Bringing Transparency in Capital Markets using Enterprise DLT

Abstract—Blockchain, the technology underpinning Bitcoin has attracted capital market participants globally with its potential to bring greater transparency, manage risk efficiently, and enable greater operational efficiency, disintermediation, and instantaneous trade settlement thereby bringing operational and business transformation. Multiple proof of concepts, pilots and solutions were developed with Blockchain 1.0 technology using Ethereum & Bitcoin for solving capital markets, which while yielding encouraging results also highlighted the severe limitations of leveraging public Blockchain networks for enterprise use. This resulted in advent of Enterprise DLT platforms coming to existence including Consortium led flavors such as Hyperledger Fabric, Sawtooth, Enterprise Ethereum Alliance’s Quorum and Proprietary technology such as Digital Asset & R3 Corda. Our paper focuses on how Enterprise DLT can bring value to Capital Market industry in certain Niche areas specifically where greater transparency is needed and risk management is of extreme importance. This paper will describe real-life DLT solutions developed by Broadridge Financial Solutions.

I. INTRODUCTION

Broadridge Financial Solutions is a global leader in providing technology enabled solutions to global markets. Broadridge processes $5+ Trillion in equity and fixed income trades daily and processes 80% of proxy meetings in North America and serves 200+ markets [1]. Broadridge India is GIC of Broadridge globally and acts as center of excellence for emerging technologies including DLT. Broadridge’s Blockchain Center of Excellence has been operational since 2014 and has built multiple applications using various DLT platforms including Quorum, Fabric, DAH, R3 Corda etc. Broadridge launched a DLT solution for Global proxy solution for Spain in 2018[2][3] and has further extended the solution as a pilot in APAC region[4]. Broadridge has also developed a DLT based Fixed income repo solution for North American markets which provides ability for firms to trade in Repo contracts using tokenization[5].


II. **Benefits of DLT to Capital Markets**

A. **Abbreviations and Acronyms**

- DLT – Distributed Ledger Technology
- APAC – Asia Pacific
- GIC – Global Insourcing Center
- PBFT – Practical Byzantine Fault Tolerance
- IDM – Identity Management Systems
- OTC – Over the Counter markets

B. **Key Features of Enterprise DLT Systems**

- Decentralization of networks is achieved in DLT through availability of multiple nodes which shared a “distributed ledger” eliminating need for an “intermediary” to maintain the ledger. Enterprise DLT solutions are often Quasi de-centralized with certain nodes acting as “validator” or “notary” nodes
- Simpler consensus mechanisms relative to public blockchain networks with implementation of variations of Byzantine Fault Tolerance algorithms (PBFT, Istanbul etc.) , Raft or Paxos algorithms
- Implementation of privacy and confidentiality through encrypted payload transmissions and private transactions in Quorum[6], Private Smart contracts[7] and Store Channels in Hyperledger Fabric[8], Rights and Obligations in Digital Asset platform and Flows in R3 Corda which entitle only participants with rights to view and act on data that they are entitled to
- Implementation of Enterprise Identity Management solutions with integration to existing IDM's and X.509 standard certificates
- Support of off chain data stores to ensure DLT systems can scale to support storage and speed requirements of enterprises in financial services industry
- Consensus driven Smart Contracts that could automate complex contractual obligations and bring high level of workflow automation without need of human interaction and interact with external world through Smart oracles

C. **Benefits of DLT to Capital Markets**

- More Efficient settlement of transactions and processing as all market participants see same data as long as they are entitled to and updates are circulated instantaneously. Widely mentioned as Single Source of Truth
- Increased transparency, with all participants receiving a unified view of real-time golden source data. Shared across all nodes / participants in the network through means of “Global State”
- Significant cost savings and operational efficiency by reduction in reconciliation systems and operations as all participants see same data reducing need for reconciliation
- Risk Mitigation and management in bilateral and OTC markets as Smart contracts enable capture of complex derivative contracts terms, eligibility and processing workflow automation thereby eliminating manual processes and errors
- Digitization of Know-Your-Customer (KYC) and Anti-Money Laundering (AML) in Capital markets industry eliminates disparate and fragmented capture of Shareholder information
- Streamlining of Security Issuance directly on DLT through concept of Security Tokens and Asset backed tokens which will accelerate trading of real world assets in DLT based networks
- Improved Corporate governance activities by having DLT driven Proxy voting which gives an end to end transparency from AGM being announced to shareholder positions and voting details captured real time
- Instantaneous securities vs cash settlement in DVP fashion through security tokens being settled against digital currency or crypto or fiat currency backed tokens
- Elimination of discrepancies and disputes related to securities reference data by having golden copy of information
- Payments of dividends, income distribution through Digital / Crypto and Fiat currency backed tokens
- Fungible usage of assets held in DLT as collateral enabling faster collateral management and handling of margin money

Many pilots have already been conducted in capital markets industry related to benefits described [2][4][5]. Use of DLT in Capital markets can be broadly categorized in to

- Shared Record Keeping
- Enhanced smart value transfer of assets
- Streamlining automation through smart contracts

III. **Broadridge’s DLT Solutions**

Broadridge’s DLT strategy is focused on bringing “greater transparency” and improved “risk management” to capital markets industry by co-innovating with clients in collaborative model. Broadridge is agnostic to underlying enterprise DLT platforms. Broadridge has built multiple DLT solutions but this paper will focus on

- Enhancing greater transparency in global proxy markets using DLT
- Enabling bilateral repo contracts to be traded on a DLT market place through tokenization

A. **When to use DLT Solution**

The biggest benefits of “DLT” Solutions is when it brings a “network effect” and involve multiple participants interacting with each other in a complex workflow and exchanging data.
We recommend that DLT solution to be considered in Capital markets if it involves following conditions

1. Network of participants who have intense interactions with each other
2. A monopolistic intermediary is currently servicing the market with observed limitations
3. High level of business risks, operational and cost inefficiency, manual intense processing
4. Need for large levels of reconciliation to handle errors and disputes
5. There is a need for security, privacy and confidentiality
6. Need for real time transparency

![Diagram](image)

**Figure 1 - Considerations for Choosing Enterprise DLT**

IV. **BROADRIDGE'S DLT BASED GLOBAL PROXY SOLUTION**

A. **Overview**

Broadridge’s Global proxy solution provides ability for Institutional investors to cast their vote electronically across 150+ markets when corporate issuers hold their annual or extraordinary general meetings. Broadridge provides services from setting up the meetings, notifying the shareholders and collecting the votes. Post collection, Broadridge transmits the votes to the local market custodians and Issuer agents

B. **Problem Statement**

In today’s world, when an Issuer holds their annual meeting or extraordinary general meeting in a country X, meeting information is shared globally with all respective shareholders of issuer. An institutional shareholder, say resident in Country Y, submits their votes through a chain of custodial intermediaries located in country X and Y. Votes are finally registered with issuer or transfer agent maintaining recordkeeping aspects of issuer. The process is not real time, prone to errors and discrepancies, operationally inefficient, has reconciliation overhead and in many markets there is no vote confirmation.

- Lack of transparency in end to end processing of proxy markets, with Shareholder unsure if their votes have been registered and counted, as there is no vote confirmation
- Operationally inefficient and error prone as chain of intermediaries across proxy lifecycle could have different records related to shareholders at any point of time
- Due to time-zone difference there is a shortened window available for shareholders to vote
- Over-voting or under-voting could result if shareholder records are not consistent across chain of intermediaries
- Reputational risk to all involved if errors in proxy processes

C. **Goals of DLT based proxy solution**

We have built a DLT based proxy solution that brings together various market participants including issuer, issuer agent, custodians, institutional shareholders and other intermediaries in a DLT network with following objectives

- Elimination of discrepancies in meeting and agenda information by having details captured directly in DLT
- Real time viewing and correction of shareholder entitlements and positions by providing ability for custodians to set up positional information directly in DLT
- Enable direct voting by shareholders from multichannel (Web, Mobile etc.) directly in to DLT
- Real time meeting quorum tracking for Issuers
• Elimination or shareholder entitlements and voting
data discrepancies between various market
participants
• Real time vote tracking
• Vote confirmation and publishing of meeting results
directly in DLT
• DLT super-highway network enabling institutional
shareholders to vote on DLT and Non-DLT markets

D. Key Design Considerations

We have adopted following key design considerations when
leveraging DLT technology for the global proxy solution. These
design consideration are important to ensure legal and regulatory compliance
• Each market participant should be able to view only data
they are entitled to in compliance with legal, commercial and regulatory rules
• Shareholder identification should ensure privacy and confidentiality of data and all PII data should be
protected under the laws of jurisdiction including European Union’s General Data Protection Regulation.
• Ability for participants to join the DLT network as Direct participants running nodes (or) indirect participant through a client application
• Integrate with existing infrastructure
• DLT solution should be generic enough to support market specific rules and regulations through Smart Contracts
• Ability for regulators to view data related to their Jurisdiction without any data viewing restrictions
• DLT solution should be in a permissioned network with only trusted participants able to join the network
• Business Network Operator should not have any access to cryptographic identifies of network participants

E. DLT Proxy Solution

1) DLT Platform

The chosen DLT platform is an enterprise adoption of
Ethereum known as “Quorum”. Smart contracts are written in
Solidity[9]. DLT platform provides JSON RPC APIs that
consume and publish JSON based messaging content to
integrate with external systems

2) Entity and Identity Management

Market participants are set up as entities mapping to their
legal identification and provided with multiple level of
access depending on their access rights. Each entity is
provided with appropriate Quorum credentials to ensure
rightful access to node data. Entities are provided read/write
or read only access depending on their business rules.
Entities are allowed to set up their nodes in on-premise or
hosted or cloud infrastructure if directly participating.
Indirect participants access DLT through Javascript based
Client applications. Nodes could be set up with view only
or read/write privileges.

Only registered and approved users from entity firms have
access to DLT. Users are set up through a US Patented (US
9967238, Dated May 8 2018)[10] cryptographically secure
process developed by Broadridge DLT team. User
credentials can be revoked or altered when a real world
event impacts user & entity relationship happen such as user
leaving firm, transfer to another department etc. Real world
user identity is mapped to Quorum identity, verified and
validated, a cryptographically secure key pair generated
without Broadridge or any other market participant having
any information related to keys. User identity keys are not
stored in any central database

3) Meeting and Agenda Setup

Meeting and agenda information is considered as “Public”
data and is available to everyone in DLT network. Meeting
and agenda information is setup by either issuer or issuer
agent. Meeting and agenda information is entered directly to
DLT (or) ingested from any other external source and
digitally signed. Smart contracts ensure that only issuer or
any entity authorized by issuer such as Issuer agent are
allowed to setup meeting information. Data is available from
DLT to any downstream system through API mechanisms

4) Shareholder Position and Entitlements

Shareholder position and entitlements refer to position or shares
held by shareholder. It is a dynamic data and can change often.
It is also private and confidential information. Data should be
visible only to shareholder and custodian holding assets on their
behalf, i.e. – If Shareholder X serviced by Custodian C, then
only participants X and C can view shareholder’s position
information and entitlements. Only X and C can view
shareholder identification and no one in the network can
view this information. This poses an interesting DLT
requirement that this information should be stored in DLT and
be part of consensus but data should not be seen by any other
participants except X and C. We have achieved this in Quorum
by using “Private Transactions” and private contract store. Data
is stored in global ledger in an encrypted manner and actual data
is stored in only X and C’s nodes. Rest of nodes has only
encrypted data, decryption keys are present only with X and C.
Consensus is performed using Istanbul algorithm on encrypted
data. Position and shareholder information is ingested from
various systems in JSON format and converted to Solidity
smart contracts. Downstream systems can request data using
APIs. One of the unique features we have implemented and
patented as part of US Patent 9967238[10] is ability to encrypt
at “data attribute” level to ensure highest level of PII protection.
Data seen by X and C differ based on their level of access. Other
participants in the network such as local market custodians and

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issuer agents can see positions and entitlements without Shareholder identity being revealed to them. Data attribute level encryption is not available in Quorum off the shelf.

5) Shareholder Voting

Shareholders can vote directly into DLT and establish their identity using cryptogenic keys. **Vote data is digitally signed by shareholder using his/her private key.** Vote data is also private data and can be seen only by shareholder, custodian servicing shareholder and other participants are able to use vote data for tabulation without knowing identity of vote.

6) Vote Tabulation

Vote tabulation is executed in real-time on DLT by a smart contract. As votes are lodged, a vote tabulator smart contact tallies votes and tabulates outcomes in real-time. Voting data is private and shared only with issuer and issuer agent in real time. Results are published publicly to all market participants and external systems only after completion of meeting. Issuer can also track vote quorum without knowing underlying shareholder identity in real time during the time meeting is live.

7) Vote Confirmation

Shareholder receives confirmation that his vote was registered during meeting by a private transaction in DLT. This vote confirmation is not visible to any other market participants.

8) Technology Stack

<table>
<thead>
<tr>
<th>DLT Platform</th>
<th>Quorum</th>
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</thead>
<tbody>
<tr>
<td>Smart Contracts</td>
<td>Solidity</td>
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<td>Server Side Runtime</td>
<td>Node JS</td>
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9) Benefits Observed

- Increased shareholder participation with real time quorum tracking enabling issuers to send reminders
- Lengthened voting window due to elimination of individual voting windows by each intermediary
- Ease of reconciliation with local market systems

Figure 2 – High Level Architecture
V. **Bilateral Repo using Tokenization**

A. **Overview**

A repo transaction in fixed income markets is a short term lending of a bond or debit instrument from a lender to a borrower. In capital markets repos can be short term with fixed term date (or) a rolling transaction. Repo transaction between two parties is conducted either through a central party or in a bilateral mode. Bilateral mode carries counterparty risk, operational risk and settlement risk. It is also operationally inefficient with manually intensive processes and reconciliation costs.

B. **Problem Statement**

A bilateral repo transaction between a Buy Side institution (Asset Managers) and a Sell Side institution (Broker-Dealers) is typically non-centrally cleared. Due to lack of a central counterparty, risks associated with bilateral repo transactions are quite high. Added to risks are associated costs involved with custodial support and reconciliation.

- Operationally inefficient and manually intensive processes as multiple systems are needed to maintain repo transaction details and reconciliation needed on a daily basis
- Custodial delivery costs for clearing and settlement
- Counterparty, Operational and Settlement risks if a counterparty was to have balance sheet problems
- Expensive process for firms to move collateral cross border between two different geographical entities
- Disputes in Collateral valuation and management process

C. **Goals of the DLT solution**

- Mitigate Operational, Settlement and Counterparty Risk
- Improve operational efficiency, better workflow automation and reduce costs
- Compliance with regulations related to Repo transaction processing, repo life cycle management and margin
- Legal and regulatory compliance related to Security tokens
- Ensure actual bond represented by security token is held at a trusted place
- Ensure data privacy and confidentiality about repo transaction

D. **Key Design Considerations**

We have adopted following key considerations when designing DLT solution:

- Repo transaction details should be visible only to bilateral parties and their custodians involved within the network
- Security token representation of actual bond should be fungible
- Security Token should be backed by a real world bond held at a trusted party
- Pricing of security token should be performed through a smart oracle fetching prices from an agreed upon data vendor
- Collateral eligibility rules for Repo transaction should be captured in DLT
- Security token settlement should happen post cash settlement of transaction

E. **DLT Repo Solution**

1) **DLT Platform**

The chosen DLT platform is Hyperledger Fabric. Smart contracts are written in Go and Node.JS. DLT platform provides RESTful APIs that consume and publish JSON based messaging content to integrate with external systems.

2) **Entity and Identity Management**

The market participants are set up as entities mapping to their legal identification and provided with multiple level of access depending on their access rights. Each entity is provided with appropriate Fabric Certificates to ensure rightful access to node data. Entities are provided read/write or read only access depending on their business rules. Entities are allowed to set up their nodes in on-premise or hosted or cloud infrastructure if directly participating. Indirect participants access DLT through Java based Client application nodes could be set up as read/write nodes or read only nodes.

Only registered and approved users from entity firms have access to DLT. Users are set up through US Patented (US 9967238, Dated May 8 2018)[10] cryptographically secure process developed by Broadridge DLT team. User credentials can be revoked or altered when a real world event impacts user & entity relationship happen such as user leaving firm, transfer to another department etc. Real world user identity is mapped to Hyperledger Fabric identity, verified and validated, a cryptographically secure key pair generated without Broadridge or any other market participant having any information related to keys. User identity keys are not stored in any central database.
3) **Security Tokenization**

The security token is a representation of actual bond held by one of bilateral trading parties. We have developed a smart contract that tokenizes asset held by trading party into security token. Token comes into existence when a trusted party holding asset of trading party agrees to tokenization. Token thus created is fungible and is traded on DLT network. Redemption of token happens through smart contract.

4) **Repo Contract Capture**

**Bilateral counterparties say A and B** pre-agree eligible tokens that can be traded. This is captured as a collateral eligibility rules smart contract. When an actual repo is traded between parties, repo smart contract checks with eligibility smart contract to ensure only allowed tokens are traded. It further checks that lending party is in possession of tokens and underlying asset with an actual trusted Party – **Say Custodian C**. Once smart contract verifies all rules, repo contract is captured and obligations generated against involved parties. Token is now auto settled in DLT post an event indicating that cash settlement has happened between the trading parties. Cash settlement happens outside of DLT.

5) **Repo Mid Life Events Processing**

Smart contracts automate repo lifecycle management by executing following functionality

- Collateral Valuation
- Collateral Substitution
- Margin Call Management
- Repo Contract Amendment
- Repo Contract Termination

6) **Technology Stack**

- **DLT Platform**: Hyperledger Fabric
- **Smart Contracts**: GoLang
- **Server Runtime**: Node JS
- **Middleware**: Express JS
- **Offchain Datastore**: Couchbase
- **Certificate Management**: Fabric Proprietary
- **Private Contract Store**: CouchDB

7) **Technology Architecture**

8) **Benefits Observed**

- Operational Efficiency and Cost Reduction in Clearing of Repo Transactions
- Instantaneous settlement of Repo Transactions through Tokenization
- Cost Savings by avoiding deliveries of actual collateral to counterparty
VI. CONCLUSION

We have conducted 10+ proof of concepts and pilots over the last 4 years using Enterprise DLT solutions in Capital markets including the 2 solutions that have been described in the document. We have additionally explored and continue to explore DLT in the areas of trade finance, securities reference data, equities settlement etc. on varied DLT platforms.

DLT platforms continue to mature and bring multiple stated benefits including risk mitigation, operational efficiencies, cost and capital reduction, business and operational model transformation. We also observe significant focus in DLT technologies to integrate with existing ecosystem to build a “network effect”. The DLT industry is working towards scalability & Interoperability that is desired in capital markets.

We consider following challenges to be addressed if DLT is to be able to achieve large scale adoption in Capital Markets

A. Challenges in Enterprise readiness

- DLT Systems suffer from relative lack of speed and scale compared to existing technologies
- DLT Systems have not achieved integration with existing IDMs, Production monitoring and logging instrumentation etc.
- Lack of enterprise scale DR/BCP infrastructure
- Lack of Interoperability between multiple flavors of DLT solutions

B. Non availability of large scale talent

Most of smart contracts are written in languages which are not widely used in capital markets industry

C. Business Model Transformation impacts incumbents

Embracing emerging technologies which has potential to disintermediate incumbents results in challenges for industry participants to collaborate leading to projects not moving forward to large scale adoption

D. Application of Enterprise DLT in Niche Areas

The Blockchain/DLT hype has created unrealistic expectations in applying DLT for all solutions. We recommend judicious use of DLT in niche areas where there is an existing network and current challenges are hard to overcome with prevalent technologies

E. DLT is still in infancy

Based on multiple industry surveys, we anticipate that enterprise DLT adoption in mainstream capital markets is still 5-10 years away. Niche solutions will go live in DLT in next 2-3 years

F. DLT does not always mean security

DLT solutions do not always mean solution is extremely secure. We recommend existing information security policies to be adopted and leveraged for maximum security. We also recommend exploration pioneering technology components like Intel’s Software Guard Extensions (SGX) [11]. Zero Knowledge Proofs. Security can currently be enhanced with Air gapped Enclave computing.

G. DLT Solutions testing and Quality Assurance is not always easy

Testing tools and techniques for DLT solutions need a mindset shift. Testing network solutions where ledger is distributed and data is available only to trusted participants mean one has to rethink test strategies

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