# EUROSYSTEM EXPLORATORY WORK ON SETTLEMENT IN CENTRAL BANK MONEY

# TOKENIZED CORRESPONDENT BANKING

Contents

## Executive summary

In the context of the Eurosystem Exploratory Work, the Tokenized Correspondent Banking project, led by the European Central Bank (ECB) in collaboration with Banque de France (BdF) and Crédit Agricole Corporate and Investment Bank (CACIB), explores the use of decentralized technologies to modernize interbank settlements using wholesale Central Bank Digital Currencies (wCBDCs). Tokenized Correspondent Banking project aims to investigate how wCBDCs can enhance interbank processes by leveraging Distributed Ledger Technology (DLT) for more efficient, secure, and transparent transactions.

It serves as a proof of concept for integrating blockchain-based solutions within cash correspondent banking frameworks. The experiment tests the feasibility of wCBDCs for immediate interbank settlements and highlights potential benefits, including improved liquidity management, reduced reliance on intermediaries, and real-time transaction processing. The project architecture incorporates the DL3S platform developed by BdF and the so|cash blockchain framework, which enables secure, programmable, and atomic transactions using smart contracts.

This experiment was conducted in multiple phases, including tests with market participants and dress rehearsals under the supervision of central banks. The successful tests demonstrated seamless execution of interbank payments and automated settlement processes. Key scenarios included payments between corporate clients at different banks, interbank transfers using treasury rules, and netting of interbank liabilities, showcasing the practical applications of wCBDCs.

A major highlight of the Tokenized Correspondent Banking experiment was the use of smart contracts and Hash Time Lock Contracts (HTLC) for atomic transaction processing. This ensured secure, simultaneous settlements between participating banks, minimizing risks, and enhancing operational efficiency. The project also showcased how programmable payments could support greater financial transparency and reduce errors associated with traditional systems.

The legal analysis surrounding the Tokenized Correspondent Banking experiment highlighted those current regulations, such as the EU Directive on deposit guarantees, may accommodate digitized deposits within DLT frameworks. However, the project noted that it did not meet in its current form the criteria of a system under the EU Settlement Finality Directive, indicating that further regulatory adaptation is needed in the industrialisation phase. The analysis also highlighted minimal compliance issues, notably under KYC/AML-FT and GDPR regulations, though a future scaling would require comprehensive evaluations.

Key takeaways from the experiment include the potential benefits for financial institutions and customers. The use of wCBDCs supports immediate payments with real-time reporting and continuous balance monitoring, empowering clients with enhanced financial control. Banks benefit from reduced counterparty risk and dependency on traditional intermediaries and gain improved capabilities for managing liquidity and interbank liabilities.

The Tokenized Correspondent Banking project emphasized the importance of certain features for future wCBDC deployment, such as 24/7 availability and programmable automation to support continuous operations and reduce operational risks. The experiment concluded that while technical feasibility has been established, further exploration is required to address governance, legal and operational frameworks, and potential impacts on monetary policy and financial stability.

Moving forward, CACIB aims to continue refining the use of wCBDCs by exploring new mechanisms for exploring other wholesale use cases. The project suggests that future iterations could involve cross-border transactions and different currencies to test scalability. Additionally, examining the economic incentives and viability on implementing on-chain commercial digital money will be essential for broader adoption.

This project lays the groundwork for future exploration and international collaboration, positioning blockchain-based solutions as transformative for interbank settlements. The results point to the need for regulatory evolution and stakeholder alignment to ensure smooth integration of wCBDCs into the global financial ecosystem.

This report presents the results of the experimentation on tokenized correspondent banking using a platform-less blockchain protocol called so|cash. The experimentation project explored on-chain deposit accounts for multiple banks, payments leveraging a tokenized correspondent banking model, and interbank settlement via wholesale Central Bank Digital Currency (wCBDC). Conducted in collaboration with CACEIS and Banque de France, with legal insights from White & Case LLP (Paris Office) as well as coordination and expertise by KPMG France, the initiative also included BNP Paribas, Santander, SEB, and Societe Generale as observers.

The experiment successfully demonstrated the feasibility of a non-platform centric blockchain approach, enabling secure transaction settlements without a centralized dedicated operator. It highlighted the benefits of a unified shared ledger for commercial bank money, showing significant improvements in efficiency and a reduction in settlement risks. The Banque de France's DL3S platform supported wCBDC operations and effectively integrated with the open-source so|cash standard, which enabled on-chain management of deposit accounts. Key objectives included validating interoperability between digital commercial and central bank money, testing real-time liquidity management, and exploring the potential for automation through smart contracts inside a shared multi-purpose ledger.

The project tested several functionalities such as instant transfer, atomic settlements, interbank liquidity management, and programmability. The results underscored the potential of blockchain-based banking solutions to enable real instant payments, reduce operational risks, and immediate execution result.

However, challenges remain, such as integrating with legacy systems, supporting interoperability across multiple currencies and blockchains, and establishing an industry wide adoption.

Collaborative efforts among regulators, market participants, and technology providers; the reliance of a non-proprietary open-source standard are essential to ensuring the secure and effective integration of digital assets into the financial ecosystem without creating few central actors that would become systemic and too big to fail. These findings offer a strong foundation for future advancements in interbank settlement and the broader application of blockchain technologies in the financial industry.

## Acronyms, abbreviations and definitions

BO - Back Office: These are the administrative and support functions that ensure the smooth processing of transactions and administrative compliance.

CBK - Correspondent Banking: A service where one bank performs transactions for another, particularly in cross-border context.

CBDC - Central Bank Digital Currency: A digital form of money issued and backed by a central bank, used in various financial settings. Two forms exist: for individual (rCBDC or retail CBDC) and for financial institutions (wCBDC, see definition).

CeBM (Central Bank Money) – Money issued by a central bank, which serves as a risk-free settlement asset. It includes reserves held by commercial banks at the central bank (for interbank payments) and physical currency in circulation. CeBM is used to settle transactions in payment systems and financial markets.

CIB - Corporate and Investment Banking: Banking services focused on corporate and financial institutions clients, including cash management and correspondent banking.

CoBM (Commercial Bank Money) – Money issued by commercial banks, representing a claim on the bank. It is used for payments and settlements among private-sector participants and can be held in various forms, such as deposits in commercial banks.

DCA (Deposited Cash Account) – A type of account within the Eurosystem that allows financial institutions to hold and use central bank money for specific payment and settlement purposes, such as TARGET2, TIPS, or securities settlement.

DL3S - Distributed Ledger Shared Settlement System: Banque de France's platform for facilitating settlement in central bank money on a shared ledger.

DLT - Distributed Ledger Technology: A decentralized system for recording transactions securely across multiple nodes.

ECB - European Central Bank: The central bank for the Euro, responsible for monetary policy in the Eurozone.

ECT - Exploratory Cash Tokens: Digital tokens tested for experimental purposes on the DL3S platform with the assumption that 1 ECT = 1 Euro.

Eurosystem – The monetary authority of the euro area, comprising the European Central Bank (ECB) and the national central banks (NCBs) of the EU member states that have adopted the euro. It is responsible for implementing monetary policy, ensuring financial stability, and managing payment systems.

EVM - Ethereum Virtual Machine: A computation engine for blockchain compatible with decentralized protocols used in banking experiments.

FX - Foreign Exchange: The exchange of one currency for another, facilitating international trade, investment, and financial transactions across borders.

HTLC - Hash Time Lock Contract: A smart contract feature that enables secure, atomic swaps between parties.

HVP - High-Value Payments: Large-value transactions processed in real-time, essential for the economic infrastructure.

MCA (Main Cash Account) – A central bank account used by financial institutions to manage liquidity and conduct settlements within the Eurosystem. It serves as the primary account for holding and transferring central bank money.

MiCA - Markets in Crypto-Assets: European Directive, adopted in 2023, regulates crypto-asset markets to ensure transparency, consumer protection, and prevention of market abuse.

Nostro Account - An account a bank holds at another bank, used for correspondent banking, liquidity and cross-border transaction management.

OpenAPI - A standard, language-agnostic framework for defining RESTful APIs, enabling developers to describe, produce, consume, and visualize API services using a structured JSON or YAML format.

Platform - A digital infrastructure or environment that supports the development, deployment, and management of applications, services, or technologies. In the context of blockchain, a platform can refer to the underlying technology and framework that enables the creation and operation of decentralized applications and smart contracts.

PvP - Payment versus Payment: A settlement mechanism ensuring that a bilateral exchange of currencies is happening free of delivery risk.

RTGS - Real-Time Gross Settlement: A system for immediate settlement of large-value transactions without netting.

SEPA - Single Euro Payments Area: A system simplifying cross-border euro payments within Europe.

so|cash - A decentralized blockchain standard used to represent bank deposit, enabling on-chain correspondent banking and programmable and instant payments.

SPCB - Solution Provider Central Banks: A service provider specializing in offering technological solutions and frameworks to support central banks in implementing and managing digital currencies, payment systems, and modernized financial infrastructures.

SWIFT - Society for Worldwide Interbank Financial Telecommunication: A global network for financial messaging services.

TARGET2 - Trans-European Automated Real-time Gross Settlement Express Transfer System 2: The European system for processing real-time euro transactions.

TCB - Tokenized Correspondent Banking: A project that explores using decentralized technologies to modernize interbank and central bank money settlements.

wCBDC - Wholesale Central Bank Digital Currency: A type of CBDC intended for interbank and high-value transactions.

# 1. Introduction

The European Central Bank (ECB) has launched several projects and experiments around the digital Euro in the form of wholesale Central Bank Digital Currency (wCBDC), aiming to explore innovative solutions for settling digital assets in central bank money (CeBM). In this context, the Eurosystem is conducting exploratory work on new technologies, particularly Distributed Ledger Technology (DLT), to facilitate the settlement of large-scale financial transactions.

Three interoperability solutions are currently under study by the Eurosystem to foster interaction between TARGET services and DLT platforms, in response to the growing demand for CeBM y solutions for the DLT Pilot Regime, launched in March 2023, and other initiatives.

These efforts aim to (i) consolidate and deepen ongoing Eurosystem central bank initiatives, (ii) gather insights on how different solutions could improve the interaction between TARGET Services and DLT platforms, and (iii) respond to market needs for CeBM solutions suited to DLT infrastructures. Over 60 financial sector companies and four central banks are participating in these trials and experiments[1]. The trials involve transactions with actual settlement in CeBM, while the experiments use a test environment with settlements in simulated money.

Indeed, the High-Value Payments (HVP) market in the Single Euro Payments Area (SEPA) is a crucial part of the European financial infrastructure. This market handles high-value transactions, often exceeding one million euros, and plays an essential role in the smooth functioning of the economy. Large-value payments are mainly processed through real-time gross settlement (RTGS) systems like TARGET2, managed by the Eurosystem. In 2023, TARGET2 processed more than 100 million transactions for a total value exceeding €560 trillion[2].

In this regard, the Tokenized Correspondent Banking project explores the use of decentralized technologies to modernize cash management services and CeBM settlement processes in the context of commercial and interbank exchanges. In a context where instant settlement for retail clients becomes the norm (e-money, SEPA Inst), corporates and financial institutions face a challenge in handling and valuing the flows as they arrive, even outside the normal opening hours. Leveraging wCBDCs, this project aims to provide a settlement solution that capitalizes on blockchain technologies and centralized clearing through Eurosystem infrastructures where execution speed and certainty join with an always open infrastructure. It addresses traditional payment challenges to create a faster, more resilient payment system compatible with the evolving digital economy.

[1] ECB Economic Bulletin, Issue 8/2023
[2] TARGET Annual Report 2023

The experiment was led using the Banque de France (BdF) Distributed Ledger Shared Settlement System (DL3S) platform within the governance of the ECB.

The main purposes of the experiment were to demonstrate:

(i) The feasibility of a platform-less blockchain protocol. It proved that transactions can be securely settled without the need for an intermediary trusted operator.

(ii) The impact of a unified ledger of commercial bank money (CoBM) for the banking industry on the efficiency and the reduction of settlement risks.

(iii) The interoperability model of wCBDC provided on the Banque de France solution, DL3S, with so|cash, an open source standard to represent deposit accounts in blockchain using the properties of distributed ledger to carry out payments services.

The project is purely experimental and does not indicate that the central banks involved intend to issue CBDCs or endorse the proposed technological solution. However, it provides insights for future experimentations and projects in the Payment versus Payment (PvP) dimension and lays the groundwork for defining new use cases in various banking sectors, particularly Corporate and Investment Banking (CIB).

This report presents the experimental architecture of the Tokenized Correspondent Banking project, its findings, and operational and policy considerations for commercial and central banks. Section 2 provides an overview of the project, while Section 3 describes the solution design. Results and the key findings learnings related to the experiment and its framework are discussed in Section 4 and 5. Section 6 concludes.

# 2. Experimentation overview

This section describes the objective and the overall challenges of the experiment, provides an overview of the architecture, including elements related to DL3S, as well as the functional requirements of the main components.

## 2.1 General Context

Nowadays, in the realm of Digital Assets, tokenized deposits and stablecoins stand out as two transformative innovations reshaping the landscape of digital finance. Stablecoins inherit their technical standard from DeFi (mostly ERC20 compatible tokens) and provide efficient interoperability solution in open blockchain ecosystems. However, they rely on different regulation than commercial bank money and European regulation (e.g. MiCA) prevent holders from earning interests on their balance.

Additionally, the issuer of the stablecoin is unique (or a formal cooperation) and must keep an equivalent amount of collateral that cannot be part of the bank liquidity for financing directly the economy.

Tokenized deposits inherit their regulation from the banking industry and provide a great solution for banks to operate their deposit accounts in a shared IT infrastructure (DLT). They however cannot be transferred directly to another bank as they are contracts that embed a relationship between the bank and the account holder.

Additionally, most of current tokenized deposits solutions are deployed in private blockchains and rely on a single operator (either for a bank or a consortium of banks). Participants banks are therefore relying on a mandatory single provider, losing their independence.

This experiment focuses on the challenges of the on-chain banking exchange model, taking the best of both world by leveraging the so|cash[3] protocol. so|cash provides the benefits of any digital form of private money (instant payment, atomic DvP, CBDC compatible) without the limitations of stablecoins and tokenized deposits. This model is further detailed in Section 3.

However, before anything else, it is important to understand the current functioning of banks and how it would operate within a tokenized deposit system.

Figure 1 compares traditional deposit accounts in a conventional bank with those hosted on a blockchain infrastructure, highlighting the fundamental differences in financial flow management and interbank operations. It explores how blockchain-based bank accounts can transform processes by eliminating messaging layers and facilitating greater automation through smart contracts.

[3] https://github.com/so-cash

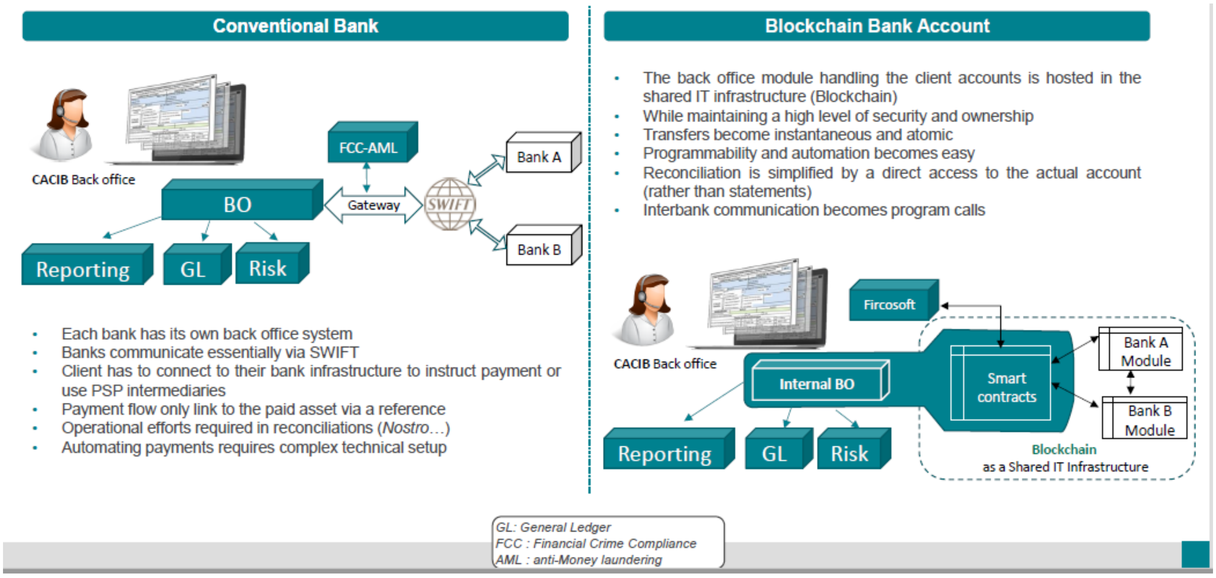


*Figure 1: Description of a deposit accounts on blockchain*

To summarize, the opportunities and pain points in the actual model are:

- **Trend for tokenization of assets:** There is a growing push for a settlement solution leveraging blockchain technology and central clearing within ECB central clearing infrastructures.

- **Payment rails (commercial and central bank):** They operate independently of the reason of payment, leading to risk of fraud and operational errors are requiring additional controls and systems (CSD, e-commerce solution).

- **Payment flows:** These are delayed by multiple intermediaries, primarily providing technical processing.

- **Message-based mechanisms:** Communication between account owners and holders requires reconciliation schemes, negatively impacting efficient liquidity management.

- **Access to central bank money:** Clients of commercial bank do not have direct access to CeBM, but they should benefit from functionalities similar to wCBDC.

## 2.2 Scope and objectives

To achieve the experimentation objectives (wCBDC integration, platform-less on-chain CBK, impact of a unified ledger) some elements were mandatory, and others were postponed for later investigation.

First the solution involved establishing a connection with Banque de France’s DL3S environment to concretely test its functionality and interoperability. Key participants ensured the effective use of DL3S application from their own infrastructure (back-office).

Then, the representation of deposit accounts (smart contracts) in a market DLT (i.e. a different blockchain than DL3S one) by each of the banks and a back-office solution to manage them. Each bank having its own.

Finally, operating inside the market DLT as a "unified ledger", a protocol to establish a secure interaction between the bank's smart contracts.

Detailed test scenarios focusing on the client-to-client EUR payment flow were meticulously defined. Collaborative testing with BdF was subsequently conducted, with the resulting test reports consolidated to assess the system's performance and operational readiness (see Section 4).

Some elements were intentionally excluded from the scope of this experiment, leaving them open for future exploration and discussion, in particular payments between two central banks in different currencies, Foreign Exchange (FX), and SWIFT interconnection.

Additionally, other aspects were deliberately kept out of scope, such as implementation of compliance requirements and safeguards, the use of real money, privacy considerations, contractual terms, and integration with legacy systems. These exclusions were made to ensure a focused and manageable scope while delivering usable conclusions.

With this scope, the experiment was able to explore the following use cases to validate the approach capabilities and confirm its adaptability:

- **Interoperability between digital commercial bank money and central bank money:** this involves testing the feasibility of an interbank payment model on the DL3S platform, and integrating DL3S with commercial bank money represented on third party DLT. This enables instantaneous and atomic exchanges between corporate clients.
- **Corporate client instructing transfer directly to its on-chain account.**
- **Improvement of liquidity and Nostro/Vostro account management:** automating liquidity position management by having commercial banks operate netting and intraday management balance via smart contracts, and simplified reconciliations.
- **Exploration of legal aspects surrounding tokenized correspondent banking.**

### 2.3 High level Workflow

To address these challenges, an open-source DLT-enabled decentralized standard (so|cash) was used to manage deposit accounts and enable payments through these accounts, including transactions between banks. This approach integrates with DL3S technology to support interbank settlement and treasury management in central bank money.

The process primarily unfolds in three main stages:

1. The first stage focuses on **Correspondent Banking on blockchain** involving full atomic transactions (which occur in a single step). It demonstrates how transfer instructions move from Corporate A at Bank A to Corporate B via Bank B using **secure accounts and mechanisms**.
2. The second stage incorporates the dimension of **Central clearing through DL3S** via the HTLC mechanism to secure no spending of the funds while the central bank payment is being made. The exchange between banks uses a DL3S account (or wallet) to validate funds and manage transactions in wCBDC.
3. The third and final stage involves the **Transfer in TARGET2**. This phase includes the conversion or redemption of wCBDC into euros within the TARGET2 system. Bank A and Bank B use their respective TARGET2 accounts to finalize the transaction in real currency (€). In the experiment, this phase is not needed since no real Target 2 money was involved, but it illustrates how in a production environment the availability of balances in DL3S is materialized.

The central diagram, in Figure 2, illustrates a transactional process, where steps numbered from 1 to 8 describe the flow of transfer instructions from Client A to Client B, passing through Bank A and Bank B, and the interactions with DL3S cash and clearing modules.

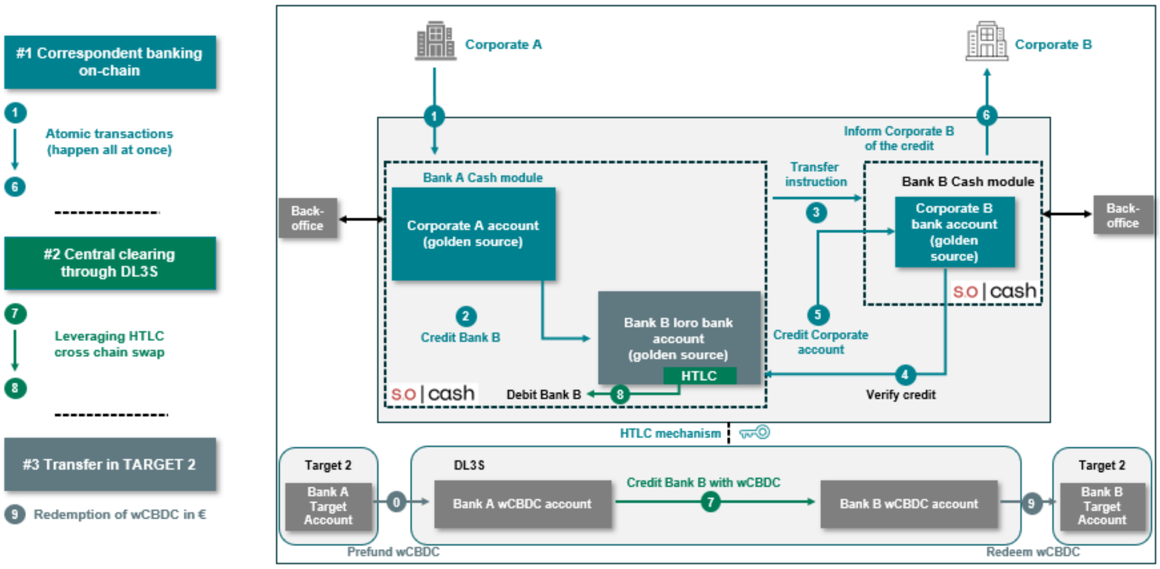


*Figure 2: Experiment to design interbank payment activities on Blockchain*

In summary, this DLT interoperability approach make each payment layer independent from the other. Therefore, the commercial bank money rail (so|cash protocol) can use any type of interbank settlement rail.

### 2.4 High level technical architecture

Before diving into the technicalities, let's introduce the **main participants** in the experiment:

- **Fictitious corporates** acting as owners of commercial bank accounts (named "Corporate A" and "Corporate B").

- **Participating banks** ("CACIB", "CA EU" and "CACEIS") acting as credit institutions to hold deposit accounts and settle interbank payments via wCBDC, with responsibilities including:
  - Issuing and receiving payments between client accounts and interbank correspondent accounts.
  - Managing intrabank and interbank treasury to ensure sufficient liquidity for transactions.

Note that "CA EU" bank is a fictive bank which residency country is in a European state other than France, so its wCBDC account is held with such local central bank (CBY).

The **technological components** included:

- **EUR modules in the form of smart contracts** deployed on the blockchain for each participant bank, ensuring the management of euro deposit accounts and transactions. Note that other currencies could be deployed. Such smart contracts are the heart of the so|cash protocol by exposing a common set of functions allowing them to inter-operate with each other.

- **DL3S nodes**: European local central bank blockchain infrastructure (here Banque de France and CBY) operating in a network to process transactions in ECT (Experimental Cash Token, the representation of a € wCBDC).

- **Off-chain Back Office modules**: a piece of software deployed by each bank to interface their internal infrastructure (user access and existing solution) with their on-chain EUR module and with their respective DL3S node.

All communications between banks occur either in the blockchain via the EUR modules smart contracts, or via their respective DL3S nodes.

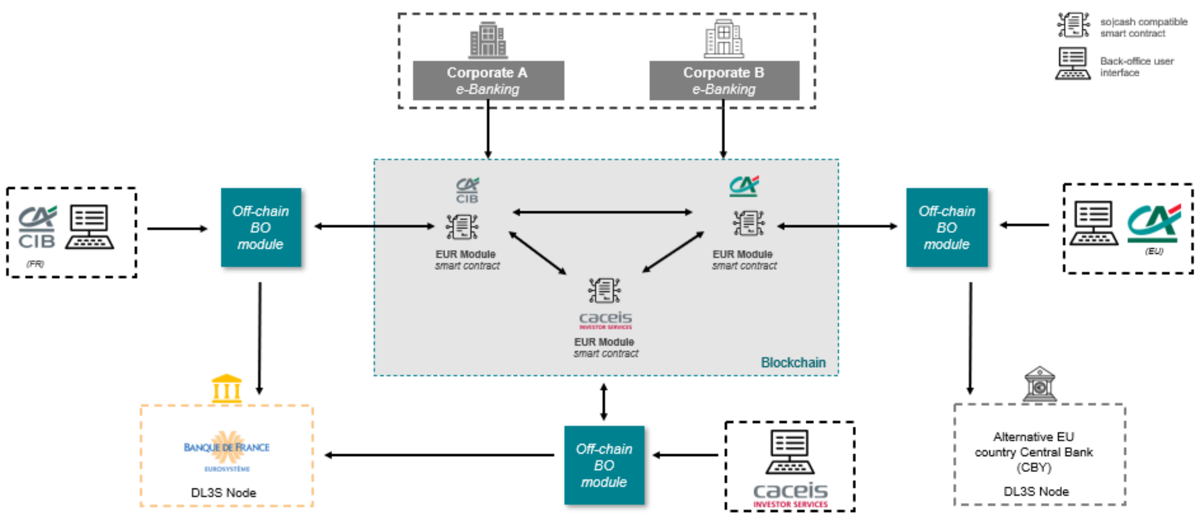

*Figure 3: so|cash - Configuration & High-level IT Architecture*

In summary, the architecture relies on a combination of two different blockchain technologies and off-chain Back Office modules to ensure secure and decentralized transactions between the various entities and Central Banks.

## 3. Solution design

This section describes the design of the solution that was enabled a successful experiment commercial to central banks interaction. It is based on three main components: (i) so|cash, (ii) DL3S and (iii) the off-chain BO module, also called "orchestrator".

### 3.1 Overview of so|cash

**so|cash** is an open source blockchain protocol that allows regulated credit institutions (banks allowed to open deposit accounts) to operate their correspondent banking activities in a public EVM based blockchain.

- **Framework overview:**
  - EVM based smart contracts: Each bank deploys a smart contract that represents, for a given currency, their liabilities toward their clients. Each client account is represented by a dedicated smart contract, the address of which holds its balance.
  - Individually, each bank smart contract exposes ERC20 compatible functions so they can be used via existing libraries and tools, like crypto wallets.
  - In addition, the bank smart contract exposes a set of interfaces. One for the back office (via the off-chain module) to drive the administrative actions; one for the other banks to send payment instructions and check statuses; and one for other parties to read balances and instruct transfer when allowed.
  - The model is open-sourced, maintained on the collaborative online platform GitHub, and intended to be freely accessible and used by any actors taking part of correspondent banking activities on top of blockchain.
  - The model is designed to comply with banking industry laws and regulations under the approach that banks are simply using a shared IT infrastructure to manage their back-office system handling deposit accounts.
- **Features: Accounts on blockchain and atomic correspondent banking**
  - Account holders with capacity to interface with the blockchain can autonomously (or via a third party) access their accounts to get their balance, transaction and initiate instant payments.
  - Banks can rely on their relationship with their partner banks, supporting so|cash, to execute transfers by composing their partner's on-chain account services with their own processing.

This leads to a chain of smart contracts calls reproducing the correspondent banking flows without messaging and with atomic knowledge of payment outcome (success of rejection).

- **Unified Ledger benefits for Instant Payments:**
  - Unified ledger has the meaning of multiple parties sharing a technological solution to record book entries for themselves under a common format/protocol, so that a set of entries done by several parties can be all completed or reversed in a single operation. By extension it also means that such shared solution can accept entries representing any type of assets class (cash, securities, equity, …) therefore making it also a multi-purpose ledger well adapted to instant DvP and PvP.

In the context of so|cash, where multiple banks manage their own ledger of cash liabilities we have the following benefits:

- **Payments can occur between accounts held by two different banks in a single operation** in an "all or nothing" result.

- **Payments become programmable** calls that can be composed within larger programs enabling payment execution when specific conditions are met (generally referred as programmability and composability).

- **All banks' ledgers are updated in one operation** only if all banks applicable conditions are satisfied or not at all (referred as atomicity).

- In an implementation where all banks use the same blockchain infrastructure then **all ledgers' updates are happening inside the same block**, hence having the same timestamp, making them effectively fully simultaneous.

In summary, so|cash implementation presents itself as an advanced infrastructure allowing fast, secure interbank payments, incorporating programmability, instantaneity, and regulatory compliance.

## 3.2 DL3S and wCBDC gateway

The Eurosystem offers three solutions to manage wholesale CBDC: (i) Trigger solution, a direct extension on top of Target2, largely relying on ISO20022 formats; (ii) TIPS Hash Link, an overlay on the instant payment solution; and (iii) DL3S constructed as a network of local central bank operated nodes on the side of the Target2 system.

Without entering in a technical description (as these are available in each respective documentation), the high-level functionalities that they offer is the so-called wCBDC scheme.

A wCBDC is a digital form of central bank money, where, in addition to conventional transfers, it becomes possible to be delivered a secret (provided by the beneficiary) against a successful payment. In addition, there is an expectation that such a solution provides fast and 24/7, cut-off-time free, payments.

The basic protocol for all 3 solutions follows these 3 steps:

- The beneficiary initiates a payment request, sharing a secret, then sharing the hash of such secret to the paying bank via an outside channel with the commitment that the secret will allow the paying bank to get hold of the paid asset.
- The paying bank makes the payment and receives the secret in response.
- The paying bank use the secret to take ownership of the paid asset.

The interesting feature is the reversal of responsibilities compared to conventional payment schemes. Both parties can remove their delivery risk using the trust in the central bank payment system without having to rely on a third party of trust.

Given the uncertainty of the future technological choice of the Eurosystem between the three options, the solution design took the approach of abstracting this future choice behind a software that mask the particularities of DL3S that was used for the experiment. This software is called the CBDC Gateway (not represented in the diagrams for simplicity).

### 3.3 Workflow and orchestration

The figure 4 below displays an interoperability diagram for the end-to-end payment flow in a system involving settlement in wCBDC within a commercial banking context operated with so|cash implementation.

It presents an on-chain payment between two entities: Corporate A and Corporate B.

- **Step 1:** Corporate A initiates a transfer to Corporate B by interacting with the smart contract representing its deposit account held at CACIB.
- **Step 2:** CACIB's so|cash on-chain module controls the transfer request; debits Corporate A's account and credit CA (EU) Nostro account.
- **Step 3:** CACIB's so|cash on-chain module calls CA (EU)'s so|cash module to instruct the transfer.
- **Step 4:** CA (EU)'s so|cash module processes this incoming instruction by first checking its nostro has been credited then it credits the Corporate B's account.
- **Step 5:** Corporate B receives a notification that the funds have been credited to its on-chain account.

Steps 1 to 5 happens in a single blockchain operation (atomicity and instantaneity).

CA (EU) bank is left with a balance on its nostro with CACIB that it wishes to convert immediately into a central bank balance instead. But it does not want its balance to be debited before it receives the money in its central bank account, nor does CACIB wants the nostro account to be spent while it is making the central bank payment. This is where the wCBDC scheme is beneficial.

- **Step A:** The orchestrator (off-chain back-office module) of CA (EU) bank initiate the payment with DL3S (via the CBDC Gateway) generating a secret.
- **Step B:** CA (EU) bank locks its nostro balance using the hash of the secret, by that instructing CACIB that it wishes to get the balance transferred via DL3S.
- **Step C:** CACIB makes the payment via DL3S and receives the secret.
- **Step D:** CACIB can use the secret to unlock the nostro balance and debits it.

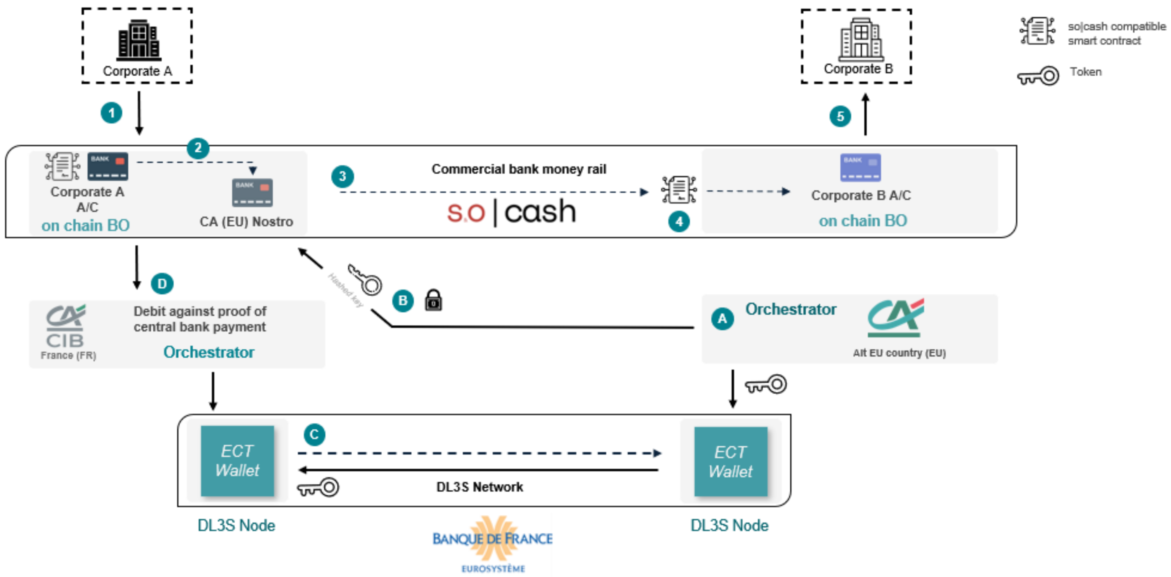


*Figure 4: so|cash / wCBDC - General scheme of interoperability*

Note that Step 2 operates the transfer via the nostro account of the recipient bank. But if the paying bank has enough money in its nostro account at the recipient bank, the transfer is executed as a local transfer from this account to the beneficiary account.

# 4. Use cases and testing

This section provides an exhaustive description of all the use cases studied during the experiment, as well as the technical tests conducted with the Banque de France. It details the verification of the interfacing between so|cash and the DL3S environment, ensuring the successful execution of test transactions. In practice the mandatory process was sequenced with a technical onboarding (called 1B), a rehearsal of the use cases (called 2A), then the actual experimentation with ECB.

While this section offers a thorough account of these processes, it is also possible to proceed directly to Section 5 to review the key findings and lessons learned.

## 4.1 (1B) testing phase – Technical tests with Banque de France

This first testing phase was essentially technical to ensure that all necessary connections and parameters have been established between so|cash and DL3S to conduct the experiment and provided evidence of the successful configuration of the setup.

Key objectives of this initial phase were:

- **Confirm the effectiveness of the solutions' plans to interact with market DLTs through the interoperability mechanism** during trials and experiments prior to the rehearsal tests
- **Improve the knowledge of DL3S environment**, its configuration, and functionalities, prior to the rehearsal tests

After a review of the DL3S protocol and the agreement between Banque de France and CACIB technical team on how the connections and flows will be constructed, each team exchanged the connections details to the other. Indeed, the bank's orchestrators (more precisely the CDBC Gateway) were connecting to their respective DL3S node via an API, and DL3S nodes were connecting to each CBDC Gateway. The information exchanged was:

- For each bank (CACIB, CACEIS, CA (EU)), Banque de France provided CACIB with the API endpoint, a user id, and a password. In addition, a wallet was created in DL3S.
- For each DL3S Node (BdF and CBY), CACIB provided Banque de France with the API endpoint, a user id, and a password.
- For each bank (CACIB, CACEIS, CA (EU)), Banque de France provided a DL3S user interface (URL) and initial admin user access.

Each team tested the API access and successful authentication via console or other technical mean. Each Admin user validated their access and provided access to other operators in their bank.

During this technical initialization the CACIB team was developing the orchestrator against a simulation of DL3S (a mock) generated against the provided OpenAPI definition (swagger file). This was an important enabler to be capable of developing without dependency on BdF planning.

After testing the distribution of ECT in the DL3S wallets and the validation that the DL3S user interface was displaying the actual balance, manual direct transfers were successfully tested.

The next tests involved basic HTLC execution where the steps A to D, described in section 3.3 above, were played in isolation to verify conformance with both API. More technically, and for reference, step A corresponds to calling the "message 1" on the DL3S node holding the wallet of the beneficiary's bank. This message receives the secret with which the receiving bank locks its balance (step B). Then "message 2" is called on the DL3S node holding the wallet of the paying bank, providing the hash (sha256) of the secret to which DL3S respond by calling the paying bank CBDC Gateway ("message 3") providing the secret (both messages forming step C).

With these technical tests, spanning over 3 months, the setup was ready to move to a functional construction phase.

### 4.2 (2A) testing phase – Dress Rehearsal

This dress rehearsal has also been conducted under BdF supervision. Tests would ensure that we successfully complete at least one or multiple end-to-end transactions (depending on the playbook) for the use case explored (including both commercial bank money and wCBDC legs).

Key objectives of the second testing phase were:

- **Test jointly all steps included in the daily process as envisioned during the execution phase of the exploratory work** including: all steps on so|cash and in DL3S environment with market participants.
- **Test all contingency procedures for failure scenarios identified**, with concrete evidence that the defined contingency procedures could provide a sufficiently high-level of confidence in mitigating the risks.

The dress rehearsal has been successfully completed. No failures have been identified. Tests details are available below.

Only basic scenarios were tested, and more focus has been put on the contingency procedures (see section 4.6 Recovery procedures).

### 4.3 Test cases – Scenarios overview

The experiment's test cases were presented to the ECB. This section covers the key aspects of the test cases overview, as well as the sequencing of scenarios associated with each.

- **Test environment:** Test cases were conducted in a sandbox environment involving fictitious clients, accounts, and balances described in section 2.4 above.

- **Client's accounts and bank nostro:**
  - **CACIB** has a so|cash nostro with both CACEIS and CA (EU)
  - **CACEIS** has a so|cash nostro with both CACIB and CA (EU)
  - **CA (EU)** has a so|cash nostro with both CACEIS and CACIB
  - **Corporate A** has a so|cash account at CA (EU)
  - **Corporate B** has a so|cash account with each of the 3 banks
  - **CACIB and CACEIS** have a wCBDC wallet with BdF DL3S node
  - **CA (EU)** has a wCBDC wallet with CBY DL3S node

  It should be noted that so|cash accounts have an actual IBAN number used to fully identify the accounts in the blockchain.

- **Configuration:** Each bank has deployed a dedicated so|cash-compatible back-office module and established a correspondent banking relationship with the other banks (see *High Level Architecture* section for further information).
- **Sequencing:** The experiment included 5 scenarios. The test cases follow a sequential order to reuse the updated balances from previous operations. Below is an overview of the sequencing of the scenarios.

| Scenarios | Description |
|---|---|
| Scenario A | Corporate A instructs CA (EU) to pay Corporate B account at CACIB (FR), with manually triggered wCBDC settlement |
| Scenario B | Corporate B treasurer transfers using an e-banking tool, the received euros, to its account at CACEIS. The interbank settlement is triggered automatically based on the balance level |
| Scenario C | Corporate B treasurer transfers money from its CACIB account to its account at CA (EU) when CACIB already has cash on its nostro at CA |
| Scenario D | CACIB and CA (EU) banks net their respective liabilities |
| Scenario E | CA (EU) manages its end of day treasury, repatriating all its funds from other banks |

More scenarios have been tested but only these 5 ones where formally tested with the ECB.

## 4.4 CACIB experiment with the ECB

The final experiment was conducted in the presence of the ECB. This section provides a detailed overview of the tested scenarios, as well as the functionalities to be demonstrated.

**Scenario A: Corporate A instructs CA (EU) to pay Corporate B's account at CACIB and manual wCBDC settlement.**

- **Presentation:**
  - This scenario aims to execute the basic use case of an international interbank transfer between two companies holding accounts in different banks, involving correspondent banking mechanisms on blockchain.
  - This operation subsequently triggers a settlement in wCBDC, manually initiated by the beneficiary bank.
  - The execution of the operation, particularly the use of a manual settlement which is somewhat unrealistic in typical governance, aims to demonstrate the step-by-step process of the scheme.

- **Demonstrated functionalities:**
  - **Instant transfer between client accounts in two different banks:** the ability to perform instantaneous and atomic interbank transfers.
  - **Interfacing with DL3S for the interbank settlement (manually triggered):** ensuring interoperability between the so|cash and DL3S environments.

- **Steps:**
  - **Preliminary step:** Corporate A holds a balance of €1 million in its account within the so|cash environment of CA (EU). The company wants to transfer €800,000 to Corporate B, whose account is so|cash compatible at CACIB. Corporate A will instruct CA (EU) to execute this transaction.
  - **Step A.1:** CA (EU) back-office captures the transfer of €800,000 to corporate B' IBAN. Corporate A account is debited by €800,000, while CACIB's nostro account at CA (EU) is credited with the same amount. Simultaneously, Corporate B's account within CACIB is credited with €800,000.

- **Step A.2:** CACIB back-office manually settles the balance in ECT triggering the HTLC mechanism. Within the DL3S environment, a transfer of €800,000 is made from CA (EU)'s central bank wallet to CACIB's central bank wallet then CACIB nostro is debited.

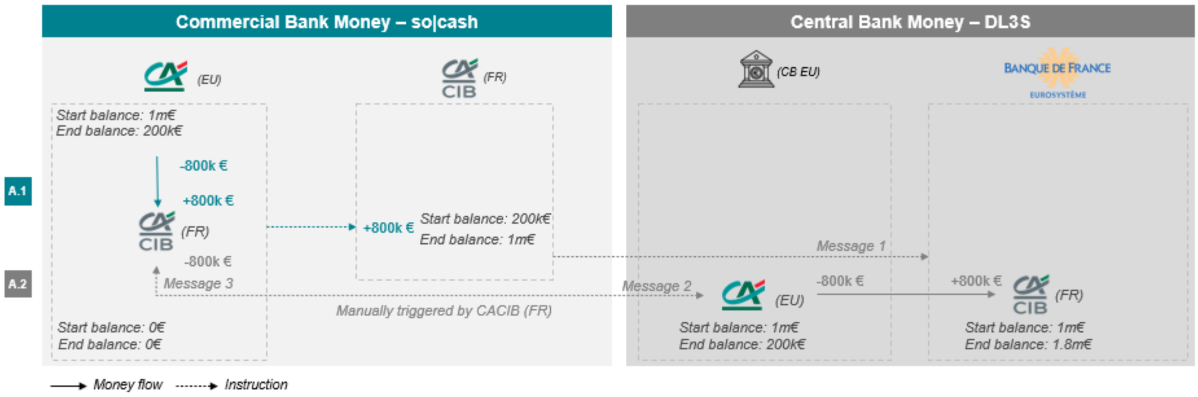


*Figure 5: Scenario A - Corporate A instructs CA (EU) to pay Corporate B account at CACIB and manual wCBDC settlement*

**Scenario B: Corporate B treasurer transfers € to its account at CACEIS with automated interbank settlement**

- **Presentation:**
  - This scenario aims to perform the same as scenario A in a fully automated way.

- **Demonstrated functionalities:**
  - **Enable clients to make transfers from their accounts:** the ability for a treasurer to manage all the company's accounts deployed on so|cash through an e-banking module, comparable to a traditional Treasury Management System.
  - **Automate the interbank settlement via DL3S:** the ability to set personalized thresholds allowing for automatic settlement of balances in ECT based on a threshold.

- **Steps:**
  - **Preliminary step:** Corporate B holds a balance of €1 million in its account at CACIB. The company wants to transfer €500,000 to its so|cash account at CACEIS. Corporate B's treasurer controls this operation.
  - **Step B.1:** In its e-banking module connected to the blockchain, the treasurer initiates the transaction and transfers €500,000 to its account at CACEIS. The account at CACIB is debited, while CACEIS's nostro account at CACIB is credited. Simultaneously, Corporate B's account at CACEIS is credited.

- **Step B.2:** Because CACEIS balance at CACIB is above the programmed threshold, CACEIS orchestrator triggers the wCBDC settlement automatically using wCBDC rail.

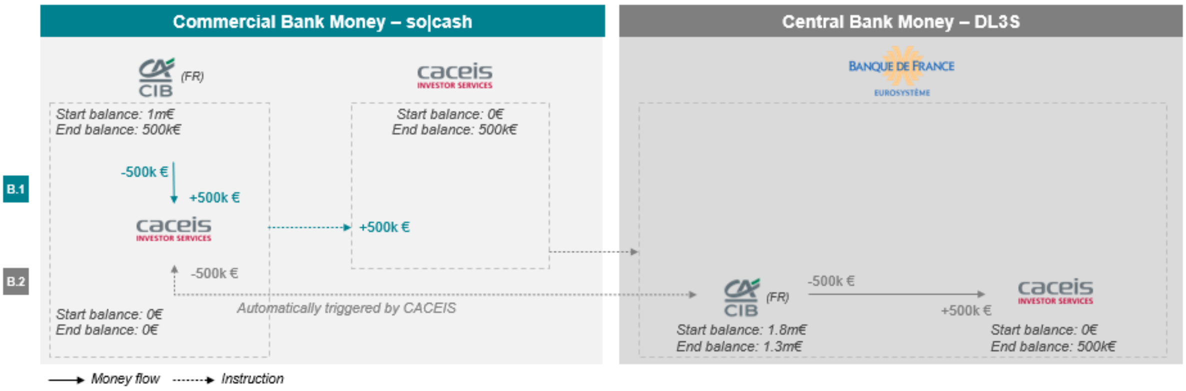


*Figure 6: Scenario B - Corporate B treasurer transfers € to its account at CACEIS with automated interbank settlement*

**Scenario C: Corporate B treasurer transfers money to its account at CA (EU) when CACIB already has cash on its nostro.**

- **Presentation:**
  - This scenario is the same as scenario B, but the paying bank uses money it holds at the beneficiary's bank.
  - The mechanism implies that the bank will use the funds available in its nostro account within the beneficiary bank, so no wCBDC is needed.

- **Demonstrated functionalities:**
  - **Use treasury rules for interbank commercial money exchange:** the ability to mobilize existing funds to execute transactions.

- **Steps:**
  - **Preliminary step:** Corporate B now holds a balance of €500,000 in its account at CACIB. The company wants to transfer €100,000 to its CA (EU).
  - **Step C.1:** First CACIB funds its nostro at CA (EU) with €300k. This can be done via a conventional SWIFT payment.
  - **Step C.2:** In its e-banking module, the treasurer initiates the transaction to transfer €100,000 to its account at CA (EU). The account at CACIB is debited by this amount, then CACIB smart contract performs a transfer from its nostro at CA (EU) to Corporate B's account.

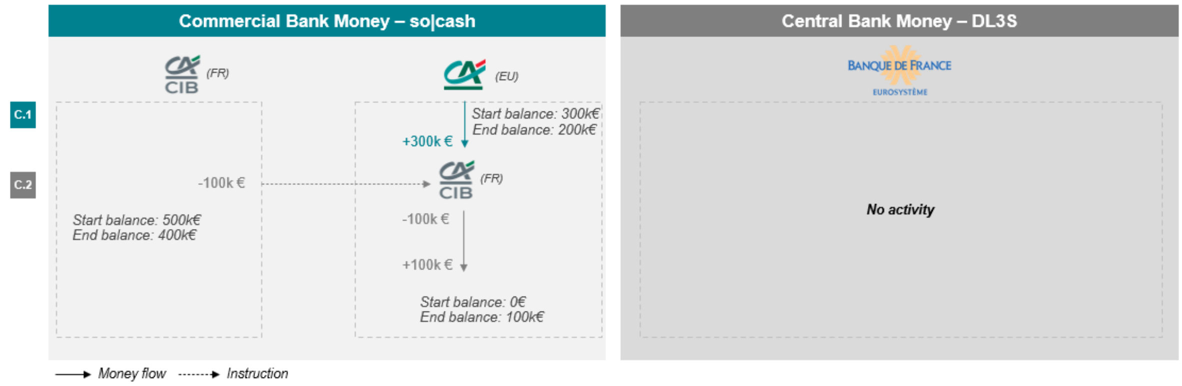


*Figure 7: Scenario C - Corporate B treasurer transfers money to its account at CA (EU) when CACIB already has cash on its nostro*

**Scenario D: CACIB and CA (EU) banks net their liabilities with each other.**

- **Presentation:**
  - This scenario aims to execute a synchronized operation to net the balances of two banks' respective nostro accounts.
  - This operation does not require settlement in ECT.

- **Demonstrated functionalities:**
  - **Atomic clearing of reciprocal liabilities between two banks:** the ability to net accounts within the so|cash environment without settlement risk.

- **Steps:**
  - **Preliminary step:** CACIB now holds a balance of €200,000 in its account at CA (EU).
  - **Step D.1:** First, we assume that CA (EU) has received €250,000 in its nostro account at CACIB (an external transfer of the result of a client transfer).
  - **Step D.2:** In its back-office module, CA (EU) requests an atomic netting with CACIB. Both accounts are thus debited by €200,000 (the minimum of both liabilities). After the atomic execution, the account of CACIB at CA (EU) has a balance of €0 and the account of CA (EU) at CACIB has a balance of €50,000. Note that the netting operation can be initiated by any of the two banks.

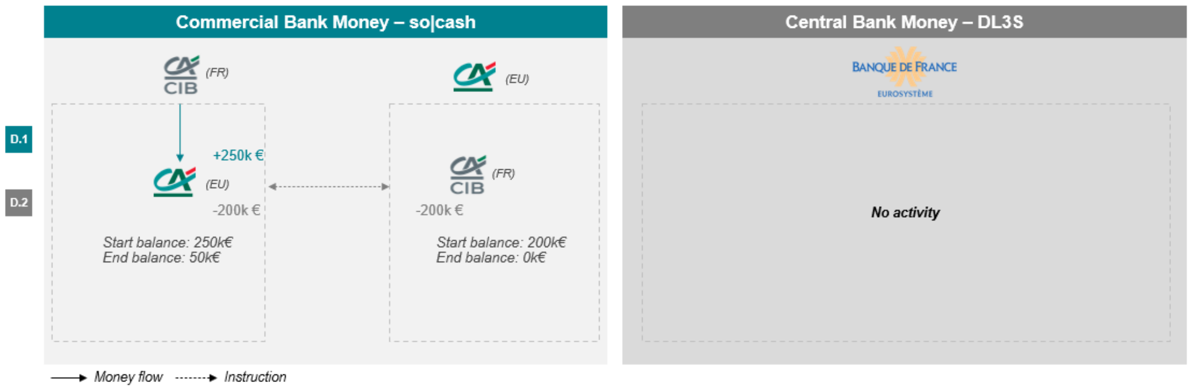


*Figure 8: Scenario D - CACIB and CA (EU) banks net their liabilities with each other*

**Scenario E: CA (EU) manages its end of day treasury to repatriate its funds to the central bank.**

- **Presentation:**
  - This scenario aims to execute an end-of day treasury procedure where all balances held at other banks will be returned to the central bank account.
  - This operation triggers multiple settlements in wCBDC, initiated in the back-office module.

- **Demonstrated functionalities:**
  - **Multiple parallel interbank settlements via DL3S:** the ability to trigger multiple settlements in ECT of balances across different accounts.

- **Steps:**
  - **Preliminary step:** CA (EU) now holds a balance of €50,000 in its account at CACIB.
  - **Step E.1:** First, we assume that CA (EU) has received €33,000 in its account at CACEIS as the result of previous operations.
  - **Steps E.2 and E.3:** The back-office of CA (EU) triggers the settlements of its balance at CACIB and CACEIS. The two settlements run in parallel as in scenario A. As a result, the nostro of CA (EU) with the two other banks is zeroed and the ECT wallet in DL3S receives €83k (€50k + €33k).

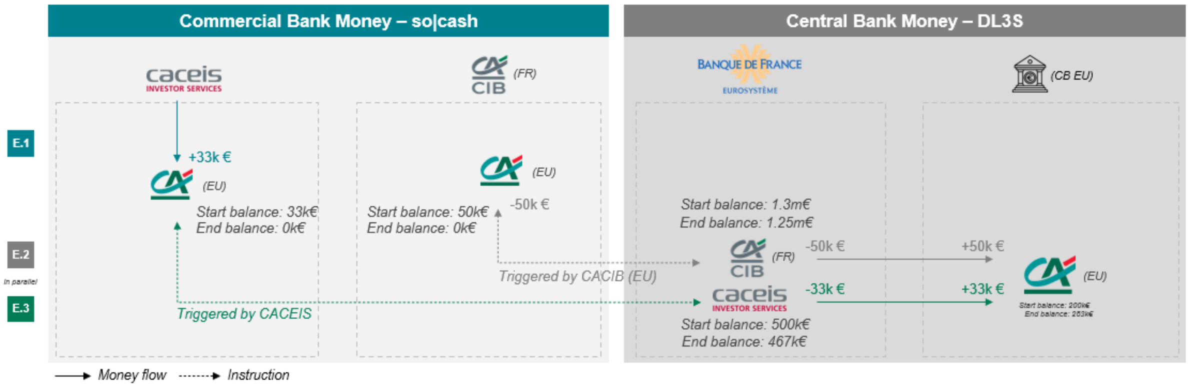


*Figure 9: Scenario E: CA (EU) manages its end of day treasury to repatriate its funds from other banks*

**All the above scenarios were successfully executed.**

## 4.5 Performance reporting and analysis

The technical solution implemented included time probes for each event of the HTLC mechanism integrating with DL3S.

Each bank has an independent orchestrator connecting the so|cash market DLT with DL3S. The orchestrators were collecting event time points prefixed by “PAY” or “RECV” depending on whether the bank was sending or receiving the ECT.

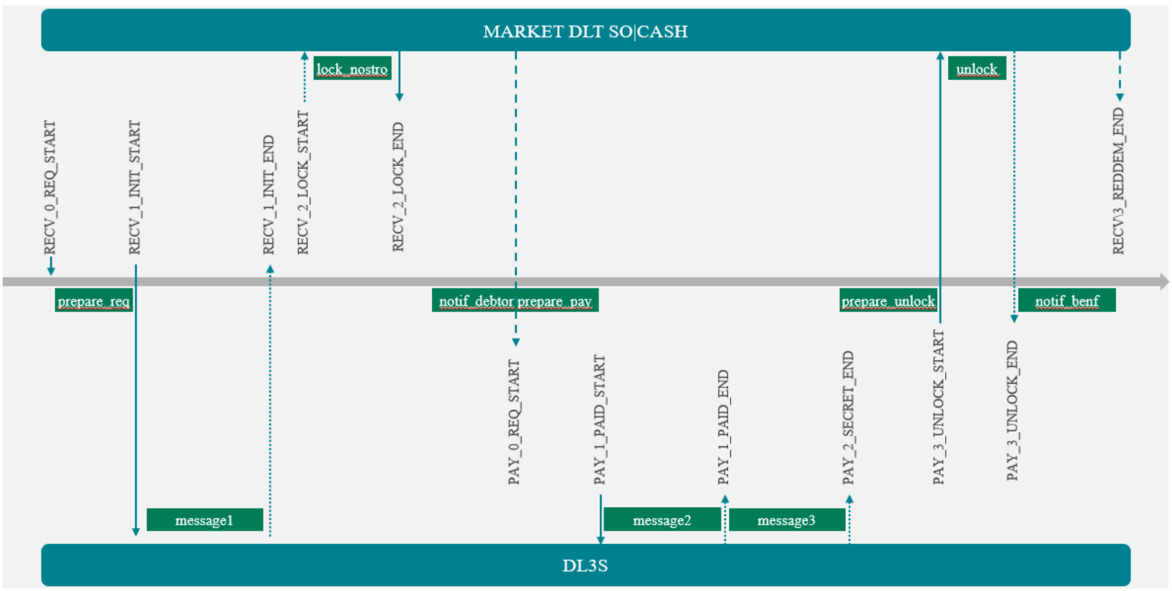


*Figure 10: Sequence diagram for so|cash market DLT with DL3S*

| Time probe | Process step |
|---|---|
| RECV_0_REQ_START | Trade is agreed between buyer & seller in the market DLT platform |
| RECV_0_INIT_START | Message 1 is sent to DL3S |
| RECV_1_INIT_END | Confirmation of message 1 is received |
| RECV_2_LOCK_END | Asset/CoBM is locked in the market DLT platform |
| PAY_1_PAID_START | Message 2 is sent to DL3S |
| PAY_2_SECRET_END | Message 3 is received from DL3S |
| PAY_3_UNLOCK_END | Asset/CoBM is released in the market DLT platform |
| RECV_3_REDDEM_END | Seller receives confirmation of completion |

*Figure 11: Key steps in transaction performance analysis*

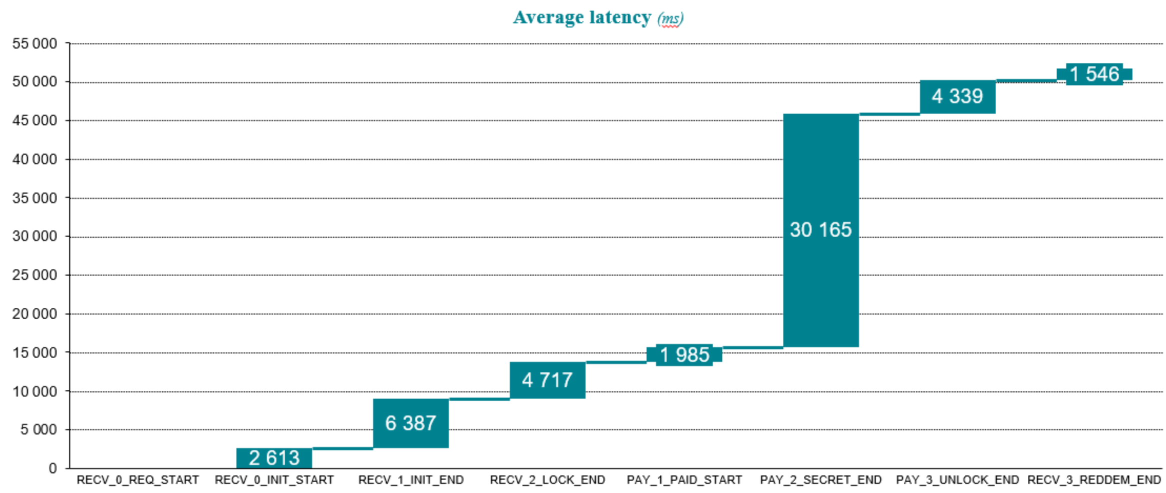


*Figure 12: Time spend end to end (milli sec) for the HTLC process*

Figure 12 displays the latency time between each sequential probe in cumulation format. The figures are the average across the 6 ECT transactions executed during the experimentations. The variation between each transaction is relatively low (min 40.8 sec; max 64 sec).

There are several elements that explain these figures among which we can list:

- The orchestrator is designed to wake up every 2 seconds to check if new events need to be processed (creating up to 2 seconds delay when receiving the secret from DL3S or the DLT lock/unlock notification).
- The DLT used in the experimentation creates blocks every 4 seconds, hence it takes a little above the time to lock and unlock the nostro balance in the DLT.
- Processing a DL3S lock and release between two different nodes (BdF vs CBY) takes longer (~ +20 sec).

Overall, the settlement process between a so|cash nostro and the DL3S wallet takes less than a minute and back office keeps visibility on the process. However, there are improvements in progress on both sides (orchestrator, DL3S) to save seconds on each part.

### 4.6 Recovery procedures

Even though the experimentations were not done with real money, it was useful to investigate how breaks in the orchestration process would maintain the funds secured on each side.

We have identified the following breaks and workaround procedure:

- Initiating a DL3S settlement after the platform is closed: The money is left on the nostro of the holding bank and the back office will have a notification of the unsuccessful execution that can be retried the next day. It is the intention of the central bank that such a wCBDC solution would in the long run remain open overnight.
- The nostro balance cannot be locked after the initiation of the repayment in DL3S: This can be due to insufficient funds in the nostro compared to what was initiated. In such case the DL3S transaction will expire by itself, and nothing happens.
- The paying bank fails to pay via DL3S: This can be due to lack of funds or the payment not being made before the expiry of the lock in the market DLT. Here, the receiving bank will cancel the lock on its nostro after the expiry time and regain use of its funds. But this can be an increase credit risk and possibly raise an event of default for the bank holding the cash.
- The paying bank successfully execute the transfer via DL3S but does not receive the secret: Three causes are possible. Either DL3S did not send the secret at all or did not send it before the expiry time of the nostro lock, or the paying bank orchestrator misses the secret message. In all cases the receiving bank will monitor the nostro and unlock it after the expiry time. This leaves the paying bank in capacity to reconcile the payments and manually debit the nostro of the receiving bank. However, we have here the risk that the balance is not available anymore. One desired procedural adjustment would be for the paying bank to have access to DL3S node to retrieve the secret on demand or at least check if the payment was successful.

# 5. Key findings and learnings

This section presents the key findings and learnings from the experimentation, highlighting the main outcomes, insights, and lessons gained throughout the process.

## 5.1 Technology insights

The experiment conducted by CACIB demonstrated the sufficiency of an open banking ecosystem on a multi-purpose EVM based blockchain in constructing smart contracts for account management and correspondent banking. This foundational framework supports seamless payment operations and account interactions. An important highlight was the successful implementation of the HTLC scheme, which provides security when processing with wCBDC, showcasing its feasibility and ease of integration.

The experiment contributed to the publication of an open-source standard (so|cash), offering valuable technical documentation for further exploration and adoption. However, privacy mechanisms, while conceptually available, were not tested, identifying an area for future study. The full assessment of integration costs also remains pending, highlighting a critical component for financial institutions to consider in the eventual scaling of wCBDC solutions.

The choice of the underlying blockchain network for the experiment was not critical, but for production setup, questions would remain on the governance of such a network and the capacity to ensure that regulation and privacy can be applied.

## 5.2 Corporates benefits

The results illustrated significant potential benefits for corporates engaging with wholesale instant 24/7 payments. Payments in commercial bank money with no cut-off time restriction requires banks to make use of a similar layer between them. The Eurosystem, with wCBDC, is in the way of providing that service to the banking system.

The real-time capability is complemented by instant statement reporting and continuous balance monitoring, enhancing transparency and financial control.

Moreover, like what DL3S provides to banks, Corporates have the capacity to lock balances in their so|cash compatible accounts to commit amounts to future payments, creating financial flexibility for planned transactions. This approach empowers Corporates by giving them autonomy to select the preferred method of accessing their accounts, whether through TMS, e-banking, or other channels, aligning with diverse treasurers/users’ needs.

What we also realize is that most of large institutions need to rely on multiple banks to access various markets and hedge their own credit risk. Because of this, corporates (and financial institutions) need to manage multiple bank accounts in the same currency and even more for all the currencies they work with. The integration of these accounts into their operations is often bank specific and heavy. Using a standard format for accounts (such as so|cash) is an important advantage for treasurer operations.

Next, we identified that third parties or other banking institutions will be able to provide digitalized services that leverage programmable instant payment. For instance, a supply chain platform can secure the invoice payment (or financing) by linking so|cash accounts to the invoices and enabling payment execution on the proper value date. FX and cross border payments can become instantaneous without settlement risk by programming the two currencies flows into a single smart contract. Such examples are near infinite and have the potential to enable a new area of services.

### 5.3 Bank impacts and implications

The integration of wCBDC will likely introduce several unique impacts on banking operations.

Firstly, the HTLC service provided by DL3S means that the payment is linked to the object of the payment. This implies an inversion of the incitation to actions: the payment is requested by the beneficiary bank and the paying bank makes the payment to retrieve the object of the payment, if it can be confirmed that the transfer of the object will be genuine. So, both parties have self interest in performing their part of the action, limiting some operational risks.

The second aspect is the technical interface with DL3S that does not rely on asynchronous messages but more modern APIs. Although yet incomplete, this technical access will allow better real-time integration with back-office processes and facilitate decision making, reconciliations. It could go even further by enabling liquidity request (against collateral) or managing liquidity between the various Main and Dedicated Cash Accounts (MCA/DCA).

Finally, two important expected changes from the wCBDC approach are the 24/7 availability of the solution and the absence of cut-off time. This will provide banks the ability to offer 24/7 cash management to their client without bearing the inter-bank credit risk. However, the next topic to tackle from here is the interests calculation and accrual on intraday balances so such benefits can be passed on to customers.

### 5.4 A modern financial ecosystem

so|cash protocol provides banks with a multi-currency platform-less correspondent banking ecosystem where all actors remain free to join, make bilateral partnerships, choose their tech providers, innovate autonomously with new services, set their own pricing… and, in one word remain autonomous. The protocol is open sourced under free licencing creating no string to its author.

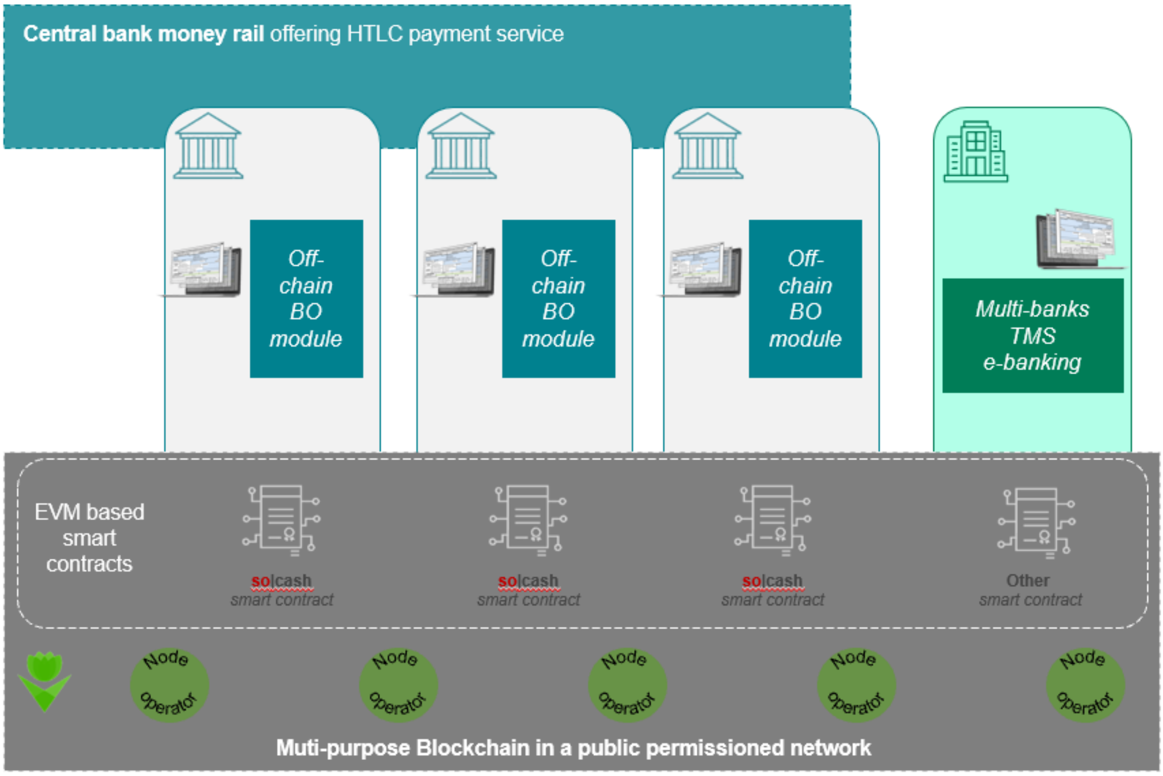


*Figure 13: so|cash - An open banking ecosystem based on a multi-purpose blockchain*

- **Central bank money is available** to banks via interoperability (until they can be made available on-chain) or via other mechanisms.
- **Each bank maintains its own infrastructure** with internal IT systems to interface with legacy systems, the CeBM layer, and a unified ledger where CoBM resides.
- **Each bank is free** to set up correspondent banking relationships.
- **Clients can operate on their accounts directly** and mix payments with their own solutions (on-chain or not).
- **Each bank deploys its own so|cash-compatible smart contracts** that can communicate with each other under a correspondent banking relationship.
- **Other smart contracts** can be operated and connected to so|cash-compatible accounts.
- **Permissioned node operators** secure transactions via a consensus mechanism, which can involve any respectable and publicly known company under a "public permissioned" network**.**

## 5.5 Legal overview

The legal review of the experiment was provided "pro-bono" by the law firm White & Case LLP (Paris office) and focuses on the existing regulatory landscape, potential impacts and areas requiring further exploration. This review does not provide a formal validation, nor does it make White & Case (Paris office) in any way liable for any decision taken by any reader.

- **Overview and Legal Characterization**

There is no precise legal definition of a "bank account" under French law, even though notions such as "deposit accounts" and "saving accounts" have been subject to specific legal recognition (CNC n° 69-02 of 8/5/1969). Some French legal scholars describe a bank account as a "table of reciprocal claims and debts" between two parties, seen more as an accounting technique than a strictly defined legal concept. This flexibility in interpretation of the criteria defining bank accounts allows for the digitisation of bank accounts within Distributed Ledger Technology (DLT) frameworks, if privacy, banking secrecy and data protection regulations are upheld. Notably, under the current regulatory regime, there are no specific technical criteria that would prevent the digitisation of bank accounts or deposits under French law.

- **Legal Considerations for Digitisation of Bank Deposits**

Under EU Directive 2014/49/EU on deposit guarantee schemes, deposits are defined by their repayable nature under specific legal and contractual terms. The experimental phase of wCBDC identified that digitised deposits could be accommodated within this regulatory framework without immediate impediments. Regulation 2024/1623 further supports that crypto-asset exposures related to tokenised traditional assets are treated equivalently to their traditional counterparts. In addition, the experiment used an "account-based model" for the actual representation of the claim (i.e. the claim is recorded on the DLT and bound to the identity of the accountholder) which, according a recent EBA report of December 2024 (EBA/REP/2024/24), is a model that resembles "most conventional deposits recorded on traditional bank ledgers". These findings suggest that the digitisation of bank deposits under an "account-based model" used in the experiment can proceed under current laws but must ensure that it aligns notably with Articles L. 312-1-1, L. 312-4, L. 511-5 and L. 571-3 of the French Monetary and Financial Code (MFC).

- **'Nostro' and 'Vostro' Accounts**

The experiment also explored the legal implications for 'nostro' and 'vostro' accounts, which, under current French regulations, are not governed by specific rules, apart from specific duty of care and AML-FT requirements (e.g., Articles L. 561-10-2 and R. 561-21 of the French MFC). These accounts are part of correspondent banking relationships, characterised by bilateral contractual agreements that are not enforceable against third parties. This legal framework suggests that while the digitisation of such accounts is possible using DLT, it requires that contracts reflect this new operational capability. Additionally, these transactions have limited impact on bank liability toward clients, further supporting their adaptability within a DLT setting.

- **Finality of Transactions**

The legal provisions for transaction finality in the context of the wCBDC experiment were examined under the EU Directive 98/26/EC, known as the Settlement Finality Directive (SFD). The so|cash solution used in the experiment does not meet the SFD's criteria for a recognised 'system,' which affects how finality is legally enforced. Currently, in Phase 1 (the experimental phase), the finality of transactions is defined within bilateral agreements outside the SFD's scope. However, in the planned industrialisation phase, a decision will be necessary to either maintain this bilateral structure or establish a system-based setup. This choice carries significant regulatory implications, including considerations of insolvency protection, contractual obligations, and governance structures.

An approach to consider is to obtain that the "unified ledger" under which the so|cash accounts are deployed is integrated in the SFD and that the timestamp of the block (where transfers are recorded) serves as a reference for the finality directive. This would not only make settlement under so|cash accounts final but will also enable any other settlement mechanism under this ledger infrastructure a provable finality.

- **Other Legal and Regulatory Considerations**

Additional insights indicate a minimal compliance impact under existing KYC/AML-FT, sustainability, cybersecurity (DORA), identification (eIDAS) and data protection frameworks (e.g., GDPR). The prudential impact remains low for the experimental phase but will require further assessment for large-scale adoption. Importantly, the analysis did not identify immediate GDPR (due to a lack of personal data registered on DLT in the experiment) or EU MiCA regulation impacts specific to wCBDC or so|cash model (due to the use of "account-based model" to digitise deposit accounts on DLT under the experiment).

- **Future Outlook**

While the initial legal exploration did not find substantial obstacles to digitisation, the need for further detailed analysis, especially concerning payment finality, outsourcing, banking secrecy, prudential impact and broader regulations, remains crucial. The ongoing exploration of contractual and governance frameworks will be key to ensuring a seamless transition from experimentation to industrial-scale implementation.

### 5.6 Challenges and actions to take so|cash forward

so|cash protocol needs to mature via an industry-wide workgroup and by being incorporated as a component in existing local and international projects, such as:

- **Integration with additional interbank settlement currencies**: Expanding support to facilitate settlement across various currencies.
- **Integration with existing infrastructure**: Ensuring compatibility with systems such as SWIFT and legacy platforms to accelerate time-to-market using off-the-shelf software solutions.
- **Real bank independence**: Achieved through multiple so|cash-compatible implementations, promoting flexibility and competition.
- **so|cash protocol improvements**:
  - Develop a transversal correspondent bank SSI referential.
  - Enable intermediary banks in payments.
  - Facilitate fully atomic interbank settlement with "distributed" CeBM or stablecoins.
  - Support interbank flows across multiple chains.
  - Enhance ISO 20022 compatibility.
- **TMS suppliers**: Should develop so|cash-compatible account management solutions to offer their clients the benefits of instant and transparent banking services.
- **Permissioned distributed governance**: Ensures operators of the "unified ledger" infrastructure are well supervised, addressing challenges of trust, reputation, and timestamping for payment finality. Such a network of operators does not necessarily imply a centralized governance nor a central technical service.
- **Public blockchain limitations**: Public blockchains do not inherently respect privacy. Implementing technologies like Fully Homomorphic Encryption is one credible option to address this issue.

This framework outlines the strategic evolution required to build a scalable and interoperable digital currency solution.

### 5.7 Validating the preference for €wCBDC in Financial Service

The experiment underscored the benefits of certain attributes in wCBDC to improve existing financial services.

First, a 24/7 settlement service would be desirable to ensure continuous corporate and client services. In particular, the support of same-business-day interbank settlements even late in the day, making cut-off time irrelevant.

Then, the capacity to secure the delivery of an externally managed asset via a successful payment without the need for a centralized intermediary is key. In the experimentation this is achieved via the delivery of a secret against the payment, that in turn can be used to get the asset. This is an elementary piece that enables embedding business rules within wCBDC payments to enhance automation and reduce operational risks (programmability).

The nature of the €wCBDC is expected to be equivalent to a balance in a Target2 DCA and that accounting would be the same. The wallet holding currently ECT (Experimental Cash Token) is therefore expected to be a nostro account held by the bank with the central bank.

The liquidity mechanism between this new type of nostro account and the rest of the MCA/DCA should be as fluid as possible, and rules should enable automatable transfers between the accounts outside of normal working hours.

Finally, one expected feature that would be desirable is the interest calculation on actual balance throughout the day (second based interests) so liquidity deposited by clients can be remunerated under the same criteria.

### 5.8 Next Steps for Continued Exploration

To build upon the findings, further experimentations will be done to assess other dimensions of the so|cash model:

- Interest calculation methods based on actual time rather than fixed value dates to assess the impact of changing a value date to a timestamp of value in the chains.
- Introduction of intermediary banks in the "so|cash" model, where the paying bank and the beneficiary bank are not directly in relation or when one bank is not in the central bank system.
- Enabling alternative settlement solutions (stablecoins, settlement networks, SWIFT, "distributed CBDC" …).

**Thus, this experimentation strengthens Credit Agricole CIB's conviction that a digital form of money following the account structures (as CoBM and CeBM) would be preferable for CIBs and their clients, as opposed to others forms of digital settlement tokens.**

## Conclusion

Fostering experimentation is critical to anticipating and preparing for the profound transformations reshaping the financial industry as digital assets continue to gain traction. To address these changes, collaborative efforts with key stakeholders, including regulators and leading market players such as central banks and commercial banks, focus on defining standards that ensure investor protection and financial system stability. These initiatives aim to create a secure and adaptive framework capable of seamlessly integrating digital assets into the existing financial ecosystem while supporting innovation.

The Tokenized Correspondent Banking project envisions a future where blockchain technologies and wCBDCs redefine interbank settlements and correspondent banking. In collaboration with Banque de France, this experiment illustrated how infrastructures such as DL3S and so|cash can facilitate secure, efficient, and programmable financial transactions. It established the feasibility of deploying wCBDCs for direct interbank exchanges, aligning with central bank requirements for safety, operational effectiveness, and regulatory compliance. These findings underscore the transformative potential of new technologies to streamline processes, reduce intermediaries, and enhance financial connectivity.

Through this experimentation, key insights emerged about how banks can independently manage wCBDC transactions and liquidity. Programmable platforms such as so|cash introduced automation into financial workflows, significantly reducing operational errors and improving transparency. These capabilities enable institutions to optimize their operations, address liquidity challenges in real time, and achieve higher levels of reliability. By effectively leveraging these technologies, the project set a precedent for incorporating digital assets into financial operations, supporting greater resilience and efficiency.

Looking forward, the outcomes of this work lay the foundation for broadening its application to other use cases. These include implementing Delivery versus Payment (DvP) mechanisms with entities like CACEIS, enhancing the efficiency of closing operations, improving corporate treasury processes, and advancing cash pooling strategies.

Furthermore, the programmable and atomic capabilities of so|cash have the potential to transform B2B payments, enable tokenized invoice management, and facilitate the digital transformation of corporate financial operations. These advancements hold the promise of streamlining complex financial workflows, enhancing liquidity management, and driving significant efficiency gains across industries. Extending these solutions to such scenarios positions the financial sector to fully capitalize on the opportunities provided by digital innovation, setting the stage for a more dynamic and interconnected financial future.

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# Appendices

### Figures List

## Contributors

| | |
|---|---|
| **Steering group** | |
| **CACIB** | Etienne BERNARD, Global Head of Cash Management |
| | Romaric ROLLET, Head of Innovation & Digital Transformation |
| **Project Leads** | |
| **CACIB** | Guénolé de CADOUDAL, Head of Digital Assets Group |
| | Sébastien RACINAIS, Head of Innovation, International Trade & Transaction Banking |
| **CACEIS** | Guénolé KERAUDREN, Programme Director |
| **Banque de France** | Caroline COLETTE JONES, Adviser ‘Central Bank Digital Currency’ experimentation project |
| | Pierre-Dominique RENARD, Adviser ‘Central Bank Digital Currency’ experimentation project |
| **KPMG** | Thomas MEURIN, Technology Adviser |
| | Antoine ROUSSEAU, Business Adviser |
| **White & Case (Paris office)** | Stéphane BLEMUS, Associate |
| **Observers** | |
| **BNP Paribas** | Daniel TURQUETY, Chief Digital Officer |
| **Santander** | Andrian WHITE, Executive Director of Crypto & Digital Assets Unit |
| **SEB** | Johan HORMARK, Investment Banking / Equities Business Development |
| | Harri RANTANEN, Business Developer |
| **Societe Generale** | Genevieve DOUHET, Global Transaction & Payment Services - Cryptoassets program Director |