ABI Associazione Bancaria Italiana

ABI Lab

Leonidas - Project Report

Experimenting benefits of a digital form of Central bank money based on DLT in interbank transactions

Executive Summary

This report offers a comprehensive overview of the outcomes and results of Project LEONIDAS, Liquidation Effective ONchaIn Dlt Asset on Spunta.

In collaboration with ABI, R3, NTT DATA, and a working group composed of 17 banks, ABI Lab presented the "Project LEONIDAS" at the 2022 Call for Proposals of the Milano Hub, the innovation centre created by the Bank of Italy to support the digital evolution of the financial market. The project focused on experimenting with the use of wholesale Central Bank Digital Currency (wCBDC) within a Distributed Ledger Technology (DLT) environment.

As a methodological note, for this paper, we will use the term wCBDC and wCeBM (wholesale Central Bank Money, the terminology used by the ECB) interchangeably.

Building on the expertise gained through previous DLT projects, particularly the Spunta Banca DLT project, which stands as the first European Blockchain/DLT-based application in production widely adopted by the Italian banking sector, the working group set the following objectives:

- Test within a distributed infrastructure the settlement of liquid balances using a simulated wCBDC implemented and issued on the ABILabChain using the Full-DLT model as interoperability solution.
- To compare the settlement process under Leonidas with the previous one.
- To introduce programmability logic into the interbank reconciliation process, extending it to the value transfer phase between banks.
- To develop additional programmability logic, both within and beyond the reconciliation process, facilitating innovative value exchange between banks.

Regarding the last point, an additional use case was identified to simulate the settlement of wCBDC in another real banking context. After gathering various use cases and conducting a vote among the banks, it was chosen the use case named "Cash in Transfer," focusing on managing and handling cash supply and demand among banks.

The project concluded at the end of 2023, having achieved all its main goals. This led to a series of findings that demonstrate the different benefits gained by using DLT in the wCBDC-based settlement process.

In conclusion, this project has imparted significant knowledge. In addition to the technical benefits of the technologies, we experienced firsthand that close collaboration between experts from different domains becomes an enabling factor for innovation. We also appreciated that true transformation occurs when technology drives the change, rather than overlay onto existing processes.

Introduction

In the context of the second Call for Proposals launched by Milano Hub, the innovation centre created by the Bank of Italy to support the digital evolution of the financial market, Project LEONIDAS has emerged as a groundbreaking initiative within the Distributed Ledger Technology (DLT) environment.

The theme of the 2022 Call for Proposals, which specifically targeted the "Application of technology based on distributed ledgers to banking, financial, insurance and payment services," presented a unique opportunity to experiment with the Project LEONIDAS. The project focus was testing the settlement of a wCBDC within a distributed ledger technology environment.

Leveraging the experience and expertise gained from the Spunta Banca DLT Project, the first European Blockchain/DLT-based application in production adopted by an entire domestic banking sector, ABI Lab, in collaboration with ABI, NTT, R3, and a group of 17 banks, has presented Project Leonidas to the initiative promoted by the Bank of Italy.

The working group involved professionals with different backgrounds (process specialists, Blockchain & DLT, and CBDC experts) and from various areas such as Operations, Cash Management, Innovation, and IT. They worked jointly and synergistically, leveraging collective intelligence with the support of the multidisciplinary team from the Bank of Italy throughout the project.

The initiative lasted six months, and the working group had the opportunity to meet at least once a month, partly virtually through remote meetings and partly in person, including meetings at the Milan Hub offices. There were also offline discussions, as banks were involved several times to gather valuable feedback and project-related insights. Additionally, in November, during the "Salone dei Pagamenti" event held in Milan, the initial partial results of the experimentation were presented.

The key objectives of Project LEONIDAS were manifold. Firstly, it aims to simulate, within a distributed infrastructure (a network of nodes), the settlement of liquid balances, the net positive or negative balance in a mutual account at a specific time, using a wCBDC implemented and issued on the ABILabChain. Moreover, it seeks to conduct a comparative analysis with the current settlement process, implement programmability logic in the interbank reconciliation process, and develop additional programmability logic for value exchange among banks. As mentioned, issuing a wCBDC is "simulated" and intended for experimental purposes only. It is not designed to recreate in any way the functions that are not within the purview of the banking sector.

The working group has opted to develop an additional use case to further enhance the programmability logic beyond the reconciliation process, involving the value exchange process in the wholesale domain. This use case served as a practical application for experimenting with DvP (delivery versus payments) logic and atomic swaps within the LEONIDAS module.

Furthermore, among the different use cases proposed, it has been agreed to focus the experimentation on the use case named "Cash in Transfer," aimed at managing and handling the cash supply and demand of banks.

In conclusion, the project aims to verify the benefits of implementing a wholesale CBDC on a distributed ledger, focusing on the functionalities, efficiency, and robustness requirements inherent in central bank systems. This is achieved by reducing operational risks and optimizing liquidity management in settlement of liquid balances among intermediaries through the exchange of a wCBDC.

This report provides a detailed analysis of the use cases, challenges, and results of Project LEONIDAS, outlining the significant contribution that a wCBDC DLT Based could make to the digital transformation of the banking sector.

We especially acknowledge the support of the Bank of Italy multidisciplinary team for their support throughout the project. Furthermore, we are grateful to the technological partners, R3 and NTT Data, for their crucial contributions to the initiative.

Finally, we would like to express our gratitude to the working group of banks, namely:

- Banca Mediolanum
- Banca Monte dei Paschi di Siena
- Banca Popolare di Puglia e Basilicata
- Banca Popolare di Sondrio
- Banco BPM
- BFF Bank
- BNL – Gruppo BNP Paribas
- Cassa Centrale Raiffeisen
- Credem Banca
- Crédit Agricole Italia
- Gruppo Cassa Centrale
- Gruppo Sella
- ICCREA Banca
- Intesa Sanpaolo
- La Cassa di Ravenna con CSE
- Mediobanca
- UniCredit

For further inquiries please contact: spunta@abilab.it

Use Case

The scope of this chapter is to describe the use cases analysed and implemented during the experimentation. For each use case the following will be provided:

- A scenario-level description
- Details about the main implementation choices
- An overview of the architecture implemented to deploy and test the solution

Liquid Balances

Use case description

The scope of the use case is to integrate two existing applications, named *Spunta* and *CBDC* Global Offering Solution. Specifically:

- Spunta is a solution that handles a bank reconciliation process, in production since March 2020.
- CBDC Global Offering Solution is an application developed by NTT Data to provide Central Bank Digital Currency (CBDC) functionalities based on R3's Token SDK. This solution has been used to mimic a possible full-DLT CBDC for wholesale transactions infrastructure.

The new use case consists of the development of such integration between the two in order to:

1. Improve the Spunta application by introducing the calculation of liquid balances among the parties.
2. Implement a debt settlement system of liquid balances with a simulated wholesale CBDCs (wCBDCs) on DLT.
3. Be able to verify and analyse the possible benefits of the introduction of a wCBDCs in the existing architecture.

Assumptions

Assumptions were considered during the use case identification and scope definition processes, in particular:

– Upload files of banks' data were synthetic and generated, no real and/or anonymized files were used.

- Liquid balances in upload files were simulated.
- For the purpose of the project, Liquid balance settlement parameters were configured through AM (Application Maintenance).
- Banks in the network had by default an adequate amount of CBDC token liquidity to settle any operation.

Implementation details

New Spunta features implementation

Each Spunta node in the network is composed by a single-page front-end, a Spring REST web service, a CordApp and a Spring batch application. Details about Spunta architecture and its functionalities can be retrieved in its dedicated technical documentation.

Spunta in a nutshell

Spunta Banca DLT is a private permissioned distributed ledger technology-based project promoted by the Italian Banking Association (ABI) and managed and implemented by ABI Lab, the Italian Research and Innovation Centre for the Banks. The project is about the reconciliation of interbank bilateral account (a sort of nostro and vostro account).

The interbank Spunta process refers to the set of activities, traditionally the responsibility of back offices, relating to the reconciliation of flows and transactions generating entries on reciprocal accounts, as well as the related management of pending transactions through investigation actions. The process in question involves the execution of Spunta operations on reciprocal accounts, ascertaining movements that do not automatically cross and proceeding to reconcile such pending movements through the possible involvement of the competent offices or the counterparty.

At the end of the operating day of the Spunta Banca DLT an 'end-of-day balance' is obtained which is settled by the counterparties periodically. From the accounting balance data (displayed on-chain), the banks derive the value they must settle, which could occur, either directly or via another bank, using the account movement procedure at the Bank of Italy (Target2 transfers).

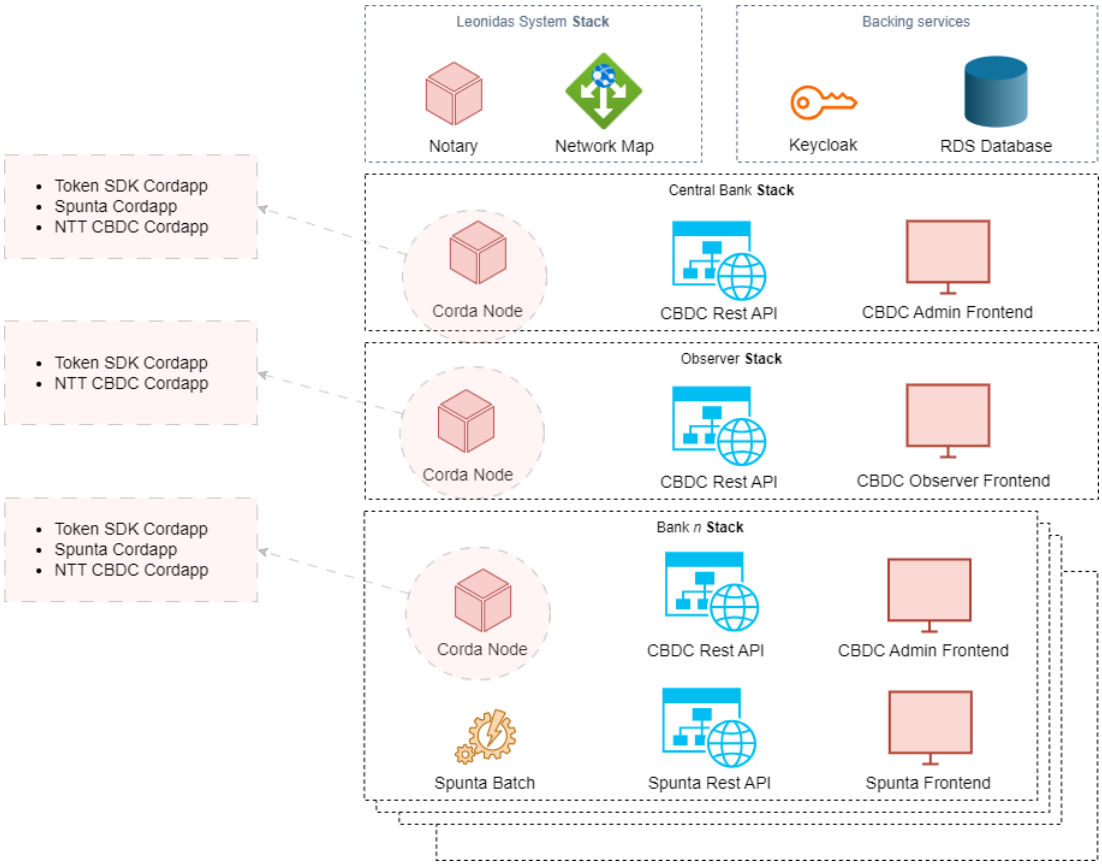

Figure 1: Cloud-Agnostic Architecture for Cash in Transfer use case

The new features required by the Leonidas solution impact every component of this stack and they can be summarized as follows:

- *Liquid balance update* –Liquid balances are uploaded in the system through the daily bank record upload process. The upload process is fed by a standard dataset that contain the movements and an upload date. The liquid balance value is inserted in each file and corresponds to the value at the given upload date.

- *Liquid balance payment* – For a given bilateral account, only the most recent liquid balance snapshot can be paid by the party that is in debt. The payment will instantly generate token movements on the CBDC side. The system enables either a manual or automated payment procedure, based on the degree of freedom to be provided to bank operators.

- *Liquid Balance visualization* – An operator, using the front-end, can browse the current and historic values of the liquid balances for each bilateral account, as well as their paid status. The same information can be downloaded as a CSV file.

Special care has been taken to avoid paying the same snapshot multiple times or paying obsolete balances. Liquid balance snapshots are represented as Corda states associated to

mutual accounts and validation logic in flows, counterflows and contracts prohibit their creation for dates earlier than the latest existing balance date, or dates in the future.

Below a diagram is provided showing the automated payment procedure implemented in the solution. Please note that the logic is the same as for the manual payment procedure. The difference between the two is that the automated procedure is triggered trough an existing batch application, while the manual one is triggered by a bank operator.

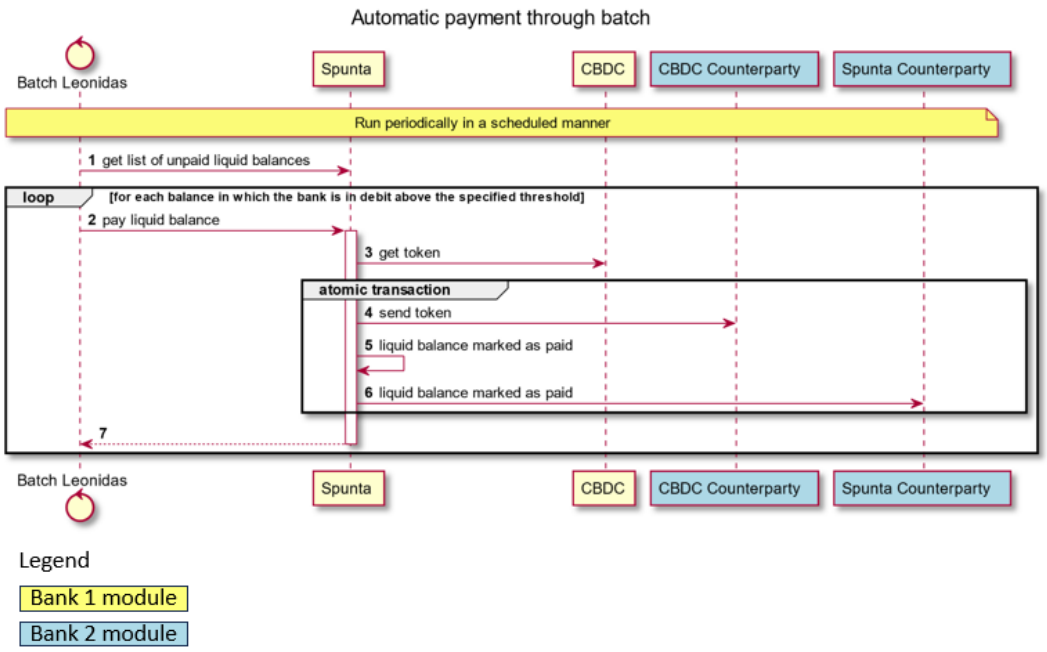

Figure 2: Sequence Diagram showing the automatization of the payment process.

After the upload and automatic match processes complete, the appropriate REST services will be called to retrieve the list of payable balances that will be settled by through the relative payment REST service provided by the Spunta backend.

CBDC Global Offering Implementation

This application consists of single-Page front-end, Spring REST web service and a CordApp that integrates with R3's Token SDK. The functionalities in scope of the Leonidas project are:

- token definition
- token issuance
- token transfer on a bank-to-bank level

The implementation uses the Corda states and contracts of the stock R3 Token SDK 1.2.4; however, the top-level flows of the SDK have been modified in order to adapt them to the interfaces and requirements of the CBDC project.

The components of the Token SDK that are used are:

- Evolvable Token – The application requires that a token can have a maximum amount of issued currency. The current issued amount and the maximum issued amount are tracked as fields in the evolvable token and they are updated as appropriate.
- Fungible Token – While the SDK supports both non fungible and fungible tokens, only the latter are used this implementation.

The front-end of the CBDC application provides some user friendly features to an operator such as:

- Check the existing tokens in the network
- Check the CBDC balance for each bank
- Monitor all the CBDC transactions involving a bank

Spunta and CBDC Integration

The two CordApps tightly integrate during the payment process – an atomic transaction changes the "paid" flag of the liquid balances and in the same times transfers the ownership of the CBDC token from the debtor to the creditor. This is achieved through integrating Corda states of both CordApps in the same transaction builder. The CBDC solution remains agnostic and can be used in other use-cases, and for the purpose of this experimentation, we used it as a simulation of the possible future feature that would be assessed, decided and managed by the Eurosystem.

Architecture overview

As stated above, in the use case there are two applications involved, i.e. CBDC Global Offering Solution and Spunta which are customised to establish a collaboration.

The involved participants in the network are:

- A Central Bank
- An Observer
- A set of Commercial Banks (20 for this PoC)

A diagram showing the overall architecture is proposed below:

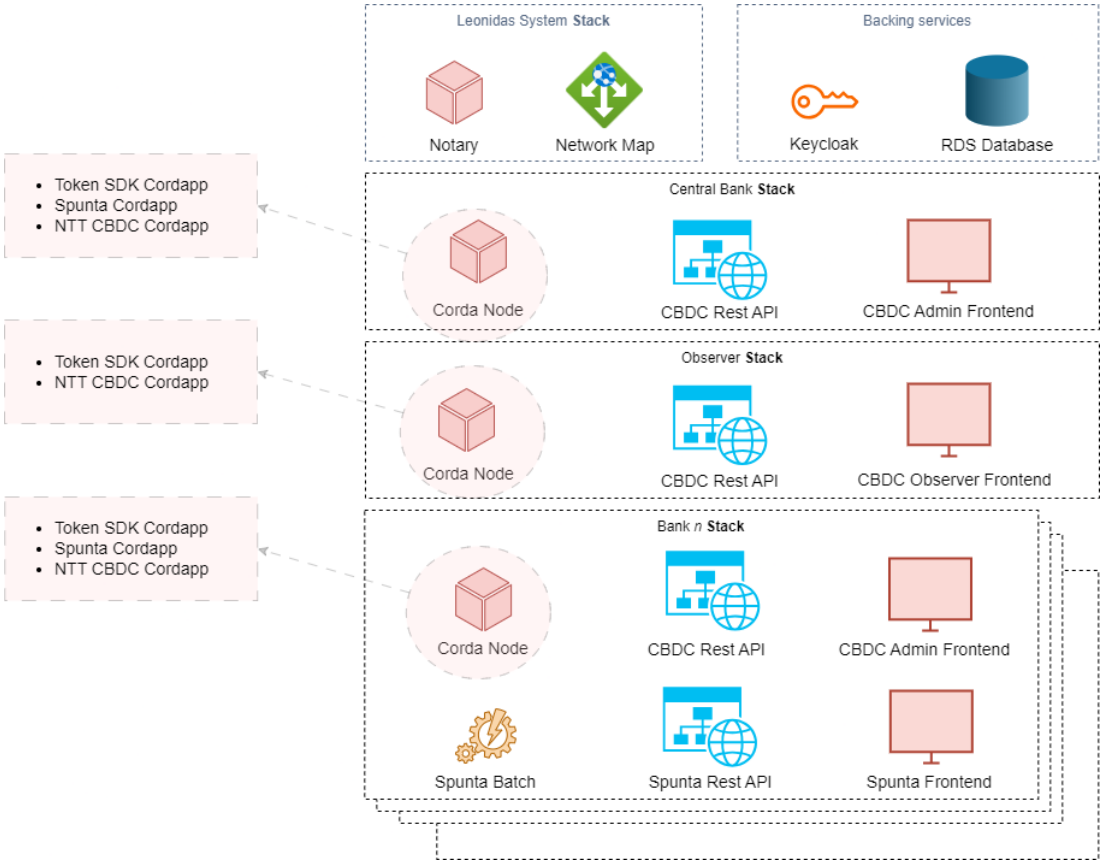

Figure 3: Cloud Agnostic Architecture for Liquid Balance use case

The stacks of Central Bank and Observer are different from the other stacks as the Spunta components are missing. All components are based on container technologies deployed on AWS cloud. The objective of the project is to create cost-efficient architecture initially but with the possibility to scale up, include high availability and improve privacy later. The existing Spunta Italia and CBDC applications have been repackaged and adapted to fit the containerized deployment model. The Corda 4 Enterprise node is based on official containers made available by R3, with the aim to move to more standardized components. The Corda node of each bank hosts both the Spunta and CBDC CordApps, along with their dependencies such as the R3 Token SDK. The network uses a single notary for both CordApps. The databases use AWS infrastructure, which means that maintenance and security patches are done directly by AWS. Finer details on the topic can be found in the technical documentation "Leonidas – Cloud Deployment."

Cash in transfer

Use case description

The focus of the "Cash in Transfer" use case aims at managing and handling the cash supply and demand of banks, building the process on what was already been achieved with an existing initiative of a group of Italian banks. In the as-is scenario, each bank has its own cash in its dedicated vault handled by a Cash Handling Company. Cash is used to supply the branches, replenishing ATMs of each bank and to collect excess cash. This amount of money can increase or decrease every day. Daily matchings are performed among banks based on needs and offers of cash money, and the regulation happens in two steps:

1. Physical movement of cash money in the vaults
2. Wire transfer among banks to update balances

A diagram representing the operation flow is shown below.

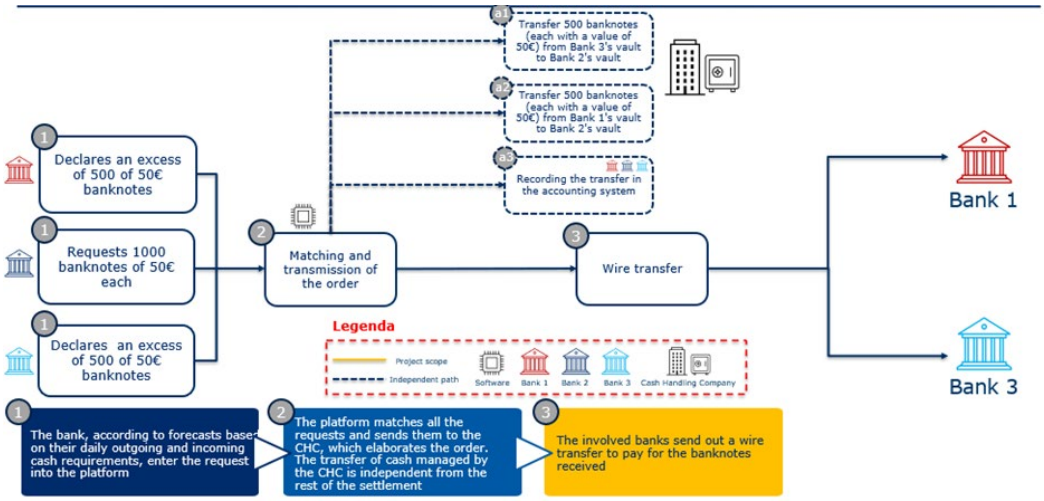

Figure 4: Diagram representing the current mechanism adopted by banks to perform cash exchange

The banks, according to forecasts based on their daily outgoing and incoming cash requirements, enter a request into the platform. After this request is entered, information is matched to identify the exchange operations that satisfy bank needs based on cash availabilities. Once a match is created it is irreversible, therefore each bank has the obligation to comply with it, i.e. provide cash or perform payments. Moreover, the physical cash exchange is performed asynchronously from the monetary payment operations.

The aim of the experimentation is to integrate the adoption of a wCBDC in the process, to analyse and evaluate possible benefits introduced by the usage of such type of digital money. Below a diagram of the proposed model, integrated with a wCBDC module:

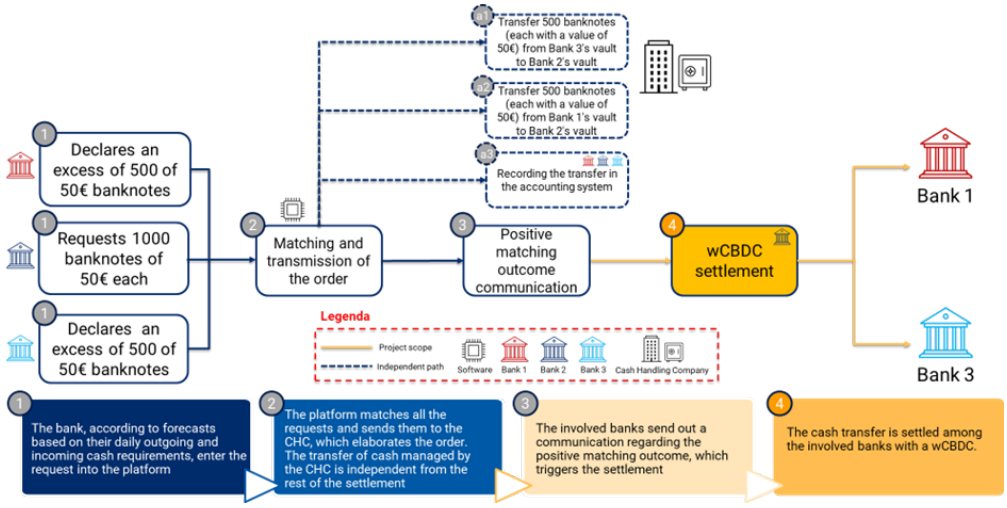

Figure 5: Diagram showing how the wCBDC solution could be integrated with the current existing system

Assumptions

During the use case identification and scope definition processes some assumptions have been considered based on activities timing and deadlines:

All the match generation logic is out of scope.

Cash Handling Company logic (i.e. cash management) is out of scope.

No integration with external running systems.

The wCBDC settlement is performed asynchronously from the physical transfer of the banknotes, as requested by the banks.

Implementation details

The overall system is modelled in line with the Full DLT Interoperability Solution, designed by Banque de France, where two DLTs are used to handle a digital asset (asset leg) and a digital money in the form of a wCBDC (money leg) respectively.

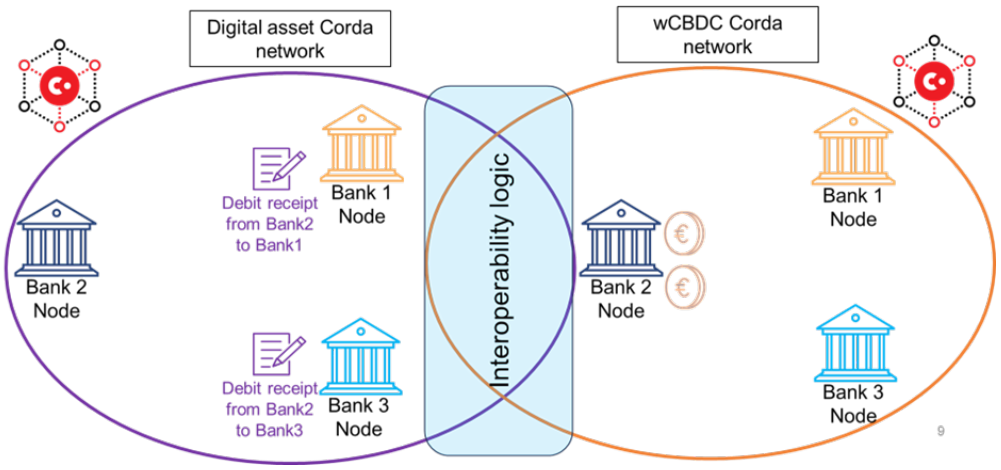

Figure 6: Configuration of the system with separate networks

Each DLT is implemented with the Corda technology developed by R3 and the overall exchanges are performed though a DvP (Delivery versus Payment) that enables the exchange of digital debit receipts (asset leg) vs wCBDCs (money leg). The debt receipts between banks are hold by the creditor banks until the debit is paid and they cannot be sold to third parties. Once the debtor bank has paid in wCBDCs, it receives the digital asset debt receipt, and it can burn it.

The operations in each leg (asset and money) are handled independently but guarantying that the bank will respect all its obligations. The choice was done since it was assumed reasonable that a bank could handle its obligations with a counterparty independently by the obligations existing with a third actor. However, the overall exchange between digital debt receipts and wCBDCs is handled atomically, i.e. a bank receives all the digital debt receipts generated from a match only if wCBDCs have been correctly exchanged with all the counterparties, and vice-versa. Moreover, DvP can be started by any involved actor. In the current implementation the starting leg is arbitrarily chosen.

A front-end application, usable by each bank in the network, has been developed to provide a user-friendly user interface and user experience to use and check the functionalities provided by the solution. Different pages have been implemented, and all the possible actions that can be performed are listed below:

Check the obligations among banks. As previously mentioned, the logic to create the matches between the banks in the network was out of scope of the experimentation, therefore the whole logic related to declaration of need or excess of banknotes and the algorithm to reconcile the requests are not managed by the solution. The environment could be filled, through a REST API call, with match objects to have data to perform functional tests and to verify the functionalities. When such matches are received, digital debt receipts are generated behind the scenes and the page of the obligations updated with the data.

- Settle the obligations between banks, through a manual payment operation. In the page where the obligations are shown, the bank user has the possibility to check them and perform a payment though a dedicated button.

- Check the balance of wCBDCs held by the bank. A dedicated screen is provided with the actual balance, that is automatically updated on each operation performed.
- Monitor all the transactions involving the banks, i.e. digital money issuance from the Central Bank, or digital money exchanged with another bank, can be monitored on a dashboard page.

Architecture overview

In this use case, a new specific application has been created. It interoperates with the R3 Token SDK CordApp to accomplish its tasks. The organizations involved are the same as for Liquid Balance except for the fact that here there are only 3 commercial banks and 1 central bank.

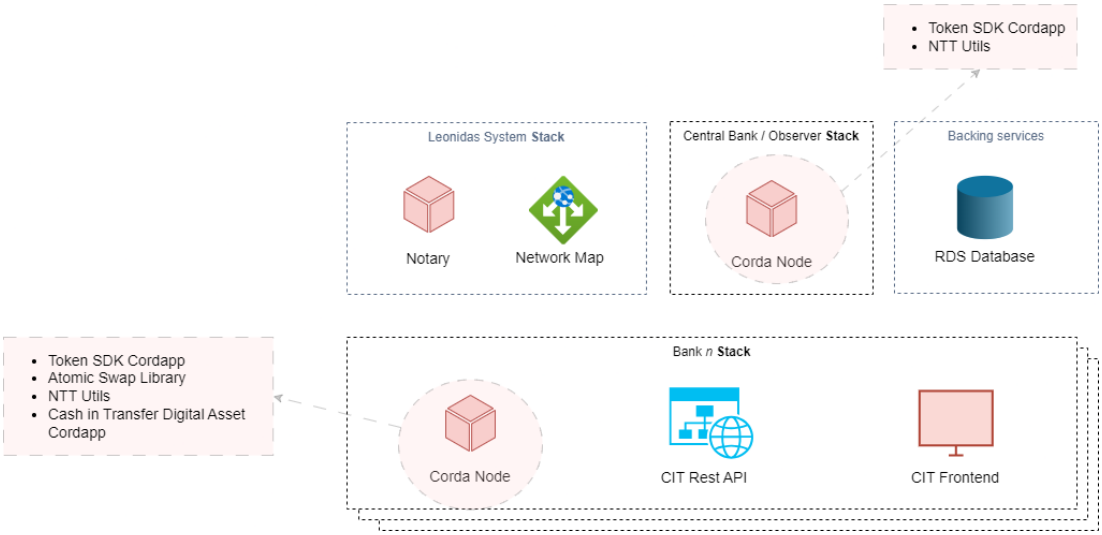

Figure 7: Cloud-Agnostic Architecture for Cash in Transfer use case

Cash in transfer shares most characteristics with the Liquid balance use case, however it is deployed on a sister network isolated from the first one. Like the other use case, all components are based on container technologies deployed on AWS cloud with cost-efficient architecture as an objective, but with room to scale up, include high availability and improve privacy in a later moment. The newly created Cash in transfer application has been developed to follow the container deployment model. The Corda 4 Enterprise node is based on official containers made available by R3, with the aim to move to more standardized components. The Corda node of each bank hosts both the Cash in transfer and CBDC CordApps, along with their dependencies such as the R3 Token SDK and the atomic swap smart contract. Notably, each CordApp uses its own notary, as to further emphasize the decupling of the Cash in transfer and the CBDC applications during the exchange. As in Liquid Balances, the databases are using AWS infrastructure to offload maintenance and security patches to AWS.

Results

The project ended in December 2023, and during the last meeting of the working group a demo was presented to showcase the results.

The primary goal of the project was to assess the effectiveness of liquid balance settlement by employing a simulated wCBDC within a distributed infrastructure like ABILabChain. We completed the whole process end-to-end, finding numerous benefits.

To achieve this, an analysis of the existing process (AS IS) was conducted, identifying key points to retain in the new solution and addressing pain points for process improvement.

The inherent benefits arising from both use cases are manifold, including the atomicity of exchanges, intrinsic transparency, and information traceability. An additional benefit observed is the application of programmability logic during the exchange of value between banks, allowing for increased automation in end-to-end process management while maintaining the central role of humans (always prioritizing the operator's intent over that of the machine).

Beyond the application component, attention has also been focused on infrastructure, proposing new cloud-based configurations, and evaluating their respective advantages and disadvantages compared to the current architecture, including cost reduction.

Lastly, it's worth specifying that the entire architecture and the underlying communication logic between the two legs of the settlement have been developed by drawing inspiration from the Full DLT Solutions designed by Banque de France. Specifically, the "Integration model" for the Liquid Balance use case and the "Interoperability model" for Cash in Transfer were considered, aiming to create a future-proof solution aligned with one of the possible Eurosystem orientations toward adopting new technologies for settlement with wCeBM.

Particularly in the "Integration model," we have explored some possible limits of the current solution, identifying challenges such as side effects arising from the union of two distinct networks. This prompted us to contemplate alternative and long-term solutions, while effectively addressing visibility concerns and ensuring smooth communication during atomic exchanges between two separated networks.

We also identified the need to add some "technological constraints" to optimize the solution, implementing a locking component like the notary to ensure protocol synchronicity. While this solution, though necessitated by technological constraints, is crucial for ensuring security and preventing malicious actions, it potentially becomes a central component for Eurosystem governance.

Conclusions

While there are further development opportunities, some unrealized due to time and effort constraints, such as the complete separation of networks in the cash-in-transfer use case, the project has laid the groundwork for future explorations and implementations. The methodology and solutions developed are a solid starting point for further iterations and improvements in the sector.

As a result of the LEONIDAS experimentation, three key lessons have been identified:

1. DLT Benefits Integration: Leveraging the DLT paradigm in settlement processes brings forth specific technological benefits, including atomic transactions, transparency, and traceability.
2. True Transformation: The application of new technologies should not merely overlay onto existing processes; instead, it should drive a fundamental transformation of processes through the integration of innovative technologies. With a wCBDC based on DLT, this transformation extends seamlessly from the reconciliation activities to the settlement phase.
3. Processes & Technology Integration: Successful innovation in process development necessitates close collaboration between technology experts and domain specialists. The intersection of expertise across various functional areas is confirmed a crucial enabling factor for innovation.

In conclusion, the work undertaken represented a significant moment of sharing and enrichment for the whole working group. It has increased awareness of the potential of the application of emerging technologies in the financial sector, paving the way for new possibilities and challenges to address in the near future.