** enables wallet account and fund management, CBDC card issuance, spend controls and CBDC payment processing using existing infrastructure.
3. **CBDC Blockchain Infrastructure**, built on ConsenSys Quorum, enables a two-tier CBDC system for central banks to issue and distribute CBDC on permissioned Ethereum network at scale.



This presentation sets forth the current vision for CBDCGo and is solely for discussion purposes. These services are in development; service availability, features, functionality and timing remain subject to change.

GLOBAL CBDC CHALLENGE WINNER: Criteo SA, Secretarium Ltd., Intel® Corporation

Atomic CBDC Solution

Criteo SA is an internet firm specialising in large-scale network computing, AI, and ad-tech that processes 21B transactions per month with 2.5B users in 104 countries.

Secretarium Ltd. is a software firm specialising in high-security cryptography and Secure-enclave Distributed Ledger Technology.

Intel® Corporation is the world's largest semiconductor chip manufacturer.

Atomic CBDC is a solution brought by Criteo, built in partnership with Secretarium and Technology Partner Intel.

Each company brought to the table unique capabilities that solve key issues required for a successful CBDC platform. Intel provided new hardware-based security in its Intel® SGX2 instruction set. Secretarium delivered a breakthrough consensus mechanism called “Proof-of-Processor” (PoP), along with a 3rd-generation “Secure-Enclave DLT” (SDLT) cryptographic platform. Finally, Criteo operates one of the fastest and largest cloud-based networks, processing up to 4 million transactions per second, across 2 billion monthly users, in 104 countries.

The SDLT’s unique architecture fundamentally resolves many of the policy trade-offs identified in the problem statements, such as privacy versus traceability. For example, the Atomic SDLT cryptographic platform handles both accounts and tokens simultaneously by design. Using completely anonymous “Chaumian blind-signature tokens”, users can leverage complete anonymity for smaller transactions (as per their central bank’s policy).

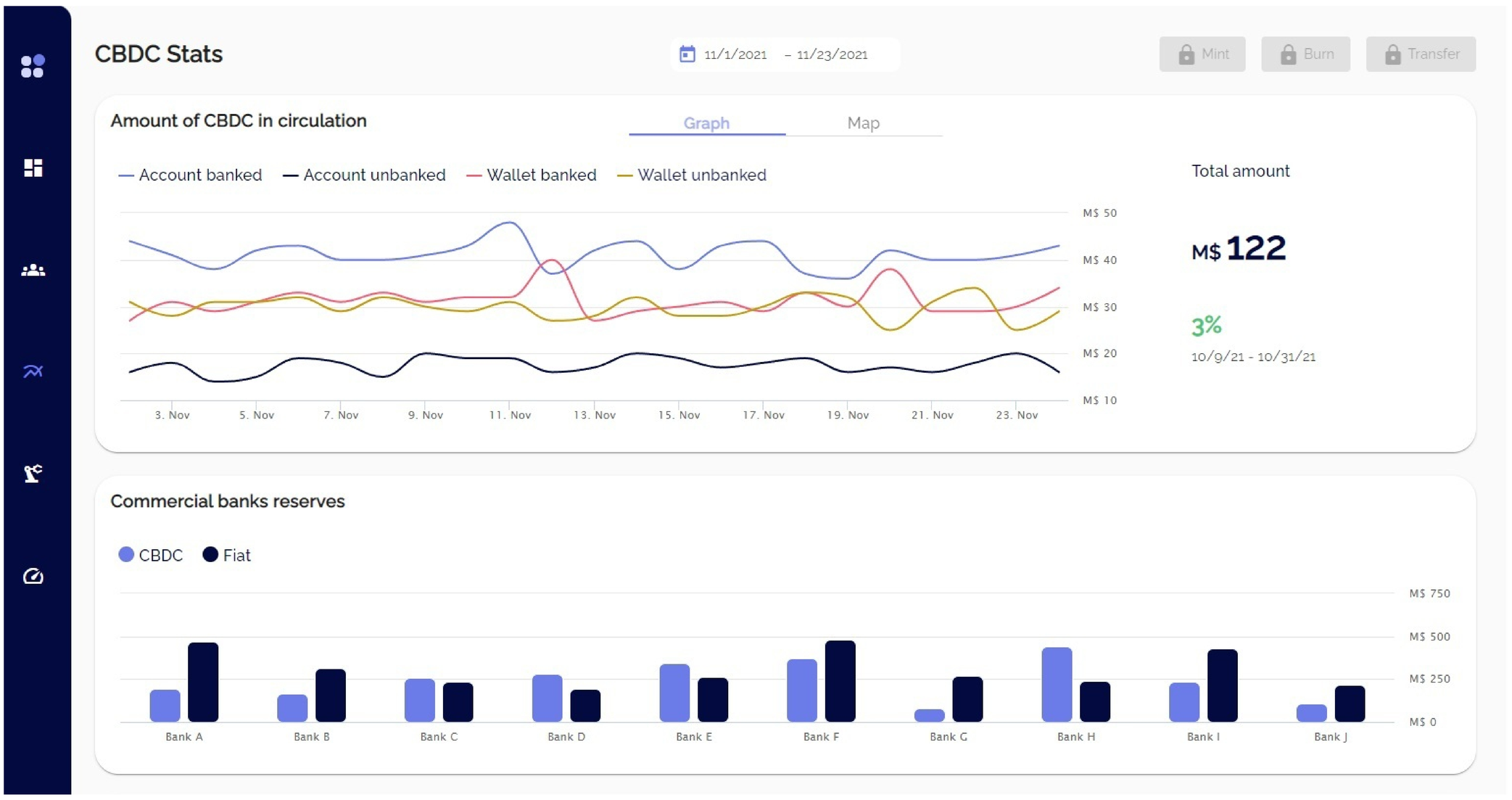
Such transactions are limited quantitatively by smart contracts to keep illegal activities in check and prevent bank runs. At the same time, the system can seamlessly switch to account-based money for larger transactions or when traceability is required for AML, CTF, and fraud detection.

This ability makes the Atomic CBDC Solution easier to integrate into all tiers of the existing banking system. The Atomic SDLT is the first DLT to fully leverage hardware-based secure enclaves to protect all CBDC functions, applications, and data. This design makes it easier to deploy smart contracts and extensible CBDC functions by leveraging common computing languages and any x86 application on Intel hardware in secure enclaves. Atomic can be calibrated even deeper than bespoke software applications. The programmable features of money allow economists and central banks to envision completely new forms of currency, tailored down to the “atomic” level for any future monetary or fiscal uses.

Complementing its modularity and security, the Atomic SDLT platform operates at rapid speeds. All transactions occur on layer-one operations — or "on-chain" — at speeds consistent with the fastest non-DLT sharded databases. The Atomic SDLT platform can easily scale with sharding for a fraction of the energy and hardware cost of other blockchains. This efficiency allows central banks to support instant micro-transactions in large volumes. Its heightened security also caters to high-value international transactions, multi-currency swaps (mCBDCs), cross-border payments, and remittances. Atomic creates an equitable playing field for FinTechs and budding entrepreneurs worldwide to thrive, preventing data monopolies from tech giants, with no mining fees built into the system.

It can even be deployed by central banks or commercial banks, allowing a user's CBDC account and activity to be managed partially and cooperatively amongst banks, FinTechs, Payment System Providers and others.

With worldwide financial and digital inclusion in mind, the **Atomic SDLT** platform supports offline transactions and numerous types of devices. **Atomic** allows users to back up their encrypted wallets, allowing wallet recoverability and allowing users without smartphones to use their vault remotely through much simpler terminals. Users' devices do not require Intel® SGX chips; they can use any device, from Apple iOS to Google Android and beyond.



Overview of the Atomic SDLT platform

GLOBAL CBDC CHALLENGE WINNER: Giesecke+Devrient advance52 GmbH

G+D Filia - Building A Truly Inclusive Public Digital Currency

Giesecke+Devrient (G+D) is a Munich-based global security technology group enabling secure payment, providing trusted connectivity, safeguarding identities and protecting digital infrastructures. Founded in 1852, G+D has grown to 11,500 employees. Giesecke+Devrient advance52 combines the expertise and trust of a deep-rooted company with the speed and flexibility of a start-up.

G+D Filia is cash for the digital age delivering substantial benefits to society and the economy in three domains:

1. A means of payment that can be used anywhere, anytime just like digital cash. Anyone can pay person-to-person, from the same room or remotely, at online shops or the point of sale, a small rural market without connectivity, or even during a natural disaster without power supply.

2. A means of payment that is truly inclusive and enables everyone to participate in the digital economy, even without a smartphone or a bank account - and no transaction fees.

3. An interoperable platform to enable the private sector to develop innovative solutions without compromising people's trust in their currency. Be it delivery-versus payments, machine-to-machine payments, or other smart contract-based use cases.

Driven by these key goals, the team built G+D Filia as a superlight payment layer consisting of three layers:

On the payment layer, Filia is a token-based digital currency resembling cash. It was designed from the very beginning to allow for consecutive offline payments without third party involvement. Payments are settled instantly and re-spendable.

Filia works on smartphones and hardware wallets, providing full privacy at the payment layer supporting programmable use cases. To achieve this, the team took a different approach than standard DLT platforms. Neither account balances nor transaction metadata are stored - only the validity of a particular token and its denomination. This can either be on a blockchain or a more traditional database.

This ultralight payment layer also assures integrity. Payment is done by transferring a piece of data from one person to another, utilising all types of devices. In most cases this will be a smartphone, but can also be a smart card or wearable device.

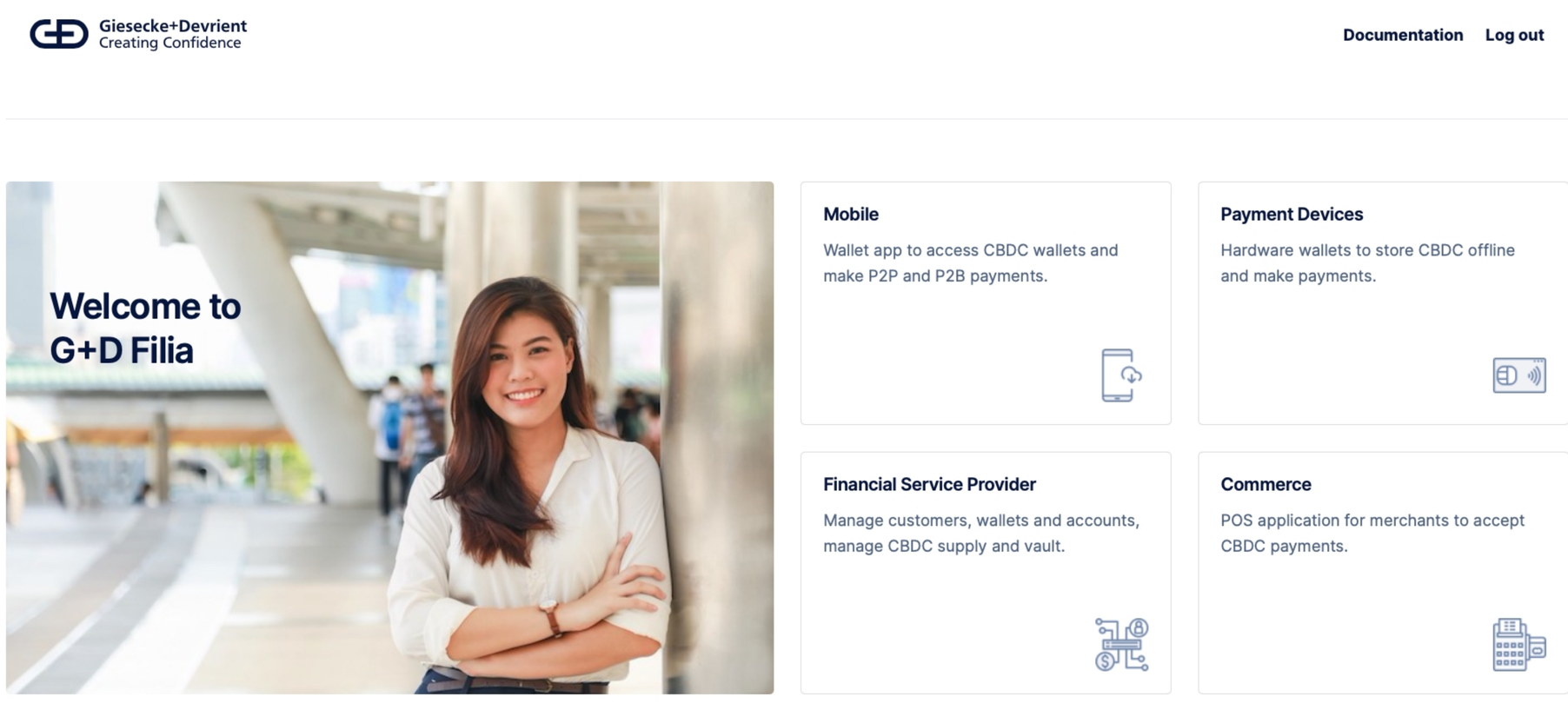
Next is the data layer that only stores pseudonymous transactions required to assure AML and CFT compliance standards. Since the payment layer does not store any payment transactions, it can be configured for the preferred degree of transparency in the system.

To enable innovation and interoperability, their Smart Wallet® infrastructure, the third layer, provides a powerful rule engine run by payment service providers which allows for triggered and conditional payments. It enables interaction with smart contracts and does not lock in central banks to one DLT or blockchain solution. Instead, it allows central banks to remain flexible, and foster market competition.

The solution consists of multiple components tailored towards the needs of all market players. Its SDKs can already be used today by central banks and financial service providers to integrate CBDC payments into their existing apps or to develop programmability use cases. G+D's economic CBDC simulator enables the analysis of potential risks of CBDC, such as commercial bank disintermediation and assists in determining parameters for rollout.

The G+D Filia solution hopes to deliver a truly inclusive public digital currency that works for all payment scenarios while providing a foundation for innovation and growth.

The core system that assures integrity of the solution is designed API-first to avoid technology lock-in. The current implementation is based on a distributed database, and another one is based on a DLT solution. All backend services, such as for commercial banks, are developed API-first using Go, with their frontends implemented in React. Components that interact with hardware payment devices use Java and portions of C++. G+D's Android and iOS applications and SDKs are developed for in Java/Kotlin and Swift. Smart cards and other proprietary devices use special purpose G+D technologies. G+D's cloud-based sandbox is provisioned and operated using Kubernetes.



Overview of the G+D Filia platform

Australia and New Zealand Banking Group (ANZ Bank)

National Integrated CBDC Ecosystem (NICE)

ANZ is a commercial bank headquartered in Melbourne, Australia. With a history dating back 180 years, ANZ provides banking and financial products and services to over 8.5 million retail, business and Institutional customers across 32 markets, 14 of which are within Asia. ANZ is also the largest Institutional Bank in Australia.

The National Integrated CBDC Ecosystem (NICE) solution, proposed by ANZ, is a model infrastructure for issuing and distributing a CBDC as an inclusive, and universally accessible public good. The holistic solution aims at improving financial wellbeing, and addressing the needs of an increasingly digital society.

ANZ's cornerstone use case for CBDC is advancing the efficiency of government cash management and treasury operations. This government infrastructure acts as primary distribution system for CBDC enabling inclusion through digital identity.

Through private partnerships, the solution provides privacy-preserving access to value added services, consent-based data sharing and enables personal data sovereignty.

The three key components of solution are described below.

A Digital Bearer Instrument issued by Central Bank

CBDC is issued as a token in specific denominations. Each token has a unique identifier, is digitally signed and issued by the central bank.

The central bank is able to monitor the circulation of different denominations. It can enforce dynamic currency management and control in real time through its nodes on the distribution networks. The prototype implements this with its eCurrency solution.

A Government DLT System as the Prime Wallet Infrastructure

Prime Wallets form the primary public access and distribution mechanism for CBDCs, which is centered on enabling direct transactions between the government, individuals, and businesses.

The solution proposes a distributed ledger technology (DLT) system for Government cash and treasury management. The prototype uses R3 Corda, with nodes for ministries and departments for recording financial transactions and hosting Prime Wallets.

These wallets are provisioned for all residents and entities, authenticated through the National ID system (like Singapore's national Singpass service). This enables convenient, universal access to CBDC without the need for additional KYC documentation.

Prime Wallets can be accessed online through the web or mobile apps, and NFC-enabled smart cards for offline storage and transfers. The Prime Wallet services can be enabled for feature phones using the Unstructured Supplementary Service Data (USSD) communications protocol, while offline cards can be administered using smartphones or CBDC kiosks.

Wallet programmability allows for effective fiscal policy implementation and monitoring. Examples include the automated direct transfer of sales tax from the point of sale to the internal revenue department, and the ability to designate spending of government grants.

The Prime Wallet prototype includes an authentication service which acts as zero-knowledge proof for digital ID. This service provides a validation mechanism for pseudonymous access to secondary wallets and other digital ID initiatives.

Secondary Wallets Provided by Regulated Commercial Operators

Secondary wallets form the innovation layer for distributing and using CBDCs. Competition within the private sector will catalyse the development of new wallet features and overlay services, such as atomic settlements across digital assets, programmable payments, and smart contracting using wallet addresses.

Secondary Wallets are provided for via encrypted linkage to the Prime Wallets and are accessed pseudonymously, allowing the abstraction of personal data from the view of commercial operators.

The prototype features four Secondary Wallets built on Corda DLT, Quorum blockchain, and a centralised database system to showcase interoperability between the different systems.

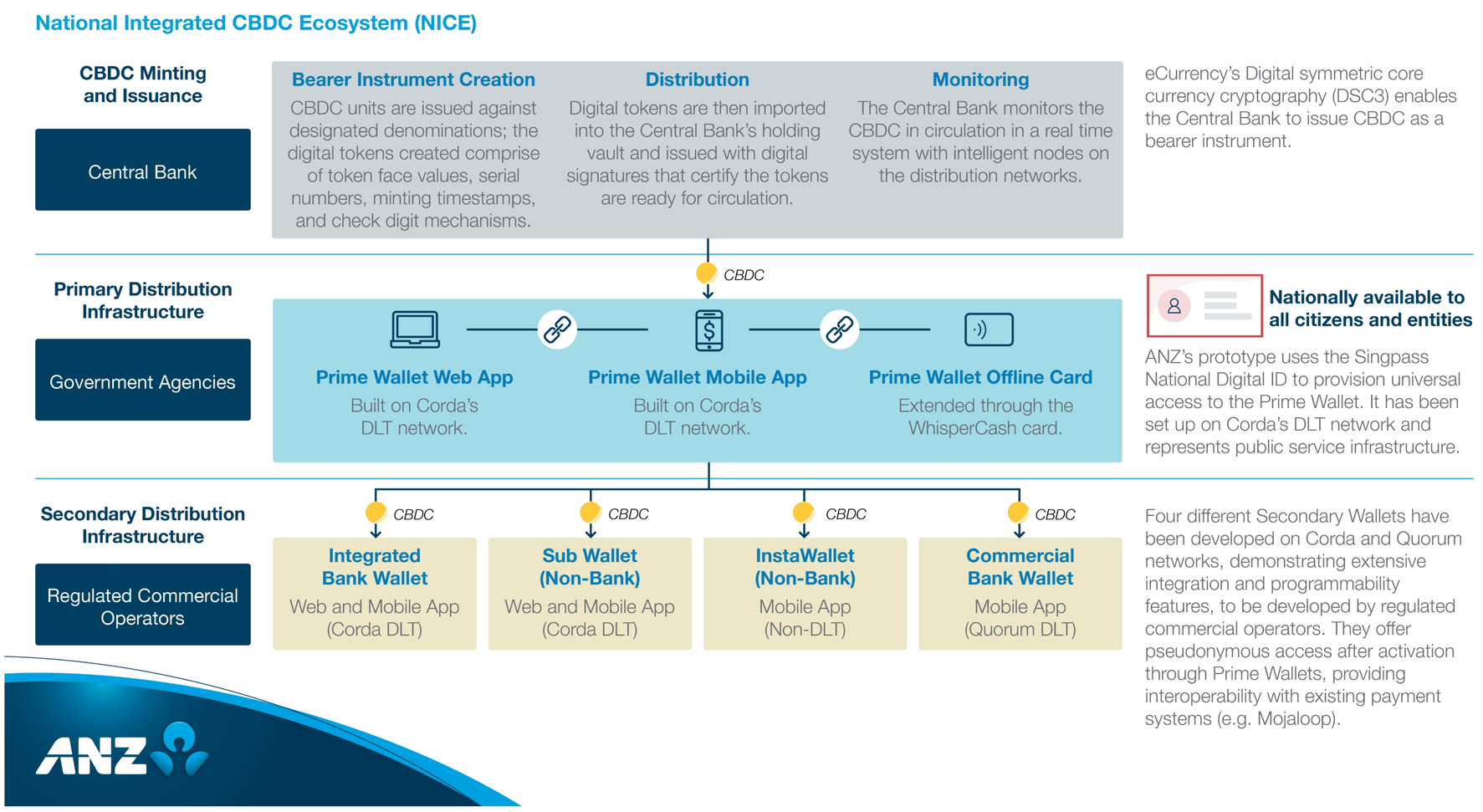
These Secondary Wallets allow for conversions between CBDCs and account balances.

The prototype also integrates with existing payment rails and alternate providers like Mojaloop via APIs for extensibility.

The technology components of the NICE prototype are:

- CBDC issued as tokens using eCurrency's DSC3 solution.
- Programmable Prime wallets with Singpass for keypair provisioning and authentication. Prime wallet system, configured on R3 Corda with nodes for Government ministries, provides authentication to secondary wallets with provision for Whispercash Offline cards.
- Secondary wallets were built on 3 different platforms, namely:
  - R3 Corda for Integrated Banking wallet services, interoperable with payment systems;
  - Quorum blockchain for Bank wallet for cross border m-CBDC transactions;
  - A MySQL-based system with wallet to hold and transfer CBDC.

The ANZ team would like to acknowledge contributions across vendors and partners to develop the NICE prototype: eCurrency Mint Ltd, Persistent Systems, Capgemini, Whispercash, Assurity.sg and Mojaloop Foundation



Overview of the National Integrated CBDC Ecosystem (NICE)

Bitt, Stellar Development Foundation

Stellar-Bitt DCMS

Bitt is a global financial technology company that provides digital currency solutions to central banks, financial institutions and ecosystem participants worldwide.

Stellar Development Foundation is a non-profit organisation that supports the development and growth of Stellar, an open-source blockchain network that connects the world's financial infrastructure.

Bitt is a regulated FinTech company, enabling monetary authorities to operationalise their own CBDC through its “Digital Currency Management System” (DCMS). DCMS includes applications for stakeholders of a CBDC: Monetary authorities (MAs), financial institutions (FIs), merchants and individuals, allowing the management of monetary policy, user onboarding/KYC, wallet accessibility, and integration with payment networks, including the Stellar blockchain.

Stellar is an open and public blockchain for global payments. It enables the issuance of digital currencies with payments settling in as little as 10 seconds, at near-zero cost. The protocol possesses built-in capabilities to ensure security, certainty and control to asset issuers (like central banks). Stellar has 5.4 million accounts and has processed 450+ million transactions.

Together, Bitt and Stellar are testing CBDC solutions in Latin America, Europe and Africa for the benefit of millions of consumers.

Personal data protection and system integrity

The DCMS maintains data segregation principles, ensuring that personally identifiable information never enters the core CBDC transaction network.

KYC information is collected and verified by AML compliance teams at licensed financial institutions and payment services providers.

Compliance officers can utilise a variety of tools for the verification of KYC including but not limited to: sanctions screening, transaction monitoring, alerts, and reporting.

Integration with the current financial system

The DCMS promotes MAs and FIs to leverage national payment rails to settle transactions in real-time, while it performs the CBDC settlements to end-user accounts. The DCMS enables MAs to maintain their role in minting, issuing, and monitoring currency, and allows FIs to maintain their traditional role in distribution, payment services, and onboarding. The DCMS does not require complex technological integrations to traditional payment systems. For example, the DCMS could integrate into the Mastercard card network to enable CBDC payments.

Decentralisation

An open network reduces the need for intermediaries and centralised processes, which decreases the cost of the offering of financial services and limits the damage any one authority can cause due to a system malfunction or a cyberattack. An open network makes it possible to develop an ecosystem where regulators and FIs can design solutions and monetary policies which foster competition and innovation. This competition helps to reduce the systemic importance of individual entities, minimising concentration risks. In this sense, the Financial Stability Board (FSB) has highlighted that the more decentralised a financial system is, the more it could benefit financial stability.

Privacy will be maintained as KYC and transactional information will be recorded in

Bitt's DCMS and managed only by FIs. While anyone can join and issue an asset, asset issuers have control on how that specific asset is utilised. An asset issuer can easily freeze wallets, and reverse fraudulent transactions.

Implementation and feasibility: in production

The implementation strategy involves a full integration with government ID services, with FIs through APIs, and with offline solutions. This model also considers transaction fees in terms of economic sustainability, and is highly scalable.

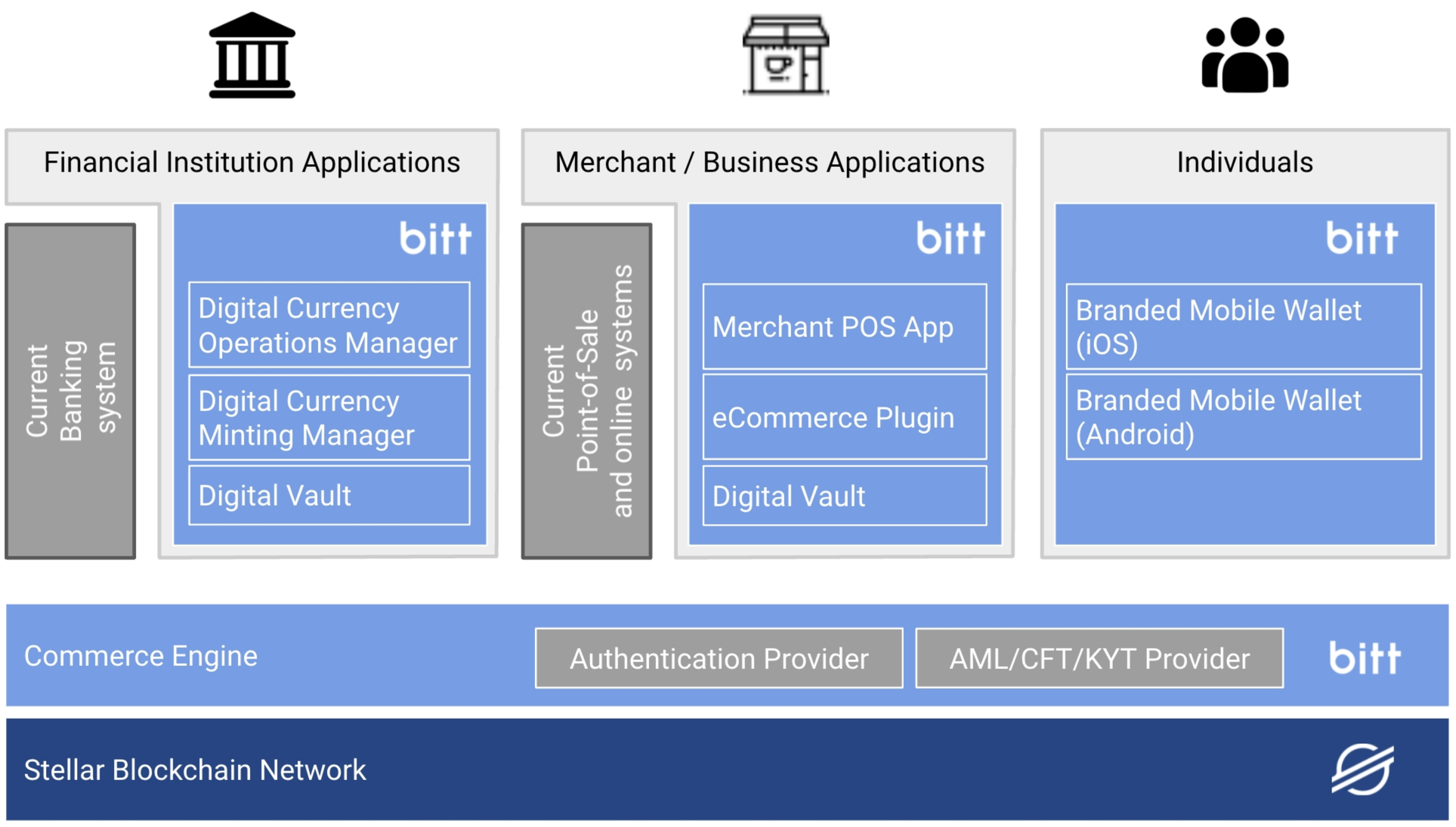
Impact

The solution allows for interoperability between digital wallets and savings accounts, and among multi-CBDCs. It also shows acceptance of CBDCs by merchants, along with the ease of use and limited friction of adding CBDCs as an option among cash and digital payments. It has the capability for offline solutions and backwards compatibility between devices accepting a CBDC and those not yet accepting a CBDC.

It also shows how the use of blockchain could generate quality insights to mitigate AML/CFT risks, and for macro and micro economic purposes.

The Bitt Digital Currency Management System (DCMS) provides applications for minting, managing and distributing digital currency at wholesale and retail levels. While integrations are supported, applications are designed to coexist and work in concert with existing banking and point-of-sale systems to improve time-to-market. Android and iOS mobile applications for merchants and consumers are also available. MFA authentication is built into applications.

DCMS APIs and applications deployed through a CI/CD pipeline, which includes automated testing. Within the Terraform-defined cloud environment, components are managed and scaled with Kubernetes. The Stellar blockchain is the foundation for transaction settlement with calls routed through non-uniform memory access (NUMA).



Overview of the Stellar-Bitt DCMS solution

Citibank N.A., Singapore Branch, SETL Limited, Payoneer Inc., Linklaters Singapore Pte. Ltd, OCBC Bank, Wells Fargo, Bank of America, The Bank of New York Mellon, Singapore Branch, Paypal Pte. Limited, Bondevalue Pte. Ltd, Goldman Sachs (Asia) L.L.C., Barclays Bank PLC

The Regulated Liability Network

The Regulated Liability Network (RLN) is a collaboration between regulated financial institution participants, working to realise the vision of regulated, global, token-based, multi-asset networks connected using distributed ledger technology. The Regulated Liability Network envisions programable instant settlement of regulated tokenised liabilities anywhere, anytime.

The Regulated Liability Network (RLN) is a proposed Financial Market Infrastructure (FMI) that tokenises regulated liabilities like central bank money, commercial bank money and Electronic-Money. RLN records the liabilities of each participating regulated institution and makes them fungible within the network.

A retail CBDC can come to life within the RLN, becoming instantly interoperable with other forms of regulated money. Retail CBDC forms an integral part of the next generation of regulated digital money. RLN provides a vision for the regulated sector to move forward together to deliver on the full promise of tokenised money.

RLN is a true ‘multi-tier’ digital money scheme incorporating both public and regulated private liabilities in a digital format. In this scheme, a retail CBDC performs multiple roles – it may be held directly by end users, but it may also be used by other RLN participants to settle obligations between each other.

RLN delivers next generation financial infrastructure, while avoiding the downsides of fragmentation that might arise with a combination of ‘narrow’ CBDCs and individual ‘bank coins’.

RLN achieves interoperability and inclusion through the tokenisation of ‘regulated liabilities’ which include central bank money, commercial bank money and E-money. These forms of money are promises to pay the customer on demand at par value in national currency units. They represent the face of the regulated financial sector – they are the face of sovereign money. RLN provides a retail CBDC in context of a broader network of sovereign money.

RLN consists of a logical/legal partition for each participating institution. For example, tokens within the central bank partition are CBDCs. Within the same network are partitions for each of the regulated private entities containing their tokens representing their liabilities.

Traditional payment systems perform messaging between institutions where the money is held. In RLN the money is on the network. This network is operates around the clock, and is programmable via smart contracts.

Payments in RLN are achieved through ‘burning’ a token in the sending partition and ‘minting’ a token in the receiving partition. Every transaction in the network is settled through the central bank partition, i.e. in central bank money in the form of CBDC.

Multiple central banks may open partitions on RLN, creating the equivalent of a global RTGS system. Real central bank money operating 24*7 on the same DLT will open a vast range of DVP and PVP use-cases.

Furthermore, RLN takes advantage of the ‘multi-asset’ nature of DLT and thus can

incorporate regulated assets as well as liabilities, e.g. bonds. RLN paves the way for a kind of financial infrastructure not seen before.

RLN delivers on interoperability across multiple dimensions:

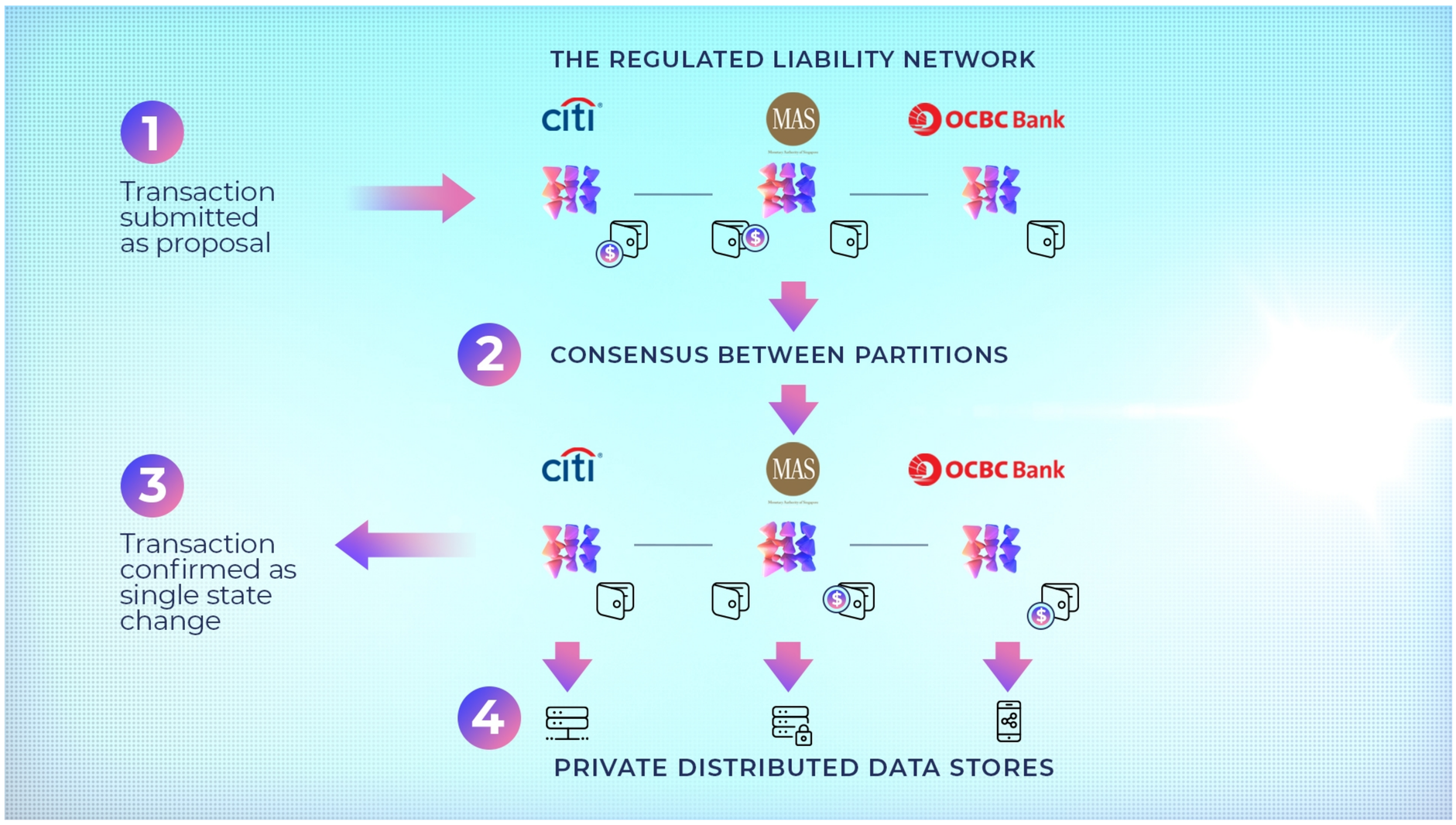
- Retail CBDC is fungible with private sector liabilities in the network
- RLN includes both regulated banks and non-banks, i.e. E-money players
- RLN may include so-called ‘stablecoins’, once regulated
- RLN is inter-operable with existing payment systems through the connectivity supported by private participants
- Participation by multiple central banks will achieve the liquidity bridges necessary to reform cross-border payments
- Connect to external blockchains enabling cross chain interoperability

For the Global CBDC Challenge, RLN has successfully demonstrated several use cases, including:

- Fungibility between retail CBDC and tokenised private sector liabilities.
- Transfers between private sector players that are settled in CBDC on the network.
- Multi-asset capability between tokenised money and tokenised securities.
- Interoperability between RLN and PayNow, the interbank peer-to-peer fund transfer service launched by the Association of Banks in Singapore (ABS)

The RLN vision has already demonstrated one of the most important features to drive interoperability, which is industry buy-in. A broad spectrum of top tier institutions have begun to congregate around the vision of retail CBDCs within the broader RLN, further supporting its development and use case applicability.

The solution is implemented on the SETL blockchain. Each Partition, including the central bank, is an issuer of tokens onto the SETL ledger. Issuers have control over token movements. A transaction is proposed to the RLN as a collection of changes in Partitions. An interbank transaction, for example, extinguishes the sending bank's tokens, moves CBDC tokens at the central bank and issues tokens at the receiving bank. The proposal is submitted as a SETL smart-contract. Balances are updated simultaneously across all partitions only when all partition owners have signed their agreement to the smart-contract.



Overview of the Regulated Liability Network

cLabs Inc., Valora

Valora

cLabs is a fintech company which built the Celo blockchain -- a mobile-first platform that makes digital currencies and decentralised finance (DeFi) products accessible to anyone with a mobile phone. Valora is a crypto wallet native to Celo, enabling people around the globe to access funds easily, within seconds at near-zero fees.

Inspired by the idea that digital currencies (including CBDCs) should be easy and safe for anyone to use, Valora is a digital wallet native to the Celo platform that makes blockchains useful and accessible even on the most basic smartphones, enabling 6 billion smartphone users worldwide to reliably save, send, and spend digital currencies as quickly and easily as sending a text message.

An important obstacle for the mainstream adoption of digital currencies is the lack of intuitive, public key infrastructures. Currently, consumers must use cumbersome hexadecimal addresses, which are hard to remember and easy to mess up. Instead, Valora improves the accessibility of digital currencies by using address-based encryption, mapping a user's phone number to their public key address in a secure and private manner. Now, users can send funds to virtually any mobile phone number.

Creating easy accessibility must be done without compromising the security of users or the financial system. To make the system secure and prevent unauthorised usage, Valora is a self-custody (or unhosted) wallet, in which only the user can access the wallet by way of a unique account key -- even Valora's team can't access a user's account.

Furthermore, to address concerns about the risks of illicit financial activities arising from the use of self-custody wallets, Valora imposes a $1000 daily transaction limit.

Should users wish to transact above this limit, Valora conducts KYC before lifting the restriction.

Should a user's mobile phone be lost, stolen, or damaged, Valora supports the recovery of lost funds without compromising user identity. In fact, Valora is simplifying the backup process by affording users the option of using a secure password or PIN-protected cloud backup of the account key, providing a faster funds recovery process, while serving as a safety net in the event the account key is lost.

Additionally, the decentralised nature of the Celo blockchain means no third party stores personal data for users wishing to stay below the $1000 daily transaction limit. However, for those wanting to transact in higher amounts, the integration of identity verification solutions directly into Valora allows KYC compliance to be performed. Furthermore, Valora allows users to connect directly to a bank account, thus leveraging existing payment rails to easily exchange digital currencies with fiat, all while allowing for the monitoring, detection, and prevention of illicit activities on the network.

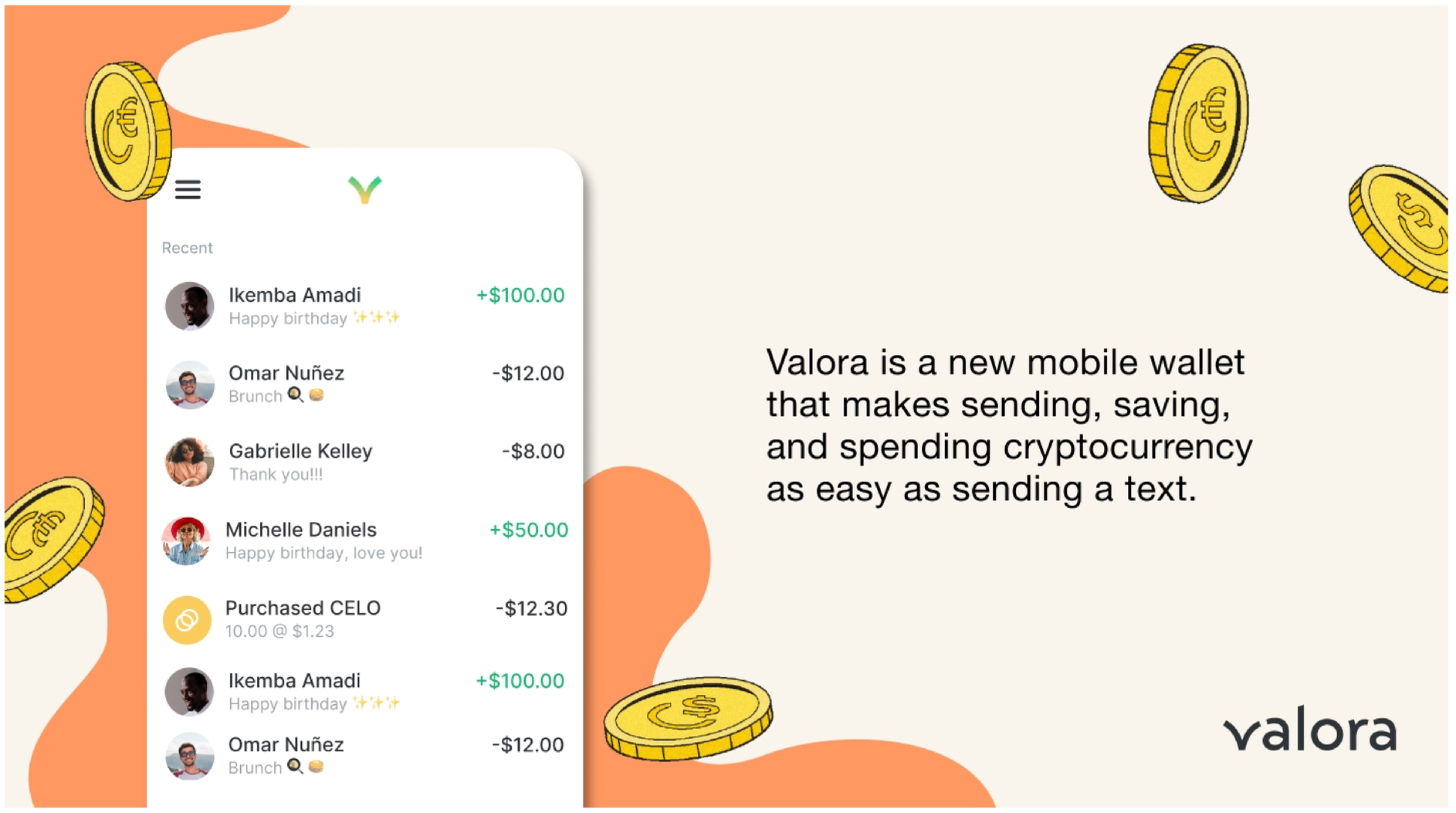
Valora's is already being utilised by non-profit organisations around the world to help distribute aid and cross-border payments to thousands of beneficiaries. For instance, Impact Market, an organisation enabling vulnerable communities to implement poverty alleviation mechanisms, is currently using Valora to distribute universal basic income and has processed almost $6 million to more than 22,000 beneficiaries in 23 countries around the world.

Additionally, the Grameen Foundation uses Valora to distribute COVID relief aid to beneficiaries in the Philippines, while

MercyCorps uses Valora as part of its digital microwork pilot in Kenya to test whether digital currencies and mobile wallets can ease frictions and reduce costs in cross-border payments for low-income youth, who gain access to digital microwork from global platforms on their smartphone and get paid through their Valora wallet.

When the time comes for retail CBDC to move from idea to reality, such a digital currency will need to meet consumers where they are. With more than 6 billion smartphone users worldwide, it’s clear that consumers are more mobile than ever. Valora’s intuitive user experience makes digital currencies accessible in a safe and easy-to-use way and it’s open-source nature means central banks can customise the mobile wallet to meet their unique requirements.

Valora is based on Celo, an open cryptographic protocol allowing applications to make transactions, and run smart contracts in a secure and decentralised fashion. Celo has a shared ancestry with Ethereum, and maintains full EVM compatibility, but uses a Byzantine Fault Tolerant consensus mechanism rather than Ethereum's current Proof of Work. Valora aims to make crypto accessible by enabling people to: send funds to virtually any mobile phone number instead of long hexadecimal public keys; use any smartphone, even with low internet connectivity; and participate without a bank account.



Overview of Valora

ExtoLabs LLC

ExtoPay

Extolabs develops comprehensive Tier 2 Retail CBDC and E-Money Solutions. ExtoPay utilises distributed ledger technology with low-cost biometric smart card hardware wallets, or mobile App wallets. ExtoPay provides universal access to smartphone or non-smartphone users, secure offline transactions, recovery of lost funds, fraud prevention, and user-controlled cryptographically-secured digital ID.

ExtoPay provides a cryptographically-secure, offline capable, tier2 retail CBDC and E-Money payment system to enable near-zero transaction costs by reducing fraud and customer service overheads due to onboarding, transaction disputes, and lost cards.

A novel hardware wallet with on-card secure enclave, biometrics, e-ink display, capacitive touch, Bluetooth, NFC and battery, enables secure off-grid transactions and provides a universal access device for consumers and merchants. ExtoLabs-Ethernom are driving down costs and power consumption by developing an ultra-low-power chip which integrates all functions.

Consumers with or without smartphones and connectivity can access ExtoPay via ExtoCard or ExtoMobile wallets. The system supports deviceless access via ExtoID authentication using a QR-Code plus fingerprint via merchant terminals.

The ExtoCard, combined with a smartphone, enables a full-featured, low-cost Point of Sale/ Money Agent Solution. Micro-merchants with a “standalone” ExtoCard wallet can accept payments from ExtoCard/ExtoMobile wallet holders and later settle transactions with Agents.

The system supports in-person online/offline, person to merchant (P2M), Peer-to-Peer (P2P) as well as remote online payments, and government-to-person (G2P) transactions.

Offline protocols, at the core of the ExtoPay transaction architecture, secure offline transactions and provide scalability, resilience and consistent quick completion for online transactions. Offline transactions are automatically posted to the ledger by both sender and recipient whenever either engages with a connected device. Unposted offline transactions can be chained, card to card, if necessary to provide funds for an outbound spend.

Widespread use of offline payments will motivate **invasive secure element attacks** to compromise private keys for black-market distribution to configurable **counterfeit** cards. ExtoCards makes such attacks uneconomical via expiring tokens, card-blocking, and on-card verifiable credentials. Furthermore, by additionally securing the display, user input and persistent storage, ExtoCards block a wide variety of attacks that may trick a secure element on a mobile phone or UI-less card into signing the wrong thing.

The system is a hybrid account-token based solution where edge-created wallets are linked to user IDs on the backend allowing for recovery of funds if a card is lost, while still preventing theft of funds via impersonation, social engineering or corrupt employees, as long as the user remains in possession of their card. Anonymous users are similarly protected, but only if they save a recovery key provided by the card on paper.

Different levels of KYC by Agents are supported for onboarding and recovery. The system secures Agent based onboarding allowing compliance personnel of Financial Institutions

full audit trails and supervision. The system supports photo ID, national e-KYC, SMS-ID, bank account-based KYC or attestations by trusted 3rd parties when permitted by regulators. While the system is fully compliant with KYC/AML/CFT, compartmentalisation preserves privacy of users' data with 3rd party counter parties.

The ExtoDLT system is based on a modified XRP Ledger to support private permissioned clusters for each financial institution. ExtoPay has modified the XRP Ledger to provide for out-of-order transactions that are required for offline modes, expiring tokens, recovery accounts and built-in digital ID features.

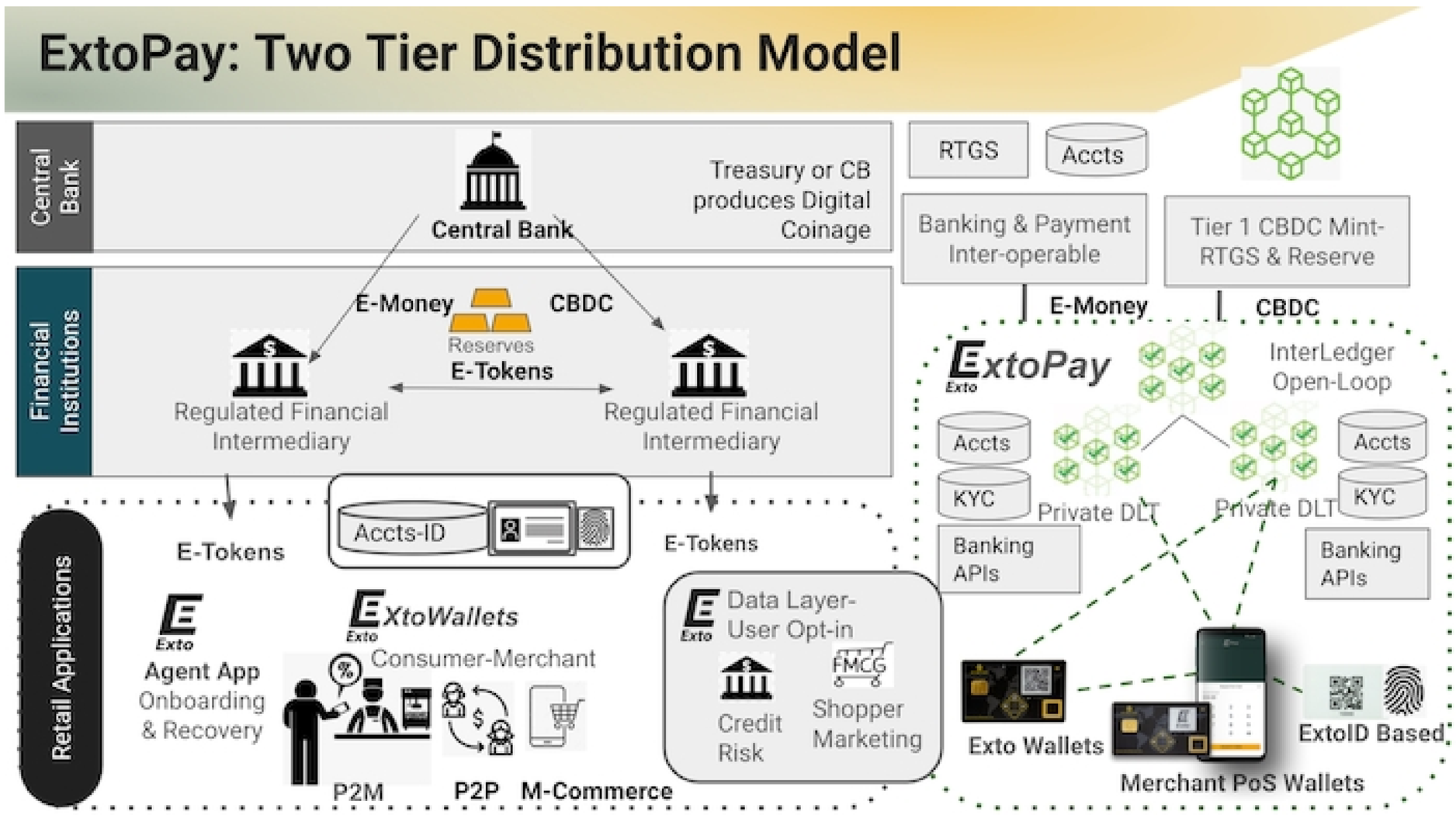
A hierarchical architecture enables an open-loop payment network. Central Banks can operate nodes on multiple layers of the ExtoDLT for full visibility into transaction details, but without linkage of accounts to personal identities. The system is designed to interoperate with banking and payment rails, operate in-jurisdiction, localising governance while keeping personally identifiable information of users private.

ExtoPay makes near zero transaction costs sustainable however the economic model involves monetisation of credit risk data for banks as well as loyalty data for shopper marketing optimisation enlisting all stakeholders to form a common-open-loop payment network. At all times, the system requires opt-in by end users.

The Global CBDC Challenge system uses ExtoPay-Ethernom Biometric Smart Cards, modified BRD crypto wallet client and XRP Ledger as the baseline for ExtoWallets and ExtoDLT. Netki's Photo-ID onboarding system was used to enable Agent onboarding.

For the proof of concept designed in collaboration with Alluvial (core banking platform partner), and utilising open-source Apache Fineract and Mojaloop switch technology, ExtoPay will connect its distributed ledger backend to bank accounts and mobile money (USSD). The proof of concept will integrate with R3 Corda as a Tier-1 CBDC layer.

ExtoLabs is ready to contribute intellectual property to an open hardware wallet standard and protocols.



Overview of ExtoPay

HSBC Bank (Singapore) Limited and HSBC Holdings plc

A Novel CBDC Evaluation Platform with Focus of DLT Consensus Algorithms and Related Operating Models

As one of the earliest banks to establish in Singapore, HSBC Bank (Singapore) Limited today is a prominent player in Singapore's financial services sector.

HSBC Holdings plc, the parent company of HSBC, is headquartered in London and serves customers worldwide from offices in 64 countries and territories.

HSBC's solution analyses 12 problem statements in this Global CBDC Challenge and uses 15 dimensions (e.g. business secrecy, latency, scalability, accessibility, etc.) to measure a retail CBDC system. Their analysis and research found that consensus algorithms and related operating models are key components of CBDC design for central banks. With this in mind, HSBC built an evaluation platform to provide central banks with consensus algorithm recommendations and operating model options.

There are a lot of differences between different jurisdictions in terms of national conditions and the focus of regulators. Thus, there is a need for a comprehensive solution that covers both technology and operational compliance of a retail CBDC. Consensus algorithms in distributed ledger technologies (DLT) play a significant role in retail CBDC systems. They have direct impacts on many properties of a retail CBDC system, including performance and privacy. It is therefore essential to properly evaluate consensus algorithms to achieve those desired properties.

Most retail CBDC pilots have shown preference for a tiered operating architecture in which privileged institutions like financial intermediaries and payment service providers distribute and circulate CBDC for non-privileged institutions. However, non-privileged institutions and the public have concerns over the monopoly of data. Non-privileged institutions, are especially reluctant to provide their customer data to privileged institutions. Yet there exist no mature technical solutions to keep business secrecy. Therefore, operating models must address data privacy and business secrecy issues.

By analysing diverse DLT consensus algorithms, HSBC built a theoretical framework that splits consensus algorithms into different components based on the desired policy goals. This framework feeds into an evaluation and recommendation platform, which recommends consensus algorithms suitable for specific national economic and regulatory conditions. After selecting the desired consensus algorithms, users can use the platform to generate a sandbox environment to test recommended consensus algorithms.

Additionally, HSBC provided operating models to improve business secrecy which could not solely be implemented from the technical side. In most retail CBDC implementations around the world, a tiered model is selected, with privileged institutions at the top, with non-privileged ones at the lower tier.

Transactions among participants of privileged and non-privileged institutions would be regarded as valid only when they are recorded ledgers of higher-tiered institutions.

However, in the tiered model, because privileged and non-privileged institutions are competitors, their data would not be shared to keep business secrecy for non-privileged institutions. Thus HSBC provides two operating models to choose from:

1) Decentralised Identifiers (virtual addresses) on the account level to support the current technical solution in CBDC tiered structure, and using dynamic virtual addresses to avoid higher-tiered institutions knowing identities of participants;

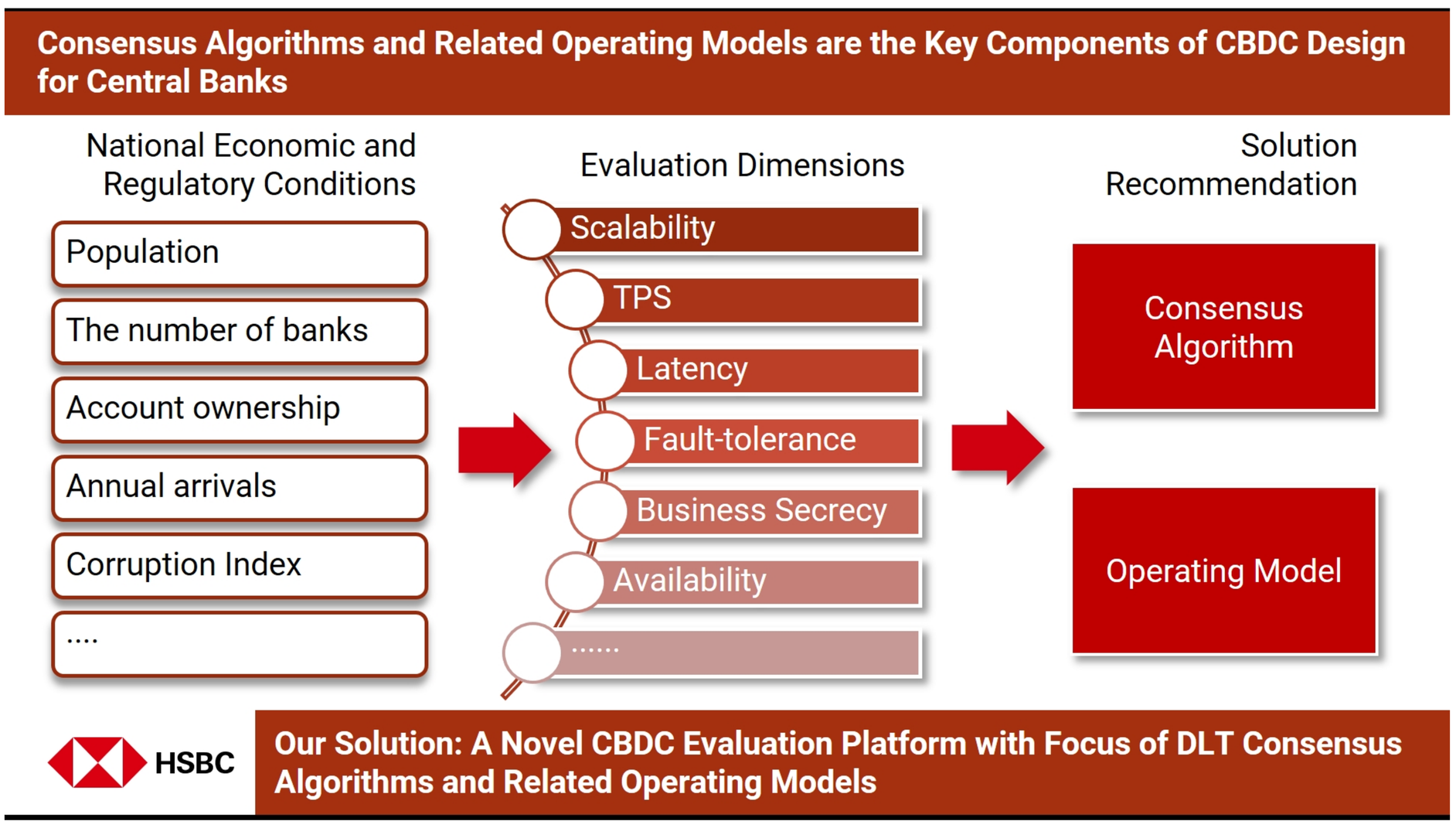
2) set up an independent operating-organisation without the interest conflicts of other participants.

HSBC's solution provides different options for achieving high performance while maintaining data privacy and business secrecy.

Depending on different national economic and regulatory conditions, the evaluation platform can provide various consensus algorithms to address retail CBDC needs of most countries. In parallel, the operating model can help non-privileged institutions retain their business secrecy.

HSBC will further develop and integrate more components of consensus algorithms. When development work on platform reaches certain degree of maturity, HSBC plans to make the whole platform and framework open source to the CBDC community.

HSBC used the R3 Corda open source platform to deploy node network and leverage AWS recourses to carry out related experiments for testing consensus algorithm's performance and other dimensions. Besides, during implementation, node.js, java packages (e.g. guava, netty-handler, protobuf), etc. were used at the code level.



Overview of the Novel CBDC Evaluation Platform with focus of DLT consensus algorithms and related operating models

International Business Machines Corporation (IBM)

EXtenium

International Business Machines Corporation (IBM) is an American multinational technology corporation headquartered in Armonk, New York, with operations in over 171 countries including Singapore. IBM produces and sells computer hardware, middleware and software, and provides hosting and consulting services in areas ranging from mainframe computers to nanotechnology and quantum computing.

“How can retail CBDC infrastructure be flexible and yet robust to support extensibility via addition of new capabilities and connection to new networks with resiliency to prevent failure and avoid systems vulnerabilities?”

A retail CBDC solution is transforming in how it will drive day to day retail and commercial activities spanning all forms of economic activities. Any retail CBDC solution must be supported by an extensible yet resilient infrastructure acting as a solid backbone to protect from any systemic risks of failure, hacking, downtime, non-availability, and other vulnerabilities. At the same time the retail CBDC infrastructure solution must support capability expansion, connection with existing payment rails and other token networks fueling new innovations while execution of appropriate fiduciary responsibilities and policy enforcements. Such robust capabilities at infrastructure level are needed to graduate from proof of concepts to in production deployment that are secured, trusted by all parties participating in a CBDC driven economic activities without fail.

IBM’s submission is the development of a unique framework for retail CBDC infrastructure deployment, named “eXtenium”, to help retail CBDC solutions deployment become extensible and yet resilient in production.

The eXtenium framework can make any retail CBDC solution to successfully deploy in production enabling privacy, anonymity, ease of usage, seamless interoperability across payment rails, token networks and other CBDC networks. It support hack-proof security and recoverability features of cash and other exiting forms of digital money. It provides the same “currency” level trust and protection without intermediaries allowing any retail CBC’s to become integral part of all economic activities both for retail and commercial transactions within the country or even at global level.

The eXtenium framework consists of four key capabilities to support any retail CBDC solution on any technology or DLT protocol deploy successfully. These are: –

- **Tokenisation Capability**: A privacy preserving token development capability to help develop retail CBDC tokens enabling exchange of assets and value across networks in frictionless and auditable way and binding ownership of the token to identity of the user. This capability is required to manage token issuance across jurisdictions, constituents and networks with privacy preserving capabilities and auditability.
- **Identify Management Capability**: To securely manage and control user’s own identity without reliance on any central authority and allowing necessary KYC with anonymity and finality. This capability is required to manage and verify credentials of all users, entities with assured confidence in anonymous manner.
- **Interoperability Capability**: To provide interoperability of retail CBDC tokens across permission or permissionless networks requiring no intermediaries allowing enabling extension of CBDC’s to work with other emerging networks and protocols within or

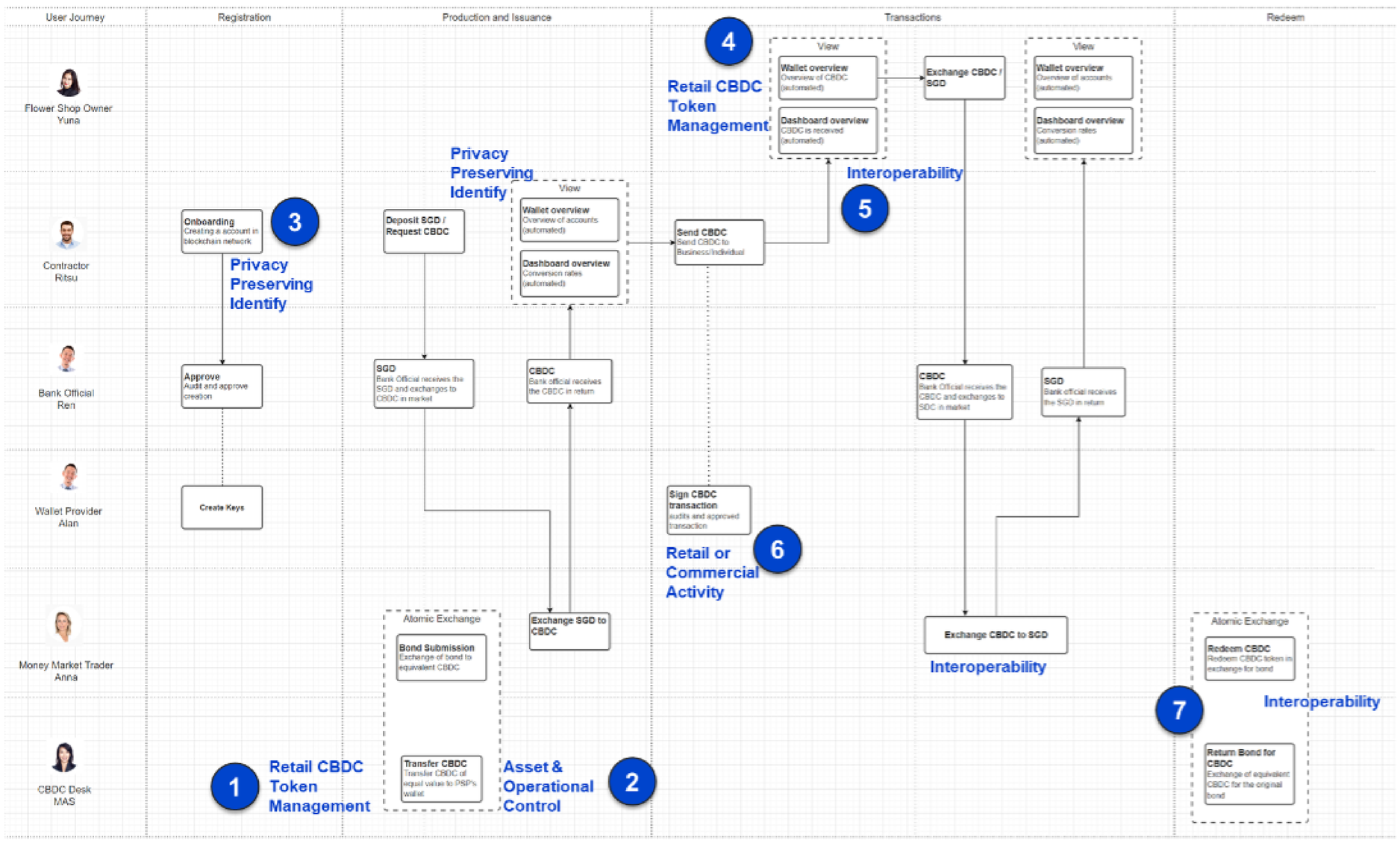
outside the country. This capability is required to work with multiple bespoke solutions, innovations, networks, and technologies to help retail CBDC evolve into a true network encompassing its usage across all facets of retail and commercial transactions.

- Security Management Capability: A unique way to manage private keys with robust security and hack-proof capability and preventing even insider threats yet with full recoverability feature. This capability is needed to institute trust and security on retail CBDC tokens but also allow design for recoverability features.

The eXtenium framework can allow any country or government deploy fully functional retail CBDC solution in production by helping them address CBDC issuance and management, integration with payment clearing houses and ensuring financial stability within the purview of banking regulations. The eXtenium framework allows better management of monetary policies, address suspicious activities, prevent parallel economies from taking shape, provides increased liquidity and deploy superior risk management and mitigation strategies.

The eXtenium framework is developed using open-source technologies and some unique hardware driven cryptographic capabilities from IBM.

- Tokenisation Capability: Hyperledger Fabric 2.2 DLT, Linux Virtual Machine, IBM Cloud, Go Lang 1.16, HTML / Angular 10.
- Identify Management Capability: Hyperledger Indy, Hyperledger Aries, Hyperledger Ursa, IoS React UI.
- Interoperability Capability: Hyperledger Weaver, IBM Cloud, Node JS 14.24, Angular 10.
- Security Management Capability: LinuxONE, H/W Protected Enclaves with IBM Secured Execution, IBM's Crypto Express 7s/ HSM (FIPS 140-2 Level 4) (private key/seed portability and management to support recoverabiltiy, and hardened operational controls.).



Overview of eXtenium

IDEMIA, ConsenSys

Secure Offline CBDC Payment Solution

IDEMIA provides a trusted environment enabling citizens and consumers alike to perform their daily critical activities, in the physical as well as digital space.

ConsenSys is the world's leading Ethereum software development company building the infrastructure, products, applications, and practices that enable a distributed world.

For this Global CBDC Challenge, IDEMIA, a leader in secure chips, and ConsenSys, a leader in blockchain, joined forces to demonstrate a Secure Offline CBDC Payment Solution, with the public interest in mind.

The solution addressed 11 of the 12 problem statements set by MAS, with a primary focus on two key areas.

The first main area of focus: financial inclusion. The team's solution can bring CBDC to everyone, even without a smartphone or bank account. It works with any device including low cost plastic cards, wearables, feature phones, etc. Biometrics can also be used to allow users to unlock their devices.

The second main area of focus: offline use. The team's solution works anywhere, anytime even in case of outages, cyberattacks or lack of mobile connectivity. It uses certified secure chips to efficiently prevent double spending and money creation. The integration between online and offline is secured by cryptographic operations in smart contracts ensuring consistency between balances and protocol integrity. Because the solution is offline capable, it is highly scalable: with most of the transactions being managed offline, the online system is less loaded and therefore can scale faster.

How does the solution work?
To pay offline, the payer uses a device with a secure chip, either a smartcard, a wearable, or a mobile phone with a SIM card. The payee can accept the payment on any device, even if it does not have a secure chip.

This allows merchants to accept payments on any existing device: point of sale, PC, mobile phone. The merchant only has to present its CBDC address, on a QR Code for example, to accept payment. For peer to peer payments, users can tap a card on a mobile, or send an SMS, or communicate between phones in offline mode.

If the payee has a secure chip, a mobile phone with a SIM card for example, he can immediately continue spending the funds offline. Otherwise they will need to go online with the blockchain to spend the funds.

How is the solution unique?

- Drawing from the recommendations from the BIS, the solution is account based and is capable of doing offline payments. The whole system is secured by design, allowing for new actors to develop innovative solutions with minimal security risks.
- It uses highly secure chips, certified by independent security/penetration testing laboratories, resistant to cache timing attacks, Meltdown, or Spectre. It does not rely on secure enclaves (TEE) as they may not be secure enough for CBDCs.
- It can integrate with existing payment infrastructure such as bank cards with no need for new devices, making migration smooth and cost effective.

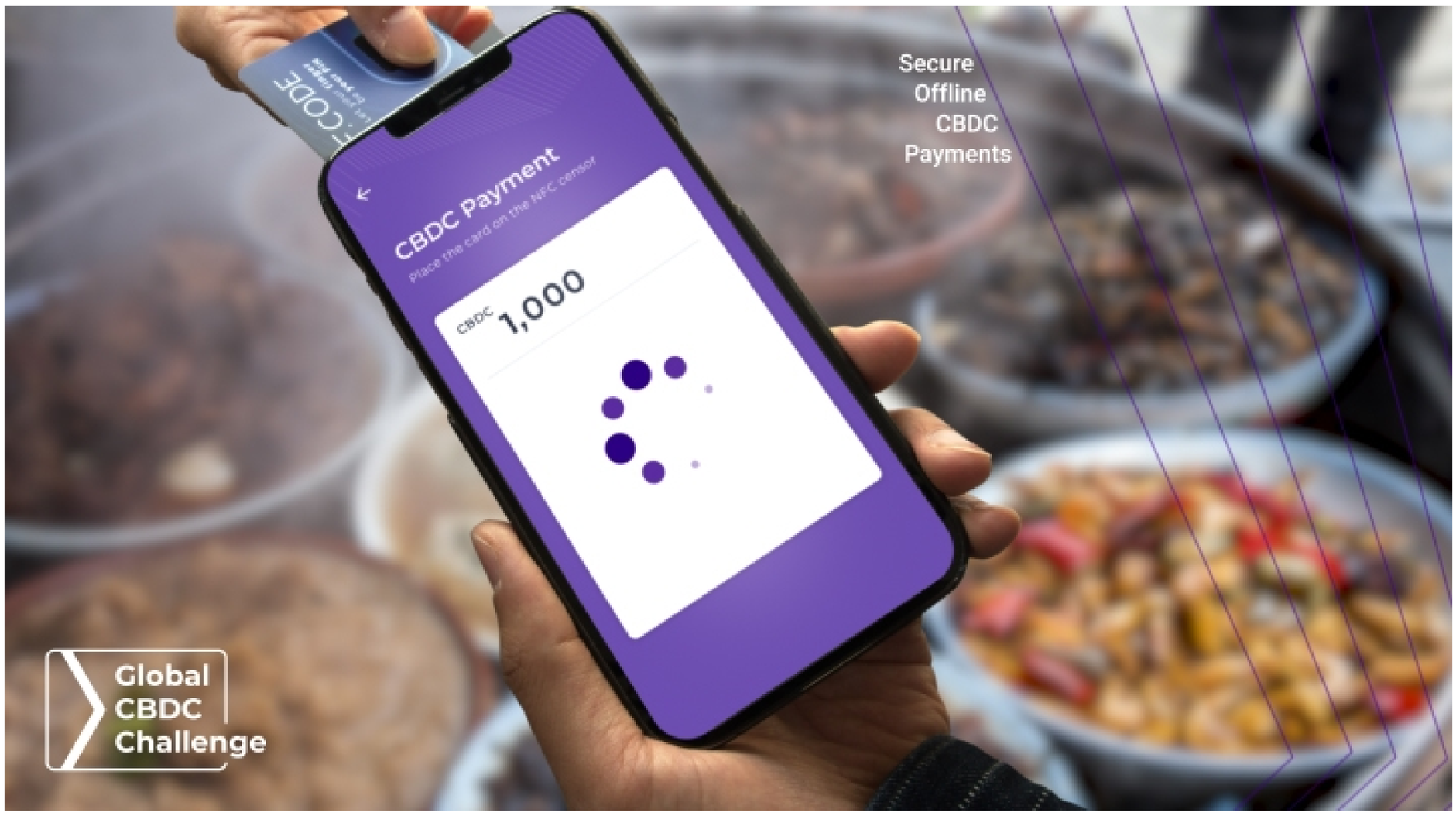
The solution also addresses the important issue of avoiding deposit outflows: central banks can define rules, such as maximum amounts or maximum number of offline transactions. These rules can be personalised to each user and are enforced by the chip itself.

Because privacy always comes up as the top priority for citizens in building a CBDC, the secure chips used are autonomous to perform transactions, ensuring complete privacy. Central banks will define rules for traceability, which will be implemented in the secure chip. On the blockchain, all transactions are pseudo-anonymous but can be monitored, traced, flagged to detect any suspicious transactions. The solution could leverage existing payment rails instead of starting from scratch, and allows the use of programmable money.

The smart cards implements secure and standard Java Card based applications for offline payment. They store the biometric templates and perform facial/fingerprint matching. They generate and store the wallet secret keys with secure cryptographic algorithms, and store the balance in a tamperproof memory. They are resistant to cache timing attacks, among others, as opposed to TEE secure enclaves.

The mobile phone uses Android OS and Java, Android OMAPI library for SIM card interaction, NFC technology for plastic card interaction, Bluetooth Low Energy for the merchant PC interaction.

Redeeming online uses an Ethereum blockchain, and two smart contracts: IDEMIA and ConsenSys ERC20.



An example of the Secure Offline CBDC Payment Solution payment page

IOG Singapore PTE

Unchained

IOG is a software engineering company that builds blockchain solutions and cryptocurrencies and offers expert consultancy for corporations, government entities, and academic institutions. Underpinned by peer-reviewed science and a rigorous approach to critical elements of the code, IOG built Cardano, an environment-friendly blockchain.

A CBDC is a digital currency issued by (and a liability of) a central bank. To be *retail*, it should be widely used. To this aim, it must be **available** and **operationally resilient**, even in areas with limited or intermittent internet connectivity or among people who, for legitimate reasons of **privacy** or lack of financial **inclusion**, would prefer or need a cash-like experience.

The solution is a non-custodial mobile wallet that mimics the functionality of physical wallets by letting users hold digital objects that are stored only locally in the wallet itself. To enable offline transfers of digital objects representing monetary value, the solution introduces *CBDC Cheques*, which are digitally signed and can be redeemed when the user is online. This works analogously to the offline exchange of physical cheques among peers who are far away from a physical bank and their redemption when the cheque holders visit the bank. The risk of double-spending is similar to the risk of receiving a physical cheque with non-sufficient funds. In both cases, the receiver must have a level of trust in the issuer of the cheque.

In contrast to traditional cheques, however, cheque creation can only be done by the holder of the private key and offline transfers of CBDC cheques are traced in the cheques themselves (by storing the anonymous public keys used to sign the transfers).

This not only provides some additional **dispute risk** protection but also could allow the implementation of AML/CFT features beyond imposing redemption limits.

By adopting a minimalistic technical design that is inspired by the familiar concept of *cheque*, the solution remains **accessible** and **frictionless**, even for people with relatively low technological literacy.

The decision to target mobile devices was based on the observation that mobile penetration is very high and rapidly increasing, even in countries with low infrastructure. Furthermore, while custom hardware solutions (e.g. trusted runtime environments) can provide additional double spending protection for offline transactions, their penetration and standardisation are still very low, which would hinder wide usage in the short-term.

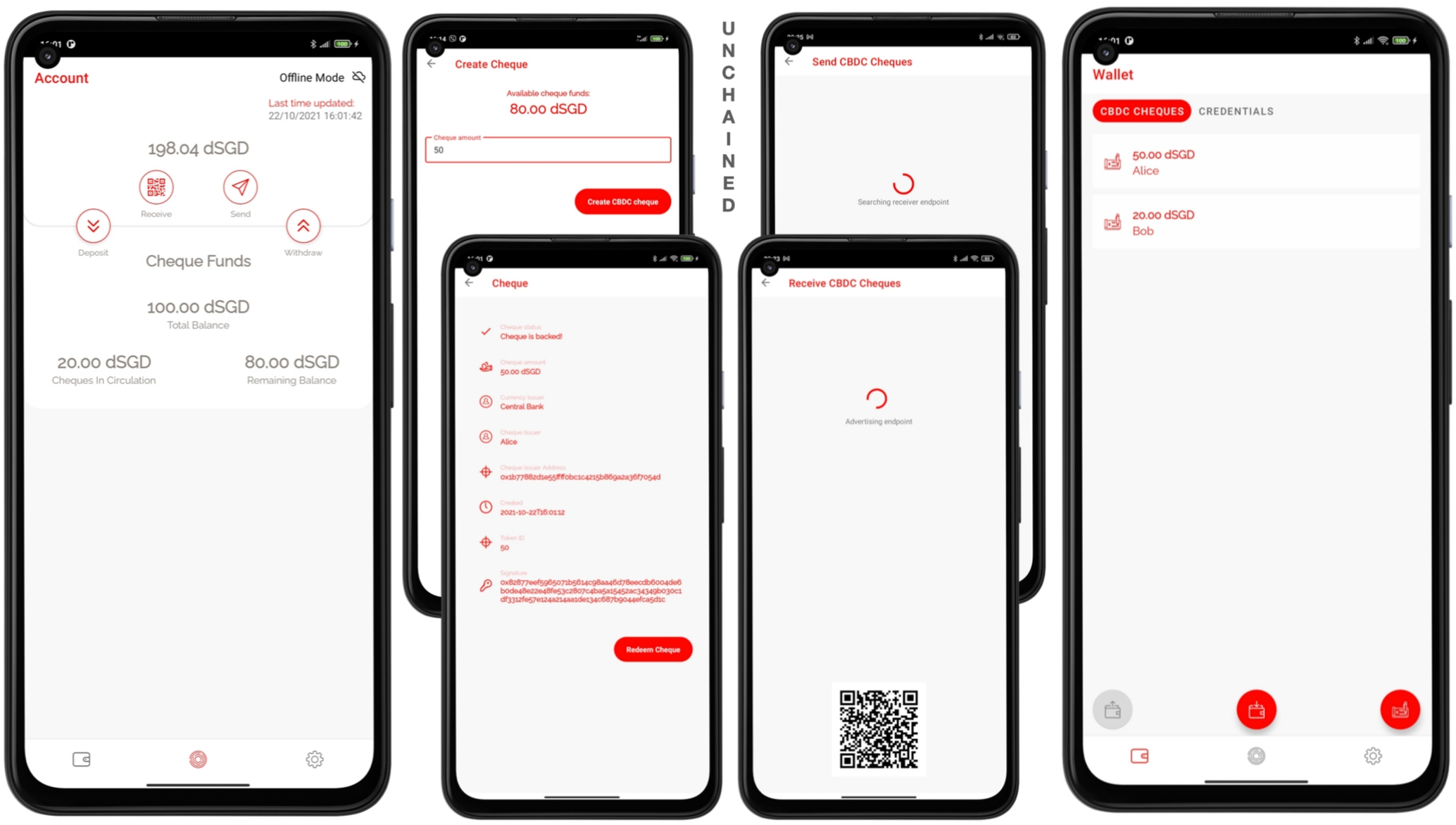
The wallet is agnostic to the CBDC backend infrastructure. Its current implementation uses a public permissionless blockchain as the backend and uses smart contracts to handle cheque redemptions automatically. It would be easy to interoperate with any distributed ledger with smart contract functionality (including private permissioned ones). It would also be easy to interoperate with any infrastructure capable of verifying CBDC cheque signatures, including centralised ones on top of existing payment rails.

Furthermore, the wallet is compatible with various CBDC design choices. For instance, it can work both with direct designs, where the central bank is directly running the backend infrastructure, or with two-tiered designs that avoid disintermediation and are run by financial institutions. It can work with both token-based and account-based CBDCs.

Through offline transactions, the solution naturally boosts the **scalability** of the underlying CBDC infrastructure, because offline transactions do not consume its resources. And, since offline transactions are free, the solution reduces overall **transaction costs** and increases **payment efficiencies**, thereby ultimately improving **financial inclusion**.

By taking these technical and socio-economic considerations into account, the team built a unique solution on top of mature technology that provides critical offline transaction functionality and that is ready-to-use today. With a focus on simplicity and a reliance on **standard** open-source technology allowed the team to build the solution with relatively low effort and cost (approximately 6 engineer-months).

The CBDC Wallet is an Android mobile app, implemented in Kotlin and following an MVVM architecture. Offline communications between wallets are made using Google's NearbyConnections API for WiFi-Direct. Interactions with distributed ledgers use the Web3J library. Any distributed ledger (public or private) compatible with the EVM (Ethereum Virtual Machine) can be used. For the demo, the app is interacting with the Rinkeby testnet blockchain through an Infura server. For digital signatures, the team uses the SHA-3 (Keccak256) standard. Finally, the team used the Room database for local storage, Kotlin Coroutines for concurrency and Dagger Hilt for dependency injection.



A prototype of the Unchained mobile application interface

SEBA Bank AG, Xfers Pte. Ltd.

Hybrid CBDC Model Leveraging on Aztec Protocol for Privacy

Xfers aims to accelerate financial access by enabling businesses to accept payments and send money seamlessly through the Xfers Business Account API and Payment Link solutions.

SEBA Bank is a pioneer in the financial industry providing a suite of regulated banking services and successfully conducted a CBDC experiment with Banque de France.

Xfers and SEBA proposed a Hybrid CBDC solution which aims to achieve both private data protection and system integrity, while leveraging credible compliance capabilities through cutting edge layer-2 security mechanisms. Their solution incorporates privacy-preserving capabilities while retaining high performance, with fast response time, low latency, and scalability to support large deployment. This enables the Central Bank (CB) to strike the right balance between personal and transaction data protection while maintaining the necessary monitoring capabilities required.

With the Hybrid model, an intermediary layer of financial institutions and a direct claim on the CB co-exist, allowing greater portability for both consumers and financial institutions and a stronger CBDC ecosystem. Authorised financial institutions issuing and distributing CBDC would perform customer due diligence and AML duties such as recording and reporting suspicious transactions, while the CB will be responsible for conducting AML regulations and supervising fulfillment. In addition, they are proposing that financial institutions should also be responsible for transaction monitoring, fraud detection and prevention, and AML/CFT efforts.

The direct CBDC model, where the CB handles payment services, would substantially affect the structure of the current financial system, causing major disintermediation, and materially increasing the responsibilities of the CB while compromising on the payment system's speed, efficiency, and reliability. CB would also be required to build and operate technical capacities at a massive scale and potentially take on KYC/AML duties.

With a hybrid CBDC model, CB can leverage financial institutions' technology, and innovation capabilities, reducing the costs of building additional infrastructure and systems.

Xfers, a fintech company in Singapore, will be responsible to issue and distribute CBDC, conduct KYC and customer onboarding, conducts transaction monitoring, address management, AML/CFT.

SEBA Bank, a digital assessts-focused bank in Switzerland, will support the implementation of layer-2 security mechanism on public blockchain, enabling a higher level of consumer protection.

Issuance of CBDC

In terms of Issuance of CBDC, CB can leverage on Xfers existing integration into payment rails for KYC and AML with customers funds being held in a CB as reserves. Tokens will be generated on the CB network, a public blockchain, and issued by Xfers. To redeem hybrid CBDC tokens, they will be burned or destroyed upon deposits from customers, and SGD will be transferred from CB to Xfers for customers to withdraw.

Compliance

In the proposed solution, Xfers, as an MPI license holder for e-money issuance, would manage the compliance aspect whereby users are required to whitelist both custodial and non-custodial addresses. The XSGD smart contract is embedded with functions to terminate suspicious and illicit activities. To solve the privacy problem without compromising on response time, a layer-2 solution with Zero Knowledge Proof (ZKP) is best suited to ensure privacy, performance and scalability. The team selected Aztech protocol to solve the concerns regarding public visibility of transactions such as issuance, transfer and redemption of CBDC.

Aztec protocol uses zkSNARK proofs to provide privacy and scaling through a zkRollup service. XSGD ERC20 tokens can be exchanged for custom zero knowledge XSGD tokens (zkXSGD), which can be transacted such that no one other than the intended recipient of a transaction is able to view the contents of the transaction including balance as well as the recipient. The zkXSGD transactions occur through encrypted UTXO like structures, called notes, stored in the zkXSGD smart contract. The notes can then be redeemed by the intended recipient and spent in a similar manner.

An overview of the Hybrid CBDC Model leveraging on Aztec Protocol for privacy

Soramitsu

Privacy-Preserving CBDC Payment Data Query System

SORAMITSU is a Japanese/Swiss technology company with expertise in blockchain-based solutions for digital asset and identity management. SORAMITSU is the developer of the open-source blockchain Hyperledger Iroha. Together with the National Bank of Cambodia, SORAMITSU developed Bakong, a Hyperledger Iroha-based payment infrastructure and digital currency live in market since 2019.

SORAMITSU has developed a full-featured, two-tiered CBDC system based on Hyperledger Iroha, which is production-ready. The solution proposed by SORAMITSU for the Global CBDC Challenge is an “overlay app” for our two-tiered CBDC system. It could also function with a reserve-backed variation on this system, such as the National Bank of Cambodia’s Bakong, or a comparable RTGS-plus infrastructure.

Context — Inefficient and costly credit underwriting processes in data-poor environments, particularly with regard to microfinance.

- There is consistency in the set of data that are relevant to FIs conducting risk assessments. While different entities have different policies, the criteria used to underwrite a loan applicant are similar on a high level:
  - Can the applicant be identified?
  - Can the applicant be traced?
  - Does the applicant have sufficient disposable income to be eligible?
  - How stable is the applicant’s financial situation?
- While these questions are simple in principle, unbanked consumers often lack documentation necessary to provide verifiable answers, resulting in costly credit underwriting processes in microfinance.

Problem — Privacy risks of leveraging payment data for credit underwriting.

- The proliferation of ICT has opened up new data streams -- such as mobile payment records -- that could be used to assess the unbanked. But, unregulated collection of such data could accelerate the formation of data monopolies, which not only inhibit competition, but also undermine public trust.

Solution — Contextual CBDC payment data queries built into a retail CBDC system.

- The solution proposed by SORAMITSU is an “overlay app” for the two-tiered CBDC system. It could also function with a reserve-backed variation such as the National Bank of Cambodia’s Bakong, or with a comparable blockchain-based RTGS-plus system. It could be furthermore be modified to interoperate with a non-blockchain-based CBDC or RTGS-plus system.
- This overlay app resolves the privacy lacuna by enabling FIs to query specific payment data points from retail CBDC wallets. Importantly, approved queries result in a yes/no response, so data cannot be used outside of the context of the specific query (and attached parameters) they are created against. The end-user’s CBDC wallet is embedded with a permission system, and must provide explicit consent to share each data point.
- Illustrative examples of data points that can be queried are:
  - Recurring inward payments, which could indicate a salary job;
  - Recurring outward payments to a non-merchant wallet address, which could indicate family support burden;

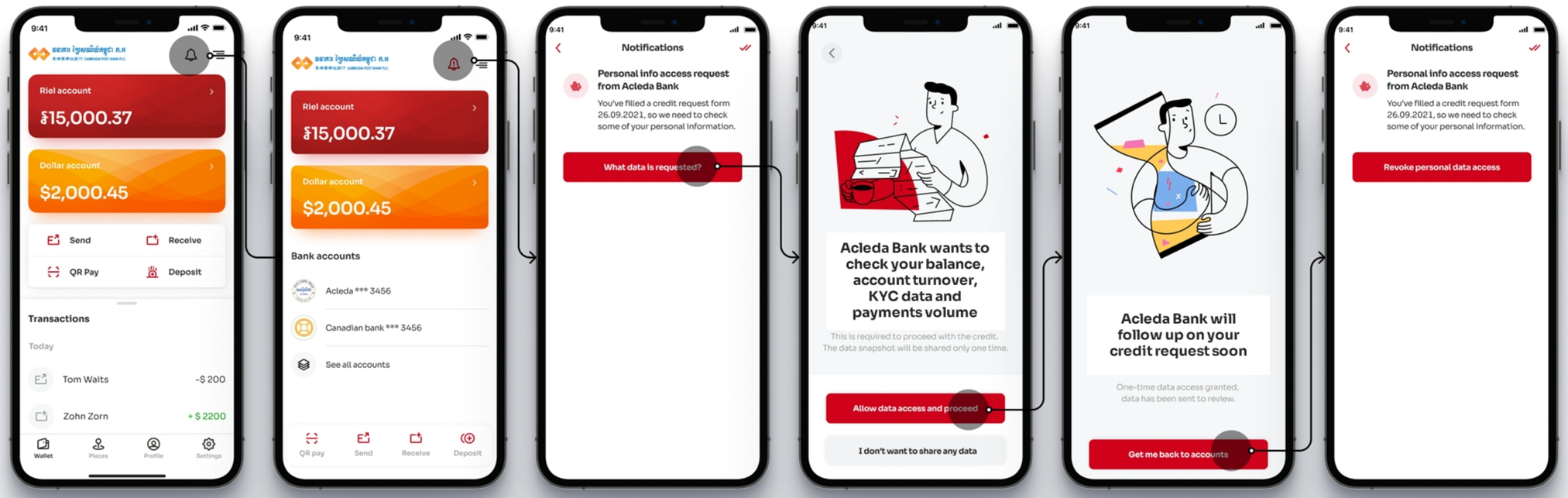
  - Geographical areas of payments, which could indicate a stable residency;
  - Recurring outward payments to wallets tagged as credit providers, which could indicate existing debt.
- The set of queries available should be designed by a supervised entity accustomed to sensitive data manipulation. SORAMITSU views credit bureaus as appropriate candidates, given their good knowledge of local credit markets and their existing role of sharing data with FIs.
- By allowing FIs to access only targeted, relevant data defined by a supervised entity, without revealing complete datasets, the application enables accurate risk assessments while limiting the ability of FIs to abuse personal data, engage in discriminatory profiling, or build financial data monopolies.

Server-side

- Spring App: Spring Boot, Spring Security, Spring MVC, Spring Data
- Microservices: Spring Cloud, Netflix Feign, Netflix Eureka
- Databases and storage: Hazelcast, MongoDB, PostgreSQL, Iroha
- Messaging: RabbitMQ, Apache Camel
- Misc: JUnit, Testcontainers, Jackson, Liquibase

Frontend

- JS, React, Bootstrap



A prototype of the Privacy-Preserving CBDC Payment Data Query System's mobile application interface

Standard Chartered Bank, SC Ventures, Shareable Assets Pte Ltd

Solution by The Shareable-Liberty Consortium

Standard Chartered is a network bank penetrating 59 markets, globally expanding financial participation. SCVentures is a proven innovator in digitisation with success in Mox Bank. Shareable Asset is a MAS-licensed tokenisation platform. Together, The Shareable-Liberty Consortium brings a new retail yield opportunity integrated with CBDCs for adoption, distribution and inclusion.

The Shareable-Liberty Consortium is a partnership formed by Standard Chartered Bank, Shareable Asset, and SCVentures.

The Shareable-Liberty Consortium's solution provides a platform for governments to issue CBDC-denominated bonds directly to retail investors in smaller nominal amounts than through traditional means. Retail bond investors are issued individual wallets on the Stellar blockchain holding tokenised representations of CBDCs and CDBC-denominated securities.

Retail investors are often excluded from tapping into higher yield opportunities afforded by government bonds versus bank deposits. The solution supports tokenisation of digital instruments with smaller ticket sizes, lowering the barrier to financial participation and enabling often-excluded individuals to earn interest in CBDCs, incentivising CBDC adoption. The solution mobilises retail transaction flows between investment and returns denominated in CBDCs, to be a self-sustainable cycle.

By creating a single point of CBDC distribution from the government to an expansive audience of retail investors who need only download a mobile application, the solution adds new functionalities to CBDCs without heavy technological investments at the end-user level.

The solution can be adapted to promote a safe marketplace and peer-to-peer distribution in CBDC-denominated digital assets – to be scaled vertically with users and volume – as well as horizontally across various platforms and services in different ecosystem hierarchies. By integrating with offline options to deepen financial inclusion, such interoperability vis-à-vis a diversity of CBDC channels translates into adoption for the general use-case of economy-wide payments.

At the crux of implementation of CBDCs, ranging from technology and governance to legal and policies, adoption and distribution are key to driving a scalable ecosystem. Solutioning against key problem statements, and enriching our integration suite, our platform has been proven to interoperate with different CBDC sandboxes by Partior and Mastercard, as well as viably complementary to applied implementations such as Mojaloop, Extolab and payment rails in a multi-layered ecosystem.

Natively compatible with a variety of CBDC models, the investor either directly holds a CBDC-account or will be incentivised to get one through a commercial bank, to accomplish the purchase of the bond. Alternatively, the solution could anchor on a central point for exchange in and out of CBDCs operated and managed by a central authority, to create an efficient one-to-many solution.

From enabling instant settlement to finality, efficiency gains emerge and effectively reduce costs associated with settlement cycle delays and margin calls. With atomic delivery, quicker flows of capital is facilitated for payment efficiencies.

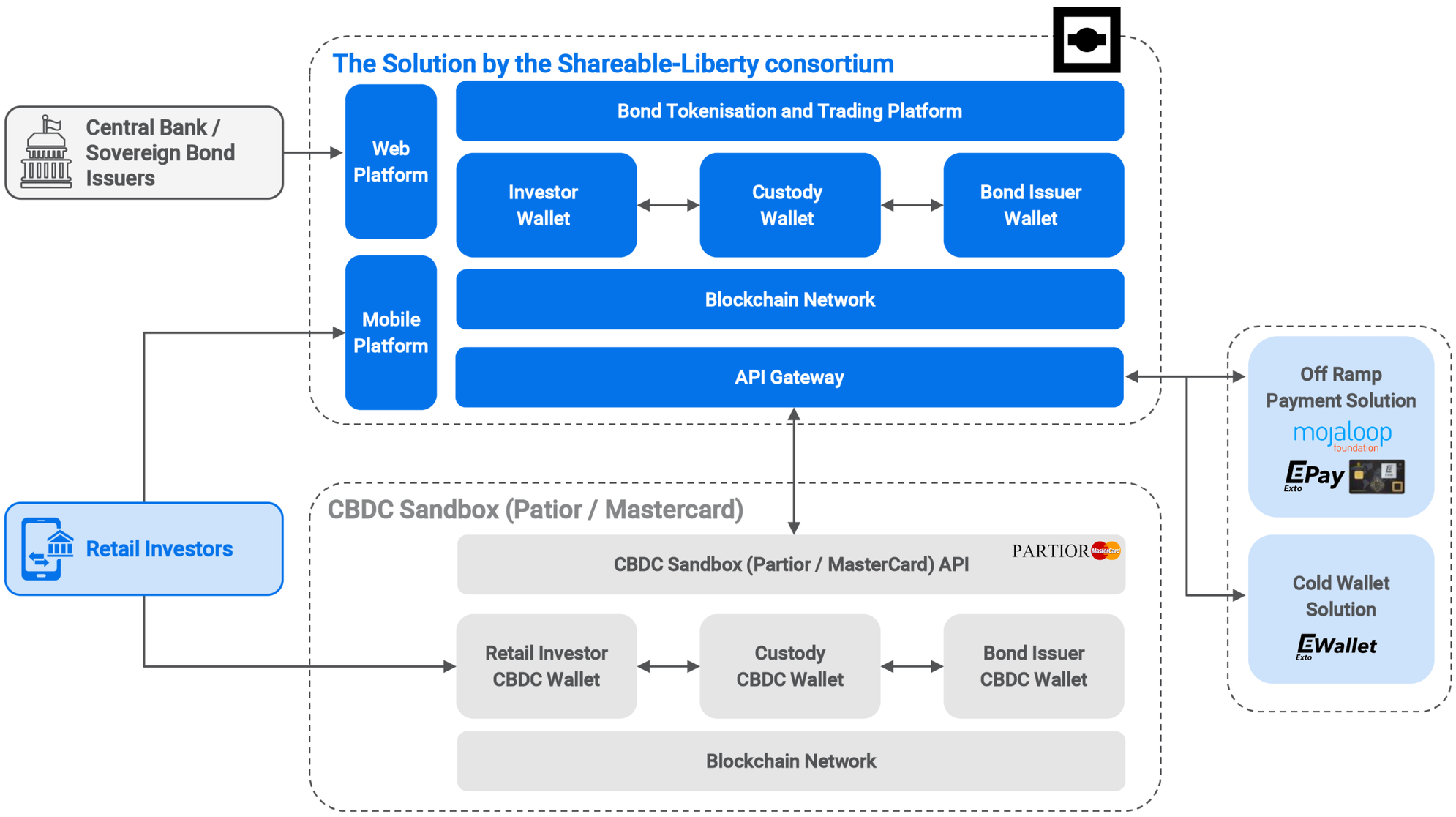
The increase in monetary transactions will lower economic-wide transaction costs, in alignment with the retail CBDC's aim of the reduction in costs of payments for broader participation and further economic activities.

The solution empowers distribution of government bonds in conjunction with CBDCs in the hands of a larger percentage of the population. Throughout this time, the solution's blockchain-enabled provenance and traceability visible among multi-parties reduces concentration and a single point of failure while enhancing account auditability.

The Shareable-Liberty Consortium is involved in BIS Innovation Hub's first green finance project, Genesis, in conjunction with HKMA exploring national-level issuance of green bonds.

The retail digital asset tokenisation solution has two frontend entries; the web platform for digital asset issuers developed in Vue.js and the mobile platform for the retail investors developed in Kotlin and Swift. The backend was largely developed in NodeJs with Stellar public blockchain as underlying digital ledger technology.

In terms of the integration with the CBDC sandboxes provided by Partior and Mastercard, the solution provides additional API endpoints written in NodeJs that enable a synchronisation of CBDC movements between the solution and the CBDC sandboxes.



An overview of the Solution by The Shareable-Liberty Consortium

Conclusion

Conclusion

Although a technical competition by design, the social aspects of a retail CBDC featured strongly in the Global CBDC Challenge. Many of the solutions demonstrated strong consideration for the user experience and included (i) elements of offline access - to suit areas without strong internet connectivity or stable electricity supply; and (ii) the ability to function on a variety of devices - smart phones, feature phones and even traditional cards that we are used to carrying. This reflected the thoughtfulness by the participants to address the digital divide in different parts of the world. References to the unbanked and the underbanked anchored several of the pitches.

The technical elements were also well explored. Almost all solutions covered aspects of privacy, scalability, security, programmability and compatibility with existing systems amongst other technical considerations. Many of the solutions were based on Distributed Ledger Technology, reflecting the evolution in the way we think data should be stored and transacted in the future. Several of the solutions covered the cost of distribution - clearly acknowledging a future where cross-border payments would be far more efficient, and significantly cheaper than the costs today. Foundational issues - impact on financial stability, Know-your-customer requirements, Anti-Money Laundering regulations, legal impediments and other regulatory elements also featured strongly in many of the pitches.

One team distilled the vision of the competition succinctly - "A retail CBDC must be accessible without a bank account, every time, at low cost. It must be private and must meet the needs of all stakeholders." The solutions did not disappoint in realising this vision. While no one solution that this Challenge produced will truly realise this intent at this stage, we now have good models of implementable solutions that shows how theoretical concepts can be actualised.

Any innovative adoption must begin with experimentation, followed by prototyping and then a staged implementation. The purpose of the Global CBDC Challenge has been to unbox the underlying technologies required for an effective implementation of retail CBDC systems that are widely applicable. In the case of retail CBDC, its issuance is governed by an additional dimension - socio-economic considerations. The question here is whether there is public demand for a state-issued currency that is as safe as cash but in digital form. If the demand is absent or weak, issuing a digital version of cash is moot. The alternative, where strong demand is present, means a strong case for a retail CBDC. This is a jurisdiction-specific analysis that is beyond the scope of this Challenge.

We hope that the Challenge and this accompanying report will galvanise the financial ecosystem to co-create the next generation of payment rails built on the latest innovations, which will present firms and households with better, cheaper, and faster opportunities to make payments. This has been an enriching journey for all involved. The finalists and solutions clearly demonstrate that the future is already here.

Acknowledgment

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Acknowledgment

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Appendix

IGOs

The International Monetary Fund (IMF) is an organisation of 190 countries, working to foster global monetary cooperation, secure financial stability, facilitate international trade, promote high employment and sustainable economic growth, and reduce poverty around the world. The IMF takes special interest in new transformations in digital money, including CBDCs, and its implications for the economic and financial stability of the international monetary system. Digital forms of money bring substantial potential benefits, but also come with risks. The IMF works closely with member countries to offer policy advice, as well as technical assistance and training, also on the topic of CBDCs.

THE WORLD BANK

The World Bank Group is one of the world's largest sources of funding and knowledge for developing countries. Its five institutions share a commitment to reducing poverty, increasing shared prosperity, and promoting sustainable development. The World Bank Group's Payment Systems Development Group supports the development and reform of national payment systems, including international remittance markets, in developing countries. More information is available on the World Bank's website.

The UN Capital Development Fund makes public and private finance work for the poor in the world's 46 least developed countries (LDCs). UNCDF offers "last mile" finance models that unlock public and private resources, especially at the domestic level, to reduce poverty and support local economic development.

UNCDF's financing models work through three channels: (i) Inclusive digital economies, which connects individuals, households, and small businesses with financial eco-systems that catalyse participation in the local economy, and provide tools to climb out of poverty and manage financial lives; (ii) Local development finance, which capacitates localities through fiscal decentralisation, innovative municipal finance, and structured project finance to drive local economic expansion and sustainable development; and (iii) Investment finance, which provides catalytic financial structuring, de-risking, and capital deployment to drive SDG impact and domestic resource mobilisation.

UNDP is the leading United Nations organisation fighting to end the injustice of poverty, inequality, and climate change. Working with our broad network of experts and partners in 170 countries, we help nations to build integrated, lasting solutions for people and planet. Learn more at undp.org or follow at @UNDP on social media.

UNDP and UNCDF – Joint Offering

The digital finance revolution can be harnessed to accelerate financing for the SDGs. UNDP and UNCDF are working on a service offering that catalyses an SDG-aligned governance of global digital finance platforms, helps steer national-level fintech ecosystems into greater alignment with national development priorities, and accelerates implementation of digital finance initiatives with large-scale impacts on sustainability financing.

Centre for Financial Health

The Global Centre for Financial Health is one of the pioneer initiatives acting as a convener, providing a platform to bring together global, regional and local actors committed to using financial and digital solutions to improve the financial lives of low-income families—helping them climb and stay out of poverty. The Centre creates space for thought leadership where best financial health practices and models are exchanged and lead to concrete action with governments and the private sector.

The UN Refugee Agency, UNHCR ensures that everybody has the right to seek asylum and find safe refuge, having fled violence, persecution, war or disaster at home. Since 1950, UNHCR have faced multiple crises on multiple continents, and provided vital assistance to refugees, asylum-seekers, internally displaced and stateless people, many of whom have nobody left to turn to. UNHCR help to save lives and build better futures for millions forced from home.

The Global Compact on Refugees, affirmed by the UN General Assembly, in December 2018, is a framework for more predictable and equitable responsibility-sharing, recognising that a sustainable solution to refugee situations cannot be achieved without international cooperation. It provides a blueprint for governments, international organisations, and other stakeholders to ensure that host communities get the support they need and that refugees can lead productive lives. It constitutes a unique opportunity to transform the way the world responds to refugee situations, benefiting both refugees and the communities that host them.

Its four key objectives are to: Ease the pressures on host countries; Enhance refugee self-reliance; Expand access to third-country solutions; Support conditions in countries of origin for return in safety and dignity.

The Asian Development Bank (ADB) envisions a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty in the region. Despite the region's many successes, it remains home to a large share of the world's poor: 263 million living on less than $1.90 a day and 1.1 billion on less than $3.20 a day.

ADB assists its members, and partners, by providing loans, technical assistance, grants, and equity investments to promote social and economic development.

ADB maximises the development impact of its assistance by facilitating policy dialogues, providing advisory services, and mobilising financial resources through cofinancing operations that tap official, commercial, and export credit sources. http://digital.adb.org/

The OECD is an inter-governmental organisation which brings together governments and stakeholders to discuss and propose good practices in light of emerging challenges, and promote decisions and recommendations to produce better policies for better lives. The OECD’s mission is to promote policies that improve the economic and social well-being of people around the world. https://www.oecd.org/daf/blockchain/

Technology Partners

APIX

The ASEAN Financial Innovation Network (AFIN) is an entity formed by the Monetary Authority of Singapore, International Finance Corporation, a member of the World Bank Group, and the ASEAN Bankers Association, with the objectives of supporting financial innovation and inclusion around the world.

APIX is the flagship product developed and operated by AFIN. It is a cross-border, open-architecture API platform, where financial institutions and FinTechs can integrate and test solutions via a cloud-based architecture. Through APIX, financial institutions and FinTech firms can discover one another on a curated global marketplace, design experiments collaboratively in the sandbox, and deploy innovative solutions rapidly at a lower cost.

Financial institutions (FIs) can discover vetted international FinTechs on APIX and minimise due diligence efforts in conducting proof-of-concepts. They can also work with these FinTechs to seamlessly build and test prototypes on the APIX' containerised, custom-built sandbox with APIs and synthetic data sets available on the platform.

FinTechs can build market credibility by being listed as a verified FinTech on APIX and easily connect with qualified clients. FinTechs can also have access to wider business opportunities by having access to problem statements posted by financial institutions.

By leveraging on APIX' secure sandbox, they can also rapidly demonstrate their API's value to financial institutions and minimise the time, effort and cost needed to secure a proof-of-concept project with a FI.

APIX platform offers the following:

- Global FinTech Marketplace for FinTechs and Financial Institutions to discover each other catalogue of APIs from FinTechs and FIs on the platform
- Custom-built API-enabled data sandbox for building prototypes for the following
  - Digital Currency
  - Artificial Intelligence
- Free (sponsored) computing resources of the platform
- Accelerated growth of innovation community that is focused on inclusion agenda
- An end-to-end online platform for global hackathons where hackathon organisers can have access to:
  - Hackathon administration workflow
  - On-cloud Build-a-Thon infrastructure
  - Publish demo applications
  - Automated solution submission
  - Online Judging toolkit
  - Hackathon sandbox/APIs

For over 15 years, Amazon Web Services (AWS) has been the world's most comprehensive and broadly adopted cloud offering. AWS has been continually expanding its services to support virtually any cloud workload and it now has more than 200 fully featured services from 81 Availability Zones within 25 geographic regions. To learn more about AWS, visit their website here.

Increasingly, central banks want to answer practical questions and make the technology choices involved to deliver a central bank digital currency (CBDC). To help organisations understand available technology options and see how cloud services can enable optimal solution designs, Amazon Web Services (AWS) authored a two-part whitepaper. Part one is, "Central bank digital currency: Objectives and architectural considerations," and part two is, "Central bank digital currency: Technology options and performance criteria." The report offers guidance and best practices surrounding CBDC objectives, architectural considerations, technology options, and performance criteria.

AWS is pleased to be a sole cloud platform partner in the Global CBDC Challenge, and culminate with demonstrations of solutions developed by the participants at the Singapore Fintech Festival. As a cloud platform provider in this initiative, AWS will be providing cloud platform with a variety of services (e.g. AWS Blockchain and AI/ML) hosting activities, and mobilising resources that AWS will co-market locally and internationally in support of the event.

Mastercard has pioneered technology to make payments simpler, smarter and safer.

Mastercard's global network enables advances in the payments ecosystem by leveraging technologies to create stronger bonds, and bring more people into a digital economy, while building simple and smart solutions that instill trust in every interaction.

Mastercard CBDC Test platform

To support governments as they explore and evaluate the launch of their own CBDCs, Mastercard has created an innovative testing environment, a CBDC Test platform to enable governments to simulate a local payments ecosystem in a controlled environment. The CBDC Test platform employs a modular approach that enables central banks to quickly conduct a feasibility assessment and determine the potential value to their markets.

The Test platform provides basic foundational capabilities—such as CBDC minting, distribution and monitoring—and enables the development and exploration of different CBDC use cases. The virtual platform can be individually customised to the environment in which the central bank operates, allowing them to:

- Simulate a CBDC minting, distribution, and exchange ecosystem with banks and consumers, including how a CBDC can interface with existing payment networks.
- Demonstrate how a CBDC can be used by a consumer to pay for goods and services anywhere Mastercard is accepted around the world.

- Examine various CBDC technology designs and use cases to quickly determine value and feasibility.

Use Case Scenarios

- Commercial use case definition: Identify and test use cases for P2P, P2M, G2P, and B2B scenarios.
- Interoperability: Test use cases of CBDCs riding on other rails; like card network.

Platform Technology Stack

- Account-based infrastructure: Simulate a traditional structure linked to assets held in an account.
- Technology stack: Currently leverages Mastercard's Blockchain Platform.
- Security and privacy: Configurable levels of data privacy and anonymity, and secure infrastructure provisioning.

mojaloop

The Mojaloop Foundation is a charitable, non-profit organisation that maintains open-source instant payment clearing software as a digital public good. We empower schemes to deliver inclusive, instant, and interoperable payments, with last mile customers and financial inclusion at the heart of the mission.

The Mojaloop Foundation and its open-source community is establishing a new initiative exploring advancement in digital technologies like CBDCs and its applications towards financial inclusion. Creating open and inclusive digital payment systems, serves to connect the underserved with the emerging digital economy in a safe, sustainable, and affordable manner.

This initiative will address pain points such as; limited direct access to domestic payment clearing and settlement services, inefficient cross-border payment and settlement processes.

The scope of this project includes the following focus areas:

- Domestic Clearing with Settlement in CBDC – Access to domestic payment systems is limited to entities that have access to settlement facilities with the central bank.
- Domestic issuing and clearing of CBDC – Extend Mojaloop as a system of record for issuance of an account-based, wholesale CBDC.
- Examine various CBDC technology designs and use cases to quickly determine value and feasibility.
- Cross border payments pilot – Currently, cross-border payments involve multiple intermediaries, which is expensive and time-consuming. This pilot will test the use of a wholesale CBDC between a pair of emerging economies, to facilitate easy and open access for participants on the network, including currency issuers, third-party platforms and their users.
- Financial inclusion workshops and hackathons – Unbanked communities run the risk of being excluded from the digital economy as digital payments come to replace cash. In addition to a global hackathon, a series of workshops will be held regarding development strategies for developing payments infrastructure, and regulatory policy approaches for payment services and CBDCs.
- CBDC Toolkit – Develop a set of resources that will serve as a starting point for launching CBDC initiatives.

CBDC technology will need to ensure it is inclusive, and consider the needs of rural users without smartphones, or internet connectivity. For this reason, interoperability with existing financial service providers connected to instant payment rails will be vital. For the hackathon, Mojaloop provided a simulated "model village" of MFIs and end customers to allow participants to simulate transferring money into existing micro-finance and mobile money accounts held by last mile customers.

Hyperledger Foundation was founded in 2015 to bring transparency and efficiency to the enterprise market by fostering a thriving ecosystem around open source blockchain software technologies. As a project of the Linux Foundation, Hyperledger Foundation coordinates a community of member and non member organisations, individual contributors and software developers building enterprise-grade platforms, libraries, tools and solutions for multi-party systems using blockchain, distributed ledger, and related technologies. To learn more, visit: https://www.hyperledger.org/.

Hyperledger Foundation's open-source community is helping central banks explore this exciting use case to bring about innovation in digital money, and financial inclusion. The Hyperledger Capital Markets SIG (CM-SIG), has been hosting conversations around the design, requirements, and implementations of CBDCs. Hyperledger continues to be a home for the advancement of CBDCs via the vibrant community, and vendor-neutral home for the technology and open collaboration. Some of the recent CBDC developments announced include:

The National Bank of Cambodia's Project Bakong, built with Hyperledger Iroha, was recognised by PwC in their [Global CBDC Index as #2 Retail CBDC globally and #1 in Asia]. Implemented by Soramitsu, this is the [first large-scale] blockchain-based, central bank-run interbank payment system in production. The blockchain-based retail interbank payment system, [reached 200,000 users in June 2021], amassing 1.4M transactions at a value of $500M. Read more: [Hyperledger Case Study]. The Central Bank of Nigeria plans to [launch "Project GIANT"] to pilot its e-Naira CBDC and chose Hyperledger Fabric. Learn more: [white paper].

- The Eastern Caribbean Central Bank (ECCB) stated that it chose to pilot its retail CBDC, ["DCash," on Hyperledger Fabric] because of its strong security architecture and open-source code. Hear lessons learned [at a presentation] to the Hyperledger CM-SIG and a [previous session on design].
- [Project Inthanon-LionRock] led by the BIS Innovation Hub and several central banks, has implemented Hyperledger Besu to demonstrate the completion of an international exchange of multiple CBDCs in seconds versus days. This could reduce costs by up to half and is part of the [mCBDC Bridge project] Phase 2 and 3.
- Fnality [is using Hyperledger Besu] for a wholesale payments system [representing USD, euro, JPY, GBP and CAD] that will allow wholesale banking transactions to happen instantly, cross-border, and 24/7. [Learn more from this presentation] to the Hyperledger CM-SIG.

[Hyperledger Besu] is an Ethereum client designed to be enterprise-friendly for public/private permissioned use cases. Its comprehensive permissioning schemes are designed for use in a consortium environment.

[Hyperledger Fabric] is intended as a foundation for developing applications or solutions with a modular architecture. Its approach to consensus enables performance at scale while preserving privacy.

[Hyperledger Iroha] is designed to be simple to incorporate into infrastructural or IoT DLT projects and features a domain-driven C++ design and crash fault tolerant consensus algorithm.

PARTIOR

Partior is designed to serve the next generation of global payments and currencies, and transform traditional cross-border payments infrastructure by leveraging blockchain technology. The firm has developed wholesale payments rails based on M1 digitised commercial bank money to enable instantaneous clearing and settlement for cross-border payments.

The Partior Sandbox provides an infrastructure hosting solution to Central Bank Digital Currencies (M0) and Commercial Bank Currencies (M1), highlighting cross-issuer and FX conversion capabilities. It provides a readily available environment for central banks, commercial banks, FinTechs, and other partners to build, test, collaborate and evaluate use cases for both Wholesale and Retail CBDCs.

The Hackathon finalists were granted access to the Partior Sandbox environment for rapid prototyping of the digital currencies solution for following use cases:

- Interoperability: Test use case for Wholesale and Retail CBDCs covering B2B, C2B, and B2C scenarios.
- Privacy solution via Tessera – safeguarding of personal data and consumer transaction while being able to monitor and guard against bad actors.

The Partior CBDC Sandbox simulates a network of 4 CBDC issuers, allowing participants to connect through APIs for CBDC wallet creation and CBDC transactions. Participants can leverage on the network for same-issuer and cross-issuer CBDC transaction experience with built-in privacy features.

r3.

R3 is a leading provider of enterprise technology and services for the development of multi-party solutions that enable direct, digital collaboration in regulated industries where trust is critical. R3 provides distributed ledger and confidential computing platforms, capabilities, and services for the development and scaling of multi-party applications and ecosystem solutions.

With its roots as a bank consortium, R3 has deep expertise working with government entities, regulators, central banks and private sector institutions to build product offerings that meet the needs of the highly regulated industries they operate in.

In 2020, R3 convened a CBDC Working Group comprised of 35 central banks, leading global supervisory organisations, major consultancies, software firms, as well as the world's leading commercial banks to focus on the technology, policy and impact of digital currencies issued by a central bank.

The CBDC Working Group comprises the likes of the Bank for International Settlements, the World Bank, the International Monetary Fund, and has published its research and findings to ignite a wider conversation around the potential features, use cases and strategies for implementing and engaging with digital currency. More information about R3's research is available here: https://www.r3.com/cbdc-research/

In addition, Corda, R3's flagship DLT platform has been used by central banks across the world for CBDC experimentation. Select projects include:

- [Jasper] by Bank of Canada
- [Ubin] by Monetary Authority of Singapore
- Inthanon [Phase 1] and [Phase 2] by Bank of Thailand
- [Inthanon-Lionrock] by Bank of Thailand and Hong Kong Monetary Authority
- [Helvetia] by the Bank for International Settlements
- [E-Krona] by Riksbank
- [Jura] by Banque De France and Swiss National Bank

As the leading provider of multi-party technology for regulated markets, R3 has developed the R3 sandbox for Digital Currencies—the only platform that combines distributed ledger technology (DLT), guided learning paths from industry experts, and a ready-made global payments network in a single environment to enable the issuance, management and distribution of CBDCs. More information about the R3 sandbox for Digital Currencies can be found here: https://www.r3.com/digital-currency-sandbox/

R3's Sandbox for Digital Currencies is a completely hosted solution for a wholesale and retail CBDC systems built on Corda Enterprise v4.7. Using a token-based, two-tier model, we have designed an application to manage the lifecycle of a token.

This includes the ability to pledge, issue, redeem, and destroy the token, and also send bilateral transfers between financial institutions and its customers. R3's APIs also allow for retail users to initiate payments to accounts across different financial institutions, make QR code-based payments, check account balances, and view their transaction logs.

R3 also has a Venture Development programme dedicated to accelerating and cultivating Corda Dapps built by early-stage startups.

R3 offers a variety of resources to support every stage of the blockchain journey, including R3 Technical consultancy support to finetune any CBDC use case, mentorship from R3's global network of 200+ industry experts and investors, events and workshops hosted by industry leaders and much more. Find more information about the R3 Venture Development programme here.

APPENDIX

Masterclasses

Under the acceleration phase of the challenge, finalists participated in masterclasses delivered by subject matter expects across different disciplines. The masterclasses covered topics related to the development of a robust retail CBDC, allowing finalists to tap onto fresh perspectives and insights to enrich their final solutions. Finalists also participated in private roundtable discussions with the industry experts.

This section highlights some of the insights from the masterclasses delivered by the subject matter experts.

1. Retail CBDCs: Global Landscape

Speaker: Dr. Raphael Auer, Principal Economist, Innovation and the Digital Economy, Bank for International Settlements

CBDC development efforts have stepped into the limelight. This masterclass presented CBDC architectures, took stock of the various approaches pursued around the globe, and presented the lessons learnt thus far. The session described how the range of designs is shaped by central banks' policy goals, and the implications for the financial system and central bank of the future.

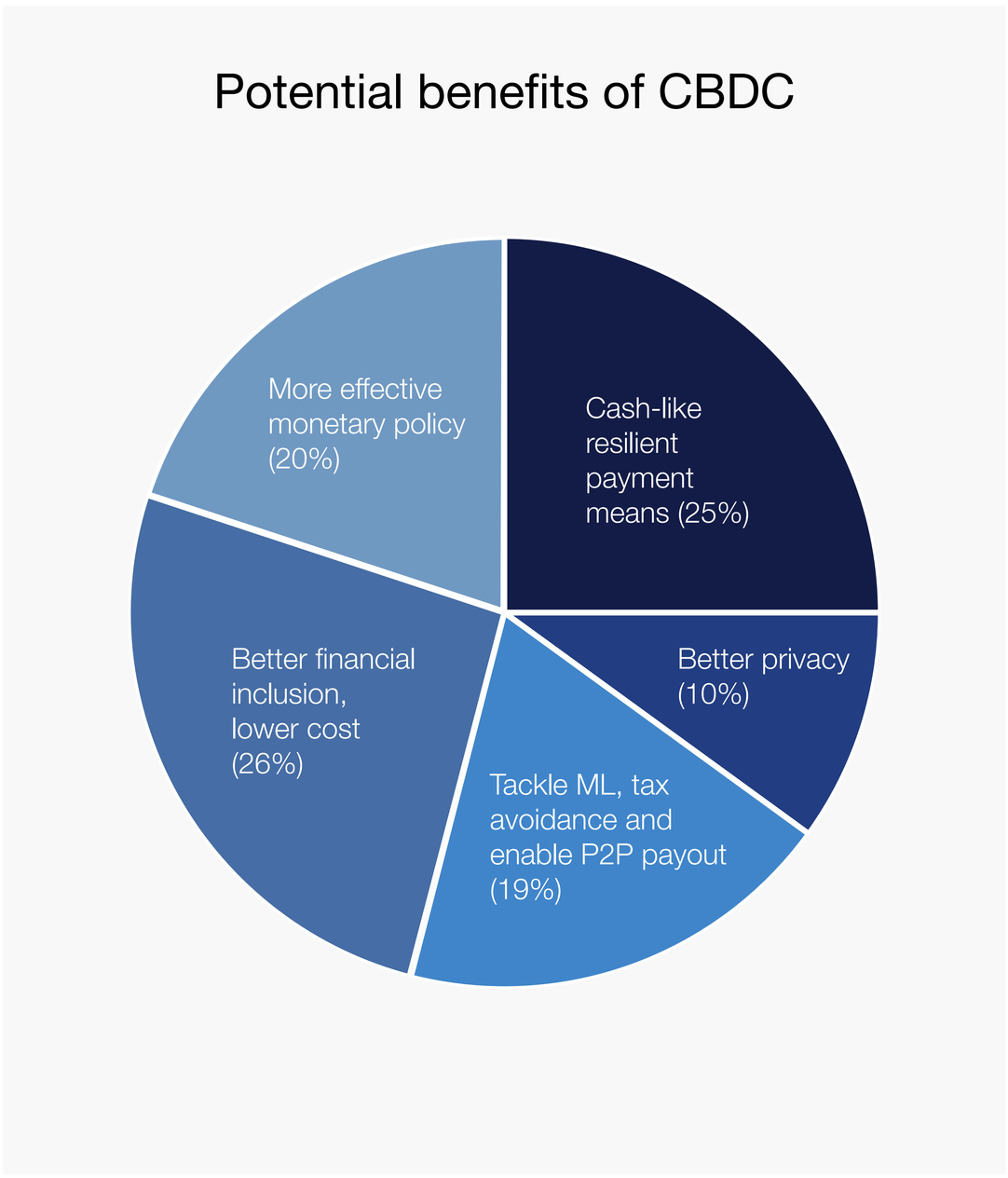
Research shows CBDC speeches have seen a change from a net negative, to a net positive stance towards adopting CBDCs, which indirectly explain central banks' increased focus on experimental CBDC related projects. CBDC design efforts are intensifying, and issuance is imminent, if not already live in some economies.

There are different approaches to design undertaken across countries. Current CBDC implementations and alternatives can be grouped into four different models.

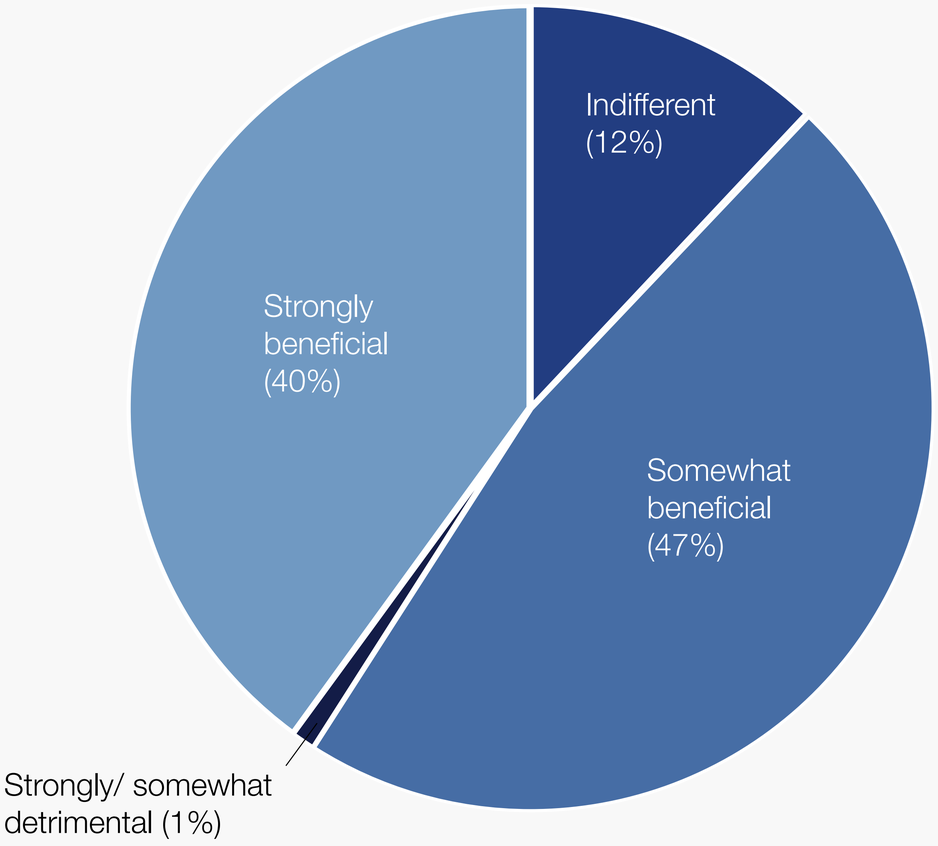
- Direct CBDC model – relies heavily on the central bank to provide the infrastructure, claims to the CBDC, and accounts.
- Intermediated CBDC – relies heavily on the payment service provider/commercial banks to be the interface with the consumers.
- Hybrid CBDC – allows for a balance of responsibility for the ecosystem, in which the central bank provides a backup infrastructure.
- Indirect approach – an alternative to issuing CBDCs, are payment accounts that are fully backed by the central bank.

CBDCs could simplify the monetary architecture and substantially streamline the cross-border payment chain. For instance, Project Dunbar, led by BIS examined multi-CBDC arrangements, running on a single platform, to facilitate cross-border payments.

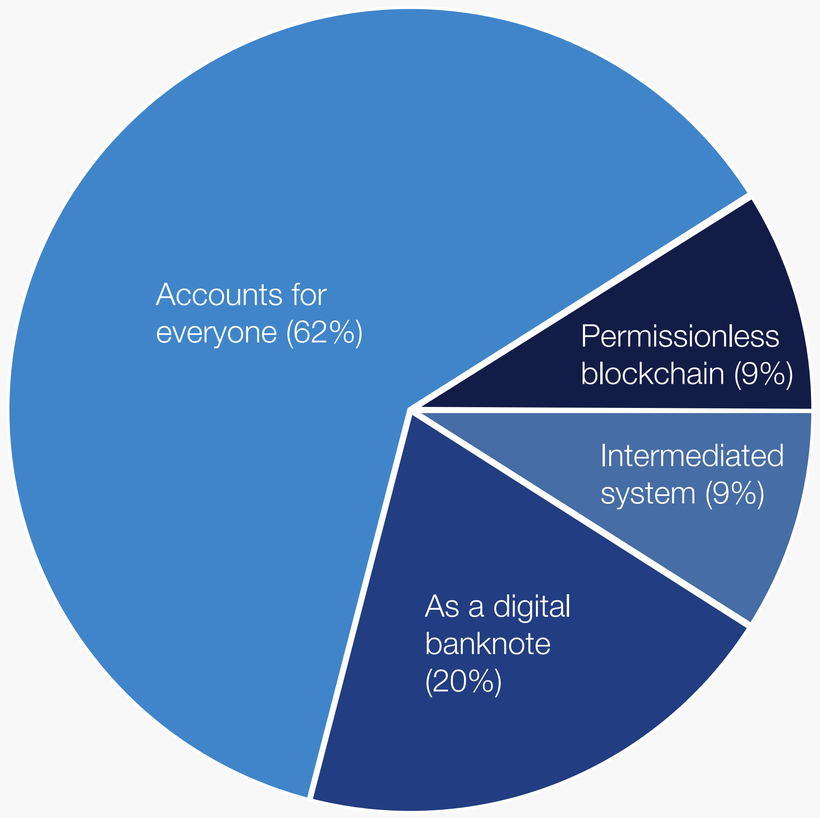
This masterclass also included a survey, the responses of which are shown below.



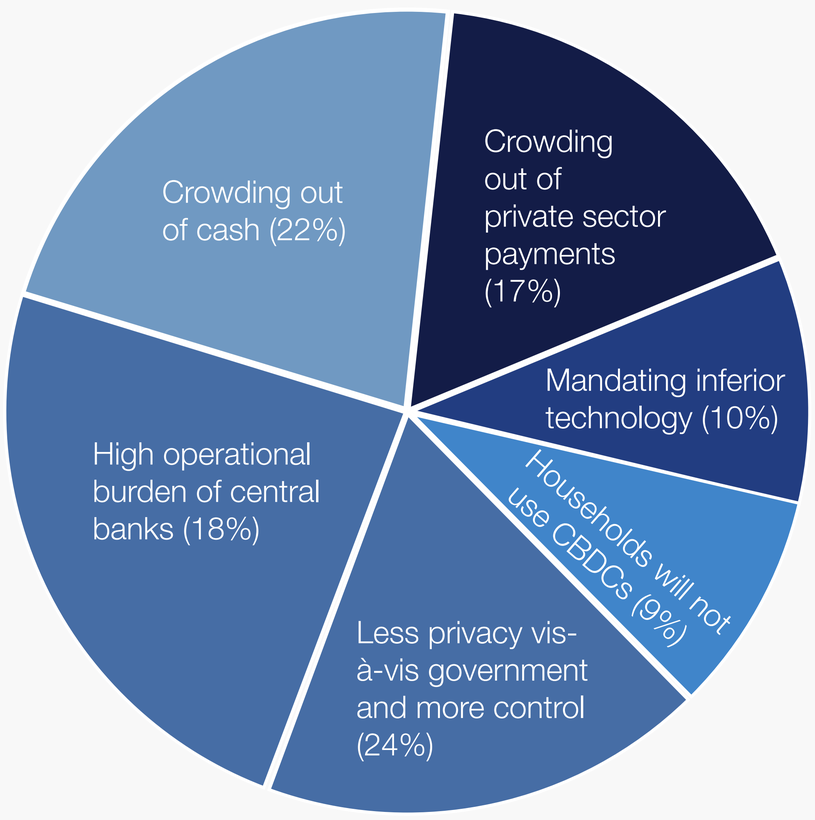
For society as a whole, issuance of a CBDC would be:



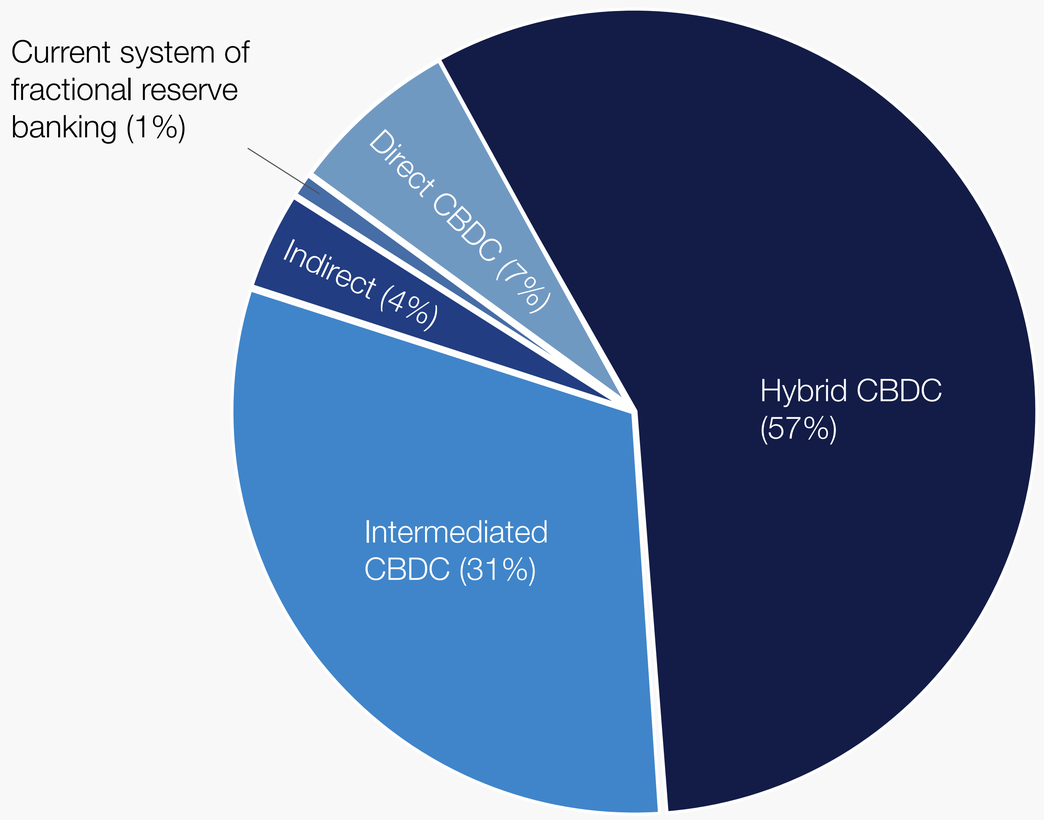
How should CBDC be designed?



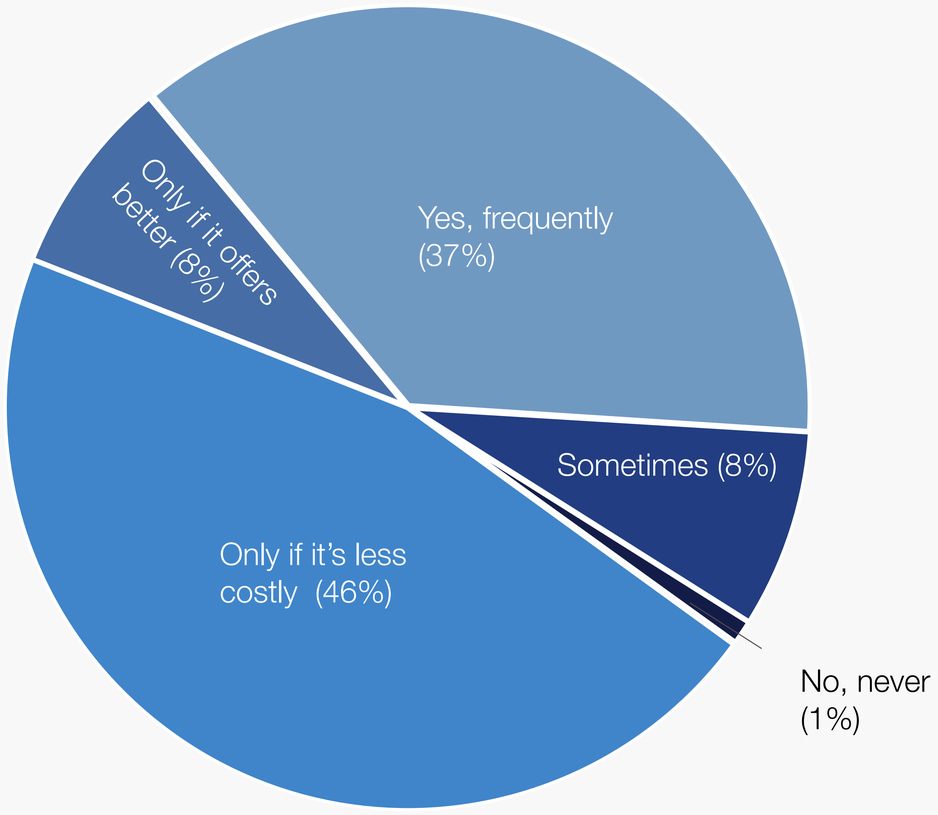
The potential downsides of CBDC issuance includes:



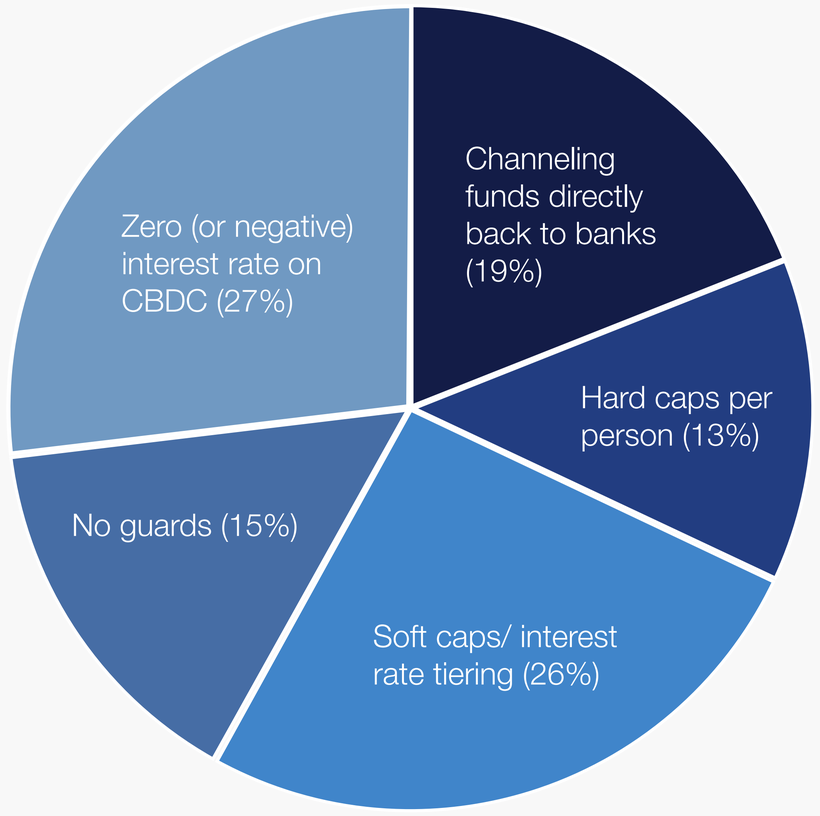
What is your preferred architecture?



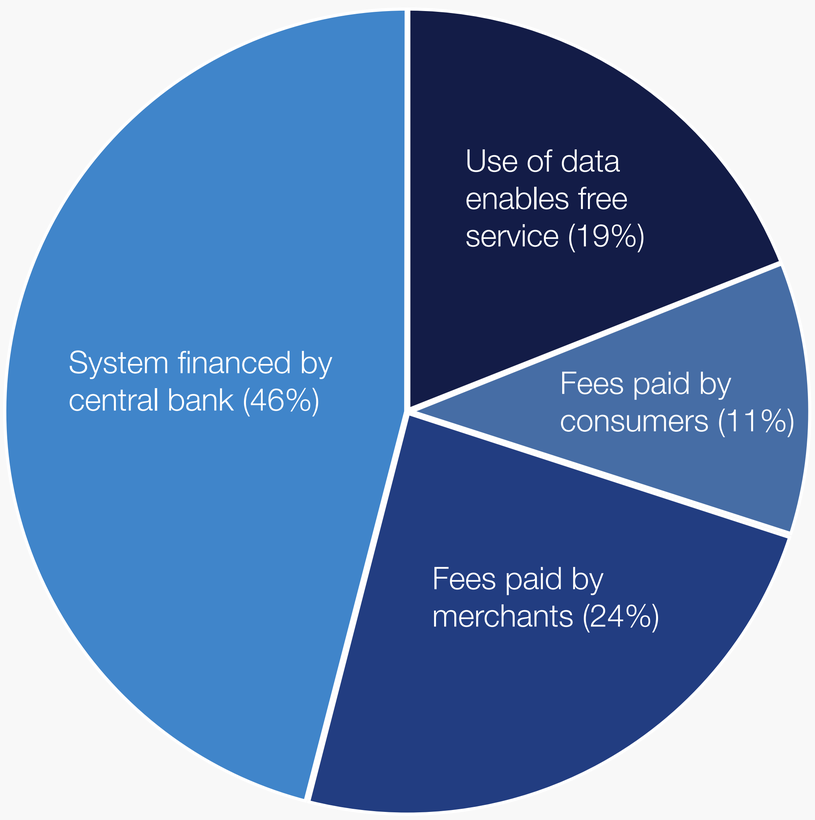
Would you use CBDC for everyday payments?



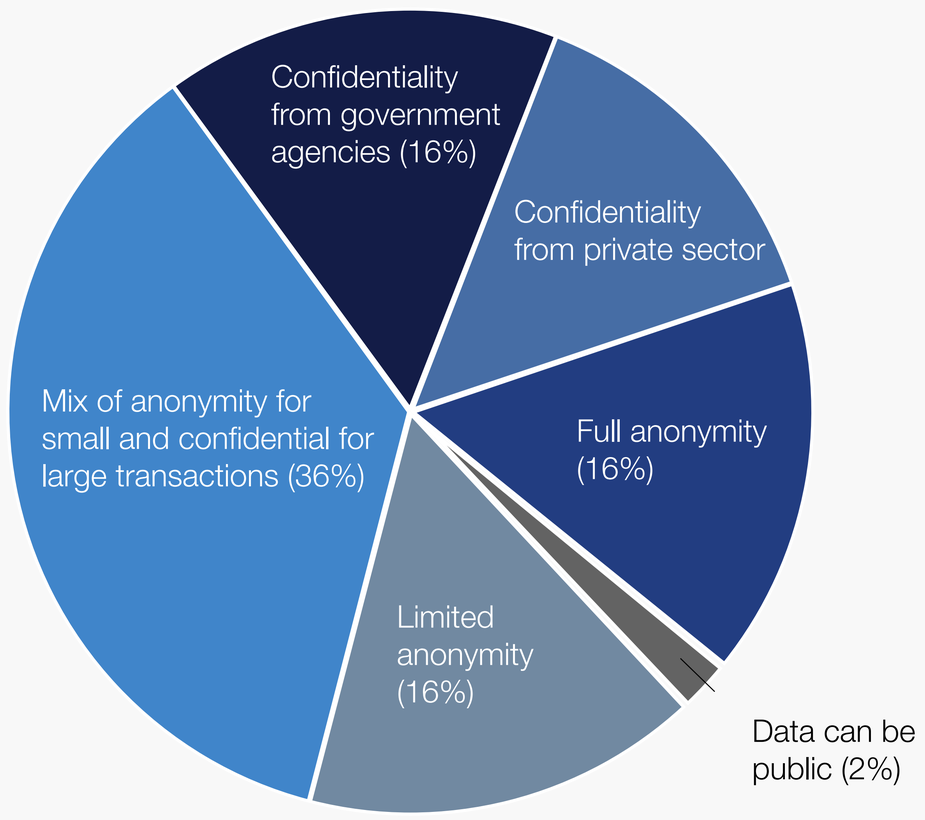
What should be the guards against disintermediation of banks?



What should be the cost recover/ business model for PSPs?



What is your preferred privacy/ data arrangements?



2. Interoperability and Co-existence of Retail CBDCs with the Existing Payments Ecosystems

Speaker: Harish Natarajan, Lead, Payment Systems Development Group, World Bank

CBDC-based payment services need to be interoperable with existing payment services for them to gain traction. This has implications for both CBDC design and other components of the national payments system (NPS). Some ramifications include the user interface design, payment system interfaces, system rules and procedures, and clearing and settlement arrangements. The Masterclass covered the importance of interoperability and what it will take to integrate seamlessly into NPS today.

Interoperability exists at different levels. In the context of CBDCs, it can be interpreted from the following perspectives:

End users – How can CBDCs be moved across banks and non-banks, like payment service providers? Can transactions be performed even if one of the counterparts does not have access to CBDC, connectivity, or is in a different jurisdiction?

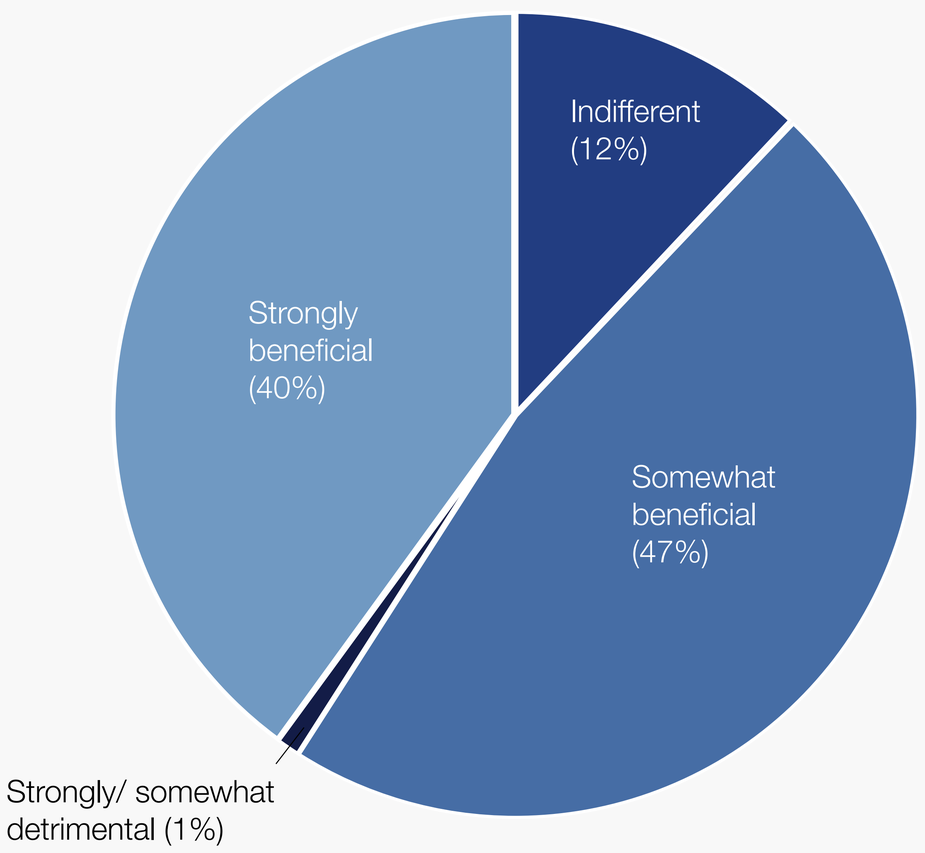
CBDC Platforms – The architecture of CBDC-based platforms need to cater to different participants (Banks & Non-Banks). It also needs to consider the different roles (e.g., Issuers, third party providers, etc) and integrate them into the existing payments infrastructure.

Other systems – Enabling 24/7 access to CBDCs would require systems that enable liquidity in CBDCs including liquidity facilities to convert regular currency holdings to CBDCs and vice versa; and interlink with other clearing and settlements infrastructures with Fiat and vice versa.

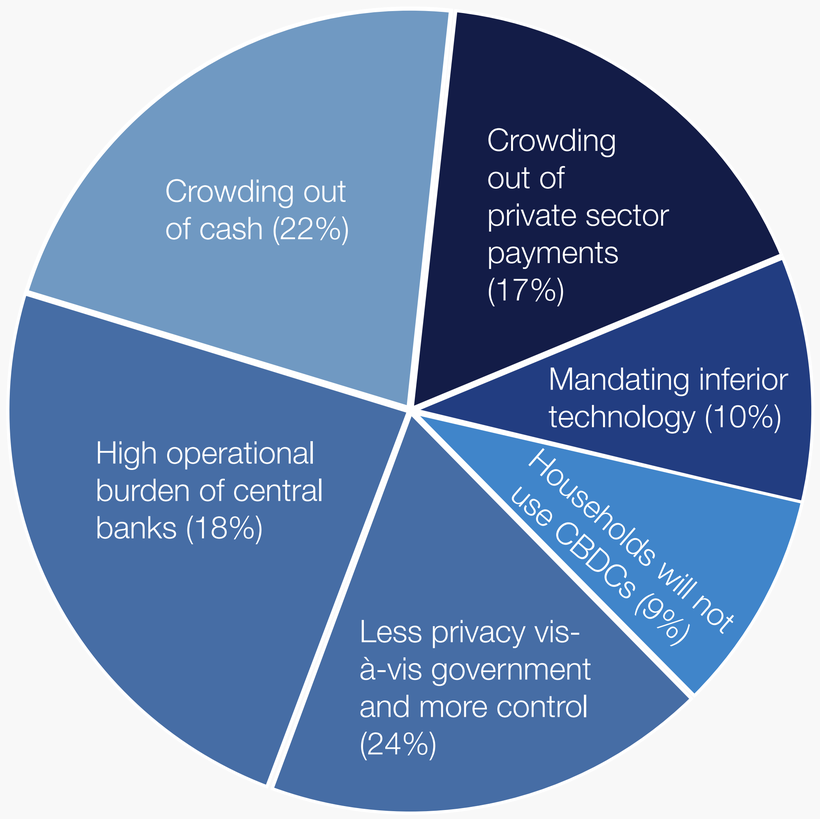
Interoperability is not just a technological consideration. It is important to consider interoperability also in the context of existing business rules and schemes as well.

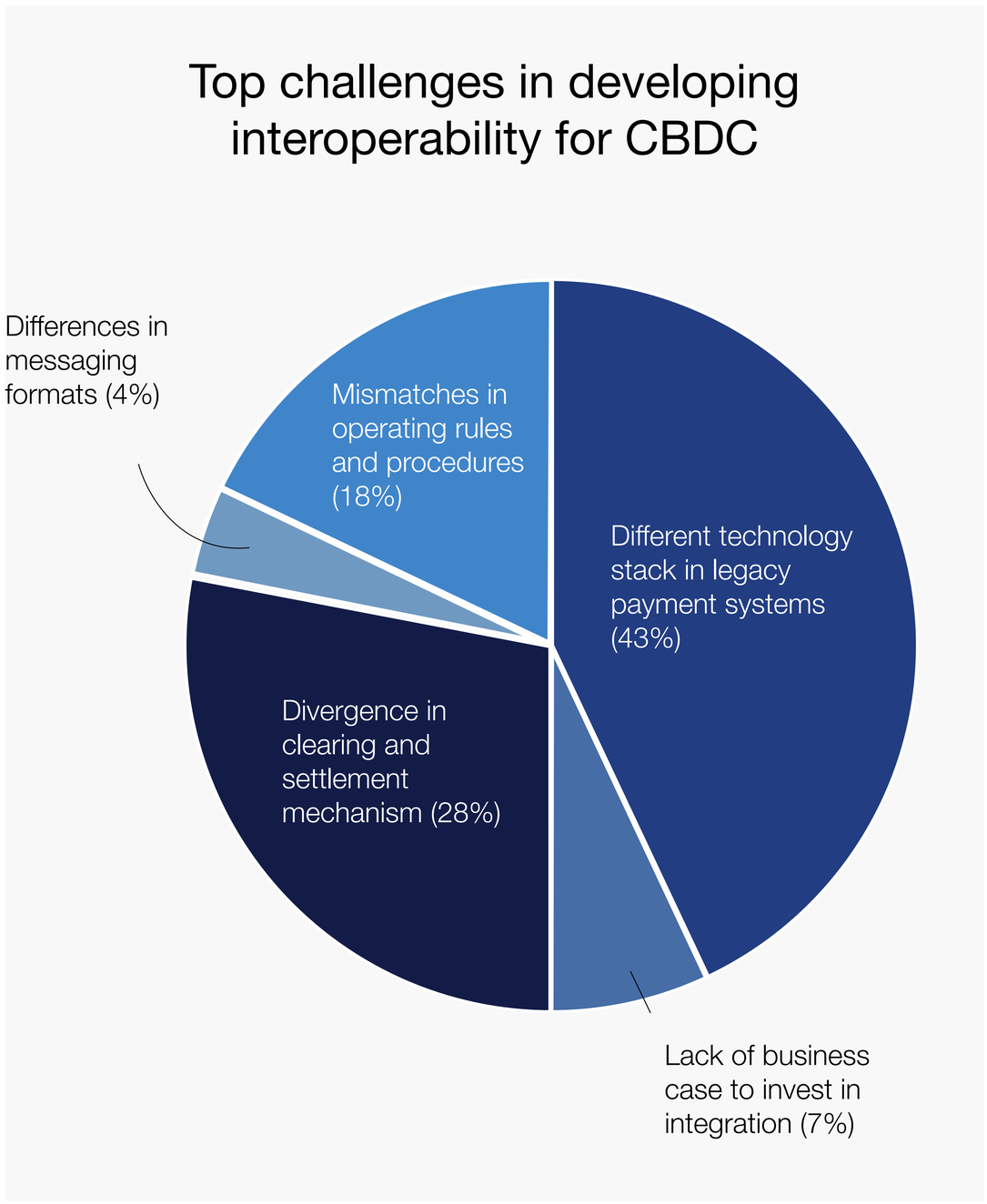
The audience was polled on three critical perspectives on interoperability which are presented below.

For society as a whole, issuance of a CBDC would be:



The potential downsides of CBDC issuance includes:





3. Financial Health & Inclusion

Speakers: Aiaze Mitha, Lead, UNDP/UNCDF Joint Digital Finance Program and Jaspreet Singh, Global Lead, Financial Health and Innovations, UNCDF

FinTech players are increasingly supporting a world that is sociologically, economically, and environmentally fairer, through the achievement of sustainable development goals.

This session provided an update on the current state of financial inclusion and introduced financial health as a broader concept that should be considered in designing retail CBDC systems.

Research has shown that countries with advanced technology infrastructures enable greater financial inclusion. However, the percentage of people who are financially healthy remains low. The Covid-19 pandemic has exposed this contrast, as much of the global population have been challenged to sustain themselves financially in the face of reduced incomes. The focus on financial inclusion has to a large extent, helped the payment system to grow. But efforts will need to go beyond payments to work on better assisting the population to build their financial health.

Focusing too much on financial inclusion is limiting, and poses a risk of providing access and usage to financial products and services, without addressing the underlying barriers to financial security, control, and freedom. The speakers for this session advocated that instead of thinking “What can my financial service or product unlock?”, innovators should instead reframe their thinking and ask “What does it take to be financially secure and free?”, or “Is my innovation or service transforming the financial lives of individuals, households and communities?”

The session also discussed the potential benefits of CBDCs in terms of inclusion, financial health, and other sustainable development goals as well as the risks, particularly in developing economies of adopting CBDC.

The introduction of CBDCs and related technologies will impact "last mile" users such as the unbanked, the non-banks, and people who lack digital literacy. The session discussed some of the design considerations and approaches that might mitigate the risks, and overcome the challenges of adoption.

- Inclusion by design
- Token-based or account-based, what you have vs who you really are.
- Custodial or non-custodial
- Payment methods, online/offline payments, QR codes etc,
- Tiered KYC, with some level of anonymity
- Transactions and account sizes limits

- Distribution
  - Re-using existing intermediaries and acceptance network
- Programmability
  - Driving monetary and fiscal policies through CBDC. E.g., inactive currency, general purpose versus programmed use

4. AML/CFT risks and implications of Retail CBDCs

Speaker: Radish Singh, Partner, Financial Crime Compliance Leader, Deloitte Southeast Asia

A retail CBDC built for next-generation financial payment platforms will broaden, and accelerate financial digitalisation, transforming a country's economy. Whilst there are gains to financial technology, potential Anti-Money Laundering/ Countering Financing of Terrorism ("AML/CFT") risks need to be considered.

If left unaddressed, this could potentially weaken a country's financial system's integrity as terrorists and criminals seek to exploit vulnerabilities in this age of digital anonymity.

The standard AML/CFT framework is still applicable when looking at CBDCs. Additionally, CBDCs can improve compliance with AML/CFT rules and provide greater oversights over money laundering and terrorist funding risks.

In this regard, the session introduced four key AML/CFT focus areas to note when designing and implementing CBDCs:

- Governance and Oversight
  - Establish clear roles and responsibilities with clear segregations on the role each party should play in managing ML/TF risks
  - Timely performance of Enterprise Wide Risk Assessment (EWRA) for identification of inherent ML/TF risks and apply appropriate risk mitigation measures
- Customer Due Diligence
  - Use facial-recognition and other artificial intelligence technologies for KYC purposes
  - Employ traditional KYC procedures and meet standards defined by FATF
  - Hold entities offering transfer, storage or custody of CBDC to equivalent regulatory standards as to firms offering similar services for cash or existing digital money
- Transaction Monitoring
  - Integrate or replace existing AML systems based on the design and implementation of CBDC
  - Uncover new typologies by integrating technologies such as artificial intelligence and machine learning
- Terrorism Financing, Proliferation Financing and Sanctions
  - Manage any circumventions in sanctions requirements by coordinating central banks of different countries and other public authorities
  - Design CBDCs to prevent transactions from wallets sanctioned by the central bank's nation
  - Allow issuer to limit anonymous peer-to-peer transactions or set a threshold to the transaction amount for anonymous transactions

The design features of a CBDC can either limit, or expand on the anonymity of CBDCs. Opting for either an account or token-based design can materially impact identity requirements, leading to potentially lower/higher risks in facilitating money laundering.

CBDC can potentially reduce the existing compliance burden faced by Financial Institutions with its inherent traceability and accountability capabilities. With the added integration of existing AML/CFT regulation, the use of CBDC can potentially aid in providing regulators with a more comprehensive

framework in monitoring transactions and identifying suspicious activities.

5. Legal aspects of Retail CBDCs

Speaker: Simon Gleeson, Partner, Clifford Chance

The way in which CBDCs can be used is largely determined by legal rules regarding the provision of money and payment services. This session examined the existing structures for banking and money services, illustrated the way in which existing laws regulate the provision of these services, considered the ways in which CBDCs may substitute or supplement these services, and considered the use cases for CBDCs and the extent to which CBDCs may be a straightforward substitute for money in everyday transactions.

Like their fiat counterparts, CBDCs serve as a unit of account, medium of exchange, and a store of value, and are issued and fully backed by a central bank. When creating a retail CBDC, the considerations will be on how it can be retained onshore legally, and how to keep it to a relatively small amount.

The way the economy works today is that central banks provide money to commercial banks, and commercial banks provide money to the real economy. Real economy participants settle their debts in commercial bank money, and commercial banks settle their debts in central bank money. This results in commercial banks holding deposits, which are lent out to provide credit to the real economy. CBDCs create the possibility for the real economy to settle its debts directly in central bank money. This bypasses the commercial banks, and means that commercial banks will no longer hold the funds to finance their provision of credit.

Thus, one of the big design challenges of a CBDC is as to how the central bank and commercial banks interact in order to preserve the supply of credit to the real economy.

The other major issue is how service providers will serve customers. There are three possible models. In commercial bank money, commercial banks own the customer deposit, the customer only has a money claim on the bank, and the bank can use the money deposited as it wishes.

Consequently, the commercial bank pays interest to the customer. In the securities world, commercial banks act as custodians - the customer owns the securities, the custodian derives no benefit from holding them, and therefore the customer has to pay the custodian for the service. In the CBDC world, wallet providers will provide custody service to hold the CBDC, but the customer owns the CBDC, so which of the two models above would apply to a CBDC? And how would the remuneration work? These are questions that require more consideration.

6. The Implications of Retail CBDCs for Monetary Policy

Speaker: Professor David Lee, Singapore University of Social Sciences (SUSS)

This masterclass focused on programmable monetary policy and retail CBDCs. While large economies rely more on interest rate policy, smaller economies rely on exchange rate policy with sterilisation.

Financial hubs such as Singapore and Hong Kong have substantial foreign reserves to maintain trust in the soundness of its monetary policy and economic system.

Different retail CBDC designs may have implications for the relevance of local currencies, financial inclusion agenda, and liquidity for trade purposes. While building foreign reserves in some emerging markets, such as Cambodia, there may be other

considerations such as de-dollarisation, lowering of remittance charges, and corporate inclusion for economic growth. After the Asian Financial Crisis in 1997, the speed of change of debt denominated in foreign currency, and withdrawal of foreign capital are also significant considerations for monetary policy.

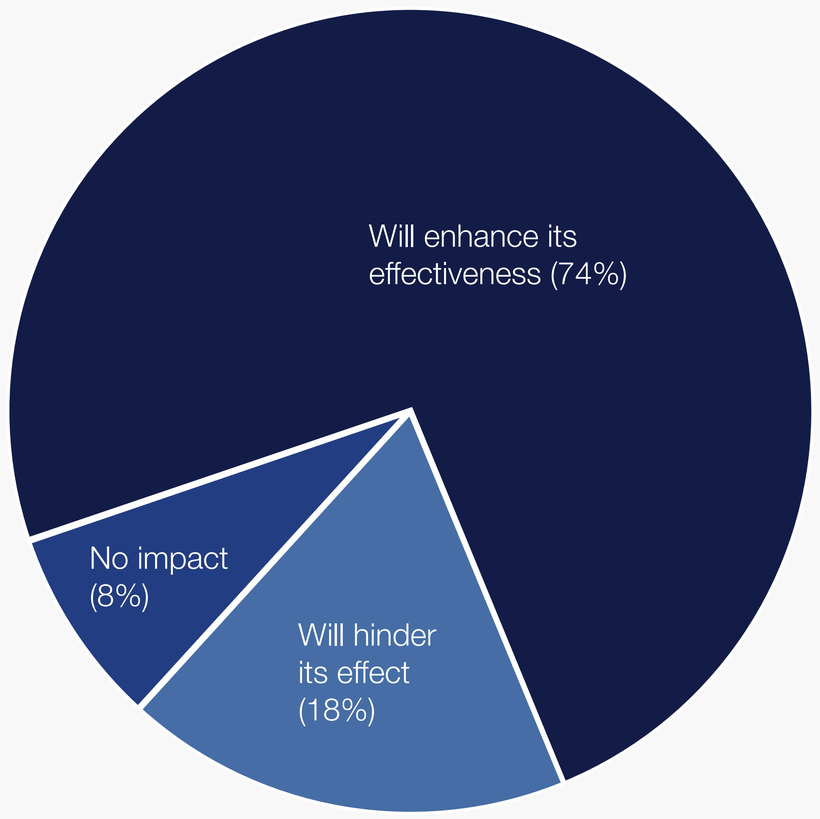
One such example is a retail CBDC with symmetric, asymmetric, or no interest rate, with an expiry date that resembles a bond. This has unknown, yet exciting implications. Innovative designs could give a discretionary programmable monetary policy to perform new and influential roles, contrary to the precise prediction of recent macroeconomic theories. This masterclass explored and questioned innovative retail CBDC designs of interest to Asian policymakers, and their implications for programmable monetary policies.

Singapore's small-sized economy, and high degree of openness to trade and capital flows, has adopted the use of the exchange rate rather than interest rate as the instrument of monetary policy. Developing economies and Asian countries are susceptible to rapid flows of capital and are vulnerable to currency and debt crises. Thus, considerations for CBDC design may not be generalisable from developed markets.

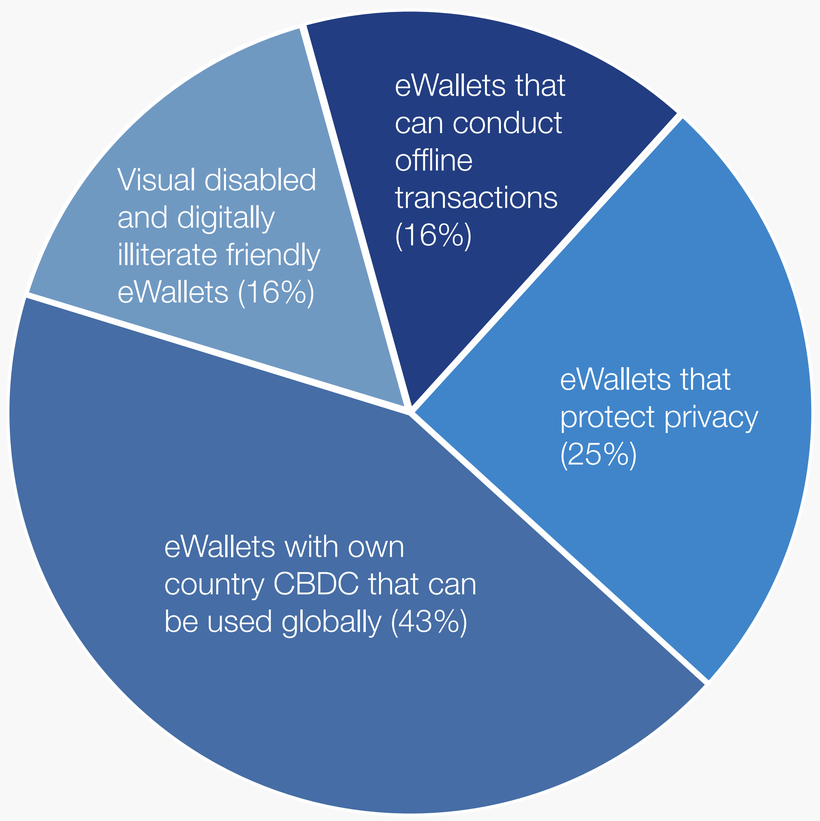
Areas of focus suggested by Professor David Lee when considering retail CBDCs from the perspective of Singapore:

- Slight interest rates differentials can lead to large and rapid movement of capital with its large offshore banking sector dealing mainly with G3 (USD, EUR and JPY) currencies.
- Transmission of exchange rates
- Singapore Dollar Nominal Effective Exchange Rate (NEER)
- Structural factors for Singapore exchange-rate based monetary policy. (e.g., High saving rates, credibility of effective and pre-emptive policy decisions)
- Payment and settlement landscape of Singapore
- Interest-paying CBDC potentially affect the conventional monetary policy on the incidence of banking panics and economic welfare
- Anticipate the exponential growth in the metaverse and Web3 in mind

How will rCBDC affect monetary policy?



Which do you favour the most for rCBDC?



About Tribe

Tribe is Singapore's first government-supported platform in driving neutrality, collaboration, and growth of the deep tech ecosystem. At its core, Tribe aims to develop and transform the deep tech ecosystem by bridging the existing gaps in tech solutions, talent, and education. Tribe works closely with global corporations, government agencies, top-tier blockchain companies, and late-stage startups to build a community that promotes collaborations and strives to power the next wave of ideas and talent in the deep tech ecosystem.