Connecting digital islands

Swift CBDC sandbox project

Results report
March 2023

Swift

Contents

The background

We've developed an important new interlinking CBDC solution capable of connecting CBDC networks and existing payment systems for cross-border transactions.

There's a drive towards CBDCs around the world, but fragmentation is a risk

Interest in Central Bank Digital Currencies (CBDCs) is gaining momentum globally: over 110 countries around the world are now exploring digital currencies according to the Atlantic Council; and a recent survey by the OMFIF Digital Monetary Institute found that 24% of central banks will be ready to go live with a digital currency in the next 1-2 years.

But there's a great deal of variation in how countries are approaching digital currencies. Central banks are looking to use this new type of money to solve different economic and social challenges, and are employing a wide variety of technologies, standards and protocols in their implementations. This could lead to continued fragmentation, which if not tackled at the global level, leads to a risk that businesses and consumers won't be able to exchange CBDCs across borders, and the benefits of new technologies not being realised.

In 2022, Swift demonstrated it can interlink the world's CBDCs and payment systems

As part of our strategy to deliver instant and frictionless cross-border transactions, we have been investigating the role we can play in the global CBDC ecosystem for some time. In 2021, we published a white paper revealing the results of our first round of experiments, which demonstrated how we could enable interoperability between CBDC and non-CBDC payment networks using existing messaging and banking structures.

Our 2022 experiments went much further, as we demonstrated an important new interlinking CBDC solution capable of connecting CBDC networks and existing payment systems for cross-border transactions. Using a simulation of our enhanced platform and an experimental connector, we demonstrated that we could interlink CBDC networks together at the technical level – thereby enabling the multi-CBDC Model 2 outlined by the Bank for International Settlements (BIS).

The sandbox testing confirmed the value of our CBDC interlinking solution for central and commercial banks.

In this project, we deployed our CBDC solution into a sandbox[1] for collaborative testing

Following the success of our 2022 experiments, we deployed our solution into a sandbox to undergo further testing by 18 central and commercial banks – including the Banque de France, the Deutsche Bundesbank, the Monetary Authority of Singapore, BNP Paribas, HSBC, Intesa Sanpaolo, NatWest, the Royal Bank of Canada, SMBC, Société Générale, Standard Chartered, and UBS. The participants were given access to the sandbox over a 12-week period where they were able to test, assess and provide feedback on our experimental solution.

Hosted by Kaleido, a blockchain and digital assets platform, the sandbox used two blockchain networks – Quorum and Corda – as well as a simulated RTGS network and was also capable of accommodating both wholesale and retail CBDC use cases. Participants were able to test transaction flows between the three simulated networks, with the findings discussed among the group in fortnightly collaboration sessions. During testing, participants sent 183 payments in the sandbox environment, with 4,736 transactions processed in total including test instance payments.

The sandbox testing proved successful

The results of the sandbox testing indicated the potential and value of our CBDC interlinking solution for central and commercial banks. It demonstrated that the solution supports interoperability between CBDCs and enables them to be used in simulated cross-border payments. Swift was able to confirm its initial assumptions about CBDC technology, implementation and transaction flows, with participants providing insights on everything from access models and intermediary roles to CBDC flows and atomic settlement.

The feedback we received from the banks was very positive. Participants saw clear potential and value in Swift's plans to continue developing its interlinking solution – and they also welcomed the opportunity to exchange knowledge with each other about factors to consider in CBDC design and implementations. Many of the sandbox participants are keen to continue this collaboration with Swift – and we're committed to driving further innovation in this space.

Swift will now develop a beta version of our interlinking solution

Following the success of the sandbox testing, we will now develop a beta version of our interlinking solution that we will use for further testing by central banks. In parallel, we will run a second phase of the CBDC sandbox, focusing on new use cases and implementing additional functionalities based on the feedback received from this project. Ultimately, our aim is to deliver a production-ready solution that's capable of supporting instant and frictionless cross-border payments using CBDCs.

Read on to learn more about Swift's collaborative sandbox project, including the detailed results, insights and findings from our testing, and our plans for the future.

[1] *Throughout this report, the sandbox is described as a technical sandbox, rather than a regulatory sandbox.*

24% of central banks expect to introduce a CBDC within the next 1-2 years

CBDCs: Gathering momentum

Interest in Central Bank Digital Currencies (CBDCs) has grown exponentially in recent years, with over 110 countries now exploring a digital currency, according to the latest Atlantic Council tracker. To date, 11 countries have fully launched a CBDC, and others are in advanced phases of their developments. According to the 2022 OMFIF Digital Monetary Institute Future of Payments survey, 24% of central banks expect to introduce a CBDC within the next 1-2 years. Recent developments, such as the digital pound consultation launched in the UK, and the Bank of Japan's decision to move to a CBDC pilot, point towards an intensification of activity globally.

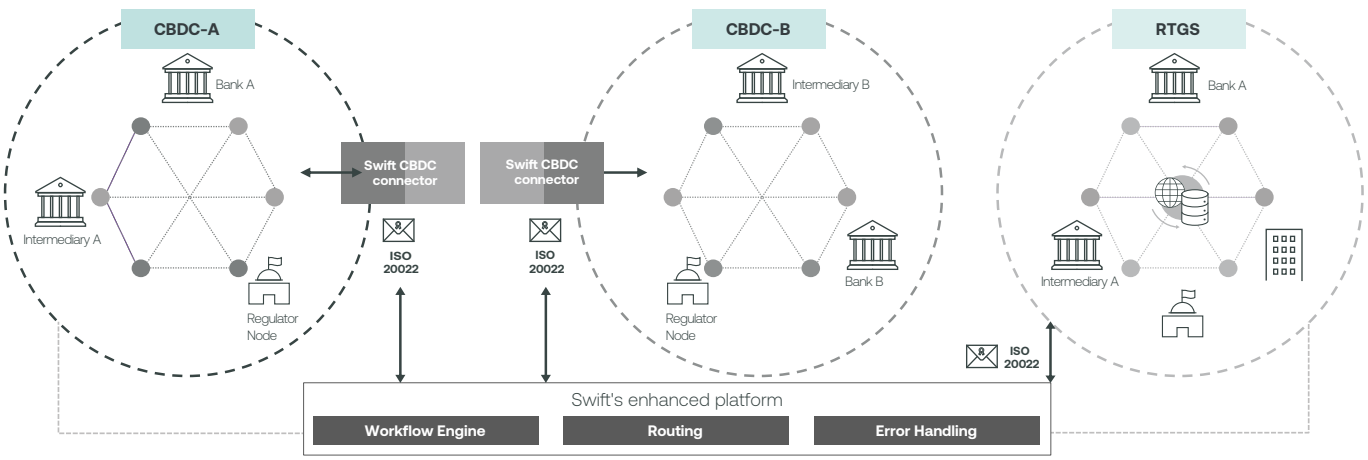
Whilst the momentum towards CBDCs is gathering pace, there remains a significant risk of fragmentation at the global level. Central banks are developing their own digital currencies seeking to solve different use cases, whilst using different technologies, standards, and protocols in their implementations. If such fragmentation persists, it could lead to unconnected 'digital islands' springing up around the world, with as a potential consequence barriers to businesses and consumers attempting to make international payments using CBDCs.

Connecting digital islands

As part of our strategy to deliver instant and frictionless cross-border transactions, Swift has been investigating the role it can play in the global CBDC ecosystem for several years. In 2021, we published the whitepaper 'Exploring central bank digital currencies: How they could work for international payments, setting out the results of our first round of experiments. This work showed how Swift could enable interoperability and, in doing so, demonstrated how we could solve for the Bank for International Settlement (BIS) multi-CBDC Model 1 of enhanced compatibility. This first round of experiments - together with other multi-CBDC projects by the BIS Innovation Hub, The Monetary Authority of Singapore, and others - have provided valuable insight to inspire the next phase of our work.

Our 2022 experiments went much further, demonstrating an important new interlinking solution capable of connecting CBDC networks and existing payments systems for cross-border transactions. Our teams were able to build a simulation of Swift's enhanced platform and an experimental connector that, when combined, are capable of linking CBDC networks together at the technical level, and thus solving for the BIS multi-CBDC Model 2 (see Figure 1 for the high-level architecture of our experiments). You can find out more about our 2022 experiments here.

Figure 1: The Swift CBDC experimental interlinking solution



Swift has connected global payments systems and currencies for over forty years. With our CBDC solution, we intend that Swift can continue to play this role in a world where both digital and traditional currencies are used to make cross-border payments. Now we are collaborating with our global community to develop a beta version of the solution to interlink CBDCs that are starting to go live around the world.

The sandbox project

As part of our commitment to collaborative innovation, we deployed our CBDC infrastructure into a sandbox, and opened up access to select Swift members for experimentation with us. Enabled by Kaleido, a blockchain and digital assets platform, and leveraging Hyperledger FireFly, the sandbox provided an environment for financial institutions to collaborate, explore, assess, and improve our experimental CBDC interlinking solution – as well as to define the next generation of supported payment flows and use cases.

Figure 2: Named participants by country*

Canada Royal Bank of Canada	**Italy** Intesa San Paolo
France Banque de France Société Générale BNP Paribas	**Japan** SMBC
Germany Deutsche Bundesbank	**Singapore** Monetary Authority of Singapore
Hong Kong HSBC	**Switzerland** UBS
	UK NatWest Standard Chartered

*Participants listed here agreed to be named publicly

In total, 18 institutions from across the globe participated in the CBDC sandbox. The participants were made up of a range of central banks, market infrastructures and commercial banks – including the Banque de France, the Deutsche Bundesbank, the Monetary Authority of Singapore, BNP Paribas, HSBC, Intesa Sanpaolo, NatWest, the Royal Bank of Canada, SMBC, Société Générale, Standard Chartered, and UBS. In parallel, we also ran an 'observer series' in which four additional central banks provided input and feedback on the solution, without having direct access to the sandbox itself.

The testing phase spanned 12 weeks during which participants had continuous access to the sandbox environment. Dedicated 'collaboration sessions' were held every two weeks in which representatives from all institutions met to discuss their feedback as a group. During these sessions, participants reviewed key elements of the experimental interlinking solution, such as the Swift CBDC connector and flows, roles and responsibilities within the network, technical and implementation considerations, identity, privacy considerations, etc (see Figure 3 for session agendas). Participants were asked to test certain scenarios or validate assumptions ahead of the next group meeting.

Figure 3: The sandbox project session agendas

Kick off

Attendees: Admin, Business Users, Technical Users

Objectives: Kick off the pilot and provide context, purpose, and high-level goals of the Swift CBDC Interlinking experiment and CBDC sandbox.

Swift: An overview of the sandbox project

Attendees: Business Users, Technical Users

Objectives: Explore the connector and flows in depth to ensure alignment for future experiments.

CBDC roles & responsibilities

Attendees: Admin, Business Users, Technical Users

Objectives: Identify the roles and responsibilities of the participants within a CBDC network.

CBDC implementation & technical considerations

Attendees: Admin. Business Users, Technical Users

Objectives: Capture insights from banks around technical implementation of a CBDC and whether it is compatible with the Swift connector proposal.

Open considerations: Identity & privacy

Attendees: Admin, Business Users, Technical Users

Objectives: Review and explore identity, access, and privacy considerations for CBDCs.

Wrap up, review, avenues for future exploration

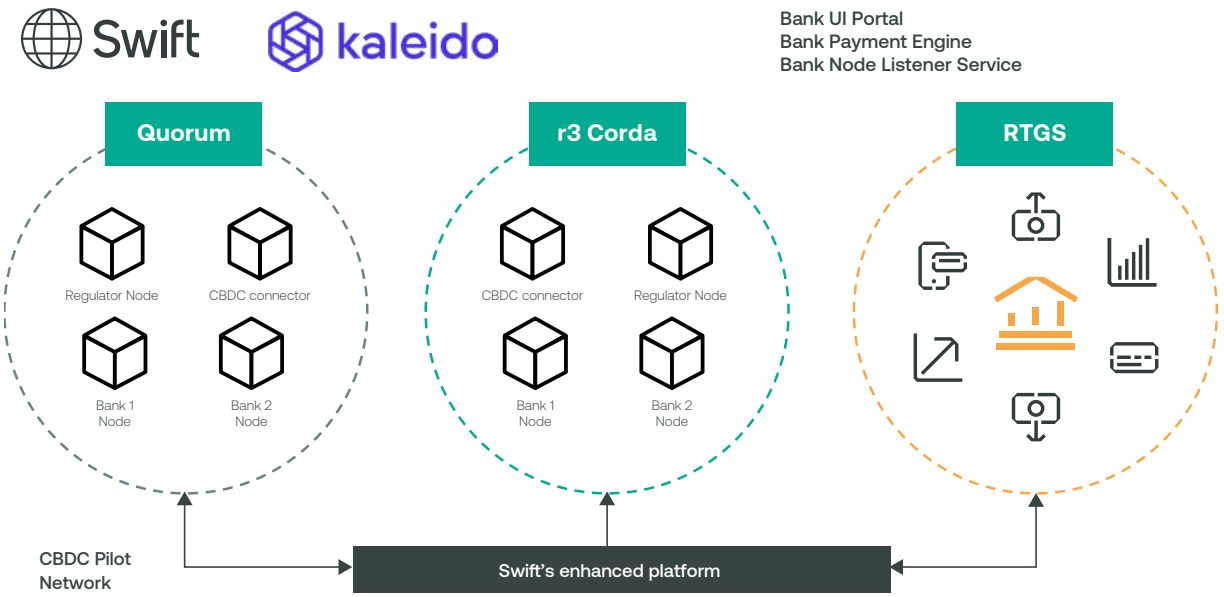
Attendees: Admin, Business Users, Technical Users

Objectives: Cover any other outstanding topics. Swift to review and present back key takeaways learned. Future areas of exploration to be discussed and considered.

The sandbox infrastructure

The sandbox offered a technical infrastructure hosted on Amazon Web Services (AWS) capable of testing CBDC transactions between different networks. As such, the sandbox hosted two blockchain networks – Quorum and Corda, as representative distributed ledger technologies (DLTs) that could be used to run CBDCs – and a simulated Real-Time Gross Settlement (RTGS) network. Incorporated in each network were the required regulator nodes, the bank nodes, as well as our experimental Swift CBDC connector which connected to a simulation of Swift's enhanced platform.

Figure 4: A high-level component view of the Swift CBDC sandbox



Swift experimental CBDC connector: The key components

Network Authority and Regulator Node: The CBDC experiments and design of the Swift CBDC connector introduces an administration role within the CBDC network called the "Network Authority". The entity (or entities) playing this role are considered to be the administrator of the network and are responsible for designing and implementing various aspects of the CBDC network. During live implementation of CBDC networks, depending on their policies, CBDC authorities may choose to implement this role differently. This role of Network Authority contrasts with the Regulator Node within the network, which is a physical entity on the network to which the Swift CBDC connector will be connected.

Cross-border message identifier: The cross-border message identifier is a component that sends messages that are identified as destined for external networks based on the scheme defined by the network authority for identifying cross-border messages. This component: a) sends the messages intended for external networks to the Swift CBDC connector; and b) uses the Swift CBDC connector to inform the global tracker of the status of a transaction in the CBDC network.

Rulebook processor: The business rule processing engine subjects messages to validation according to the rules defined by the network authority. Based on the results of the evaluation, the network authority can configure the Swift CBDC connector to execute the appropriate API exposed in the API server.

Message Translator: A tool provided to the network authority to map message translation from one format to another. It translates the native CBDC message format into the corresponding ISO 20022 messages and vice-versa.

CBDC access server: An API endpoint is implemented by the network authority and is required to complete the processing of the message within the CBDC network. The network authority sets rules in a business rule processor engine that invokes the appropriate API in the API server. As envisaged, the network authority could be operated by a relevant central bank (or central bank system) or other designated payment network operators or entities.

The CBDC transactions

Network Transaction	Transactions Processed
Quorum ▶ Corda	**98**
Corda ▶ Quorum	**58**
RTGS ▶ Corda	**27**
Test Instance Payments	**4,736**

Participants were able to test transaction flows between three different simulated networks: 1) Quorum-to-Corda; 2) Corda-to-Quorum; 3) RTGS-to-Corda. See Annex 1 for diagrams of the flows. During testing, a total of 4,736 transactions were processed throughout the networks (including test payments), whilst 183 of these transactions were sent by participants in the sandbox environment.

The flows used the ISO 20022 pacs.008 message to initiate a payment, and the pacs.002 message to communicate acknowledgements between the various financial institutions involved in the payment. To ensure non-repudiation and digital integrity, all messages were digitally signed using Swift's unique Public Key Infrastructure (PKI). By leveraging the ISO 20022 standard – as well as the widely used Swift PKI – we were able to ensure interoperability between various networks operating using different technologies.

One of our key assumptions was that CBDC tokens will remain within their own jurisdictions or monetary zones. So, in order to facilitate cross-border fund transfer under these restrictions, an intermediary model was used to demonstrate funds transfer between two CBDC networks.

The Swift CBDC connector on each CBDC network acted as the bridge to connect to other payment systems via Swift's enhanced platform. The Swift CBDC connector implemented the local message processing and CBDC network accessing logic. This approach removed the need for each participant, or Swift's enhanced platform, to know how to process the message and access the destination network.

To support atomicity, as well as the settlement process, the solution supports the creation of a conditional payment, through which the funds were escrowed in each of the network prior to settlement. While our solution is flexible to meet most escrowing situations, for the demonstration purposes we limited our implementation to: 1) escrow on receiving side only; and 2) escrowing on both sending and receiving side.

To enable this, and to ensure that the atomic settlement implemented follows the traditional settlement process, a ReleaseFund mechanism was used. This required a settlement instruction in the form of pacs.002 message initiated by the intermediary; the Swift CBDC connector on the local network then orchestrates the release of the escrowed Fund.

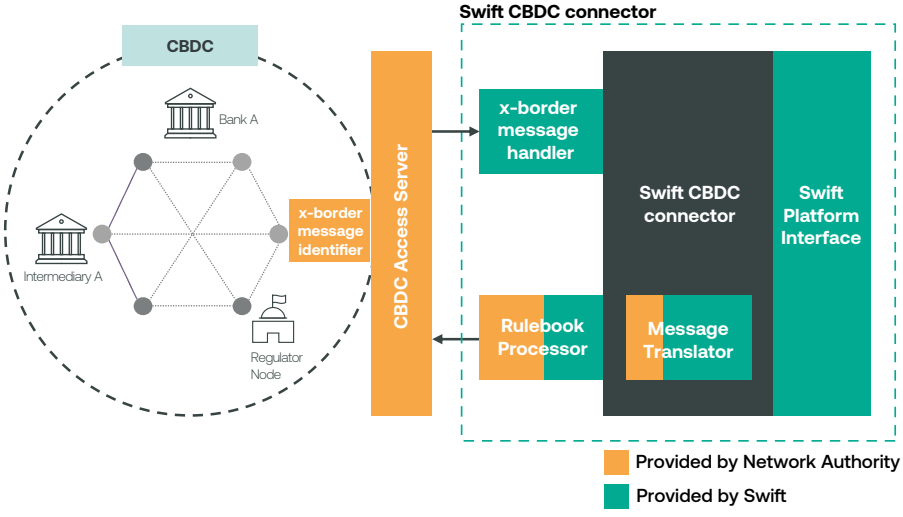


Figure 5: A high-level component view of the Swift CBDC connector

The findings

Overall, the results of the sandbox testing found that Swift's experimental interlinking solution can meet the needs of central and commercial banks for CBDCs interoperability, ensuring CBDCs can be successfully used in cross-border payments. Furthermore, there was a strong degree of alignment between the sandbox participants as to how CBDCs are likely to function in the future, providing greater confidence to Swift around the design of the solution.

Through the interactive collaboration sessions, participants provided valuable input for Swift to consider as we build the next beta version of the CBDC interlinking solution. The range and diversity of the technical feedback received will enable us to iterate our solution to better meet the needs of multiple CBDC design types and implementations.

The testing showed that our solution can meet the interoperability needs of central and commercial banks

CBDC access models and intermediary roles

The sandbox participants shared their considerations regarding access models for a CBDC network, affirming the expectation that CBDC tokens would likely remain within their own jurisdictions. Participants expected CBDC networks to follow the access models of current domestic payment networks, with no assumed extension of access to foreign payment service providers. Given these conditions, intermediaries are likely to continue to be commonly used to facilitate cross-border CBDC transactions, with the potential to evolve the current correspondent banking model.

It was widely discussed that from an operational model perspective, it could make sense to build on current structures, such as nostro/vostro accounts of intermediaries at the settlement level. Whilst alternatives may be available, such as central bank swap lines, these are typically not used today for daily operational purposes, and so the design of alternative mechanisms still needs to be assessed.

CBDC implementation and technology selection

Participants agreed that CBDC networks could be implemented using permissioned DLTs or centralised architectures, due to ongoing privacy and regulatory concerns with Public DLT implementations. With this in mind, Swift was able to confirm the feasibility of hosting a cross-border message identifier on the network, which would require a permissioned network. And, importantly, despite potentially diverse CBDC implementations, no concerns were expressed by participants with regards to connecting with Swift's CBDC connector or to its orchestration requirements – opening up the opportunity to enable an efficient and scalable 'hub and spoke' model that can leverage known standards and practices.

Whilst the sandbox simulated CBDC networks using the DLT technologies Corda and Quorum, some participants are using proprietary technologies and non-DLT technologies to build their CBDC networks. A number of participants are also exploring further private/permissioned DLT's such as Hyperledger Fabric in particular and Swift will look to support this technology, along with other proprietary and centralised architectures, in the future development of the solution.

CBDC flows and messaging standards

The participants agreed that the ISO 20022 standard, currently being adopted for non-CBDC payments, could be appropriately reused as a language for cross-border payments with CBDCs, including the use of pacs.008 and pacs.002 messages. Whilst the sandbox currently uses these messages to create a payment flow, some participants requested that other message types be supported going forward, such as pacs.004, camt.052/053, camt.054, camt.029 and camt.057. There were contrasting views among participants as to whether serial and cover payment flows would be required, and whether atomic settlement could apply within these flows. Some thought both flow types would be needed, others only considered serial payment flow necessary, whilst another group believed neither would be required in the future CBDC cross-border model. This will continue to be assessed with the community as we progress further future exploration.

Swift's initial assumptions about CBDC implementations were largely validated by the sandbox participants.

Atomic settlement

We previously explored the use of Hash Time Lock Contracts (HTLC) for atomic settlement in our 2021 experiments. However, for the reasons outlined in our October report, we proposed the use of an alternative new ReleaseFund mechanism for our 2022 solution, described above.

Participants asked us to consider implementing a further enhanced atomicity scheme, whereby the solution orchestrates simultaneous atomic settlement between the participating networks. Thanks to the orchestration capability of our enhanced platform, we can further develop the solution to enable the escrow fund to be orchestrated simultaneously; as such, the Swift platform will know the escrow condition of the transaction. When atomicity is required, the Swift platform will request the intermediaries to initiate the ReleaseFund request. Once all intermediaries have submitted the ReleaseFund requests, they will be simultaneously released to all the CBDC connectors involved for the escrowed fund to be released. As a result, this enhancement can increase the level of atomicity.

Liquidity

The topic of liquidity management was heavily discussed by sandbox participants. There were diverse opinions as to the overall net impact of a CBDC on the efficiency of liquidity management. Some participants felt that there could be a material reduction in the time to process and complete a cross-border payment and therefore liquidity costs could also be reduced through lower duration of holding liquidity. A countervailing factor however could be the potential fragmentation of liquidity between existing forms of fiat currencies and CBDCs, depending on level of fungibility. Furthermore, faster transaction speed combined with gross settlement could reduce the efficiency of liquidity management if netting mechanisms were not available for CBDC transactions. We will work with participants to assess whether some level of liquidity management research can be scoped in the next phase to enhance the understanding of liquidity impacts and mitigations.

Foreign exchange

In-depth discussions also took place around FX settlement, and if this would happen within the payment flow or not. Many participants thought an out of network approach to FX settlement would be likely, given current market structures. If FX settlement were to happen, off or on-chain, a further suggestion was to ensure that synchronicity should be ensured between the off and on-chain movements. It was suggested that CLS would continue be used for FX settlement; however, with CLS settlement coverage applying to 18 currencies, there is also the potential to explore addressing settlement for non-CLS settled currencies.

Identity and privacy

In our implementation, Swift PKI signatures were applied by the initiating institution on the pacs. message, and were subsequently added to the CBDC network. Whilst this was acceptable for most participants, some requested Swift to consider applying the PKI signature at the Swift CBDC connector, as well as reusing the PKI key implemented in the local network.

The use of Personally Identifiable Information (PII) in payment messages was highlighted as an important area for consideration, for example in Singapore's context with the Personal Data Protection Act (PDPA). In cases where PII is included in an ISO message, then it is the responsibility of the network authority to ensure adequate security measures are taken to protect that information within their network.

Careful consideration should be given by authorities in deciding whether a message containing PII should be stored in their CBDC network. In cases where it is decided that PII should not be stored in network, it would be possible to store a hash of the message, then send the message securely via out-of-band channels such as API. This was demonstrated in the CBDC sandbox's Quorum network leveraging Hyperledger FireFly's private messaging capabilities. However, this assumes both that the network is using a DLT technology that supports such capabilities, and that the DLT's internal secure message exchange is not adequate or is too complex to implement. It still needs to be determined how interoperability between CBDC networks can be ensured if no PII is stored in the respective network and a DLT is not used.

Support for value-added services

Finally, some participants requested that the solution be enhanced to leverage more value-added services already offered by Swift, such as sanctions screening, Anti-Money Laundering (AML), payments pre-validation, and exception handling. Moving forward, we will look to enhance our offering based on these requests.

Conclusion and next steps

The overall feedback we received during the course of the sandbox project was very positive, with the participants seeing clear potential and value in Swift's experimental CBDC interlinking solution, and in its further development. The participants also found value in being able to engage with other central and commercial banks to exchange knowledge and share views about important design considerations for CBDCs. Many participants were keen to continue their collaboration with Swift as we iterate our solution into a beta version, with a particular focus on extending interoperability capabilities and testing further use cases.

Many participants were keen to continue their collaboration with Swift as we iterate our solution into a beta version.

The sandbox feedback confirmed the importance of considering interoperability for cross-border as well as domestic payments at the design stages of a CBDC i.e., to mitigate potential global fragmentation by 'building it in' from the start. Participants also emphasised the desire to extend the scope of the industry vision for interoperability between existing RTGS systems, faster payments systems and market infrastructure interlinking initiatives. It was thought that this would support the industry to achieve full interoperability between existing and new forms of payment.

In terms of further use cases, participants cited that Delivery-versus-Payment (DvP) and more sophisticated Payment-versus-Payment (PvP) mechanisms would be highly relevant and identified potential use cases in securities settlement, trade finance and conditional payments. Participants indicated that to further explore DvP, we should leverage existing progress that has been made in the developments of the tokenisation of assets more widely (such as token creation, de-tokenisation, collateralisation and reconciliation), topics that Swift explored in parallel experiments published in October 2022. In such cases, the solution would need to be generic to both the underlying asset and the technology implemented.

What's next?

With a growing momentum towards CBDCs, and digital assets more broadly, we are committed to continuing to drive collaborative innovation in this space. Specifically, we now intend over the coming months to:

1. Develop the CBDC interlinking solution into a beta version for payments with enhanced atomicity, that can be tested further by central banks, considering security and other requirements.

2. Run a second phase of the CBDC sandbox, focused on new use cases, in order to enable the Swift community to further collaborate and test with each other, and so contribute to the next generation of CBDC solutions.

As a result, we hope to develop a genuinely useful solution, capable of supporting instant and frictionless cross-border payments using CBDCs, and, in doing so, enable the financial industry to realise the benefits of new forms of digital currencies across the globe.

Want to learn more?

To provide feedback, or if you would like to learn more about our tokenised assets experiments and solutions, please reach out to your Swift account manager or contact innovate@swift.com.

Annex 1: The transaction flows

Figure 6: Quorum to Corda Flow

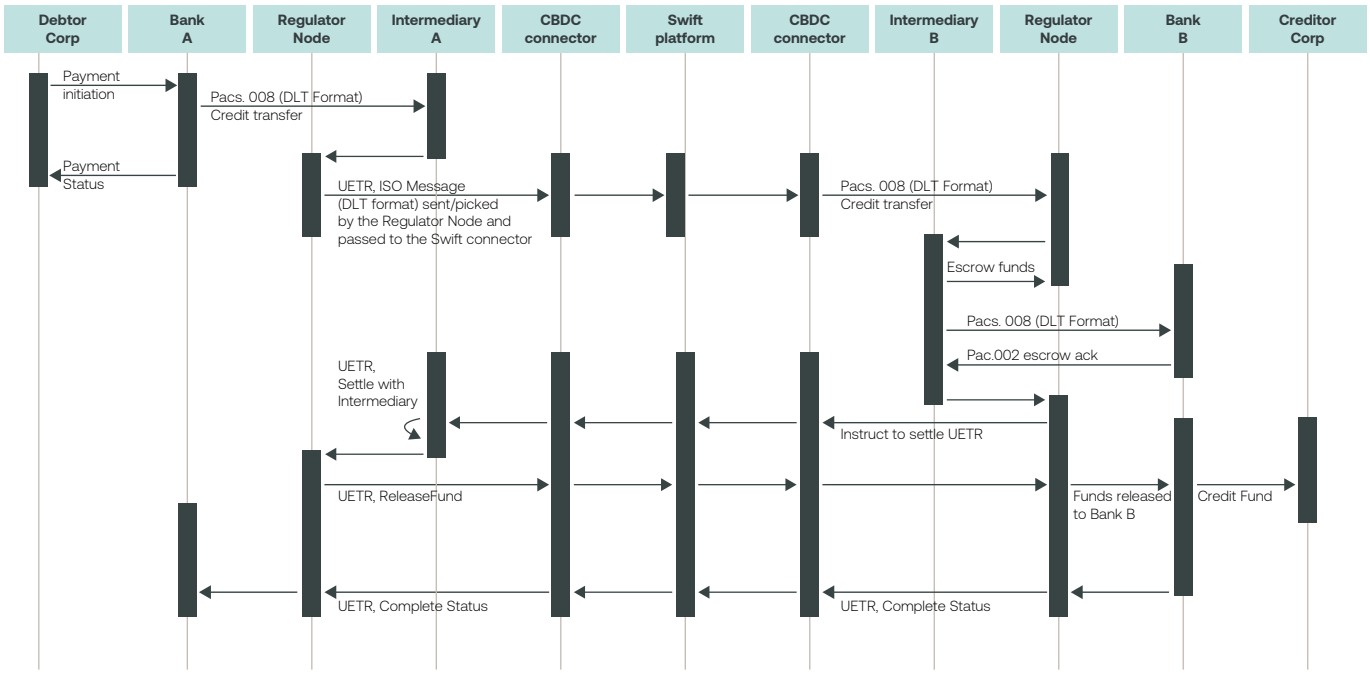


Figure 7: RTGS to Corda Flow

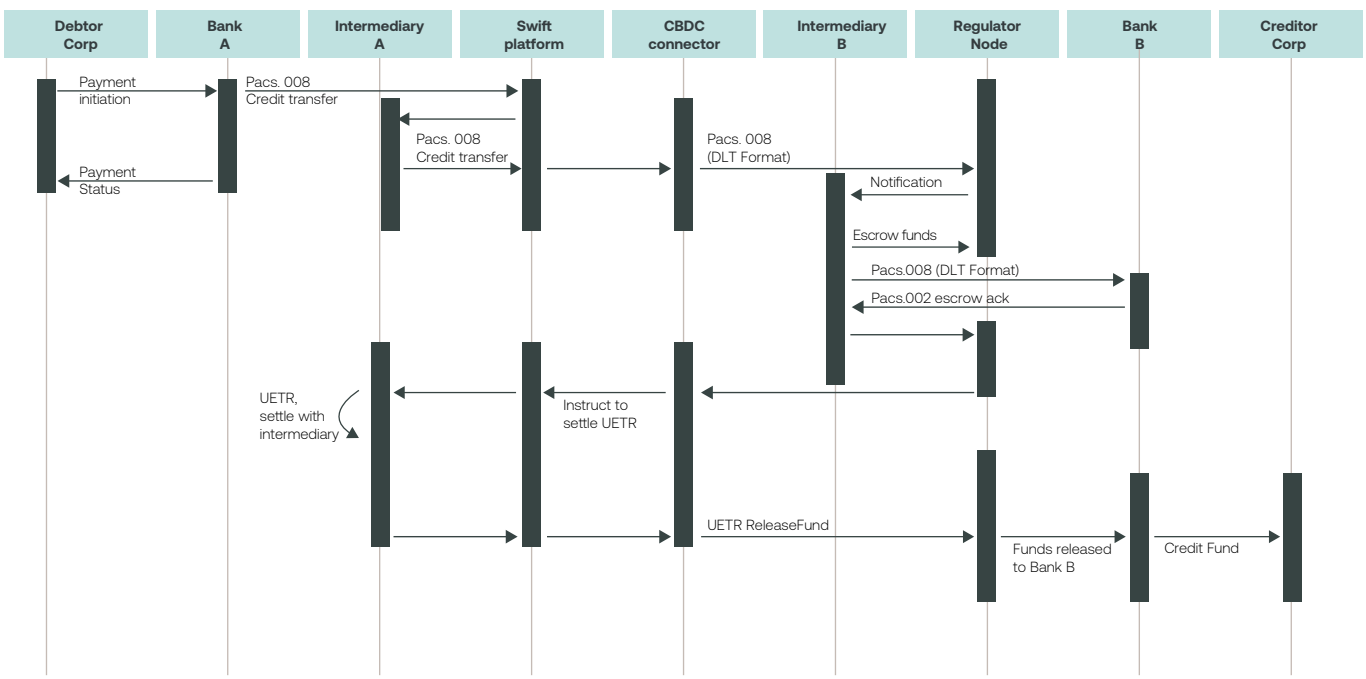
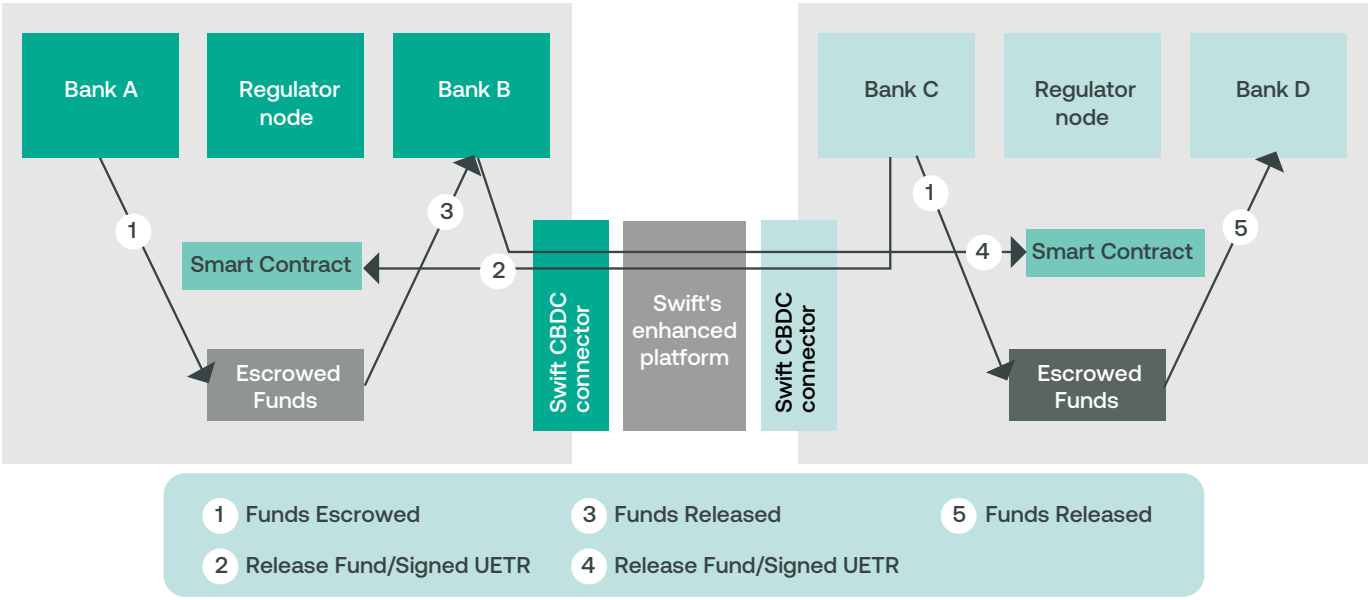


Figure 8: Conditional Payments Flow



Acknowledgments

Swift Team

Tom Zschach
Chief Innovation Officer

Nick Kerigan
Managing Director, Head of Innovation

Rachel Levi
Head of Innovation Engineering

Giri Krishnapillai
Innovation & Architecture

Kaleb Fry
Product Strategy & Innovation

Travis Moe
Senior Innovation Engineer

Mike Ninov
Innovation Engineer

Swift would like to give a special thanks to the 110+ colleagues from the 18 central and commercial banks that participated in this sandbox project.

About Swift
Swift is a global member-owned cooperative and the world's leading provider of secure financial messaging services. We provide our community with a platform for messaging, standards for communicating and we offer products and services to facilitate access and integration; identification, analysis and financial crime compliance. Our messaging platform, products and services connect more than 11,000 banking and securities organisations, market infrastructures and corporate customers in more than 200 countries and territories, enabling them to communicate securely and exchange standardised financial messages in a reliable way.

As their trusted provider, we facilitate global and local financial flows, support trade and commerce all around the world; we relentlessly pursue operational excellence and continually seek ways to lower costs, reduce risks and eliminate operational inefficiencies. Headquartered in Belgium, Swift's international governance and oversight reinforces the neutral, global character of its cooperative structure. Swift's global office network ensures an active presence in all the major financial centres.

For more information, visit
Web: www.swift.com
Twitter: @swiftcommunity
LinkedIn: Swift