ICIS 2019 Proceedings

Human Computer / Robot Interactions and Interfaces

Assets under Tokenization: Can Blockchain Technology Improve Post-Trade Processing?

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Ross, Omri and Jensen, Johannes, "Assets under Tokenization: Can Blockchain Technology Improve Post-Trade Processing?" (2019). *ICIS 2019 Proceedings*. 8.
https://aisel.aisnet.org/icis2019/human_computer_interact/human_computer_interact/8

Assets under Tokenization: Can Blockchain Technology Improve Post-Trade Processing?

Short Paper

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Abstract

Recent years have seen rapid growth in IS scholarship addressing the efficacy and utility of blockchain technology in trade-processing and financial services. Numerous IS scholars encourage applied research into the ostensible synergies between the nascent technology and its various use cases. Yet the vast majority of published research approaches the issue from a purely contemplative or theoretical perspective. Addressing this gap in the IS literature, we apply the design science research methodology in the construction a software artefact for the abstract representation of physical assets in the form of blockchain tokens, a process colloquially referred to as tokenization. We present the final iteration of the artefact, evaluating our results against the requirements collected through the design search process. This informs a rigorous evaluation of the conceptual limitations of blockchain-based software artefacts. We conclude that, provided the aforementioned requirements are adequately observed within the design search process, blockchain technology can indeed improve post-trade processing.

Keywords: blockchain, post-trade, tokenization, settlement, clearing.

Introduction

In this time of rapid transformation in financial processing, leading scholars within IS and in the financial industries are pointing to the use of blockchain technology for disintermediating legacy infrastructure in payments and the trade of financial assets (Avital, King, Beck, Rossi, & Teigland, 2016; Beck, Avital, Rossi, & Thatcher, 2017). Blockchain technology, it is argued, enables broad cost saving potential, opening new avenues for growth by mitigating legacy requirements for intermediated trade-processing thanks to its capacity to establish a single source of truth among untrusting parties (Nofer et al. 2017). An emerging concept in the financial industries is the *tokenization* of various assets, by which the exchange of assets is mediated through the use of public blockchain infrastructure. Tokenization is generally defined as the process of representing a given financial asset as a unit on the distributed ledger—a representation maintained by the individual nodes running versions of the blockchain client software. By representing a given asset as a transferable *unit of account* on the blockchain, proponents argue, counterparties can leverage the technical features of the underlying technology to reduce both cost and settlement time, while mitigating risks traditionally associated with the transfer of ownership of financial assets. For this work, we set out to answer the research question: Can blockchain technology improve post-trade processing? In producing an adequate answer to this question, we employ the DSR methodology for the design and development of an artefact capable of deploying and managing bespoke digital assets on the blockchain. By demonstrating how digital assets can be deployed to the blockchain, we show how the technical advantages of the technology can enhance post-trade processing by reducing settlement time while mitigating counterparty risks and reducing costs. Akin to similar use cases in the financial supply chain (Castellanos, Coll-Mayor, & Notholt, 2017), the process of tokenization uses a blockchain protocol for the abstraction of financial assets such as securities, commodities, or forex, on blockchain infrastructure (Glaser, 2017). Asset representation methodologies range over a broad array of practices, with the shared aim of representing ownership and the transfer rights of a digital asset, redeemable for the value of the underlying asset through trade on any publicly available exchange on which the digital asset is listed. For the purpose of clarity we follow the general discourse, referring to tokenized assets as *digital assets*, while blockchain native assets are referred to as *virtual assets* or cryptocurrencies.

Literature Review

Following the seminal work of Webster and Watson (Webster, & Watson, 2002) we carry out a concept-driven literature review, categorizing relevant work within the broader backdrop of the IS genre and industry applications, building on the pioneering work of scholars advancing the discourse on blockchain technology within IS (Avital et al., 2016; Beck et al., 2017). Recent years have witnessed a growing tendency within the genre for framing and standardizing taxonomies and terminology for blockchain-based business models (Beinke & Nguyen Ngoc, 2018; Johansen, 2018). This tendency is accompanied by the pursuit of relevant applications within a wider set of organizational challenges (Fridgen, Radszuwill, Urbach, & Utz, 2018; Hawlitschek, Notheisen, & Teubner, 2018). As a result of the foundational work of IS scholars, emphasizing clarity and standardization in the conceptualization of infrastructure and components, scholars are now in possession of valuable frameworks (Glaser, 2017) and taxonomies (Xu et al. 2017) on which to base practical evaluations of the utility, quality, and efficacy of practical and theoretical artefacts. We now find ourselves at a critical juncture in the technology adoption life cycle (Liao, Palvia, & Chen, 2009). At this point, it is incumbent on IS scholars to contribute to the emerging discourse on practicality and usability, solidifying a number of practical applications for these promising technologies. To this day, few examples of design science research presenting practical implementations of functional artefacts—using blockchain technology to solve issues in financial services—exist. Within the broader field of financial services, scholars in IS have contributed towards understanding the practical applicability of blockchain technology in a variety of circumstances (Castellanos et al., 2017) some exploring KYC/AML services (Parra-Moyano et al. 2018; Parra-Moyano and Ross 2017). Others, the secure execution of financial contracts (Egelund-Müller et al. 2017). Moving outside the IS genre, contributions examining the use of blockchain technology in post-trade processing and beyond have emerged from a variety of fields and industries. Primarily, scholars in the managerial sciences have contributed towards establishing a proficient understanding of the utility of blockchain technology in the settlement and clearing processes associated with the post-trade cycle (Micheler & von der Heyde, 2016), a tendency reflected within the growing body of industrial literature on the topic (Pinna & Ruttenberg, 2016; Platt & Csoka, Peter, Morini, 2017).

The Post-trade Cycle

The generalized term “post-trade processing” encompasses all the relevant processes, actors, and infrastructure used from the agreement of a price for a security on the financial markets until the trade is finally settled (Evangelos Benos, Rodney Garratt and Pedro Gurrola-Perez, 2017). Settlement, in this context, is considered as complete when all parties have received, accounted for, and reported all outstanding items relating to the trade of a given security. Securities trading is largely facilitated by central securities depositories (CSDs)—central organs tasked with servicing counterparties in conjunction with a number of supporting institutions and external facilitators. CSDs act as regulated intermediaries, performing a number of compulsory services in the post-trade cycle. Dependent on the institution, offerings may include custody, reporting, or securities lending facilities. In Table 1 we list three core functions of CSDs alongside the illegitimate activities each is designed to deter, informed by the seminal work of Benos, Garratt, & Gurrola-perez, (2017).

Function	Description	Mitigating	Requirements
Notary Functions	Maintaining shared records of all issued and traded securities.	Creation and trade of fraudulent securities with no claim for real cash flows.	Universal and impartial records, trusted by all parties and compliant with regulatory standards.
Settlement Functions	Facilitating the transfer of legal ownership between counterparties.	Counterparty default, execution risks, and fraudulent short-selling activities.	Transparent delivery-versus-payment processes with stipulated recourse to grievance.
Accounting Functions	Reconciling accounts and managing physical and cash-based transactions.	Manipulation of books and ownership records following transactions.	Centralized third-party accounting facilitator.

Table 1. Core functions of the CSD

Needless to say, the post-trade processing regime levies heavy fees on market participants, generating a significant source of revenue for market intermediaries, such as CSDs, and related institutions or subcontractors (BIS Markets Committee 2016). Observers have estimated the aggregate costs for activities relating to post-trade processing may approximate up to 13% of the total value of a given trade (Benos et al. 2017). The general consensus among IS scholars is that excessive costs tend to accrue in cases where sensitive data is processed in protected and siloed environments (Alter 2003). This description certainly applies to the post-trade cycle, in which a sequence of institutions individually process information before handing it off to the next link in the value-chain (Pinna and Ruttenberg 2016). The combination of a general lack of standardization and a growing global demand for interoperability and fast process times has resulted in a cumbersome reconciliation procedure, adding additional cost burdens to the post-trade cycle. Hence our question for this short paper: Can blockchain technology improve post-trade processing?

Method

The artefact presented in this paper is the result of a cross-organizational development process (Fanning and Centers 2016; Ken Peffers et al. 2007) hosted by a leading online brokerage firm with strong competencies in applied blockchain technology. We employed the design science research (DSR) methodology (Gregor and Hevner 2013a), opting for short iteration cycles with frequent recursive feedback loops with selected groups of representatives from the host organization, industry and academia. The DSR methodology informed a cross-organizational "build–demonstrate–evaluate" workflow (Fridgen, Radszuwill, Urbach, & Utz, 2018) aimed at producing applicable IT artefacts for the specified organizational problem. Following the general approach to conducting DSR advocated in the literature (Ken Peffers et al. 2007) we define an iterative and cyclical six-step process, emphasizing the feedback loop between intermediate evaluation and testing of the artefact (Hevner 2007).

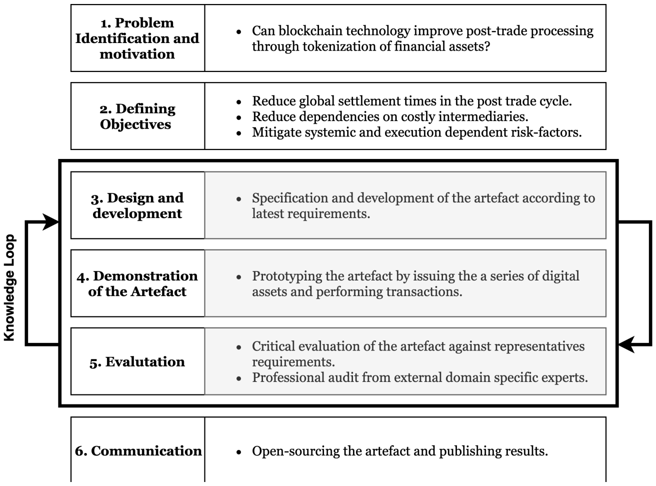

Figure 1. The DSR methodology

To solidify a concrete understanding of the design problem, design requirements were gathered through a series of unstructured qualitative interviews with executives, financial regulators, customers, and domain specific experts (Myers and Newman 2007). Concurrently, a survey of existing implementations was performed, establishing a number of industry-wide best practices while gathering experiences from past attempts at producing similar artefacts (Ken Peffers et al. 2007). The data gathering process generated a set of fundamental requirements for a successful artefact, presented in Table 3. In Table 2, we introduce the interviewees, denoted by their involvement in the creation of the artefact.

Role of the Interviewee:	Involvement:
CEO of host organization	Vision and general guidance.
Managing Director of host organization	Several feedback loops and partial involvement in artefact specification process.
Trade executive at host organization	Several feedback loops and partial involvement in artefact specification process.
Product executive at host organization	Several feedback loops and partial involvement in artefact specification process.
International regulator (EU)	In-depth compliance review and evaluation.
External code auditor	Static analysis, manual review, and in-depth evaluation.

Table 2. Interviewees queried for artefact requirements

Artefact Requirements

While iterating through the design, development, demonstration, and evaluation phases depicted in Figure 1, we iterated through sets of of core requirements for the artefact, in alignment with the interview respondents presented in Table 2. The extraction and compilation of user requirements is widely recognized as a challenging aspect of the design search process amongst IS scholars (Kuechler and Vaishnavi 2008). The compilation of the requirements for this artefact was subject to a number of technical limitations, native to the underlying blockchain technology. Drawing on pioneering scholarship within the IS genre, we composed a set of conditions for the specification of design requirements for robust blockchain-based artefacts (Seebacher and Maleshkova 2018; Xu et al. 2017). Prior to all engagements, we briefed the interviewees carefully on the following constraints, native to blockchain technology:

a) **Non-retractability:** Sound requirements must address the immutability of the distributed ledger as a core characteristic. Once deployed to the blockchain, neither transactions nor smart contracts can be reversed or reconfigured. This imposes high costs for production or design errors.
b) **Pseudonymous agency:** The use of public-key infrastructure in public blockchain technology implies the existence of pseudonymous agents. Sound requirements must address the presence of non-identifiable actors through succinct and well-defined identity management schemes.
c) **Standardization:** Given the relative novelty of the underlying technology, thorough design requirements for blockchain-based artefacts ought to promote consolidation around a set of identifiable and universally compliant standards.

Through the course of a six-month timeframe, we completed several iterations of the “knowledge loop” presented above. This informed a sequence of tentative artefacts, all of which emerged as products of a cyclical process of design, development, demonstration, and evaluation (Fridgen et al. 2018; Ken Peffers et al. 2007). The process informed a process of gradual reduction, leading to three final core requirements for the artefact, presented in Table 3.

Requirement:	Description:
Control Flow Security Optimization	Security breaches can occur through two primary vectors: a) exploitable bugs in the smart contract code; b) abuse of privileged accounts by a malicious party obtaining access to the private key of an account with privileges that will enable a single agent to assume control of the system. Given the prior conditions of non-retractability and pseudonymous agency, these concerns were prioritized among the requirements. To accommodate this requirement, the artefact must conform to best practices in software engineering, while limiting the possibility and effect of privileged account abuse through a secure and limited control flow.
Heterogeneous Asset Representation	Existing implementations of tokenized assets have a single-faced representation, meaning that the tokenization platform supports a single asset class only. To accommodate the production of a diverse portfolio of digital assets, the artefact must be able to produce and monitor multiple digital assets, fully compliant with existing standards for digital assets.

Usability and Broad Integration	The artefact must be usable by non-technical personnel and comply with existing standards, allowing seamless integration with surrounding infrastructure.

Table 3. Artefact requirements

Artefact Description

We present the artefact from a conceptual level of abstraction, favoring the general applicability of the artefact design over detail orientation (Gregor and Hevner 2013). As the basis for implementing our solution, we chose the Ethereum blockchain (Antonopoulos and Wood 2018; Wood 2018). The Ethereum blockchain provides a suitable foundation for supporting our needs due to its relative maturity as a smart contract platform and its broadly applicable set of features and ecosystem-wide consolidation around recognized development standards. This enables seamless interoperability between the host organization and external stakeholders.

Permission Management

To promote the secure execution of critical processes in the creation and management of each digital asset class, we created a hierarchical permission management system, drawing on existing best practice implementations. To reduce the impact of assigning critical privileges to a single owner role, we separated all core functionalities into independent sub-roles, assigned to key stakeholders within the host organization. The roles and their assigned functionalities are presented in Table 4.

Role:	Assigned functionalities:
OwnerRole	Creating the digital asset category.
MinterRole	Minting digital assets to a single account.
BurnerRole	Removing digital assets from an owned account.
PauserRole	Temporarily pausing digital assets on the blockchain.
WhitelistAdminRole	Nominating and removing WhitelistRole accounts.
WhitelistRole	Adding and removing accounts to and from the whitelist contained within the AccessList.
BlacklistAdminRole	Nominating and removing BlacklistRole accounts.
BlacklistRole	Adding and removing accounts to and from the whitelist contained within the AccessList.

Table 4. Overview of roles for each digital asset class

Separating Data Storage from Functionality

Immutability is an important functional characteristic of smart contracts as it provides a guarantee that a contract, once deployed, will behave exactly as prescribed by its code, embodied by the popular proverb *code-is-law*. However, as frequently observed in the literature, immutability creates a number of design challenges, revolving around updating critical functions in the contract system (Luu et al. 2016). Various strategies to address these issues exist in the literature. (Delmolino et al. 2015) The vast majority of these rely on the implementation of post-deployment reconfigurable code paths, enabling contract calls to be proxied to a specified location. A key aspect in the design of an upgradable token is the issue of data migration. In blockchain-based smart contract systems, data is explicitly tied to the functionality of the contract system. Nevertheless, storage of data on blockchain technology often adds exorbitant computational costs, as migrating large amounts of data between contracts can become infeasibly expensive. Consequently, to achieve upgradable smart-contract systems, we must separate storage of data from contract functionality. In practice, this separation is implemented by creating a separate contract exclusively supporting data load and store operations. In order to prevent multiple tokens from accidentally or intentionally writing to the same storage, the storage contract will only accept requests from a single contract at a time. To mitigate the existence of inconsistent state between functionality and data storage, the artefact relays requests through a proxy function, effectively passing information to the latest existing token deployed on the network, depicted in Figure 2.

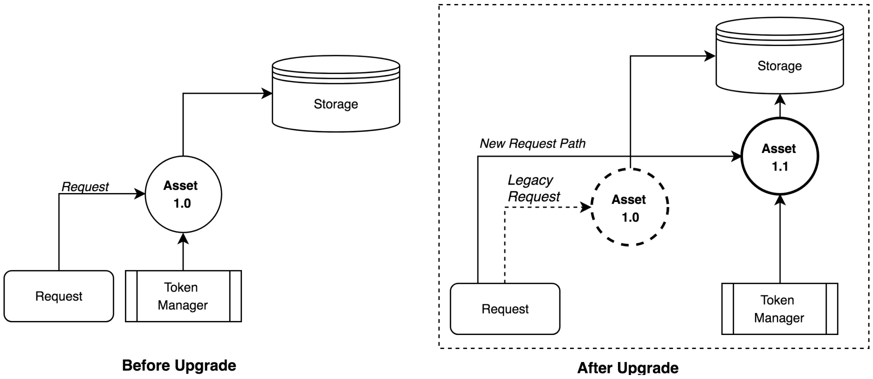

Figure 2. Separating storage from functionality

Access Management

With the aim of minimizing the risk that an internal function is unintentionally exposed to a compromised external actor, we introduce a four-layered security scheme. This was achieved by dividing the design into four layers, each implementing a clearly defined set of functions. A description of these layers is presented in Table 5.

Interface Layer	The Interface layer implements the public interface of a digital asset. If an upgraded token is called, the call is forwarded to the proxy interface of the token next in the chain of upgrades. If the token is not upgraded, the call is forwarded internally to the access-control wrappers.
Proxy Layer	The Proxy layer implements the chaining of calls through multiple generations of upgraded tokens. All upgrade targets must implement this interface. When the chain of calls eventually reaches the currently active token, the call is forwarded to the appropriate function. The functions exposed by this layer are public, but they are only callable by their immediate parent.
Access Control Layer	The Access control layer implements "wrappers" around internal functions. This enforces access control by reading the white/blacklist storage contract, managed by the roles assigned in table 4. All access control checks that are performed on the request sender use the explicit sender parameter passed down for each digital asset.
Functionality Layer	The core functionality comprising the token is implemented in the final layer. This functionality is only exposed through internal functions, which are wrapped by the outer layers.

Table 5. The four layered design

In Figure 3 we visualize the implementation design, emphasizing the sequential pathway through the four layers described in table 5:

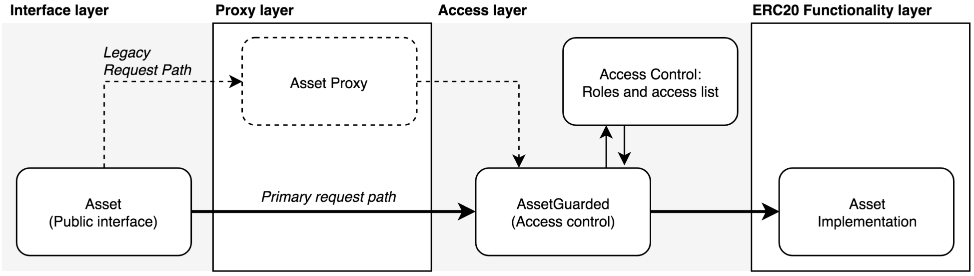

Figure 3. Visualization of the layers comprising the implementation

Artefact Evaluation

As noted above, the *design–build–evaluate* approach to the design search process (Ken Peffers et al. 2007) informed an iterative workflow in which several cycles of the *knowledge loop,* depicted in Figure 1, promoted an emphasis on recursive evaluation of the artefacts' commensurability with the stated requirements over permissible complexity in the implementation. In evaluating the extent to which the requirements have been met, we compare them to the final implementation of the artefact.

Control Flow Security Optimization: To ensure the correct implementation of the core functionality of the tokens, significant effort was made to ensure that the process of deploying additional digital assets was provably simple, robust, and reproducible. While not traditionally associated with security measures in software design, these aspects carry significant importance, as the artefact must be usable by a hypothetical end user (vendors or custodians of tokenized assets) without significant problem-solving ability or intricate knowledge of the code base. We approached the requirement for control flow security optimization with a three-pronged solution: a) The introduction of a hierarchical distribution of functions among several administrative "roles" assigned to multiple addresses mitigates the critical risk of frequently exposing all functions through a single administrative role. b) The separation of the storage from the implementation functionality enables the artefact to call a shared registry of addresses, approved within a predefined white/blacklist. c) The implementation of a four-layered security scheme guarantees that all function calls are passed through evaluation and proxied to the latest implementation of the digital asset. To ensure the quality of the artefact, the code base underwent several iterations of professional auditing including automated static analysis and manual review. Static analysis tools were used to identify common code issues using predefined patterns and control flow graph analysis.

Heterogeneous Asset Representation: The artefact was demonstrated by the production of a body of twelve digital assets deployed on the Ethereum blockchain. Notwithstanding fluctuating currency and commodity rates, these digital assets represent an aggregate value in the area of USD 100M, which is currently traded actively among digital asset and cryptocurrency exchanges.[1]

Usability and Broad Integration: Early in the process, we recognized the importance of adhering to established standards in order to ensure ecosystem-wide interoperability. This foresight was validated through the integration of the artefact with supporting digital-asset infrastructure. The digital assets produced by the host organization are currently traded on cryptocurrency exchanges and accessible through wallet software applications.

Discussion and Implications

A commonly cited beneficial property of blockchain technology is the capacity for enabling untrusting counterparties to make transactions with each other in a secure manner without requiring a trusted central facilitator. This property is due to the mechanism used by blockchain validators when achieving consensus among the pool of nodes maintaining the ledger of accounts (Glaser 2017b; Johansen 2018). Drawing on the qualities and properties of blockchain technology defined in the growing body of literature within the IS genre, we submit that blockchain technology might adequately replace the notary, settlement, and accounting functions described in Table 1. In this paper, we demonstrate how a heterogeneous portfolio of digital assets can be implemented on public blockchain infrastructure through the process of tokenization. We contend that parties involved in the post-trade cycle may successfully replace legacy infrastructure to unlock significant cost saving potential in the post-trade cycle.

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[1] We invite the reader to view one, or more, of the digital assets currently deployed on the Ethereum Blockchain by navigating to the following URL: https://etherscan.o/address/0x4e3856c37B2fe7FF2Fe34510cdA82a1DFfD63CD0.

Conclusions and Future Work

In this work, we have demonstrated that blockchain technology is sufficiently mature to support the implementation of a complete and functional platform for the tokenization of assets. This introduces new opportunities for cost savings within financial services, particularly in the post-trade cycle. By presenting a functional artefact for the representation of assets on blockchain technology, we address a gap in the IS literature, inviting fellow scholars to criticize or build upon the work presented in this paper. Future contributions to this topic may include artefacts for monitoring transaction propagation on blockchain technology, alongside improvements in risk-management and security of the existing artefact.

Acknowledgments

The authors remain indebted to Yoni Assia, for his visionary support and guidance in identifying and advancing the opportunities for tokenization in the financial services. We would like to express our sincere gratitude towards: Doron Rosenblum, Elad Lavi, Jonathan Dayan, Professor Fritz Henglein, Professor Michel Avital, Peter Emil Jensen and Mads Jørgensen.

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