Connecting digital islands

Swift CBDC sandbox project – Phase 2

Results report
March 2024

Swift

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Our Phase 2 sandbox project is one of the largest global CBDC collaborations ever.

CBDC development is accelerating, but action is needed to achieve interoperability

Interest in Central Bank Digital Currencies (CBDCs) continues to grow. According to the Atlantic Council tracker, more than 130 countries are now exploring a CBDC – and research by OMFIF has found that almost 70% of central banks expect to issue a CBDC within the next decade. But as the development of CBDCs gathers pace, different central banks are using a variety of technologies and standards. As such, there's a risk that in the future, the use of CBDCs by businesses and consumers could be hindered by the existence of unconnected 'digital islands'.

Against this backdrop, Swift has been investigating whether and how it can enable the global CBDC ecosystem. In 2021, we published the results of a first round of experiments that showed how Swift could enable interoperability between CBDCs. Further experiments in 2022 demonstrated a new interlinking solution for connecting CBDC networks and existing payment systems. We opened this up to testing by the Swift community through our first phase of sandbox testing, with results published in March 2023. Following that, we released an enhanced beta version of our connector solution, tested with three central banks.

Our Phase 2 sandbox project is one of the largest global CBDC collaborations ever

In July 2023, we launched a second phase of our CBDC sandbox project to build on the learnings from Phase 1 and introduce more complex use cases. The project – which is the focus of this report – was carried out over six months, with participation from 38 central banks, commercial banks and market infrastructures from around the globe.

The project included two streams of work. During the course of 20 collaborative working group meetings, an average of 60 representatives from participating institutions discussed use cases, experiment designs and potential solutions, as well as providing input on the further development of Swift's interlinking solution, the Swift connector. Once the design for each use case had been approved, participants were able to carry out hands-on testing of the resulting solutions in a sandbox environment.

The Phase 2 sandbox explored more complex use cases

Four different use cases were explored: (1) Digital Trade; (2) Foreign Exchange (FX) Trade & Settlement; (3) Delivery-versus-Payment (DvP); and (4) Liquidity Saving Mechanism (LSM). In total, over 125 users tested 750+ transactions in the sandbox environment.

Use case 1: Interoperability was achieved between digital trade platforms and CBDC networks

The first use case set out to demonstrate how digital trade networks could be interlinked with CBDCs. The Swift connector was used to facilitate automated trade payments – in other words, payments that are completed programmatically, alongside the transfer of assets, rather than manually.

Using a simulated digital trade network, we simulated real-world trade scenarios including the tokenisation of purchase orders, issuance of invoices, and automated payment execution. Smart contracts were used to ensure that payment events were triggered automatically once trade conditions had been met.

The experiment demonstrated that it was technically feasible to automate trade payments using distributed ledger technology (DLT) and CBDC networks. Automating pre-approved payment workflows once certain conditions had been met meant that trade flows could potentially be automated on a 24x7 basis. Participants also highlighted that the solution could help to reduce delays in global trade, reduce fraud risk and improve trust among parties, as well as significantly reducing transaction costs.

Use case 2: The Swift connector successfully enabled two new approaches to FX trade and settlement

The goal of the second use case was to explore the role the Swift connector could play in foreign exchange – namely in combining FX trade and settlement into a single step.

The working group shortlisted two models for sandbox experiment. The first of these involved developing a conceptual International Foreign Exchange (IFX) Marketplace to explore how CBDCs issued in different jurisdictions could be traded and settled on one network. The second involved exploring how the capabilities of CLS could be used to mitigate settlement risk for cross-CBDC FX settlement.

The Swift connector is able to support different emerging interlinking models.

Both models successfully fulfilled the requirements set out by the working group. The IFX Marketplace model showed how CBDCs issued in domestic markets could be escrowed, wrapped in rules if needed, and reissued on an external network through the Swift connector. The CLS-inspired settlement system, meanwhile, was able to demonstrate how the CLS-inspired netting and settlement engine could add value to the FX market, facilitating netting and settlement via CBDCs.

Use case 3: The Swift connector achieved atomic settlement (DvP) across digital token platforms

The third use case explored how the Swift connector could address the current lack of interoperability between tokenisation platforms. The focus was on interlinking asset networks with different CBDC networks to facilitate DvP.

The sandbox set-up included a tokenisation platform, which supported the buying and selling of simulated tokenised bonds, alongside CBDC networks. A DLT and smart contract layer was used to maintain records of transactions. During the experiment, participants executed DvP scenarios, with smart contracts used to ensure that payment events could occur atomically.

By simulating real-world DvP scenarios, the experiments successfully demonstrated that the Swift connector could facilitate atomic DvP across the platforms. The experiment also focused on the interactions between trade participants through customised dashboards to optimise ease of use in trade and payment processes.

Use case 4: We also explored how LSM algorithms could address liquidity fragmentation

The goal of the fourth use case was to explore models which could reduce the fragmentation of liquidity across different currencies and platforms. The working group discussed two approaches: the use of smart contract-enabled payment tokens, and the use of LSM algorithms to orchestrate transactions between digital networks. For the latter approach, the working group explored the potential of implementing a netting algorithm at Swift Transaction Manager to orchestrate transactions between digital networks.

The solution in this case was a paper-based exercise, accompanied by bilateral discussions with a subset of participants. Participants welcomed the prospect of implementing netting capabilities at Swift Transaction Manager; however, this was not seen as a pressing need. While working group participants agreed that the fragmentation of liquidity between digital networks presents a challenge, the discussions revealed that there are multiple reasons for why financial institutions choose to fragment their liquidity.

The participants agreed upon three principles for interoperability

The experiments made it clear that, while interlinking cannot be achieved through a single model, the Swift connector is able to support different emerging interlinking models. Participants agreed upon the following three principles for interoperability:

1. **Interlinked networks.** It is essential to ensure native technical interoperability between different digital networks. There is an opportunity to achieve interlinking by leveraging the industry's investment in ISO 20022 messaging as the common language for payments across new and established networks.
2. **Single point of access.** A single point of access provided by Swift can enable institutions to reuse their existing channels, reach new networks, and bring down participation costs.
3. **Co-existence.** With new digital networks expected to co-exist with traditional market infrastructures, seamless interactions will be needed between the new and the old.

Our collaborative innovation in this space is set to continue

Following these experiments, we plan to continue collaborating with our global community in 2024 to further drive innovation. One key initiative will be to continue enhancing the Swift connector to support additional Payment-versus-Payment (PvP) and DvP use cases, while adding functional enhancements and new technical capabilities. Other key areas of focus will include implementing smart contracts on digital networks based on different DLT technologies; cryptographically locking and releasing tokens; and moving tokens between networks.

We further aim to develop a productisation roadmap for the Swift connector, based on market developments and readiness.

In parallel, we plan to demonstrate how the Swift connector could interlink other networks, such as bank-led tokenised deposit networks. And, as ever, we will continue to support community efforts to further innovate in this area, both by participating in industry initiatives and by contributing to network capabilities.

The business context

In recent years, it has become increasingly clear that for CBDCs to be used cross-border, interoperability will be critical.

Interest in Central Bank Digital Currencies (CBDCs) has grown exponentially in recent years, with more than 130 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 development. Almost 70% of central bank respondents to OMFIF's 2023 Future of Payments survey expect to issue a CBDC within the next decade. China's digital yuan has passed $250 billion in transactions within one-and-a-half years of its launch, while the ECB is now in the preparation phase for a digital euro. In India, meanwhile, commercial banks are processing a million transactions per day throughout the country for the digital rupee.

Growing fragmentation

While the rise of CBDCs is accelerating, there remains a significant risk of fragmentation at the global level. Central banks are developing their own digital currencies and are seeking to solve different use cases, with different technologies, standards, and protocols. If such fragmentation persists, it could lead to unconnected 'digital islands' springing up around the world, presenting barriers to businesses and consumers attempting to make international payments using CBDCs.

Swift's CBDC journey to date

In recent years, it has become increasingly clear that for CBDCs to be used cross-border, interoperability will be critical. Swift has therefore been investigating whether and how it can enable the global CBDC ecosystem as part of its strategy to deliver instant and frictionless cross-border transactions.

Our 2021 whitepaper, 'Exploring central bank digital currencies: How they could work for international payments', set out the results of our first round of experiments. This work showed how Swift could provide 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 and others, proved invaluable in informing the next phase of our work.

Developing the Swift connector solution

Building on this, our 2022 experiments demonstrated a new interlinking solution which could be used to connect CBDC networks and existing payments systems for cross-border transactions. Our teams built a simulation of Swift's enhanced platform and an experimental connector that, when combined, can link together CBDC networks at the technical level, thus solving for the BIS multi-CBDC Model 2. You can find out more about our 2022 experiments here.

Following a first phase of community sandbox testing with 18 central and commercial banks that culminated in our March 2023 report, Swift committed to developing a beta version of its connector solution, with participants recognising the solution's 'clear potential and value'. In particular, the risk of cyberattacks and fraud meant that it was crucial to develop robust security protocols within the CBDC networks and the Swift connector. The beta solution was released in mid-2023, with three central banks integrating the solution with their own infrastructures for direct testing.

Swift's Phase 2 sandbox project

Building on the learnings of sandbox Phase 1 – and following demand from the community to continue expanding the scope and complexity of the use cases – Swift kicked off a second phase of CBDC sandbox experiments in July 2023 with the key objective of introducing more complex and sophisticated use cases for multi-CBDCs, as well as integration with existing payment systems.

This project was one of the largest global collaborations carried out on CBDCs to date: an extensive exercise carried out over six months with 38 financial institutions participating from across the globe, representing a diverse mix of central banks, commercial banks and market infrastructures.

The following report sets out the key results and conclusions from our Phase 2 sandbox experiments.

The project

Central banks

- Australia
- Czechia
- France
- Germany
- Singapore
- Taiwan
- Thailand

Commercial banks

- ANZ
- Citibank
- DBS Bank Limited
- Deutsche Bank
- HSBC
- Hua Nan Commercial Bank, Ltd.
- Intesa Sanpaolo
- NatWest Group
- Santander Bank
- Société Générale
- Standard Chartered
- Sumitomo Mitsui Banking Corporation
- The Shanghai Commercial & Savings Bank (Taiwan)
- The Standard Bank of South Africa
- United Overseas Bank
- Westpac Banking Corporation

Financial market infrastructures

- CLS Group
- DTCC

Figure 1: Named sandbox participants[1]

The collaborative working groups

The project was divided into two streams of work – a series of working group sessions, and hands-on exploration in a sandbox environment. We ran 20 working group sessions with an average of 60 participants in each session. The sandbox infrastructure was then provisioned for the 38 organisations involved for a period of four months. See Figure 1 for the list of participants that have agreed to be named in this report. As part of the project, we onboarded 125 users from the participating organisations to carry out testing in the sandbox.

Collaborative innovation in action

Participants met regularly to discuss use cases and potential solutions in dedicated working group sessions, which were divided into business and technical sessions for each use case. During the sessions, representatives from all the participating institutions reviewed key design options and decisions, roles and responsibilities, and implementation considerations for each of the use cases.

All participants reviewed the key elements of the Swift connector as the interlinking solution. Once a use case had been locked in with an approved design, the Swift team implemented the solution in the sandbox for the participants to carry out testing and validation, and provide feedback for future consideration.

A diversity of perspectives

The working groups included a diverse range of institutions from across the globe, representing a variety of policies, regulatory frameworks, AML standards and counter-terrorism requirements. They also included a strong mix of central banks, commercial and regional banks, and market infrastructures.

The working groups played a critical role in exploring and discussing the implementation of potential solutions in a collaborative manner, while also taking into consideration the differences between participants. Meanwhile, the 'show and tell' approach, with hands-on testing of the solution in the sandbox, provided an additional practical element to the project.

The sandbox experiments

A sandbox environment was provided so that participants could carry out meaningful hands-on testing of the solutions explored during the working groups sessions.

The environment – hosted by Kaleido, a blockchain and digital assets platform – included seven simulated CBDC networks, a foreign exchange network, a digital trade network, a digital asset network, and a simulated CLS application, representing a mix of digital and traditional networks, as shown in Figure 2 on page 7.

Leveraging their experience in helping to build the first version of the connector solution, which was described in our March 2023 report, Swift partnered with Capgemini to enhance the beta version of the Swift connector solution. The enhanced solution needed to support different use cases and payment types across a multitude of technologically different networks, including established payment rails.

The enhanced version of the Swift connector was integrated into the sandbox environment setup, along with the Swift Transaction Manager simulator. User interface screens were also built to enable the participants to test and explore the use cases.

Once integrated into the environment, the Swift connector and Swift Transaction Manager simulator were used to interlink the various simulated networks and facilitate payment flows between them for each of the use cases. Participants were able to test transactions between different networks and share their feedback and findings with Swift. During testing, the participants completed 750+ transactions in the sandbox environment across our use cases.

[1] *Note that only participants that agreed to be named in this report are listed.*

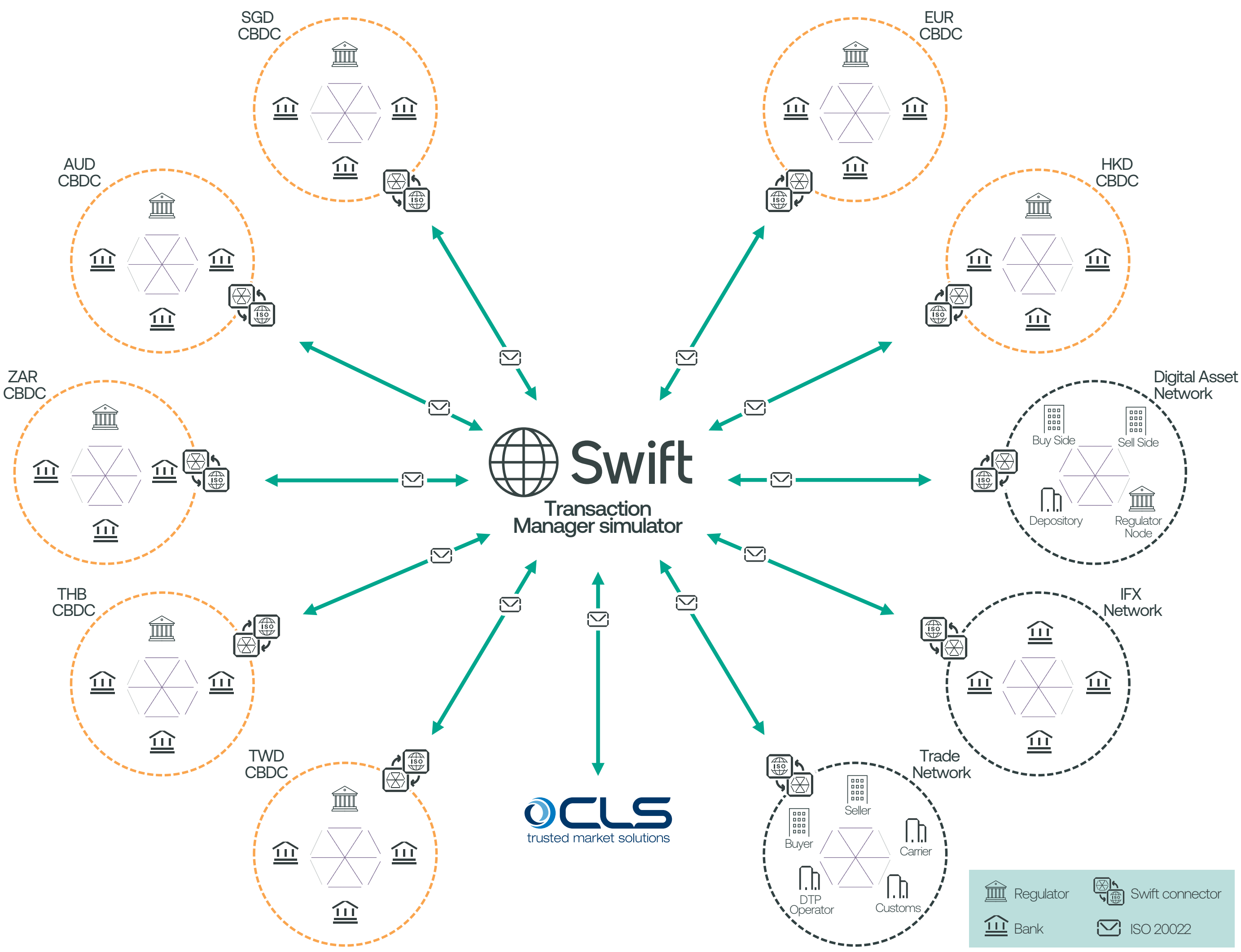
The technologies employed

The experiments included a mix of blockchain and distributed ledger technology (DLT) in order to demonstrate how the Swift connector's technology-agnostic capabilities could provide an interoperability solution. These networks were randomly deployed on a combination of three private permissioned DLT platforms, as outlined below.

- **Corda:** R3's Corda is a distributed ledger platform developed by R3, designed for businesses to build interoperable, secure, and private decentralised applications (CorDapps) for various industries, with a primary focus on the financial services sector. In the sandbox, four CBDC networks were simulated on Corda: SGD, THB, TWD and HKD.
- **Hyperledger Fabric:** Hyperledger Fabric is a permissioned blockchain framework and is part of the Hyperledger project hosted by the Linux Foundation. In the sandbox, five networks were simulated on Fabric: AUD, ZAR, EUR, International Foreign Exchange Marketplace (IFX), and a simulated Digital Trade Network.
- **Hyperledger Besu:** Besu is an open-source Ethereum client developed under the Hyperledger project hosted by the Linux Foundation. In the sandbox, one network was simulated on Besu: the Digital Asset Network.

Each network consisted of DLT nodes, off-chain applications and a user interface for testing. The off-chain applications, which included a bank application backend, trade application backend, user interface (UI) application and security services, were deployed on a Kubernetes cluster.

Figure 2: An overview of the sandbox environment: simulated networks and currencies



The use cases

Building on the core foundation of cross-border payments, this experiment explored the four use cases outlined below.

1. Conditional/trigger-based payments – Trade-versus-Payment (TvP)

Swift has developed an API specification for digital trade platforms in order to support interoperability between trade platforms. The trade payments use case demonstrated how complex, cross-jurisdictional payments could be automated for a clean/open account trade, using smart contracts, orchestration by the Swift Transaction Manager simulator, and the Swift connector for communication between trade and CBDC networks.

2. Foreign exchange – Payment-versus-Payment (PvP)

Off-chain settlement was previously explored in Phase 1 of Swift's experiment. Given the current market infrastructure, Phase 2 explored partially off-chain and on-chain FX settlement. We explored this use case in two ways – one more conceptual, and one closer to market practice today. The former involved alternative FX models like an International FX Marketplace (IFX) concept, whereby global commercial banks could perform FX trade and settlement on a single digital network. The latter solution involved a simplified processing engine for FX settlement inspired by the existing CLS settlement service. Given that CLS plays a major role in global FX settlement, and based on demand from the working group, the experiment explored how CLS could expand its settlement methods to include CBDCs. Both solutions featured the use of the Swift connector and the Swift Transaction Manager simulator.

3. Delivery-versus-Payment (DvP)

Digital assets have so far moved at a faster pace than digital currencies. Most of the live digital networks have some form of on-chain cash issued within the network for settlement. In order to achieve scale and network benefits, it is therefore important for digital assets networks to have an on-chain form of cash to facilitate true atomic settlement.

There was significant interest from the working group in interlinking digital assets networks to multiple CBDC networks in order to explore cross-network interoperability and settlement. This required the involvement of securities market infrastructures to design and test a solution.

4. Liquidity Saving Mechanism (LSM)

New digital networks have the potential to impact liquidity management in numerous ways, both positive and negative, with the overall net impact currently unclear. There is risk and cost associated with managing liquidity across networks. As such, the experiment created models to assess the implications of these developments for liquidity management, and to explore the potential benefits of incorporating liquidity saving mechanisms into the interlinking solution.

Use case 1: Trade payments

The key objective of this use case was to demonstrate how digital trade networks could be interlinked with other networks such as CBDCs.

Background, problem statement, key objectives

In the realm of international trade, the mechanics of payments have long been characterised by complexity and inefficiency. Recent years have seen a surge in the volume of global trade, with the World Trade Organization reporting a significant increase in merchandise trade volume. While extremely encouraging, such growth has magnified the challenges inherent in trade finance, particularly in the realm of payment settlements. The current landscape for trade payments is fraught with delays, high costs and risks, primarily due to the reliance on legacy systems and paper-based processes.

There are numerous industry initiatives currently underway which are looking at digitising global trade, including the adoption of electronic bills of lading (eBL), which has the potential to speed up the transfer of documents and reduce associated fraud. But the current lack of technical interoperability between existing eBL platforms presents a significant obstacle to wholesale adoption.

The key objective of this use case was to demonstrate how digital trade networks could be interlinked with other networks such as CBDCs. The experiment also explored the technical feasibility of automating complex trigger-based payment events across different networks.

The high level solution

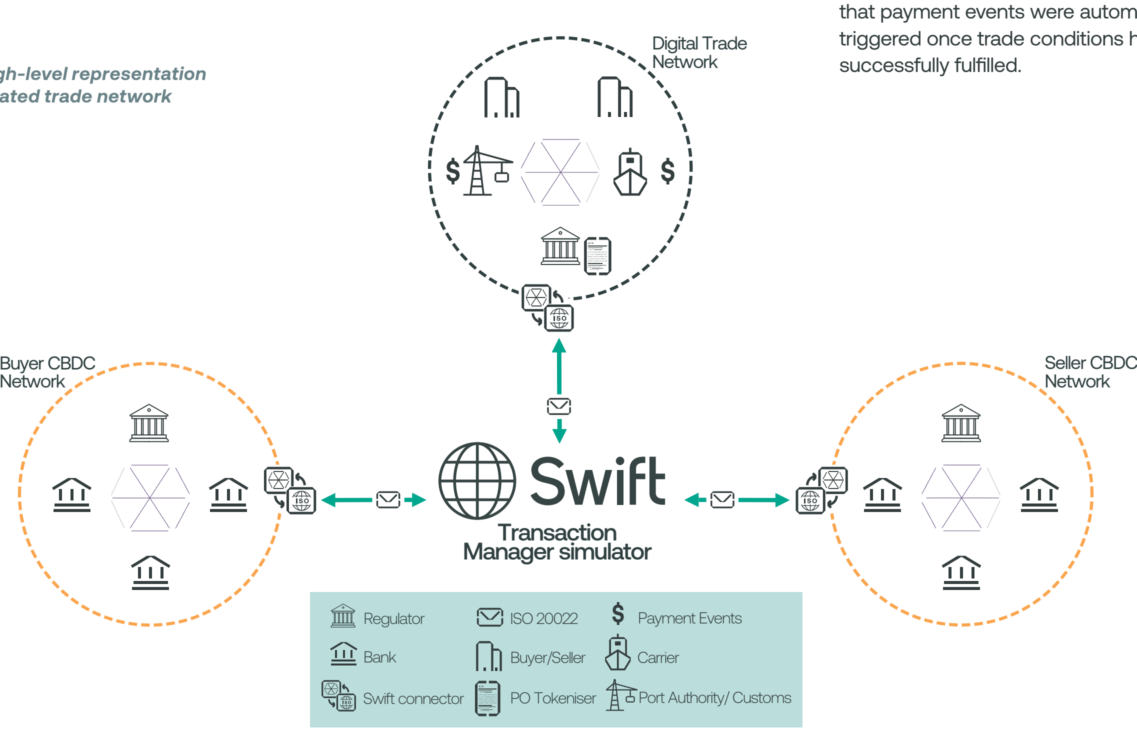
To test the solution in the sandbox, we simulated a Digital Trade Platform (DTP) on Hyperledger Fabric. A core assumption was that a digital trade network could act as a trusted network for global trade, involving diverse participants like buyers, sellers, carriers, and financial institutions. It would also support the tokenisation of trade purchase orders (POs), enabling a digital representation of trade agreements on the blockchain.

The simulated digital trade network – see Figure 3 – includes corporate participants which are pre-configured as buyers, sellers, carriers and port authorities, along with a network authority like the DTP Operator. This setup, integrated with standard CBDC network configurations, ensures a comprehensive testing environment.

Our approach was based on key assumptions – for example, that one PO represented one trade agreement, and that one PO could map to multiple invoices. The focus was on facilitating the seamless exchange of goods and funds using DLT and smart contracts, and thereby revolutionising the TvP paradigm.

The testing was structured to simulate real-world trade scenarios that included the creation and fulfilment of POs, issuance of invoices, and automated payment execution. Participants interacted with the system through their respective dashboards, executing trade and payment processes as per the designed workflows. The use of smart contracts ensured that payment events were automatically triggered once trade conditions had been successfully fulfilled.

Figure 3: High-level representation of the simulated trade network



Ultimately, the experiment demonstrated seamless interoperability between different digital networks across technology stacks using the Swift connector.

Results and feedback

The experiment successfully demonstrated the technical feasibility of automating trade payments using DLT and CBDC networks. Integration between the DTP and CBDC networks through the Swift connector was seamless, facilitating real-time communication and transaction processing.

Notable outcomes of the experiment included the following:

- **Trade lifecycle.** The DTP comprised the buyer, seller, carrier, port authority and their respective banks. Through the 'open account' approach, we were able to represent most of the actors present in a trade lifecycle.
- **Smart contracts.** The DLT-based DTP allowed us to implement effective smart contracts for capturing trade clauses in a typical trade contract.
- **Payment workflows.** Event-driven programming implemented on the digital trade network allowed us to automate pre-approved payment workflows between two networks using the Swift Transaction Manager simulator. For payments processed outside operating hours, this meant that the need for manual intervention was reduced. Payment events were programmed based on documentary evidence, such as customs certificates.
- **Fraud risk.** We found that tokenising a PO, and managing the lifecycle of a PO token and associated payment events via smart contracts, can reduce fraud and double financing issues. This is made possible because the PO token is escrowed until a pending invoice is settled.
- **Intermediaries.** The experiment showed that interlinking multiple digital networks and streamlining payments can help reduce the number of intermediaries needed in cross-border trade payments. Peer-to-peer atomic trade-versus-payment was possible.
- **Trade digitisation.** The continued use of ISO messaging standards will help with trade digitisation and bring in a common interoperability layer.
- **Interoperability.** Ultimately, the experiment demonstrated seamless interoperability between different digital networks across technology stacks using the Swift connector.

Participants highlighted the potential of this solution to reduce trade payment delays, enhance trust among trade parties, and significantly lower transaction costs. Participants also provided valuable insights into potential areas of improvement and additional features that could be incorporated in future iterations.

Next steps

In 2024, as part of our wider strategy to support the digitisation of trade, we will continue to engage with our members, and with the broader trade industry, to address additional challenges in the areas of legal interoperability, technical accessibility, ecosystem-wide standards and adoption. We plan to bring together multiple trade initiatives, such as this work on CBDCs and our recently reported work on Electronic Bills of Lading (eBL), to explore how Swift can play an important role in enabling digitisation and interoperability. We aim to prioritise initiatives that could have a tangible near-term impact on the trade ecosystem.

Some of the areas to be explored are:

- **Wider implementation:** Expanding the implementation to include more global trade participants, providing a more comprehensive testing environment.
- **Advanced regulatory compliance features:** Integrating advanced regulatory compliance features to navigate the complex landscape of international trade law.
- **Deeper integration with existing financial systems:** Ensuring deeper integration with existing financial systems and infrastructures to facilitate a smoother transition to this new paradigm of trade payments.
- **Developing an eBL interoperability model:** Working closely with the eBL platform providers to facilitate the exchange of data between eBL platforms and banks over Swift with a standardised API layer, thereby enabling different systems to interoperate via a single connection and single identity.
- **Promoting the eBL Declaration:** Continuing to encourage banks and corporates within our community to sign the Declaration as part of the industry's drive to deliver faster transactions, reduce costs and lower fraud risk through the use of digital authentication systems.
- **Assessing the value of a trade repository:** Collaborating with our FIT Alliance partners, we will assess the value of creating a trade repository to eliminate the need for a 'peer-to-peer' integration and share digitised files in a standardised and secure way.

Taking into consideration ongoing global trade initiatives at Swift, our efforts will be geared towards evolving this solution, embracing a network of networks approach, and integrating AI – all of which is intended to help shape the future of international trade payments.

Use case 2: Foreign exchange

We believe there are benefits to researching new market constructs, enabled by technological innovation such as DLT-based CBDC networks.

Background, problem statement, key objectives

The foreign exchange market includes all aspects of buying, selling, and exchanging currencies at current or determined prices. In terms of value, it is the largest financial market in the world, trading about $7.5 trillion a day as reported by the BIS.

Today, FX trade and settlement are two different steps. FX trades require both a buyer and a seller, and a way to match them in order to settle. While the markets for highly traded currencies like the United States Dollar, Euro, British Pound Sterling, Swiss Franc and Japanese Yen are highly efficient, other currencies can be less efficient. Platforms like CLS support the world's largest currencies and mitigate settlement risk accordingly. Currencies not supported by CLS need to go via other routes, which can entail settlement risk due to unsynchronised currency flows.

The feedback from the first sandbox exercise revealed an appetite for exploring new market structures which can effectively collapse the two steps of trade and settlement into a single step. We believe there are benefits to researching new market constructs, enabled by technological innovation such as DLT-based CBDC networks.

The key objective of this use case was to explore newer models. Multiple models were presented to the working group, and by popular demand, two approaches were shortlisted for sandbox experimentation. These are outlined below:

A. International Foreign Exchange Marketplace (IFX): A conceptual solution which explores how CBDCs issued in different jurisdictions can be both traded and settled on a single network in a safe and efficient manner. The marketplace explores trading and settlement of spot FX transactions between commercial banks using CBDCs.

B. CLS-inspired settlement system: There was enthusiasm for exploring an alternative solution which builds on the existing ecosystem structure. This solution leverages the capabilities of a CLS-like settlement engine to mitigate settlement risk for cross-CBDC FX settlement, with similar protection as for fiat currency.

Approach A: International Foreign Exchange (IFX) Marketplace

High level solution

Central banks around the world are exploring the design of CBDCs, their implications, and the innovation that they can bring. In this experiment we investigated and developed a secondary network, the International FX Marketplace, which uses multiple CBDCs to facilitate efficient, secure, real-time FX trade and settlement, with the potential to reduce the cost of international transactions. By leveraging distributed ledger technologies, CBDCs inherently include features like atomic settlement/swaps, if transactions occur within a single network.

For the purposes of this experiment, a simple FX trade functionality was built which could be expanded and enriched in the future. The experiment focused on providing an infrastructure that would enable participants to simulate various FX trade scenarios, and provide feedback on how this concept could be further enhanced (see Figure 4). This experiment also lays the foundation for a network on which further models like Automated Market Makers could be explored in the future.

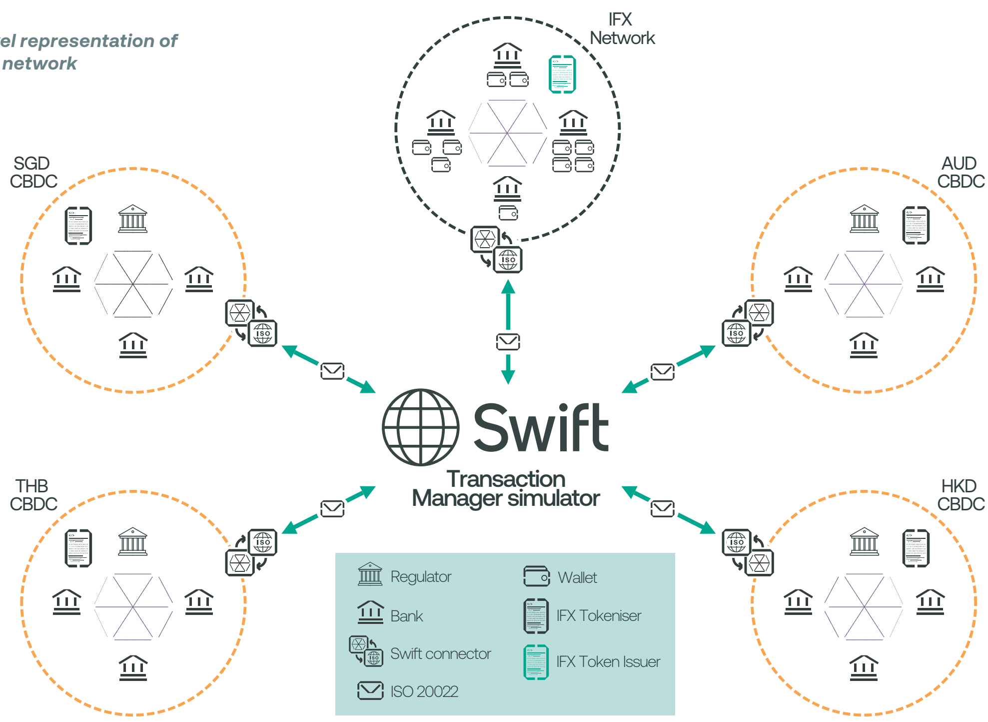
Central to the solution is the implementation of a decentralised network or marketplace that can facilitate FX currency trading and settlement.

Participants in the network are global financial institutions with access to multiple CBDCs. The solution requires a designated 'Network Authority' role, which is responsible for maintaining the network and safekeeping smart contracts. This network can hold various equivalent ERC-20 currencies belonging to domestic CBDCs.

Design and development

- **Issuance.** In the first instance, institutions transfer funds from domestic CBDCs to the IFX network. The issuance of tokens is facilitated by an 'IFX Tokeniser' smart contract developed on the CBDC network.
- **FX trade.** Once currencies have been transferred and made available on the IFX network, institutions can then conduct spot FX trades. Smart contracts developed on the IFX network swap the currency pair between the institutions as agreed in the IFX smart contract.
- **Redemption.** After an FX trade is complete, and the required currency has been obtained, currency from IFX can be redeemed on the domestic network through the redemption process.

Figure 4: High-level representation of the simulated IFX network



Approach B: CLS-inspired settlement system

Background

CLS runs the world's largest multicurrency FX settlement system, CLSSettlement. It is used by 74 settlement members and more than 35,000 indirect participants, and settles an average daily value of approximately USD 6.5 trillion in 18 of the world's largest currencies. CLS settles in central bank money with funding and de-funding being effected through the real-time gross settlement (RTGS) systems of the participating currencies.

CLSSettlement mitigates FX settlement risk by synchronising the settlement of payment instructions for the two currency legs of an FX trade. It provides PvP functionality, in which a party's payment instruction in one currency is not settled unless the corresponding payment instruction in the counter currency is settled.

Cross-CBDC settlement

This settlement risk, which is currently addressed for fiat currencies, will also exist with CBDCs if no similar protective arrangement is organised at industry level.

In a world where RTGS systems and CBDCs will coexist, participants will want to leverage existing industry capabilities to continue mitigating FX settlement risks and accelerate the digital journey. Swift and CLS therefore collaborated on a cross-CBDC settlement use case to explore the synergies between the Swift connector and CLS' capabilities. To meet this use case, Swift simulated a sandbox set up with multiple domestic CBDC networks in a two-tier architecture that allows central banks to issue CBDCs/central bank money to financial institutions (FIs). In the resulting model, which replicates the model currently in place with RTGS systems, CLS has a node in each of the domestic CBDC networks and is able to hold and transact in CBDCs.

The experiment required the design and development of a lightweight CLS processing engine. This processing engine was inspired by the existing CLS settlement service, with a focus on basic multilateral netting and settlement capabilities. While today's set-up provides one daily settlement window, three settlement sessions at different times of the day were considered for this experiment.

CLS processing takes place outside the chain, linking different CBDC networks using the Swift connector and Swift Transaction Manager simulator. FX trades that have been pre-matched and confirmed by FIs are uploaded to the CLS processing engine. Multilateral netting is performed by the CLS processing engine and the netted position for each session is provided to the FIs and CLS on the network. FX trades then undergo atomic settlement using the Swift connector and Swift Transaction Manager simulator. See Figure 5 for details of how the CLS-inspired settlement system was set up.

Design and development

- **FX trade.** FIs trade with each other using their existing trading venues. Payment instructions for the two legs of each trade are sent to CLS.
- **Multilateral netting.** At the times configured in the system, the CLS processing engine conducts multilateral netting for every settlement cycle. After netting is finished, the engine informs FIs about their pay-ins and pay-outs in their respective CBDCs.
- **Settlement cycles.** The domestic CBDC networks each have a set of FIs eligible for settlement with CLS. Pre-matched FX trade instructions, with session IDs indicating a settlement cycle, are received by the CLS processing engine from the participating banks:
- Three settlement cycles are performed by the CLS processing engine every 24-hour period for five days per week.
- The settlement cycle is configured in a way that broadly aligns with the time zones of APAC, Europe, and America.

Atomic settlement

CLS is a participant/node in each of the domestic CBDC networks, with permission to hold and transact in CBDCs. It has preauthorisation to pull funds from FIs, which is needed for settlement. The CLS processing engine initiates transactions across networks, pulling funds (pay-ins) from the FIs due to pay, conducting settlement, and pushing funds (pay-outs) to the FIs due to receive payment.

Each settlement cycle is composed of three steps which occur simultaneously on an all-or-nothing basis (i.e. atomic):

1. **Pay-in of net amount** – CLS debits FIs' accounts/wallets in CBDC where they have short positions (pull), and credits the account/wallet of CLS in the CBDC. This differs from market practice today, which uses a 'push' rather than 'pull' model.
2. **Settlement of gross amount** – the CLS processing engine settles the individual underlying FX instructions on the FIs' account/wallets on the CLS processing engine.
3. **Pay-out of net amount** – CLS debits the account/wallet of CLS at the CBDC and credits the FI account/wallets in the CBDC where they have long positions (push).

Formats

The native DLT format is used for all communication on the chain and within the CBDC networks. The Swift connector and Swift Transaction Manager simulator facilitate message format conversion between the CLS processing engine and CBDC networks.

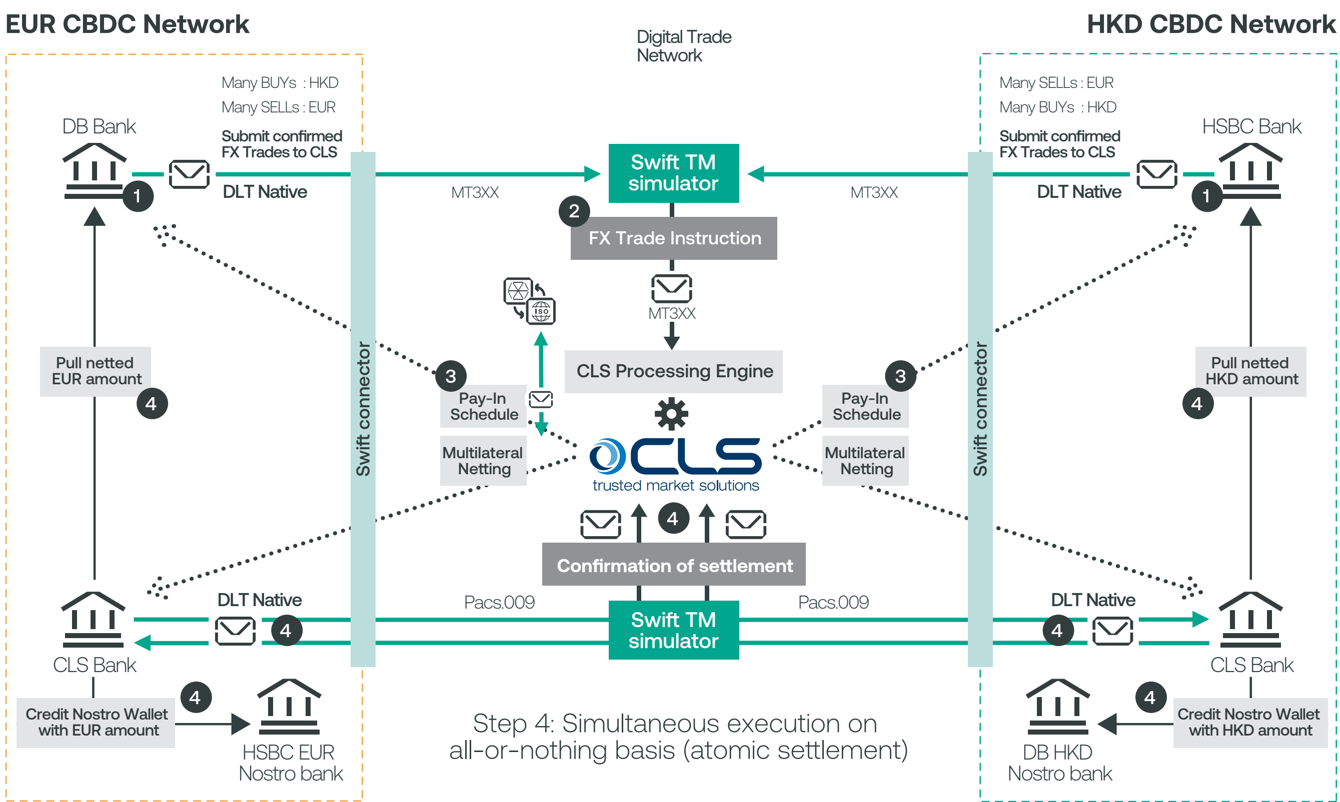


Figure 5: Experiment set-up of the CLS-inspired settlement system

Both models successfully demonstrated technical feasibility by fulfilling the requirements set out by the working group.

Overall results and feedback

Both models successfully demonstrated technical feasibility by fulfilling the requirements set out by the working group.

The IFX Marketplace showed how technology can be leveraged to experiment with newer models, whereby central banks can manage CBDCs without necessarily operating or controlling the underlying infrastructure. Commercial banks could use CBDCs to engage in instant FX trading and settlement, avoiding credit and settlement risk and improving efficiency. Future considerations for such models should include the legal, governance and regulatory aspect of operating such decentralised networks, the incentive mechanism for commercial banks to participate in such an arrangement, and nonfunctional capabilities like security, scalability and data requirements.

The CLS-inspired settlement system demonstrated how an existing critical infrastructure, widely adopted by the FX industry, could successfully be used to remove settlement risk from cross-CBDC transactions, as it currently does for fiat currencies in central bank money. Through a simulated CLS processing engine, we demonstrated how standard matching and netting can bring material liquidity optimisation. Netting capabilities embedded into the CLS processing engine significantly reduce the amount for liquidity needed to settle FX transactions, especially when fragmentation of liquidity due to pre-funding of accounts is required.

In addition, the experiment explored the possibility of using multiple settlement cycles to strike a balance between atomic/instant settlement, and settlement and liquidity optimisation ('molecular settlement'). It also tested the conduit for timed payment synchronisation, which is essential for efficient PvP settlement.

As CBDC live trials gain momentum, some considerations for future exploration are as follows:

1. Move from the simple and basic process flow of the CLS processing engine to a more sophisticated and realistic set-up, for example by including a CBDC network on one side and a fiat currency through its local RTGS on the other side.
2. Bring in real world considerations such as failure cases, e.g. due to insufficient liquidity.
3. Broaden the analysis of non-technical aspects (e.g. legal, regulatory, geopolitical).

Next steps

Through the interactive collaboration sessions, participants provided valuable input for Swift to consider as we continue to enhance our interlinking solution.

In the FX space, Swift's approach is to support innovation that fosters frictionless, risk-free cross-currency flows. Given the increasing market demand for on-chain settlement of cross-border payments and FX trade, a beta version of Swift's interlinking solution will be enhanced to support a PvP use case. With the enhanced version, we will aim to support industry test initiatives around PvP use cases. This will provide valuable feedback to help develop a genuinely useful solution for the community.

CLS will continue to engage with its community to gather feedback on the experimental solution. We will continue to engage and collaborate with CLS as a trusted partner in order to enhance the solution further.

Use case 3: Delivery-versus-Payment (DvP)

This exercise involved the interlinking of multiple asset and cash networks to facilitate DvP in a cross-border setting where the buyer and seller are in different CBDC networks.

Background, problem statement, key objectives

The industry interest in tokenised assets is being driven by demand for improved liquidity, lower transaction costs, enhanced transparency, and security. By allowing fractional ownership, tokenisation opens up investment opportunities to a wider audience, democratising access to assets that were previously out of reach for many.

Tokenised assets offer a digital alternative to traditional securities settlement processes, which often take place over multiple days. Smart contracts can automate and expedite the settlement process and automatically execute transactions when predefined conditions are met. This efficiency reduces the time from trade initiation to completion. However, a central challenge to the wider adoption of tokenised assets is the lack of interoperability and maturity of tokenisation platforms. Each platform may operate on a different underlying digital ledger technology, which may be incompatible with other systems or applications without introducing additional means of connecting them.

Cross-chain bridging protocols are presented as a potential solution to interoperating between disjointed tokenisation platforms and digital ledger technologies more broadly. However, these bridges have been repeatedly attacked and exploited, leading to billions in stolen cryptocurrency over the past few years, demonstrating a lack of security and technological maturity.

Blockchain-based interoperability

In 2023, Swift and its community explored an approach to blockchain-based interoperability to remove friction from tokenised asset settlement. Building on Swift's existing position in securities, the model enables institutions to interact with different public and private blockchains using Swift as a central connector. Financial institutions may leverage their existing Swift infrastructure to build and send MT messages, which contain instructions to move tokenised assets across different blockchain systems. This experiment demonstrated the seamless integration of bridging solutions with existing message standards.

Transforming DvP

Today, live digital assets networks often fall short of providing optionality for the payments leg. Assets and cash are issued on a common platform to reduce complexity around interoperability. The objective of this use case was to explore alternate solutions.

This exercise involved the interlinking of multiple asset and cash networks to facilitate DvP in a cross-border setting where the buyer and seller are in different CBDC networks. The same solution can be implemented in a domestic setting where buyer and seller are in the same cash network.

In addition, the experiment also explored the technical feasibility of locking asset tokens via a smart contract implemented on the network. Upon successful DvP confirmation, the custodian was trusted with executing the release of the asset tokens. This process ensured that the seller had the ownership of the tokens until a DvP was executed.

High level solution

The sandbox set-up for this use case included multiple DLT networks as follows:

1. **The tokenisation platform built on Hyperledger Besu.** This platform acts as a trusted network for a global securities exchange involving a regulated tokenised asset issuer and a network authority – for example, with a Central Securities Depository acting as the platform operator. Hyperledger Besu was chosen as the technology for the platform based on the participants' request to support Besu, given its common use as a technology for digital asset platforms.
2. **The buyer's and seller's CBDC networks built on Corda or Hyperledger Fabric.** These CBDC networks have the buyer's bank and seller's bank as direct participants, through which payment settlement is instructed.

Interface and application layer

The solution features a simple and straightforward front-end, providing users with various securities trade offers. The interface and underlying application layer enable activities such as purchase request creation, validation and confirmation, as well as the monitoring of key transaction milestones.

The application layer manages requests from the user interface. These include validation of the request against the corresponding trade offer, generating offline signatures for on-chain asset delivery, and generating messages for communicating across networks via the Swift connector.

DLT and smart contract layer

At the core of our solution is the DLT and smart contract layer which maintains consistent records of transactions – thereby providing greater transparency over business contract logic and transaction monitoring. Each of these networks implements several smart contracts to enable payments or asset delivery.

The tokenisation platform supports the buying and selling of simulated tokenised bonds, with payment events taking place across two separate CBDC networks. During the experiment, participants interacted with the system through their respective dashboards, executing DvP scenarios by acting as a buyer for each test. The use of smart contracts as asset escrow accounts ensured that payment events could occur atomically, with final settlement of the tokenised asset to the buyer's own wallet.

At the core of our solution is the DLT and smart contract layer which maintains consistent records of transactions.

The process flow is as follows:

- **Off-chain signatures** (see Figure 6, step A) Off-chain signatures are generated by the buyer via their bank application and embedded in a message to be relayed to the buyer's CBDC network via its Swift connector.

  Our blockchain interoperability experiment enabled us to adapt Ethereum-based standards for off-chain signatures to this application-specific use case, which was rooted in a separate set of requirements including integration with the Swift connector. As a result, each system of off-chain signatures is compatible only with the corresponding set of smart contracts, which can correctly validate those signatures and relay them to additional contract methods as needed.

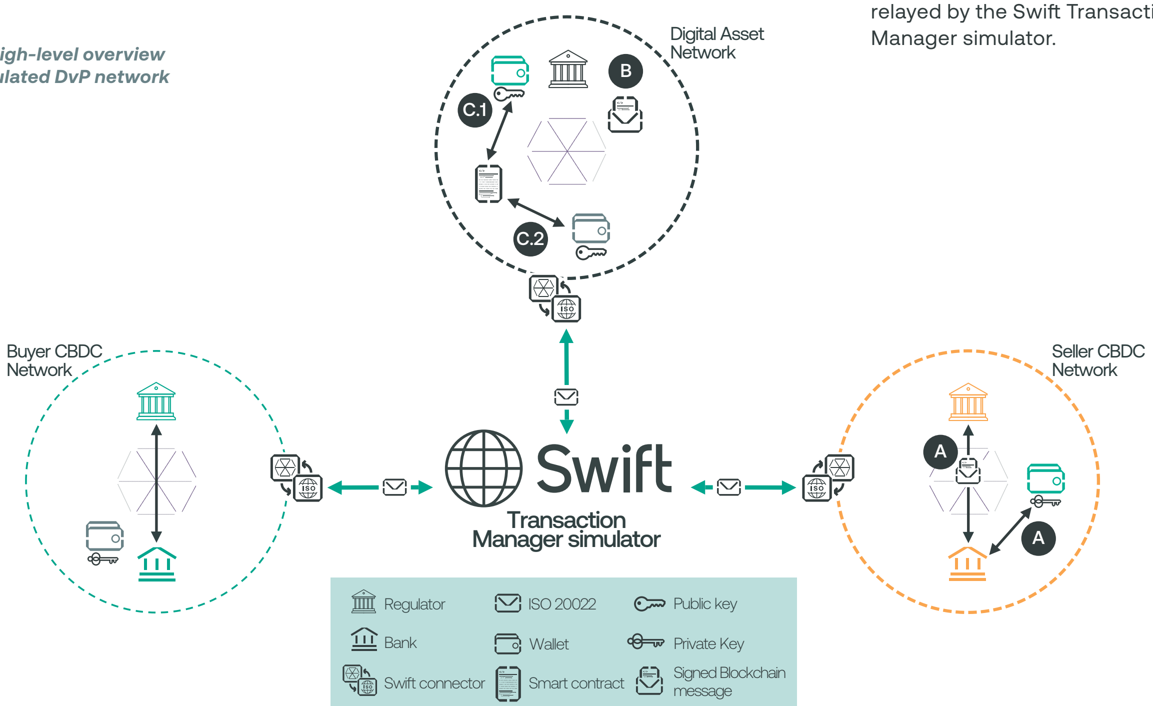
- **Execution** (see Figure 6, step B) The off-chain signatures specific to this use case also demonstrate the capability of delegating a trusted third-party to execute the underlying instructions at a later point, on behalf of the signer. By combining this off-chain signature and delegation with a series of confirmation messages orchestrated by the Swift Transaction Manager simulator, each trade executes atomically with the corresponding transfer of funds.

- **Delivery** (see Figure 6, step C) For the delivery leg, each seller has a corresponding smart contract wallet which helps facilitate the two-stage delivery process of the tokenised asset. This smart contract wallet exists as a single smart contract for each seller.

  The two-stage delivery process is as follows:

1. The asset is escrowed and stored at this contract until payments are received.
2. Final settlement occurs from the appropriate smart contract wallet to the relevant buyer once payment confirmation has been received and relayed by the Swift Transaction Manager simulator.

Figure 6: High-level overview of the simulated DvP network



The system reliably executed automated payment events based on asset exchange milestones and confirmation messaging.

Pre-configured entities

The simulated tokenisation platform includes pre-configured entities, such as the issuer responsible for asset issuance and minting, and the tokenisation platform operator. Securities trade offers were also pre-configured but provided a sufficient dataset to enable comprehensive testing across all in-scope scenarios.

Results and feedback

The sandbox experiment allowed for testing to simulate real-world DvP scenarios, which involved the creation and fulfilment of tokenised asset purchase requests, along with automated payment and delivery execution.

The experiment demonstrated the following:

- **DvP through integration with multiple digital networks.** We tested the integration of the existing CBDC networks with a tokenisation platform simulated on Hyperledger Besu, emphasising straight-through processing of transactions between multiple disparate networks built on different technology stacks.
- **Atomic DvP orchestration.** The primary focus for this use case was to demonstrate atomic cross-border DvP scenarios. This included testing automated triggers, from payment and asset escrow events to final settlement of funds and delivery of the tokenised asset. The system reliably executed automated payment events based on asset exchange milestones and confirmation messaging.
- **User interface interaction.** The interaction of various trade participants through customised dashboards was a key focus area, ensuring alignment on ease of use and clarity in the trade and payment processes.

Next steps

Through the interactive collaboration sessions, participants provided valuable input for Swift to consider as we continue to enhance our interlinking solution.

Given the increasing market demand for on-chain cash for the settlement of tokenised assets, a beta version of Swift's interlinking solution will be enhanced to support DvP use cases. As we continue to develop the Swift connector, we will aim to support industry test initiatives around DvP use cases, which will provide valuable feedback to help develop a genuinely useful solution for the community.

Use case 4: Liquidity Saving Mechanism (LSM)

The objective of this use case was to explore models which can help reduce the fragmentation of liquidity.

Background, problem statement, key objectives

Liquidity Saving Mechanisms (LSMs) are sophisticated algorithms used in the financial industry, particularly by banks and other large financial institutions. Their role is to optimise the processing of payments and settlements in a way that minimises the need for liquid assets, while still ensuring the timely and efficient completion of transactions.

With the rise of digital currencies and assets, fragmentation of liquidity is a real concern, particularly when considering atomic settlement across different payment systems. Many digital currencies and blockchain platforms operate in silos, lacking native interoperability. For atomic settlements to function seamlessly across different currencies and platforms, a robust framework is needed for cross-chain transactions.

Liquidity costs, meanwhile, are driven by three factors:

1. **Operational cost:** Driven by manual and repetitive processes.
2. **Opportunity cost:** Driven by the need to maintain cash/collateral across multiple parties to enable settlement across multiple systems such as nostros, central counterparties (CCPs), custodians and CLS.
3. **Tokenisation:** Driven by the need for instant atomic settlement, requiring accounts to be pre-funded in the dedicated systems. This will lead to further cost and fragmentation of liquidity.

The objective of this use case was to explore models which can help reduce the fragmentation of liquidity, thereby reducing the costs and risks associated with holding high levels of liquid assets across different payment systems. Developing and adopting standards for interoperability is essential when it comes to facilitating liquidity in a multi-currency, multi-platform environment.

High level solution

The working group discussions explored the following two approaches:

Approach 1: Can smart contract-enabled payment tokens help with effective liquidity management?

DLT-based payment tokens with smart contract programming logic can enable near-real-time or programmed settlement of transactions, without the need for manual intervention. This immediacy reduces the need for holding large amounts of liquidity in anticipation of transaction settlements, thus freeing up capital that can be used more efficiently elsewhere.

Instant repo in domestic markets, and liquidity management across CLS settlement cycles, were the two use cases discussed through the exercise.

Approach 2: Can LSM algorithms optimise netting between digital networks?

The LSM experiment carried out by Project Ubin involved simulating a payment system in which transactions between parties could be settled in real-time on a blockchain or DLT platform. The LSM was tested for its ability to aggregate multiple transactions, netting them off against each other to minimise the total amount of liquidity needed for settlements. This approach is particularly useful in a system where participants have multiple incoming and outgoing payments, as it allows for more efficient use of funds.

Taking inspiration from the above experiment, the working group explored the potential of a netting algorithm implemented at the Swift Transaction Manager simulator, which orchestrates transactions between multiple digital networks. See Figure 7 for an overview of the proposed approach.

High level flow

1. Payments are submitted in a central queue maintained at Swift Transaction Manager simulator.
2. Offsetting payments are matched to create an optimised net position.
3. Banks receive a notification to initiate a new payment instruction, created with the netted amount.
4. The Swift connector facilitates settlement across networks with new payment instructions.

The netting capabilities can be utilised in different scenarios and to meet different needs. For example:

1. Financial institutions can agree to participate in a market utility such as this based on consent.
2. Netting is initiated based on payment types.
3. Netting is triggered as part of business continuity to ensure the timely settlement of end customer payments.

Results and feedback

There was a consensus among the working group participants about the challenges presented by the fragmentation of liquidity between emerging digital networks. However, participants also observed that these digital networks currently lack maturity and scale.

Due to the nature of the use case, the solution was a paper-based exercise. The Swift team conducted additional bilateral discussions with a subset of participants to understand the need for exploring or building such a solution. There was a clear support for implementing netting capabilities at Swift Transaction Manager; however, this was seen as a medium-term rather immediate requirement.

Next steps

There are no immediate next steps for this particular use case. We will continue to explore this solution as a paper-based exercise this year. Swift is additionally funding research around liquidity optimisation through payment tokens.

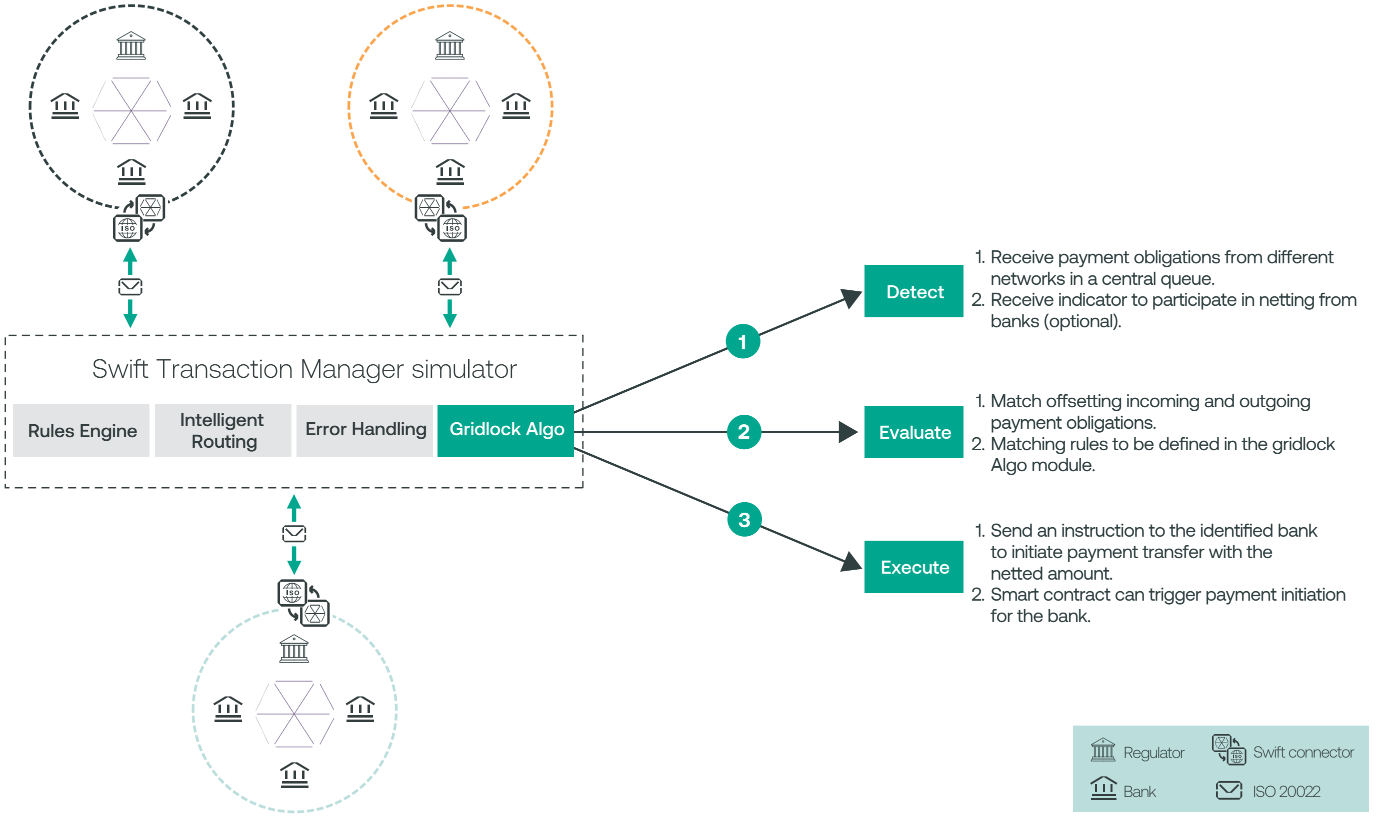


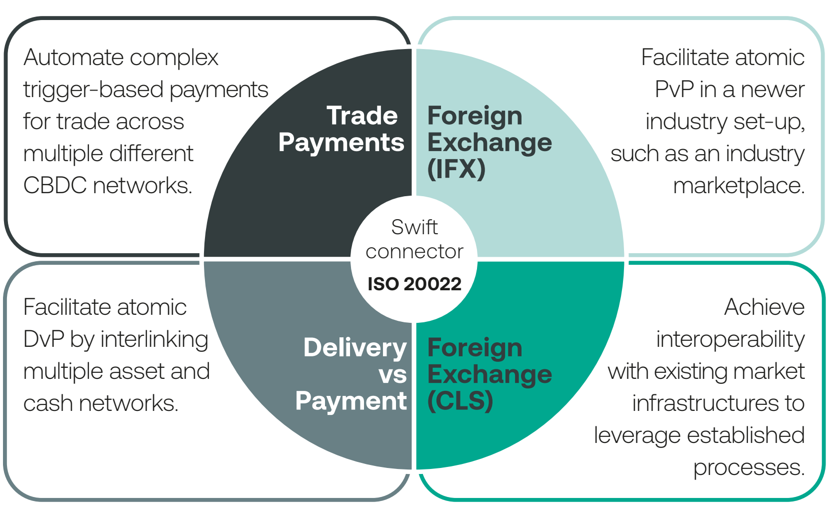
Figure 7: Net obligations between platforms via Swift connector and Swift Transaction Manager simulator

Key findings

The feedback received through the working group sessions and the technical sandbox experiment has corroborated key findings across the use cases outlined below. The feedback from participants on the capabilities of the Swift connector is also summarised in Figure 8 below.

- **Trade payments:** Tokenisation built on the foundations of digitised trade has clear potential when it comes to improving efficiency, reducing costs and minimising fraud. We demonstrated how complex workflows for cross-border trade payments can be automated and orchestrated through the Swift connector in order to settle preauthorised payments on a 24x7 basis.
- **Foreign Exchange (IFX):** There was excitement about exploring alternate spot FX trading and settlement solutions, such as the conceptual International Foreign Exchange Marketplace. We demonstrated how CBDC issued in domestic networks can be escrowed, wrapped with rules if needed, and re-issued on an external network through the Swift connector by maintaining the integrity of tokens. Central banks can have visibility over tokens for monitoring purposes, without necessarily managing the marketplace infrastructure. Much future work would be needed on multiple aspects of the IFX concept, including legal and regulatory issues, commercial incentives for banks to participate in such a network over existing FX markets, and the development of more pioneering models like Automated Market Makers for cross-border FX trade.
- **Foreign Exchange (CLS-inspired settlement engine):** This joint effort by CLS and Swift demonstrated the value-add that a CLS-inspired netting and settlement engine brings to the FX market, and the potential to settle in CBDCs alongside RTGS systems. The Swift connector demonstrated seamless interoperability between the new and existing market infrastructures.
- **Delivery-versus-Payment:** In order to scale digital assets platforms that are either already live or soon to go live, interoperability with multiple on-chain and off-chain cash networks is absolutely critical. We demonstrated a true atomic exchange of digital assets vs. CBDCs in a cross-jurisdictional set up facilitated and orchestrated by the Swift connector.
- **LSM:** Based on the feedback from the working group session and multiple bilateral interviews that we conducted, it became clear there are multiple reasons for why financial institutions choose to fragment their liquidity. These may include risk management, business continuity, customer preference and cost of payment. There is no immediate demand to explore this use case any further in the short term.

Figure 8: Summary of the Swift connector capabilities per use case



Conclusion and next steps

The Swift connector is capable of supporting a variety of emerging interlinking models via a standardised approach that can help reduce fragmentation.

The second phase of Swift's CBDC sandbox project has received great support from the financial community. The participants valued the opportunity to engage with other central and commercial banks across the globe, exchange knowledge, and share views about important design considerations for different use cases. As such, our collaborative innovation approach has delivered results that can benefit the whole industry.

While we learnt that there is no one single model for interlinking, our experiments demonstrated that the Swift connector is capable of supporting a variety of emerging interlinking models via a standardised approach that can help reduce fragmentation.

All participants agreed to three guiding principles for interoperability which are detailed below and summarised in Figure 9:

1. **Interlinked networks:** With the rise of DLT-based networks, it is essential to ensure native technical interoperability between multiple networks, agnostic of the asset class and technology platform. To achieve interlinking in a standardised and scalable manner, there is an opportunity to leverage the industry's investment in ISO 20022 messaging as the common language for payments across new and established networks.
2. **Single point of access:** Most financial institutions want to re-use their investments in infrastructure and are relying on Swift to provide a single point of access to multiple digital networks. This will bring down the cost of participation in the networks. It will also benefit the networks by bringing additional volume through Swift messaging and interfaces.
3. **Co-existence:** We foresee a world in which new digital networks will co-exist with traditional market infrastructures, so it will be important to provide seamless communication and interactions between the new and the old.

What's next?

Following the conclusion of these experiments, we aim to continue our collaborative innovation in 2024 with our global community. We will be working on two distinct initiatives in particular:

1. Develop Swift connector – beta version 1.5

We will continue to enhance the Swift connector to support additional PvP and DvP use cases, while working on functional enhancements to improve the connector's capabilities in line with community feedback. We will also add more technical capabilities identified through the exercise such as:

- The ability to implement smart contracts on digital networks that are based on different DLT technologies.
- The ability to cryptographically lock/release tokens on digital networks that are based on different DLT technologies.
- The ability to port/move tokens between networks while ensuring integrity of token data, signature and embedded programmability.

We further aim to develop a productisation roadmap for the Swift connector, based on market developments and readiness.

2. Industry interoperability initiatives

In parallel, we plan to demonstrate how the Swift connector can be extended to interlink other networks such as bank-led tokenised deposit networks, and thereby enable network effects. We will also support the community in driving innovation in this area forward by convening industry groups and contributing to core network capabilities.

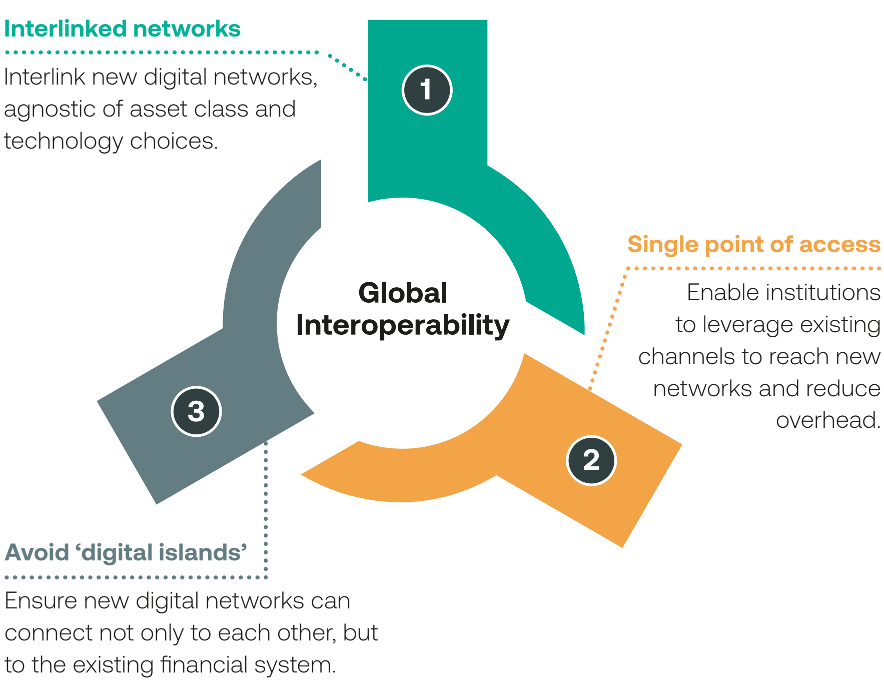


Figure 9: Guiding principles for interoperability

Want to learn more?

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

Acknowledgments

Swift would like to give a special thanks to the 175+ colleagues from the 38 central banks, commercial banks and market infrastructures that participated in this sandbox project.

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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.

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