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Project Samara Research Paper

Bank of Canada
Rakesh Arora, Umar Faruqui,
Scott Hendry, Dinesh Shah
and André Usche

RBC
Alex Caridia, Chris Meston,
Teresa Venturino and Devon Read

TD
Mark Byrne, Caroline Cook,
Kevin Fraites and Wally Forsyth

EDC
Chadrick Buffel, Anne Boulanger,
Sylvie Lacombe and Marsha Loraas

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Executive Summary

Project Samara is a collaborative initiative between the Bank of Canada (BoC); RBC Capital Markets (RBC); RBC Investor Services Trust (RBC IS); TD Securities, a division of The Toronto-Dominion Bank (TD); and Export Development Canada (EDC). Project Samara evaluates how distributed ledger technology (DLT) can improve bond issuance, settlement and life-cycle management. The Project tested the feasibility and implications of a DLT-based platform for capital markets, using a Canadian dollar–denominated tokenized bond issued by EDC and settled in wholesale central bank digital money (W-CAD).

The Samara Platform was designed to support end-to-end transaction workflows—including primary issuance, secondary trading and life-cycle events—on a permissioned DLT infrastructure. Built using Hyperledger Fabric, the platform integrates separate bond and cash ledgers and enables atomic settlement through smart contracts and interledger protocols.

The issuance stage of the experiment revealed both the potential benefits and limitations of DLT in a real-world financial setting:

- Efficiency gains: Automation, reduced reconciliation and same-day (T+0) settlement improved operational efficiency. A single source of truth enhanced the integrity of data and streamlined workflows across participants.
- Operational and governance complexity: Efficiency gains were partially offset by greater system complexity, higher liquidity costs (due to pre-funding requirements) and the need to develop and implement new governance structures. Decentralized architecture created challenges for coordination, reporting and platform oversight.
- Risk management: Atomic delivery versus payment (DvP) across independently governed ledgers reduced counterparty and settlement risk but introduced new operational risks related to key management, auditability and fallback mechanisms that require mitigation.
- Regulatory and legal considerations: Close engagement with regulators of capital markets was required to address issues such as legal status, custody arrangements and compliance frameworks. The expectation for centralized roles—such as a marketplace operator, custodian and reporter—highlighted gaps between the current regulatory framework and DLT principles.
- Adoption barriers: Despite it being technically feasible, high infrastructure costs, integration challenges and market participants' reluctance to make changes to core infrastructures may affect broader adoption. Market uncertainty about the technology demonstrates the need for an ongoing role for central authorities or intermediaries.

Overall, Project Samara provided valuable insights into the practical application of DLT in capital markets. Although the technology shows promise for improving efficiency and resilience, its benefits remain uncertain. Due to the nature of a limited experiment involving the issuance of a single security to a closed investor group, the net impact remains uncertain. Additional experimentation, regulatory clarity and market engagement will be essential to determine whether DLT can deliver meaningful transformation in financial infrastructure.

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1. Introduction and Project Scope

1.1. Background

Secure value transfer is foundational to modern financial markets, spanning activities from securities trading to cash payments, and is typically facilitated by intermediaries for a fee. Despite decades of operational experience and refinement, inefficiencies and risks persist, revealing clear opportunities for improvement. For example:

- transaction costs remain elevated due to the layered involvement of intermediaries in execution, settlement, and custody, increasing both operational risk and reporting burdens;
- bond and cash settlements are not fully integrated, relying instead on separate systems and multiple interfaces;
- the institutional complexity and number of actors involved remain high, even as other areas have seen efficiency gains and reduced complexity (see Figure 1).

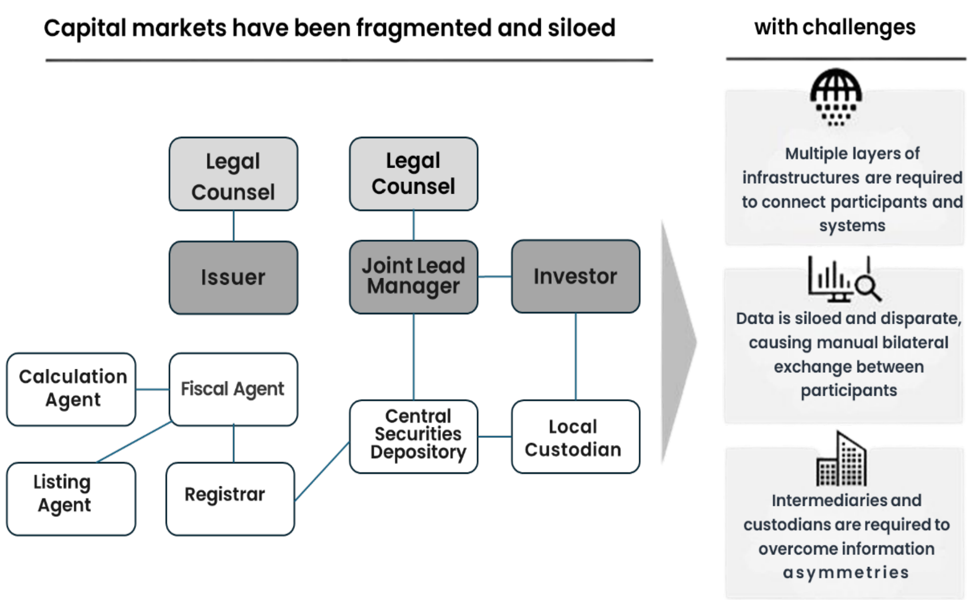

Figure 1: Challenges in the Debt Capital Markets

Knowledge of how emerging technologies can enhance capital markets infrastructure has advanced rapidly in recent years. DLT, in particular, is seen as a promising tool for improving efficiency by synchronizing ledgers across participants and automating complex, multi-party workflows.

A substantial body of academic and policy work has examined the role of DLT, cryptocurrency and tokenized central bank money in financial transactions. According to the 2023 survey by the Bank for International Settlements, 94% of 86 central banks were researching, experimenting with, developing, piloting, or operating a retail or wholesale central bank digital currency (BIS, 2024). Some of this work also involved exploring the potential for DLT innovations to improve payment and securities settlement at the wholesale level.

The BIS Innovation Hubs have been actively looking at potential improvements in cross-border payments (see for example, Projects Nexus). At the same time, the Swiss National Bank (Project Helvetia and its work with the SIX exchange) and the Banque de France have been advancing real-world experiments and pilot programs.

The BoC has been a pioneer in this field, having engaged in public-private partnerships on a multi-phased financial technologies experiment (Project Jasper) since 2016.[1] Its primary focus was to investigate opportunities leveraging DLT to support settlement and promote innovation in the payment and financial market infrastructure ecosystem. Early phases, conducted in partnership with Payments Canada, R3, Accenture and a selected set of Canadian commercial banks (including RBC and TD), focused on interbank payments and securities settlement. In later phases of the work, the BoC partnered with the Monetary Authority of Singapore and the Bank of England to work on cross-border, cross-currency settlement. That joint collaboration combined Project Jasper and Singapore's Project Ubin to explore faster, lower-cost international payments.[2]

Building on the Project Jasper series of experiments, BoC, commercial banks (TD and RBC), and EDC joined together (the "Consortium") to launch Project Samara (the "Project").

The Project involved the development of a consolidated DLT-based platform comprising: (i) the issuance by EDC in Canada of a Canadian dollar bond that was created, traded and managed throughout its life cycle in a legally valid manner, and (ii) atomic settlement of trades of such bonds in W-CAD. Currently all this functionality is spread across several platforms and intermediaries. Combining functionality (in this case primary market issuance, secondary market trading, life-cycle event management, and post-trade clearing and settlement) into a common platform is one of the primary benefits of the DLT movement. The W-CAD, issued by BoC, is only accessible by the banks and wholesale

[1] Project Jasper was the first time in the world that a central bank participated in a distributed ledger technology ("DLT") experiment in partnership with the private sector. This collaborative research initiative between the public and private sectors aims to understand how DLT could transform the wholesale payments system. For more information on this multi-phased W-CAD exploration, see https://www.bankofcanada.ca/research/digital-currencies-and-fintech/projects/.

[2] Jasper-Ubin Design Paper: Enabling Cross-Border High Value Transfer Using DLT, May 2019

investors authorized to participate on the permissioned private capital markets platform.[3] The platform is composed of the cash ledger and the bond ledger, collectively referred to as the "Samara Platform."

1.2. Project Rationale

Project Samara examines the integrated use of DLT-based tokenized assets and digital currency across bond issuance, securities settlement, and life-cycle management. As part of the initiative, EDC issued a Canadian dollar–denominated (CAD) bond governed by Canadian law using DLT, with payments settled in a W-CAD issued by the BoC specifically for this transaction. The bond was sold and traded and will be managed throughout its life cycle on the Samara Platform, which combines both cash and bond ledgers.

The Project also explores secondary market functionality—including market-making and request for quote (RFQ) workflows—to assess the platform's capacity to support key features of a well-functioning market. More broadly, Project Samara aims to deepen understanding of DLT's potential impact on capital markets and payment infrastructure.

Project Samara builds on several exploratory digital innovation initiatives led by its participants:

- For BoC, Samara continues the research initiated under Project Jasper in 2016 to understand the value proposition and consequences of DLT in the financial system. While previous phases confirmed DLT's technical viability for capital market transactions, Project Samara provides a production-level test of its potential advantages over existing systems in terms of cost, efficiency, governance, and risk. It may also help to better identify and understand barriers to broader adoption of decentralized DLT based systems beyond the cryptocurrency space.
- For RBC, as a joint lead manager (JLM) and bond lender platform operator, Samara follows RBC's participation in Project Jasper and the World Bank's Project Bond-I (World Bank, 2018a,b) and adds experience from its role in the European Investment Bank's 2023 digital bond issuance denominated in pounds sterling.
- For TD, as a JLM, Samara builds on TD's involvement in Project Jasper, Project Bond-I with the World Bank (World Bank, 2018a,b), its role in the inaugural digital native note issuance on Euroclear's "Digital Financial Markets Infrastructure" with World Bank in 2023, and BIS Innovation Hub experiments into the Regulated Liability Network and the new Project Agora, which explores how tokenization can enhance wholesale cross-border payments.

[3] Open systems are those that accept all interested entities that have the technical ability to participate. Closed or permissioned systems have additional membership criteria that must be satisfied for an entity to be permitted to operate a node (Mills et al., 2016).

- For EDC, as issuer, Samara represents an opportunity to participate and contribute to the development of DLT and digital currency. It also provides an opportunity to understand the nuances and the possible risks involved in the new platforms being developed worldwide. Full engagement and direct issuance bring about a strong focus on all aspects of the securities life cycle and examines the benefits and challenges that new technologies can bring.

1.3. Market Overview: Participant Challenges and Potential Benefits

The overarching objective of the Consortium members was to deepen their understanding of the potential benefits and challenges of using DLT in financial market clearing and settlement. One potential benefit of a distributed infrastructure model based on a common source of truth disseminated across participants is the possibility of reducing the risks posed by single points of failure that are inherent in centralized systems. Another potential benefit is a reduction in the fragmentation of capital markets and their relative inefficiency due to separate, non-standardized systems that give rise to unexpected costs, delays, and risks. Separate systems in the traditional space often require complex, time-intensive coordination to achieve secure settlement, typically measured in days. The resulting complexity has created a costly chain of intermediaries and infrastructure that are required to overcome information asymmetries, manage investments, and connect disparate systems.[4] Decentralized systems that interoperate well, especially if they can execute atomic transactions across component sub-systems, may reduce types of failure that could lead to broader market-wide shocks in the event of a crisis.

In capital markets more broadly, blockchain technology is widely expected to reduce fragmentation and complexity, thereby lowering operational risks, delays, and costs. Figure 2 outlines both the theoretical benefits of large-scale DLT adoption and the specific expectations of Project Samara participants.

[4] There are additional potential benefits of a decentralized model, including greater transparency and easier auditability.

Issuers	Issuers may get lower cost execution, increased efficiency, faster time to fund, investor insights, real-time market feedback on debt supply and secondary market liquidity.
Investors	Investors get access to a comprehensive view of the debt market investment opportunities, with built-in analytics, treasury and custodial services.
JLM / Dealers	JLMs/dealers get access to a more efficient tool to orchestrate and manage primary issuance processes, thus reducing capital cost associated to execution, settlement and operational risks.
Market Makers	Market makers benefit from digital nature of such marketplace, which can enhance price discovery and visibility; this can lead to an ecosystem with deeper liquidity and reduced risks.
Custodians	Custodians will have access to a ubiquitous market utility that allows for efficient custody services across multiple jurisdictions, asset classes and currencies.
Regulators Central Banks	Access to comprehensive real-time market activity delivers efficient and effective regulatory oversight and control.

Figure 2: Potential benefits of DLT compared to the current organization and functioning of capital markets from a practitioner's perspective

The short and long-term expected or potential benefits for the participants can be summarized as follows:

Issuers may benefit from faster settlement times, reduced reconciliation efforts, and fewer settlement discrepancies. Additional potential advantages include lower execution costs, improved funding timelines, and real-time insights into investor behavior and market conditions.

The BoC gains a controlled environment to evaluate the practical implications of a W-CAD and blockchain-based securities settlement. Key areas of focus include settlement mechanics, large value payment efficiency and security, legal frameworks for digital platforms, and applications such as programmable payments using smart contracts.[5]

JLMs could see gains through real-time market making, streamlined regulatory reporting, reduced book-building delays, reduced back-office reconciliation, and real-time settlement.

Investors are expected to benefit from self-custody capabilities, enhanced visibility into debt market opportunities, and integrated treasury and custodial services.

Regulators may gain access to better information, enabling more effective oversight. The distributed nature of blockchain technology would also potentially improve operational resilience of the platform, a clearly desirable feature for systemically important systems.

At a broader level, DLT is supposed to offer a globally trusted ledger without relying on a central authority, opening the door to new business models and operational paradigms in capital markets.

1.4. Project Samara Objectives

The Project tested four hypotheses related to the use of native digital assets and W-CAD in a real-world capital markets transaction:

a) Efficiency Gains: DLT has the potential to reduce operational, execution, and administrative (such as reconciliation and reporting) costs across all participants, including central banks, issuers, investors, JLMs and regulators.

b) Risk Mitigation: Atomic settlement and the elimination of physical documentation and wet signatures may help reduce operational risk across the transaction life cycle.

c) Market Innovation: DLT could enable new business models by lowering barriers to entry, increasing competition, and tightening integration between primary and secondary markets.

d) Enhanced Settlement Infrastructure: DLT-based cash settlement using W-CAD may offer significant advantages over existing payment rails by ensuring settlement finality[6] and accelerating transaction timelines for wholesale market participants.

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[5] Smart contracts and programmable payments refer to computer code that will automatically execute on the blockchain once certain prespecified conditions are met.

[6] Settlement finality refers to the point at which a transfer of funds or securities becomes irrevocable and unconditional, meaning that the transaction is complete and cannot be reversed.

Project Samara was structured as a limited experiment, involving the issuance of a single security to a closed investor group. Any assessment of its benefits relative to traditional bond issuance in Canada therefore remains preliminary and largely illustrative of potential future outcomes if DLT-based systems were to be adopted more broadly.

Given its scope, the Project did not address all theoretical advantages of DLT and W-CAD in large-scale capital markets. For example, it did not incorporate full interoperability with existing payment and accounting systems, automated sanctions screening, fraud detection, or integration with external data sources, such as oracles.[7] Similarly, client interactions with correspondent banking channels remained unchanged.

1.5. Potential Cost Savings

In terms of potential operational cost savings for network participants, Figure 3 outlines some potential areas where savings could be realized by having the full life cycle of the bond on a single DLT platform.

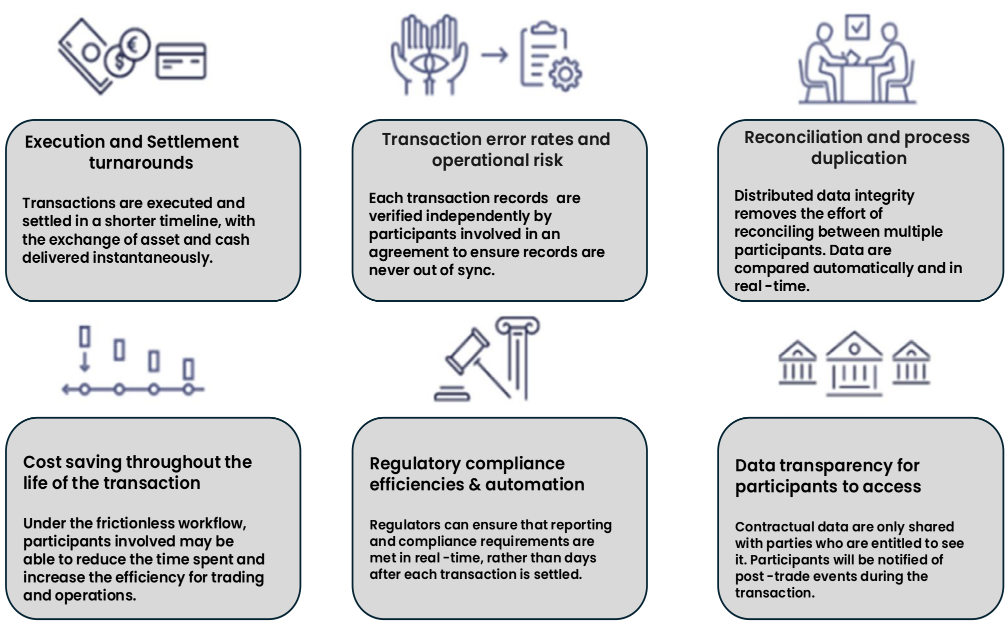

Figure 3: Potential savings for participants

[7] Blockchain oracles are entities that connect blockchains to external systems, thereby enabling smart contracts to execute based upon inputs and outputs from the real world.

2. Proposed Financial Transaction

2.1 Overview of Transaction Based on DLT: Primary Market

A transaction flow is provided below in Figure 4 to describe the difference between the conventional CAD bond and the Samara bond.

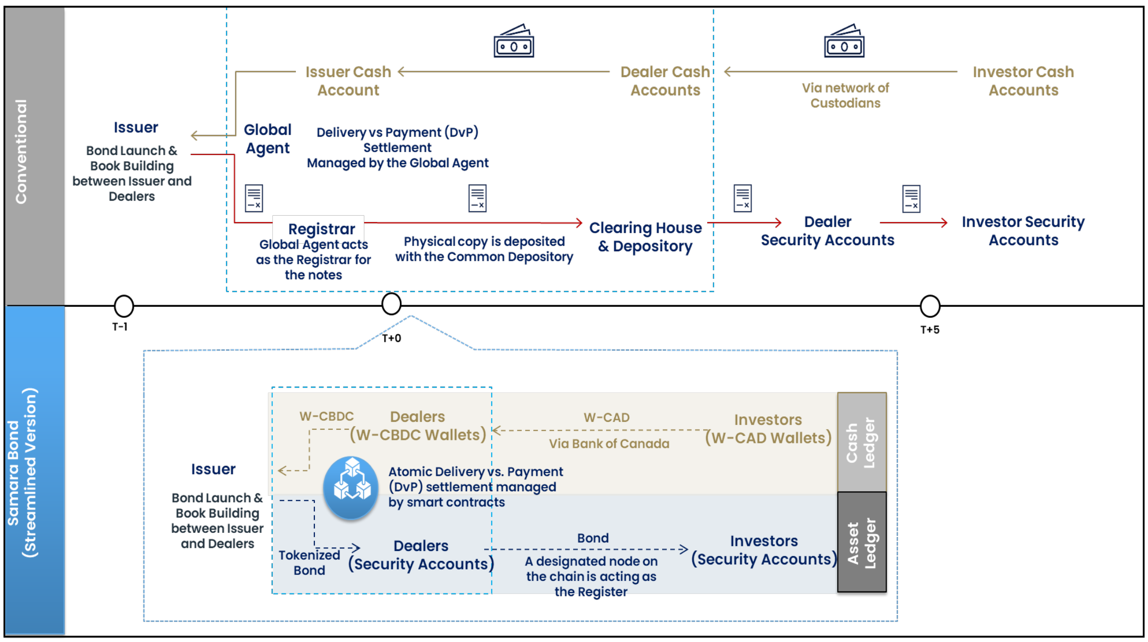

Figure 4: Conventional CAD Bond vs. Samara Bond Issuance Process

2.2 Comparison Between a Traditional Canadian Bond and the Samara Bond

This section outlines the key differences between the Samara bond issuance and a bond issuance in the Canadian market (see Figure 5). Traditional CAD bond issuance is a complex, manual process involving multiple intermediaries—such as a registrar, fiscal agent, paying agent and transfer agent, clearing house, central securities depository (CSD), custodians, and one or more dealers, legal counsels, and agents—operating on different systems to authenticate and deposit signed notes. Due to legal documentation and settlement procedures, the process typically requires 3 to 5 business days (T+5) to complete.

In the Samara bond issuance, the use of tokenized securities, W-CAD, smart contracts, and an interledger protocol enabled same-day (T+0) settlement. This approach eliminated the need for many intermediaries, reducing execution and administrative costs. Atomic DvP occurred shortly after bond creation. The roles of registrar, fiscal agent, paying agent and transfer agent, clearing house and CSD were replaced by the platform operator and its node, which served as the authoritative record of the issuance and associated settlements.

Real-time data access reduced the need for reconciliation, and the shortened settlement cycle with atomic DvP reduced settlement risk.

	Traditional Issuance	Samara Issuance
Number of Parties Involved	**Multiple Players Working on Different Systems:** • Issuer, Dealers, Investors, Paying Agent, Registrar, Common Depository, Clearing House, Multiple Custodians, and Regulators	**Streamlined Participation:** • Issuer, Dealers/Investors, Central Bank, and other Regulators (each may hold a node on the DLT platform
Number of Steps	**Manual & Time Intensive Multiple-Step Issuance Processes:** • Manual due diligence during bond launch, creation etc. • Physical copy of the bond is deposited with the common depository • Settlement occurs via a layer of custodians operating in different time zones	**Simplified & Efficient Processes:** • More automated issuance process • Digitized workflows using smart contracts allow automated and efficient settlement process
Documentation & Record Keeping	**Complex & Time-Consuming Process:** • Manual steps involved in drafting and finalizing a long list of legal documents that contribute to a long settlement cycle • Time-consuming reconciliation process among participating systems	**Automated Documentation on a Single Platform:** • Final term sheet can be generated, approved and shared on the platform on issuance date • One single version of bond records removes the need for reconciliation
Time	**Long Clearing & Settlement Cycle (T+5 or more):** • Settlement cycle can take up to 10 days depending on the legal documentation and settlement setup requirements	**T+0 Settlement:** • Streamlined issuance and settlement processes enable a same-day atomic DvP settlement
Transparency & Risks	**Less Transparency leading to more risk:** • Less transparent with limited audit trail due to the involvement of Intermediaries and multiple systems • Potential operational and counterparty risk due to the long and complex settlement processes	**Increased Transparency with reduced risk** • Increased transparency and immutability in transaction record keeping • Automation and improved settlement cycle reduces operational and counterparty risks

Figure 5: Structural differences between CAD Bond and Samara Bond

3.0 Samara Operational Framework

This section outlines the operational framework of the Samara Platform and discusses details related to the primary and secondary markets, coupons and redemption, and risk controls.

3.1 Operational Expectations

Project Samara explores how DLT can streamline and automate operational tasks, enhance communication workflows, and reduce processing times compared to the current systems used in Canadian bond issuance. The Project also examined potential operational benefits such as reduced reconciliation needs through a single, shared ledger; improved data governance via distributed nodes; fewer market intermediaries; and automated reporting capabilities.

This section focuses on key operational considerations, including:

- the impact of DLT on settlement mechanics of digital securities, including timing and the benefits of DvP,[8] using W-CAD;
- the effects on the security and efficiency of large-value payments in bond markets;
- the implications for oversight of payment, clearing, and settlement systems;
- enhancements to payment monitoring capabilities; and
- changes to workflow procedures for various bond market events.

3.2 Primary Market Bond Issuance

The bond issuance process involves a series of multi-party workflows that must be carried out in sequence to complete issuance and settlement. Project Samara aimed to demonstrate how these workflows could be streamlined and automated using DLT. The Samara Platform supports most primary issuance steps on-chain, with the exception of certain pricing and legal documentation tasks, which still require manual input and document uploads to the platform's repository.

In contrast to conventional CAD bond issuance, Samara integrates key multi-stakeholder processes—such as term sheet generation, deal announcement, book-building, bond allocation, settlement instruction set-up, and atomic settlement (DvP) in central bank money into a single platform. All participants can be onboarded to the platform directly, reducing the need for bilateral reconciliations and manual validations at each step. The

8 Glossary___Committee on Payments and Market Infrastructures, BIS: https://www.bis.org/cpmi/publ/d00b.htm?selection=26

platform also minimizes reliance on off-chain artifacts like email confirmations, contributing to a more streamlined and efficient process.

A detailed comparison between the traditional and Samara issuance workflows is provided in Appendix I.

3.2.1 Primary Market Settlement (T+0)

In the Canadian debt securities market, the standard settlement process typically takes 5 business days following the trade date, including clearing and settlement of the bonds in CDS and the final settlement of payments through designated bankers and the Lynx system, ultimately settling at the BoC. In contrast, the Samara Platform enables same-day (T+0) settlement within a DLT-based environment, allowing for the direct real-time exchange of digital bonds and W-CAD. This improves record keeping and significantly reduces settlement time while enhancing controls related to review, confirmation, and approval—key elements in mitigating operational risk (see Section 5.6).

The Samara settlement workflow is divided into on-chain and off-chain components. On-chain activities—executed and recorded on the Samara blockchain—include the bond launch, book-building, allocation, and atomic DvP. Off-chain activities, such as issuer-JLM negotiations, investor coordination, pricing calls, and final documentation, occur outside the platform. A summary of both workflows is provided in Appendix II.

All transactions on the Samara Platform are settled on a real-time gross basis using DvP Model 1, eliminating intra-day credit and counterparty risk. One drawback of DvP Model 1 is that it may increase liquidity costs for participants. While netting mechanisms have been explored in other DLT initiatives (e.g., Project Jasper Phase 2 and Project Ubin Phase 2), they were not implemented in Samara. Further research is needed to evaluate the trade-offs between reduced settlement risk and increased liquidity demands.

3.2.2 Atomic Swap (Bond vs. Cash DvP)

The Samara Platform enables atomic DvP settlement, where digital bonds and W-CAD are exchanged instantaneously using a Hashed Time Lock Contract (HTLC) protocol (see Figure 6). Smart contracts on the bond and cash ledgers coordinate the validation and execution of key tasks, including account balance verification, transaction validation, bond creation in the issuer's account, ownership confirmation, and execution of the asset exchange.

The settlement process occurs in two sequential stages. In Stage 1, the issuer delivers the bond to the settlement bank—one of the JLMs—which also acts as the billing and delivery (B&D) agent. In Stage 2, the B&D JLM delivers the bond to the allocated primary market investors. This two-step atomic DvP process ensures secure and efficient settlement across all parties.

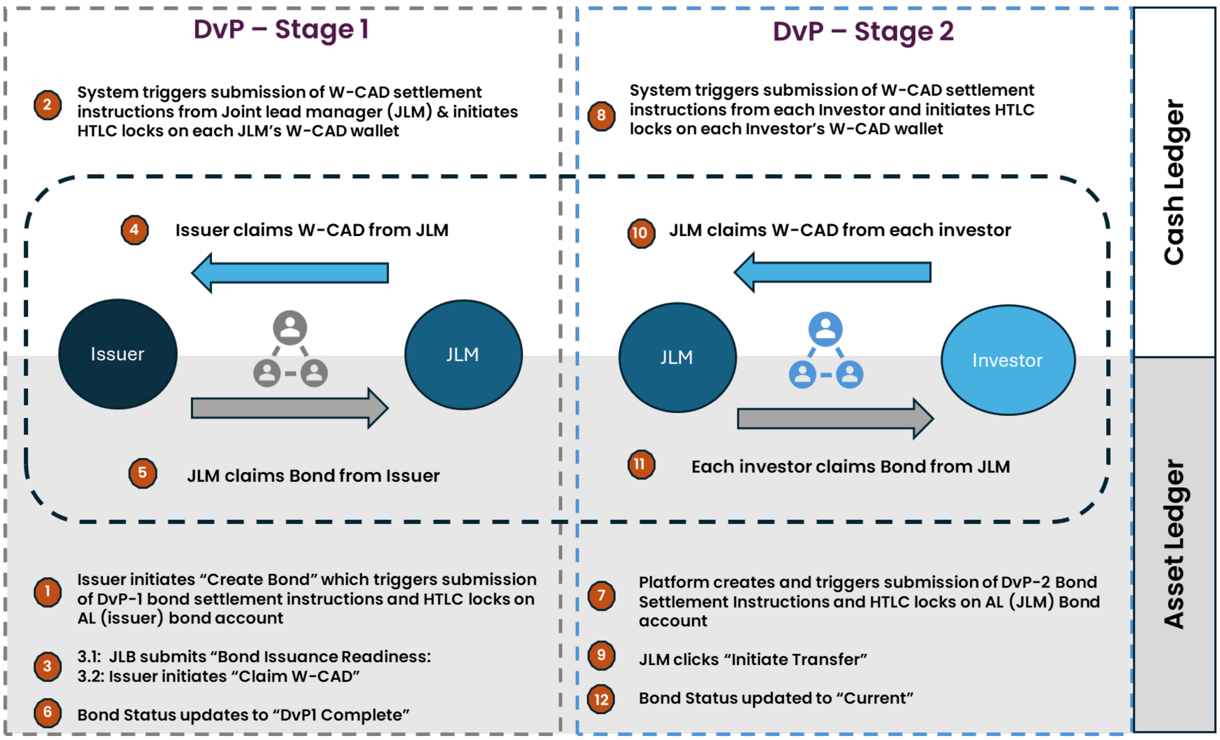

Figure 6: Samara DvP Workflow

3.3 Secondary Market Transactions

A key feature of the Samara Platform is its support for secondary market trading and settlement of digital securities directly on-chain. The platform enables investors to initiate RFQs, allows market makers to respond, and facilitates trade execution and settlement through smart contracts and the HTLC protocol. Upon execution, bond holdings are updated in real time.

To participate in secondary market transactions, users must pre-fund their wallets with sufficient W-CAD to ensure successful atomic DvP settlement. Unlike traditional platforms, Samara eliminates the need for post-trade workflows or dedicated settlement operations, enabling same-day (T+0) settlement and significantly reducing processing time.

3.4 Post-Issuance Life Cycle

3.4.1 Coupon and Redemption Payments

3.4.1.1 Record Date—Achieving a shorter cut-off for payments

For the Samara bond, coupon and redemption payment workflows begin one business day before the settlement date—significantly shorter than the conventional 4–5 business day lead time typically required for payment confirmations with agents and intermediaries. The platform uses a record date cut-off, set at 5:00 PM Eastern Time, to capture a snapshot of bondholders and automatically generate payment instructions based on their holdings. Coupon amounts are calculated using standard Canadian market conventions.

The Samara Platform facilitates seamless coordination between the bond and cash ledgers, providing real-time visibility into payment status for all participants, including the issuer, investors, and JLMs.

3.4.1.2 Payment Schedule

The Samara bond is structured as a fixed-rate coupon instrument, with its full payment schedule—covering both coupon and redemption events—available immediately after primary market settlement. This schedule is accessible to all parties involved, including the issuer, primary market investors, and JLMs, via their respective dashboards on the graphical user interface for the bond ledger. Investors who acquire the bond through secondary market transactions can also view the relevant payment schedule for their holdings upon successful trade execution.

3.4.1.3 Payment Instructions

Once the record date cut-off is reached, the platform automatically generates payment instructions, which are made available for review through the payments schedule menu on the bond ledger user interface. The issuer can review and validate these instructions and is responsible for ensuring that its W-CAD wallet is sufficiently funded before the settlement date. Investors can also view their respective payment instructions for upcoming coupon or redemption entitlements based on their holdings.

3.4.2 Bond Maturity

Once the final coupon and redemption payments are successfully processed on the scheduled maturity date, the bond ledger automatically updates the bond's status to "matured," confirming the completion of all issuer obligations. This update is triggered by an automated batch process scheduled for 5:00 PM Eastern Time on the maturity date.

The Samara Platform is designed to handle various maturity scenarios, including those falling on weekends or holidays, by applying multiple bond status indicators such as "settled" or "yet to be settled." These ensure accurate tracking and continuity across different conditions.

All participants—issuers, investors, and JLMs—can view the bond's maturity status on their respective dashboards. The platform also issues timely dashboard and email notifications to keep all parties informed without disrupting workflow.

3.5 Operational Controls

During the design and implementation of the Samara Platform—across both the bond and cash ledgers—a range of operational controls were established to mitigate risk. These include due diligence during user onboarding, acknowledgment of platform rules, segregation of duties, and a four-eye (maker-checker) validation process. Additional safeguards, such as audit trails, system notifications, and platform-generated reports, support oversight throughout the bond issuance life cycle.

The Consortium also implemented business continuity processes to address potential disruptions, with mitigation strategies tailored to different failure scenarios.

While Samara remains an experimental platform, and some risks may emerge due to the novelty of the technology, these operational controls and continuity measures are designed to reduce exposure and maintain platform integrity.

3.5.1 Platform Operator Roles (Bond Ledger and Cash Ledger)

The Samara Platform design includes a designated super-user role—referred to as the platform operator—for each of the bond and cash ledgers. The platform operator serves as the central point of contact for all platform functions within their respective ledger, overseeing user onboarding, managing workflow execution, and supporting error resolution and validation processes.

3.5.1.1 Bond Ledger—Platform Operator

On the bond ledger, a dedicated business unit within RBC—separate from its role as JLM—serves as the platform operator to ensure segregation of duties and avoid conflicts of interest. The bond ledger platform operator is responsible for:

- onboarding participants, including the issuer, JLMs, and investors, including by granting access to the bond ledger through a secure UI
- accessing payment instructions and other read-only data related to issuance, coupons, and redemptions

- executing specific functions to support manual interventions if system errors or exceptions occur, subject to consultation with, and agreement by, the issuer, such as:
  - manually generating coupon or redemption payment instructions if the automated batch process fails
  - transferring bond ownership in the event of an interruption during atomic DvP settlement
  - updating bond status to "Matured" if the automated process does not complete as scheduled
  - submitting payment instructions on behalf of the issuer in cases of system access issues

3.5.1.2 Cash Ledger—Platform Operator

On the cash ledger, a designated unit within the BoC—issuer of W-CAD—acts as the platform operator. The cash ledger platform operator has read access to user-level transactions and is responsible for:

- validating and approving W-CAD minting (settlement balances to W-CAD) and withdrawal (W-CAD to fiat) requests from onboarded institutional cash wallet users
- overseeing transaction activity within the cash ledger for audit and regulatory compliance
- managing administrative tasks, including the onboarding of new institutions to the cash ledger, including by granting access through a secure UI

3.5.1.3 Platform Administrator

The Consortium selected IBM Canada Limited ("IBM") as the technology service provider to develop the Samara Platform in accordance with their specifications. Having developed the Platform, IBM was well-positioned to provide cloud and node administration services (in this capacity, the "platform administrator") with respect to both the bond ledger and the cash ledger.

The Samara Platform was designed to permit participants to select their own technology providers for cloud and node administration. However, for the purposes of this experimental bond issuance, IBM was selected as both the cloud and node administrator for most of the nodes on both the bond ledger and the cash ledger. IBS was also selected to secure the cryptographic keys that control the movement of bonds and W-CAD on each ledger.

If a participant wished to execute a transaction on the platform, the participant's authorized user transmitted its instructions through the bond ledger UI, which automatically mapped the transaction instructions received to the key(s) to that participant's on the bond ledger. RBC, as bond ledger platform operator, did not intermediate this process and therefore had no opportunity to prefer certain orders. While RBC was ultimately responsible for supervising the platform administrator in its role as custodian of the private keys to bond ledger wallets, the execution of transactions on the bond ledger was conducted by authorized users on behalf of each participant directly through the bond ledger UI, without the intervention of the platform operator or platform administrator.

3.5.2 Cash Ledger Account Set-up, Funding, and Withdrawal

W-CAD wallets on the Samara Platform are funded through participant payments made via the Lynx real-time gross settlement (RTGS) system to the BoC (see Figure 7). Upon receipt of funds in its High-Availability Banking System (HABS), BoC operators credit an internal suspense account designated for W-CAD minting. In a separate manual step, an equivalent amount of W-CAD is issued to the participant's wallet on the cash ledger.[9] Participants receive notifications of balance updates and can monitor their W-CAD holdings in real time through the Samara cash ledger UI.

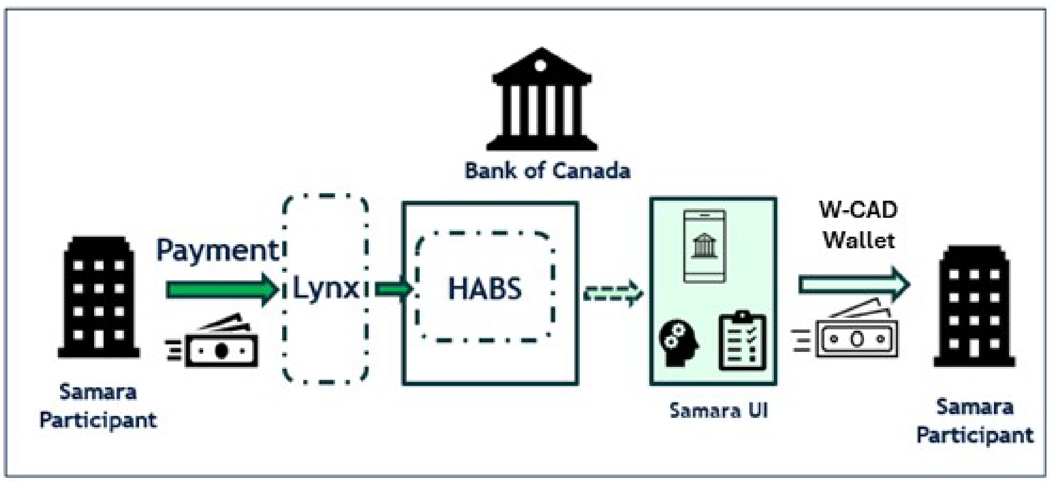

Figure 7: W-CAD Minting Process for Samara Participants

Provided that funds are not locked for an in-progress transaction, participants may initiate a withdrawal of W-CAD from their wallets on the cash ledger at any time (see Figure 8). This functionality allows users to convert their W-CAD balances back into settlement balances for transfer elsewhere. Withdrawal requests are submitted through the cash ledger UI and, once fully authorized within the Samara Platform, the BoC operations team manually initiates the corresponding outgoing Lynx payment.

[9] If the Samara Platform were to move past the experiment stage, then the funding and defunding processes could be fully automated to remove the risks of manual interventions.

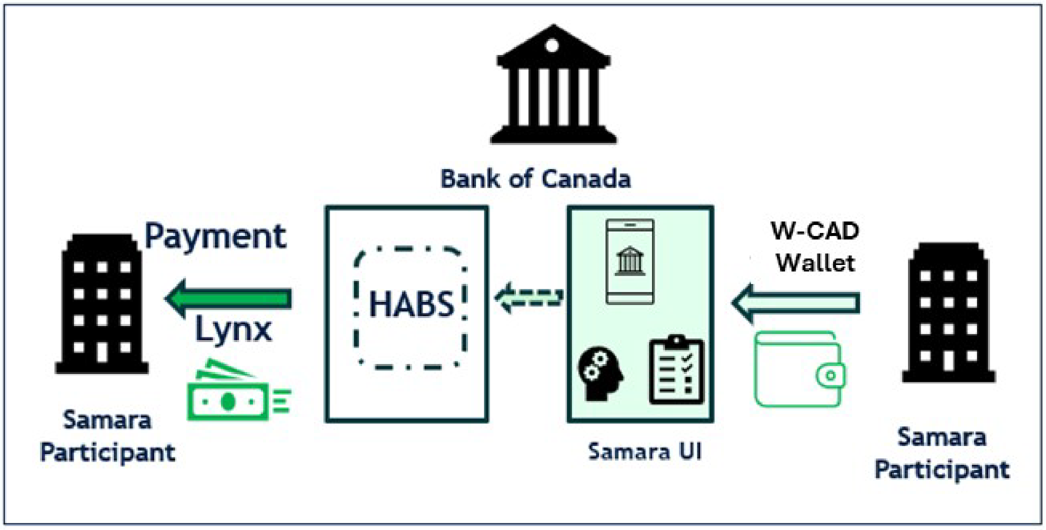

Figure 8: W-CAD Withdrawal Process for Samara Participants

3.5.3 Platform Notifications

Notifications are a key control mechanism on the Samara Platform, designed to inform relevant users of critical events and milestones related to bond issuance, life-cycle payments (e.g., coupons, redemptions), payment statuses, secondary market activity, and administrative actions such as user onboarding and profile updates.

The platform incorporates intelligent checks to detect and flag system or user-generated errors. For example, in the event of a payment failure due to business reasons (e.g., insufficient wallet funds or incorrect settlement instruction details), the bond ledger promptly alerts the relevant participants (e.g., issuer or investor back-office) via on-screen and email notifications. This facilitates prompt investigation and resolution, enabling participants to re-submit instructions without workflow disruption.

3.5.4 Risk Management, Manual Interventions and Controls

During platform development, the Consortium identified key risks that could impact workflow and implemented targeted controls to mitigate them:

Settlement Risk

As a principal risk, settlement risk is addressed through account validation and the use of HTLC within smart contracts for DvP transactions. These smart contracts ensure the presence of sufficient funds or bond quantities in participant accounts and validate settlement instructions prior to execution.

Operational Risk

The Samara Platform's integrated bond life-cycle management, supported by embedded checks and controls, significantly reduces operational risk across platform processes.

As part of its risk management framework, the Samara Platform incorporates robust manual intervention controls through a suite of mitigating actions that can be executed by the bond ledger platform operator, subject to consultation with and agreement by the issuer, if system errors occur. This capability is a key differentiator of the platform (for examples, see section 3.5.1.1).

3.5.5 Asset Protection and Segregation

Generally, market intermediaries are required to hold securities on behalf of their clients and on their own behalf in a manner that achieves safeguarding and segregation standards set by capital markets regulators. Traditionally, securities are held with a custodian that is a clearing member of a CSD. Technologically, the custody solution of the Samara Platform operates through the interaction of certain control functions that are built into its design. Consequently, traditional custodial functions performed by a third-party custodian are performed by the Platform. Segregation is achieved through the unique bond wallet addresses of the participants, and more generally though the closed loop feature of the Samara Platform, which precludes any bond transactions from occurring off-platform. Participants do not have direct access to keys for their wallets on the bond ledger or the cash ledger. Rather, the platform administrator safeguards keys under the supervision of the applicable platform operator.

The key management system for both the bond ledger and the cash ledger includes the capability to generate new keys. The loss of a key will not result in the loss of the bonds or W-CAD held in the wallet associated with that key. Because neither the bonds nor W-CAD can be transferred off-platform (subject to the issuer's exit right in limited circumstances), administrative control over the keys by the platform administrator does not give rise to the custodial risks associated with private keys to public blockchain ledgers. The role of RBC IS, as off-platform recordkeeper, provided an additional layer of asset protection by maintaining an up-to-date copy of the bond register and transaction history, if the Samara Platform malfunctions and cannot be restored.

3.5.6 Reporting Module

A reporting module has been developed to support platform participants to monitor their activity and positions on the bond ledger and cash ledger, fulfilling regulatory reporting requirements, enhancing risk management, and informing internal teams within participant institutions. Key reports—such as daily positions, end-of-day W-CAD balances, and trade history—are essential for:

1. reconciling records between Samara Platform and internal systems at JLM and issuer
2. regulatory reporting
3. generating client statements
4. off-platform record keeping

A notable feature of the module is the introduction of a “Samara Provider” role, assigned to a designated business unit within RBC IS, which was engaged by the bond ledger platform operator to provide off-platform record keeping and reconciliation services to both RBC and TD, as JLMs. This role is distinct from the bond ledger platform operator to ensure segregation of duties. It is configured with appropriate access controls to generate institution-specific reports on the bond ledger, accessible via the bond ledger user interface. These reports may also be used to respond to regulatory inquiries.

On the cash ledger, an “audit-user” role has been created for designated BoC users, enabling them to generate ad-hoc reports on transaction history and wallet balances and to manage subscriptions for automated reporting.

4.0 Samara Technology

The Samara Platform comprises two distinct blockchain ledgers, namely the bond ledger and cash ledger, which seamlessly interact using an interledger protocol (ILP) based on HTLC. The ILP runs on the nodes for both ledgers and allows information to be shared across ledgers, including for the purpose of settling transactions by atomic swap.

4.1 DLT Principles and Potential Benefits

The Samara Platform protocol incorporates core blockchain principles to enhance functionality across both the bond and cash ledgers. These principles are as follows:

- **Consensus-driven:** The platform employs a crash fault tolerant (CFT) consensus algorithm, enabling participants to collectively validate the state of each ledger. This decentralized model was designed to distribute trust across the network, removing dependence on a central authority.
- **Cryptographically secure:** The platform leverages cryptographic techniques—including secure key management, encryption, digital signatures, and hash functions—to safeguard data integrity and prevent unauthorized access or tampering.
- **Immutability:** Once recorded, data on the ledger cannot be altered or deleted. This ensures that no single entity can retroactively modify records, reinforcing the trustless and decentralized nature of the system.[10]
- **Transparency:** Participants independently verify transactions and validate ledger accuracy. This is supported by public key cryptography and distributed consensus, promoting accountability and trust within the network.

4.1.1 Hyperledger Fabric

The Samara Platform leverages the Hyperledger Fabric framework to support both the bond ledger and the cash ledger. Hyperledger Fabric is an open-source, permissioned DLT platform developed under the Hyperledger Project. It provides the structural foundation and operational logic for the ledgers.[11]

A Hyperledger Fabric blockchain network is composed of three key components: peers, orderers, and certificate authorities:

- Peers serve as foundational nodes that host ledger data, execute smart contracts (via chain code), and deliver event notifications such as transaction statuses. Each peer maintains a state database reflecting the current ledger state and a local ledger file containing the ordered blocks of validated transactions.

[10] Note that, as mentioned in the Operations section, Samara is not fully immutable in that the bond ledger platform operator can, under certain special circumstances, manually make adjustments to the ledger.

[11] For further details, refer to the official Hyperledger documentation (Hyperledger Foundation, 2020).

- Orderers implement a deterministic[12] consensus protocol to ensure all peers process transactions in the same sequence. They provide an atomic broadcast service that guarantees total transaction order across the network.
- Certificate authorities manage network membership by issuing digital identities to participants. This supports the permissioned nature of the network, enabling secure and controlled access.

Hyperledger Fabric provides a modular and flexible architecture for implementing consensus algorithms. By default, it supports CFT consensus using the Raft protocol. It also offers the capability to integrate byzantine fault Tolerant consensus mechanisms. The Samara system uses Raft as a consensus protocol.

4.1.2 Fabric Token SDK

The cash ledger in the Samara Platform is implemented using the Fabric Token software development kit (SDK), which provides a comprehensive set of application programming interfaces (APIs) and services for developing token-based distributed applications within the Hyperledger Fabric framework.

Key features of the Fabric Token SDK include:

- UTXO Model: The SDK adopts the unspent transaction output (UTXO) model for managing transactions within Hyperledger Fabric.
- Wallet-Based Key Management: Secure and accessible key management is enabled through the use of wallets.
- Privacy Options: The SDK supports multiple privacy levels, from no privacy to advanced zero-knowledge-based implementations that conceal ledger content while enforcing defined invariants.
- Auditability: Built-in support for audit trails ensures transparent and accountable transaction histories.

Two design approaches were considered for the Samara ledgers: a token-based model using the Fabric Token SDK and a direct account-based model. In line with an experimental approach, the cash ledger was implemented using the token model, while the bond ledger adopted the account model.

4.1.3 Hyperledger Weaver

The Samara Platform uses the ILP to enable secure data sharing and asset exchanges between the bond ledger and the cash ledger, leveraging the Hyperledger Weaver ILP implementation (Hyperledger Labs, 2023).

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[12] Deterministic finality results from certain consensus mechanisms that guarantee settlement once consensus has been reached. In probabilistic consensus protocols, such as proof-of-work, finality only becomes more likely over time as each block is accepted.

Weaver employs HTLC to preserve data integrity, authenticity, and confidentiality during interledger communication. It transmits encrypted messages, message hashes, and digital signatures between ledgers to ensure secure and verifiable exchanges.

HTLC enables trustless, conditional transactions across networks by using cryptographic hash functions and time locks. Assets are only released when predefined conditions are met within a specified time frame. This mechanism is widely used in payment channels, atomic swaps, and decentralized applications to facilitate secure, conditional transfers without requiring mutual trust.

4.2 Samara Architecture

For this experiment, separate DLT networks were established for the bond and cash ledgers to reflect a realistic deployment model in a heterogeneous DLT environment. This separation ensures that each ledger can independently fulfill its designated functions: the bond ledger records positions and trades in securities, while the cash ledger handles issuance, withdrawals, and payments of cash without dependency on bond ledger management processes.

The platform is deployed on two different cloud providers (Microsoft Azure and IBM Cloud) to evaluate performance, scalability, and resilience under real-world conditions.

Both ledgers are built on a multi-tier Hyperledger Fabric architecture. While they share core components, each has distinct characteristics. For example, the bond ledger network includes nodes operated on behalf of each of RBC and TD, acting as JLMs, dealers, and market makers, as well as the issuer, EDC. The cash ledger includes similar participants, along with a dedicated W-CAD issuer node operated by the BoC.

Each ledger supports multiple orderers to maintain transaction sequencing and ledger integrity, ensuring all nodes have a consistent view of the transaction history. Dedicated certificate authorities manage network membership: BoC for the cash ledger and RBC (as platform operator) for the bond ledger. These authorities issue digital certificates to authenticate and authorize participants, ensuring that only verified entities can access the network, thus preserving system integrity.

Figure 9 illustrates the high-level architecture used by both the cash and asset ledgers. The diagram represents the core components and interactions for a single ledger, as both ledgers follow the same structural design.

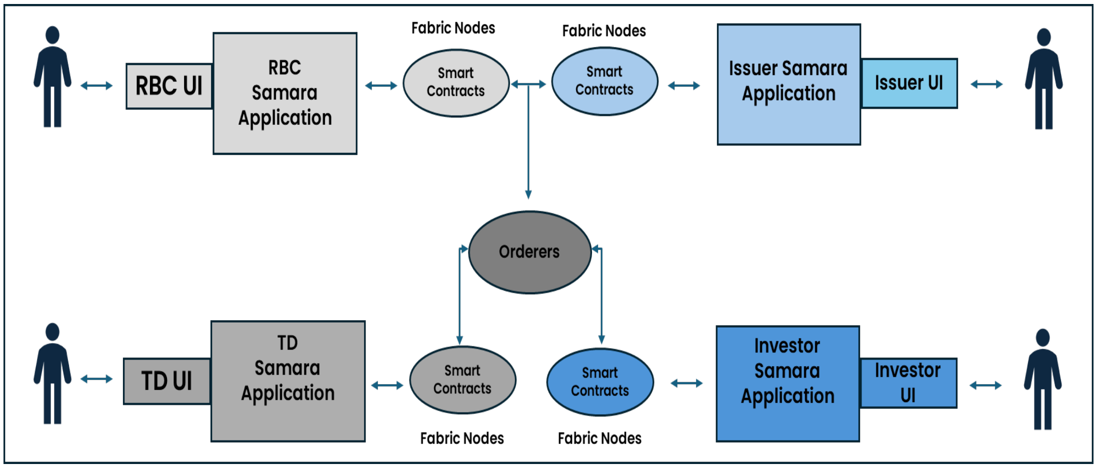

Figure 9: Samara Ledger Architecture

Each participant on the Samara Platform has access to both the bond ledger and the cash ledger, deployed via Kubernetes clusters in the cloud. Each deployment includes multiple nodes across different cloud locations to ensure high availability and disaster recovery.

Investors may choose to run their own nodes or access the ledgers through their JLM. The platform supports full infrastructure segregation, multiple participation models, and deployment flexibility across Microsoft Azure and IBM Cloud. This flexibility has enabled participants to select their preferred cloud provider, with some deploying on Azure and others on IBM Cloud.

A node in the Samara Platform represents a logical grouping of hardware and software resources, encompassing components such as the user interface, APIs/services, network modules, and databases. Figure 10 illustrates the solution stack for the Samara node highlighting the layers and components that enable the Samara node's functionality.

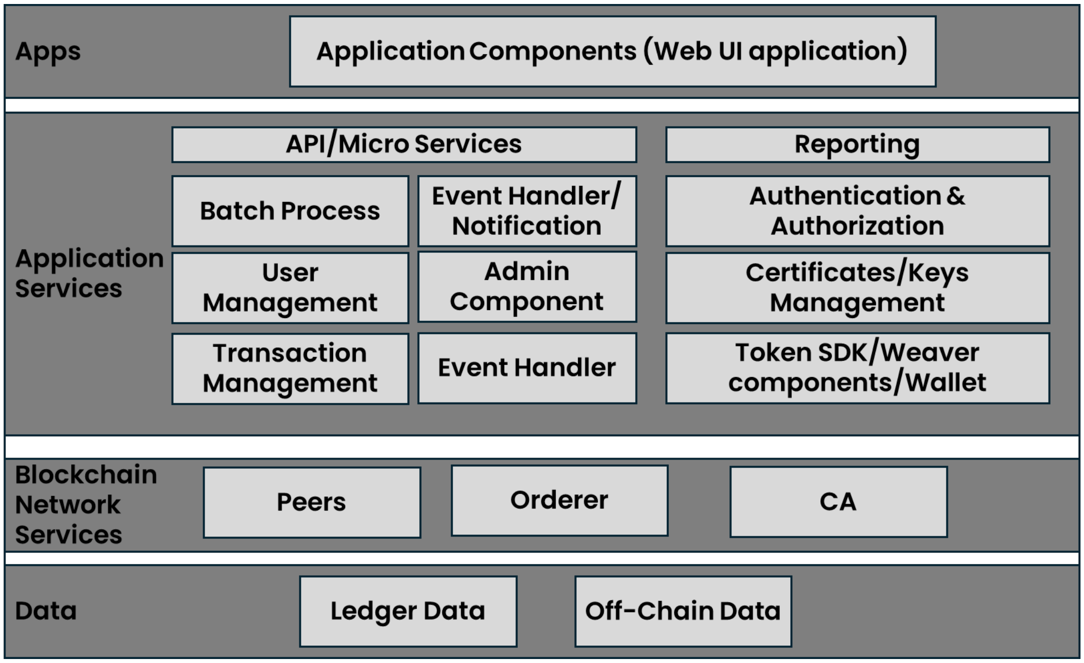

Figure 10: Samara Node Solution Stack

Two deployment models are available:

- Full stack: participants may choose to operate their own full-stack node, offering complete control and privacy over infrastructure and operations. This option involves higher costs but ensures full autonomy.
- Shared stack: participants may opt to access the platform through their JLM's nodes. This cost-free model offers a simplified set-up with reduced control and privacy over system components.

Institution users get access to the platform through a web application (Samara Dashboard UI) that is linked to a node that is operated in either "own full stack" or "shared stack" mode.

The following sections describe the key characteristics of the Samara technical design.

4.3 Fund Models

Samara supports two accounting models for managing digital assets: the account-based model and the UTXO-based model.

The **bond ledger** adopts an account-based model, where transactions are recorded as changes in account balances. This model, commonly used in platforms like Ethereum, offers a simplified programming structure, supports concurrency control,[13] and facilitates the enforcement of regulatory rules—making it well-suited for managing securities.

In contrast, the **cash ledger** is implemented using the Fabric Token SDK and follows the UTXO model. This model enhances scalability by limiting data processing to participants who are directly involved, supports privacy through transactional anonymity and zero-knowledge proofs, and enables parallel transaction processing for improved throughput. While preserving privacy, the system ensures the BoC receives sufficient information to meet compliance requirements for anti–money laundering, sanctions and countering the financing of terrorism.

To enable interoperability between the two ledgers, Samara uses the Weaver ILP, allowing secure and conditional asset and data exchanges between the bond and cash ledgers.

4.4 Consensus and Endorsement Policy

In Hyperledger Fabric, endorsement and consensus serve complementary roles to ensure transaction validity and ledger consistency.

Endorsement validates transactions against predefined rules before they are submitted for ordering. In Samara, these rules are tailored to each transaction type. For example, a W-CAD transfer requires endorsements from all involved parties, including the BoC, to confirm the transaction's legitimacy and accuracy.

Consensus follows endorsement and ensures that transactions are ordered and committed consistently across the network. Samara uses Hyperledger Fabric's CFT consensus mechanism, which relies on an ordering service to establish a definitive transaction sequence. This guarantees that all peers maintain a synchronized view of the ledger, even in the event of node failures. As long as the transacting parties remain online and connected, the network can continue to operate reliably.

4.5 Key Management

Users access the bond ledger by entering a set of credentials, consisting of a user ID and password, on the bond ledger user interface. When a user logs in successfully, their credentials are linked to the corresponding keys, which grant access to the bond wallet owned by the participant represented by the relevant user.

For the cash component, each end-user is linked to a specific account, and keys are associated with these accounts. Accounts are owned by a dealer, investor, or issuer

[13] Concurrency control involves managing simultaneous access to account data to prevent conflicts and maintain the integrity of transactions.

through a BoC account agreement, which grants them access via a web-based cash wallet. Upon successful login, a user's credentials are mapped to the corresponding keys, enabling access to the relevant accounts, including the ability to transfer or withdraw W-CAD.

The keys used for the cash ledger and the bond ledger are separate, and each ledger employs its own method for linking user credentials to these keys. In the bond ledger, each dealer, investor and issuer has one or more users associated with their identities that are mapped to respective users' keys. In the cash ledger, each user is associated with its dealer's, investor's or issuer's account.

It is crucial to understand that end users never directly access or handle the keys themselves. The keys are securely maintained within a cloud-based secret management service, such as Azure Key Vault. Users are provided only with credentials, which the Platform uses internally to link them to their respective keys.

4.6 Security and Privacy

Access control across all layers of the Samara Platform ensures secure and role-based interaction with both the bond and cash ledgers. Authentication is performed at the UI layer, triggering role-based authorization to validate whether users have the necessary permissions to execute specific operations.

The platform's endorsement and administrative frameworks are designed to support governance across two distinct networks of participants, each with defined roles and responsibilities. These frameworks enforce structured protocols for all transactions and administrative actions, safeguarding system integrity and reliability.

Data privacy is a core design principle for both ledgers. On the bond ledger, Hyperledger Fabric's channels and private data collections restrict data visibility to authorized parties, ensuring that sensitive information is shared only on a need-to-know basis.

On the cash ledger, privacy is maintained through zero-knowledge proofs (ZKPs) integrated into the token SDK. ZKPs allow participants to prove transaction validity without revealing underlying details, ensuring confidentiality while still meeting compliance requirements.

4.7 Settlement of Transactions

4.7.1 Settlement Instructions

Samara leverages settlement instructions that mirror standard practices in traditional securities transactions. These instructions specify the source and destination wallets on each ledger, transaction amounts, and other relevant details.

The BoC cash ledger node provides an access-controlled, four-eyes–approved user interface for:

- issuing W-CAD to participants' wallets upon receipt of funds via Lynx
- approving withdrawal requests to manually initiate outgoing Lynx payments (see Section 3.5.2 for details)

The bond ledger serves as the origin for both bond and W-CAD settlement instructions because the cash ledger maintains only balance information and is not aware of bond life-cycle events.

For bond transactions—such as bond issuance from the issuer to the JLM and onward to investors or secondary market trades between market makers and investors—the platform automatically generates both bond and W-CAD settlement instructions using pre-configured standard settlement data.

In contrast, for coupon and redemption payments, only W-CAD settlement instructions are generated because no asset exchange is involved.

4.7.2 Automated Cross-Chain Transactions

The Samara Platform automates cross-ledger transactions using settlement instructions, smart contracts, and Weaver ILP based on HTLCs.

For bond exchange transactions, the process begins with the submission of bond settlement instructions when the seller initiates a transaction. This triggers the platform to generate a secret, hash it, and place an HTLC lock on the bond amount. The hashed secret is then shared with the buyer.

Subsequently, the platform submits the W-CAD settlement instructions to the cash ledger. A separate secret is generated, hashed, and used to place an HTLC lock on the corresponding W-CAD amount. The hashed secret is also shared with the buyer, and the cash ledger proceeds only after confirmation of a successful lock.

Once both locks are in place, the atomic swap is initiated. The protocol coordinates the secure and conditional exchange of assets, releasing the bond and W-CAD to their respective recipients and completing the transaction.

After the transaction is completed, users can immediately view updated ownership of both bonds and W-CAD, along with the transaction status through the bond ledger UI. The cash ledger UI shows cash positions only.

For coupon and redemption events, the workflow is streamlined. Only W-CAD settlement instructions are generated on the bond ledger and then sent to cash ledger. The final W-CAD transfer status is returned to the bond ledger to complete the process.

5.0 Legal and Regulatory Considerations

5.1 Capital Markets Regulation

The Samara Platform touches a number of capital markets regulatory frameworks, including financial markets infrastructure regulation applicable to marketplaces and clearing agencies, and the investment dealer registration regime.

From an early stage, the Consortium engaged with the principal regulators for the marketplace and clearing agency:

- the Ontario Securities Commission ("OSC"), and
- the Autorité des Marchés Financiers du Québec ("AMF," together with the OSC, the "CSA").

the Consortium also engaged with Canadian Investment Regulatory Organization ("CIRO"), as the self-regulatory organization ("SRO") for investment dealers and regulation service provider for marketplaces.

After the regulators received demonstrations of the Samara Platform and written submissions, it was determined that RBC (as bond ledger platform operator) would require exemptive relief from the requirement to be recognized as a marketplace in Ontario and Quebec and the requirements to be recognized as a clearing agency (settlement system) in Quebec.

The Consortium worked collaboratively with the OSC's Office of Economic Growth and Innovation and the AMF to obtain exemption orders that would allow RBC to operate the bond ledger for a two-year period.[14]

[14] One of the prescribed terms and conditions is that RBC Capital Markets and TD Securities Inc. remain a member in good standing of CIRO and that the Samara Platform upholds applicable core principals of Canada's marketplace regulatory framework.

CIRO staff also conducted a detailed review of all aspects of the Samara Platform. CIRO's objective was to ensure that the securities dealing and marketplace activities on the Samara Platform are broadly conducted in accordance with the CIRO rules. The Consortium articulated Samara Platform's consistency with CIRO's requirements for asset protection, segregation and regulatory reporting through a combination of legal agreements, service provider engagements and detailed technical submissions reviewed by CIRO staff. These included:

- RBC (as bond ledger platform operator) and each of RBC and TD (as dealers) entered into an asset protection agreement to confirm the safekeeping and custody of bonds on the bond ledger.
- RBC IS was engaged to provide off-platform record-keeping services.
- CIRO reviewed technical specifications of the node operations, key management and access, platform ownership and intellectual property and other matters.
- RBC and TD adopted processes to report the primary distribution and all secondary market trades of bonds made on the Platform through the Bloomberg Trade Order Management Solutions ("TOMS") execution and order management system so that CIRO could conduct trade surveillance and supervision using its regular processes.

Overall, CIRO reviewed and approved participation by RBC and TD in the Platform as an "InnovateSafe Tokenized Bond Offering Pilot"[15] within its new "InnovateSafe" regulatory sandbox.[16] CIRO worked collaboratively and expeditiously with the Dealers to finalize terms and conditions that reasonably balance CIRO's market integrity concerns with support for innovation in the capital markets.

5.2 Bond Issuance and Documentation

As a distributed blockchain network, each node on the bond ledger maintains a distinct copy of the current state of the ledger. Transactions on the bond ledger are finalized when there is consensus across all nodes regarding a transfer of bonds from one wallet to another. However, corporate law dictates that a corporation must maintain a securities register and a register of transfers of securities at a location designated by the director of the corporation.

While corporate law contemplates that securities may be uncertificated and maintained in book-entry only form, it does not contemplate the maintenance of records on a distributed ledger. Consequently, to simplify compliance with existing corporate law and

[15] CIRO launches InnovateSafe, a regulatory sandbox designed to accelerate the safe development of transformative technologies | Canadian Investment Regulatory Organization

[16] In connection with its approval, CIRO imposed specific terms and conditions on the dealers relating to scope, responsibilities and accountability, and other items.

related CIRO rules, the copy of the bond ledger recorded on the platform operator's node was designated as the official register of bonds.

The documentation used in EDC's bond issuance was a hybrid of the conventional and the novel. For example, the bonds were issued by way of a customized Deed Governing the Issuance of Canadian Digital Notes, Pricing Supplement and Offering Memorandum. The documentation included provisions explaining how the bonds would be recorded and transferred on the bond ledger on the Samara Platform. As well, the documentation confirmed the location of the definitive register and prescribed mechanisms for transferring the bonds off the platform and issuing the bonds in certificated or book-entry form. The documentation also set out an early redemption option at the election of the issuer if a platform malfunction occurred and could not be cured to the satisfaction of the issuer.

In addition, the Consortium developed and documented protocols for primary distribution and secondary trading that were prescribed in a manual that governs all activities on the Samara platform (the "Platform Manual"). These protocols must be accepted by all participants and their authorized users as a condition of accessing the platform. Similarly, all participants were required to enter into a user agreement with the bond ledger platform operator and a BoC account agreement with the BoC. This off-chain documentation prescribed the rights and obligations of the platform operators and all participants, providing the legal foundation for on-chain processes that occurred on the platform.

5.3 Central Bank Money on the Platform

The BoC operates the cash component of the Samara Platform pursuant to the authority granted to it under the Payment Clearing and Settlement Act (Canada) ("PCSA"). Paragraph 12(c) of the PCSA specifically authorizes the BoC to accept deposits from, and offer accounts to, participants of a Canadian clearing and settlement system. Pursuant to the PCSA, the Platform is a clearing and settlement system because it is an arrangement for the clearing and settlement of bonds (securities) transactions, which also clears payment obligations arising from those securities transactions for the purpose of settlement of such obligations effected through adjustments to the participants' accounts. For the purposes of the Platform, the cash wallets represent the participants' accounts.

As noted above, participants on the cash component are required to enter into a Samara account agreement with the BoC and to accept the terms of the Platform Manual. Pursuant to section 13.2 of the PCSA, the BoC is authorized to enter into agreements with a participant of a clearing house, notably, in respect of the exercise of the BoC's powers and the performance of its duties and functions. The W-CAD is a digital representation of wholesale Canadian dollars created and managed by the BoC on the cash ledger. The BoC controls access to, and monitors activity on, the cash component as the operator of the cash component.

6.0 Lessons Learned

6.1 Efficiency Gains

Project Samara demonstrated that a DLT-based capital markets platform can generate operational efficiencies across the full bond life cycle. Automation of key processes—such as term-sheet creation, trade booking, settlement instruction generation, and reporting—reduced manual interventions and off-platform coordination. Same-day (T+0) settlement accelerated transaction completion relative to conventional multi-day settlement cycles.

The use of a single, shared ledger architecture provided a common source of truth for all participants, materially reducing reconciliation efforts across dealer, issuer, and investor back offices. Real-time visibility into bond positions and cash balances enhanced data integrity and streamlined workflows across issuance, settlement, and post-issuance life-cycle events. Over the life of the bond, consolidating issuance, settlement, and servicing functions onto a single platform reduced fragmentation relative to traditional infrastructures.

6.2 Operational and Governance Complexity

The efficiency gains noted above were partially offset by increased operational and governance complexity. The decentralized architecture required participants to operate or access distributed infrastructure, increasing set-up, operating, and cyber security costs compared with those of centralized systems. For Samara, the estimated cost of deploying a node was about CAD$65,000, with an additional CAD$15,000 per month in cloud expenses to operate it. Each node-operating participant is also required to have a robust IT framework. Consensus and endorsement mechanisms also duplicated certain processing activities across nodes, raising system-wide operational overhead.

Liquidity costs also increased because of the pre-funding requirements needed to support atomic settlement under a real-time gross settlement model. In addition, decentralized system design required the creation of new governance arrangements, including defined platform operator roles, exception handling procedures, and coordination mechanisms across independently governed entities. Compared with traditional centralized models, these arrangements increased governance and required closer coordination among participants and regulators.

6.3 Risk Management

Atomic DvP across independently governed bond and cash ledgers significantly reduced counterparty and settlement risk by ensuring that securities and cash were exchanged simultaneously or not at all. Automated validation and straight through processing reduced the likelihood of failed settlements and post-trade disputes.

At the same time, Project Samara also introduced new aspects of operational risk. These included risks related to management of cryptographic keys. Key management forms a risk in any blockchain network because transactions need to be approved and digitally signed by the counterparties. On the Samara Platform, keys are stored and managed via standard key management services in IBM Cloud and Microsoft Azure Cloud. Key management adds to both the complexity of the system relative to traditional password management and the overall operational costs involved.

While these risks were mitigated through layered operational controls, platform operator interventions, and off-platform record-keeping arrangements, they highlight the importance of tailored risk management frameworks for DLT-based infrastructures.

From a resilience perspective, the distributed node architecture reduced reliance on single points of failure. Outages affecting one participant's infrastructure did not necessarily result in system-wide loss of access, contrasting with centralized systems. However, resilience benefits may be partially offset if JLMs emerge as key access points for issuers and investors, reintroducing some degree of functional centralization.

6.4 Regulatory and Legal Considerations

Close engagement with regulators of capital markets was essential to the execution of Project Samara. The designation of RBC as platform operator for the bond ledger enabled the Consortium to obtain exemptive relief from the marketplace and clearing agency (settlement system) requirements of applicable securities laws. This exemptive relief implies that the marketplace and clearing agency functions are, in fact, being performed by the platform operator.

Existing legal and regulatory frameworks governing securities issuance, custody, marketplaces, and clearing agencies are built around centralized intermediaries and required exemptions or adaptations to accommodate a DLT-based model. One instance of this was with regards to the CIRO rules that expect its members to hold securities on behalf of their investors at an "acceptable securities location" (typically at a CSD). Without the involvement of a CSD in Samara, CIRO needed to be satisfied that the Samara Platform is an "acceptable internal storage location" for securities. This was done via legal agreements, service provider engagements and detailed technical submissions (See Section 5.1).

The continued necessity of centralized roles such as a marketplace operator, custodian, and off-platform trade reporting highlighted areas of misalignment between current regulatory frameworks and core DLT principles such as decentralization and consensus-based record keeping. Corporate law requirements for a centralized securities register further constrained the ability to rely exclusively on a distributed ledger. Taken together, these experiences suggest that broader adoption of DLT in capital markets would likely require legal and regulatory evolution in addition to technological change.

6.5 Technical Design Lessons

Project Samara yielded several technical design insights relevant for future DLT-based capital markets platforms.

First, the platform deliberately employed different accounting models across ledgers: an account-based model for the bond ledger and a token-based model for the cash ledger. This design choice was made to test both approaches rather than to promote a single preferred model. The account-based model simplified smart contract design for securities life-cycle management, while the token-based model was better suited to cash settlement, scalability, and privacy requirements. The experience suggests that technical design choices should be driven by functional requirements and use cases rather than a one size fits all architectural preference.

Second, operating a distributed system requires careful consideration of infrastructure and operating costs (see Section 6.2). Participants could choose to operate their own nodes or access the platform via shared infrastructure; running a node involved non-trivial deployment and ongoing cloud costs. These costs may limit full node participation to larger or more frequent market participants, with implications for market structure and access.

Third, the use of cryptographic keys and multiple certificates, while offering enhanced security, presents significant challenges compared to traditional credential systems, such as ledger credentials. Although managed key services and credential-based access can shield end users from much of this complexity, production-scale platforms must still address critical issues, including certificate rotation, key recovery, access control, and compliance requirements.

6.6 Adoption Barriers

Despite technical feasibility, several factors may limit broader adoption of DLT-based capital markets infrastructure. First, there continues to be uncertainty among market participants about the maturity, reliability, and cost-effectiveness of DLT. This would point to a persistent role (at least over a transition period) for central authorities or intermediaries, which is contrary to the ethos of using a DLT framework. In Samara, there was a reduced reliance on certain traditional intermediaries, but participants generally did not expect fundamental changes to core roles such as JLMs, market makers, or platform operators.

Second, the current legal and regulatory structure is not set up for DLT-based infrastructures. Amendments to corporate law and exemptions from securities regulation will be necessary to accommodate the use of DLT to record ownership and transfers of securities. Exemptive relief under special innovation initiatives or sandboxes can serve as a useful regulatory tool to foster innovation. However, without legal and regulatory certainty, it would be difficult for DLT-based systems to truly show their potential.

As a result, adoption is likely to be gradual, with hybrid models combining decentralized technology and centralized oversight emerging as the most practical near-term path.

7.0 Conclusion

The Samara Project was designed as an experiment to test the benefits and costs of DLT in a real-world financial market setting. The Project revealed many fundamental lessons for participants about the technology and its value for tokenized securities trading and settlement over the full life cycle. Experiments such as this are an important part of the learning process for new technology and are especially useful in a real-world setting as part of a public-private collaboration. The extra effort of building out the system in a real-world setting was valuable at identifying legal, regulatory, governance, operational, cost and risk management issues compared with lessons that could not be revealed by previous tests, such as Project Jasper.

Overall, the main lesson of the work is that DLT seems to offer some promise of net efficiency gains compared with traditional technology, but that benefit is unlikely to be as significant as some argue or believe. There are observable benefits in some areas, but there are costs or increased risks in others that may offset those gains. The cost and complexity of the technology will likely make its wide-spread adoption long and difficult. The overall payoff in many ways is still uncertain and will only be revealed by a large-scale production system that is fully tested by:

- the economic ups and downs of the financial system over the business cycle. and
- the typical operational events that any system would experience during that time.

Continued experimentation and collaboration between the public and private sectors are essential for further advancing understanding and informing future developments. Future experiments could usefully look at leveraging smart contracts to enable complex derivatives on DLT. The role of the regulator on a DLT platform (to improve its information access and oversight while respecting the confidentiality expected by participants) would be another avenue for investigation. Fully automated links to traditional systems and participant internal systems was not explored in the Samara Project but would be an essential bridge towards wider adoption of the technology.

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Appendix I: Comparison of Current Process for Issuing Bonds against. Samara Platform Process

Process	Current		Samara	
	Timing	Description	Timing	Description
Draft Term sheet	T-1	Draft term sheet (docx, pdf) is exchanged by email for review and comments by issuer and JLMs.	T+0	Draft term sheet is created digitally on the platform for review and comments by the issuer and JLMs
Deal Announcement	T-1	Email, Bloomberg	T+0	On Samara Platform, email and Bloomberg
Book Building	T+0	e-Book platform (investors send orders to JLMs, and JLMs enter them in the e-Book)	T+0	On Samara Platform, Direct entry by investors
Allocation	T+0	Allocation review is typically done with the e-book extract (spreadsheet) and finalized through emails	T+0	Draft allocation shared via Samara Platform for the issuer to directly comment or update; Final allocation released by JLMs on-platform after incorporating issuer's comments
Pricing	T+0	Recorded phone line	T+0	Recorded phone line
Final Term Sheet	T+0	Final term sheet is sent by email for review and approval by the issuer	T+0	JLMs update the final pricing information on the Samara 'digital' term sheet and send it for the issuer's review and approval on-platform
Legal Documents	T+4	Reviewed and finalized offline	T+0	Reviewed and finalized offline except for the final term sheet; Relevant finalized documents uploaded to Samara Document Repository and viewable by appropriate parties
Trade Booking	T+0	Manually booked in a separate system	T+0	No separate booking; Final term sheet translates into the digital bond on the platform and is updated on the bond and cash ledgers

Trade Review	T+1	Operations team reviews trade booking for accuracy post-booking	T+0	Operations team can concurrently review the final term sheet on-platform even while in draft stage; four-eye check is in place before final term sheet approval
Settlement	T+7		T+0	

On-chain bond ledger

On-chain cash ledger

Off-chain

Appendix II: Summary T+0 Settlement Events in both Cash and Bond Ledgers

Off-Chain	On-Chain	
	Bond Ledger	**Cash Ledger**
JLM vs. Issuer negotiation and signing of Final Terms [Process initiated prior to T+0]		
Advance preparation of fiat settlement accounts (at BoC) by all parties	• Upload the Platform Rules and Procedures • Participants onboarded by bond ledger-platform operator • JLMs initiate indicative term-sheet • Issuer reviews and approves indicative term-sheet	• Participants onboarded by cash ledger platform operator • Advance preparation and set-up of W-CAD and bond settlement accounts by all parties
	JLMs announce issuer-approved bond launch with initial economics	
Marketing of the deal	Investors and JLM submit Expression of Interest (EOI) through their dashboards	
	Book allocation is reviewed and confirmed	Investors/JLM transfer fiat to fund wallets
	Investors agree to the bond purchase	BoC mints appropriate W-CAD to fund Investor/JLM wallets
Pricing call	Final term sheet is agreed on and distributed	
	Bond settlement process is reviewed	Smart contract triggers verification and locking of W-CAD
Confirmation	Investors approve the total settlement	Releases lock on unused prefunded amounts
	Bond created in issuer's account	
	Security Instruction DvP ready	
Finalized and signed legal documentation	Final terms (with authorized signatures) are uploaded	
Off-chain communication by JLM with all participants prior to executing atomic swap	System initiates atomic swap between issuer and JLM [DvP1]—Transfer of bonds from issuer to JLM account	Issuer wallet gets credited and JLM wallet gets debited
	System initiates atomic swap between JLM and investors [DvP2]—Transfer of bonds from JLM to Investor(s) account	JLM wallet gets credited and investors' wallets get debited
	Notification of final DvP status to all participants	Confirmation of successful W-CAD transfer