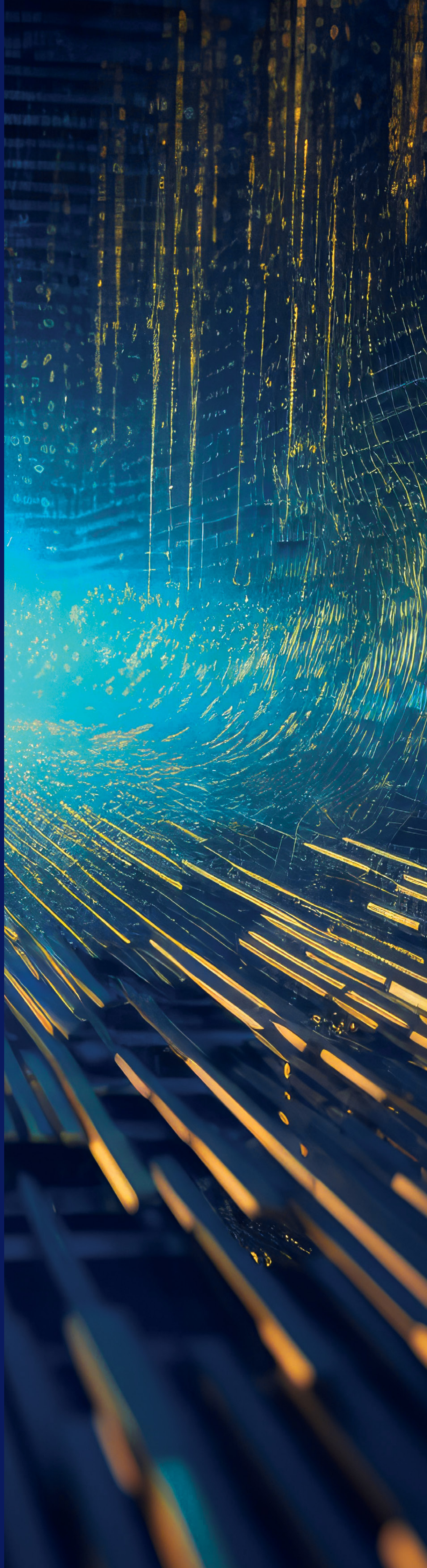
Project Guardian

Enabling Open and Interoperable Networks



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Contents

Executive Summary

Digital assets and Distributed Ledger Technology (DLT) based networks are emerging as alternative financial infrastructures supporting financial transactions such as the clearing and settlement of payments and securities. However, the nascency of these technologies means that there is insufficient precedence in understanding the potential opportunities, risks, and limitations of these networks as Financial Market Infrastructures (FMI).

Project Guardian aims to advance best practices and technical standards amongst the industry to prevent fragmentation of markets as digital assets and decentralised protocols proliferate. The project also seeks to explore the role of regulated financial institutions as trust anchors to screen, verify and issue credentials, enabling participants to only trade with verified parties.

This report highlights one of the foundational principles of Project Guardian – the establishment of open and interoperable networks. A common framework is introduced for understanding the design options to enable the trading of digital assets across networks and liquidity pools. This framework considers the core principles

of financial market infrastructure and takes reference from projects that have sought to push the boundary on these topics.

This begins with an overview of Project Guardian and its motivations. Next, the characteristics of digital asset networks and their common archetypes are discussed. In subsequent sections, the principles of FMIs and their applications are considered. The final section of the report discusses the aforementioned concepts through illustrative use cases contributed by financial institutions participating under Project Guardian.

To support the development of a responsible and innovative digital asset ecosystem with well-managed risks in financial stability and integrity, concerted private and public sector collaboration is needed. This report strives to provide a foundation for global collaboration of private and public sector financial industry participants towards safe and efficient financial market infrastructures.


OCBC Bank
River Valley Rd
KEEP RIGHT

2 — Introduction

Traditionally, ownership of financial assets and real economy assets are represented in physical and in electronic form through account balances. These accounts reside across different proprietary platforms, for instance deposits take the form of balances in accounts at deposit taking financial institutions like banks. Other examples include securities such as bonds that are custodied in accounts with Central Securities Depositories (CSD).

The advancement in technologies like smart contracts and distributed ledgers have prompted interest in new models of delivering financial services. Distributed ledgers offer the potential for transactions to be performed on a peer-to-peer basis without centralised intermediaries. Meanwhile, the use of smart contracts to model financial transactions such as borrowing, lending, and trading activities enable financial activities to be performed autonomously.

While much of the public and media attention has focused on the speculation[1] of unbacked digital assets, the real value in the digital asset ecosystem comes from the representation of real-economy and financial assets digitally in a tokenised form using smart contract technology to enhance the efficiency, accessibility, and affordability of financial services. Once represented as digital tokens, they can be exchanged readily and used to facilitate more efficient economic transactions across pre-trade to post-trade capital market activities.

Asset tokenisation can potentially unlock liquidity to power economic growth, as well as improve access to and widen investments options. However, the market is still largely untapped as only a very small proportion of the pool of tokenisable assets in the world are being traded today. A report[2] from Boston Consulting Group and ADDX predicts that some US$16 trillion worth of assets, most of which are illiquid, would be tokenised by 2030.

This report introduces a framework for designing open and interoperable digital asset networks based on tokenised real-economy assets and financial assets. The examples cited here are intended as references to illustrate key concepts and for broad learning only. The report should not be interpreted to reflect any policy directive or legal advice, nor to endorse any specific solution or systems.

[1] Yes to Digital Asset Innovation, No to Cryptocurrency Speculation (Menon, 2022).
[2] Relevance of On-chain Asset Tokenization in "Crypto Winter." (Suresh et al., 2022).

3 — Problem Statements and Motivation

The advancements in digital technology in the form of digital assets and distributed ledgers hold promise to facilitate the growth of cross-border transactions[3,4]. However, it is observed that existing digitalisation efforts fall short of the expectations of efficiency improvement, greater financial access, and improved revenue opportunity which proponents of digital assets and DLT tout. In this section, the current state of digital asset networks is discussed.

Governance

Centralised governance structures, involving a single entity operating the financial market infrastructure, and accountable for its decisions, are more established today. Meanwhile, decentralised governance models whereby anyone from anywhere in the world may participate and vote for change, are gaining interest.

While truly decentralised models are more resilient to the failure of an operator, they are rare and hard to execute in practice. For instance, the Financial Stability Board (FSB) report on the *Financial Stability Risks of Decentralised Finance*[5] highlights risk of heavy concentration of voting powers in decentralised protocols today, and in practice decisions are made and carried out only by a few controlling actors.

Additionally, the FSB report discusses the implication of decentralised governance arrangements for financial stability, where there may not be full disclosure and alignment between the developers of the DeFi protocols and the users. Unlike centralised organised markets, decentralised market infrastructures do not offer the same level of accountability in terms of its operations today.

Consortium governance, whereby there is a curated set of operators who makes decisions on behalf of the participating entities, attempts to bridge between centralised and decentralised governance models. However, this requires the active leadership of credible actors who are experienced in operating financial market infrastructures and knowledgeable in digital asset technology, to organise and provide strategic guidance on such decentralised governance arrangements.

Network Effect

Metcalfe's law[6] states the value of a network is proportional to the square of the number of members in the network. In the context of digital asset networks, this could refer to the number of participants using the network or independent validators operating the network. Additionally, the nature of the transactions on these networks and the economic value that they represent could be metrics to assess the value and long-term viability of these digital asset networks.

Public networks are open to participation by any entity without requiring any pre-approvals or authorisations. Since there are no restrictions on who may participate in the network, public networks tend to have a larger number of participating entities relative to private networks.

Meanwhile, in a private network, participating organisations need to be invited by the governing body of the network to gain entry to the network. Accordingly, private networks are formed by a closed and exclusive group of participants who are selected beforehand.

In practice, applications deployed on public networks (e.g., Ethereum) have been able to reach millions of users immediately, while those running on private networks reached hundreds and thousands at peak. While the number of participants and transactions executed on private networks may be lower, the economic value that the transactions represent may be higher.

[3] Tracking the Flow of Cross-Border Payments Around the World (Gani, 2023).
[4] How new entrants are redefining cross-border payments (EY Global, 2021).
[5] The Financial Stability Risks of Decentralised Finance (Financial Stability Board, 2023).
[6] Moore's Law, Metcalfe's Law, and the Theory of Optimal Interoperability (Yoo, 2015).

Unless digital asset networks are interoperable, both with each other and with traditional FMIs, fragmentation would reduce the network benefits and can create frictions such as inaccessibility, increased liquidity requirements due to separation of liquidity pools, and pricing arbitrage.

Liquidity

The launch of digital asset networks could result in a proliferation of financial market infrastructures, at least in the short term, as not all financial activity is likely to transition to tokenisation at the same time[7]. Unless digital asset networks are interoperable, both with each other and with traditional FMIs, fragmentation would reduce the network benefits and can create frictions such as inaccessibility, increased liquidity requirements due to separation of liquidity pools and pricing arbitrage[8].

Another area of concern is liquidity and maturity mismatch between the tokens that are traded and the assets that are used to back them. For example, a tokenised asset may offer the opportunity for its holders to redeem its underlying value at any time, but if the tokenised asset is backed by reserve assets that have a maturity profile that does not match, this might increase the redemption run-risk scenarios described in the FSB Report[9].

Technology Readiness

All digital infrastructures are subject to planned and unplanned outages. For financial market infrastructure, system availability and recovery are especially important to preserve trust and confidence in a financial institution's operational capabilities. The nascency of digital asset technology means that most existing protocols may not support enterprise grade requirements and offer sufficient robustness and resiliency.

Currently, many central banks and financial institutions are researching and experimenting on DLT through proof of concepts but these efforts are not yet sufficient for commercial scale[10]. The lack of clear accountability and service level agreements in public permissionless platforms imply that it might be possible for outages to occur[11, 12], with no guarantee of recovery within an acceptable time period. Furthermore, legal considerations and general guidelines for the usage of private permissioned platforms compared to public permissionless platforms are areas that need to be investigated to enable standardisation in the industry.

Financial institutions have primarily focused on private and permissioned platforms which provide assurance that transactions happen with known counterparties. Meanwhile, emerging FinTechs are leveraging the distribution power of public and permissionless platforms, which offer ease of access but potentially introducing risks to financial stability and integrity. Project Guardian seeks to provide a framework to leverage the strength of these different approaches and mitigate their limitations to enable a future financial infrastructure that is fit for purpose.

[7] On the future of securities settlement (Bank for International Settlements (BIS), 2020).
[8] How Illiquid Open-End Funds Can Amplify Shocks and Destabilize Asset Prices (Natalucci and Qureshi, 2022).
[9] The Financial Stability Risks of Decentralised Finance (Financial Stability Board, 2023).
[10] The Future of Money: Gearing up for Central Bank Digital Currency (Georgieva, 2022).
[11] Solana suffered its second outage in a month, sending price plunging (Sigalos, 2022).
[12] Ethereum Briefly Stopped Finalizing Transactions. What Happened? (Nijkerk, 2023).

4 — Objectives and Focus Areas

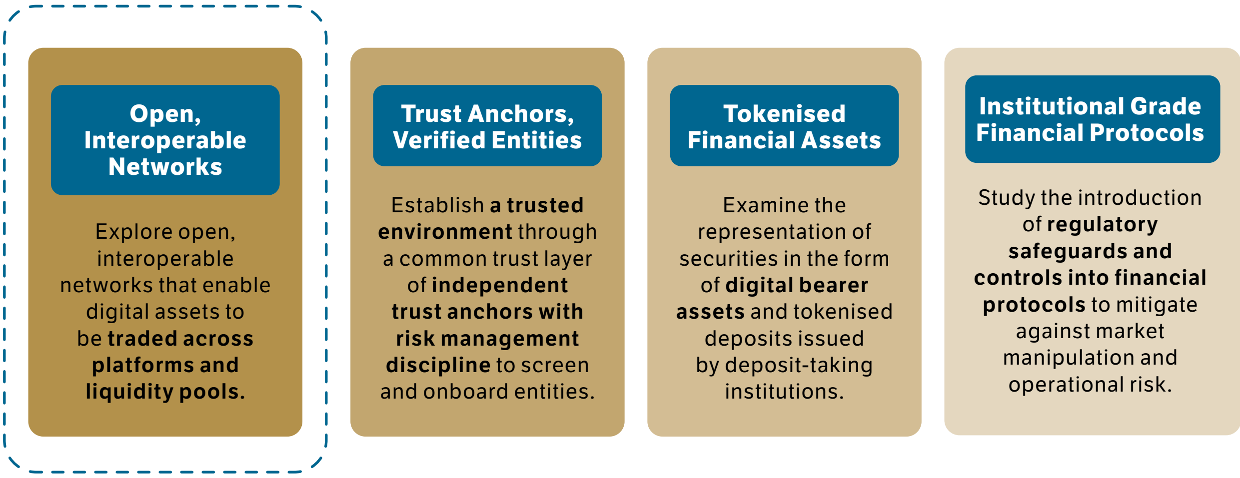


Figure 1: Guardian Themes

Project Guardian aims to advance the development of efficient and safe financial networks. The industry pilots conducted under the initiatives support the following objectives:

- Improve understanding of the opportunities and risks of digital assets and assess longer-term transformational impact.
- Enable interoperability across different platforms, use cases, and amongst participating entities.
- Define standards and best practices for risk management and operational execution.

4.1 Focused Themes

Project Guardian covers four key areas: Open, Interoperable Networks; Trust Anchors; Assets Tokenisation; and Institutional Grade DeFi Protocols. This report focuses on the first theme and will put forth best practices and design considerations of digital asset networks with an emphasis on Openness and Interoperability.

That said, digital assets cover a broad range of financial assets across equities, fixed income, foreign exchange (FX), and alternative asset classes such as investment funds. Each of these asset classes exhibit characteristics that are distinct from an economic, legal and regulatory standpoint. Future work could include the study and consideration of the unique characteristics of each asset class and their implications to digital asset networks as FMIs.

4.2 Reference Model

Project Guardian references a four layered model to describe technology components in a digital asset network. The reference model provides the context for considering the interactions between different component layers in a digital asset solution. Each layer could be governed and implemented by different actors.

The component layers in the reference model are described as follows:

A. **Access Layer**
The access layer describes the mechanism by which users such as borrowers, investors, issuers, access the range of services directly or indirectly via different interfaces (custodial and non-custodial).

Meanwhile, a tokenised asset refers to existing ownership representing real-world or traditional financial assets being tokenised and represented on a platform which would normally be placed with a custodian to ensure that these tokens are constantly backed by these assets.

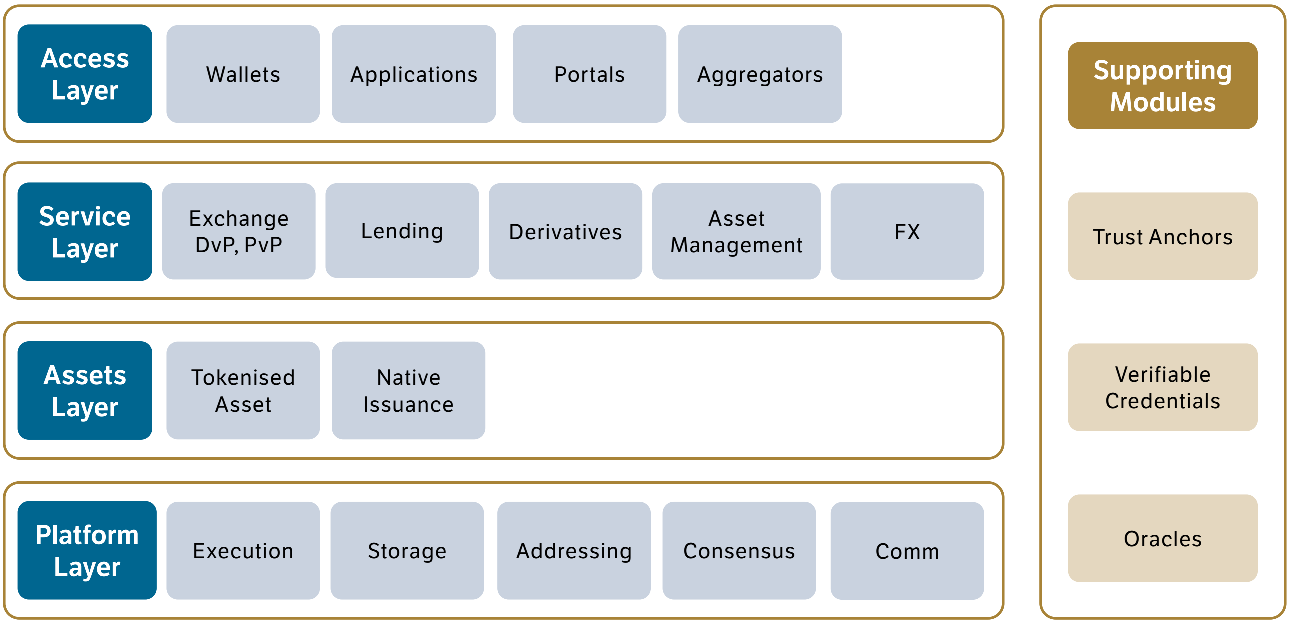


Figure 2: Reference model for Open and Interoperable Digital Asset Networks[13]

B. Service Layer
Services such as payment, lending, borrowing, FX, and exchange that are implemented through smart contracts, may interact with different types of digital assets.

C. Asset Layer
The asset layer records ownership of assets. Native issuance refers to assets issued and represented on a platform. Meanwhile, a tokenised asset refers to existing ownership representing real-world or traditional financial assets being tokenised and represented on a platform which would normally be placed with a custodian to ensure that these tokens are constantly backed by these assets.

D. Platform Layer
The platform layer refers to the infrastructure upon which the ownership of digital assets is recorded and service transactions executed. The platform is assumed to be programmable and flexible, supporting different types of digital assets including tokenised securities and central bank money. The technology used to implement the platform may be blockchain or non-blockchain based.

This report focuses on studying the asset and platform layers for a digital asset network. The subsequent section of the report examines archetypes of how this could be implemented in practice.

[13] System architecture jointly developed with International Monetary Fund (IMF).

5 — Archetypes of Digital Asset Networks

This section looks at common archetypes of digital asset networks. This sets the context for the subsequent section on how the principles of financial market infrastructure may be applied.

5.1 Platform Type

In public discourse, the terms public and permissionless are often used interchangeably when describing blockchains that operate over the Internet. Notwithstanding, these terms refer to different qualities that a platform might possess. This segment introduces participation and control as two qualities or dimensions to be considered in the analysis of the platform used for a digital asset network. Combinations of each of these qualities may result in different design options when designing a digital asset network.

- Participation: Public (open) vs Private (closed)
- Control: Permissionless vs Permissioned

Participation

The term "Public" here refers to the level of participation that a platform allows rather than whether data is publicly visible to everyone. In the context of this report, public platforms, just like the public internet are open to participation by any entity. Any entity may join a public platform. On the other hand, private platforms are closed to a selected group of members only and operate on an invite-only basis, where invitations are extended to participants for entry into these platforms.

Control

The second dimension refers to the level of permissioning or extent to which the type of activities that participants may conduct in are controlled. In permissionless platforms, all participants may view, edit and conduct activities, including deploying smart contracts on the platform. Meanwhile, in permissioned platforms, the governing body is tasked to decide and permit the type of activities that each participant can conduct. For instance, only designated service providers may be permitted to deploy smart contracts, while financial regulators may be allowed to view transactions within the platform, based on their authorisations.

Given the analysis above, platforms may be classified into three common models listed below. As there is no precedence for private (or closed) and permissionless platforms, they are not included in this report.

Public and Permissionless (P1)

Under this model, any participant can join and take part in activities within the platform. As the platform is permissionless, any participant may be able to deploy smart contracts on the platform, while being able to leverage and use the smart contracts created by other participants. This is because in a platform that is public and permissionless, no single organisation or individual is in control of it and users are all anonymous.

DLT based networks feature the use of validating nodes or validators which process and check the transactions submitted by network participants. Collectively, validators in a platform work to ensure the integrity of the platform, ensuring data is consistent and secure. Validators under model P1 are typically anonymous and since it is permissionless, anyone can become a validator to ensure the integrity of the transactions that are recorded. For their effort, validators are often paid using the native token (e.g., ETH) of the distributed ledger network (e.g., Ethereum). Validating nodes in public and permissionless platforms are anonymous and are not pre-qualified. Consequently, platforms that are public and permissionless, are particularly susceptible to malicious attacks such as a complete takeover of a network.

Private and Permissioned (P2)

In this model, participants will require an invitation from the consortium who owns the platform or an appointed operator to join the platform. Activities that can be performed by the invited participants are subject to different levels of control. For instance, the governance of the network may dictate that all participating entities may be able to view transactions, but only selected members may deploy smart contracts or onboard other participants. Private and permissioned platforms are typically controlled by a single organisation or a consortium that permits members to join only if they have been verified.

Validators, under this model, are known entities and permissioned by the consortium or operator and serve to ensure the integrity of the transactions that are recorded. For their effort, the validators may be paid in fiat currency either on a transaction basis or for a fixed fee. The closed nature of P2 typed platforms, suggest that they tend to offer better security and privacy options to participants. However, as only members may participate in the platforms, the number of participants and the volume of activities in each of these platforms tend to be relatively lower than P1. The proliferation of P2 typed networks which are not interoperable with each other could lead to greater fragmentation in the financial market landscape.

Public and Permissioned (P3)

In this model, like P1, any participant can join the platform and participate in activities hosted by entities within the platform without requiring approval beforehand. However, participants will need to identify themselves and adhere to the platform's terms governing activities within the platform.

The platform is governed by a group of organisations that defines its rulebook and dictates the types of activities that are permissible on the platform. For example, the governing body may determine that the deployment of smart contracts can only be done by selected members or by participants who adhere to the standards imposed by the platform[14].

Validators, under this model, are known entities who are also permissioned by the governing body of the platform, and serve to ensure the integrity of the transactions that are recorded. For their effort, the validators are paid in fiat currencies. In some models, the validators may be regulated financial institutions, and subjected to technology risk management controls. While transactions are conducted in the open, and visible to all, it may be complemented by privacy preserving technologies such as zero knowledge proofs and homomorphic encryption.

The open nature of such a platform allows for a greater number of participants, which increases the volume of activities, while ensuring a certain level of governance in this platform.

	Model P1	Model P2	Model P3
Category	Public and Permissionless	Private and Permissioned	Public and Permissioned
Access	Anyone may join	Requires approval from consortium members	Anyone may join (subject to identification and acceptance of terms)
Validators	Anonymous	Known Entities	Known Entities
Fees	Paid in native crypto tokens	Paid in Fiat	Paid in Fiat
Consensus Algorithm	Probabilistic settlement	Deterministic settlement	Deterministic settlement
Governance	Decentralised Governance	Consortium Governance	Consortium Governance
Example	Ethereum	Partior	LACChain

Table 1: Illustrative Platform models

[14] A Multi-Currency Exchange and Contracting Platform (Adrian et al., 2022)


Manulife
Oxley Tower
CapitaLand


WESTIN
MIZUHO
DBS

5.2 Asset Type

In the context of Project Guardian, digital assets refers to tokenised real economy assets and financial assets. This section discusses the different ways these assets could be represented.

Non-Native Tokens or Tokenised representation of assets (T1)

This refers to tokens which represent a claim against the issuing institutions. In the case of tokenised deposits and similar tokenised liabilities, the depository institutions that issued the token is liable to the holder for the fiat amount of the claim evidenced by the token[15]. While for tokenised securities, this involves creating a digital token to represent the securities that are traditionally issued and custodied. The value of these tokens mirrors the value of the underlying traditional securities. For the first pilot of Project Guardian, DBS Bank and SBI Digital Asset Holdings tested the concept of tokenised Singapore Government Securities (SGS) bonds and Japanese Government Bonds (JGB) and conducted bilateral trades involving them.

Native Tokens (T2)

Tokens that are native to a particular platform, whereby its primary system of record is the platform, are referred to as native tokens or asset tokens. In the event of a dispute, these records are treated as the source of the truth. An example of a native token could be a digital currency issued by a central bank. The central bank digital currency in this context is a store of value itself and there are no separate cash reserves backing the central bank digital currency. The legal basis of these tokens and the rights that holders of these tokens have is a subject of ongoing review in many jurisdictions.

Account-based (T3)

For completeness, some digital asset projects are modelled representing traditional accounts such as deposits held by financial institutions. In such a scenario, the owner of the account owns the value represented in the account. The accounts themselves are non-transferable, although the value held could be moved across different accounts and the transfers recorded on a platform.

Fungibility of tokens

Tokens could be further distinguished between those that are fungible and those that are not. Non-Fungible Tokens (NFT) have unique identifiers and are not directly interchangeable with other tokens of the same type.

5.3 Service Access

The reference model described in Section 4.2 consists of a series of component layers. With reference to this model, it is possible to introduce additional levels of control at the service component layers such that activities on the network are permissioned while the platform component layer of a network may be permissionless.

To limit access to specific functions to selected parties, mechanisms such as the use of address whitelisting, partitioning through subnets or sidechains, and verifiable credentials may be employed.

Address Whitelisting (A1)

Digital asset networks feature the use of wallet addresses which are used to identify and receive digital assets. These addresses are unique identifiers in the form of alphanumeric characters. A method that can be employed to limit access to functions within a network, is to encode conditional logic within smart contract code that checks if it involves transactions originating from or targeted at addresses that have been pre-qualified. A variation of this could be a denied party list, whereby wallet addresses that are in the list will be denied access to functions. Whitelisting requires service providers to screen and onboard participants individually to gain access to its function. Consequently, service providers will need to ensure they have adequate risk and compliance processes and controls in place.

Partitioning (A2)

Network partitioning can take place with subnets or sidechains. Subnets are network partitions with its own set of rules on participation and control. Sidechains run independently but they maintain a two-way bridge connection to the main network and leverage the native tokens of the main network.

For instance, when a network is partitioned, multiple subnets are created such that network participants

[15] Deposit Tokens: a foundation for stable digital money (Ozcan et al., 2023)

	Model A1	Model A2	Model A3
Category	Address Whitelisting	Partitioning	Verifiable Credentials (Trust Anchors)
Access to network / protocol	Allowed by a single controller/ protocol	Allowed by a single controller or a consortium	Allowed by any authorised Trust Anchor
Permission	The controller onboards and grants permission to every participant required	Minimal to no permission required depending on the scope of the network	VCs states what participants are allowed to do. Protocol validates if VC has the sufficient rights to permit
KYC data locality	All protocols/token issuers	Controller/consortium of the network	Trust Anchors only
Composability between protocols	Low (bilateral arrangements)	Medium to High	High
Example	AAVE ARC	Project Mariana[16]	Liquidity pool[17]

Table 2: Illustrative Types of Network Access Control

will only record and have access to data on a need-to-know basis – transactions that are specific to the parties are recorded on its own partition and validated by a subset of authorised network parties. Access to the data in the subnet will require approval from the controllers of the subnet. While preserving privacy between participants, the management of such networks could become complex as the network scales.

Verifiable Credentials (A3)

The first pilot of Project Guardian explored the concept of verifiable credentials (VC) and financial institutions as trust anchors. As trust anchors, regulated financial institutions screen, verify and issue digital identities in the form of verifiable credentials to entities that wish to access specific financial services. This ensures that participating entities trade only with verified counterparties.

Verifiable credentials provide a rapid way to validate identity and screen participating entities. The information stored in physical credentials today can be represented within the VCs, together with digital signatures which makes it more tamper-resistant and reliable.

The provision of services may be a third-party service provider with a trust relationship to the trust anchor. Once a trust relationship is established, it removes the need for service providers to onboard participants individually, as they could delegate that responsibility to a trust anchor.

Implementing this model in practice is non-trivial as it requires the availability of trusted institutions with strict controls and are trusted to undertake the process of screening individual participants at the onset and on an ongoing basis. The responsibilities and the liabilities of a trust anchor must be clearly defined as well. In addition, there must be sufficient incentive for financial institutions to take on the added responsibility of being a trust anchor.

5.4 Network Structure

In the analysis of interactions between networks, it is assumed that each network should be interoperable and could constitute part of a larger digital asset networks[18]. This report distils three models of network interactions:

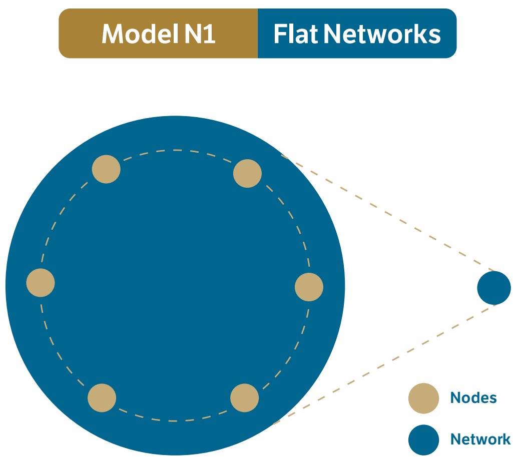


Figure 3: Illustration of Model N1 - Flat Networks

[16] Project Mariana investigates the use of automated market-makers (AMM) specifically for foreign exchange (FX) trading and settlement (BIS, 2023).
[17] Project Guardian tested transaction with verifiable credentials issued by trust anchors to ensure transactions were executed in a safe and compliant manner (Oliver Wyman Forum, DBS Ltd, SBI Digital Asset Holdings, & J.P. Morgan, 2022).
[18] III. Blueprint for the future monetary system: improving the old, enabling the new (BIS, 2023b)

Under this model, all participants interact with a common ledger. The transactions related to the transfer of ownership of digital assets are recorded directly on the common ledger. This enables digital assets to be exchanged directly without the need for bilateral setups between organisations or with other networks. As all transactions are performed on a common ledger, it means that by default, transactions are visible to all participating nodes who have a copy of the ledger data. Accordingly, additional controls could be setup such that transactions are only sent to validating nodes on a need-to-know basis. While on a common ledger, exchange of digital asset and digital currency can be performed in a single transaction block. This is often described as atomic settlement, as the exchange is completed in a single irreducible unit. Hence, there is no possibility for desynchronised states for the different legs of the transaction, as they are completed in a single transaction block.

In addition, in flat networks, all transactions are executed on a common ledger. Hence, when the volume of transactions increase, congestion may occur and the performance on these networks may degrade.

Model N2 | Layered Networks

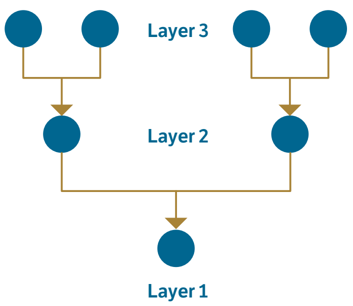


Figure 4: Illustration of Model N2 - Layered Networks

Under this model, the network is setup as a series of layers. The upper layers (e.g., Layer 2) in such a network, process individual transactions and record them on its own ledger while a summary of the transactions are then posted on to the lower levels' ledger (e.g., Layer 1). Such a setup offloads the traffic hitting the core ledger (e.g., Layer 1), and consequently improves the scalability and performance of the layered network as a whole.

The layer 1 network in this setup is likely to be more globally distributed with more validating nodes and serves as the common backbone across multiple layer 2 networks. The upper layers would therefore inherit the security of the lower layer. A malicious actor that seeks to tamper a transaction unilaterally, would be required to reverse or modify a transaction on layer 2 as well as layer 1.
Layer 3 solutions are an emerging area, which seeks to support cross-chain interoperability, by facilitating asset transactions across layer 2s, but these will not be covered in this report.

Layered networks however place heavy reliance on the bridging or coordination mechanism between the upper and lower levels. If such a mechanism is compromised, the upper layers could suffer from a loss in monetary values.

To ensure business continuity, the upper layers must constantly keep up with the changes made on the lower levels to ensure continuing operations. This could become untenable if the lower levels change frequently and the networks get increasingly complex, which results in potential compatibility issues.

Model N3 | Interlinked Networks

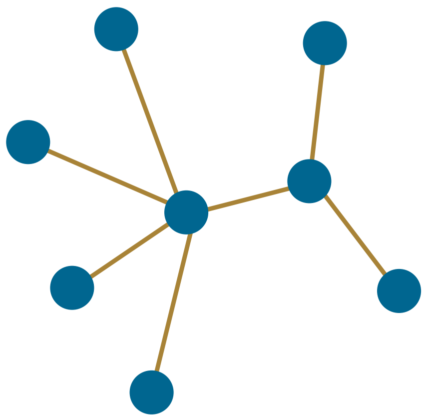


Figure 5: Illustration of Model N3 - Interlinked Networks

This model consists of a network of independent networks or sidechains, each with their own distinct governance models. Unlike layered networks, sidechains do not rely on the validators of another network to ensure the integrity of its transactions. Transactions in sidechains are recorded on its own ledger and are not posted to a separate network's ledger periodically. To move between these independent networks, tokens may be held in custody in one network and reissued on the other network. This process is commonly referred to as wrapping. This makes it easier for assets to be moved across different networks. Another model involves cross-chain communication, wherein assets do not leave their respective chains, but instead a communication layer exists to ensure that the movement of assets that exist on different chains is orchestrated.

Sidechains enable a larger network to be partitioned into smaller and more specialised subnetworks. Thus, this indirectly improves the performance of the overall network as workload may be processed in parallel on each of these networks rather than processed serially in a single flat network.

When the digital assets and currencies reside on different networks, DvP (Delivery versus Payment) settlement may be achieved with smart contracts replicating and replacing the processes performed by a trusted intermediary. This is typically implemented through a two-phase-commit model of ensuring both assets and currencies are available and locked, prior to releasing them and completing settlement. As compared to atomic settlement in a single transaction block, this model requires additional steps to synchronise states across platforms and retains a low residual risk of failure under specific exceptional scenarios.

One possible technical implementation is Hashed Time-Locked Contracts (HTLC), which was examined previously in the Project Cedar Phase II x Ubin+ report[19]. HTLC uses a set of hash-locks and time-locks implemented through smart contracts on different networks, and through the release of a “secret,” all actions making up a transaction are coordinated such that either they all happen, or none happens.

5.5 Composability

The features described in the previous section are intended to be composable. A given digital asset network may utilise a combination of different platforms, network structures and service access types in its deployment.

To illustrate the concept, two examples have been provided that demonstrate how the features could be combined. The first example is based off Partior[20] while the second one is based off the pilot design by DBS Bank, J.P. Morgan Chase Bank and SBI Digital Asset Holdings[21] cross-currency transactions on a layered network.

These examples are not intended to be exhaustive; it is foreseeable that there are other combinations that might be practical in the field. Additionally, there may be other forms of mechanisms to achieve the desired goals of being a financial market infrastructure that might not be covered in the above examples.

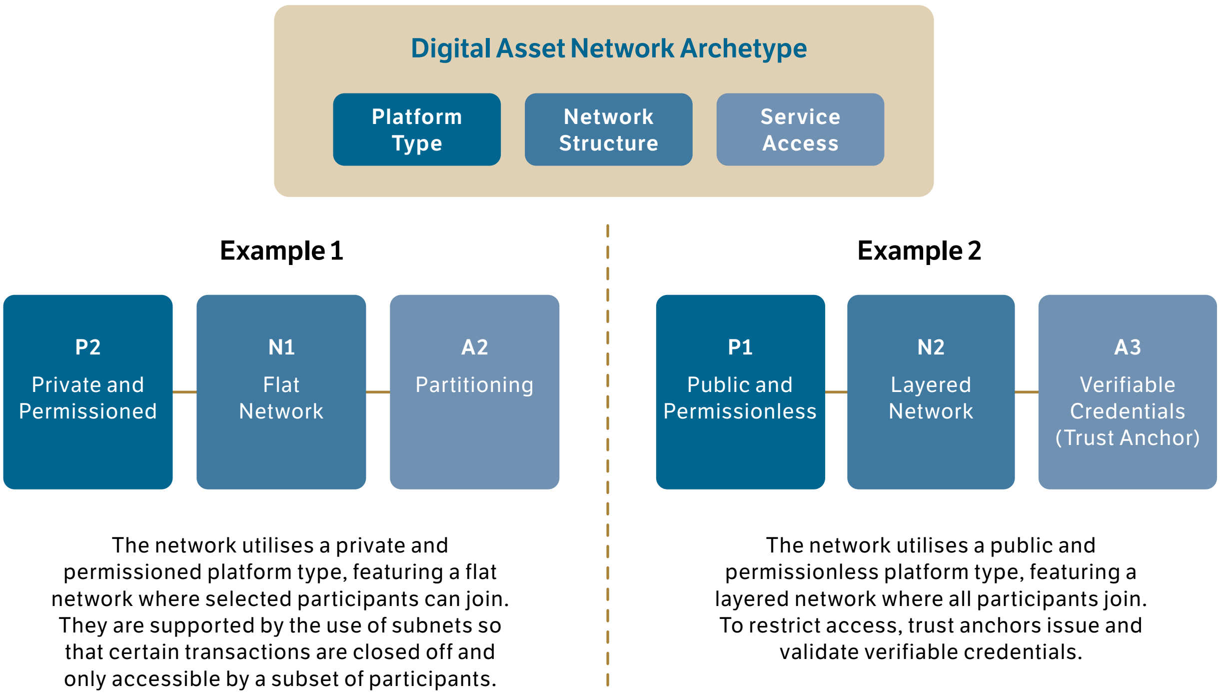


Figure 6: Composability

[19] Project Cedar Phase II x Ubin+ examined whether distributed ledger technology could be used to improve the efficiency of cross-border payments and settlements involving multiple currencies (New York Innovation Center (NYIC) & Monetary Authority of Singapore (MAS), 2023).
[20] Partior is a private and permissioned digital ledger platform based off Quorum.
[21] Institutional DeFi - The Next Generation of Finance (Oliver Wyman, DBS Ltd, SBI Digital Asset Holdings, & J.P. Morgan, 2022).

6 — Principles for FMIs and Application to Digital Asset Networks

The Principles for Financial Market Infrastructures (PFMI), jointly developed by the BIS Committee on Payments and Market Infrastructures (CPMI) and the International Organization of Securities Commissions (IOSCO), are the international standards for FMIs. They apply to all systemically important payment systems, central securities depositories, securities settlement systems, central counterparties (CCPs) and trade repositories. The PFMI define an FMI as a multilateral system among participating institutions, including the operator of the system, used for the purposes of clearing, settling or recording payments, securities, derivatives or other financial transactions. The PFMI takes a functional approach, focusing on the function that a certain arrangement performs. Consequently, a digital asset network, such as the ones that are the focus of this report, could fall under the scope of the application of the PFMI, to the extent such a network performs a function that an FMI does.

While the PFMI are broadly designed to apply to all FMIs, there are some principles and key considerations that only apply to certain types of FMIs[22]. However, the FMI functions performed by digital asset networks may be a mix of the functions that are expected to be performed by each of the existing categories of FMIs. Therefore, when applying the PFMI to a digital asset network, it is important to identify which FMI functions are relevant[23]. Such variation in FMIs is not unforeseen in the PFMI. The PFMI acknowledge that FMIs can differ significantly in organisation, function and design. FMIs can be legally organised in a variety of forms. Depending on organisational form, FMIs can be subject to different licensing and regulatory schemes within and across jurisdictions. Applying the PFMI to a digital asset network will depend on the nature of the functions it performs and to what extent these functions are considered as equivalent to the functions of certain types of FMIs.

In addition to PFMI, other relevant international standards might need to be considered, if the extent of the functions performed by digital asset networks (such as trading, issuance, custody and client asset protection, asset servicing and depositor protection) overlap with these standards[24]. The relevant standards include:

- IOSCO's *Objectives and Principles of Securities Regulation,* including the *Policy Recommendations for Crypto and Digital Asset Markets*[25] that are currently subject to public consultation; these recommendations apply the IOSCO standards to crypto asset markets.
- The Basel Committee on Banking Supervision (BCBS) Standards, including its standard on the *Prudential Treatment of Crypto Asset Exposures*[26].
- The Financial Action Task Force's (FATF) Recommendations, including its Updated Guidance for a *Risk-based Approach to Virtual Assets and Virtual Asset Service Providers*[27].

This is consistent with the approach for existing FMIs.

While the CPMI and IOSCO have not issued guidance on the application of the PFMI to digital asset networks, there are three reports that particularly provide insights into the application of the PFMI to such networks (in addition to the PFMI themselves):

- CPMI (2017) *Distributed ledger technology in payment, clearing and settlement – an analytical framework*[28],
- CPMI (2019) *Wholesale digital tokens*[29], and
- CPMI and IOSCO (2022) *Application of the principles for financial market infrastructures to stablecoin arrangements*[30].

[22] Annex E for matrix of applicability of key considerations to specific types of FMIs (BIS, 2012, p. 158.).
[23] Annex D for a high-level description of various institutional designs of traditional FMIs (BIS, 2012, p. 148.).
[24] IOSCO Decentralized finance report (International Organization of Securities Commissions (IOSCO), 2022).
[25] Policy Recommendations for Crypto and Digital Asset Markets (IOSCO, 2023).
[26] Prudential treatment of crypto asset exposures (BIS, 2022c).
[27] Updated Guidance for a Risk-Based Approach to Virtual Assets and Virtual Asset Service Providers (FATF, 2021).
[28] Distributed ledger technology in payment, clearing and settlement - an analytical framework (BIS, 2017).
[29] Wholesale digital tokens (BIS, 2019).
[30] Application of the Principles for Financial Market Infrastructures to stablecoin arrangements (BIS, 2022a).

Drawing on this set of prior work, the section considers the implications of the novel and notable features of digital asset networks as seen and experienced from Project Guardian, compared to traditional FMIs. The 24 Principles in the PFMI are organised into nine themes: (i) general organisation; (ii) credit and liquidity risk management; (iii) settlement; (iv) central securities depositories and exchange-of-value settlement systems; (v) default management; (vi) general business and operational risk management; (vii) access; (viii) efficiency; and (ix) transparency. Each of these themes are considered in turn in the following. The application of the PFMI to new technologies is likely to evolve over time and therefore the considerations set out below are likely to be revisited over time.

6.1 Novel and Notable Features of Digital Asset Networks

Digital asset networks or at least certain variants of them may be characterised with several novel features that may provide challenges when they seek to observe the PFMI (and other relevant standards). There are some features that may not be unique to digital asset networks but may be accentuated such that they could make it more challenging to observe the PFMI (and other relevant standards). In relation to the PFMI, such features would include:

- Use of stablecoins or tokenised securities (including use of native tokens);
- Multiple interdependent functions;
- Use of smart contracts; and
- Decentralisation of operations and governance.

Challenges that these features may bring about are discussed in the following sections.

6.2 General Organisation

The foundation of an FMI's risk-management framework includes its authority, structure, rights, and responsibilities. The principles on the legal basis for the FMI's activities (Principle 1), the governance structure of the FMI (Principle 2), and the framework for the comprehensive management of risks (Principle 3), provide guidance to help establish a strong foundation for the risk management of an FMI.

The distributed nature of a digital asset network is a novel and notable feature that needs to be considered when applying the principles around general organisation. It can potentially have implications for the legal basis, governance and the framework for the comprehensive management of risks.

In terms of legal basis, the distributed nature of a digital asset network may mean that the network is more likely to operate in a multi-jurisdictional environment. While identifying and mitigating the risks arising from a potential conflict of laws across jurisdictions is not a new issue for FMIs, the distributed nature of the arrangement may make it more complex to identify all of the relevant jurisdictions. Separately, the novel nature of tokens and smart contracts may mean that there is uncertainty regarding their legal status and enforceability.

In terms of governance, FMIs are expected to have governance arrangements that are (amongst other things) clear and transparent; this includes having documented governance arrangements that provide clear and direct lines of responsibility and accountability. If responsibility for the digital asset arrangement is distributed across multiple entities, including potentially anonymous legal entities, this may be more challenging to demonstrate. However, a digital asset network may be able to address this through its framework for the comprehensive management of risks, under which it is expected to regularly review the material risks it bears from and poses to other entities (including service providers) as a result of interdependencies and develop appropriate risk-management tools to address these risks[31].

6.3 Credit and Liquidity Risk Management

An FMI or its participants may face credit and liquidity risks arising from the FMI's payment, clearing, and settlement processes. The principles on credit risk management (Principle 4), collateral (Principle 5), margin (Principle 6), and liquidity risk management (Principle 7) form the core of the standards for financial risk management and financial resources. Taken together, these four principles are designed to

[31] Committee on Payments and Market Infrastructures (CPMI) and IOSCO (2022) provides guidance on how to apply this principle in the context of stablecoin arrangements.

provide a high degree of confidence that an FMI will continue operating and serve as a source of financial stability even in extreme market conditions.

A potentially novel and notable feature of digital asset networks is shorter settlement cycles, including potentially instant settlement. This has implications for both credit and liquidity risks. Faster (or instant) settlement could reduce (or eliminate) replacement cost risk (a form of credit risk) and therefore reduce (or eliminate) the amount of margin required. However, this would likely involve pre-positioning cash and digital assets pre-trade, which would increase liquidity costs.

Digital asset networks may perform other functions than those of FMIs for financial transactions, such as issuance of tokens, listing, registration, trading/market making, asset servicing and credit provision. These other functions may give rise to credit and liquidity risks to digital asset networks and their participants, and the relevant international standards (other than the PFMI) that may apply to those functions would need to be considered.

6.4 Settlement

A key risk that an FMI faces is settlement risk, which is the risk that settlement will not take place as expected. An FMI faces this risk whether settlement of a transaction occurs on the FMI's books, on the books of another FMI, or on the books of an external party (for example, a central bank or a commercial bank). The principles on settlement finality (Principle 8), money settlements (Principle 9), and physical deliveries (Principle 10) provide guidance on managing this risk.

A novel and notable feature of a digital asset network could be the settlement mechanism used. Therefore it is important to understand how settlement is achieved operationally, and how settlement finality is protected under the applicable legal framework. This includes clearly defining the point at which settlement becomes irrevocable and unconditional[32]. Some digital asset networks may feature "probabilistic settlement", which could result in a misalignment between the operational state of the ledger and the transfers that are legally final. For example, a misalignment could occur because the probability of revocation of a transaction validated by nodes converges to, but never reaches, zero with the passage of time with certain consensus mechanisms used, or because a "fork" occurs. In such circumstances, even if the relevant legal framework and the digital asset network's rules and procedures have defined the point at which final settlement occurs, a possibility remains that the validation of a transaction on the ledger cannot be achieved with absolute certainty[33].

Another potentially novel and notable feature of settlement in a digital asset network is the nature of the asset used for money settlement. FMIs are expected to conduct their money settlements using assets with little or no credit or liquidity risk. Money settlements in traditional FMIs involve updating balances in account records on a centralised register or ledger of a settlement institution, such as a central bank, FMI or commercial bank. While the cash tokens used in a digital asset network could similarly represent a claim on a specific settlement institution, they could represent a claim on underlying assets or funds or some other right or interest. Consequently, in order to understand the credit and liquidity risks from money settlements it is important to understand the nature, timeliness and enforceability of the claim, the nature and sufficiency of the assets or funds backing the claim, how the value of that claim might be affected by changes in the value of the underlying assets or funds[34]. If the assets backing the cash tokens are claims on institutions other than central banks, FMIs or commercial banks, or the claim is uncertain, this could introduce credit risk relative to traditional FMI arrangements. Similarly, if the claim cannot be realised in a timely manner, then this could introduce liquidity risk relative to traditional FMI arrangements.

6.5 Central Securities Depository and Exchange-of-Value Settlement

Central securities depositories (CSDs) and exchange-of-value settlement systems have unique risks associated with their function and design. While the nature and scope of activities performed by CSDs vary based on jurisdiction and market practices, CSDs play a critical role in the protection of securities and help ensure the integrity of securities transactions. Similarly, exchange-of-value settlement systems play a critical role in mitigating principal risk by linking the final settlement of one obligation to the

[32] CPMI and IOSCO (2022) provides guidance on settlement finality in the context of stablecoin arrangements.
[33] CPMI and IOSCO (2022) provides guidance on settlement finality in the context of stablecoin arrangements. While this guidance relates to stablecoins and their use for money settlement, most if not all discussion provided in the guidance would be applicable to the transfer of tokenized securities.
[34] Guidance on these in the context of stablecoin arrangements is set out in CPMI and IOSCO (2022).

Digital asset networks or at least certain variants of them may be characterised with several novel features that may provide challenges when they seek to observe the PFMI (and other relevant standards).

final settlement of another. The two principles provide specific guidance to CSDs (Principle 11) and exchange-of-value settlement systems (Principle 12).

A novel and notable feature of digital asset networks is that the securities are tokenised rather than immobilised or dematerialised. Principle 11 states that a "CSD should maintain securities in an immobilised or dematerialised form for their transfer by book entry"[35]. There are parallels between native tokens (i.e., tokens that only exist on the network) and dematerialised securities (which only exist in electronic form). Similarly, there are parallels between non-native tokens (i.e., representations of an asset that has been issued outside of the network) and immobilised securities (where paper-based securities are held in a depository and transfer of these securities are through book entry). These parallels provide a starting point for considering the appropriate risk management arrangements for tokenised securities. For example, similar to the existing arrangements for immobilised securities, in the case of non-native tokens, the underlying assets should be kept in custody and should not be used while their tokens are in circulation; otherwise, such "double-duty" would effectively lead to unauthorised creation of securities[36]. However, the novel nature of tokens may result in additional issues that should be addressed.

Furthermore, as set out in Section 6.1, the novel nature of tokens and smart contracts may mean that there is uncertainty regarding their legal status and enforceability.

As mentioned above, the settlement mechanism could potentially be a novel and notable feature of a digital asset network. This would relate to how final settlement of linked obligations is achieved (ie delivery-versus-payment or payment-versus-payment).

6.6 Default Management

An FMI should have appropriate policies and procedures to handle participant defaults. A participant default, if not properly managed, can have serious implications for the FMI, other participants, and the broader financial markets. The principles on participant-default rules and procedures for all FMIs (Principle 13) and segregation and portability issues for CCPs (Principle 14) provide guidance on this.

A novel and notable feature of digital asset networks is that it may involve a digital ledger that acts as the single source of truth regarding beneficial ownership. To the extent that a digital asset network provides CCP services, this may make it easier for the digital asset network to observe the Segregation and Portability Principle. Decentralised nature of digital asset networks or use of automation (e.g., smart contracts) might make it more challenging to manage contingent situations that may not be anticipated ex ante but may arise in a default.

6.7 General Business and Operational Risk Management

The inability of an FMI to continue as a going concern could have systemic risk implications for its participants and the broader financial markets. Guidance on managing these risks is set out in the principles on general business risk (Principle 15), custody and investment risks (Principle 16), and operational risk (Principle 17).

As the operational arrangements (e.g., DLT) supporting a digital asset network are novel and notable, thorough consideration of how the operational arrangements affects observance of the Operational Risk Principle is necessary. This consideration would need to draw on the considerations around the principles on general organisation.

[35] Principle 11, Key Consideration 3 (BIS, 2012, p. 72.).
[36] Principle 11, Key Consideration 1 (BIS, 2012, p. 72.).


Keppel
DBS
HSBC

Given the novel nature of digital asset networks, it may also be more challenging to identify, monitor and manage its general business risk. For example, it can be difficult to develop a viable recovery or orderly wind-down plan for a new and novel business.

As mentioned above, a digital asset network may involve a digital ledger that acts as the single source of truth regarding beneficial ownership. This may affect how the FMI safeguards its own and participants' assets under the Custody and Investment Risks Principle. While having a digital ledger that is a single source of truth is similar to a direct holding system[37], unlike those systems where custodians may still be involved in maintaining the records of beneficial ownership. It would be a more significant change from traditional FMIs that operate an indirect holding system. Under an indirect holding system there is no single source of truth; custodians hold securities on behalf of their clients in omnibus accounts in the CSD's ledger and then separately maintain their own records on clients' beneficial ownership of securities.

The discussion above on the legal nature of tokens and the asset used for money settlements is also relevant to a digital asset network's observance of the Custody and Investment Risks Principle, under which an FMI is expected to safeguard its own and participants' assets and minimise the risk of loss on and delay in access to these assets.

6.8 Access

Fair and open access to an FMI by direct participants, indirect participants, and other FMIs is important because of the critical role many FMIs play in the markets they serve. Guidance on this is set out in the principles on access and participation requirements (Principle 18), the management of tiered participation arrangements (Principle 19), and the management of FMI links (Principle 20).

A novel and notable feature of digital asset networks that use a public network is that access is not restricted. This is in contrast to the presumption that reasonable risk-related participation requirements are necessary to allow for fair and open access to an FMI's service[38]. Consequently, such a digital asset network would need to justify why risk-related participation requirements are not necessary in order to manage the risks that an actual or prospective participant may pose to the FMI and other participants.

The existence of layered networks in digital asset networks may also mean that the FMI Links Principle is more relevant for digital asset networks than traditional FMIs.

6.9 Efficiency

Efficiency and safety are important to an FMI in performing its payment, clearing, settlement, and recording functions. The following two principles provide guidance to FMIs on efficiency and effectiveness (Principle 21) and communication procedures and standards (Principle 22), which is one traditional aspect of efficiency.

A digital asset network is expected to meet these principles, where relevant.

6.10 Transparency

Transparency helps ensure that relevant information is provided to an FMI's participants, authorities, and the public to inform sound decision making and foster confidence. Guidance for all FMIs on the disclosure of rules, key procedures, and market data to enable participants and other interested parties to have a clear understanding of the risks and controls on risks associated with an FMI, as well as fees and other costs incurred by participation in the FMI is set out in Principle 23. In addition, there is a specific principle for trade repositories on the disclosure of market data to allow participants, authorities, and the public to make timely assessments of OTC derivatives markets and, if relevant, other markets served by the trade repository (Principle 24).

A digital asset network is expected to meet these principles, where relevant.

[37] In a direct holding system, each beneficial owner has an individual account with the CSD.

[38] As per explanatory note 3.18.5 (BIS, 2012, p. 102.), an FMI should always consider the risks that an actual or prospective participant may pose to the FMI and other participants. Accordingly, an FMI should establish risk-related participation requirements adequate to ensure that its participants meet appropriate operational, financial, and legal requirements to allow them to fulfil their obligations to the FMI, including the other participants, on a timely basis.

7 — Case Studies

Previous sections in this report introduced the framework for the design of open and interoperable networks. This section discusses how the framework and associated concepts may be applied in practice. Three industry initiatives were used as the context for this analysis.

Case Study	Participating Institutions	Network Type	Network Structure	Platform		Service Access	Asset Type
				Participation	Control		
Global Liquidity Pool	SBI, DBS	P1-N2-A3	Layered	Public	Permissionless	Verifiable Credentials	Tokenised assets
Trade Finance Asset-backed Securities	SCB	P1-N1-A1	Flat	Public	Permissionless	Whitelist	Asset Tokens
Structured Notes	HSBC, UOB, MN	P1-N2-A1	Layered	Public	Permissionless	Whitelist	Asset Tokens

Table 3: Comparison of Network Types

The industry initiatives included a study of the feasibility of public platforms and their equivalent private implementations. The inclusion of these platforms in this report are for learning purposes and should not be inferred as an endorsement on their suitability as financial market infrastructures. Future research includes the study of public and permissioned platforms as well as the interlinking of private and permissioned platforms.

7.1 Case Study 1 – Global Liquidity Pool

Background

The FX market is the largest market in the global financial system with over-the-counter (OTC) FX transactions amounting to more than $7.5 trillion in daily turnover as at April 2022[39]. Currently, FX and government securities are primarily transacted in the OTC markets involving multiple intermediaries resulting in frictions in the settlement process. These layers of intermediaries add to processing time and cost. Additionally, setting up counterparty lines is an onerous process and consequently liquidity is fragmented across multiple trading venues today.

Approach

DBS Bank and SBI Digital Asset Holdings are collaborating to explore the feasibility of conducting foreign exchange and government bond transactions against liquidity pools comprising of tokenised Singapore Government Securities (SGS) Bonds, Japanese Government Bonds (JGB), Japanese Yen (JPY) and Singapore Dollar (SGD).

For this solution, the network type used is P1-N2-A3. The participants will be issued verifiable credentials to partake in activities on a public permissionless platform which is covered in further detail below. The network structure is layered, specifically a layer 2 is used for lower costs, and to increase scalability and performance of transaction processing. Non-native tokens or tokenised representations of assets will be used to mirror the value of the underlying traditional securities and cash.

Tokenised representations of these assets will be issued and supplied to a common liquidity pool. This enables traders to trade against a pool of tokenised assets as the counterparty instead of multiple different counterparties. The trade will comprise the outright purchase and sale of tokenised SGS bonds, SGD, JGB and JPY. The participating financial institutions will play different roles of liquidity provider and trader in each liquidity pool.

The traders and liquidity providers have to be screened through onboarding processes by trust anchors before they will be issued verifiable credentials. This enables the validation of verifiable credentials for traders to access the liquidity pool and trade through non-custodial wallets. This will be tested on a public permissionless platform where the permissioned decentralised exchange protocols will be deployed.

[39] OTC Foreign Exchange Turnover in April 2022 (BIS, 2022b).

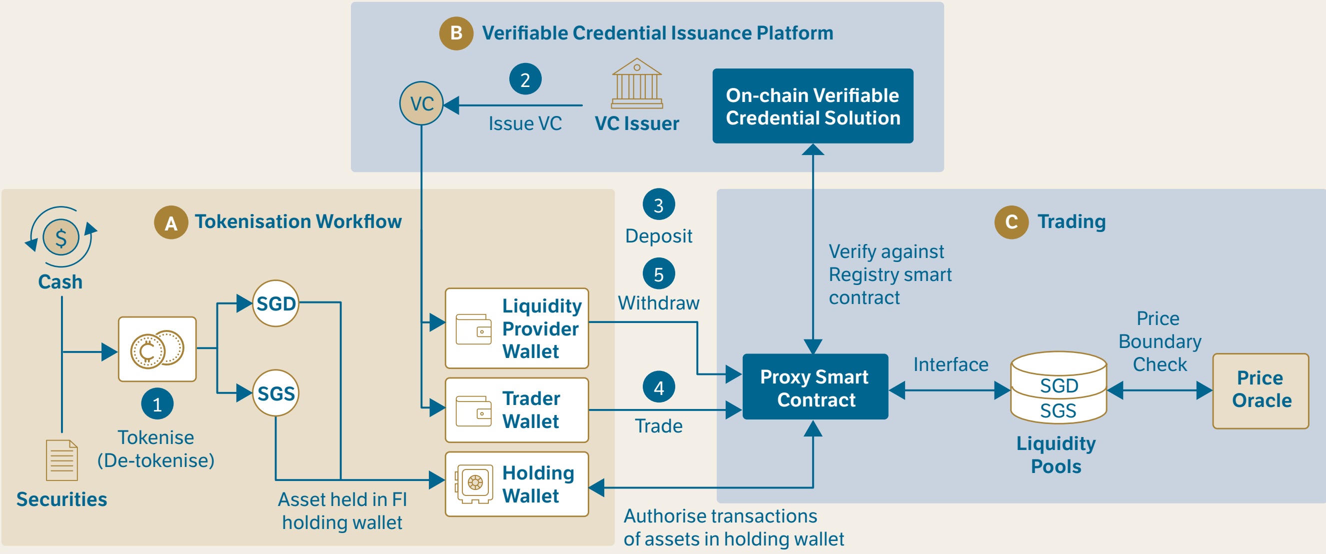


Figure 7: Solution Overview of Global Liquidity Pool[40]

The Global Liquidity Pool initiative focuses on the following capabilities:

- **Tokenisation:** This describes the process whereby cash and the underlying securities are tokenised and distributed to a financial institutions' holding wallet. Tokenised assets and cash held in the holding wallets of respective financial institutions were implemented using the ERC-20 token standards.
- **Verifiable Credential Issuance Platform:** A common set of processes for issuing Verifiable Credential tokens has to be established with specific authorisations (i.e., for Liquidity Provider, Trader). The VC tokens enable the provision of access and activities into Liquidity Pool. VC Tokens will be implemented in the form of a NFT in accordance with ERC-721 token standard.
- **Liquidity Pool Protocol:** A liquidity pool is setup using smart contracts with an Automated Market Marker (AMM) based on the Constant Function Market Maker Algorithm. The liquidity pool protocol incorporates an additional control point, whereby users will be required to provide proof of ownership of a VC token as an authorisation check for depositing, withdrawing, and trading within the liquidity pool.

The protocol also references price oracles for off-chain data on asset prices as a boundary check. This acts as a circuit breaker in the event of an extreme price deviation from the rest of the market.

Key Roles and Responsibilities

Role	Responsibility	Participant
Issuer	Responsible for the issuance of tokenised SGD and tokenised SGS bonds.	DBS
	Responsible for the issuance of tokenised JPY and tokenised JGB.	SBI
Trader	Conduct trading activities against the liquidity pool made up of tokenised JPY, JGB, SGD and SGS.	DBS, SBI
Liquidity Provider	Responsible for the provision of liquidity into the liquidity pools in the form of tokenised SGD and SGS.	DBS
	Responsible for the provision of liquidity into the liquidity pools in the form of tokenised JPY and JGB.	SBI
Protocol Developer	• Develops and maintains liquidity pool and AMM smart contracts. • Performs modifications on lending and borrowing DeFi protocols for asset trading.	DBS
Verifiable Credentials Developer	Develops and maintains smart contracts for verifiable credentials.	DBS
Trust Anchor	• Responsible for permissioning access to traders and participants. • Performs screening on participants (i.e. Traders) and issues verifiable credentials with specific authorisations (i.e., for Liquidity Provider, Trader) to authenticate identity of participants on-chain.	DBS, SBI

[40] On-chain verifiable credential and proxy smart contract solution leveraged concepts developed by JPM during Project Guardian. Refer to Institutional DeFi - The Next Generation of Finance (Oliver Wyman, DBS Ltd, SBI Digital Asset Holdings, & J.P. Morgan, 2022).

Process Overview

The global liquidity pool initiative consists of the following steps:

Registration and Verifiable Credentials Flow

1. Onboard Liquidity Provider or the Trader and conduct KYC.
2. KYC is successfully completed and the VC is issued to the Liquidity Provider or the Trader.
3. The VC administrator identity is stored in the Registry Smart Contract for VC verification.
4. The VC token is then minted and issued to the Liquidity Provider or the Trader's wallet.
5. The VC is signed by the administrator's wallet key.
6. Liquidity Provider or the Trader initiates the transaction through the front-end user interface.
7. The transaction is then signed with the Liquidity Provider and Trader's key.
8. The roles and identity are verified through the earlier issued VC in the Liquidity Provider or Trader's wallet by the Verifier Smart Contract with the registry.
9. The tokenised assets will be drawn from the DBS holding wallet.
10. Liquidity Provider or a Trader can deploy the tokenised assets into the liquidity pool to provide liquidity or trade.

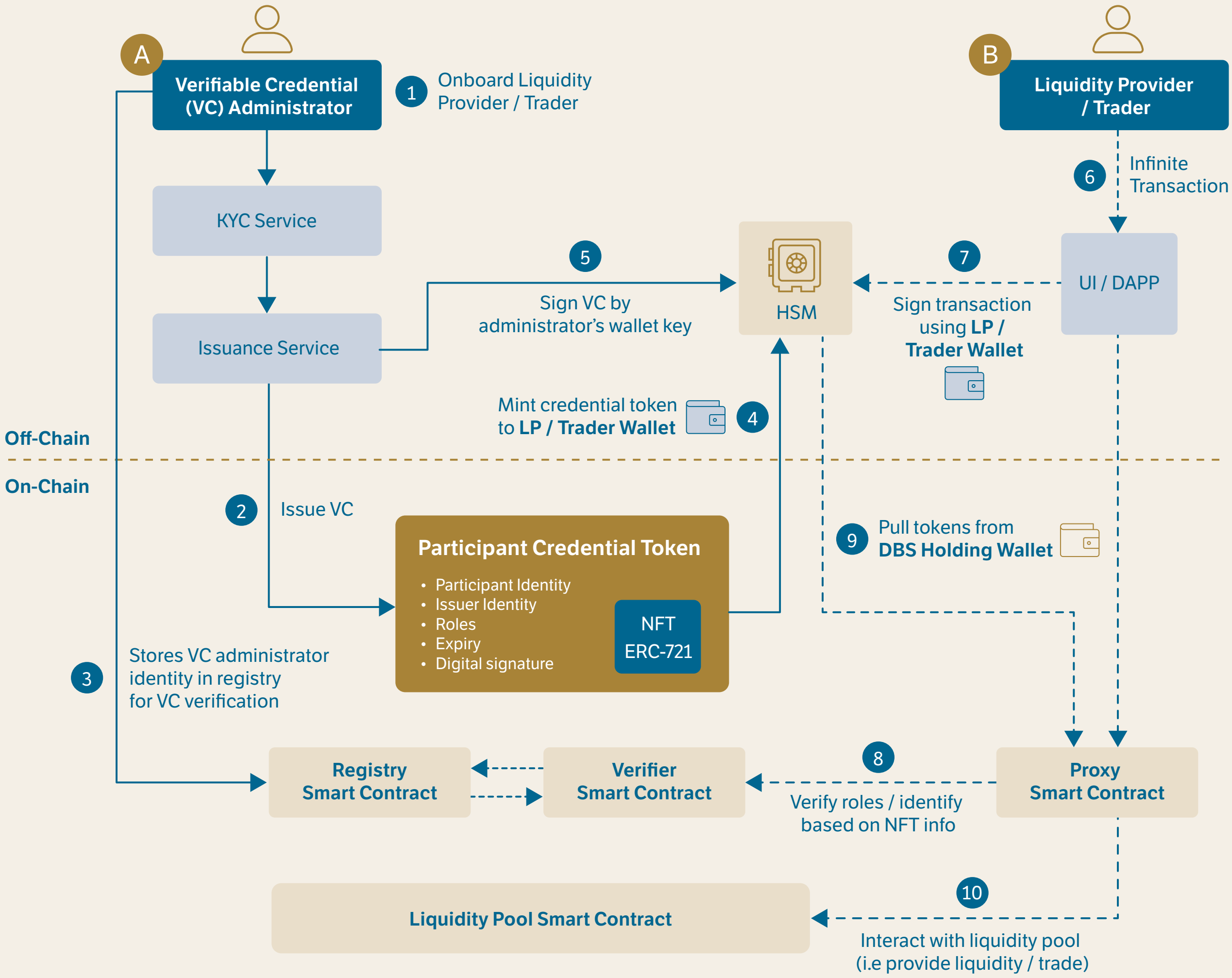


Figure 8: Registration and Verifiable Credentials flow[41]

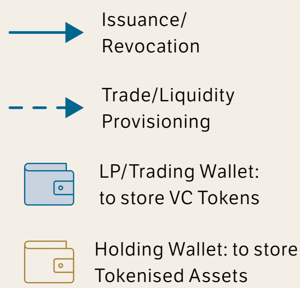
A. Administration of VC

- Administrator assigns VC token with appropriate role (i.e. Trader or Liquidity Provider) to wallet address, after verification/ KYC
- Administrator can set expiry or manually revoke issued VC tokens
- Issuances and updates to VC tokens will update the Registry Smart Contract

B. Users (Liquidity Provider/ Trader)

- Users will need to hold the correct type of VC token in own wallet to be able to perform the necessary actions on the Liquidity Pool Smart Contract
- Interactions with the Liquidity Pool Smart Contract will involve verification against the Registry
- Successful verification of liquidity provider/ trader wallet with the VC tokens, will authorise use of Tokenised Assets from the Holding wallet to perform the appropriate actions (i.e. provide liquidity / trade)

Legend



[41] On-chain verifiable credential and proxy smart contract solution leveraged concepts developed by JPM during Project Guardian. Refer to Institutional DeFi - The Next Generation of Finance (Oliver Wyman, DBS Ltd, SBI Digital Asset Holdings, & J.P. Morgan, 2022).

Funding the wallets

1. *Minting SGD and SGS tokens*: DBS mints tokens representing SGD cash and SGS.
2. *Minting JPY and JGB tokens*: SBI mints tokens representing JPY cash and JGB.

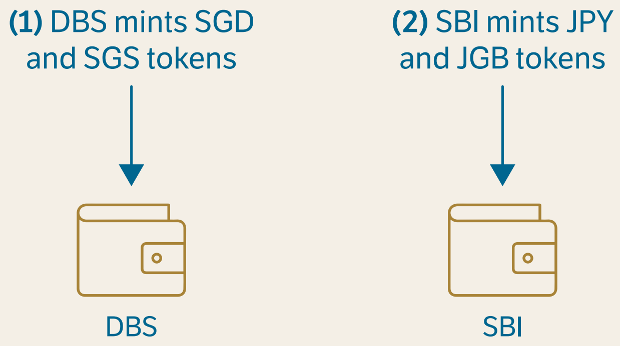


Figure 9: Minting tokens and funding wallet

Trading

1. OTC Trade – JPY and SGD tokens

a) *Conducting the trade*: DBS and SBI enters into an OTC FX (JPY/SGD) spot trade.

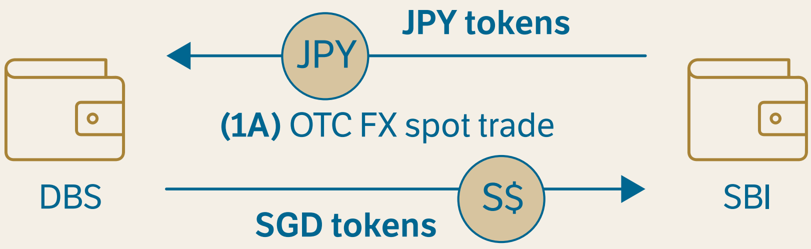


Figure 10: OTC Trade – JPY and SGD tokens

2. Liquidity Pool 1 – SGD and SGS tokens

a) *Funding the liquidity pool*: DBS (liquidity provider) invests SGD and SGS tokens in Liquidity pool 1.

b) *Conducting the trade*: SBI (trader) buys SGS and pays SGD to the Liquidity Pool 1 in a single atomic transaction.

c) *Withdrawing from the liquidity pool*: DBS withdraw liquidity from Liquidity Pool 1.

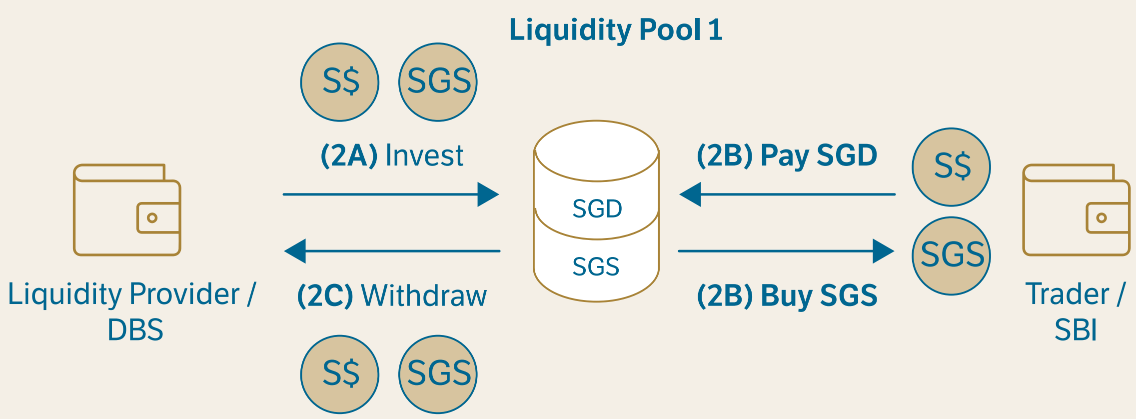


Figure 11: Liquidity Pool 1 (SGD – SGS bond tokens)

3. Liquidity Pool 2 – JPY and JGB tokens

a) *Funding the liquidity pool*: SBI (liquidity provider) invests JPY and JGB tokens in Liquidity Pool 2.

b) *Conducting the trade*: DBS (trader) buys JGB and pays JPY to the Liquidity Pool 2 in a single atomic transaction.

c) *Withdrawing from the liquidity pool*: SBI withdraws liquidity from the Liquidity Pool 2.

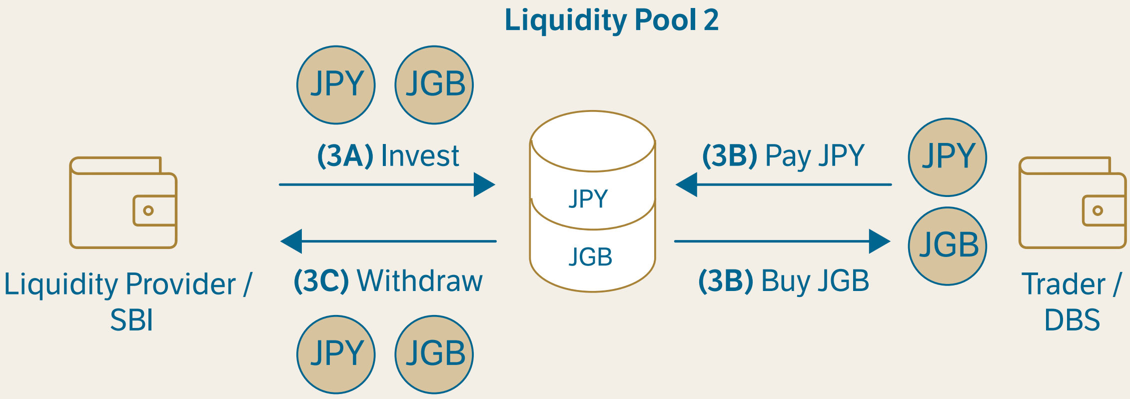


Figure 12: Liquidity Pool 2 (JPY – JGB tokens)

4. Liquidity Pool 3 – SGD and JPY tokens

a) *Funding the liquidity pool*: DBS and SBI (liquidity providers) invest SGD and JPY tokens in Liquidity Pool 3.

b) *Conducting the trade*: SBI buys SGD and pays JPY to Liquidity Pool 3; DBS buys JPY and sells SGD to Liquidity Pool 3 in a single atomic transaction.

c) *Withdrawing from the liquidity pool*: DBS and SBI withdraw liquidity from Liquidity Pool 3.

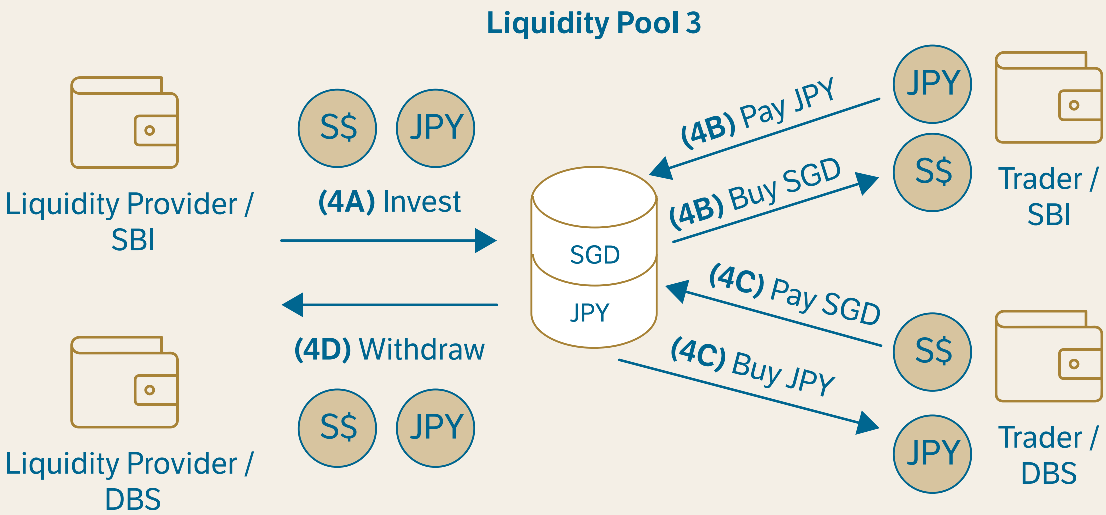


Figure 13: Liquidity Pool 3 (SGD – JPY tokens)

Case Studies

This has the potential to transform current trading and settlement processes, as trading in a permissioned liquidity pool protocol achieves greater efficiency by reducing friction and minimising risks, while the tokenised assets bring the benefits of atomic settlement.

Limitations of proposed solution

Privacy Concerns

Under the existing market infrastructures, transactional privacy applies generally to all transactions except for certain scenarios as required by regulation. However, on a public network, there is full transparency over trades originating from each wallet address. This may cause concerns where participants to a trade and such activity can be traced through transactions and wallet addresses. Although, given the pseudonymity of wallets, only the wallet addresses can be identified, while the information on the owners of the wallets will continue to be privately maintained with the trust anchors. In such cases, only the trust anchors and authorised financial regulators will be able to identify the owner of the wallet.

Regulatory and Legal Treatment

The legal and regulatory landscape for tokenised financial assets and DeFi is still evolving. For instance, the legal treatment of digital financial assets as property, settlement finality and the regulation of DeFi protocols, are all subject of ongoing research and consultation. Furthermore, the complexity is compounded as DeFi trades are subject to differing regulations across different jurisdictions. Hence, a coordinated international approach amongst financial regulators and international standard setting bodies is required to achieve common regulatory outcomes across jurisdictions and reduce frictions in cross-border transactions.

Smart Contract Vulnerability

The liquidity pool and trading functionalities are developed mainly using smart contracts. Hence, smart contract vulnerabilities are an important area of concern from an operational and business continuity perspective. Examples of potential vulnerabilities include transaction frontrunning whereby frontrunners can submit subsequent identical transactions to the ledger to be prioritised for processing with incentives such as additional fees.

Key learnings and future developments

The use of a liquidity pool could increase efficiency while reducing the number of intermediaries in executing a trade. The increase in trading velocity and volumes with deeper liquidity pools creates more pricing and spread efficiencies when trading in the AMM. This is a virtuous cycle, as a highly liquid market attracts more participating investors.

These tests highlight the benefits of atomic settlement and the potential for creating deeper secondary liquidity across multiple financial assets and markets. In this solution, pricing will be available pre-trade before the trader decides to accept the trade conditions. The combination of steps in the trade and settlement process brings about operational efficiencies in the trade execution and reduces settlement risks. With fewer intermediaries required in a trade, costs can be reduced, and transaction speeds can increase.Transactions are immutable and transaction statuses are visible on the network without the need to trace these transactions manually. That said, the protocols need further development to cater to and cope with the complexity of multi-asset pools and efficient price discovery.

This has the potential to transform current trading and settlement processes, as trading in a permissioned liquidity pool protocol achieves greater efficiency by reducing friction and minimising risks, while the tokenised assets bring the benefits of atomic settlement.

7.2 Case Study 2 – Asset Backed Security Token with Underlying Trade and Working Capital Loans

Background

Trade finance is a critical part of the global real economy, facilitating cross-border transactions for businesses of various sizes. Currently, up to 80% of global trade is facilitated by financing solutions or credit insurance. The global trade finance market size is projected to reach USD 10 trillion by year 2027, an increase of 24% since year 2020. Trade finance offerings include sale of invoices

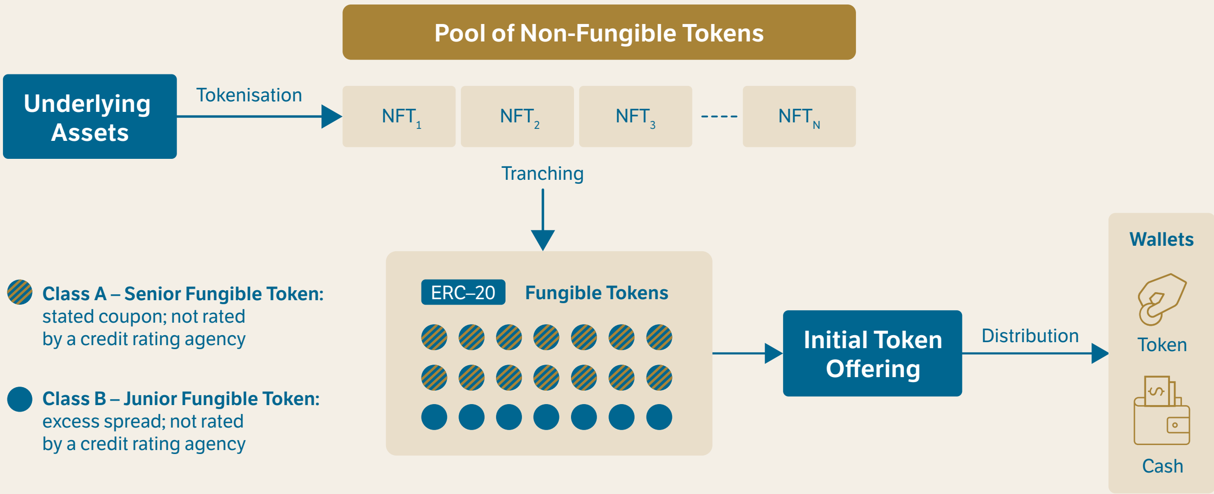


Figure 14: Solution overview of ABS tokenisation scheme

or accounts receivables as well as short-term lending solutions to optimise cash flows.

Trade finance assets, while typically difficult to access, are seen as low risk investments. The low risk involved with trade finance makes owning trade finance assets a great way to diversify investments. However, history has shown that the lack of liquidity in trade finance assets paired with duration risks have made it difficult for non-institutional investors to gain access to these assets. On the other hand, there has been increasing demand for digital assets and there is also growing interest amongst investors to diversify their portfolio with new forms of tokens with traceable intrinsic value.

Approach

Standard Chartered is leading an Asset-Backed Securities (ABS) tokenisation initiative to develop a platform and marketplace to transform real-economy assets such as import/export financing assets into standardised digital assets instruments. The initiative aims to allow a broader base of investors to access bank-originated real economy assets, such as trade finance and working capital loans.

For this solution, the network type P1-N1-A1 will be used. The participants are to be whitelisted to partake in activities on a public permissionless platform which is covered in further detail below. The flat network structure allows for the ABS tokens to be exchanged directly without needing intermediaries.

The ABS tokenisation initiative focuses on the following capabilities:

- **Tokenisation** of Trade Finance Receivable Assets in the form of **non-fungible tokens**.
- **Tranching,** the core of securitisation transactions where the risk/rewards on a portfolio of risky assets are allocated between senior tranches and junior tranches according to strict cashflow allocations (e.g. ‘cashflow waterfall’), where:
    - → the junior tranche is the most exposed to the variability, performance and ultimately default risks of the underlying assets and;
    - → the senior tranche is insulated, to a certain extent, by a buffer in the form of the junior tranche
- **Production of two new types of Fungible Tokens:** the fungible tokens are linked to the same portfolio consisting NFTs of Trade Finance Receivable Assets with senior/junior split. This is per a typical securitisation where the senior fungible token will be linked to the senior tranche and the junior fungible token, to the junior tranche.

To support these capabilities, the ABS token leverages smart contract technology for the token offering, asset pool creation, NFT assignment, redemption and replenishment, maturity redemption and payout to token holders. Process automation through smart contracts streamlines and enhances efficiency, enabling investors to invest in asset-backed securities securely and transparently without relying on intermediaries. For example, the calculation of token holder interest is automated by the smart contract, eliminating the need for a third party to perform the calculation.

This initiative seeks to investigate the primary issuance of real-economy digital assets tokens. The initiative aims to increase the capability to support real economy flows and provide digital asset investors to diversify their portfolios, as well as greater transparency and reduced information asymmetry.

Key Roles and Responsibilities

Role	Responsibility	Participant
Issuer	Responsible for the issuance of the asset-backed token, and the issuer will be a Special Purpose Vehicle (SPV).	Standard Chartered
Asset Originator	◆ Responsible for originating the trade finance assets (e.g., in form of lending money to obligor and collecting the principal plus interest at maturity). ◆ Asset Originator will surrender ownership of the assets it owns through a legal outright sale but will continue to service the underlying trade finance assets.	Standard Chartered
Arranger	Arranges, underwrites and facilitates the sale of ABS tokens in the Initial Token Offering.	Standard Chartered
Listing Venue	Review of the ABS token offering and publication of the information under the sandbox for digital bond listings.	SGX Group
Protocol Developer	◆ Develops ABS token product smart contracts. ◆ Enables the transfer and settlement of ABS tokens. ◆ Performs the on-chain registration, record keeping and lifecycle management of ABS tokens.	Linklogis
Cash settlement Bank	Responsible to perform the cash leg settlement for the issuance to achieve Delivery vs Payment.	Standard Chartered

Process Overview

There are four stages to transform the underlying assets into transferable tokens.

1. **Legal Outright Sale of Assets**
   The first step in the process is the legal sale of assets from the originator to the SPV. In this transaction, all the rights and interests to the underlying assets, including the associated risks, are transferred to the SPV.

Figure 15: Sale of Assets from Originator to SPV

2. **Tokenisation of Underlying Assets**
As the assets are transferred to the SPV, the underlying assets are tokenised as NFT records. Each underlying asset corresponds to one count of NFT, whose ownership record on the ledger represents the legal ownership of the assets. This facilitates the recording of ownership changes on the ledger, with transparency and traceability, and reduces information asymmetry between Issuer and Investors.

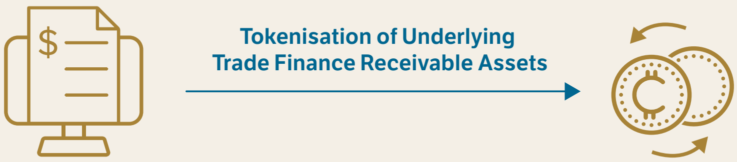


Figure 16: Tokenisation of underlying assets

3. **Repackaging of Tokenised Underlying Assets to Fungible Tokens**
Asset pools can be used to diversify geographical, sectorial, and business risks to avoid over-concentration on a particular industry or business. In this case, multiple NFTs are assigned to an asset pool (a smart contract programmed to automate interest compounding and pay-outs). This asset pool is then bifurcated into a two tranches (senior and junior) with distinct risk and reward characteristics. Fungible tokens with different levels of seniority are then issued, which each representing fractional ownership of the corresponding tranche.

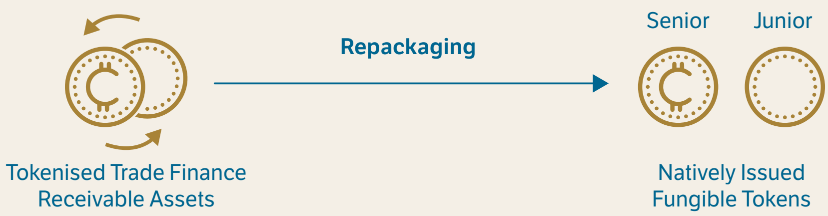


Figure 17: Natively Issued ABS tokens

4. **Token Offering**
Institutional investors can purchase fungible tokens through an Initial Token Offering exercise. They can submit subscription requests to the issuer through the token offering, and the arranger makes allocation decisions accordingly. If the tokens are allocated, investors pay fiat currency for tokens. For this trade, settlement is handled outside of the network, through traditional payment mechanisms such as SWIFT, or e-banking transfers facilitated by Standard Chartered. In future, a digital currency based atomic DvP could enable more efficient exchange of digital asset and currency tokens.

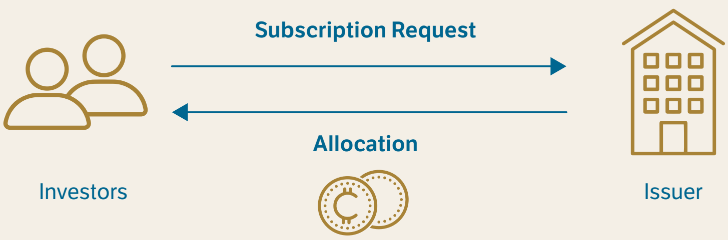


Figure 18: ABS token and Initial Token Offering process

The transformation of trade assets into native digital tokens could broaden the investor base for real economy assets. Additionally, standardisation and automation efforts are expected to bring cost savings in the set-up and ongoing operations.

Limitations of proposed solution

Privacy Concerns

In this trade, the NFTs and fungible tokens are published on a public permissionless platform. The choice of a public platform was based on the consideration of enhancing transparency and confidence for investors, allowing them to track the provenance of their tokens and view the number of NFTs held in the asset pool. To address concerns around data privacy, the underlying obligor names in the NFTs are kept private to protect the interests of the lending customer and originator.

Credit and Liquidity Risks

Like any investment product, the underlying assets in the ABS token are subject to default risk, which could reduce the expected returns of the tokens. If the underlying assets default, any shortfall in the replenishment of the underlying assets will lead to early repayment of the senior ABS token, thereby lowering the yields on the junior tokens.

Additionally, there is a risk where the issuer is unable to fulfil the obligations to replenish the assets due to unforeseen market conditions or other liquidity issues with the originator that may result in insolvency.

Technical and Operational Risks

The issuance of ABS tokens on a public permissionless network increases the complexity and potential surface area of attacks. As such, there is a risk of software or smart contract vulnerabilities such as attacks or cybersecurity breaches. The use of open-source public protocols that are not maintained by regulated financial institutions would mean that it is possible for the underlying software to be forked or enhanced which may render the ABS token incompatible.

Key learnings and future developments

The transformation of trade assets into native digital tokens could broaden the investor base for real economy assets. Additionally, standardisation and automation efforts are expected to bring cost savings in the set-up and ongoing operations.

Asset Tokenisation Standards

The asset tokenisation standard of underlying assets was adopted and modified from Bankers Association for Finance and Trade (BAFT) best market practices. As shown in Table 1: Ledger Infrastructure Models, the NFT Data Schema contains most of the data fields recommended by Distributed Ledger Payment Commitment Working Group ('DLPC' Working Group). In addition, NFTs encapsulate a rich set of attributes that can comprehensively present asset information and facilitate effective asset lifecycle management. Smart contracts were built on the Solidity programming language, leveraging industry-standard tokenisation technologies and protocols. Specifically, smart contracts for fungible tokens were developed using the ERC-20 standard.

Future Extendibility

The use of the ERC-20 standard is significant because it enables interoperability with the digital assets ecosystem as well as decentralised finance (DeFi) protocols. The availability of fungible tokens on the public network opens possibilities for future extendibility, with investors potentially being able to sell down their investment holdings via institutional DeFi platforms that are operated 24/7, and further expand liquidity pools and reaching more investors globally.

7.3 Case Study 3 – Digital Native Issuance of Structured Notes

Background
Over the counter (OTC) structured notes are a popular wealth management product with substantial traction and demand in Asian wealth centres such as Singapore. The products' popularity notwithstanding, there remains opportunities to improve upon existing operational processes.

The current structured note issuance process is relatively manual and requires multi-party coordination (i.e., with involving layers of custodians, sub-custodians, middle offices, etc.). Meanwhile, due to their bespoke nature, servicing of structured notes can be operationally intensive, leading to higher risks of operational errors such as incorrect or delayed payments.

Approach
HSBC, Marketnode, and UOB (the "Parties") are creating an asset and wealth management ("AWM") 'token factory' to enable the creation, distribution, and transfer of these assets.

For this solution, the network type used is P1-N2-A1. The Parties have to be mutually whitelisted for the native issuance and distribution activities of the AWM tokens on a public permissionless platform. The network chosen is a layered network, specifically a layer 2 for scalability and performance of transaction processing.

The AWM token factory was designed to be used across multiple products and participants in the future. In designing the infrastructure, the Parties focused primarily on (i) appropriate asset class selection in an AWM context and (ii) a sequenced modular build plan. Structured notes were eventually selected due to their frequent issuance nature and asset lifecycle management challenges. As opposed to being a captive platform, AWM token factory was designed at the onset to be an accessible market-wide platform.

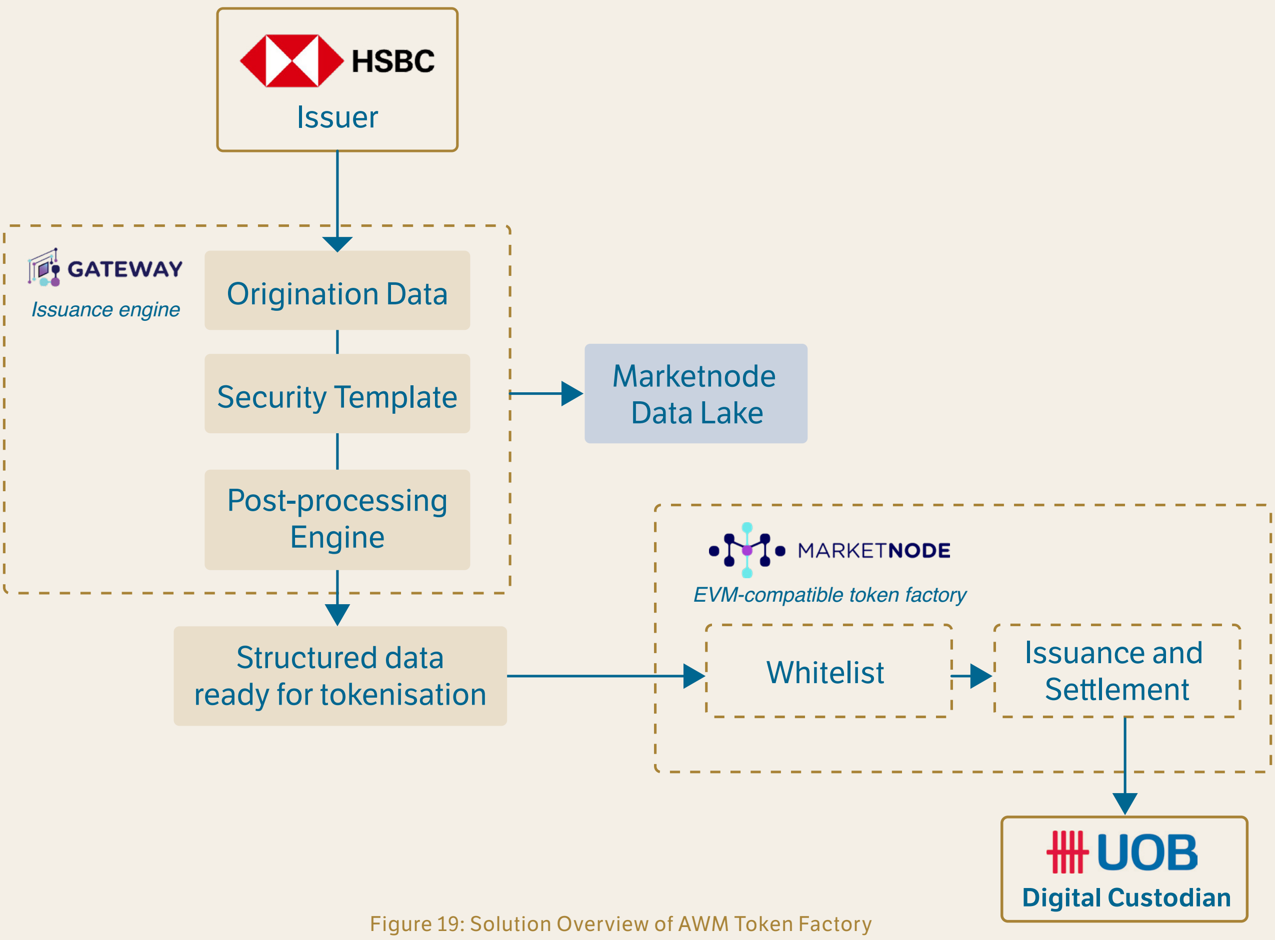


Figure 19: Solution Overview of AWM Token Factory

By utilising DLT, structured products that are created digitally can be safekept and distributed using distributed ledgers on-chain, reducing creation and distribution times.

The AWM token factory aims to achieve the following goals:

- **Digitalisation of issuance process:** The platform digitalises and automates issuance workflows, lowering issuance costs and time to create, record and distribute structured notes in a digital format.
- **Automation of lifecycle events:** The platform digitalises and automates lifecycle events such as creation, recording, coupon payments and payoff calculations to ensure a single source of truth and real-time updates to wealth managers and investors.
- **Enhancing transparency across asset lifecycle:** The platform also serves to unify participants and enhance transparency throughout the entire lifecycle of the asset, allowing access to important information such as the workflow status or movements of cash and securities during settlement, redemptions, fixing and events.
- **Business model enablement:** As a result of a lower overall cost structure and a more efficient issuance and asset servicing process, business models based around smaller issuance sizes, deeper customisability and wider distribution are now feasible. These allow issuers and wealth managers to provide greater access to products, potentially attracting greater issuance volumes through a digitally native format.

Key Roles and Responsibilities

Role	Responsibility	Participant
Issuer	Responsible for the issuance of the digital structured note under an existing medium-term note (MTN) programme.	HSBC
Arranger	Underwrites and facilitates the sale of the structured notes.	HSBC
Issuing Agent	Responsible for delivering the structured product against the proof of payment.	HSBC
Protocol Developer	• Develops AWM products' smart contracts • Enables the transfer and settlement of AWM tokens • Performs the on-chain registration, record keeping and lifecycle management of AWM tokens.	Marketnode
Registrar	Responsible for the maintenance of the register of wallet addresses and the mapping to accounts.	Marketnode
Escrow Account Manager	Manages an escrow cash account for fiat payments related to the transaction.	Marketnode
Wealth Manager	Responsible for distribution of AWM products to end investors (i.e., institutional, or accredited investors).	UOB
Digital Custodian	Provides solutions for the storage of private cryptographic keys for the tokens.	UOB

Process Overview
The digitally native structured product initiative consists of the following steps:

Issuance
1. The arranged deal terms are automatically restructured into a smart contract readable format.
2. Security tokens are automatically issued to the Issuer; and Restricted Settlement Units (RSUs) are automatically issued to the Distributor.
3. Effect the settlement transaction with atomic DvP.

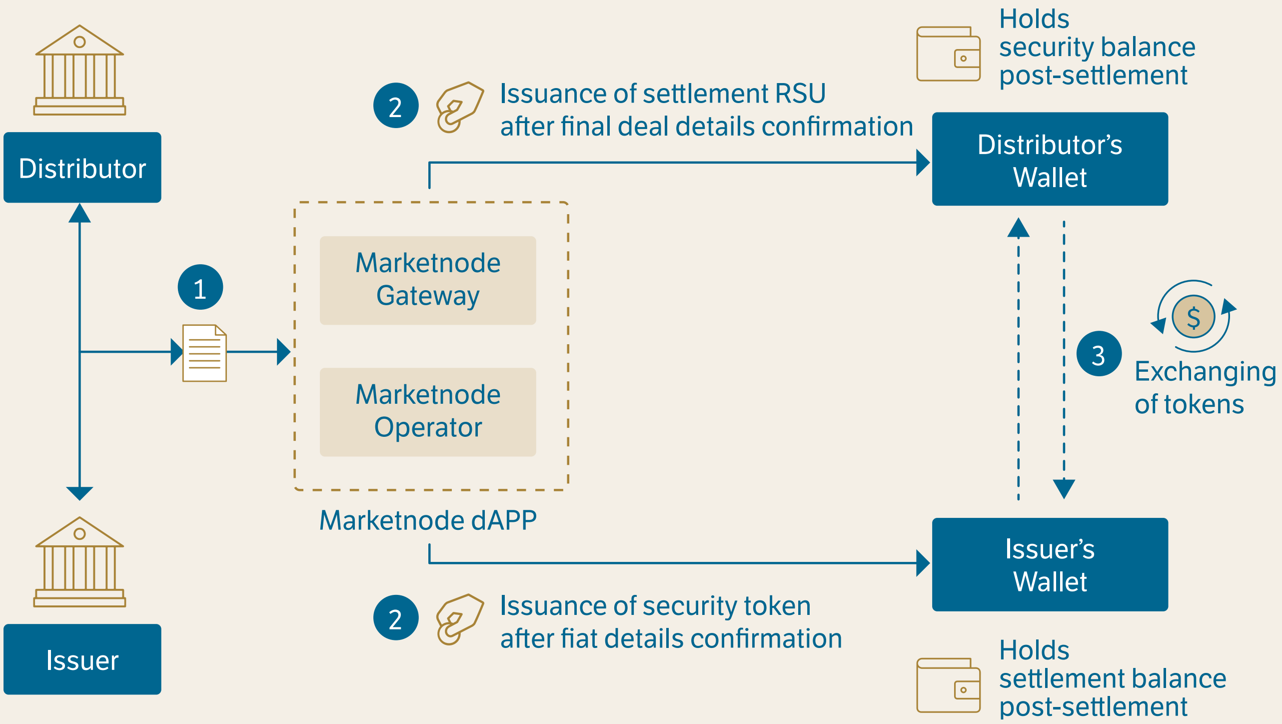


Figure 20: Issuance Cycle Flow

Registration
1. Upon confirmation that settlement will proceed, the smart contract will be automatically deployed to mint a non-fungible token (NFT) representing registration of the security.
2. The minted NFT will sit in Registrar's wallet.

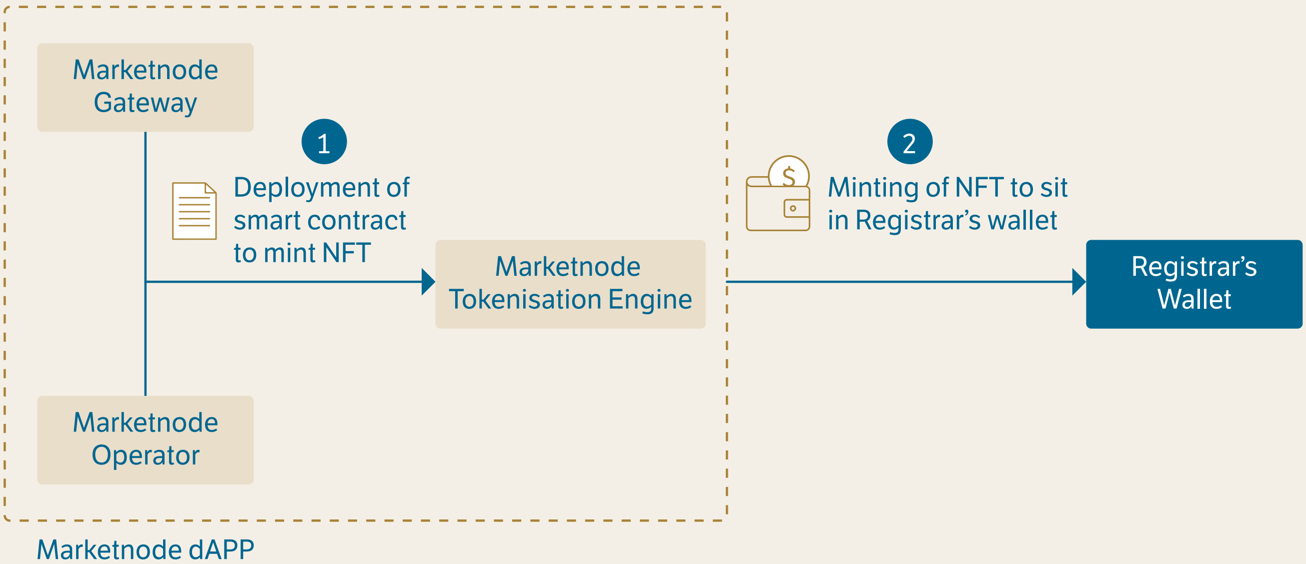


Figure 21: Registry Mechanism Flow

Coupon Payment

1. On coupon payment day, Marketnode will programmatically confirm the fiat details for the coupon payment.
2. The coupon RSU will be automatically issued after matching value in fiat.
3. Once confirmed, fiat will be released to the Distributor for payment to investors, and the corresponding security tokens are burnt.

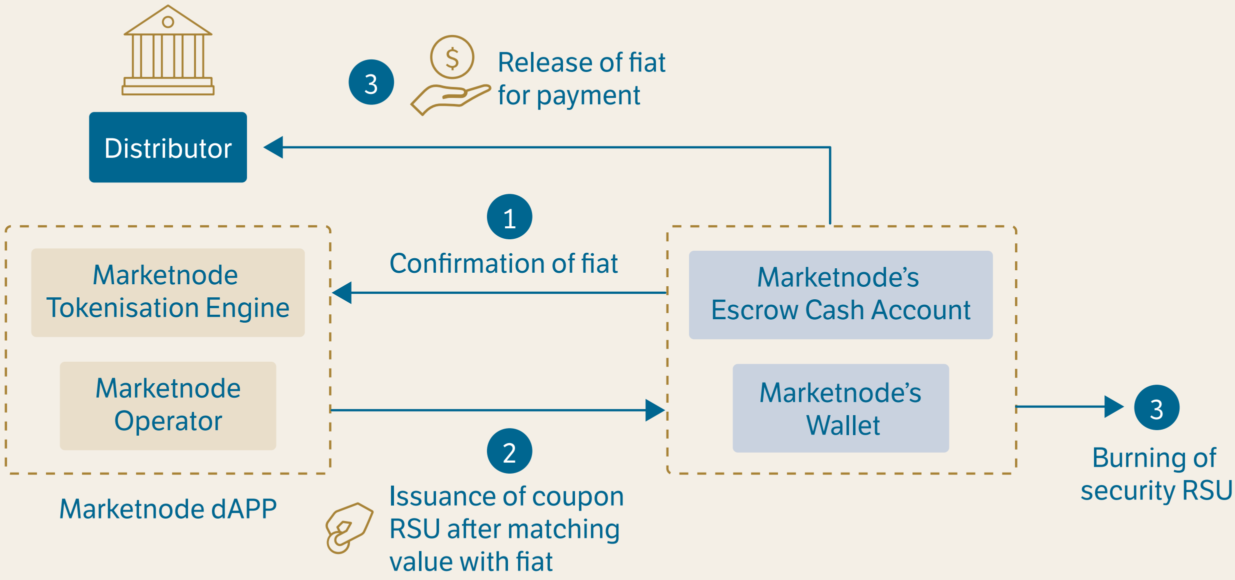


Figure 22: Coupon Payment Cycle Flow

Limitations of proposed solution

Regulatory and Legal Considerations

There is little legal precedence for digitally native securities today. For instance, greater legal and regulatory clarity on the treatment of digitally native securities as property as a first step, especially across jurisdictions, will be a key factor to promote adoption by the wider global financial ecosystem.

Operational Risks

With smart contracts, most of the operational risks such as incorrect or delayed payments, can be greatly reduced. But due to the bespoke nature of structured products, the servicing of such products can still be operationally intensive. For instance, there can still be errors when information such as pricing or duration are incorrectly inputted by the issuers into the smart contract.

Key learnings and future developments

Structured notes that are created digitally can be safekept and distributed using distributed ledgers on-chain, reducing creation and distribution times. Additionally, digital structured products in combination with the digital representation of cash could allow for atomic settlement through real-time, instantaneous DvP autonomously, thereby shortening the settlement cycle.

To ensure that the operational risks are carefully managed, a series of repeated and iterative testing on a multitude of scenarios is required. For example, the participating entity developed a platform-wide business continuity plan to cover potential platform and registrar events alongside remedial actions across various scenarios. The participating entities performed extensive quality assurance testing and multiple runs before successfully executing the issuances.

To achieve the scale and potential of the solution, the project team is contributing to industry-wide efforts to establish a set of common industry standards for asset issuance and exchange. Future integration to capabilities provided by the broader asset ecosystem will also be necessary to unlock the maximum potential of tokenisation, such as enhancing distribution via connecting to platforms such as ADDX or HSBC Orion.

8 — Conclusion

This report on enabling open and interoperable networks sought to provide a framework for considering the types and implementation of digital asset network through the core principles of financial market infrastructure. To illustrate the concept of open and interoperable networks, real world case studies and examples of solutions were provided in the report. The inclusion or exclusion of specific technologies should not be used to interpret their suitability as a financial market infrastructure.

Technological advancements and innovations in digital assets and DLT continue to develop at a rapid pace. Hence, it is possible that future technological developments and ongoing industry implementations will yield insights that will supersede the observations highlighted in this paper. Policymakers and operators will need to review the standards and practices for risk management and operational execution on an ongoing basis.

Digital asset networks may play a foundational role in a future-state financial landscape where digital assets and currencies can be exchanged seamlessly across different networks. Project Guardian continues to foster collaboration with the financial industry to ensure financial market infrastructure serves the needs of market participants, ensures financial integrity, and maintains financial stability. Future areas of exploration as part of the Project Guardian report will encapsulate the other focused themes of Trust Anchors and Institutional DeFi.

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10 — Acknowledgements

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