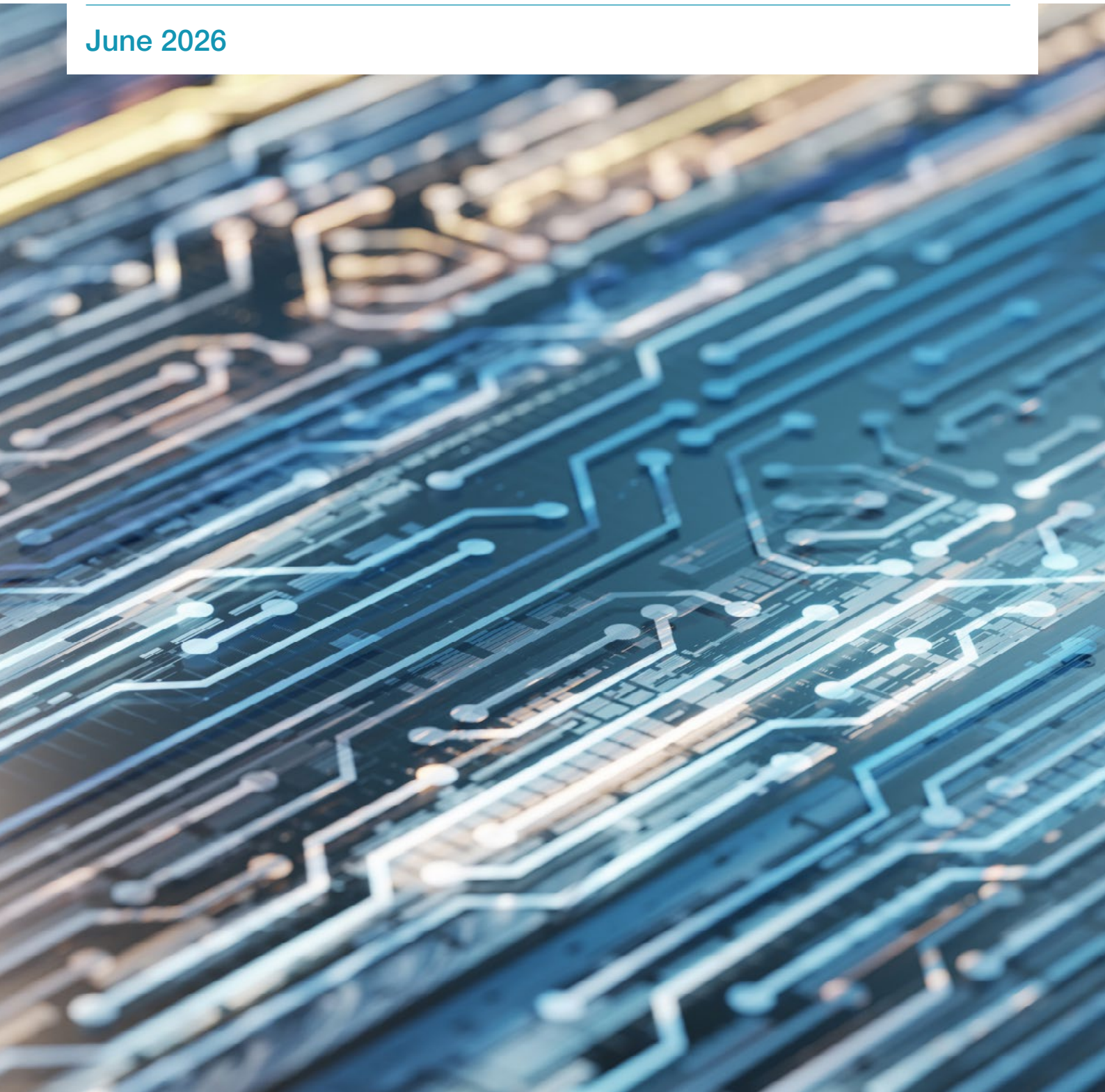
ICMA
International Capital Market Association

DLT and repo, Part I

June 2026



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1 Executive summary

This report is the first of two parts. This first part describes how far the application of distributed ledger technology (DLT) to repo had progressed by the end of 2025 and offers a definition of what is meant by a DLT.

The second part of the report will look at how and when DLT might be adopted across the repo market. The potential benefits for repo are enormous. DLT has been proposed, in particular, as a solution to the frictions in the current hierarchical account-based architecture within which repo is cleared and settled. This requires messaging, reconciliation and transfers, often manually-processed, along chains of settlement intermediaries in order to achieve finality. In contrast, DLT employs a network of computers, each of which is directly connected to every other computer in the network and shares an identical record or "distributed ledger" of holdings and transfers of cryptographically-secured and programmable digital representations of cash and securities. It is proposed that directly-interconnected computers could replace sequential intermediation with near-instantaneous or event-driven and fully-automated peer-to-peer processes to reduce the delays, errors, costs and risks of settlement inherent in the current settlement arrangements. In repo, a particularly popular and potentially near-term use-case that aims exploit these benefits is intra-day transactions.

DLT also offers ways of aggregating and co-ordinating the use of collateral held in multiple or hard-to-reach locations, while more efficient settlement of collateral may open up entirely new contracting possibilities. However, as the second part of the report makes clear, the shape of a future DLT-based architecture is still uncertain, not all of the proposed benefits of DLT are likely to be relevant to repo and along with the benefits come new types of risk.

Notwithstanding the potential impact of DLT on the repo market, it is taken as axiomatic that DLT cannot change the functional and legal character of repo, any more than did the dematerialisation of securities posted as collateral. The unchanging underlying nature of repo can be seen in the Digital Asset and Bond Annexes to the GMRA. Rather than changing repo, the new technology is expected to impact the infrastructure on which repo is traded, settled and managed. For this reason, a DLT repo has been defined as "a repurchase agreement for which OTC trading and some post-trade operations are implemented on one or more distributed ledgers".

Between the advent of the first DLT repo in 2017 and the end of 2025, there were 34 publicised tests and transactions. The only regular and substantial commercial use of DLT repo over the period has been on Broadridge's DLR platform and JP Morgan's Kinexys subsidiary. What has commonly been described as the "DLT repo market" was, by the end of 2025, almost entirely composed of these two distinct and isolated pools of activity. And, while the two platforms have undoubtedly been successful for their operators, their impact in terms of introducing DLT into the repo market has been limited.

There is little doubt that DLT will transform the infrastructure of the repo and other financial markets, by both replacing and enhancing the systems and processes currently in place, and perhaps adding new use-cases, but the evidence to date suggests that the horizon for such a transformation is still some way off. This is notwithstanding bold claims that we have already reached or are about to reach some sort of inflection point. The future path and prospects for DLT in the repo market will be the subject of the next part of the report.

2 The purpose of the report

This is the first of a two-part report looking at the application of distributed ledger technology (DLT) to repurchase agreements (repo). It offers a definition of "DLT repo" and sets out what had been achieved by the end of 2025 by reviewing publicised tests and transactions, which are classified into four basic models. This information is intended to help those in the repo market understand the potential impact of DLT and gauge the current speed of change. It will also hopefully help ground the often-hyperbolic discussion of DLT repo.

The target audience for the report is repo market participants, rather than those involved in the development and implementation of DLT in that market. Accordingly, this first part of the report includes a non-technical introduction to DLT that explains the origins of and drivers behind DLT, the concept of a distributed ledger and essential terminology, as well as classifying the main types of digital cash and assets.[i]

The first part of the report prepares the ground for the second part, which will look ahead, assessing the prospects for a repo market based on a DLT infrastructure and how such a new infrastructure might impact the marketplace and its users. The second part of the report is expected to be published in the summer.

There are three areas which fall outside the scope of the report. First, although the deployment into production of DLT repo is still being held back, to varying degrees, by legal and regulatory obstacles and uncertainty affecting digital cash and assets, the report does not delve deeply into these problems but focusses primarily on technological and market issues. Second, the report does not investigate the direct economic impact of DLT on the repo market that may arise through the links between repo and stablecoins as a result of the use of reverse repo as a reserve asset and to generate additional income through leverage.[ii] Finally, the report focuses on the digitalisation of "real-world assets", as opposed to crypto assets, so does not consider the use or attempted use of repo against crypto assets.[iii]

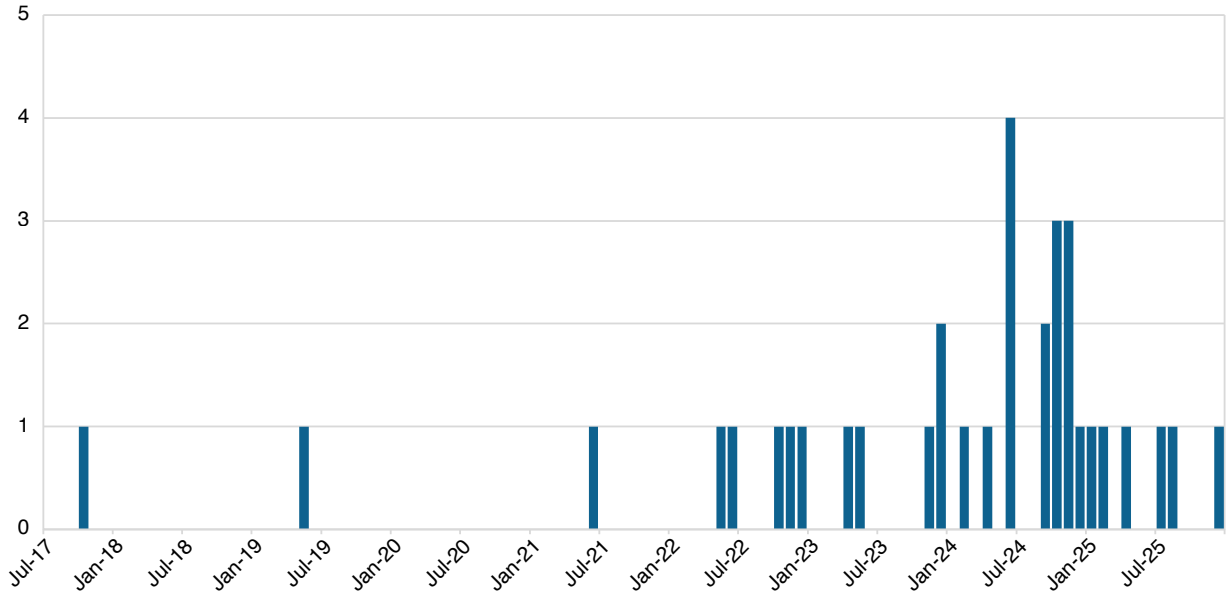
3 Summary of DLT repos executed or tested to date

Between 2017 and the end of 2025, there were 34 publicised tests and transactions in which market participants and infrastructures applied DLT to repo (with some tests consisting of multiple instances).[iv] These tests and transactions are catalogued in the table in Appendix I, which provides a breakdown in terms of counterparties, economic terms, digital technology and settlement infrastructure. The workflows of the publicised tests and transaction are visualised schematically and sorted for comparison into four basic models on the basis of their workflows and types of assets.

The majority of the DLT repos which have been catalogued in this report were proofs-of-concept, trials, pilots, experiments and other tests. Many were partial tests and some were simulations that did not settle real assets. Some or all of the transactions labelled in Appendix I as "commercial" may have been real business diverted onto a DLT platform to support a test. Only Broadridge's DLR and JP Morgan Chase's Kinexys (formerly Onyx) had been in regular and substantial commercial use by the end of 2025.[v]

It can be seen from the table in Appendix I and in Figure 1 below that the history of DLT repos is short, only going back to a single proof-of-concept in late 2017. Over the following three years, other than the regular commercial business on DLR and Onyx/Kinexys, there was just one more proof-of-concept but also the first purported commercial transaction. Five more DLT repos followed in 2022 and four in 2023. There was then a surge in activity in 2024, largely experimental, with 15 individual tests or ensembles of multiple tests. 2025 was quieter, with one possibly commercial transaction and five more tests.

Figure 1: Number of DLT repo tests and transactions per month, 2017-25



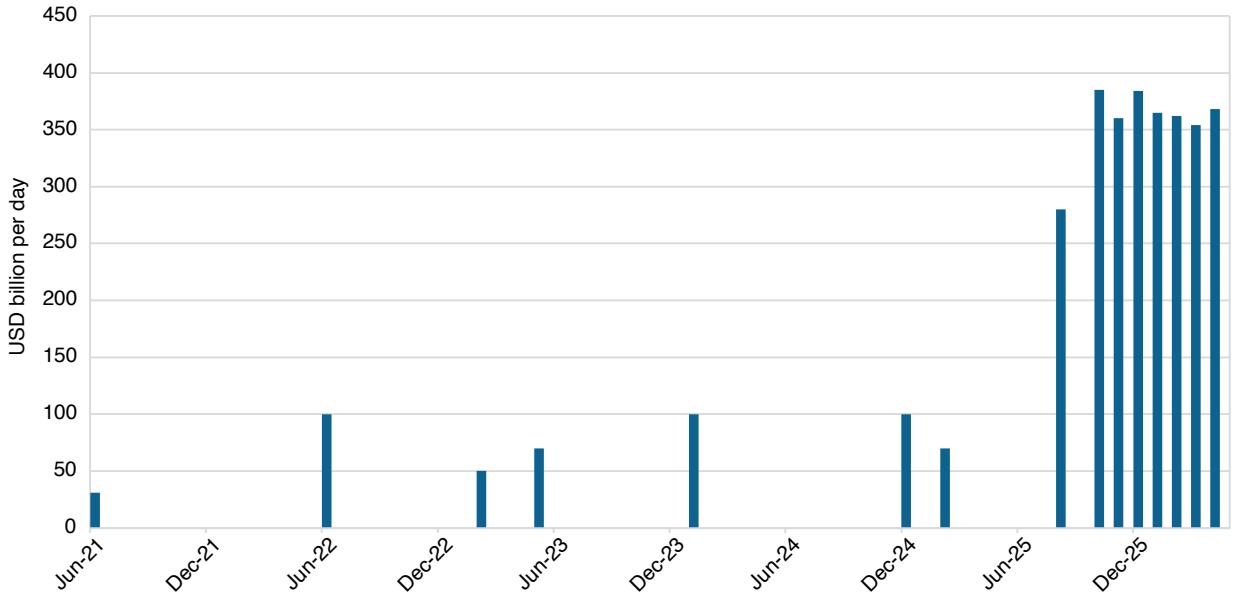
Note: excludes regular business by Onyx/Kinexys and Broadridge DLR

Volumes

Over the period from 2017 to 2025, at least EUR 11.4 billion was announced as having been transacted in more than 289 individual DLT repos outside DLR and Onyx/Kinexys.[vi] However, USD 11.1 billion of this total was through a single set of 240 simulations. This means that the cumulative turnover in DLT repo over the last nine years, excluding DLR and Onyx/Kinexys, is unlikely to have been greater than about USD 300 million, but most of this was experimental and some involved simulated settlement.

In the cases of DLR and Onyx/Kinexys, the release of data on repo turnover has been sporadic. Published daily turnover on DLR is illustrated in Figure 2 below.[vii] The surge in turnover in the second-half of 2025 was reportedly driven by Sponsored Repo in the US, not least, by European banks (including Commerzbank, HSBC, Natixis, SocGen and UBS).

Figure 2: Average daily turnover on Broadridge DLR per month, 2021 to April 2026



Source: Broadridge, author's calculations

In April 2025, Kinexys revealed that their turnover had reached USD 2 billion per day and their joint venture with digital collateral management company HQLA^X was reported as initially adding as much as USD 1 billion a day.[viii] In addition, in May 2026, Kinexys reported a cumulative turnover of USD 3 trillion. Given that they reported a cumulative turnover of USD 300 billion in July 2023, it can be inferred that the average daily turnover since that date has been about USD3.7 billion. This is consistent with the USD 2 billion per day reported in April 2025.

It seems likely that the combined average daily turnover on DLR and Kinexys had reached about USD 370 billion per day by the end of 2025.[ix] However, combining the turnover of DLR and Kinexys is akin to adding apples and oranges, given the significant difference in the degree of digitalisation of the two platforms (compare examples 1.2 and 3.2 in the table in Appendix II). It is also necessary to remember that DLR and Kinexys are "walled gardens", only serving clients who are already using their services and are often inter-affiliate transfers, so do not represent competitive markets (although JP Morgan has provided some market-making on Kinexys).

Types of DLT repo transacted and tested

Of the 34 transactions and tests catalogued in the table in Appendix I, the majority involved:

- cash and collateral legs settled on different distributed ledgers ("cross-chain")

- US dollars in the form of commercial bank money, paid either over the conventional payment infrastructure or in the form of "tokenised deposits"
- US Treasuries or other traditional securities that were settled on the conventional settlement infrastructure or were tokenised
- domestic transactions
- intra-day transactions
- directly-executed transactions — in other words, transacted in the over-the-counter (OTC) market, not on an organised repo trading venue.

To summarise the 34 transactions and sets of tests in more detail:

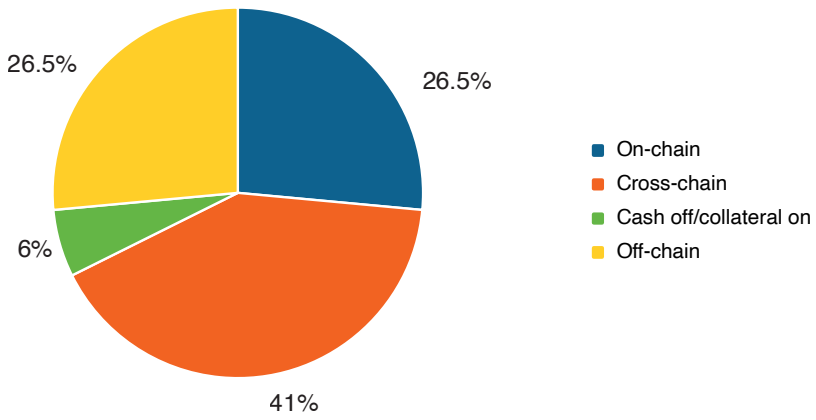
tests versus transactions

- Only 11 repos might qualify as commercial.
- Four purportedly-commercial transactions were on DLR and six on Onyx/Kinexys (both of whom have routinely conducted many more unpublicised commercial DLT repos). These repos have been included in the table in Appendix I because they were specifically publicised. This means that just one of the 11 transactions may actually have been commercially-driven.
- Five sets of tests, involving at least eight repos, were part of the trials organised by the ECB.[x]

on, off or cross-chain

- Seven tests and transactions were settled using the conventional settlement infrastructure ("off-chain"). This is how DLR appears to pay cash, although on-chain payment solutions are apparently being implemented, and how collateral was originally settled.
- Another nine tests and transactions were settled on the same ledger ("on-chain"). Onyx/Kinexys settles on-chain.
- One transaction had the cash leg settled off-chain, while the collateral leg was settled on-chain.
- 14 tests and transactions were cross-chain. In fact, the largest number (but not volume) of tests and transactions were cross-chain.

Figure 3: On-chain versus off-chain repo tests and transactions



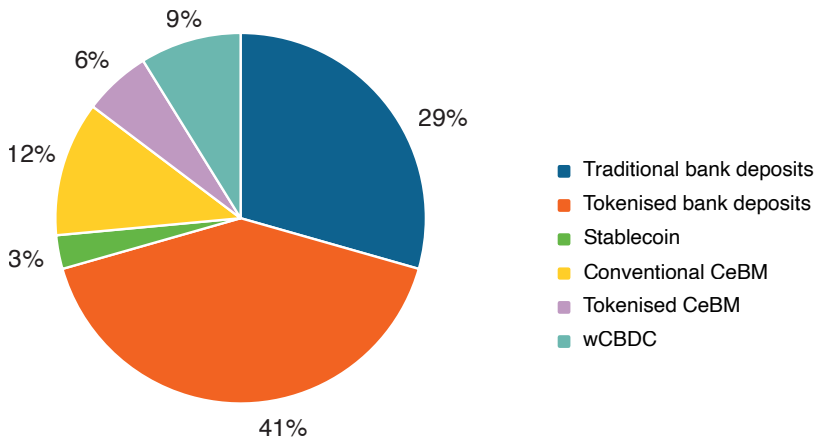
- One cross-chain test was synchronised by a network of non-DLT network peer-to-peer routers (Ownera). This particular solution (between Kinexys and HQLA[X]) went into production in August 2025.
- Another cross-chain transaction was synchronised by a ledger (the Regulated Settlement Network consortium) using SWIFT's "interlinking" solution (see Annex IV).

- One transaction which combined on- and off-chain settlement, and one purely cross-chain test, were synchronised by central securities depositories (CSD) --- HKMA's CMU and SIX, respectively.
- Three cross-chain tests were synchronized by an application to which they were connected across a common network (Canton Network and its Global Synchronizer).

cash

- Payments in 14 transactions or tests were in tokenised deposits.
- Payments in one transaction and eight tests were in central bank money.
- Three cross-chain tests used wholesale central bank digital currencies (wCBDC) issued experimentally by the Banque de France and the Swiss National Bank.
- Four cross-chain tests used the Deutsche Bundesbank's "Trigger Solution", where a "smart contract" operated by the central bank instructed payments in traditional central bank money on the wholesale real-time gross settlement (RTGS) payments system.
- Two cross-chain tests involved payments in tokenised central bank money.
- One test used a stablecoin. However, adopting alternative classifications could increase this to nine, as another six tests and transactions used JPM Coin, which is considered by the EU banking regulator, EBA, to be a stablecoin, while two more tests (by Fnality) used tokenised central bank money, which has also been classified by the BIS as a stablecoin.

Figure 4: Type of cash

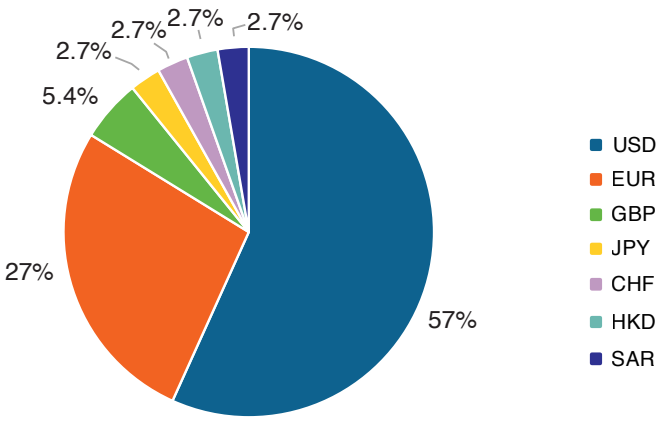


Note: CeBM stands for central bank money; JPM Coin is classified as tokenised deposit.

cash currencies

- 21 tests and transactions included US dollars, including a US dollar stablecoin, as well as most (if not all) of the trades on DLR and Onyx/Kinexys.
- Nine tests and one transaction included euro.
- Two tests were in pound sterling.
- There was one test or transaction each in Japanese yen (test), Swiss francs (test), Hong Kong dollars (transaction) and Saudi riyals (test).

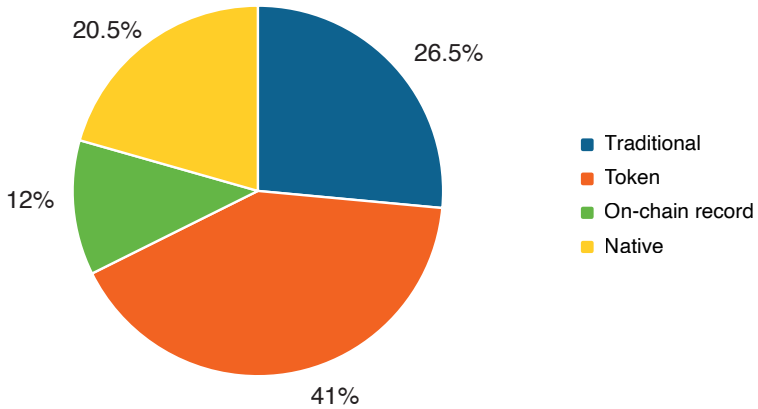
Figure 5: Cash currencies



collateral

- At least four tests and nine transactions involved US Treasuries.
- Six tests were against baskets of collateral.
- Two tests were against commercial paper.
- There was one test each against agency securities, German bunds and covered bonds, and one transaction in central bank bills.
- Collateral was denominated in eight currencies: 22 in USD, 11in EUR, two in GBP and one each in CHF, CNY, HKD, JPY and SAR.
- Seven collateral securities were native-digital.
- One collateral security was a green bond.
- One collateral security was a Sukuk bond (albeit simulated).

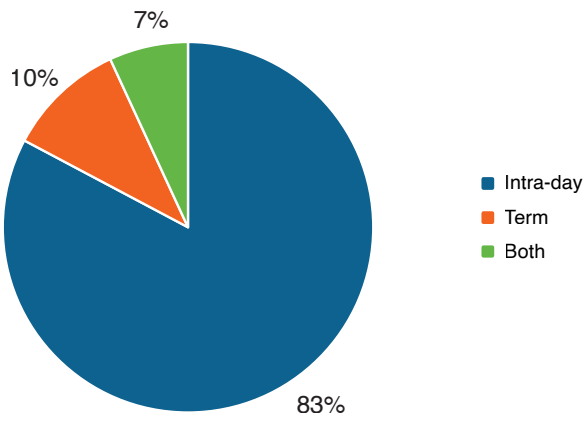
Figure 6: Types of collateral



tenor

- 15 tests and nine transactions were purely intra-day.
- Two tests and one transaction were purely for term.
- Two tests and transactions involved intra-day, overnight and term repos.

Figure 7: Tenors



geography

- Most DLT repo tests and transactions were domestic.
- Just two were cross-border.

infrastructures

- Two tests involved central banks as counterparties and were simulations of central bank refinancing.
- Most tests and transactions were executed directly between the counterparties, rather on an organised trading venue.
- 10 tests employed five organised trading or negotiation venues (Eurex F7, Finteum, SIX Repo, Tradeweb and Wematch), as well as a trading application hosted by a network of platforms (provided by the Canton Network).
- 10 tests and one transaction employed tri-party collateral management agents.
- CCPs took part in three tests.

contractual characteristics

- Most of the catalogued tests seem to have conducted within isolated legal and regulatory environments, although many smart contracts are likely to have been based on existing standard master repurchase agreements such as ICMA's Global Master Repurchase Agreement (GMRA).
- Given that the ICMA's Digital Asset Annex to the GMRA was only published in August 2024, it may only have been employed to document intra-day DLT repos settled under the joint venture launched in August 2025 between Kinexys and HQLA^{X}.
- There was a simulation by four banks of nine Islamic DLT repo using a double wa-ad contract under Saudi law based on the Saudi National Bank's master repurchase agreement.

4 What is a DLT repo?

Legally and functionally, repos involving DLT are identical to "conventional" repos. The fact that cash or collateral exist only on a distributed ledger is not, of itself, distinctive. Cash already mainly exists in digital form on conventional accounts at central and commercial banks. Traditional collateral securities already largely exist as digital certificates in book-entry form on conventional accounts at central securities depositories (CSD) and custodians. The defining characteristic of DLT is the decentralisation of distributed ledgers but this is not significant for the legal and functional nature of repo.

The unchanged nature of repo when DLT is applied is implicit in the Digital Asset and Bond Annexes to ICMA's Global Master Repurchase Agreement (GMRA) (about which see Appendix IV). The Annexes do not redefine a repo but rely on the existing definition in the main body of the GMRA. Rather, they clarify that the types of digital asset defined in the Annexes are encompassed by the existing definition of a security, allow the use of digital cash and confirm that delivery on a ledger is good delivery. The Annexes also address issues such as: what is equivalent to a digital asset at repurchase; how a tokenised security should be valued, margined and settled in the event that the operation of the ledger is disrupted or ceases to function altogether; what happens to a repo of a digital asset in a default; and how intra-day repo interest should be calculated.

So how do DLT repo differ from conventional repo? This section of the report distinguishes between them by comparing conventional and DLT repo in each of the main stages in the life of a repo: pre-trade preparation, trading and post-trade processing.

Pre-trade preparation

Important pre-trade activities — such as know-your-customer (KYC) procedures to meet the requirements of anti-money-laundering (AML), countering-financing-for-terrorism (CFT) and proliferation-financing (PF) regulations, as well as counterparty credit checks for internal risk management — are not specific to repo. The application of DLT to these functions is therefore not of special relevance to a discussion of DLT repo.[xi]

While there are pre-trade activities with special relevance to repo (for example, monitoring collateral eligibility, value and availability), these are likely to be implemented as components of post-trade collateral management systems across all securities financing transactions (SFT) and derivatives, rather than being dedicated solely to the pre-trading of repo. In this way, a firm could build a holistic view of its collateral across divisions and branches, as well as across subsidiaries. There would also be valuable economies of scale. Therefore, while the application of DLT to pre-trade activities will undoubtedly impact repo, the particular needs of the repo market are unlikely to be a major driver in the adoption of that technology in pre-trade processing.

Trading

By the end of 2025, there were no DLT-based organised repo trading venues in commercial use (see the first part of Appendix III). DLT repos were traded using conventional technology and then reported to a distributed ledger for post-trade processing.[xii]

DLT-based organised trading venues are perfectly feasible. Indeed, there is a venue for intra-day repo which is preparing to launch (see the description of Finteum in Annex III) and others (typically, also for intra-day repo trading) are likely to appear in 2026 within the EU DLT Pilot and UK Securities Sandbox (DSS) frameworks. These venues operate a request-for-quote (RFQ) trading protocol between the nodes on a blockchain. As RFQ trading is an automated version of over-the-counter (OTC) trading, and OTC markets are decentralised, RFQ is a natural protocol for DLT-based trading.

In contrast, central limit order-books (CLOB), which are the other main electronic trading protocol in the repo market, by virtue of being centralised, have little to gain from DLT (and have only been used off-chain in tests).[xiii] The application of DLT to repo trading and the issue of crypto-exchanges using CLOBs are discussed in the first part of Appendix III.

If and when more DLT-based repo trading platforms emerge, and a more complete DLT ecosystem starts to come together, potential synergies from the use of common technology may exert a "gravitational pull" on repo trading, away from existing platforms and the OTC market. However, because of the cost and risks of migration, as well as the risk of fragmenting liquidity, DLT-based repo trading venues seem more likely to emerge as enhancements implemented by existing venue-providers, incorporating DLT to protect their franchises, rather than as disruptive technology deployed by new entrants.

Post-trade processing

The key differences between DLT and conventional repo, at present, lie in their post-trade processing. For some post-trade processes, those differences are likely to persist into the long-term. This is most notably the case in repo clearing, where proposals for decentralised alternatives to central-clearing by a CCP would face fundamental legal objections and seem to require the CCP to be replaced with multiple alternative third-parties, in effect, fragmenting rather than cleanly replacing the CCP. No credible alternative has emerged in the crypto-asset markets. Consequently, there does not appear to be a realistic possibility of CCPs being displaced by DLT-based alternatives. The obstacles to the decentralisation of central-clearing are discussed in detail in the second part of Appendix III.

While a DLT-based alternative to the central-clearing of repo is not in prospect, there is a very strong and generally-accepted case for adopting DLT in the final stage of repo post-trade processing, that is, settlement.

It is therefore in the post-trade processes of settlement and collateral management that DLT seems to offer the earliest and most significant gains for repo, specifically, by enhancing the efficiency and accuracy of book and records, and by facilitating the mobilisation and transfer of cash and assets.

There is an argument that DLT will encourage the emergence of integrated trading, clearing and settlement systems, through the emergence of new entities offering a comprehensive range of post-trade services or by one type of financial market infrastructure competing with other types. For example, a CSD might operate its own organised trading venue, while an organised trading venue might provide clearing and settlement services. Integrated trading, clearing and settlement is permitted in the EU Pilot Regime,[xiv] which envisages new entities called DLT TTS (trading and settlement systems), combining the functions of a multilateral trading facility (MTF) and settlement agent on the same distributed ledger. In the UK, the Digital Securities Sandbox (DSS) provides a similar framework for so-called DSS Hybrids.[xv]

Integrated trading, clearing and settlement infrastructures are already being tested in sandboxes, but a number of doubts have been expressed about their viability. Existing trading venues and conventional clearing and settlement providers are well-entrenched in their respective domains by their expertise and strong relationships with different functions within customers. It is also argued that the persistence of traditional securities will limit the incentive to an organised trading venue to move into the clearing and settlement of tokenised or native-digital securities.

However, the success or failure of integrated trading, clearing and settlement infrastructures does not affect the argument that the application of DLT to repo will be limited to OTC trading and post-trade processing.

Defining DLT repo

On the basis of the previous discussion, which concludes that DLT is only likely to distinctively change the way in which OTC repo is traded and the post-trade processing of bilaterally-cleared repo, this report proposes to define a DLT repo as **a repurchase agreement for which OTC trading and some post-trade operations are implemented on one or more distributed ledgers**. Specifically, it is proposed that the DLT-based trading of repo will employ the RFQ trading protocol and that DLT-based post-trade processing of repos will not include central-clearing. The essence of a repo itself remains untouched by DLT, even though the use and management of such a repo may be profoundly affected.

5 Tokens and other digital assets

This section and the next describe, respectively, the digital forms of cash and securities that have been used in the DLT repos observed during 2017-25. For those unfamiliar with the underlying technology, key concepts and terminology, there is a primer on DLT in Annex II.

There are three types of digital asset: tokens; native-digital assets; and digital records.

Tokens

"Tokenisation" is commonly defined as the operational and legal process of creating a digital representation on a distributed ledger of ownership of, or of contractual rights to or claims on, an asset. Such a representation is commonly known as a "**token**".[xvi] Where such a representation is secured by cryptography, it falls into the genera of "**crypto-assets**", but this term is often reserved for digital representations without intrinsic value, that is, a value entirely reliant on the balance of supply and demand for the crypto-asset.

Tokens can also be issued that represent processes rather than assets. One example is the SBA Deposit Token described in Annex IV.

Tokens representing an asset are almost complete substitutes for a conventional custody account. In the latter, information about registered assets and their ownership is segregated from the rules that govern custody, transfer and settlement, including collateral management. Thus, the BIS talks about a conventional account having a "core layer" and a "service layer", respectively. In contrast, tokens incorporate both asset data and platform rules. Consequently, they are said to integrate "messaging, reconciliation and asset transfer into a single, seamless operation", thereby "overcoming the frictions and inefficiencies of the conventional architecture".[xvii]

Economically, a token representing an asset can be either:

- **asset-backed —** sometimes called a "non-native token"[xviii] — which is a digital representation of a traditional asset held in a conventional account, where the traditional asset may be called a "real-world asset", while the representation on a distributed ledger is called its "digital twin".
- **synthetic —** sometimes called a "native token" — which is a digital representation of value with a price that is indexed one-to-one to the value of another asset, which could be digital or traditional, and which creates an exposure to risk that requires hedging.[xix] In the ICMA Digital Bonds Annex to the GMRA (see Appendix IV), a synthetic token is referred to simply as a "digital bond" and defined as "a debt security that is issued, held, transferred, cancelled and/or redeemed using blockchain or distributed ledger technology".

The act of creating a token on a distributed ledger is called "minting" and the act of destruction at the end of the life of a token is referred to as "burning". In the case of asset-backed tokens, minting them on a distributed ledger requires the underlying asset to be immobilised or "locked" in a conventional account to act, in effect, as collateral for the token (legally, the immobilisation of the underlying asset is said to "staple" the token to the asset). The locking of a traditional asset and the minting of a token should be simultaneous, while the burning of a token on a distributed ledger should immediately unlock access to the underlying asset in the conventional account.

The procedures and infrastructures required to lock (unlock) a traditional asset in a conventional account and allow the simultaneous minting (burning) of a token of that asset on a distributed ledger, are called "ramps". Minting is said to require an "on ramp" from the conventional account into the distributed ledger, while burning requires an "off ramp" from the distributed ledger back into the conventional account.

Native-digital assets

In addition to taking the form of tokens, assets on ledgers can also take the form of "native-digital assets", which are digital representations of value that do not and have never existed in any form other than a record on a distributed ledger. Native-digital assets are often classed as tokens (eg being referred to as "security token offerings" in the US and "bearer tokens" by ISDA).[xx] However, in this report, native-digital assets and tokens will be distinguished from each other, on the grounds that it is more meaningful to distinguish between a digital representation of something else (a token) and a digital representation that is an asset in and of itself, without reference to anything else (a native-digital asset).

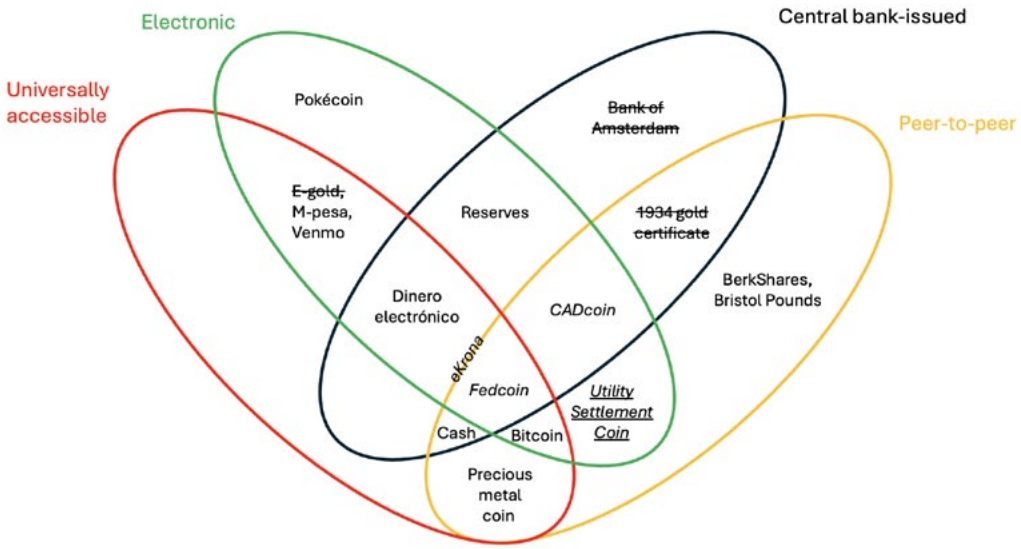
Digital records

A third approach to transferring assets on a distributed ledger has been taken by the digital collateral management firm HQLA^X, which makes passive use of a distributed ledger to produce, not a token, but a digital record --- called a Digital Collateral Record (DCR) --- of the ownership of a real-world asset that is itself authoritatively recorded in a conventional account (HQLA^X is described in Annex III).[xxi] In the case of a token, ownership is changed by transfer. In the case of a DCR, ownership is changed by amending the DCR. The process might be described as ad hoc digital registration, given that HQLA^X offers the temporary digitalisation of traditional securities held in a conventional account, unlike a digital CSD or registry, on which registration is as permanent as the asset.

6 Digital cash

Digital cash can take many forms. A comprehensive classification of current and historic forms of cash/money has been constructed by the BIS and visualised in the form of a "money flower". Digital cash falls within the "electronic" petal.

Figure 8: the BIS money flower



Note: A standard font indicates that a system is in operation; an *italic* font indicates a proposal; an *italic and underlined* font indicates experimentation; a ~~strikethrough~~ font indicates a defunct company or an abandoned project.

Digital cash (loosely defined) can take the form of:

- **crypto-currency —** A medium of exchange, store of value and unit of account which is not issued or managed by any central authority (eg a government or central bank). It exists only on a distributed ledger. That ledger records the issuance, ownership and transfer of the crypto-currency. Issuance requires a consensus among the nodes of the ledger, who may also validate transfers of ownership. In terms of the BIS money flower, crypto-currency would be classified as peer-to-peer, universally-accessible and electronic cash. Examples are Bitcoin, Dogecoin, Ether and Ripple. This type of digital cash has not been observed in DLT repo to date.
- **stablecoin —** A type of crypto-currency that takes the form of a token with a value that purports to be stabilised by being pegged one-for-one to the value of a traditional asset.[xxii] This is a second type of peer-to-peer, universally-accessible and electronic cash. Stablecoin are often described as digital bearer instruments. They were devised to provide an on-chain store of value in response to the volatility of Bitcoin. The first was launched in July 2014 by Tether, which remains the largest stablecoin. The various types of stablecoin are analysed below. There is one example of a stablecoin being used as cash in an otherwise conventional DLT repo during 2017-2015.
- **tokenised deposit —** The claim of a depositor against a bank recorded on a distributed ledger, rather than on a conventional account. The legal rights of the depositor derive from his account with the bank, rather than from his possession of a token. The issuance of tokens should therefore make no difference to the contractual relationship between the depositor and his bank.[xxiii] Unlike stablecoins, tokenised deposits cannot be directly transferred peer-to-peer (although it should be noted that intermediaries are also often used in the transfer of stablecoins and there are tokenised deposit interoperability solutions --- see Annex IV). Tokenised deposits were the most common type of digital cash in DLT repos publicised during 2017-25.

- **tokenised deposit transfer instructions —** A novel tokenisation approach to deposits was evaluated in a proof-of-concept completed in September 2025 by the Swiss Bankers Association (SBA) and some of its members.[xxiv] This involved a "Deposit Token",[xxv] which was not a token representing a deposit and having intrinsic value, but a token representing standardised programmable instructions to make debits or credits to traditional bank accounts (for more information about the SBA experiment, see Annex IV). The Deposit Token was not included in the table in Appendix I because it has not yet been used to test a DLT repo.
- **central bank digital currency (CBDC) —** A native-digital representation of a fiat currency issued and controlled by a central bank in the form of a token issued on a distributed ledger operated by the central bank. A wholesale central bank digital currency (wCBDC) is recorded on a private permissioned ledger restricted to payment banks and authorised payment agents who are also connected to the RTGS payment system operated by the central bank. Although CBDC is not asset-backed, some have argued that it is a stablecoin, by virtue of being pegged to the value of a fiat currency, but this is not a generally-accepted classification. CBDC can also be considered a crypto-currency, since it exists only on a distributed ledger. Within the BIS money flower, this type of digital cash simply constitutes central bank reserves. The ECB exploration of DLT in 2023-24 (generally referred to as the "ECB trials") included wCBDC issued on the D3SL ledger developed by the Banque de France (the so-called "Full DLT Interoperability" solution to DLT-based payments in central bank money).[xxvi]
- **tokenised central bank money —** A token on the distributed ledger of an RTGS participant which is a digital representation of reserves held by that participant at the central bank. This was the solution tested by Fnality UK at the Bank of England (Fnality is described in Annex III). The BIS have classified Fnality's token as a stablecoin.

The Digital Asset Annex of the GMRA defines digital cash as "a central bank digital currency, tokenised deposit, electronic money token or other cryptographically secured digital representation of value denominated in a single fiat currency, which can be used for the settlement of payment obligations". It therefore expressly encompasses CBDC, tokenised deposits, tokenised central bank money and single-currency stablecoins. It does not expressly include (other) crypto-currency, but the general category at the end --- "cryptographically secured digital representation of value denominated in a single fiat currency, which can be used for the settlement of payment obligations" --- is very wide.

Stablecoins

There are three types of stablecoin:[xxvii] [xxviii]

- **fiat-backed —** An asset-backed token, the value of which purports to be stabilised by reserves owned by the issuer in the form of a deposit of fiat cash, highly-liquid securities or a fund, either of equal value (eg Tether/USDT and Circle/USDC) or of a greater value (eg DAI, now rebranded as Sky/USDS).[xxix] [xxx]
- **commodity-backed —** An asset-backed token, the value of which purports to be stabilised by asset-backing in the form of a stock of commodities owned by the issuer, often gold (eg Tether Gold and Pax Gold).[xxxi] This type of stablecoin would not be covered by the GMRA Digital Asset Annex.
- **algorithmic —** A synthetic token, the value of which purports to be stabilised by means of an algorithm, which dynamically adjusts the supply of the stablecoin in response to deviations from par with the fiat currency (examples include FRAX and formerly TerraUSD).[xxxii] This type of stablecoin would also not be covered by the GMRA Digital Asset Annex.

Stablecoins are often issued on, and are therefore native to, several distributed ledgers at once ("multi-chain issuance"). For example, Tether (ticker: USDT) is hosted by 104 ledgers and USD Coin (ticker: USDC) by 122.[xxxiii] Alternatively, stablecoins issued on one platform can be made transferable (at par) to another through cross-chain bridges ("bridged stablecoins").[xxxiv]

The boundary between tokenised deposits and stablecoins is not always clear. For example, JPM Coin, which is JP Morgan Chase's on-chain payment solution, is not classed as a tokenised deposit by the EU banking regulator, EBA. Rather, it been judged to be an electronic money token (EMT) or stablecoin, because it has been deemed, unlike a

traditional deposit, to be a bearer instrument (albeit only within Kinexys). However, this categorisation is contested. The BIS see JPM Coin as a non-bearer instrument, although not necessarily a tokenised deposit.[xxxv]

Payment in conventional commercial bank money

Instead of using cash tokens to settle a DLT repo, ledgers can also instruct payment off-chain, on the conventional infrastructure. For example, payments in US dollars can be made in commercial bank money by a clearing bank (eg Broadridge DLR employs Bank of New York Mellon).

Payment in conventional central bank money

Payments can be made in conventional central bank money through interoperability links between the wholesale RTGS operated by the central bank and external distributed ledgers. Two types of central bank payment mechanism were tested in the ECB trials, but only one for DLT repo.[xxxvi] This was the Deutsche Bundesbank's "**Trigger Solution**", which was a bridge between the T2 RTGS operated by the Eurosystem and private distributed ledgers operated by financial institutions. The "trigger" mechanism at the core of this solution was a smart contract operated by the Bundesbank which controlled payments from or into reserve accounts at the central bank, respectively, into or from an interim account. In one instance, the trigger released a payment in response to instructions from the external ledger, which was responsible for synchronising the exchange (atomic settlement) of assets being settled. In a second instance, the trigger incorporated a "hashed time-lock" (HTLC) mechanism, which locked a payment made by a buyer into the interim account until the seller enabled the buyer to claim the asset being purchased, subject to the condition that the transfers had taken place within an agreed period of time.

7 The drivers of DLT in the repo market

At the risk of pre-empting the second part of this report, which will look at how and when DLT might be fully adopted across the repo market, it may be helpful to summarise the expectations that are driving interest and investment in DLT in the repo market (see also Annexes I and II).

As reflected in the definition of a DLT repo proposed in section 4, the focus of DLT in the repo market is on post-trade processes. The post-trade benefits of DLT are expected to come mainly in settlement, collateral management and margining, and perhaps through the mobilisation of new sources of collateral.

Possibilities in repo settlement

The basic case for the use of DLT in repo settlement is that the hierarchical account-based chains of intermediaries (custodians and transfer agents) currently required to settle financial transactions — and the sequential messaging, manual end-of-day batched reconciliation and repeated transfers of cash and securities needed to connect them --- creates material delays, errors, operational costs and risks. These problems then translate into and are compounded by significant capital, liquidity and collateral requirements. The proposition for DLT is that the current multi-tiered account-based settlement architecture could be rendered redundant by giving counterparties direct, near-instant and simultaneous transparency into the settlement status of their transactions and balances through shared copies of a distributed ledger (which, in the case of blockchain DLT, would also be immutable records). The estimated savings from such disintermediation are enormous.[xxxvii]

To use DLT for settlement, either traditional cash and assets would have to be replaced by native-digital versions, or the ownership of such assets would have to be represented by ledger-based tokens or digital certificates. Native-digital assets avoid the settlement frictions of the conventional settlement infrastructure altogether. Tokens or digital certificates sooth settlement frictions by immobilising traditional assets on the conventional settlement infrastructure and transferring or updating the digital representations instead.

In addition, DLT promises further reductions in the delays, errors, costs and risks of settlement through the programmability or self-executing capability of smart contracts built into digital representations of cash and assets. Programmability has the potential to allow actions to be initiated automatically upon the occurrence of pre-defined events, thereby enabling autonomous management of the consequent post-trade workflows, in other words, automation.

Using the programmable settlement capability of smart contracts to choose the precise time of settlement would permit firms to allocate instructions to specific settlement cycles in order to align payments and deliveries with the availability of liquidity and inventory, which would minimise failed settlement. The precise choice of settlement cycles may also be essential in facilitating the acceleration of settlement to T+0, as it could be used to concentrate settlement at particular times of the day and thereby maximise technical netting to help offset the increase in liquidity that is required by faster settlement.

An application of the greater settlement precision that is specific to repo would be to enable intra-day transactions, by allowing the exact times of sale and repurchase to be agreed for the same day. Intra-day repo should be able to reduce financing costs by removing the need to borrow overnight in order to cover intra-day shortfalls in liquidity and by shrinking the size of precautionary liquidity buffers.[xxxviii] Intra-day transactions seem likely to be where DLT will make its first market-wide impact on repo. It is unlikely to be coincidence that intra-day repo was the most common application of DLT to repo that in the various tests that are listed in the Appendix I. It has also been a key objective of one of the first commercial DLT repo platforms (Kinexys).

Another way in which the DLT programmability could boost repo settlement efficiency is by enabling the composability (bundling) of related transactions. This means the automatic and simultaneous settlement of a set or sequence of related

transactions, where the execution and settlement of each transaction is contingent upon the execution and settlement of another or other transactions or upon the occurrence of some other event. Simple examples would be the settlement of a repo on condition that the collateral security is successfully purchased in the cash market and repo roll-overs. Composability could reduce failed settlement, in part by increasing the rate of technical netting (reinforcing the impact of settlement precision).

Digitalised settlement, whether of native-digital or digital representations of traditional cash and assets, could also be used to relax the constraints imposed by cut-off times in conventional infrastructures and widen the windows for the settlement of transactions between time zones. At the extreme, it opens the way to 24x7 trading --- so-called "always-on" markets --- that can be immediately settled, or at least significantly-extended settlement windows.

The core case for DLT-based settlement is therefore one of cost and risk reduction, and enhanced speed and efficiency through the elimination of messaging, reconciliation and transfers between settlement intermediaries, the automation of other post-trade processes and the realisation of settlement that can be precisely-timed, faster and available 24x7.

Possibilities in collateral and margin management

Another post-trade activity in which DLT is expected to make dramatic improvements is firm-wide or group-wide collateral management, in particular, to enhance the optimisation of collateral allocation and the efficiency of variation margining.

A distributed ledger encompassing all the collateral sources, inventories and uses within a firm or across a group would effectively unify the fragmented collateral pools held by different business silos, deposited in different locations or deployed in different market infrastructures, without needing to merge businesses or re-engineer collateral systems. The ledger would act as an "abstraction overlay" that unifies the fragmented pools of collateral into a single virtual collateral "lake".

Variation margining also offers a compelling collateral use-case for DLT, given that it is generally managed on a portfolio basis and independently of the underlying repo settlement process and could therefore be conducted separately using standalone DLT, where the settlement of the main collateral (the Purchased and Equivalent Securities in GMRA terminology) remains on the conventional infrastructure. This would allow faster margining to reduce exposures, which should translate into lower risk capital requirements.

The use of smart contracts could also facilitate the automation of collateral management processes, including collateral substitution and manufactured payments. In the case of repo collateral substitution, there is the additional benefit that digitalisation, composability and atomic settlement enable delivery-versus-delivery (DVD), which is currently not provided by the existing infrastructure and offers significant balance sheet and liquidity savings.

The possibility of new collateral

A third area where it is suggested that the advent of digital cash and assets might be significant for the repo market is the use of tokenisation or digital registration to widen the range of collateral that can be financed with repo. As explained, the transformation of traditional assets into digital assets allows the transfer of legal ownership to be divorced from the delivery of the underlying asset. It has been suggested that this should allow the mobilisation, for use as collateral, of so-called "trapped assets", which have previously been underused because of the cost or inconvenience of access, or not used at all because of more fundamental obstacles such as the complexity of the legal requirements for transfer.

In addition to releasing trapped assets, it has been suggested that new types of collateral could be created by unbundling the rights and obligations of existing assets, eg the right to take control of collateral in the event of a default or the obligation to meet margin calls.

Finally, as well as making more collateral available to the repo market, it is also proposed that DLT could broaden ("democratise") participation by allowing collateral to be broken down into smaller units. Such "fractionalisation" is aimed specifically at the retail market.

Cautions

As the second part of the report will make clear, while DLT is likely to be transformative and the potential benefits are dramatic, a DLT-based architecture could evolve in several alternative directions. Key questions are how individual ledgers can be made interoperable and which forms of digital representation will be used for which types of business. It also seems inevitable that the disintermediation at the heart of DLT will have limits, with some current clearing and settlement intermediaries surviving and adopting DLT to enhance their operations (eg CCPs) and others surviving by extending their services to digital cash and assets (eg CSDs), while DLT will need new types of intermediary (eg wallet-providers and oracles).

It also needs to be remembered that DLT will introduce new types of risk. Moreover, several of the proposals to widen the range of collateral and participation through the application of DLT are unlikely to gain much traction in the repo market, given its wholesale low-risk character.

8 Comparing DLT repo

In this section, the publicised tests and transactions that are catalogued in the table in Appendix I (many of which are illustrated in Appendix II) are generalised and compared in terms of four simple models which differ in terms of their workflows through six sequential or alternative stages in the life of a DLT repo:

- trading
- booking on a distributed ledger and possible on-chain or cross-chain settlement
- booking on a conventional account
- tokenisation
- collateral management, including tri-party operations and CCP-clearing
- custody and transfer of any underlying traditional assets on the conventional payment and settlement infrastructure.

The four models differ in terms of three key parameters (see the table below). The first is whether the counterparties use the same distributed ledger or there is more than one ledger. The second and third parameters are whether cash, collateral or both are digitalised (tokenised, digitally-recorded or take the form of native-digital assets). The resulting four possible models are therefore:[xxxix]

1 single ledger with digital collateral and digital cash — on-chain

2 double ledger with digital collateral and digital cash — cross-chain

3 single ledger the digital collateral and conventional cash — on/off-chain

4 double ledger with conventional collateral and conventional cash — off-chain

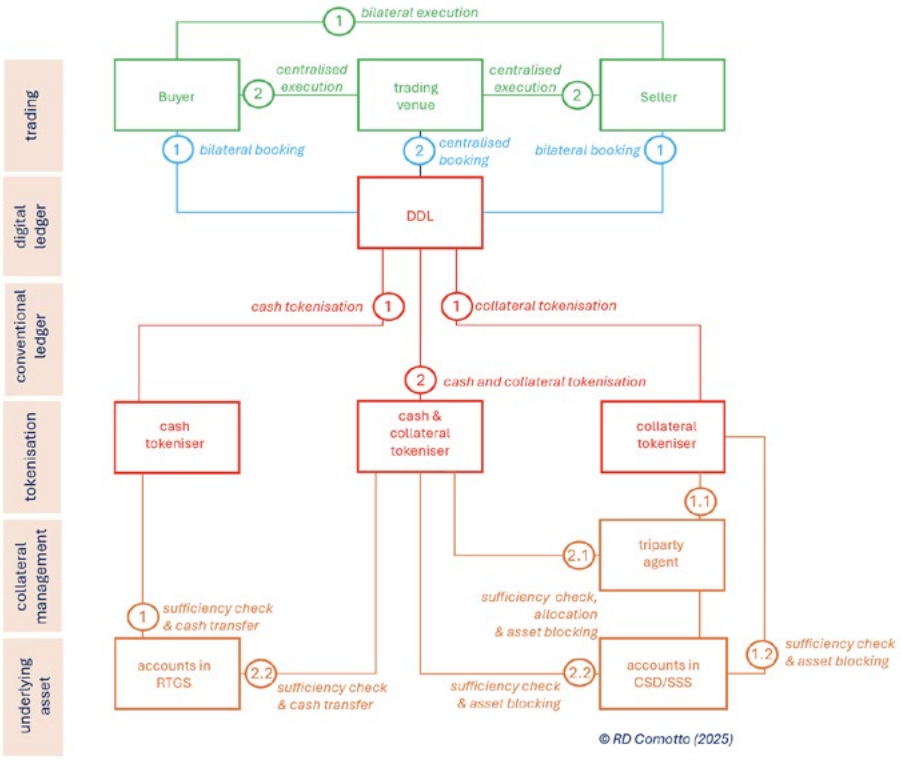
model	1	2	3	4
technology	on-chain	cross-chain	on/off-chain	off-chain
collateral security	digital	digital	digital	traditional
cash	digital	digital	traditional	traditional

In theory, there could be a fifth model, which would be a single-ledger version of Model 4. This would involve the use of a distributed ledger as a purely passive record. Broadridge DLR seems to have started in this form.

Inevitably, cross-chain arrangements are complicated by the need to synchronise separate ledgers. The digitalisation of cash and/or collateral by means of the tokenisation of assets in the conventional infrastructure looks as though it complicates settlement arrangements, but this is only really true where tokenisation is at ledger-level. Where tokens are minted by conventional infrastructure-providers (eg DTCC offering US Treasury tokens), matters are a lot simpler and more akin to being able to use native-digital assets. Tokenisation at infrastructure-level is effectively a half-way house to native-digital assets.

Where native-digital assets are not used, tri-party collateral managers are a frequent feature of DLT repo. However, tri-party repo is a specialised segment of the market. In Europe, it has a limited footprint in the market. These facts question whether tri-party will be such a common feature of DLT repo in production. In the US, where tri-party repo is a core market segment, the outcome may be different. Indeed, tri-party is a feature of Broadridge DLR, which is currently the largest commercial DLT repo infrastructure.

Model 1 — On-chain — single-ledger digital collateral vs digital cash

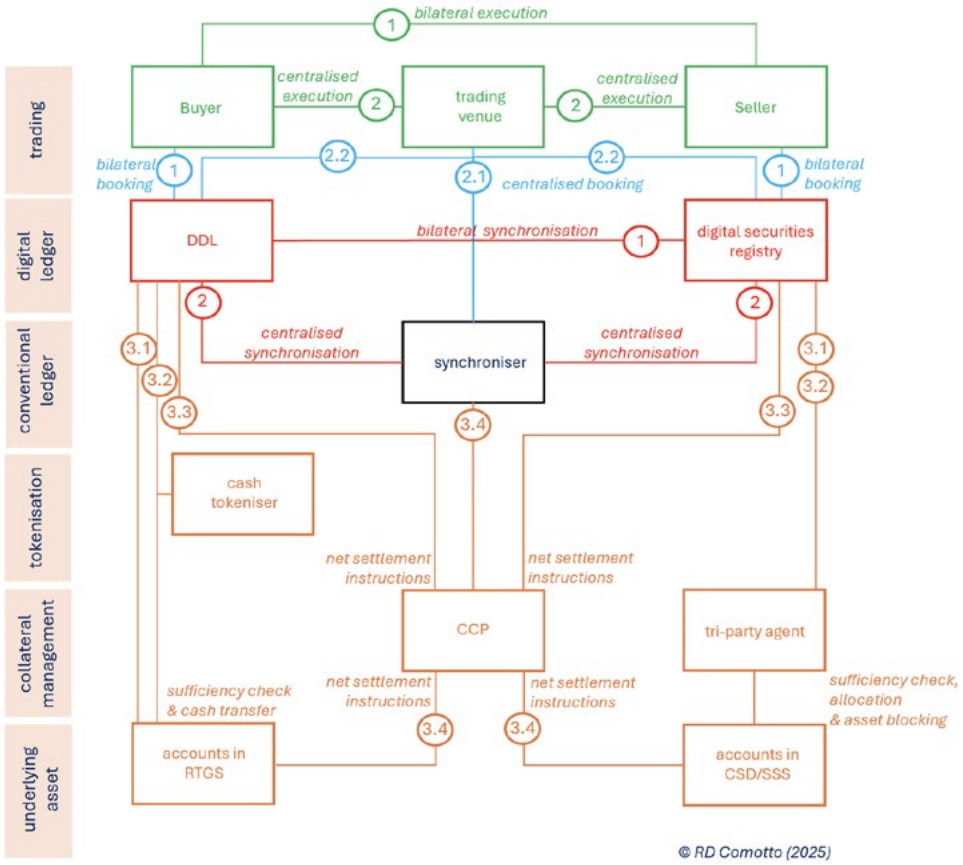


NB: Numbers indicate alternative workflows within each stage.For example, 1 and 2 identify two alternatives; and 2.1 and 2.2 identify two alternatives within alternative 2. The same number identified simultaneous workflows.

In Model 1, a single ledger was operated by one of the counterparties or by a third-party. Transfer of ownership was by atomic settlement, on the single ledger, of cash and collateral tokens (but not native-digital securities, for which, see Model 2). However, payment and settlement were ultimately on the conventional infrastructure.

A tokenisation engine was required to convert cash and collateral securities into tokens, or separate tokenisation engines for each, operated by one or both of the counterparties or by a third-party. The tokenisation engine(s) instructed the conventional settlement infrastructure — the RTGS and CSD/securities settlement system (SSS) --- either directly or indirectly through a tri-party agent. The tokenisation engine(s) or tri-party agent first checked the sufficiency of the underlying cash and collateral securities. They locked the tokenised collateral securities in the CSD account of the repo seller while they were out on repo and, at maturity, redeemed the cash token by making a payment in fiat currency from the RTGS account of the repo buyer to that of the repo seller.

Model 2 — Cross-chain — double-ledger digital collateral vs digital cash



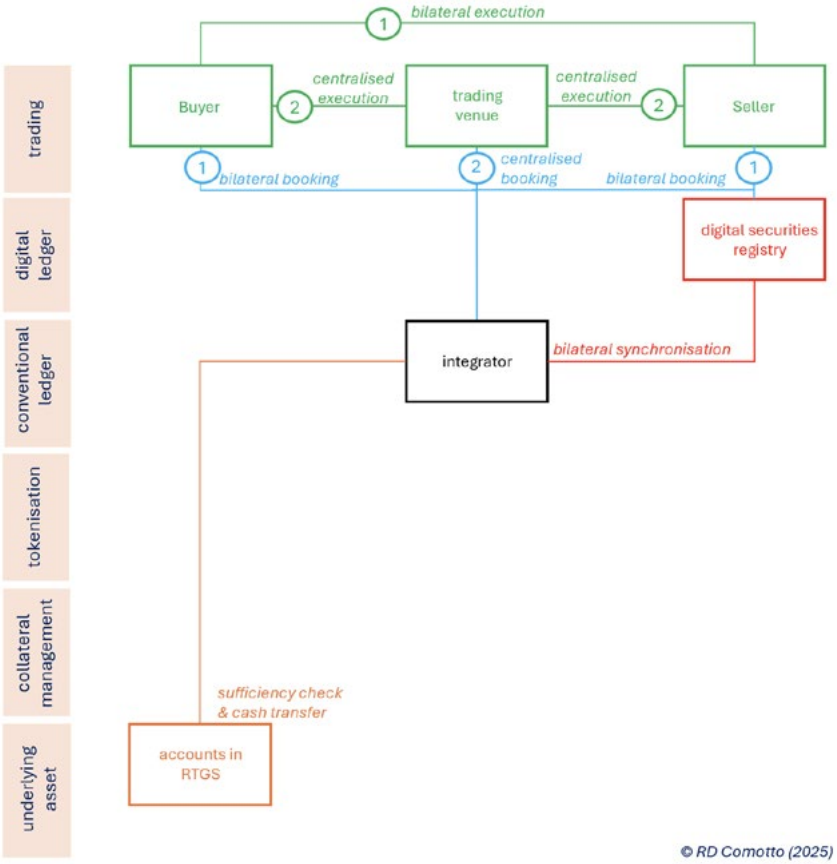
This was the most common model for DLT repo but only in tests and mostly as part of the ECB trials.

Collateral securities were usually native-digital. Where traditional securities were used, they were managed by a tri-party agent and represented by an ad hoc digital record. Otherwise, the conventional payment and settlement infrastructure were instructed by a ledger. Collateral tokens were not used. Cash tended to be central bank money, mostly in the form of wCBDC; cash in central bank accounts accessed by the Deutsche Bundesbank Trigger Solution; or in the form of tokenised CBDC. However, a tokenised deposit minted by one of the parties was also tested.

A CCP was involved in some ECB trials, netting transactions and sending net settlement instructions back to the cash and collateral ledgers or to the conventional settlement infrastructure. A tri-party agent was used to manage the collateral in two trials where ownership was represented by ad hoc digital records.

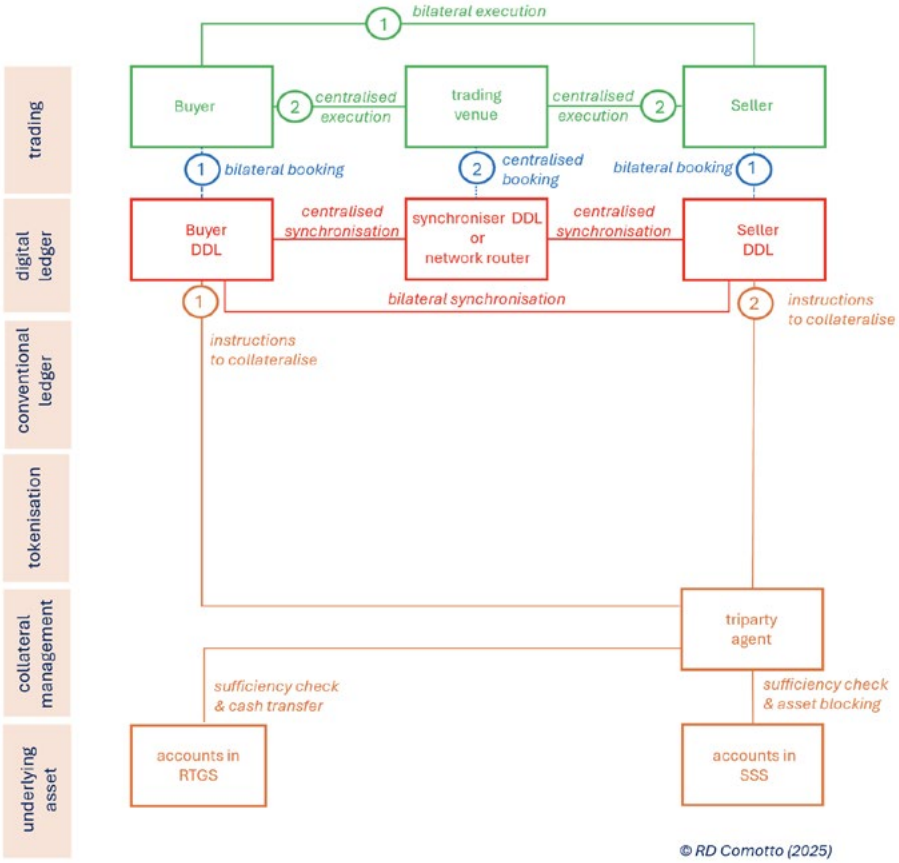
Settlement and life-cycle events were bilaterally synchronised by the two ledgers or by a third-party, which was sometimes another ledger (as shown in the diagram above) or by a non-DLT network router.

Model 3 — On/off-chain — single-ledger digital collateral vs cash account



In this structure, collateral was settled on-chain at a digital securities registry, but cash was paid off-chain in fiat currency using the conventional RTGS wholesale payment system. The off-chain cash payment and on-chain collateral transfer were synchronised by a conventional third-party.

Model 4 — Off-chain — double-ledger collateral-account vs cash-account



In Model 4, the buyer and seller operated their own ledger to book DLT repos. These instructed the conventional settlement infrastructure through a tri-party agent. The ledgers were therefore essentially just booking systems (for which reason, the model has been described as a "books and records approach"). The two ledgers were synchronised by a third-party, which was either another ledger or a non-DLT network router.

Appendix I: Catalogue of DLT repos 2017–2025

date	programme	purpose	type of repo	cash-collateral link	seller	buyer	size	execution venue		cash							collateral							
								operator	DLT	type	ccy	form	tokeniser	DLT	operator	off-chain payment location	type	ccy	issuer	form	tokeniser	DLT	operator	off-chain settlement agent
Oct-2017	private	POC	?	off-chain	Natixis	SocGen	?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	Canton Network	Canton Network	BoNYM	traditional	USD	US Treasury	off-chain	n/a	Canton Network	Canton Network	BoNYM
May-2019	private	POC	term	on-chain	Commerzbank	Deutsche Borse	c.EUR10 million	OTC	OTC	CoBM	EUR	tokenised deposit	Commerzbank	proprietary	Commerzbank	T2	traditional	EUR	KfW	token	Commerzbank	proprietary	Commerzbank	?
Jun-2021	private	commercial?	intraday (03H 05M)	on-chain	Goldman Sachs	JPMorgan	?	OTC	OTC	CoBM	USD	tokenised deposit* (JPM Coin)	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD	US Treasury	token	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	?
May-2022	private	commercial?	intraday, ON, term	off-chain	BNPP	?	?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	Canton Network	Canton Network	BoNYM	traditional	USD	US Treasury	off-chain	n/a	Canton Network	Canton Network	BoNYM
Jun-2022	private	experiment (mock settlement)	intraday triparty	off-chain	14 banks incl. Barclays, BNYM, Citi, NatWest		USD11.1 billion	Finteum app 75 x CLOB 165 x RFQ	n/a	CoBM	EUR USD	off-chain (traditional deposit)	n/a	Canton Network	Canton Network	EUR - Euroclear USD - BoNYM	traditional	EUR USD	basket	off-chain	n/a	n/a	n/a	EUR - Euroclear USD - BoNYM
Oct-2022	private	POC	intraday tri-party	cross-chain	?	?	?	Wematch	n/a	CoBM	USD	tokenised deposit* (JPM Coin)	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD	basket	Digital Collateral Record	n/a	R3 Corda	HQLAX	Clearstream International
Nov-2022	private	commercial?	intraday tri-party	on-chain	DBS	JPMorgan?	?	OTC	OTC	CoBM	USD	tokenised deposit* (JPM Coin)	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD	US Treasury	token	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	?
Dec-2022	private	POC	intraday triparty	cross-chain	Banco Santander, Goldman Sachs, UBS		?	OTC	OTC	CeBM	GBP	tokenised central bank money** (Fnality Settlement Asset)	UK FnPS	private Enterprise Ethereum	Sterling Fnality Payment System	Fnality-Adhara Ecosystem TestNet	traditional	GBP	basket	Digital Collateral Record	n/a	R3 Corda	HQLAX	Clearstream International
Apr-2023	private	commercial?	intraday cross-border	off-chain	UBS	DBS	?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	Canton Network	Canton Network	BoNYM	traditional	USD	US Treasury	off-chain	n/a	Canton Network	Canton Network	BoNYM
May-2023	private	commercial?	intraday	off-chain	DRW	SocGen, another Tier 1 bank	?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	Canton Network	Canton Network	BoNYM	traditional	USD	US Treasury	off-chain	n/a	Canton Network	Canton Network	BoNYM

date	programme	purpose	type of repo	cash-collateral link	seller	buyer	size	execution venue		cash							collateral							
								operator	DLT	type	ccy	form	tokeniser	DLT	operator	off-chain payment location	type	ccy	issuer	form	tokeniser	DLT	operator	off-chain settlement agent
Nov-2023	MAS Project Guardian	POC	intraday cross-border (plus purchase & redemption of collateral)	cross-chain	SBI Securities	DBS	?	OTC	OTC	CoBM	JPY	tokenised deposit	Shinsei Trust and Banking	public DLT		Shinsei Trust and Banking	native	JPY	bond	native	UBS Tokenise	public DLT		n/a
Nov/Dec-2023	private	pilot	intraday	cross-chain	45 financial institutions and others		?	Canton Network	trading app	CoBM	USD	simulated tokenised deposit	Canton Network	Canton Network	Canton Network	n/a	simulation	USD	none	token	Canton Network	Canton Network	Canton Network	n/a
2023	private	POC	intraday	cross-chain	members of Regulated Settlement Network (RSN)		?	OTC	OTC	CeBM	USD	tokenised deposit	Broadridge DLR	VMWare Blockchain	Broadridge DLR	n/a	traditional	USD	US Treasury	token	Broasridge DLR	VMWare Blockchain	Broadridge DLR	n/a
Feb-2024	private	commercial?	term	on/off-chain	HSBC	Bank of East Asia	?	OTC	OTC	CeBM	HKD	off-chain (traditional deposit)	n/a	n/a	n/a	HKMA CMU	native	USD EUR HKD CNY	Hong Kong green bond issued in February 2024	native	HSBC	Orion	HKMA CMU	n/a
Apr-2024	private	experiment (mock settlement)	intraday triparty	off-chain	14 banks		?	Finteum	n/a	CoBM	USD	off-chain (traditional deposit)	n/a	n/a	n/a	BoNYM	traditional	USD	US Treasury	off-chain	n/a	n/a	n/a	BoNYM
Jun-2024	private	commercial?	intraday	on-chain	BNPP	JPMorgan?	?	OTC	OTC	CoBM	USD	tokenised deposit* (JPM Coin)	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD	US Treasury	token	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	?
Jun-2024	private	end-to-end test	intraday triparty repo	cross-chain	Banco Santander, Goldman Sachs, UBS		EUR 1.65 million	Eurex Repo F7	n/a	CeBM	GBP	tokenised central bank money** (Fnality Settlement Asset)	UK FnPS	private Enterprise Ethereum	Fnality Payment System	Fnality-Adhara Ecosystem TestNet	traditional	GBP	basket	Digital Collateral Record	n/a	R3 Corda	HQLAX	Clearstream International
Jun-2024	SNB Project Helvetica III	pilot	open market operation	cross-chain	various banks	SNB	?	SIX Repo	n/a	CeBM	CHF	wholesale CBDC	SIS Interbank Clearing (SIC)		SIS	SNB	native	CHF	SNB bills	native	n/a	SIX Digital Exchange (SDX)	SDX	n/a
Jun/Jul-2024	private	pilot	?	cross-chain	prime broker	investor	?	Canton Network	trading app	CoBM	USD	simulated tokenised deposit	Canton Network	Canton Network	Canton Network	n/a	simulation	USD	none	token	Canton Network	Canton Network	Canton Network	n/a
Sep-2024	private	commercial?	HQLA management	off-chain	Canadian Tier 1 bank	?	?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	Canton Network	Canton Network	BoNYM	traditional	USD	?	off-chain	n/a	Canton Network	Canton Network	BoNYM
Sep-2024	ECB trials	experiment (mock settlement)	intraday CCP-cleared	cross-chain	DZ Bank	JP Morgan	EUR 5.1 million	Eurex Repo F7	n/a	CeBM	EUR	off-chain (conventional central bank money)	Trigger Solution		Deutsche Bundesbank	T2 UTEST	native	EUR	CP issued by DZ Bank	native	n/a	n/a	n/a	n/a
Oct-2024	private	commercial?	intraday <120 minutes	on-chain	JP Morgan	OCBC	?	OTC	OTC	CoBM	USD	tokenised deposit* (JPM Coin)	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD	US Treasury	token	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	?
Oct-2024	private	commercial?	intraday <120 minutes	on-chain	OCBC	JP Morgan	?	OTC	OTC	CoBM	USD	tokenised deposit* (JPM Coin)	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD	US Treasury	token	Onyx Digital Assets	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	?

date	programme	purpose	type of repo	cash-collateral link	seller	buyer	size	execution venue		cash						collateral							
								operator	DLT	type	ccy	form	tokeniser	DLT	operator	off-chain payment location	type	ccy	issuer	form	tokeniser	DLT	operator	off-chain settlement agent
Oct-2024	ECB trials	trial (actual settlement)	2 intraday 2 overnight CCP-cleared	cross-chain	ABN Amro Bank	ABN Amro Clearing, Rabobank	?	Eurex Repo F7	n/a	CeBM	EUR	wholesale CBDC	DL3S		Banque de France	Banque de France	native	EUR	ECP	native	Clearstream D7		Clearstream Banking SA	n/a
Nov-2024	ECB trials	trial (actual settlement)	5-day	cross-chain	Deka Bank	LBBW	EUR 1.0 million	OTC	OTC	CeBM	EUR	off-chain (conventional central bank money)	Trigger Solution		Deutsche Bundesbank	T2 UTEST	traditional	EUR	DBR	token	Deka Bank SWIAT (Hyperledger Besu) (Enterprise Ethereum)		Deka Bank	?
Nov-2024	ECB trials	trial (actual settlement)	2 intraday	cross-chain	Deka Bank	NatWest Markets	EUR 1.0 million total	OTC	OTC	CeBM	EUR	off-chain (conventional central bank money)	Trigger Solution		Deutsche Bundesbank	T2 UTEST	(1) native (2) traditional	EUR	(1) Siemens AG (2) DBR	(1) native (2) token	Deka Bank SWIAT (Hyperledger Besu) (Enterprise Ethereum)		Deka Bank	?
Nov-2024	ECB trials	trial (actual settlement)	intraday triparty	cross-chain	Goldman Sachs	Clearstream Banking SA	EUR 50 million	Eurex Repo F7	n/a	CeBM	EUR	off-chain (conventional central bank money)	Trigger Solution		Deutsche Bundesbank	T2 UTEST	traditional	EUR	basket	on-chain record	n/a	R3 Corda	HQLAX	Euroclear
Dec-2024	private	POC	central bank refinancing	cross-chain	Societe General-Forge	Banque de France	?	OTC	OTC	CeBM	EUR	wholesale CBDC	DL3S		Banque de France	Banque de France	native	EUR	covered bond issued by SocGen SFH in 2020	native	Societe General-Forge	public Enterprise Ethereum	Societe General-Forge	n/a
Jan-2025	private	commercial?	2 intraday (3H)	on-chain	Santander	JP Morgan	USD 50 million EUR 50 million	OTC	OTC	CoBM	USD, EUR	tokenised deposit* (JPM Coin)	Kinexys Digital Payments	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	JP Morgan	traditional	USD, EUR	?	token	Kinexys Digital Payments	Consensys Quorum Blockchain (private Enterprise Ethereum)	JP Morgan	?
Feb-2025	private	pilot	intraday triparty	off-chain	UBS	Swiss Re	?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	n/a	n/a	BoNYM	traditional	USD	?	off-chain	n/a	n/a	n/a	BoNYM
Apr-2025	private	demonstration	intraday triparty	off-chain	Santander and Rabobank bothways		?	OTC	OTC	CoBM	USD	off-chain (traditional deposit)	n/a	n/a	n/a	BoNYM	traditional	USD	?	off-chain	n/a	n/a	n/a	BoNYM
Jul-2025	private	POC	intraday + re-use of collateral	on-chain	BoA, Circle, Citadel, Cumberland DRW, Hidden Road, SocGen, Virtu Financial		?	Tradeweb	n/a	CoBM	USD	stablecoin (USDC)	Tradeweb	Canton Network	Canton Network	n/a	traditional	USD	US Treasury	token	DTC	Canton Network	Canton Network	DTC
Aug-2025	private	POC	9 intraday incl. CCP-cleared Islamic	on/off-chain	Saudi Awwal Bank, Bank Albilad, GIB, Saudi Arabian Investment Bank		SAR 110 million	OTC	OTC	CoBM	SAR	simulated tokenised deposit	n/a	Oumla	Oumla	Edaa	traditional	SAR	simulated sukuk bond	token	Oumla	Oumla	Oumla	n/a
Dec-2025	private	POC	intraday	on-chain	Cumberland DRW, Virtu Financial		?	Tradeweb	n/a	CoBM	USD, EUR	tokenised deposit (LSEG DiSH Cash)	LSEG DiSH	?	LSEG DiSH	n/a	?	USD, EUR	US Treasury EGB	?	Canton Network	Canton Network	Canton Network	?

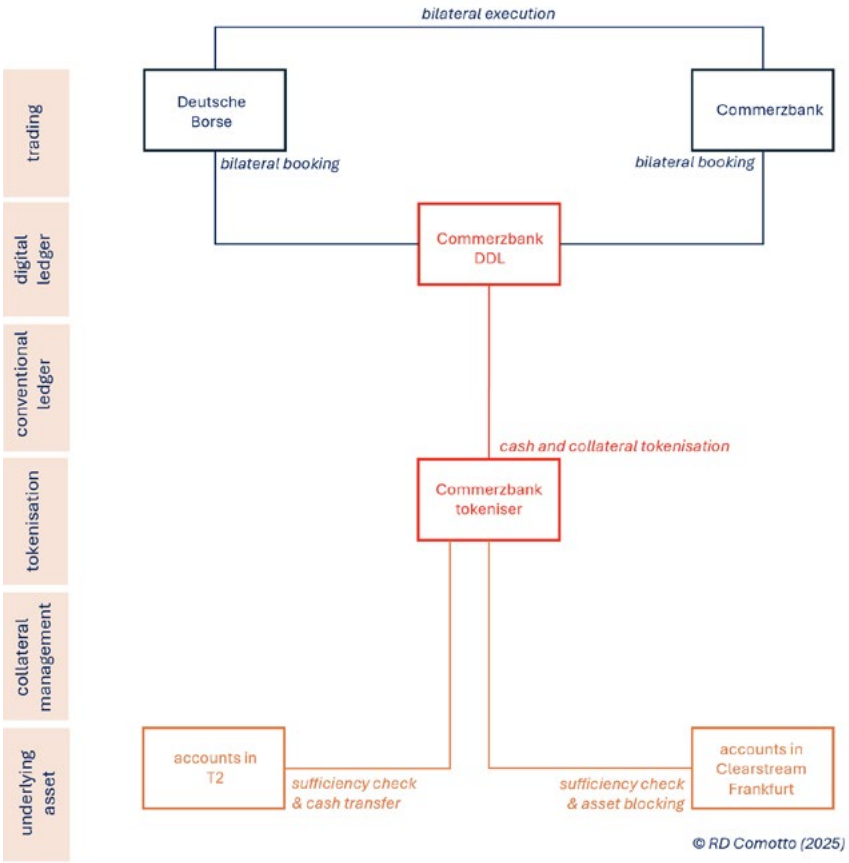
Abbreviations: CoBM = central bank money; CeBM = central bank money; CBDC = central bank digital currency; BoNYM = Bank of New York Mellon; POC = proof-of-concept

** JPM Coin is classified by the EBA as an Electronic Money Token (EMT) or stablecoin.*

*** Fnality's tokenised central bank money is classified by the BIS as a stablecoin.*

Appendix II: Examples of DLT repo tests and transactions, 2017-25

Example 1.1 — Commerzbank-Deutsche Borse, May 2019

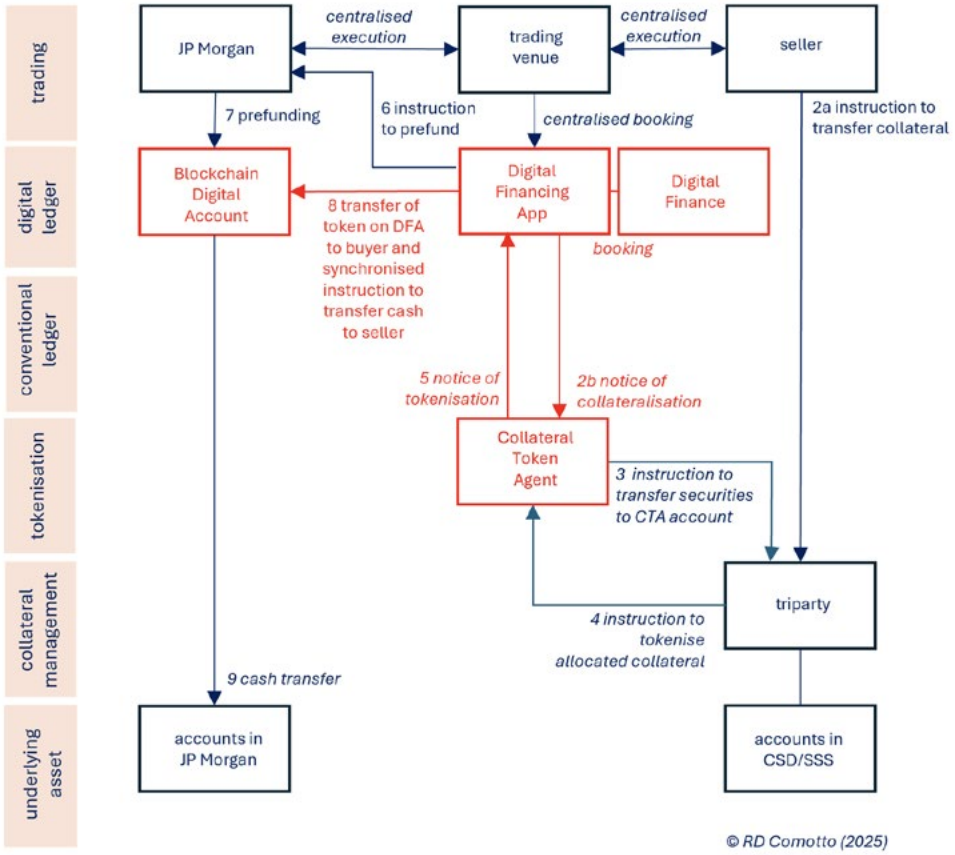


Transaction:

- private proof-of-concept
- term repo in EUR
- OTC execution
- collateral — tokenised traditional security
- cash — tokenised deposit

One of the earliest DLT repos, albeit a proof-of-concept, was executed in May 2019, between Commerzbank and Deutsche Bourse. The EUR 10 million test was for term. The collateral took the form of a token minted on a proprietary ledger operated by Commerzbank and representing a traditional security issued by the German state development bank, KfW. The cash was also tokenised by Commerzbank. Transfer of ownership was therefore by atomic settlement on the Commerzbank ledger. The underlying collateral securities were blocked at Clearstream Bank Frankfurt while they were being repoed out and the cash was ultimately paid off-chain in fiat currency in the T2 RTGS.

Example 1.2 — Onyx/Kinexys, 2021 to 2024



Transactions:

- mostly commercial
- intra-day tri-party repo in USD
- execution on a conventional (RFQ) trading venue
- collateral — tokenised traditional security
- cash — tokenised deposit

In 2019, JP Morgan Chase launched its DLT subsidiary, Onyx Digital Assets, on the private Quorum blockchain, which is a fork of the Enterprise Ethereum network. In marketing, Onyx used the name JPM Coin for its cash token. This was widely assumed to be a stablecoin but JP Morgan Chase have seen it as a tokenised deposit, that is, a digital representation of a US dollar deposit in the account of an institutional client at JP Morgan Chase. This token could be transferred between accounts on a distributed ledger more efficiently than deposits on a conventional account, in order to allow payments to settle transactions on a DvP or PvP basis.

Onyx and JPM Coin were driven by JP Morgan Chase's need to reduce the unsecured intra-day exposure and credit risk on cash transfers between institutional clients. DLT was the answer to intra-day exposure and repo was the answer to credit risk. DLT also allowed 24/7 transfers, which accommodated different time zones. For the borrowers, DLT repo offered reduced cost, lower credit line usage and more flexibility. And for both sides, there were operational efficiencies. But given that the purpose of Onyx is to facilitate payments between JP Morgan Chase's corporate clients, it presents a "walled garden", with no interoperability with other banks' ledgers.

Because of confusion with a crypto-currency token called Onyxcoin (XCN), the Onyx name was abandoned in November 2024. The subsidiary was renamed Kinexys Digital Assets, with a payments division called Kinexys Digital Payments.

The Kinexys Digital Assets platform has several parts and the stages in its sequential operation are numbered in the diagram above. The DLT component is a passive ledger called Digital Finance, which is used purely for record-keeping.[xl] The counterparties to a repo trade on a proprietary JP Morgan request-for-quote (RFQ) trading venue. JP Morgan can also act as a market-maker for intra-day repo.

Transactions are booked on an existing web-based booking system called the Digital Financing App (DFA). Using a conventional MT527 message, the DFA notifies the Collateral Token Agent (CTA) — the Kinexys tokenisation engine — of an intended delivery of collateral from the seller. The CTA then instructs a tri-party agent to allocate and deliver a basket of collateral on behalf of the seller, from the latter's account to the CTA's Tokenisation Account. The tri-party agent then matches the seller's instructions with those from the buyer and, upon matching, instructs the CTA to tokenise the collateral allocated to its Tokenisation Account and to notify the DFA. The DFA instructs the transfer of funds from the buyer's conventional deposit account at JP Morgan Chase in order to prefund its Blockchain Digital Deposit Account. At a pre-agreed time, the buyer's Collateral Token balance on the DFA is credited and the DFA simultaneously transfers the value in the Blockchain Digital Deposit Account of the buyer to the Blockchain Digital Deposit Account of the seller. The seller can subsequently transfer the cash token to his other accounts or to other institutional clients of JP Morgan Chase. A recipient can redeem the token with JP Morgan Chase for fiat currency at par.

At the repurchase time, the DLT repo automatically unwinds. Tokens are burnt, and cash (including repo interest) and collateral are returned to the buyer and seller, respectively.

Because the cash token in Kinexys is a representation of a deposit at JP Morgan Chase, Kinexys/Onyx has been used almost entirely to make transfers between affiliates of financial institutions which bank with JP Morgan Chase.

Onyx hosted its first DLT repo in June 2021 between JP Morgan Chase and Goldman Sachs. In October 2022, Onyx ran a proof-of-concept in which the CTA was substituted by the digital collateral management platform, HQLA^X, with ownership of collateral allocated and blocked at an independent tri-party agent, while ownership was transferred by HQLA^X updating a dedicated Digital Collateral Record (DCR) issued on its ledger. The exchange of cash tokens at Onyx and DCR at HQLA^X were synchronised by Ownera's non-DLT network routers. Execution was supported by the matching, negotiation and transaction management platform, WeMatch.

In August 2025, it was announced that the integration of the Kinexys and HQLA^X platforms via Ownera's routers had gone into production to enable intra-day repos between JP Morgan customers. It was reported that turnover was USD 5 billion in the first month and reached as much as USD 1 billion per day thereafter.

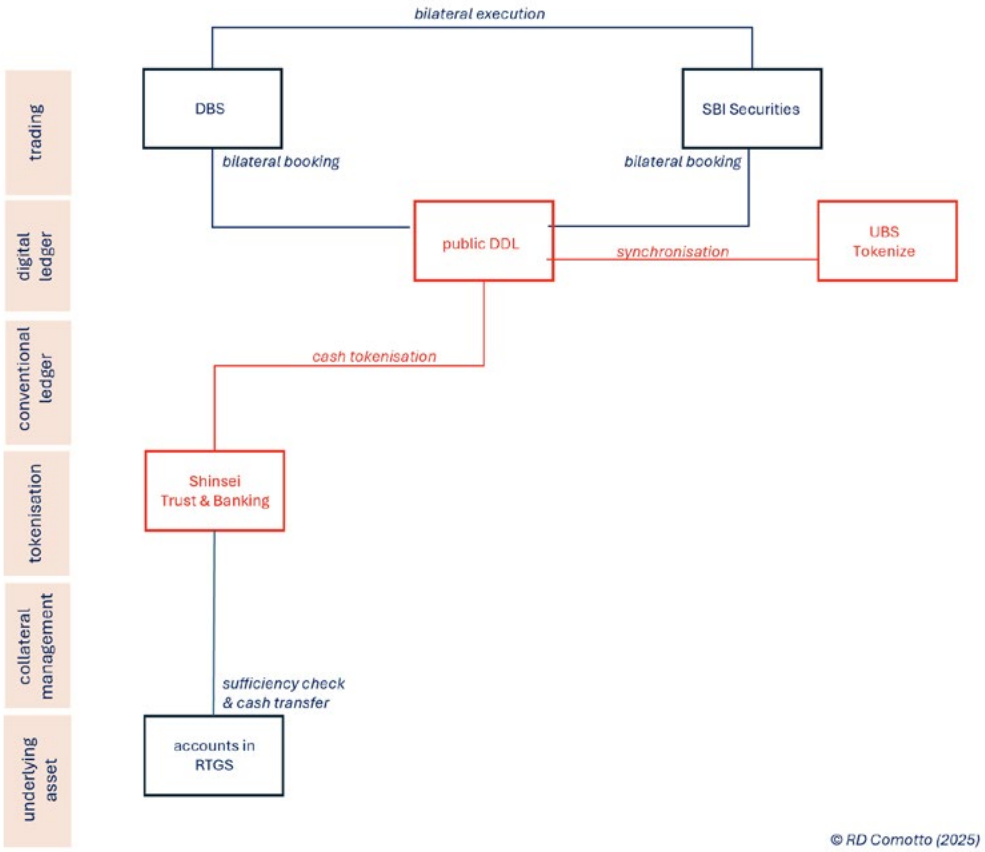
Since May 2024, Broadridge has allowed settlement of the cash leg of DLT repos on its DLR platform to take place cross-chain at Onyx/Kinexys, but it has not been revealed whether this facility has been used much, if at all.

In June 2024, Onyx hosted DLT repos between JP Morgan Chase on the one hand and DBS and BNPP on the other. In October 2024, JP Morgan Chase acted as buyer on one DLT repo and, for the first time, as the seller in another, versus Chinese bank, OCBC.

In November 2024, at the same time as the rebranding of Onyx as Kinexys, euro-denominated transactions were enabled. All previous transactions had been US dollars against US Treasuries. JP Morgan Chase executed DLT repos with Banco Santander in both US dollars and euro in January 2025. Sterling cash and equity collateral options were added in April 2025.

By December 2022, a cumulative total of USD 500 billion of DLT repo had been settled across Onyx. By October 2024, over 1,200 transactions, worth some USD 1.5 trillion, had been settled.

Example 2.1 — DBS-SBI Securities, November 2023



Transaction:

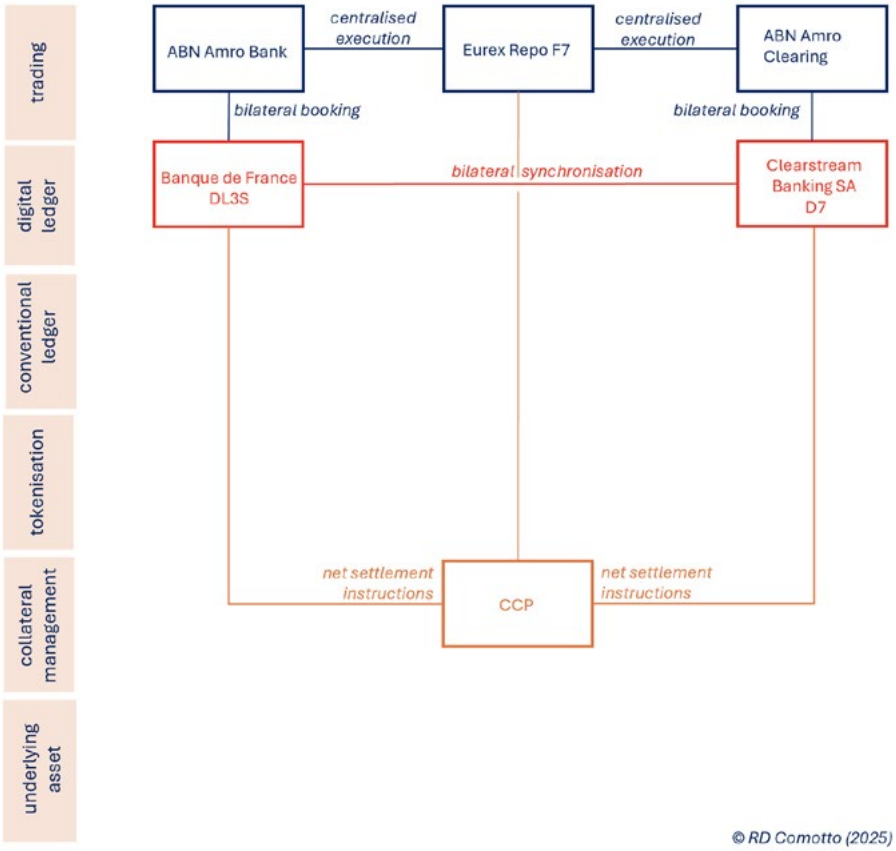
- proof-of-concept in MAS Project Guardian
- intra-day cross-border repo in JPY
- OTC execution
- collateral — native-digital security
- cash — tokenised deposit

In November 2023, an on-chain DLT repo was transacted and settled as part of Project Guardian — which is the DLT experimental programme of the Monetary Authority of Singapore (MAS) — between a local bank, DBS Bank, and a Japanese investment bank, SBI Securities. This transaction was notable for being the first cross-border DLT repo and for using a public blockchain, albeit a permissioned fork.

The tokenisation of cash was undertaken by an SBI Securities subsidiary, Shinsei Trust and Banking. On the other hand, the collateral was a native-digital security. These were issued into and held by UBS Tokenise, which is a platform operated by UBS to originate, distribute and provide custody of digital assets. The exchange of cash token and native-digital security was bilaterally synchronised between the main ledger and UBS Tokenise.

The test of the DLT repo in this proof-of-concept was accompanied by the simulated purchase and redemption of the native-digital security used as collateral in the repo.

Example 2.2 — ABN Amro Bank-ABN Amro Clearing/Rabobank, October 2024



Transactions:

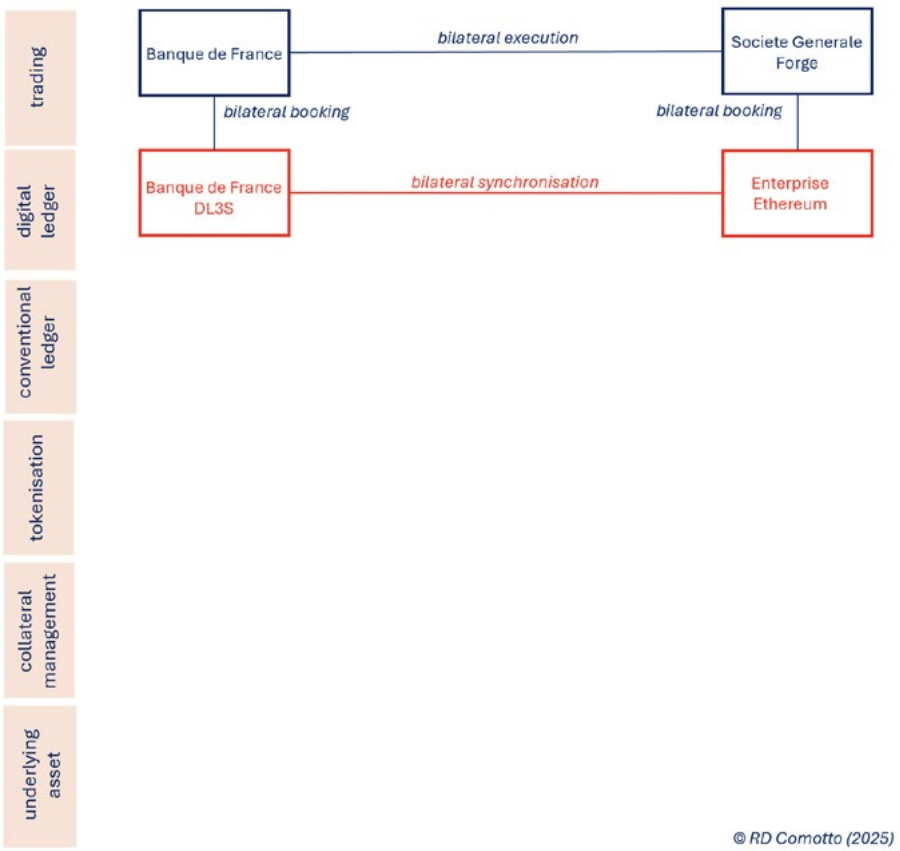
- part of ECB Trials
- 2 intra-day and 2 overnight repos in EUR
- execution on a conventional trading venue
- CCP-cleared
- collateral — native-digital security
- cash — wCBDC

The wCBDC was issued by the Banque de France on its DL3S ledger and was the first use of wCBDC to settle a EUR-denominated DLT repo (the first use of wCBDC in any currency was in Swiss francs in June 2024 as part of the SNB's Project Helvetica III pilot — see example 2.4). The use of wCBDC distinguishes this example from the previous one.

The collateral was native-digital euro-commercial paper (ECP) issued on Clearstream Banking SA's D7 digital registry, which synchronised bilaterally with the Banque de France. Execution was on Eurex Repo's conventional repo trading venue F7.

This trial was the second example of the CCP-clearing of DLT repos. The first was in the previous month as part of another ECB Trial, involving DZ Bank and JP Morgan Chase (see Example 2.6). The CCP in both cases was Eurex Clearing AG (ECAG).

Example 2.3 — Banque de France-SocGen Forge, December 2024

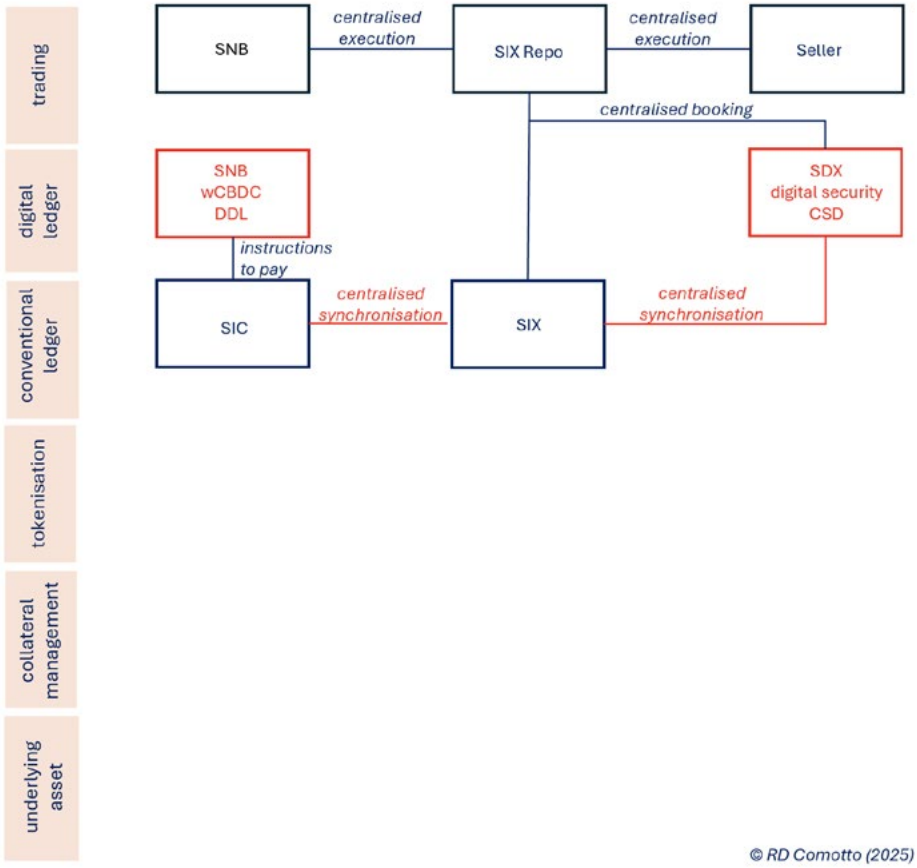


Transaction:

- private proof-of-concept
- central bank refinancing in EUR
- OTC execution
- collateral — native-digital security
- cash — wCBDC

This proof-of-concept was of a DLT repo for use in refinancing by a central bank. It follows Example 2.2 in using and a native-digital security, but it differs in not being CCP-cleared. The cash ledger was the Banque de France's DL3S ledger for wCBDC, the second such use in a DLT repo. The collateral was a native-digital covered bond issued by SocGen SFH in 2020 onto a public blockchain on Enterprise Ethereum. This was the second use of a public blockchain (the first being a cross-border DLT repo between DBS and SBI Securities as part of the MAS's Project Guardian — see Example 2.1). There was therefore no need for integration with the conventional settlement infrastructure. The two ledgers synchronised themselves bilaterally.

Example 2.4 — SNB, November 2024



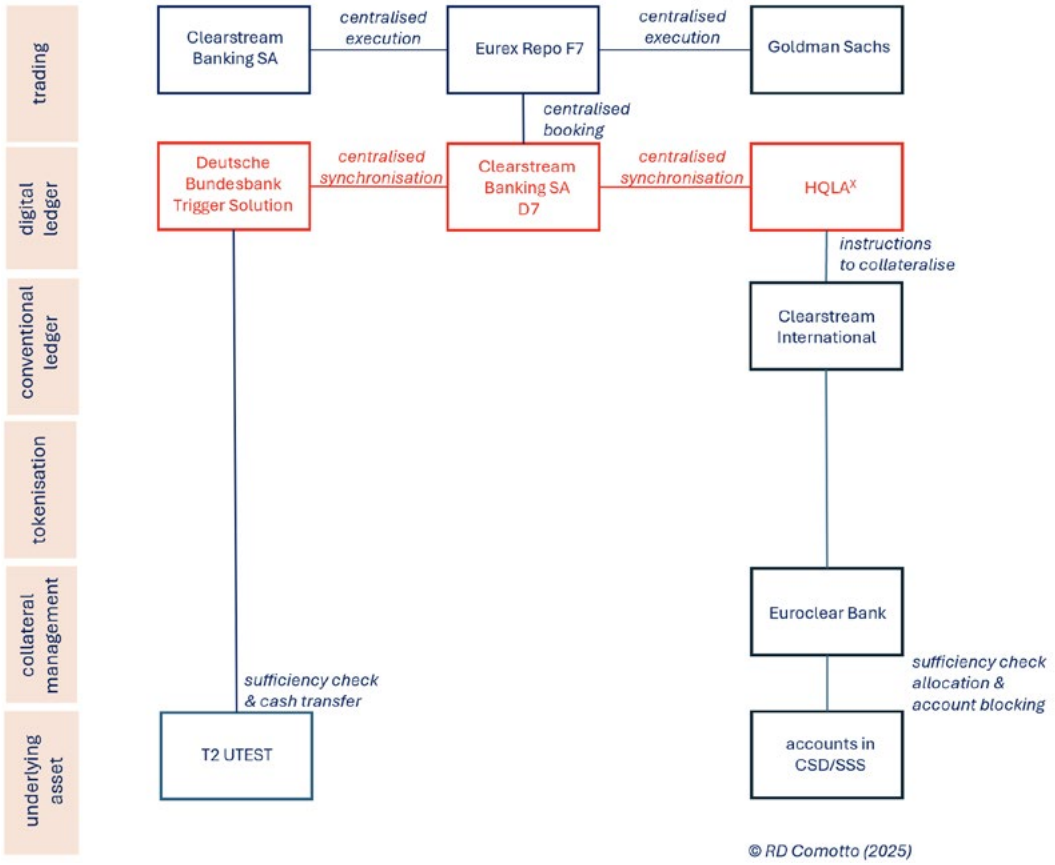
Transaction:

- pilot under Project Helvetica III
- central bank refinancing in CHF
- execution on a conventional trading venue
- collateral — native-digital security
- cash — wCBDC

Like Example 2.3 above, this earlier pilot was of a DLT repo for use in refinancing by a central bank using wCBDC and a native-digital security. In this case, the security was a bill issued by the Swiss National Bank (which SNB subsequently decided not to issue again).

This pilot differs from the previous example in its digital infrastructure. On the cash side, this involved the SNB's wCBDC ledger and, on the collateral side, the digital securities registry, Swiss Digital Exchange (SDX), which is owned and operated by Swiss Exchange (SIX). The Swiss Interbank Clearing System (SIC) instructed settlement at the SNB. The exchange of ownership of the wCBDC via SIC and of collateral at SDX was synchronised by SIX. The transactions were executed on the SIX Repo platform, which is a conventional request-for-quote or RFQ trading system.

Example 2.5 — Clearstream Banking SA-Goldman Sachs, November 2024



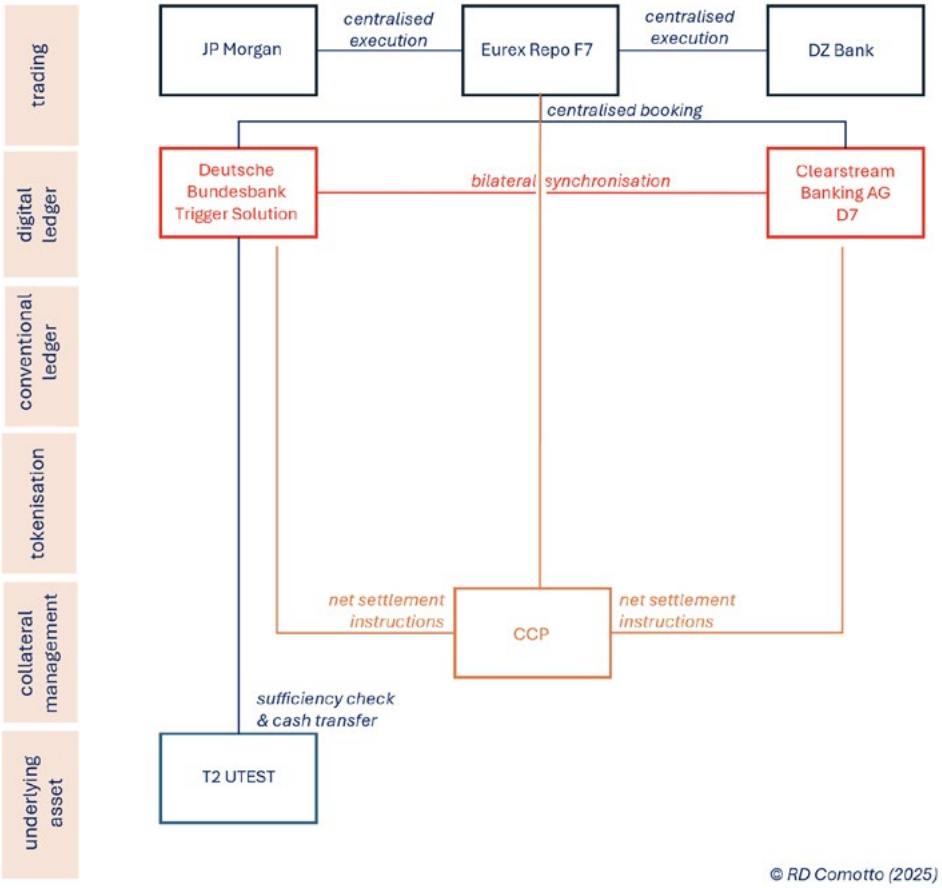
Transactions:

- part of ECB Trials
- intra-day tri-party repos in EUR
- executed on a conventional trading venue
- collateral — a basket of traditional securities represented by a Digital Collateral Record on HQLA^X
- cash — simulated payment of central bank money using the Bundesbank's Trigger Solution

In November 2024, as part of the ECB's DLT trials, Goldman Sachs and Clearstream Bank SA executed several intra-day DLT repos totalling EUR 50 million on Eurex Repo's conventional repo trading platform F7. The payment of cash was simulated on the Bundesbank's T2 UTEST RTGS digital test environment through its Trigger Solution. Collateral was allocated and managed on the conventional settlement infrastructure by Euroclear Bank acting as tri-party agent for the digital collateral management platform, HQLA^X, which managed the transfer of ownership of the collateral using its Digital Collateral Records (DCR).

This example differs from the previous examples in using conventional central bank money rather than tokenised deposits (as in Example 2.1) or wCBDC (as in Examples 2.2-2.4) and a digital record of ownership rather than native-digital securities (as in Examples 2.1-2.4).

Example 2.6 — JP Morgan-DZ Bank, September 2024



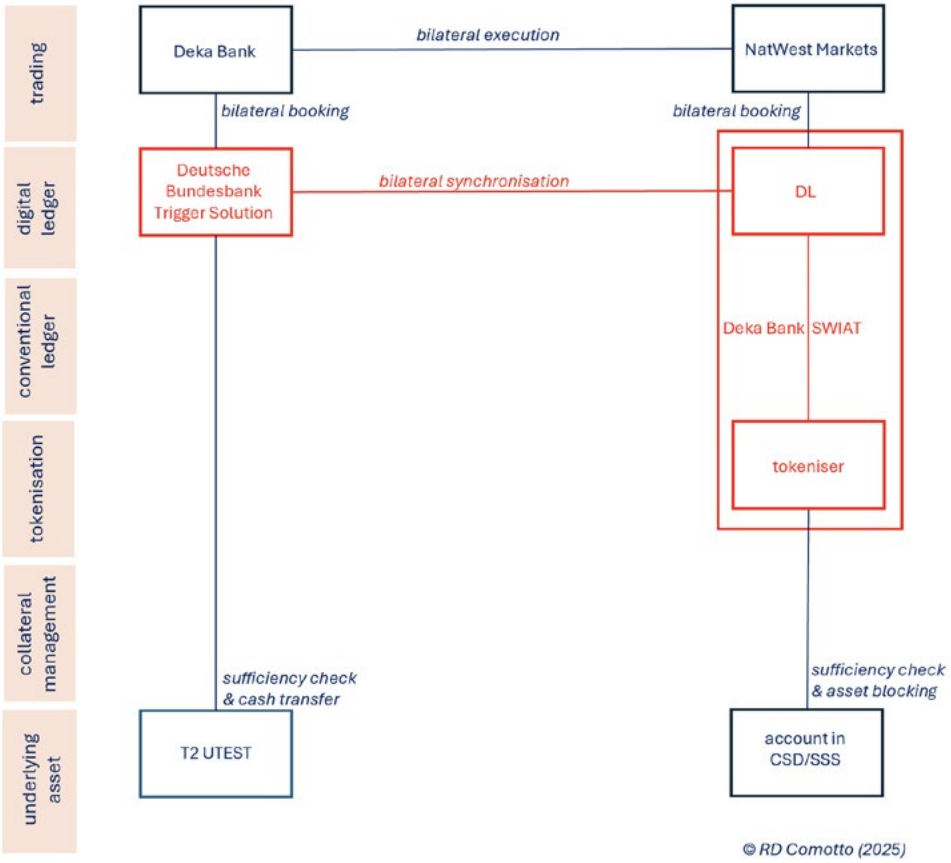
Transaction:

- experiment as part of ECB Trials
- intra-day repo in EUR
- executed on a conventional trading venue
- CCP-cleared
- collateral —a native-digital security
- cash — simulated payment of central bank money using the Bundesbank's Trigger Solution

In September 2024, in an "experiment" (mock settlement) that inaugurated the ECB's DLT Trials in repo, DZ Bank and JP Morgan Chase executed several intra-day repos totalling EUR 5.1 million on Eurex Repo's conventional repo trading platform F7. The collateral was native-digital commercial paper (CP) that had been previously issued by DZ Bank on Clearstream Banking AG's D7 digital securities registry. The repos were centrally-cleared by Eurex Clearing AG (ECAG). The payment of cash was simulated on the Deutsche Bundesbank's T2 UTEST RTGS digital test environment using its Trigger Solution. The two ledgers bilaterally synchronised each other.

There was nothing novel about these particular tests, but they combined the use of the Trigger Solution (as in Examples 2.5 and 2.7), bilateral synchronisation (as in Examples 2.2, 2.3 and 2.7), CCP-clearing (as in Example 2.2) and execution on a conventional trading venue (as in Examples 2.2. 2.4, 2.5).

Example 2.7 — Deka Bank-NatWest Markets/LBBW, November 2024



Transactions:

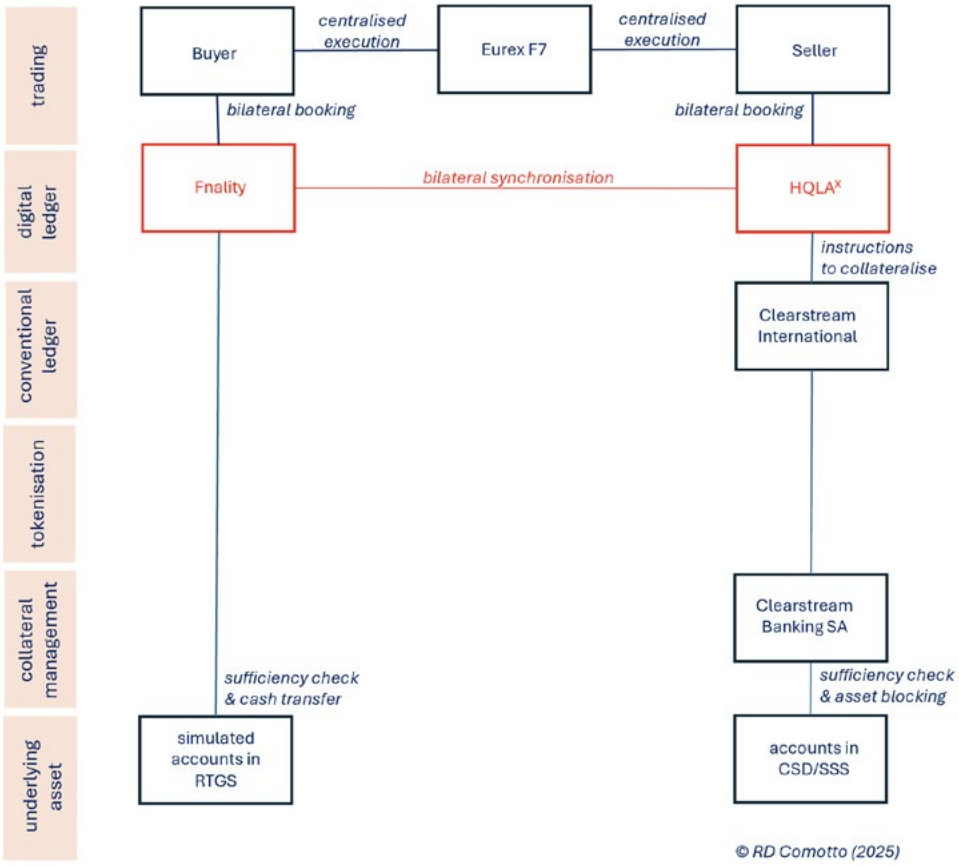
- part of ECB trials
- 2 intra-day repos (with NatWest Markets) and one 5-day repo (with LBBW) in EUR
- OTC execution
- collateral -- (1) a native-digital security and (2) a tokenised traditional security
- cash — simulated payment of central bank money using the Bundesbank's Trigger Solution

In November 2024, as part of the ECB's DLT trials, Deka Bank sold two intra-day DLT repos totalling EUR 1 million to NatWest Markets and one 5-day DLT repo for EUR 1 million to LBBW.

One of the intra-day repos with NatWest Markets was against a native-digital corporate bond issued by Siemens AG. The other was against a tokenised traditional bund. The term repo with LBBW was also against a tokenised bund. Tokenisation was by Deka Bank's ledger, SWIAT. This used Hyperledger Besu, which is a private permissioned Layer 1 blockchain on the Ethereum Virtual Machine, to provide inter-node communication and a proof-of-authority consensus algorithm. SWIAT was integrated with and instructed the blocking of collateral in the conventional settlement infrastructure.

The payment of cash was simulated on the Bundesbank's T2 UTEST RTGS digital test environment through its Trigger Solution. SWIAT and the Trigger Solution bilaterally synchronised with each other.

Example 2.8 — Three banks using Fnality and HQLA^X, June 2024

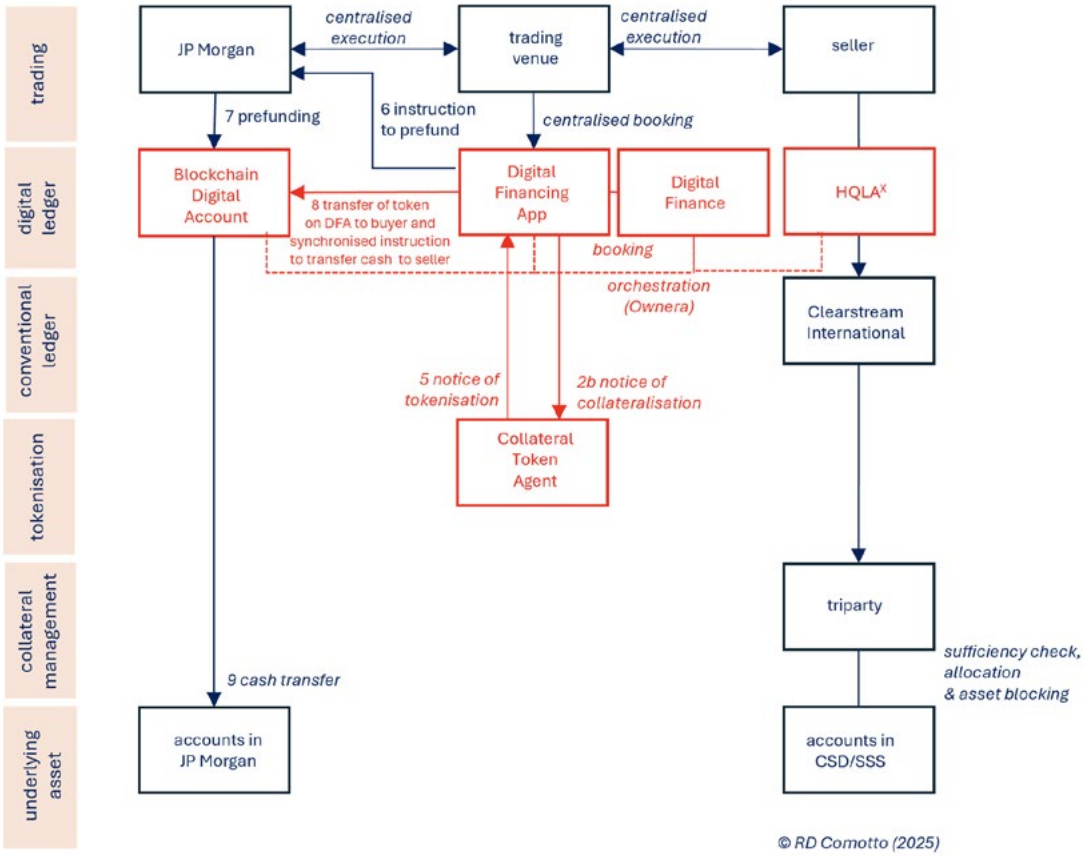


Transactions:

- proof-of-concept
- intra-day triparty repo in GBP
- executed on a conventional trading venue
- collateral — a basket of traditional securities represented by a Digital Collateral Record on HQLA^X
- cash —central bank money token minted by the Sterling Fnality Payments System (FnPS) (but classified by the BIS as a stablecoin).

In June 2024, an end-to-test of GBP-denominated intra-day triparty repo was conducted between Banco Santander, Goldman Sachs and UBS. The Fnality-Adhara Ecosystem TestNet environment was used to simulate a cash payment on the Enterprise Etherium-based Sterling Fnality Payment System. The digital collateral management platform HQLA^X managed the transfer of ownership of the collateral using a Digital Collateral Record (DCR). Execution was on Eurex Repo's conventional repo trading platform F7.

Example 2.9 — Kinexys-HQLA^{X}, June 2025

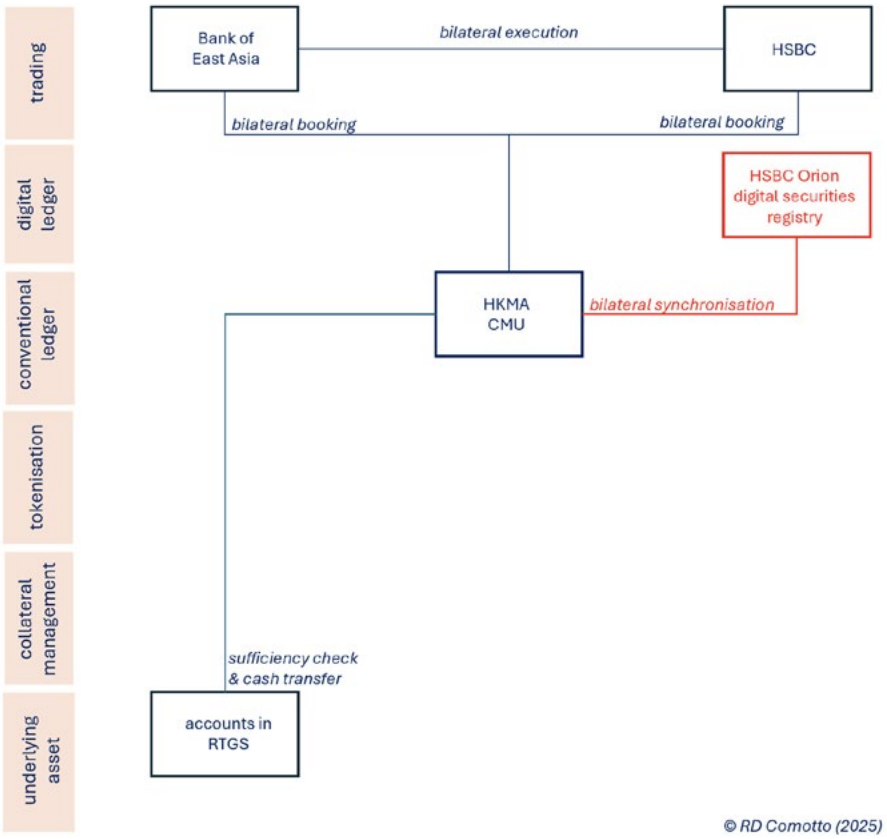


Transactions:

- commercial
- intra-day tri-party repo
- execution on a conventional (RFQ) trading venue
- collateral — a basket of traditional securities represented by a Digital Collateral Record on HQLA^{X}
- cash — tokenised deposit (but classified by the EBA as a stablecoin).

This cross-chain solution is the production version of HQLA^{X}'s Project Prince. It is a joint venture between Kinexys, which provides the transactions and cash settlement (see Example 1.2), and HQLA^{X}, which provides collateral management and settlement. Orchestration is by non-DLT network routers (Ownera).

Example 3.1 — HSBC - Bank of East Asia, February 2024

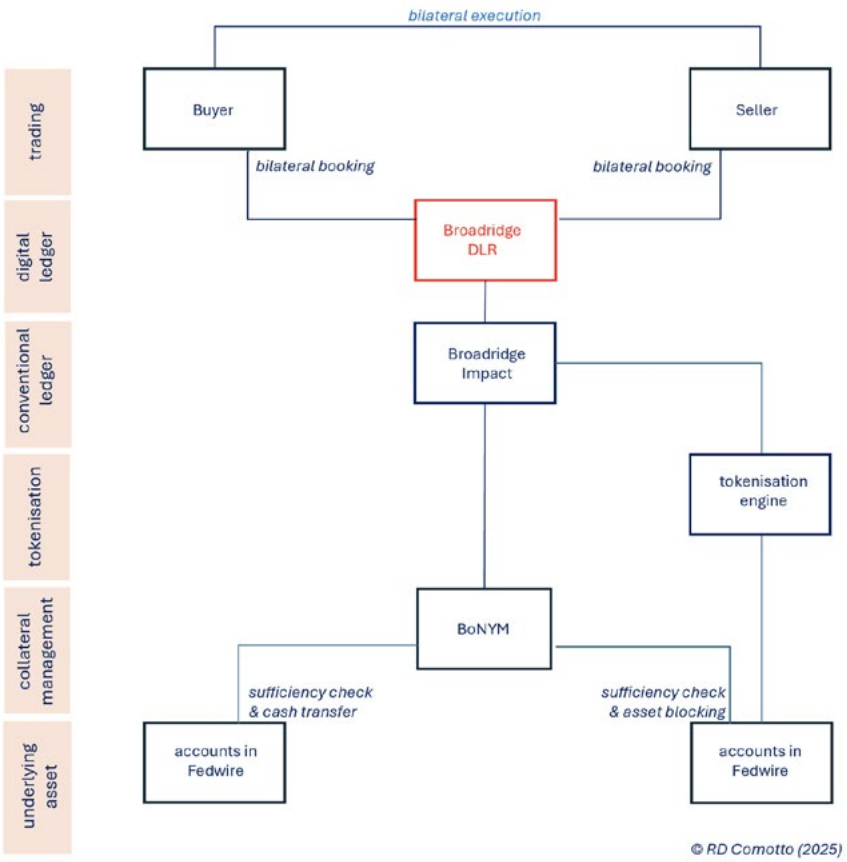


Transactions:

- possibly commercial
- term repo in HKD
- OTC execution
- collateral — native-digital security
- cash — central bank money on the conventional infrastructure

In February 2024, HSBC executed an apparently commercial HKD-denominated term DLT repo with the Bank of East Asia. The collateral was part of a native-digital two-year four-currency green bond issued by the Hong Kong government. Clearing and settlement was by the Central Money Market Unit (CMU) of the Hong Kong Monetary Authority (HKMA) but the record of legal title was hosted by the HSBC Orion digital security registry, which was deployed by HSBC to the CMU and is operated by the latter as an extension of its existing CSD.[xli] The cash payment was in central bank money on the conventional payment infrastructure through the CMU, which made this transaction a hybrid, ie on/off-chain. The CMU synchronised the exchange of cash and collateral between the digital and conventional accounts. Execution was OTC.

Example 3.2 — Broadridge DLR, from October 2017



Transactions:

- commercial
- intra-day, overnight and term repo in USD
- OTC execution or conventional trading venue (RFQ)
- collateral — tokenised traditional security
- cash — tokenised deposit

Launched in October 2017, Broadridge DLR is the most successful DLT repo platform in terms of volume. It originally consisted just of a distributed ledger bolted onto a conventional account (called Impact). In other words, it was a purely passive implementation in which only books and records were digitalised. Custody was formerly provided by the Bank of New York Mellon (BNYM), which segregated and immobilised the collateral securities. From or after October 2024, DLR appears to have switched to the use of US Treasury tokens minted by the Depository Trust Company (DTC), who acts as custodian and locks the tokens in segregated accounts. A smart contract on DLR synchronises the transfer of collateral tokens at DTCC and the payment of cash between accounts at BNYM.

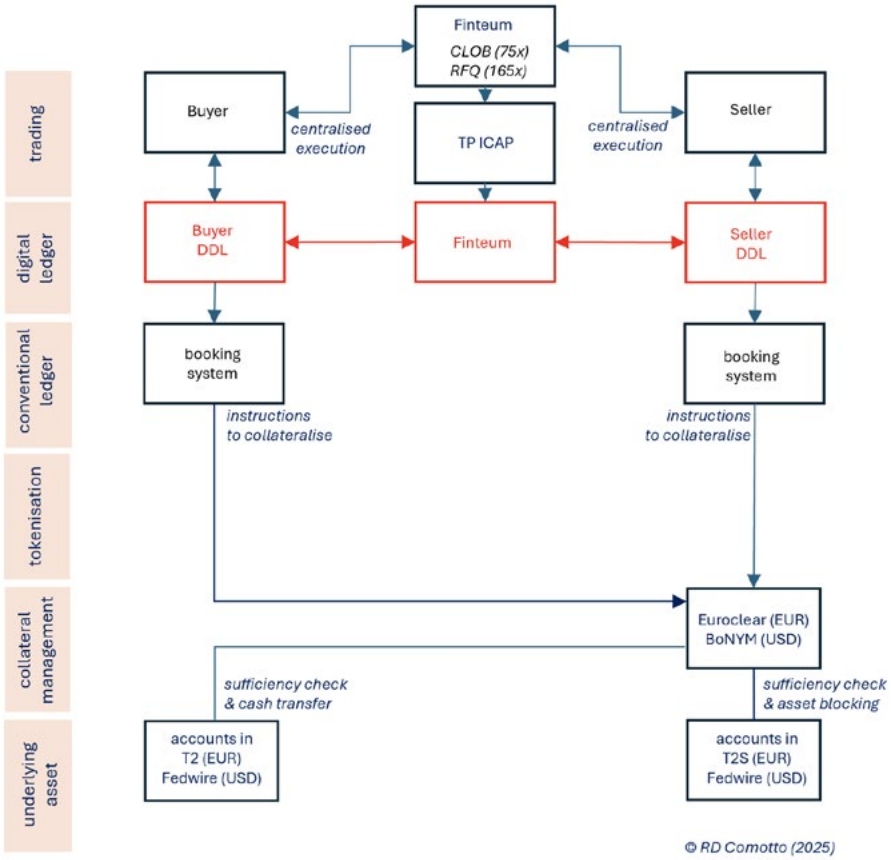
Execution of repos settled on DLR was formerly only OTC, but RFQ platforms have recently become available (Brokertec Quote, GLMX and Tradeweb). Business has largely been overnight.

DLR leverages Broadridge's post-trade management services to integrate repo settlement by the affiliates of a bank group (eg a banking subsidiary with a broker-dealer subsidiary) by co-ordinating their accounts using a blockchain for each group. DLR also provides collateral management services such as GC and block trade allocation.

In May 2024, Broadridge opened access to Kinexys Payment Systems (formerly, JPM Coin) to provide a "cash-on-chain" option and atomic settlement in DLR. However, access to Kinexys remains limited to JP Morgan Chase account-holders.

In April 2025, Broadridge announced that they had successfully demonstrated interoperability between DLR and Fnality, which would allow Broadridge to add another on-chain payment option to DLR and enable intra-day repo against central bank money.[xlii]

Example 4.1 — Cross-chain — 14 banks using Finteum, June 2022 and April 2024



Transactions:

- private experiment (mock settlement)
- 240 intra-day triparty repos in USD and EUR
- execution on conventional trading venues (75 on a CLOB and 165 using RFQ)
- collateral — traditional security on the conventional infrastructure
- cash — central bank money on the conventional infrastructure

Finteum organised some experimental intra-day triparty DLT repos in June 2022 and again in April 2024 with 14 partner banks. The repos were both USD and EUR-denominated. USD collateral was allocated by tri-party agent Bank of New York Mellon and EUR collateral by Euroclear Bank. The June 2022 experiment simulated 240 DLT repos to the value of USD 1.1 billion. Execution in June 2022 was simulated on both a central limit order book (CLOB) and a request-for-quote (RFQ) platform, 75 transactions in the case of the CLOB and 165 as RFQs. Settlement was only simulated, that is, it did not actually take place with real cash or securities.

Appendix III: The digitalisation of repo market infrastructures

The use of distributed ledgers as trading venues for repo

Press releases about DLT repo often imply that "trading" --- in other words, the negotiation and execution or conclusion of transactions --- is already taking place on distributed ledgers. In fact, by the end of 2025, there were no DLT-based organised repo trading venues in commercial use. Instead, DLT repo transactions and tests had mainly been traded over-the-counter (OTC), with a handful executed on conventional organised repo trading venues or network apps using conventional technology. Transactions had then been recorded on a distributed ledger for post-trade processing.

However, DLT-based organised repo trading venues are perfectly feasible. Indeed, there is already one venue for intra-day repo which is preparing to launch (see Finteum in Annex III). This operates a request-for-quote (RFQ) trading protocol between the nodes on its blockchain. As RFQ trading is an automated version of over-the-counter (OTC) trading, and OTC markets are intrinsically decentralised, RFQ is a natural protocol for DLT-based trading.

In contrast, central limit order-books (CLOB), which are the other main trading protocol in the repo market, would gain little from DLT, given that CLOBs are intrinsically centralised. This is reflected in the fact that the CLOBs used in DLT repo tests were off-chain.

True DLT-based organised trading venues do exist in the crypto-asset market, in the form of "decentralised exchanges" (DEX). Indeed, the largest DEX (Uniswap) was used to execute a tokenised (FX) transaction as part as Project Guardian in 2024. However, by definition, DEXs are not CLOBs, so do not correspond to the automatic order-matching systems operating in the repo market. Nor can they be compared with conventional exchanges.[xliii] Most DEXs operate so-called "automated market-makers" (AMM) that incentivise "liquidity-providers" to deposit two or more issues of stablecoin (in effect, crypto crowd-funding) and use an algorithm to fix the exchange rate between the coins on the basis of the relative supply of the two coins. This provides instant liquidity. However, AMM is not a model for repo or the cash trading of securities, since it requires sufficient quantities of the traded assets to be deposited and immobilised by third-parties. Such balances could never be as large as the trading interest in a conventional market, as the latter represents the entirety of available supply and demand, and not just particular contributions of assets. There is anyway no incentive to make such deposits in the existing repo market.

Could a repo CCP be replaced by a distributed ledger?

There have been few systematic analyses of the potential impact of DLT on the central-clearing of repo.[xliv] The literature tends to bundle CCPs with other financial market infrastructures, in particular CSDs, and then lose sight of them.

Moreover, studies that do address the application of DLT to CCPs usually fail to recognise the nature of the core services actually provided by a repo CCP. Instead, there is a focus on the use of clearing in its most basic sense, which includes the routine netting of members' coincident payment and delivery obligations in order to reduce the frequency and size of daily settlements.[xlv] Consequently, proposals to replace repo CCP with a decentralised clearing network are based on (1) smart contracts simultaneously performing (multilateral) netting calculations on each node on a distributed ledger to determine a net settlement obligation for each node and (2) atomic settlement to eliminate exposure to default risk at the point of settlement.[xlvi]

The first problem with such a proposition is legal. While the net settlement amounts to be paid or delivered by the nodes of a decentralised clearing network can be calculated by smart contracts, the irrevocable payment of these amounts between nodes would legally require a central entity. It cannot be performed by a clearing house acting as an agent, because netting is restricted to mutual and therefore bilateral principal obligations (the term "multilateral" only describes

the operational configuration, not the legal relationships between clearing members). This was the lesson of the seminal *British Eagle* judgement, where netting by an agency clearing house had to be unwound following a default by one of the members.[xlvii] A bilateral principal relationships between a CCP and each member is therefore a prerequisite for the legally-binding multilateral netting of obligations.

The second objection to decentralised clearing is that it proposes to eliminate only the risk of the loss of principal at the point of settlement, commonly known as "Herstatt" risk. This arises when one side of an obligation delivers or pays on a sale, but the other side does not. The DLT solution is atomic settlement, which is a form of delivery-versus-payment (DVP). DVP or atomic settlement can indeed eliminate Herstatt risk but that is all, which means that DVP or atomic settlement is only relevant for transactions involving single exchanges, such as cash transactions in securities and spot FX. It cannot eliminate the current or potential future exposures arising from the forward legs of repo, securities lending or derivatives. For such future exposures, variation margining is required in order to eliminate current exposures and a guarantee backed by capital and liquidity is required to hedge potential future exposures.

A theoretical DLT-based solution to the current or potential future exposures arising from the forward legs of transactions would be decentralised multilateral netting to minimise the exposures and continuous real-time variation margining. But continuous real-time margining is impracticable, if only because of the very urgent liquidity requirements it would impose, at least until the entire financial infrastructure had been accelerated to settle in real-time, and the margin period of risk (the gap between the last margin received and the close-out of exposures with a defaulting counterparty).

The need for real-time margining could be relaxed by requiring initial margins and default funds to be posted to cover the intervals between variation margin calls. But who or what would perform and enforce valuation and variation margining, and manage initial margins and default funds? The DLT proposal is that these tasks could be delegated to a smart contract, which would autonomously and automatically manage variation margining, initial margin, default fund contributions and commitments, and any event of default. Thus, the Global Financial Market Association (GFMA) has speculated that "participants could…develop a distributed capital market infrastructure, where the responsibility of a CCP in managing default funds and setting margin requirements is spread among market participants and agreed through predefined smart contracts or encoded in market-wide infrastructure".[xlviii]

There are a number of problems with this vision. First, as explained already, enforceable multilateral netting requires a CCP. Second, a trusted third-party would also be required to collect, safeguard and manage margin and default funds prior to any default. But the need for third-parties would defeat the whole idea of decentralisation.

The third problem is the practical difficulty (if not impossibility) of using a smart contract to autonomously and automatically perform the default management functions of a CCP, which is the most essential function of such an infrastructure. To encode default management, there would have to be perfect foresight of future scenarios and the invention of a complete range of procedures to deal with every contingency.

In reality, there are challenges at every stage of default management which require the exercise of judgement. It is not necessarily straightforward even to identify and validate a default. And once a default has been confirmed, the decision to close-out against a defaulting counterparty cannot be automatic. For good reason, this decision is reserved for the considered judgement of senior management (among other things, because it could be reputationally, commercially and systemically counterproductive to kill off a major counterparty that might be rescued).

If and when a decision to close-out is made, there is the question of when to do so and the need to co-ordinate close-out across the non-defaulting firm and its affiliates. Moreover, processes such as collateral valuation and liquidation, particularly in a stressed market, are not mechanical and require careful judgement about prices and liquidation strategies. In the case of illiquid collateral, valuation typically defaults to mark-to-model, using ad hoc methods and whatever data are available, based on an appraisal at the time. The resulting Default Market Value of collateral then has to be adjusted for transactions costs, legal and professional expenses, as well as replacement or hedge-unwind costs. Moreover, these

processes are not static. They would have to be periodically updated, which means a smart contract would be subject to fairly-continuous revision by some sort of third-party, who would look very much like the managers of an existing CCP.

Decentralisation would also require substitutes for the clearing members of a CCP, given that, during a default, clearing members are required act in concert to liquidate collateral and hedge exposures on behalf of the CCP. This responsibility would have to be redistributed among specialist third-parties, such as price oracles and brokers. But third-party agents introduce agency risk. Agency risk is the reason that a CCP is required to have "skin-in-the-game", in the form of a capital commitment to default resources. How would this principle work with decentralised clearing?

Finally, could the governance structure of a network satisfy regulators? Acquiring regulatory approval would be no easy task, given that the systemic importance of a CCP means that it is the most intensely regulated type of financial market infrastructure.

The various challenges involved in decentralising clearing, and doubts about the point of replacing a CCP with multiple agents, make it unlikely that DLT will lead to the replacement of central-clearing by a network. It seems rather more likely that DLT will be adopted by CCPs to enhance their current processes. Thus, a CCP could continue to manage more sophisticated risk management functions, while delegating more mechanical functions to a smart contract. In effect, the smart contract would be used as an automated rulebook.

It should be noted that the crypto-asset market does not offer practical alternatives to a CCP. While alternative risk management mechanisms embedded in smart contracts are being developed in the crypto-asset market for both centralised exchanges and decentralised arrangements, these have, so far, not proved reliable. For example, some crypto-exchanges protect themselves with a forced liquidation mechanism that kicks in and closes out an under-collateralised position and covers any losses by using an auto-deleveraging (ADL) system to capture the profit on the other side of an under-collateralised position. Decentralised networks may also embed protocols to value collateral and identify under-collateralised positions. The collateral on such positions is then auctioned or made available for sale to independent "liquidator bots" incentivised by being offering a bonus in the form of a collateral haircut. But such mechanisms are fundamentally problematic for the real-world financial markets, as they are purely reactive "survivor-pays" mechanisms, whereas CCPs try to strike a balance with "defaulter-pays" rules in order to disincentive the moral hazard created by full insurance against default. Then, there is the question of scaling up such mechanisms for real-world assets. It has also been argued that the mechanism used in the crypto market amplified the crypto crash of October 2025.

Appendix IV: Progress towards a GMRA for DLT repo

Digital Asset Annex

This annex to the GMRA (Global Master Repurchase Agreement) was published by the International Capital Market Association (ICMA) in August 2024.[xlix] It can be used to govern repos under a GMRA to the extent that the Purchase Price or Cash Margin includes digital cash and/or that the Purchased Securities or Margin Securities include either an asset-backed digital asset or a so-called "Platform Transferred Security" (as defined below).

The Annex makes amendments to the GMRA to reflect the fact that collateral and/or cash may now be digitalised, and to accommodate operational enhancements facilitated by DLT (eg intra-day repo). Matters addressed include: delivery on a distributed ledger constituting good delivery; the definition of what is equivalent to a digital asset for repurchase; how a tokenised security should be valued, margined and settled in the event that the operation of a ledger is disrupted or ceases to function altogether; what happens to a repo of a digital asset in a default; and how intra-day repo interest should be calculated.

The assets subject to the Digital Asset Annex are:

- **Digital cash —** which can be a central bank digital currency (CBDC), tokenised deposit, electronic money token or some other "cryptographically-secured digital representation of value denominated in a single fiat currency which can be used for the settlement of payment obligations".
- **Asset-backed digital asset —** a digital asset, other than digital cash, which represents ownership of, or a contractual claim on, or a contractual right to, an underlying asset. The underlying asset can take the form of a tokenised traditional security — which is a digital asset representing ownership of, or a contractual claim on, or a contractual right to, an underlying asset, where the underlying asset is a traditional physical or dematerialised security — or it can be another asset-backed digital asset.
- **Platform Transferred Security —** a traditional physical or dematerialised security which is held or recorded in a form that means it is capable of being transferred in a cryptographically-secured manner on a platform. A platform is defined as a technology platform used for the holding, transfer, payment and/or settlement of an asset-backed digital asset, Platform Transferred Security or digital cash.
- **Digital asset —** a cryptographically-secured digital representation of value, or of contractual rights, which can be transferred, stored or traded electronically using technology that supports the recording or storage of data (which may include DLT). The Annex is not intended to cover other types of digital asset, including crypto-currencies (but these could qualify as digital cash).

Digital Bond Annex

The second annex to the GMRA dealing with the application of DLT to repo was published in May 2026. It extends the express coverage of the GMRA to native-digital bonds, which are referred to in the annex simply as "digital bonds". A digital bond is defined as "a debt security that is issued, held, transferred, cancelled and/or redeemed using blockchain or distributed ledger technology". The definition makes clear that the documented terms of the digital bond must envisage the use of DLT.

In most other respects, the Digital Bond Annex builds on the Digital Asset Annex. In particular, the former relies on the definition of digital cash in the latter (which may mean using both Annexes where a native-digital bond is repoed out for digital cash and the two Annexes are accordingly intended to operate alongside each other).

The references to cancellation and redemption in the Digital Bond Annex refer to the right of the issuer to substitute or exchange a digital bond for traditional physical or dematerialised securities. If such a Digital Bond Conversion Event occurs, unless the parties agree otherwise, a fixed-term repo of that digital bond would become terminable-on-demand (ie an open repo), allowing the buyer to unwind and receive equivalent securities, which may be in traditional form. It is worth noting that a converted bond, although traditional in form, would continue to be treated as a digital bond under the Annex.

Separately, in the event of the prolonged or permanent unavailability of the platform which hosts a digital bond or a critical third-party service-provider (a so-called Platform Event), a fixed-term repo of that bond would become terminable-on-demand (ie an open repo), once again, allowing the parties to unwind the transaction and receive equivalent securities. However, the parties can waive this provision.

The Digital Bond Annex clarifies that all requirements to deliver a digital bond will be satisfied by valid transfers on the relevant platform. The Annex also notes that the minimum customary period to deliver a digital bond may differ from those of bonds issued wholly or partly in traditional form.

Clause Library and Taxonomy

The Clause Library and Taxonomy (CLAT) is an ongoing exercise at ICMA that is intended to lay the foundation of a formal industry-led digital data model for master agreements that will directly support smart contracts. It is a project led by ICMA in repos, ISLA in securities lending and ISDA in OTC derivatives.

The CLAT has three components:

- **clause definitions —** a common understanding of what is meant by a particular clause in a master agreement and the scope of the clause (and, often more importantly, what it is not in scope);
- **clause variants —** the enumeration, in terms of possible business outcomes, of the defined clauses in the master agreement;
- **model wording —** text implementing each variant of each clause.

The clauses covered by the CLAT for a particular product are being selected by a legal working group at the relevant market association, who also craft the model wording, drawing on samples of text provided by members.

Common Domain Model (CDM) for repo and secondary market securities

The CDM is intended to provide an authoritative and granular digital data model of various classes of financial instrument, how they are traded and how they are managed post-trade. It acts as a translation layer to which the different descriptive terms used in any proprietary data model and employing any messaging standard can be mapped. Mapping to a common model enables precise communication between different systems using different messaging standards without having to re-engineer internal processes or amend standards. CDM is therefore not itself a competing data model or messaging standard. Rather, it is a way of overcoming the lack of standardisation of models and standards used across the market.

The process of translation using CDM consists of ingesting an input file written in a standard or proprietary language into the model, which links concepts expressed in that language to synonymous concepts in the CDM, to create an output file, written in a selected language. The translation ensures that the output file will be consistent with every other output file that has been produced in the same language about the same class of financial instrument.

CDM can claim to be an authoritative model of financial products and life-cycle events because it is being constructed collectively by users of particular classes of financial products under the aegis of their representative market associations, ICMA, ISLA and ISDA. Market associations can also ensure that the representation of trading and post-trade management in the model incorporates industry best practice.

The granular nature of CDM means products, life-cycle events and workflows, including calculations, are constructed from reusable ("composable") components. This ensures consistency and enhances efficiency.

CDM was originally commissioned by ISDA in 2017 for derivative instruments and based on the data model implicit in ISDA's FpML messaging standard. However, extensions have since been launched by ISLA for securities lending and, more recently, by ICMA for repo and cash bond trading. Although these extensions can leverage many of the existing components of CDM, the specificities of repo and securities lending have required generalisations of some existing components and the addition of supplementary components, which means CDM has moved away from the FpML template.

CDM is open and accessible to all. To facilitate global access, with effect from February 2023, the CDM repository has been hosted by the Fintech Open Source Foundation (FINOS).

Annex I: A brief history of distributed ledger technology (DLT)

The origins of DLT lie in technical and ideological dissatisfaction within the emergent internet community with the centralised and hierarchical structure of today's "account-based" financial settlement infrastructure. At the top of that hierarchy is usually (1) a central set of accounts operated by a CSD, providing a record of securities, typically held in custody, by the top layer of intermediaries, and (2) a central set of accounts for balances of cash at the central bank held by the top layer of payment intermediaries. Securities settlement and payments are ultimately made by debiting one account and crediting another at the CSD and at the central bank, respectively.

In most cases, there are chains of independent nominee accounts to link the central accounts to the ultimate owners, each operated by a "trusted" settlement or payment agent. Because each account in such a tiered and intermediated "indirect holding system" only identifies one level of aggregated holdings, information about ownership is fragmented between tiers and dispersed along the chain. New transactions or corporate events require the whole chain of accounts to be realigned by means of sequential asynchronous messaging, manual end-of-day batched reconciliation and repeated transfers of securities or cash. These steps are inherently time-consuming, error-prone and costly. The wide distribution of data can also compromise its confidentiality.

Moreover, the centralised and hierarchical structure of the account-based settlement infrastructure, in the view of some, is exploited by intermediaries to restrict access to financial services and exercise unwelcome control over users.

Critics of the account-based architecture and its tiers of intermediaries have looked to DLT to deliver faster, cheaper, more inclusive and more confidential financial services by enabling direct or "peer-to-peer" communication, protected by cryptography, across networks of computers, each sharing an identical record — a distributed ledger — of holdings and transfers of digital representations of value (digital assets and digital cash). By thus short-circuiting the traditional chains of intermediation, peer-to-peer communication should dispense with intermediate messaging, reconciliation and transfers, thereby reducing the delays, errors, liquidity requirements and cost of financial services, as well as providing better protection of data while allowing open access. Distributed ledgers should, in principle, also be more resistant to tampering and, not having any single point of failure, should be more resilient and more easily recoverable after a systemic failure.

However, the elimination of trusted intermediaries requires "trustless" ways to validate the confidentiality, authenticity and integrity of data. This includes the prevention of double-spending, which is conventionally addressed through checks made by intermediaries using double-entry accounting.

The prototype DLT solution was the blockchain (and the prototype digital asset was Bitcoin). The confidentiality and integrity of transaction data on a blockchain is protected by asymmetric cryptography. The validation of authenticity was originally performed collectively by network participants acting as self-interested record-keepers ("miners"), who are rewarded for reaching an acceptable consensus and generating a "block" of records of validated activity --- thus the name. New validated blocks are linked to a chain of previous blocks by a shared encrypted signature to provide an immutable record visible to all on a ledger.

In the case of blockchain, the ideological desire to escape from centralised control was originally reflected in the delegation of the governance of blockchains to user consensus. And to ensure freedom from censorship or surveillance, users were not required to post personal data to prove their identity but were simply known by their internet address ("pseudonymity").

However, the original blockchain concept has disadvantages. At a fundamental level, there is the "blockchain trilemma" (a term coined by Vitalik Buterin, co-founder of Ethereum), which is the challenge of simultaneously balancing the

decentralisation, security and scalability of a blockchain. Typically, only two qualities can be maximised at the same time, as enhancing one usually compromises another, eg decentralisation tends to weaken security.

Other problems are that universal access to a blockchain allowing all users to see all data is not desirable for many user-groups. Pseudonymity is also inherently problematic for market integrity, as the original consensus mechanism does not verify the probity of participants. In addition, blockchain has proved vulnerable to cyberattack, is not scalable, is energy-intensive and can only offer probabilistic rather than deterministic settlement (because validation takes time and there is a risk that a transaction will have to be reversed because validation may fail).[1] There is also the challenge posed by the fact of there being multiple blockchains and the consequent need for interoperability.

Consequently, there has been a shift for some uses towards permissioned ledgers (the antithesis of the canonical blockchain concept), the appearance of new consensus mechanisms to speed up and provide more certainty to validation, the introduction of greater flexibility into ledger architecture in order to facilitate upscaling and a growing resort to new types of trusted intermediaries (eg to provide services such as the management of the digital wallets which store the identification needed by owners to access digital assets).

New use-cases for DLT have also emerged. Ledgers are being used to host programmes in the form of smart contracts to automate processes such as the settlement and life-cycle management of digital assets. They are also being used as tools for the co-ordination of multiple parties, for example, to manage the movement of assets between affiliated entities or to collect data from multiple contributors to complete a workflow or compile a composite record.

Annex II: A primer on distributed ledger technology (DLT)

Distributed ledgers, smart contracts and oracles

What is a distributed ledger?

A distributed ledger is a database of records that is shared across a dedicated network of computers, each referred to as a "**node**" of that network. Each node may itself also be a network. All nodes are equal, in that there is no central node feeding the others. Instead, each node holds a copy of the same ledger. In other words, a common ledger is shared or "distributed" rather than being centralised.[li] Interactions across a ledger are therefore said to be "peer-to-peer" rather than intermediated.

A distributed ledger records the "state" of each node and any "transitions" to a new state. The state of a node could take the form of holdings of an asset by the operator of that node or his client. In that case, transitions would be transfers of assets between entities on the network, such as through sales, pledges and margin transfers.

Transitions in the state of a node have to be authenticated or "**validated**", after which, they are automatically, simultaneously and (on a blockchain type of ledger) immutably shared across the network in a process called "synchronisation".[lii]

Access to a distributed ledger

Given that multiple nodes can access a ledger, it is important that measures are incorporated to protect the integrity of data against fraudulent or malicious interference by one of the nodes, or by external actors who succeed in penetrating the network. In addition to a mechanism to authenticate transitions, the integrity of a ledger is ensured by securing messaging over the network with asymmetric cryptography, which can be used to restrict who can:[liii]

- enter transitions onto the ledger — access to ledgers can therefore be "**private**" or "**public**"
- participate in the validation of transitions — ledgers can therefore be "**permissioned**" or "**permissionless**"
- hold and view a full copy of the ledger or only a partial copy — ledgers can therefore be "**hierarchical**" or (typically in the case of third-party agents who do not need access to a full record) "**non-hierarchical**".[liv]

Private permissioned ledgers are better able to meet legal, regulatory and institutional security and confidentiality requirements, because these can be built into the ledger. Such ledgers are generally limited to use by intra-company or collaborative inter-company networks.

Public permissioned ledgers are also well-placed to satisfy legal, regulatory and institutional requirements but can permit wider access, which means they have the potential to reach a larger market.

Public permissionless ledgers, along the lines of the canonical concept of blockchain, are universally accessible and can therefore offer the greatest market reach and economies of scale. On the other hand, their openness means that they may struggle to meet legal, regulatory and institutional requirements, while the reliability of their cybersecurity measures has sometimes proved inadequate. In addition, the typical consensus-based validation mechanisms of blockchains also constrain scalability, preclude deterministic settlement finality and can be energy-intensive.[lv] [lvi] However, there are an increasing number of solutions to these weaknesses and the majority of stablecoins are currently issued and distributed on public permissionless ledgers.

A participant in a ledger can participate directly as a node ("node-hosting") or indirectly through external interfaces, which are either an application programme interface (API) or a dashboard or user interface (UI).

- Node-hosting means that a participant has his own copy of the ledger and direct access to the network, which reduces reliance on third-party intermediaries but may come with higher costs and greater operational and cyber risks.
- APIs and UIs offer standardised interfaces with ledgers, avoiding the cost of running a node and reducing the expense of onboarding and integration, but possibly creating cyber vulnerabilities of their own by virtue of providing an intermediate entry point into the ledger.

The architecture of distributed ledgers

A distributed ledger can be structured in a variety of ways. The BIS has identified a "continuum of unification" in the architecture of ledgers. The continuum ranges from a single ledger through to interconnected multiple ledgers.[lvii] The degree of unification depends on the balance required between, on the one hand, data privacy and autonomy in governance and, on the other hand, "**programmability**" or the degree to which the processes on a ledger can be automated. In other words, there is a trade-off between the ability to control and the ability to automate.

At one end of the continuum of unification is a single or "unified" ledger. This allows maximum programmability but no autonomy, which would mean a uniform data and governance regime, including legal and regulatory frameworks. A unified ledger has been compared to a mobile phone, in that it allows multiple applications on a single operating system. Unified ledgers have been proposed by the BIS and are to be investigated by the Bank of England, ECB and Banque de France.[lviii]

At the other end of the continuum, there are independent ledgers necessarily connected through a common communication protocol. Independent ledgers offer maximum autonomy but the need for interoperability between ledgers complicates programmability. The operation of independent ledgers has been compared to that of applications such as instant messaging systems, which run seamlessly across different independent mobile phone operating systems.

Between the two extremes of the unification continuum are intermediate architectures. One is layered ledgers. These consist of a single base ledger (Layer 1 or L1) running the core protocol for common functions such as the consensus mechanism, network cryptographic security and settlement for the multiple otherwise-independent ledgers that form a second layer (Layer 2 or L2). Layer 2 usually hosts rules on access (although these are sometimes a Layer 1 function). Layer 2 can accommodate distinct functionalities to allow, for example, compliance with legal and regulatory requirements in different jurisdictions. Layer 2 can also be used to increase through-put and reduce costs by offloading transactions from Layer 1, processing them separately and returning the results. On the other hand, Layer 2 adds complexity and creates cybersecurity vulnerabilities. Its governance will also differ from that of Layer 1.

Another intermediate ledger architecture is a "subnet" or "subnetwork", which is a set of overlapping networks with largely-independent governance within a common primary (Level 1) framework. The primary framework ensures consistency in programmability across subnets. The primary ledger can be partitioned into one or more subsets based on attributes such as jurisdiction, asset class and preferred transaction processing rules. Subnet ledgers therefore offer more autonomy but less programmability than a unified ledger.

Smart contracts

The programmability of ledgers, and therefore the potential to use DLT to automate processes, is provided by "smart contracts". These are discrete pieces of computer code that run on a ledger. A key use is the automation of the processing of transactions or positions, endogenously triggering defined actions when certain pre-agreed conditions are met (the so-called "contingent self-execution of actions"). In the case of repo, smart contracts could allow the automatic implementation of routine rights and obligations under a master repurchase agreement and automate more complex tasks by prompting the user to make a decision or take an action. But smart contracts can also be used to enforce regulatory compliance and control participation on a ledger.

Of course, all computers are programmable, including those hosting the conventional infrastructure. The difference is that smart contracts can exist at a transaction level and can therefore be tailored to particular types of business. This lower-

level focus offers greater flexibility in automation and the ability to customise different processes on the same ledger. One important benefit of customisation is the ability to schedule settlement at a precise time. This enables intra-day repo and would facilitate T+0 settlement.

A particularly important example of contingent self-execution is "**atomic settlement**". This means payment of cash conditional upon simultaneous delivery of an asset and vice versa. It also enables operational (but not necessarily legal) final settlement almost immediately after execution (faster than conventional same-day or T+0 settlement).

Atomic settlement already exists in the form of delivery-versus-payment (DVP) but, unlike DVP on the conventional infrastructure, atomic settlement is instructed at transaction-level and is not dependent on the infrastructure.

Near-instant settlement is the extreme form of real-time gross settlement (RTGS), which also already exists on the conventional infrastructure.

The ability of a smart contact to self-execute also enables what is called "**composability**" or "bundling".[lix] This is the simultaneous or sequential settlement of combinations of related transactions by using a smart contract on one ledger to trigger smart contracts on other ledgers, for example, a cash purchase of a bond and a repo of that bond to finance the purchase.[lx] Composability already exists in limited form on the conventional infrastructure (eg the linking of settlement instructions) but is not widely used. Its use on ledgers would be easier and could significantly expand the scope for the automation of settlement by making it easier to add more use-cases.

In the case of repo, the smart contracts currently in development are based on proprietary code to automate the operative and deterministic provisions of the Global Master Repurchase Agreement (GMRA), which is published by the International Capital Market Association (ICMA) and represents the international standard for repo. There is, at present, no digital version of the GMRA but there are initiatives by ICMA in this direction and there are annexes to facilitate repos of digital assets and/or digital cash (described in Appendix IV). Issues confronting the development of smart contracts will be discussed in more detail in the second part of this report.

Oracles

Given that a smart contract can automatically initiate a pre-defined action when a pre-agreed condition is met, an essential requirement for automation through the use of DLT is access to sources of information on the state of that condition. Such information includes asset prices, payments and deliveries, news of events such as weather and random numbers needed for functions such as cryptography. The problem is that a distributed ledger cannot itself generate information on the outside world and many of sources of the information that it needs are not directly accessible to a distributed ledger.[lxi]

The solution takes the form of an "**oracle**". This is a type of infrastructure that acts as a bridge between a distributed ledger and the off-chain world of data-providers, API or third-party web-servers, cloud-providers, conventional payment systems, other distributed ledgers and other infrastructures. Oracles can also bridge smart contracts on independent ledgers. At least one solution to the problems of interoperability between and the orchestration of distributed ledgers employs an oracle (see the SWIFT "interlinking" solution in Annex IV).

Oracles monitor a distributed ledger for requests for off-chain data by users or smart contracts. In response, they retrieve data from one or more off-chain sources by translating requests into a format that is readable by the external source(s); perform any necessary calculations off-chain; translate the results into a ledger-compatible format; validate the answer with a cryptographic proof; broadcast the resulting data to the network for consumption by the smart contract; and, if required, pass the resulting data to an external system such as a conventional payment system.

The choice of an external infrastructure to connect to the off-chain world, rather than building the functions of an oracle into the base layer of a distributed ledger, is intended to ensure the quality of information, by allowing the use of reputable specialised off-chain third-parties but also to avoid the cost of having to build new sources from scratch every time the

functionality of a distributed ledger is expanded, as well as the delays imposed by governance requirements to integrate new sources and the possibility of inadvertently opening weak points into the network.

On the other hand, a centralised oracle creates vulnerabilities of its own, in particular, as to the quality of data and dependence on single sources. This has encouraged the creation of solutions such as a network of networks of independent oracles, where each of the networks of independent oracles specialises in a particular field. In addition, services can be provided to allow users to assess the reputation of each node on a particular oracle network and the quality of data that has been provided using historical performance measures.

The structure and operation of a distributed ledger

A distributed ledger can be passive or active.

A passive ledger acts purely as the shared books and records of the counterparties to a transaction. This appears to be the initial model at Broadridge DLR. In this role, it is basically a hi-tech ledger, giving the counterparties (and any agents involved in post-trade processing), near-instant, simultaneous and (on a blockchain type of ledger) immutable visibility over validated data about past transactions and the progression of new transactions towards final settlement. The sharing of the ledger eliminates the need for the confirmation or affirmation of transactions. Passive use of a ledger does not imply use of digital assets or digital cash in settlement.

There are two active uses for a distributed ledger.

- The first is for the ledger to be employed as the place of settlement (at least operational settlement or custody: legal settlement may be elsewhere). For this purpose, the assets being settled need to be digitalised, either as "**tokens**" or digital records, or in the form of "**native-digital assets**". Alternatively, settlement on a distributed ledger can drive settlement across the conventional infrastructure.
- The second active use of a distributed ledger employs smart contracts to extend the role of the ledger beyond settlement to the management of the whole life-cycle of a transaction. This could include inter-life events such as margining, manufactured payments and collateral substitutions, and (in principle) termination events such as mini close-outs in the event of failed repurchases or close-out netting in an event of default.

Cross-chain collateral management and settlement

A fundamental challenge for DLT repo (and other types of digitalised financial transaction) arises where assets, cash or services are hosted on different distributed ledgers. There are various solutions offered to this cross-chain challenge. The linking of independent ledgers is variously described as achieving the objective of "interoperability" or the enabling process of "orchestration" or "synchronisation". While these words are often used synonymously, it is helpful to allocate them to describe different purposes and processes. The taxonomy to be used in this report is explained in the Box below.

Interoperability, orchestration and synchronisation

The definition of **interoperability** in this report draws on the meaning of the word in traditional finance, which is to link two competing systems (eg interoperability between two tri-party agents). In the context of DLT, this means linking distributed ledgers hosting competing digital representations of the same asset or fiat currency. The most relevant examples are the linking of ledgers offering competing stablecoins or tokenised deposits. Another distinguishing characteristic of interoperability is that it involves settlement, either the transfer of digital assets or the use of cross-chain bridges to exchange data.

Orchestration will be used in this report to mean co-ordination to effect simultaneous or sequential operations on complementary distributed ledgers, for example, an exchange of ownership of an asset on one ledger for cash on another. Orchestration will also be used to describe the co-ordination of distributed ledgers and conventional accounts, including the immobilisation of traditional assets and creation and transfer of a digital representation.

Synchronisation will be employed to mean the orchestration of simultaneous operations on two or more complementary distributed ledgers, eg the exchange of digital cash and securities, each on a different ledger. In this sense, synchronisation is merely a type of orchestration.

In practice, the use of these terms may differ depending on whether they are being used in a business, legal and regulatory context or in a technical or operational discussion.

Interoperability, orchestration and synchronisation can be achieved using:

- **cross-chain bridges**[lxii] based on smart contracts
- **middleware** --- such as a network of non-DLT network routers attached to each distributed ledger and using peer-to-peer protocols to interconnect the ledgers (eg Ownera, which uses its FinP2P application orchestration protocol)
- a **network-of-networks** — a constellation of multiple distributed ledgers that are interconnected via a private permissioned Layer 1 ledger and co-ordinated by a third-party synchronisation operator, which may be the network operator (see the use of Canton Network by DiSH in Annex IV).

The Bank of England distinguishes cross-chain bridges from cross-chain protocols. The former perform the operational processes to transfer specific assets between ledgers, whereas the latter provide the messaging rules to allow communication between ledgers.

Cross-chain bridges can be divided into three models:[lxiii]

- **lock-and-mint** — A token is "**locked**" by a smart contract on its native distributed ledger, which triggers the sending of a "proof-of-asset-locking" or "proof-of-reserve" to a second ledger, upon receipt and validation of which, a special version of the locked token — called a "**wrapped token**" or "**pegged token**" — is created or "**minted**" on the second ledger. This is a process analogous to the immobilisation of traditional assets on a conventional account in order to create a digital representation.[lxiv]
- **burn-and-mint** — Instead of locking a token on its native distributed ledger, it is destroyed or "**burnt**" by a smart contract. When burning is validated by a second ledger, an identical token is minted on the second ledger.
- **lock-and-unlock** — Where the same token is hosted on two distributed ledgers, a token on one ledger can be locked by a smart contract and, upon proof of locking, an identical token can be unlocked from an available liquidity pool by a shared contract on the second ledger.

The design of a secure cross-chain bridge requires robust cryptography, a means of "attesting" the authenticity of one network to another and the recruitment of a community of validators that is sufficiently diverse to minimise the risk of collusion. However, the consequent complexity can open the way to cyber-attack and bridges are seen as a weak-spot in DLT systems.[lxv] Moreover, cross-chain bridges are dedicated solutions that are specific to the ledgers they connect. This

makes them efficient in connecting the ledgers for which they are designed, but less flexible in subsequently extending interoperability to additional ledgers.

Middleware, such as non-DLT routers, have been described as a means of orchestration or synchronisation at the application or business layer of cross-chain arrangements that is agnostic to the type of distributed ledger. In contrast, a network-of-networks is seen as orchestrating or synchronising at an infrastructure level. Both approaches ensure that the operational transfer of a token or native-digital asset between two ledgers also achieves legally-enforceable settlement finality by also being orchestrated or synchronised at a legal and regulatory level within a framework provided by a common rulebook or contract. Being generic, they can be agnostic to the assets being transferred, which would make them broadly applicable and more straightforward to implement.

Oracles can also be described as interoperability solutions but link distributed ledgers with non-DLT systems rather than only linking ledgers (see the use of Chainlink by SWIFT in Annex IV).

Oracles and networks-of-networks are sometimes described as creating “abstraction layers”, in that they present the user with a single virtual interface that simplifies their interaction with the underlying system.

Annex III: Dedicated infrastructures supporting DLT repo

HQLA^X --- ad hoc temporary digital record of ownership[lxvi]

HQLA^X produces on-chain digital evidence of the ownership of traditional securities which are being immobilised by and authoritatively recorded on a CSD or by a custodian. This digital evidence is called a Digital Collateral Record (DCR). It is held on a distributed ledger operated by HQLA^X.[lxvii] A DCR is not in itself an asset.[lxviii] The asset is the underlying security or basket of securities, which are immobilised at a CSD or custodian in the name recorded in the DCR.

In the event of a sale of securities that are evidenced by a DCR, HQLA^X updates the record to reflect the transfer of ownership between the accounts of the seller and buyer at the underlying CSD or custodian.[lxix]

In the event of a default by one of the parties, HQLA^X would freeze the affected DCR and allow the non-defaulting party to access the underlying securities.

To protect underlying assets, HQLA^X uses Clearstream International as a Trusted Third-party and custodian. Clearstream International is responsible for organising any necessary sub-custodians (currently, these are Clearstream Bank SA, Bank of New York Mellon, Euroclear and JP Morgan Chase) and for arranging collateral management by opening accounts at tri-party agents.

Finteum --- DLT-based organised repo trading venue[lxx]

Finteum operates a blockchain-based venue for the interbank trading of intra-day liquidity. Currently, it offers a service in intra-day FX swaps but is due to go into production with intra-day repo in 2026.

Finteum's venue offers request-for-quote (RFQ) trading between the nodes of its blockchain but also has an off-chain central limit order book (CLOB). The nodes of the counterparties are behind their own firewalls and not on Finteum's server, so Finteum does not have sight of RFQ negotiations. Once a transaction is agreed, the details are passed to the multilateral trading facility (MTF) of the voice-broker, TP ICAP, so that the transaction is formally executed on a regulated trading venue. TP ICAP shares a copy of the trade details with Finteum, which updates its ledger, subject to validation by the counterparties. Validation triggers FIX messages from each party's node into its own booking system.

Fnality --- tokenised central bank money[lxxi]

Fnality UK is a subsidiary of Fnality International, which was established in 2019 by a consortium of international banks and financial market infrastructures to build a regulated payment system based on DLT. Fnality UK operates the Sterling Fnality Payment System (£FnPS), which is a blockchain based on a private Enterprise Ethereum network that is connected to the Bank of England's RTGS, that is, the conventional infrastructure across which final payments in sterling are settled and in which Fnality holds an omnibus account.

The use of Fnality requires funds to be deposited in its omnibus account (pre-funding). This triggers the creation of a token on the £FnPS ledger --- tokenised central bank money --- which can then be used in digital payments. The use of a token enables Fnality to provide 24/7 near-instant settlement finality in sterling using an on-chain cash leg to complement a digital collateral leg on another synchronised ledger.

Fnality's aim is to roll out FnPS in other currencies to establish a "network of networks" (Fnality Global Payments). This overarching network would allow 24/7 near-instant cross-currency payment-versus-payment (PvP) and delivery-versus-payment (DvP).

In the event of a default by Fnality, users would have a collective claim on Fnality's balance in its central bank account.

The BIS have categorised Fnality's digital record as a stablecoin, in line with the classification of JPM Coin by the European Banking Authority (EBA), but Fnality argues that the bankruptcy-remote character of central bank money represents a material difference.

To date, Fnality have participated in two proof-of-concept DLT repos, one in partnership with HQLA^X and the other involving Banco Santander, Goldman Sachs and UBS.

Annex IV: Interoperability solutions

LSEG Digital Settlement House (DiSH)[lxxii]

This interoperability solution was launched in January 2026 by the Post Trade Solutions Division of London Stock Exchange Group (LSEG), in which 11 global banks had taken a stake.

DiSH is a public permissionless blockchain that connects banks, their clients and custodians, as well as CSDs and other financial market infrastructures, across the Canton Network. It differs from the other interoperability solutions in that it is intended to offer interoperability for bank deposits, whether these are held on- or off-chain.

A bank deposit is made interoperable by being placed in a trust account at the depositor's bank (which must be connected to DiSH through the Canton Network). The trust account is in the name of LSEG, which acts as a trustee for the depositor, who remains the beneficial owner.

To make a payment to a depositor at another bank connected to DiSH, the depositor pre-funds the trust account from his main account, then instructs DiSH to make the transfer. DiSH digitalises the deposit into a DiSH Cash token on the Canton Network, transfers that token to the payee's bank and updates the DiSH ledger.

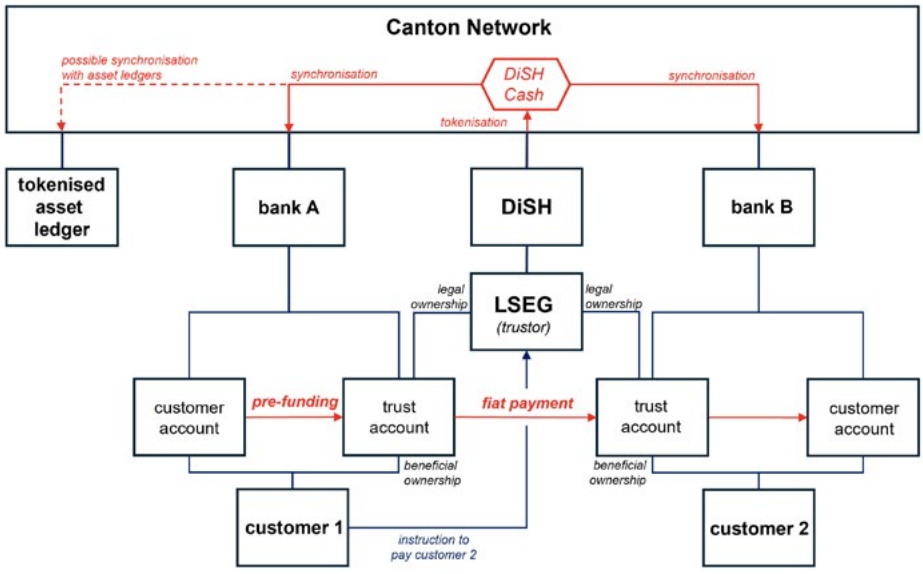
If the payee is the customer of a bank which is not connected to DiSH, DiSH can redeem the DiSH Cash token by making a payment in fiat currency to the payee's bank.

The schematic workflows and transfers are illustrated in the diagram below.

DiSH can orchestrate payments in DiSH Cash denominated in different currencies, enabling payment-versus-payment (PVP), where both deposits are DiSH Cash or where one is held on another distributed ledger or in a conventional account. DiSH can also orchestrate the atomic settlement of a sale of a digital asset held on another ledger or a traditional asset held in a conventional account. Settlement can be DVP in DiSH Cash or in digital cash held on another ledger.

DiSH can offer payment in multiple currencies, between multiple jurisdictions, intra-day or term, and on a 24/7 basis.

Figure 1: Workflows on LSEG DiSH



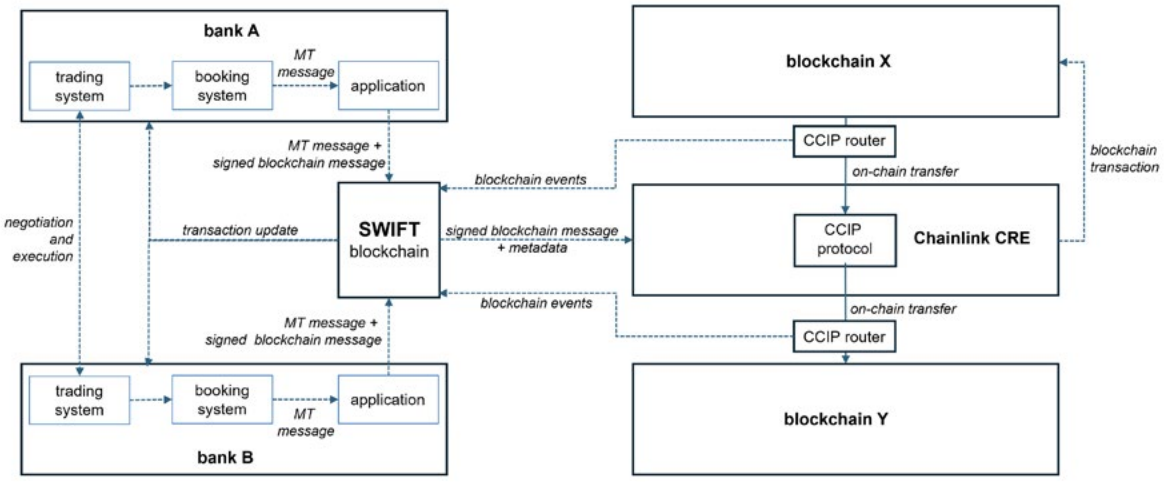
SWIFT “interlinking”

SWIFT offers an abstraction layer in the form of an oracle to achieve interoperability, either between distributed ledgers or between distributed ledgers and the conventional settlement infrastructure. The launch of this solution was announced in September 2025 and was due to come onstream in November.[lxxiii] It enables financial institutions to use their existing SWIFT infrastructure and its ISO 20022 messaging standards to send conventional MT messages via a SWIFT blockchain to initiate transfers of digital assets on or between any public or private distributed ledger that is also connected to the SWIFT blockchain. The SWIFT blockchain therefore provides a single point of entry to multiple other distributed ledgers. Alternatively, transactions can be orchestrated between a distributed ledger and the conventional infrastructure, thereby proving a bridge between digital and traditional assets.

Data for on-chain transfers are extracted from the MT messages, which include some additional fields of blockchain data. Other than this message upgrade, the SWIFT blockchain can be accessed without the need to upgrade infrastructure or overhaul legacy processes (and has consequently been described as a “plug-and-play” solution).

The routing of conventional SWIFT messages and the implementation of settlement instructions by smart contracts on other distributed ledgers is orchestrated by the Chainlink Runtime Environment (CRE). This is part of the oracle platform provided by Chainlink. Communication between the SWIFT blockchain and other distributed ledgers is governed by Chainlink’s CCIP (Cross-Chain Interoperability Protocol) cross-chain messaging protocol.

Figure 2: Workflows on SWIFT interlinking



Tokenovate Novat settlement token[lxxiv]

A novel interoperability solution was proposed in December 2025 by DLT post-trade infrastructure company, Tokenovate. This takes the form of a single-use token --- named a “Novat” --- hosted on Tokenovate’s public permissionless blockchain. A Novat represents both title to an asset and self-executing settlement instructions. Upon the recognition of a settlement event by a CDM-based smart contract on the Tokenovate blockchain, the relevant custodian would be automatically instructed to immobilise the underlying asset, upon which a Novat would be minted. The Novat would instruct an irreversible change of title on the Tokenovate blockchain, at the same time as the relevant custodian (who retains the authoritative record of title) is instructed to transfer the asset between accounts. Once settlement finality at the custodian has been confirmed, the Novat would automatically be burnt to avoid any re-use.

Novats are intended to automate and accelerate settlement to T+0, while ensuring there is legal as well as operational finality. The aim is to reduce the capital, liquidity and operational resources required by the conventional intermediated account-based infrastructure but without necessarily requiring the digitalisation of the custodial layer of that infrastructure. Thus, the custodian can be conventional or digital. In the case of a conventional custodian, the Novat would send

standard settlement messages, so would fit into existing workflows. However, the ability to instruct digital custodians means a Novat could also work with native-digital securities.

Simplistically, a Novat could be considered a tokenised settlement instruction, in essence, similar in concept to the Deposit Token invented by the SBA (see below) but asset-agnostic, self-executing and organically supporting sales and swaps, rather than just payments. A Novat also operates within a contractual framework rather than directly under a statutory framework, although the solution would benefit from designation as systemically-important under settlement finality regulations.

SBA Deposit Token[lxxv]

The Deposit Token was an experimental digital representation of tokenised payment instructions. It was minted, managed and burnt by a smart contract on a permissioned public Ethereum blockchain. Use of a public blockchain facilitated interoperability between several banks.

The minting and burning of the tokenised instructions were tied to corresponding debits and credits through "mirror accounts" held off-chain at banks (these were purely informational interfaces to the underlying deposit accounts), ensuring alignment between the tokens/instructions and underlying fiat bank deposits. Settlement was across the Swiss Interbank Clearing (SIC) system, ensuring the legally-binding final settlement of the transfers. In other words, instructions were on-chain, but settlement was off-chain, with off-chain transfers being triggered by on-chain tokens.

To make a payment, the payor's bank debited the payor's deposit account, credited the payor's mirror account and then invoked the smart contract to mint a token in the payor's wallet. Once the payor had instructed a payment to the payee, the payor's bank instructed the smart contract to transfer the token from the payor's wallet to that of the payee. The payor's bank also debited the payor's mirror account, credited its own account at the SNB and initiated a payment in central bank money to the account of the payee's bank at the SNB. The payee's bank invoked the smart contract to burn the token, then debited the payee's mirror account and credited his deposit account.

Use of the conventional payment infrastructure meant that transactions fell naturally within the existing legal and regulatory frameworks, including AML, CTF, PF and sanctions-screening requirements.

The SBA consortium tested two use-cases: a payment from one client to another; and an "escrow-like" payment for an asset.

Future work will explore ways of connecting with other distributed ledgers by using native tokens/instructions, with on-chain master records, to reduce reliance on internal legacy systems. It is also planned to add settlement in digital cash such as wCBDC. SBA see deposit tokens as providing the foundations of a digital commercial bank payments system in Switzerland.

Endnotes

i The report uses the terms “digitalisation” to distinguish the application of DLT from the digital technology that was introduced by digital computers and has been in place for many years. The distinguishing feature of digitalisation is that digitalised assets exist on a distributed ledger.

ii The IMF has estimated that the largest stablecoin, Tether (ticker: USDT), invests over 9% of its reserves in reverse repo, while the second, Circle (USDC), invests over 45%.

iii See section 6 for a definition of “crypto” assets. An example of what has been claimed to be a repo between crypto assets was announced in December 2025 by Membrane Labs. This involved an exchange of two stablecoins (USX and USDC). As such, it has not been considered in this report. However, a repo between a stablecoin and a tokenised US Treasury in July 2025 has been included.

iv The term “test” is used for a proof-of-concept, pilot, experiment, trial or some other investigative simulations, some involving multiple instances. Some tests involved multiple instances. The term “transaction” is used for repo that may have been transacted for commercial purposes, although some apparently commercial transactions may have been one-offs, where genuine business was diverted from the conventional infrastructure to be used in end-to-end tests of DLT.

v A joint venture for intra-day repo between Kinexys and HQLA^{X} began commercial operations in the summer of 2025.

vi Many tests for which the number of repos was not published involved multiple institutions and are therefore likely to have consisted of multiple tests. If each participant was involved in at least one test, that would imply another 76.

vii The average daily volumes (ADV) published by Broadridge were: USD 31 billion in June 2021, USD 100 billion in June 2022, about USD 50 billion in February 2023 (USD 1 trillion per month) and USD 70 billion in May 2023. A monthly figure of USD 1.5 trillion was published in February 2025, which would average to about USD 70 billion a day. In Broadridge’s most recent earnings report, the monthly turnover was put at USD 4 trillion. Data have been published more frequently in 2025. In August 2025, ADV for DLR was equivalent to USD 100 billion per day over “most of 2024” (peaking at USD 200 billion in June 2024). In September 2025, it was reported that ADV was USD 280 billion in August (and USD 5.9 trillion over the month). By October, Broadridge reported ADV of USD 385 billion. In September, ADV was reported as USD 280 billion. In November, that had fallen to USD 360 billion (nominal value of USD 368.7 billion) and the average daily trade count was 8,137. Average daily turnover in December was USD 384.0 billion.

viii See https://www.hqla-x.com/post/hqla-j-p-morgan-ownera-and-wematch-demonstrate-a-cross-ledger-repo.

ix That compares with average daily volume of over USD 386 billion in US repo on BrokerTec alone in November 2025.

x “ECB trials” refers to the Eurosystem’s “exploratory work on new technologies for wholesale central bank money settlement”, aimed at understanding how interaction could be facilitated between its T2 RTGS wholesale payments system and distributed distributed ledgers operated by market participants. They took place in two overlapping waves during May-November 20024 and July-November 2024 involving 64 participants settling over EUR 1.59 billion in more than 200 transactions. In fact, the term “trial” was reserved for transactions that were actually settled in central bank money in the T2 production environment, while mock transactions in which cash was settled in the T2 UTEST test environment were called “experiments”. A temporary bespoke legal and operational framework was put in place to support the trials and experiments. In the case of trials, at the start of the day, participants prefunded an escrow account at their national central bank, against which tokens were issued, and were refunded at the end of the day.

xi The implementation of Know-Your-Customer (KYC) checks currently depends on trusted parties to perform monitoring and reporting. In contrast, public permissionless blockchains eschew trusted third-parties. The BIS has therefore suggested an indirect approach to Anti-Money-Laundering (AML) for DLT platforms. This is based on the analysis of transaction flows to identify suspicious patterns of activity, score transactions and regulate off-ramps to the banking system.

xii Some confusion may have arisen about trading using DLT from the use of the word "execution" as a synonym for "final settlement". "Execution" strictly-speaking means the successful conclusion of negotiation to create a contract. An example of the misuse of the word is the phrase "…ISO 20022 messages trigger on-chain execution, enabling blockchain settlement…"

xiii The Global Financial Market Association (GFMA) report on *The impact of Distributed Ledger Technology in Capital Markets (August 2025)* considered the overall impact of DLT and DLT-based securities on secondary market trading, including repo. Its assessment was that "DLT itself is not viewed as an impactful force; however, DLT-based investor platforms using new features such as Tokenization and fractionalization could drive impact over the long-term. Secondary trading liquidity must first be established to support a DLT-based ecosystem." However, this comment implies that the trading of conventional and digital securities will remain separate.

xiv See https://www.esma.europa.eu/sites/default/files/library/esma70-460-111_report_on_the_dlt_pilot_regime.pdf.

xv See https://www.fca.org.uk/firms/innovation/digital-securities-sandbox.

xvi See also Financial Stability Board (FSB), 2023 and Bank for International Settlements (BIS), 2023.

xvii III. The next-generation monetary and financial system, June 2025, p77.

xviii See ECB 2024, p6.

xix The Global Financial Market Association (GFMA) refers to native-digital securities as "securities tokens" as opposed to tokenised securities.

xx See https://en.wikipedia.org/wiki/Security_token_offering.

xxi ISDA would refer to a DCR as a "registered token".

xxii The Bank of England argues that stablecoins are not a type of crypto-currency but a digital asset, as cryptocurrencies tend not to be asset-backed.

xxiii EU regulation distinguishes between "tokenised deposits" and "electronic money tokens" (EMT) --- see footnote xxxiv. A tokenised deposit has the same legal status as a claim on a bank in the form of a traditional bank deposit. An EMT is a claim on the bank that is not a deposit for legal purposes.

According to the European Banking Authority (EBA), where a customer can re-allocate its claims on a bank from a conventional account to a ledger (where it would take the form of a token), or vice versa, by debiting one account and crediting the other, claims on either would be deposits for legal purposes. But where a conventional account is the master record of claims on the bank, from which customers must remove claims in order to receive, in exchange, a token on a ledger that represents a direct claim on the bank (rather than a claim on an off-chain deposit), the token would not be seen as a deposit but as a bearer instrument that would be classified as an EMT.

Moreover, EMTs do not require the holder to have a deposit account with the issuing bank and the purchase of an EMT can be a one-off transaction rather than part of a continuing relationship.

A key difference with deposits can be seen by comparing what happens when a depositor wishes to make a payment from his account with what happens when he uses an EMT to make a payment. When a payment is made from a deposit account, the claim on the payor's bank is reduced and the payee's claim on his bank is increased, with settlement between the banks being made in central bank money and both changes being reflected on the balance sheets of the banks. In contrast, the use of an EMT would transfer the payor's claim on his bank to the payee, so there would be no change in the balance sheets of either bank.

In the case of tokenised deposits, tokens on a ledger can be the sole representation of a claim on the bank (native) --- there is no off-chain asset --- or they can represent a claim on a deposit that exists on a conventional account (non-native) --- an off-chain asset. The Global Financial Market Association (GFMA) refers to native tokenised deposits as "deposit tokens", defining these as transferable deposit claims against a bank.

Furthermore, the representation of a claim on a bank could be "account-based" or "token-based". In the former, a claim on a bank is bound to the identity of an account-holder and cannot therefore be transferred directly to someone who is not another customer of the bank (it is therefore considered a non-bearer instrument). In contrast, a token-based claim could be a bearer instrument, although this would likely fall outside the regulatory definition of a bank deposit.

xxiv The members were PostFinance, Sygnum Bank and UBS.

xxv See https://www.swissbanking.ch/_Resources Persistent/9/4/1/1/941178de59b98030206fc15ac8c99012f65df30b/SBA_The_Deposit_Token_EN_2023.pdf.

xxvi The central bank platform provided a "hashed time-lock" (HTLC) mechanism to ensure that the transfer of securities was conditional upon payment, ie atomic settlement or delivery-versus-payment (DvP). A hashed time-lock (HTLC) mechanism is a protocol embedded in a smart contract that enforces conditional transfers of assets. The time-lock element restricts the transfers to an agreed period of time, after which the assets due to be received in exchange would be returned unused to the sender. This was intended to prevent parties from claiming assets without fulfilling other conditions laid down in the smart contract.

xxvii The EU MiCA (Market in Crypto-Assets) regulation classifies stablecoins into (1) **electronic money tokens** (EMT) — which are purported to maintain a stable value by referencing the value of a single fiat currency; (2) **"asset-referenced tokens"** (ART) — which are purported to maintain a stable value by referencing to another value or right, or a combination thereof, including one or more fiat currencies; and (3) **"other crypto-assets"** — which include other tokens described as stablecoins but which are controlled by algorithms or other types of stabilisation mechanism.

xxviii For a review of regulation across jurisdictions, see the ICMA paper on The Stablecoin Question: An Impractical Distraction or a Powerful Alternative? (pp6-7).

xxix Solana-based crypto trading platform Jupiter has issued a stablecoin (ticker: JupUS) that is 90%-backed by USDtb, another stablecoin that is backed by shares in BUIDL (Blackrock USD Institutional Digital Liquidity Fund), BlackRock's on-chain money market fund. The remaining 10% is backed by USDC, which is intended to provide immediate liquidity using a dynamic liquidity market-maker (DLMM), which is a digital exchange (DEX) that allocates its liquidity into "bins" of trading at different prices (see footnotes l and xlix about DEX). As trading shifts from one bin to another, the DLMM re-allocates liquidity between the bins.

xxx Securities held as a reserve for an asset-backed stablecoin are likely to be chosen so as to qualify as High Quality Liquid Assets (HQLA) under the Basel Liquidity Coverage Ratio (LCR).

xxxi Tokens backed by commodities are another type of "asset-referenced token" (ART) under EU MiCA.

xxxii The failure of TerraUSD has severely damaged investor confidence in algorithmic stablecoins. Partly as a consequence, they are effectively banned under EU MiCAR (Market in Crypto-Assets Regulation).

xxxiii See https://defillama.com/stablecoins.

xxxiv Stablecoin bridges can be divided into: (1) asynchronous "lock-and-mint" bridges, which rely on a custodian to lock the reserves of one stablecoin in an escrow account and issue a new stablecoin on the other ledger; (2) probabilistic relay bridges, where a consensus verification mechanism applies across both ledgers. See Neira, *The Bifurcated Ledger*, December 2025, at www.borjaneira.com.

xxxv Garratt and Shin, Stablecoins versus Tokenised Deposits: Implications for the Singleness of Money, BIS Bulletin 73, April 2023.

xxxvi The ECB trials also used a "TIP Hash-Link" solution for digital central bank money developed by the Banca d'Italia, but this was not used to test a DLT repo. This solution enabled settlement of wholesale financial transactions in

central bank money in accounts on a replica of the Eurosystem TIPS platform.

xxxvii A report from the Boston Consulting Group and Ripple claims that tokenisation could save a global bank with USD 100 billion in daily repo volume an estimated USD150-300 million per annum through faster settlement and by collateral optimisation.

xxxviii JP Morgan has estimated that intra-day repo could more than halve the cost of intra-day borrowing. A BIS study calculated that the average liquidity buffer held by major Fedwire participants to cover intra-day mismatches between payments in and out over 2008-18 was USD 639 billion. The average liquidity holdings at T2 were USD 443 billion (peaking at USD 800 billion).

xxxix The Global Financial Market Association (GFMA) report on the Impact of *Distributed Ledger Technology on Capital Markets* also identifies four models, albeit not specifically for repo (see pp83-85). Their model SS0 corresponds to model 4 above; SS1 to model 3; SS2 to model 2; and SS3 to model 1.

xl Onyx/Kinexys use the Quorum blockchain developed by JP Morgan Chase but now owned by Consenys. Quorum was built on the Enterprise Ethereum blockchain as a private permissioned enterprise network. Its simpler consensus mechanism makes it faster than the Ethereum blockchain.

xli The bond was issued by the Government of Hong Kong on 7 February 2024. It was a two-year green bond denominated in US dollar, euro, Hong Kong dollars and renminbi, worth about HKD 6.0 billion in total. The bond conforms to ICMA's Bond Data Taxonomy, which is a standardised and machine-readable description of the key economic terms of the bond and the issuance information included in term sheets.

xlii See https://www.broadridge-ir.com/news/news-details/2025/Broadridge-Collaborates-with-Fnality-to-Enable-Real-Time-Settlement-for-Intraday-Repo-Transactions/default.aspx.

xliii So-called order-book DEX have been held back by the need to post every quote and transaction on the order book onto the ledger. This requires a throughput higher than most ledgers can handle or necessitates expedient compromises on security or decentralisation. Scalability solutions such as Layer-2 structures have revived interest in order-book DEX, but there is also growing interest in hybrid order-books, where the order-book is off-chain and settlement in on-chain.

xliv One of the most thorough analyses of the potential impact of DLT on CCP has been by EACH (European Association of Clearing Houses) in a paper, drawing on economic theory, about the drivers and types of intermediation. EACH noted the confusion caused by the interchangeable use of the words "clearing" and "central-clearing" (where basic clearing is defined as "the process of transmitting, reconciling and, in some cases, confirming transfer orders prior to settlement, potentially including the netting of orders and the establishment of final positions for settlement"). EACH concluded "that, under the current offering, it seems challenging to foresee a scenario where any of the main services provided by a CCP would disappear or become fully disintermediated" by DLT. On the other hand, it is generally accepted that DLT could improve the efficiency of central-clearing, for example, by updating the positions of members almost instantaneously".

EACH noted that several entities have started, or announced that they have plans to start, clearing crypto-related contracts. However, their default management procedures rely (or will rely) on a central party and on other intermediaries to support liquidation when market becomes illiquid.

xlv Moreover, the type of netting considered is merely an operational convenience (what is commonly called "technical netting") and does not seek to reduce the gross legal obligations of the parties.

xlvi The GFMA cites Feenan et al, Decentralised Financial Market Infrastructures: *Evolution from Intermediated Structures to Decentralised Structures for Financial Agreements, The Journal of FinTech, 2021*. However, the paper only addresses the settlement risk on cash transactions in securities and not transactions with future exposures, such as repo and derivatives. It therefore assumes that atomic settlement can eliminate risk. The paper also seems to misunderstand mutualisation, which it refers to as "metallisation".

xlvii *British Eagle International Air Lines Ltd v Cie Nationale Air France* [1975] 1 WLR 758.

xlviii See https://www.gfma.org/wp-content/uploads/2025/08/1.-full-report-impact-of-dlt-in-cap-mkts-final-1.pdf.

xlix A similar annex was published by ISLA (International Securities Lending Association) for the GMSLA (Global Master Securities Lending Agreement).

l The need to verify the identity of participants conflicts with the "pseudonymity" of the blockchain concept but is vital to preserving the integrity of the financial market. Solutions include the use of intermediaries to perform verification or, in the spirit of blockchain, emerging decentralised identity (DID) techniques such as Zero-Knowledge Proof (ZKP). The latter verifies the credentials of a participants without revealing the data used to confirm the credentials (eg verifying a participant is over 18 without revealing the birth date). However, such methods have been criticised as merely replacing one trusted party with another, potentially without the regulatory supervision or track record of those being replaced.

li In this respect, Broadridge DLR is different, as it hosts all its client nodes. Such control of nodes by the operator is not uncommon but means that the ledger is effectively centralised.

lii Blockchain is a type of ledger, but not all ledgers are blockchains. Blockchains are characterised by the linking of a new "block" of authenticated records to a "chain" of previously-authenticated blocks in the order in which they were authenticated. The order of a blockchain is ensured by incorporating the cryptographic ("hash") signature of the immediately-preceding block in the new block. Any attempt to retrospectively amend a block will change its signature, leading to the rejection of the altered block by the network, given that it would then be out of sequence with the chain.

liii Asymmetric cryptography used two keys to encipher a message. The "public key" is made available to everyone, but messages encoded using the public key can only be deciphered by the holder of the corresponding "private key" and cannot be reversed back into plain text using the public key --- this is the asymmetry in this method of encryption. The public key can be used to decrypt messages encoded using the private key (which is a means of ensuring the authenticity of the message). Although the public and private key are related, it is practically impossible to compute one from the other (at least, given the current state of mathematical knowledge and computing capacity).

liv The governance of a ledger --- who decides about access, permissions and operations --- can be centralised or decentralised. Decentralisation of governance (ie governance by consensus) is a key characteristic of the original blockchain concept.

lv The Global Financial Market Association (GFMA) report on *The impact of Distributed Ledger Technology in Capital Markets (August 2025)* draws interesting analogies between public permissionless ledger and the internet and between private permissioned ledgers and intranets, while internet applications (such as web browsers and e-mail clients) are described as permissioned applications on permissionless public networks.

lvi Consensus mechanisms such as proof-of-work cannot guarantee the speed of reaching a consensus, so settlement is inexact and described as being "probabilistic". This means there could be a misalignment between the state of a ledger and legal finality of settlement, in other words, between technical or operational settlement (the point at which a ledger records the settlement of a payment, transfer instruction or other obligation) and legal settlement (the point at which the payment, transfer instruction or other obligations is legally irrevocably and unconditionally discharged). The probabilistic nature of settlement can also be a consequence of the occurrence of a "fork" in the ledger. This a bifurcation in the ledger, whereby separate and irreconcilable ledgers are created, usually due to an unresolved disagreement among developers or others (such as miners), as well as changes of the code in the underlying protocol which are incompatible with the previous version. See CPMI-IOSCO, Application of the Principle for Financial Market Infrastructures, July 2022, pp16-17.

lvii See https://www.bis.org/publ/arpdf/ar2025e3.pdf.

lviii In June 2025, a vision for the next-generation monetary and financial system appeared in the BIS Annual Economic Report, based on work led by the BIS in Projects Agora, Rosalind and others. This restated a blueprint published in 2023, for a unified ledger hosting tokenised central bank money, commercial bank deposits and government bonds.

The adoption of the unified ledger proposal by the BIS would represent a transformation of the conventional infrastructure, although not a complete transformation, as the unified ledger would not be built on blockchain technology but would instead rely on APIs to interlink, not only DLT networks, but also conventional accounts. The unified ledger would, however, digitalise the bulk of the repo market at a stroke. It is uncertain, however, how much support the BIS proposal has among its members, not least because of issues of sovereignty.

lix A different definition of composability is used by the Bank of England in its DLT Innovation Challenge Final Report which refers to interoperability between ledgers: "The ability of applications or assets to interoperate safely. Protocol level composability (within a single ledger system) provides strong guarantees; cross chain solutions lack these cryptographic assurances.

lx Composability can be defined more generally as the creation of links between digital assets. This includes linking an existing token to a new token, by "locking" away the original token in exchange for issuing a new token representing the original token (called a "wrapped" version of the original token) (see section 5). The purpose of wrapping is to enable the interoperability of a token on more than one platform. For example, Ether, which is the native token of the Ethereum network (ETH) can be wrapped into ERC20 tokens (WETH) for use on other platforms.

lxi Ironically, the natural isolation of a ledger was the feature that made the original concept of a blockchain secure and reliable, as it only needs to form a consensus on the answers to a basic set of binary question using data already on the ledger, such as did the public key-holder sign a transaction with the corresponding private key, does the public address have enough funds to fulfil the transaction and is the transaction valid in terms of the particular smart contract running on the ledger. The narrowness of a blockchain consensus means they execute exactly as coded and with a much more certainty than traditional arrangements. This is why smart contracts are described as "deterministic", while the enforcement of existing contracts by humans is described as "probabilistic". Confusingly, uncertainty over when the consensus mechanism succeeds in validating a block leads to such mechanisms being described as "probabilistic".

lxii In addition to being used to transfer digital assets between ledgers, a cross-chain bridge can also be used to transmit other data that might be used to enrich instructions on the second ledger involving the transferred asset. This type of link is called a "**programmable token bridge**".

lxiii https://chain.link/education-hub/cross-chain-bridge

lxiv Aldasoro et al, BIS Apr-2023.

lxv See, for example, the report by a US law firm, Clyde and Co.

lxvi See https://www.hqla-x.com/.

lxvii The Global Financial Market Association (GFMA) refers to digital certificates, such as DCRs, as "settlement tokens".

lxviii Under ICMA's Digital Asset Annex, a DCR is a type of "Platform Transferred Security", which is defined as "a traditional physical or dematerialised security held or recorded in such a way that it can be cryptographically transferred".

lxix Where a DCR records the ownership of a basket of collateral securities, the value of the basket is maintained through margining managed by a tri-party agent.

lxx See https://finteum.com/.

lxxi See https://fnality.com/.

lxxii See https://www.lseg.com/en/media-centre/press-releases/2026/lseg-launches-digital-settlement-house.

lxxiii SWIFT is the Society for Worldwide Interbank Financial Telecommunication. It is the bank-owned global messaging network across which financial institutions send the payments instructions to each other that drive the conventional settlement infrastructure.

lxxiv See https://www.tokenovate.com/use-cases/the-novat/.

lxxv See https://www.swissbanking.ch/_Resources/Persistent/9/4/1/1/941178de59b98030206fc15ac8c99012f65df30b/SBA_The_Deposit_Token_EN_2023.pdf.

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