The Design and Implementation of Blockchain Technology in Academic Resource's Authoritative Metadata Records: Enhancing Validation and Accountability

by

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Dedication

This dedication is to my family, who has put up with my years of pursuit in higher education and been an amazing support group. Thank you for teaching me some things are worth fighting for.

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Table of Contents

Table of Tables

Abstract

This study endeavors to address the growing needs of research intuitions to unify the MARC metadata records as they are passed between systems. To support research intuitions in locating and track resources the MARC metadata records provide a backbone for research and tracking purposes. However, the MARC records are not unified across the many distributed systems, and this results in confusing and fuzzy record logic. To assist in remedying the fuzzy MARC logic, this study attempts to assimilate a metadata record into a custom blockchain to allow for unification, accountability, and validation of a MARC metadata authority record.

Introduction

According the American Library Association (2006), in 2012 there were over 1.5 billion in-person visits to libraries across the United States. These visits are recorded in the Public Library Survey (PLS) federal report and are released by the Institute of Museum and Library Services (IMLS) (American Library Association, 2006). The PLS and subsequent reports are reviewed and released to the public to assist in determining how libraries are being utilized, who is utilizing them, and the general public's assessment on the libraries' community services and the resource materials being provided (Grimes et al., 2012).

The local libraries provide resource materials and services to meet the needs of their resident communities, but sometimes libraries need a little extra assistance to meet those demands while working with increasingly restrictive budgets (Grimes et al., 2012). To assist in meeting the growing demands of their communities, libraries collaborate with other institutions to perform a greater variety of services as well as expanding their material selections for their respective communities (Grimes et al., 2012; Library of Congress, n.d.-a). These collective partnerships and collaborative efforts assist in stretching the libraries budgets further, thus allowing libraries to expand their resources and offerings. These collaborative partnerships and resource collaborations on the libraries' behalf will henceforth will be referred to as research institutions (RI) for the purposes of this research paper. The RI partnerships and smart resource utilization allows an RI to enhance its learning opportunities, expand research capabilities, and enrich academic life (Grimes et al., 2012; Library of Congress, n.d.-a). Furthermore, the growth and increased breadth of the communities academic purists places a demand for an RI to expand their services and academic resource offerings to meet the growing needs of their respective communities (Grimes et al., 2012).

To assist in meeting the communities growing demands RI are turning to new and emerging technologies. The emerging technology known as blockchain is being heavily investigated and discussed by the RI communities as a way to assist in the dissemination of scholarly works (American Library Association, 2017). The hypothesis that is currently being discussed by the American Library Association (2006) is if blockchain technology can assist in unifying the distributed RI systems that are being used for collaboration and resource sharing.

This study investigated the validation and accountability of the blockchain technology and how it can be applied to the RI record systems. The blockchain technology is used to store information in a widely distributed and largely tamper-resistant setting by relying on a series of encrypted and hashed codes inside a publicly distributed ledger (Hoy, 2017). In using the blockchain technology for validation and accountability of changes to an RI records, RI should be better positioned to service the growing needs of their local communities by unifying the records that are being disseminated between the highly differentiated RI systems.

Background

To assist in meeting the growing demands of their communities, an RI may use a mixture of shared systems, collaboration technologies, and cooperative programs that help to expand their learning services, public outreach, and material resources (Library of Congress, n.d.-a). These collaborative partnerships and shared systems assist in spreading the burdens of cost and maintenance (Library of Congress, n.d.-a). These shared systems enrich the academic resources available to all partners by allowing them all to access resources at a reduced rate with less budgetary overhead (Library of Congress, n.d.; Van Rossum, 2017). Resource sharing and collaborative programs between RI are made technically possible because they are structured and dependent on the MAchine-Readable Cataloging(MARC) standards (Library of Congress, n.d.).

The MARC standards provide a ridged structure that allows RI and their vendors to standardize their resource records within the cooperative cataloging systems (Library of Congress, n.d.-a). MARC metadata authority and bibliographic records are often obtained by RI subscribing to third party bibliographic utilities such as the Online Computer Library Center (OCLC), Western Library Network (WLN), and Research Libraries Information Network (RLIN), or by the RI maintaining their own records (Library of Congress, n.d.-b).

The MARC standards are critical to RI collaborative cataloging systems as it allows for quick referencing of records and research materials. The cataloging systems organize each resource's metadata which typically consists of both an authority record for the author and bibliographic record for the works (Library of Congress, n.d.-a). The bibliographic records for a resource identify the resources' descriptions, main organizational entries and additional suborganization entries, subject headings, and classifications/call numbers (Library of Congress, n.d.-b). Moreover, an authority record purpose is to identify the author's comprehensive works. The author's metadata compilation allows for cross-referencing with the author's alternative works, and includes the author's name and known aliases, prior titles, and subjects the used on the bibliographic records (Library of Congress, n.d.-a, n.d.-b).

While MARC records provide a signpost in the catalog databases that the RI utilize to disseminate their materials to the general public, there is a lack of unification among the individual MARC records in the RI databases (Library of Congress, n.d.-a). Each RI can keep their own MARC records and update them in their personal databases at will, which creates an on-going issue of which MARC record should be used to query information (Library of

Congress, n.d.-a). In addition to the privatization of metadata records, there is an issue with fuzzy MARC records (Steverman, 2017). Fuzzy MARC records occur when the information in the authority and bibliographic metadata records lack a certain amount of completion (Steverman, 2017). The fuzzy MARC records are a problem because records containing start, end, and merger dates are very rare (Steverman, 2017). The problem with the rarity of dates in the metadata authority records means that the correct identification of just a single record be extreme ambiguous (Steverman, 2017). Missing dates in authority records are not the only problem that RI have with the metadata records, there is also a problem with identifying relationships between organizational hierarchies (Steverman, 2017). Records that have hierarchy relationships often experience a problem with the limited character length in the relationship field signpost that are used to lead the user to the next relevant record (Steverman, 2017). The limited character length hinders a researchers ability to accurately describe parent and child organizational relationships (Steverman, 2017). The limited ability to describe parent and child organizational relationships results in unnecessary record complexity when trying to navigate to related works (Steverman, 2017).

Bibliographic and authority records allow researchers to locate given works within the cataloging system (Library of Congress, n.d.-a). As an example: for a researcher to locate a book by a given author, a query would be submitted to the RI or collaborative partner/vendors database(s) to locate the desired author. The query returns all known resource materials that were written by the author with bibliographic records, in addition to the author's separate authority record. The authority record allows the RI catalog to return any known pen names or maiden names that the author also published works under. By utilizing the authority record, search results return a more comprehensive listing of the author's published works.

It can be informative for RI's to know which authors are in high demand and have a comprehensive listing available of an author's given works. Knowing both the comprehensive listings and which works are most demanded is important to RI because some resources, especially online materials, are often obtained through contract negotiations and subscription-based databases (Davis, 2016). These types of contracted and subscription-based materials are referred to as paywalled materials, and these pay-to-access restricted materials is the reason why knowing which works and authors are in demand is critical to RI (Davis, 2016). These paywalled, vendor distributed, resource databases vary widely depending on vendor and the RI utilizing them, but the authority and bibliographic records behind the databases are standardized through MARC (Library of Congress, n.d.-a).

The unification and dissemination of MARC authority records is still being discussed by the RI community at length (American Library Association, 2017). The American Library Association (2017), believes that in the future it is going to be critical for RI and their partners to develop a way to distribute information and resources in a tamper-resistant setting. One such tamper resistant technology which is quickly gaining popularity today is the blockchain technology.

The newly emerging blockchain technology has been speculated as a potential solution to resolving the RI growing concerns of unifying the metadata authority and bibliographic records, as well as their concerning inability to distribute and track resource usage (Davis, 2016). The main attraction to utilizing the blockchain technology is that it can be used to store information in a widely distributed and largely tamper-resistant setting (Hoy, 2017). Blockchain is still a relatively new technology, where the conceptual white paper was only submitted in 2008 (Hoy, 2017). The white paper was written under the pseudonym "Satoshi Nakamoto" (Hoy, 2017).

Although while blockchain's creator has yet to be formally recognized, the technology has quickly become disruptive to many industries (Hoy, 2017). For example Sony is discussing exploring the blockchain technology to give students control of their education records, while health professionals are discussing the possibilities of using blockchain technology for drug tracking and patient records (Hoy, 2017). Furthermore, RI are looking at the blockchain technology to create a tamper resistant chain of control for records and resources (American Library Association, 2017; Hoy, 2017).

Possessing a tamper resistant chain of transactions is a major allure for financial businesses. Financial businesses, such as banks, are starting to turn their attention and take interest in the capabilities of the blockchain technology. An early financial businesses adapter of the blockchain technology was Bitcoin (Hoy, 2017). Bitcoin and its ever-increasing number of offspring cryptocurrencies have been using blockchain technology as their foundation for accountability and authentication in a tamper-resistant setting. To assist Bitcoin with matters of accountability and authentication, Bitcoin utilizes a decentralized authority in the form of distributed ledgers (Hoy, 2017). Bitcoin's decentralized ledgers keep track of the private-public key digital signatures and transaction agreements in a hashed transaction unique to blockchain (Hoy, 2017). These hashed values are unique to the adjacent blocks, which creates the immutable legacy chain.

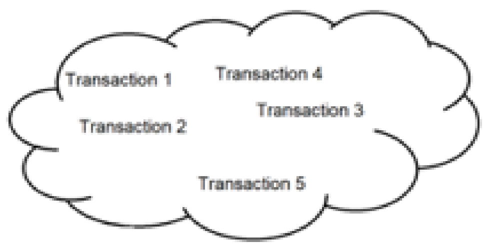
Blockchain excels at decentralized, self-regulating datasets by using open ledger systems distributed to all users, as a way to validate, verify, and hold users accountable for information exchanges (Van Rossum, 2017). To provide a quick reference to how blockchain works, Figure 1 illustrates the general blockchain process, in addition to displaying how blockchain technology verifies a transaction before committing changes to the ledger.

As the final step in the process blockchain transaction is then verified by the entire network via the publicly distributed ledger. These blocks are secured in place by storing hashes from that last block to the new block, chaining the transaction's position in line (Fedak, 2018). The further back in the chain a record is, the more secure it is because of the chain becomes more immutable (Fedak, 2018). The chain is immutable because it would require a malicious user to convince 51% of the network that the malicious changes to the ledger are valid before the next block has been added to the chain (Fedak, 2018).

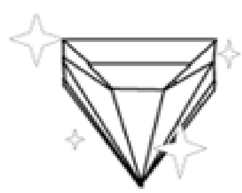
The hashed immutable legacy chain is very enticing for the financial sector, but the possibilities are being discussed by many different areas of business. RI are just one of the businesses that are heavily discussing the opportunities that the blockchain technology possesses. RI are wondering if the blockchain technology can assist in changing current business practices, and this study will be focusing on the unification of metadata authority and bibliographic records among the many diversified databases, as well as assisting in distributing information and resources in a tamper-resistant setting.

Step 1: User A requests system transaction on node 1 with User B on node 2.

Step 2: The transactional agreement between Node 1 and Node 2 is tracked out and broadcast to the entire network.



Step 3: The transaction is verified and accepted into the pool of pending transactions.



Step 4: Miners race to validate the transaction, competing against other miners to unlock the transaction's security algorithm, thus completing the transaction.

Step 5: Once a miner unlocks the security algorithm the transaction is committed to the general ledger and a new block is added to the blockchain.

Figure 1. Blockchain Process Flow.

Statement of the Problem

The research problem that this study will address is the validation and accountability of MARC authority metadata records when transferred from system to system. The validation and accountability of a resource's utilization impacts the RI ability to disseminate scholarly works to the general public (Davis, 2016; Hoy, 2017; Van Rossum, 2017). The dissemination of scholarly work is vital to a RI ability to meet the ever-growing needs of their local communities. As the demands of local communities grow, RI are at the forefront to service these growing needs; however RI are facing a funding shortage that began in 2009, and continues as local, federal, and state governments cut back on spending (Goldman, n.d.). With limited funding, there is a growing need to cross-collaborate to reduce costs and increase material availability (Library of Congress, n.d.-a). Many RI are discussing the possibilities of the blockchain technologies capabilities to meet their growing needs for the unification of metadata authority and bibliographic records, in addition to developing the ability to distribute information and resources in a tamper-resistant setting (Davis, 2016; Hoy, 2017; Library of Congress, n.d.-a; Van Rossum, 2017).

Purpose of the Study

The main goal of this research study is to enhance authoritative MARC records by utilizing the blockchain technology to develop an immutable, sequential, chain of records that can assist in the validation and unification of metadata authority records. The validation and unification of metadata authority records is important to RI because the blockchain enchantment would allow for further unification of records while allowing the systems to track author data changes between systems. The need for this work is demonstrated by a need to validate and unify authority metadata records (Hoy, 2017; Van Rossum, 2017). The many discussions among RI and their partners have led to the blockchain technology being proposed to assist with the dependency on third-party scholarly works. By implementation of the blockchain technology into RI systems, the desired effect is that the RI systems would become more flexible with the blockchain assisting with authentication and usage accounting (Davis, 2016). The American Library Association (2017), and Dr. Joris Van Rossum (2017), speculated that the blockchain technology would assist in alleviating some of the constraints placed on scholarly communications such as legacy workflows and publishing formats. Additionally, it is speculated that a blockchain might assist in reducing record keeping costs, while improving accuracy, creditability, and disaster recovery capabilities (American Library Association, 2017).

There are several objectives that this research study hopes to understand by implementation of the potential utilization of the blockchain technology to provide enhancements to MARC metadata authority records. The first objective utilizes the blockchain technology to transfer a single static MARC authority record along a two-node network while keeping a distributed ledger on each node. The second objective allows for the passage of multiple authority records within the system, with a minimum of three records being committed to the distributed ledger. The second objective also includes making sure all distributed ledgers, on all network nodes, are being kept up to date with the block-chained changes to the authority record. Lastly, this research should address the question on if it is possible that the blockchain technology will be able to link cataloging systems together for the sake of authority metadata records unification. In addition to the potential unification across systems, the implementing of the blockchain technology might be able to hold users accountable for modifications to the metadata fields to the MARC authority records.

In summary, by implementing blockchain technology to enhance metadata authority records, this study would like to understand if unification and accountability can be achieved for RI to utilize within their diverse systems by creating a single record for authority metadata to be read into library catalog.

Rationale

The rational for blockchain development being applied to metadata authority records is centered around meeting RI business needs to organize and unify systems. The RI need to organize and unify systems is due to diminishing RI budgets (Grimes et al., 2012). There are many discussions being held by experts such as Dr. Van Rossum (2017), Matthew Hoy (2017), Phil Davis (2016), to explore if the blockchain technology is a suitable solution to assist in resolving legacy workflows, correlating historical records, and improving scholarly communications to assist in the dissemination of scholarly works to the public.

Research Question(s)

This study will answer the following research question(s):

1) Can the blockchain technology distributed ledger be used to validate changes to the MARC metadata authority records?
2) Can blockchain technology be used to hold users accountable by tracking who is making editorial changes to the metadata authority records?

Nature of the Study

This is an exploratory design science study which will provide research on if blockchain technology can be applied to metadata authority records. The exploration into applying the blockchain technology to metadata authority records will assist in determining if the technology is a suitable vehicle for disseminating the authority records for the sake accounting and validation within RI databases. As the distributed ledgers increase in size, the less energy effect blockchains become, which can make the blockchains unwieldy and unsustainable vehicle for all systems (Greenspan, n.d.). As the result of the blockchain's high demand in computational overhead, it is necessary to see if blockchain is even a valid technology that will assist RI in unifying MARC authority metadata records across unrelated databases. The unification of authority metadata records across disjointed systems serves to assist RI in their ability to meet the growing needs of their communities by creating accountability and validity in resource materials disseminated the general public.

Significance of the Study

This significance of this study will primarily be of interest to libraries, research communities, publishers, and third-party mediators. Academics and researchers widely use disjointed and incompatible systems in their workflows, those research contributions are then passed along the chain to publishers, and then to RI who will use additional systems to catalog and cite the works (Van Rossum, 2017). Gideon Greenspan, the CEO of Coin Sciences (2017), reports that for a workflow system to even be considered suitable to fully utilize the blockchain process eight conditions should met: (1) the presence of shared databases; (2) databases with multiple writers; (3) writers in the multiple databases have a profound absence of trust; (4) that absence of trust turns into a need for a trusted intermediary; (5) there is a need for interaction between transactions;(6) limited and restricted transactions being performed, (7) require an authoritative final transaction, and (8) a way to back the assets in the log. RI meet these criteria in the following ways: (1) as they often subscribe to multiple bibliographic databases; (2) RI often maintain their own authority and bibliographic records, however (3) RI also can edit other RI authority and bibliographic records, which leads to (4) the necessity to subscribe to multiple databases to verify metadata records (Library of Congress, n.d.-a). Criteria (5-8) are met as publishers and record owners must validate the records as they are updated and report the changes across the different databases, these verifications limit who and how literary works can be accessed (Van Rossum, 2017). The RI problems and current workflow methods are highly demanding, as a result there is an excellent opportunity to implement the blockchain to help resolve these quandaries (Van Rossum, 2017).

Definition of Terms

- ALA: American Library Association
- API: Application User Interface
- Authority Record: Records that contain standardized forms for names, titles, and subjects that are used on bibliographic records and provide cross references in catalogs (Library of Congress, n.d.-a).
- Bibliographic Record: Records that contain information about a book, serial, sound recording, video recording (Library of Congress, n.d.-b).
- Bitcoin: Digital payment system that uses its own currency to conduct transactions between users in an open, verified and shared network (Van Rossum, 2017).
- Blockchain: A transactional history of all transactions that had ever been completed on the network and requires an agreement to lock a transaction into the sequential ordering chain (American Library Association, 2017).

- Cryptocurrencies: Digital tokens that are exchanges on a virtual network using cryptographic algorithms and digital signatures to verify purchases in attrition to avoiding double transactional charges (Hoy, 2017).
- Fuzzy MARC: Metadata records that are missing, have ambiguous, or relationship conflicts (Steverman, 2017).
- IMLS: Institute of Museum and Library Services (American Library Association, 2006).
- LC: Library of Congress
- Ledger System: Accounting systems that work to record transactions (Hoy, 2017).
- MARC: Machine-Readable Cataloging (Library of Congress, n.d.-a).
- Metadata: A set of data that relates to another set of data and provides information.
- Open Source: Applications and/or code that is available for general public use or medication from its original design.
- Paywall: Applications that prevent users from accessing restricted materials unless the user logs in and had paid tolls (Davis, 2016).

Assumptions

Developer has skill, knowledge, and resources to implement all known aspects and keep the project limited, but transferable, legible, and well document for further expansion and collaboration.

Limitations

Project only spans twelve weeks from of start to completion. The official start date of the project is May 15th and runs until August 5th. Another limitation is that blockchains require large and interactive user based communities to work efficiently and securely, the smaller the user base on the application the less secure the blockchain is and the less likely that implementation will work as intended (Al-Saqaf & Seidler, 2017).

A known limitation of blockchain's in that in order to physically overtake the entire network and create faulty transactions a malicious user would need to takeover 51 percent of the network (Fedak, 2018). This is a particular problem with cryptocurrencies that deal with banking information, however any system that uses a decentralized ledger to account for transactions would also be at risk for this vulnerability. This security flaw is critical while the system gains traction, however once there are enough users in the system, controlling and convincing over 50% of the network that the flawed ledger is correct becomes more difficult (Greenspan, n.d.). Legacy code is even more difficult to change, as changing a single character on a historic block changes every block that comes after it. There only way to mitigate this flaw is to be selective on who uses the network. Blockchain allows for private or public ledger systems, which could help mitigate this flaw (Greenspan, n.d.). However, strictly speaking it is a documented risk of using the blockchain technology.

Lastly, a known limitation is the restricted sample size of the MARC metadata authority record itself. The record was selected for convenience and ease of implementation, but as a result more complex records such as those with fuzzy MARC, parent or child organizations, or even name changes are outside the scope of this study.

Unknowns

Current unknowns that are operated on is that all the details and parts that blockchain will require to be fully implemented. If time allows the scope of the project can include security, web client interface, expansion of record information, and record validation.

Chapter 2 Literature Review

The validation and accountability of MARC authority metadata records is problem for most RI (Gardner, 2012; Steverman, 2017). According to Grimes et al. (2012) the PLS report for the 2012 fiscal year resulted in over 2.2 billion RI materials being circulated within the public libraries (Grimes et al., 2012). The 28 percent increase in circulation of RI materials has allowed for an increase in RI material acquisitions, where expenditures for electronic materials have increased by 92.2 percent between 2011 and 2012 (Grimes et al., 2012). This is upward trend in material acquisitions is primarily because of an increase in demand for electronic materials. The increasing demand for electronic materials has resulted in the purchasing of new electronic media, which encompasses approximately 16 percent of the RI total resource collection budget (Grimes et al., 2012). However, RI resource collections have been greatly hindered over the past ten years as budget reductions of over 15 percent have forced many RI to become very selective of which resources to add to their collections, be it a digital resources or other varieties of resources (Grimes et al., 2012). The importance of decreasing budgets for the purchasing of collection materials means that RI are being forced to be more selective of their collection materials. The decrease in funding pushes RI towards cross collaboration with other RI, vendors, and publishers to assist in maximizing their returns within their limited budgets (Library of Congress, n.d.-b).

As RI continue to work with limited budgets to meet the needs of their ever-expanding communities, tasks like the digitalization and maintenance of MARC authority metadata records have become more burdensome. The University of Michigan's Library I.T. Division outlines the difficulties when working with MARC records (Steverman, 2017). These problems range anywhere from the issues surrounding fuzzy and outdated MARC records: (1) explicit and implicit relationships involving parent and sub organizations; (2) details regarding metadata authors using alternative names, organizations, or employers when filling out relationship subfields; (3) and a lack qualifier data centered around the omission of founding/birth, end/death, or merger dates on an authority record (Steverman, 2017).

The University of Nebraska details that part of the problem with MARC standards is that MARC is based off legacy RI methods (Gardner, 2012). MARC is a legacy technology that assists computers in replicating what a traditional cataloging card would detail to a consumer on a 3x5 index card (Steverman, 2017). Another limitation to using MARC is there is no effortless way to distill the different MARC fields for seamless integration into the Web (Gardner, 2012). As a result of the current incompatibility between MARC authority records and computer technology and the issues surrounding fuzzy and outdated MARC authority records, there is a necessity to review the accountability of MARC authority metadata records and discover a better way to validate them.

The American Library Association (2017), purposes that the use of the blockchain technology could be way to assist validating MARC metadata authority records. The American Library Association (2017), proposes that by digitalizing the record keeping processes with blockchain technology, it could improve the authority and reputational integrity of digital credentials. While discussions and theory is rampant in the RI communities, the implementation and physical application for applying the blockchain technology to MARC authority metadata records has not been attempted at this time.

Currently, the San José State University Research Foundation is working to investigate the possibilities of integration of blockchain technology within library resources (Enis. Matt, 2017; Institute of Museum and Library Services, 2017). The scope of San José State University

Research Foundation investigations centers around comprehensive discussions with blockchain specialists to detail scenarios centered around how the blockchain technology might disrupt the current RI industry (Figueroa et al., 2018). The project proposal for the San José State University Research Foundation granted funding for a dedicated website and blog, discussions on a national forum, and hosting a Library 2.018 conference (Figueroa et al., 2018). The purpose of the project is to discuss how the open source technologies' leverage of securely distributed blockchain principles can revolutionize the current RI systems (Enis. Matt, 2017). The conference was scheduled for June of 2018, and the project is still ongoing with Alman claiming the principle objective is to discover and investigate if blockchain technology is really an applicable technology for RI moving into the future (Johnston, 2018).

While the San José State University Research Foundation is busy with discussions on if blockchain is an applicable technology for RI, LibChain from Technische Universität Berlin, is working on implementing the blockchain technology into their current RI loaning services (Cabello, Janßen, & Mühle, n.d.). The German based university reviewed RI loan statistics from both Germany and United States and realized that there is a collective need for a sharable, trackable exchange system to transfer books in an accountable, verifiable, and secure manner (Cabello et al., n.d.). In Germany, RI face a growing demand to share and distribute their resources using library-to-library and user-to-user collaboration, as the result of students utilizing smart devices to search library catalogs and offerings to locate their desired resources (Cabello et al., n.d.). To assist RI in meeting their communities growing demands, LibChain attempts to utilize blockchain technology to create a decentralized lending system where RI patrons and partnered RI can distribute resources at will.

LibChain is open source application on available on Github (LibChain, 2017). The LibChain application allows administrators to purchase books; while users can borrow or return books, see which books have been borrowed, and to see usage statistics for books, libraries, and publishers (LibChain, 2017). The end result of this study concluded with Libchain being prototyped and is currently open to RI and their consumers to utilize (LibChain, 2017). However, there is no additional researching being completed at this point now that the application is in the prototype stage (LibChain, 2017). The developers are asking for further representation and adaption of the application to trigger additional support for blockchain integration within RI, but currently the project has reached a conclusion at this time (LibChain, 2017).

The lack of creditability is a posing a problem for the many consumers of the RI databases, were over 1.5 billion people visited RI across the United States in 2012 (American Library Association, 2006). The ALA relies on the information published by the IMLS which conducts the PLS for usage accounting of the public library systems. However, the problem with the PLS are that it is a survey, and currently the most recent federal report dates back to 2012. The 2012 PLS report shows that the decreasing cost of computers and the increasingly popularity of mobile technology has negatively impacted the use of RI computer systems (Grimes et al., 2012). However, the public's usage of libraries has been steadily increasing over the last ten years with a growth of approximately 20.7 percent (Grimes et al., 2012).

With increasing usage statistics, RI are becoming more engrained into their communities. The need to digitalize and upgrade current technologies is rapidly becoming relevant to meet the needs of their consumers within their communities (Grimes et al., 2012). RI continue to add to their digital holdings, which include e-books, audio, and videos, but their record keeping systems are suffering from legacy MARC records (Grimes et al., 2012; Van Rossum, 2017). MARC records only encode data from catalog records, not to the authority or bibliographic entities directly (Gardner, 2012). This creates a problem because systems need a way to extract data in a structured way, not with an arbitrary cataloging language that depends on the librarian cataloging the records (Thomale, 2007). These heading data signposts on a MARC metadata record cannot be easily extracted into individual data point to be incorporated into the web or other databases (Gardner, 2012; Library of Congress, n.d.-a). So, even with the high demands to automate and improve efficiency to meet the growing needs of their communities, RI are having a hard time working between systems and databases because there is no easy way to export MARC metadata records across systems.

It is acknowledged by the Library of Congress (LC) that there are issues within the MARC authority records (Library of Congress, n.d.-a). The LC (n.d.-a), recommends evaluating the answers to certain questions about: data quality, which MARC 21 fields are present, if the data is based on the LC MARC records, and if the data is completely filled out or if there has been new data added. In addition to questions regarding the data quality of the records, there are concerns with current automation service systems that the RI utilize to make use of the MARC records (Library of Congress, n.d.-a). Such concerns are if the system is fully utilizing the given catalog information and returning accurate results, and if the metadata record retains all the MARC 21 content designators signposts (Library of Congress, n.d.-a). MARC standards are reviewed by two groups, the MARC Advisory Committee and the ALCTS/LITA Metadata Standards Committee (formerly known as the Machine-Readable Bibliographic Information Committee) (American Library Association, n.d.).

After almost 50 years since the implementation of MARC metadata record creations, there still is a pressing concern that authority metadata records are not unified across the many diverse RI databases (Library of Congress, n.d.-b). Standards are often set to organize, conform, and unify process within business and systems, so it is intriguing that even with federal mandates to adhere to MARC standards that RI and vendor systems that process metadata records are still not concise or uniform in nature. However, it is easy to see why unification of metadata records is still a problem across multiple databases. With RI developing and maintaining their own metadata records, and subscribing multiple to fee-based services for additional records, the result is multiple metadata records overlapping across the many databases (Library of Congress, n.d.-b).

This disorganization within the RI metadata record systems is the result of having many metadata record authors. The metadata record authors are distrustful due to lack of verification of editor identities of who exactly is making the changes to the records within the many decentralized systems, and the RI are lack the capabilities to validate changes in an adjacent systems (Griffery, 2016).

To reflect on what the LC has to say on the current known issues involving MARC metadata authority records, Dr. Joris Van Rossum (2017), has also detailed that there is a significant issue revolving around scholarly communications. RI use the metadata records to locate research to assist in expansion and collaboration of the scholarly communications. However, the current work flow to get scholarly works published and distributed to RI to disseminated the findings to the public, continues to suffer from outdated legacy workflows where researchers must work within several databases and systems to even produce work to submit to the publishers (Van Rossum, 2017).

Then once the work is in the hands of the publishers, there are several problems revolving around if the work will even be published. There is a distinct lack of publications involving failed works, because the inherent sigma that failure does not contribute value to the collective knowledge base (Van Rossum, 2017). Another limitation imposed on scholarly works is the impediment of cooperate greed, which frequently overpowers the necessity of open communication (Van Rossum, 2017). However open channels of communication is a vital requirement for the expansion to the collective body of knowledge in the name of science (Van Rossum, 2017). Cooperate greed and lack of publications about failed research is just some of the many problems plaguing scholarly research; however, the problem still stands that scholarly research is being hindered by lack of communication. The lack of communication can be traced back onto the many databases being used to disseminate the published research works. Without open communication lines with RI and standardization of MARC metadata records across the many databases results in a lack of creditability to the metadata authority records.

Even with a centralized database for metadata authority records from the LC there is still a lack of validity regarding which metadata authority record is correct, because of the many different versions of the MARC records being stored within multiple databases. Changes to metadata authority records become difficult to track because all the disjoined systems. Vendors, publishers, and even RI work to create and modify the MARC authority metadata, and yet, there is a lack of uniformity and validation on which record is correct. This deformity makes a great proponent for the necessity to attempt to utilize the blockchain technology to assist in adding in the dissemination of scholarly works and communications. Gideon Greenspan (2017), makes a compelling argument on if blockchain is an essential technology for a project, while attempting to identify if the blockchain technology is vital to the system’s longevity or if the system if better off with a centralized relational database.

Greenspan (2017) points out that database systems like Oracle and MySQL have years of experience and development into their applications, which allows them to have the creditability to back up their technologies. Blockchain is only around ten years old, and is not without its own problems such as high energy cost, shady business dealings, and data forks with legacy code all make blockchain an unsuitable technology for the project if current business needs can be meet by utilizing the capabilities of traditional relationship database (Greenspan, 2017; Hoy, 2017).

A study done in 2016 by Irving and Holden (2016), tested the use of a forked Bitcoin blockchain to track and verify a timestamped version of a clinical trial report. The study was deemed successful, as the researchers were able to verify the authenticity of the tested blockchain as well as any changes to the record (Hoy, 2017; Irving & Holden, 2016). The problem with Irving and Holden's (2016) study to track timestamped protocols to improve the trustworthiness of medical science is that it has been retracted during the peer-review phase, as the methodology has been deemed unreliable. So, at this point it is still only hypothesized that the blockchain technology can pass records outside of cryptocurrency blockchains. This still possess the question for preventing tampering of records for authenticity, and there is still an authentication problem (Davis, 2016; Hoy, 2017).

With cryptocurrency blockchain technology, authentication of the resources and the users relies on the private/public key pairing, so users cannot turn to alternative resources to access the system unless the private-public key pair matches up (Irving & Holden, 2016). Therefore, users who choose to edit MARC authority metadata records could be tracked on a public ledger if the blockchain is coded to incorporate user data. This helps to dispel the accountability problem plaguing MARC records by holding editors to the metadata authority records accountable for the changes.

Chapter 3 Methodology

Methodology Introduction

The primary objective of this research study is to enhance authoritative MARC metadata records by utilizing blockchain technology to developing an immutable, sequential, chain of records that can assist in the validation and unification of metadata authority records. This helps to investigate ways to validate and account for MARC authority metadata records when records are transferred between systems. To investigate solutions to this problem, RI are discussing how blockchain can applied to existing RI systems (American Library Association, 2017). This study is an exploratory design science study that will be focusing on quantitative data collection. By collecting quantitative data about the design, implementation, and execution of a controlled test environment, this study will attempt to determine if the blockchain technology is a suitable vehicle for MARC authority metadata records.

Currently, blockchain has a large following in the financial sector and is regarded as a reliable technology, however expert Gideon Greenspan (2017), warns that if the problem can be resolved by traditional databases it is wiser to stick with the older technology. However due to the diverse systems within RI it is difficult to keep track of the MARC records using current methods. Joris Van Rossum (2017) takes a special interest on how the blockchain technology can impact the trust, reproducibility, transparency, and accessibly of scientific research. As R use many different databases to collaborate and share resources, it becomes harder to track and account for research and material usage. Thus, theories and discussions have been debated in the attempt to answer if the blockchain technology is adaptable enough to be incorporated into RI systems, in this study's case, the blockchain will be tested and applied to the accountably and validity of MARC authority metadata records.

Research Approach

The steps listed in Figure 2 outline the experiment from coding to implementation. These steps were designed as an explorative design science study to discover if how blockchain technology can be applied to MARC metadata authority records. This approach was taken to allow for the quantitative collection of data to answer the two main research questions: (1) if the blockchain technology's distributed ledger can be used to validate changes to the authority records; (2) if the blockchain can track who is making the editorial changes to the records.

These questions stem from the ongoing discussions between many RI professionals and committees, on if blockchain is a suitable technology for RI to adapt to (American Library Association, 2017; Hoy, 2017; Johnston, 2018; Van Rossum, 2017). Currently, there are many ongoing discussions on attempting to apply blockchain to library resources, and most of them have used small scale approaches or discussions (Figueroa et al., 2018; Irving & Holden, 2016; LibChain, 2017). Researchers Irving and Holden (2016), conducted a study back in 2016 that attempted to fork preexisting cryptocurrency code and validate the timestamp and authenticity of the report they were passing, however ultimately their research was withdrawn over concerns on the methodology. Initially the transfer and tracking process within the blockchain was deemed successful, however it is worth revisiting to see if this is a possibility (Irving & Holden, 2016). LibChain (2017), reports that they have reached beta testing on their library loan blockchain application, but they are experiencing difficulties getting participants. By collecting quantitative data, this study hopes to provide a bases and garner support, that MARC metadata authority record changes can be tracked, validated, and verified by authenticating the users who make changes to the records.

This study's research approach was to (1) create object classes for business and personal records; (2) identify a suitable coding platform; (3) create an application to extract MARC authority metadata record information; (4) initialize a static record; (5) designate nodes 1, 2, and 3 on virtual windows machines; (6) implement a test using a static authority record; (7) make changes to the single record 8) test run with the blocks for the original record and the modified record; (9) verify and record the changes have been added to the blockchain on node one.

Sample Selection

The three restricted nodes and single authority record provides a limited, but controlled environment for testing that can easily scale for additional testing. This study will be utilizing Ferris State University's Woodbridge N. Ferris's authority record. Woodbridge N. Ferris's authority record was selected from Ferris State University's metadata database as a convenience sample because the record includes birth, death, and relational data which helps to complete the record. Woodbridge N. Ferris's authority record does not include fuzzy MARC information that would inhibit the coding and transfer process. In addition to being complete, Woodbridge N. Ferris's authority record does not account for alternative aliases, parental companies, sub companies, however because Woodbridge N. Ferris is deceased, the authority record is historical in nature and is not subject to change.

Data Collection

Resource monitoring on the virtual machine nodes will be collected prior to, during, and post blockchain application implementation using Microsoft Excel. The researcher will be responsible for the data collection of resource utilization by manual recording. The blockchain should naturally track authority record changes via the distributed ledger. The system administrator to the blockchain should be able to track changes from each node through the distributed ledger using the private-public key pairings. The blockchain should also have the capacity to look up which metadata authority record is being passed between the two client nodes.

Data Analysis Technique

Data analysis of the metadata authority records will occur by manually reviewing the blockchain's individual transactions to ensure the changes are being committed to the ledger properly. The distributed ledger will be collected from each of the two nodes and the committed changes will be compared to the original metadata record visually for accuracy. The analysis of the ledger and comparison to the original record will assist in answering the question of if the blockchain technology's distributed ledger can be used to validate changes to the MARC metadata authority records. Additional analysis of the blockchain ledger, should answer the research question on if blockchain technology can be used to track who is making changes to the metadata authority record. The analysis will consist of an investigating the ledger's transaction values and the public key information. It will be possible to answer what kind of demands the blockchain requires after will be analyzing the collected data in the excel spreadsheet at prior, during, and post blockchain application implementation.

Summary

In summary by investigating the possibilities by enhancing MARC metadata authority records by implementing a blockchain this study hopes to answer two questions regarding validation of authority records and authentication of changes to the records. The research approach is using an experimental design science to collect quantitative data for the tracking changes to the authority records within the blockchain. To test the blockchain this study is using a restricted network and a single authority record to control the environment. This controlled environment is essential to the data collection phase where the blockchains distributed ledger is tracked, as well as measures who and what changes were made to the record. The data will be collected by the researcher and compiled into tables for review and analysis. Known limitations of this process are that the small sample size does not reflect more complex records and that blockchain has known security vulnerabilities within limited networks. It should also be noted that there is a limitation within the processing technology for blockchain, and that replication and implementation in additional studies should be aware of the limits of the machine capacities.

Chapter 4

Results

The research problem that this study worked to address is the validation and accountability of MARC authority metadata records when transferred between RI systems. By investigating and utilizing the emerging blockchain technology as a possible vehicle for distributing MARC metadata authority records across the disseminated RI systems, this study hoped to impact the RI ability to disseminate scholarly works to the general public.

By enhancing the RI material's metadata records, this study looks at the capabilities of the blockchain technology to see if (1) the distributed ledger can be used to validate the changes to the MARC metadata authority records, and (2) if the blockchain technology can be used to track who is making the editorial changes to the metadata authority record.

This study is an explorative design science study that was focused on quantitative data collection of passing MARC metadata authority records within a blockchain. The objective of this study was to address the validation and accountability of MARC authority metadata records as they are being transferred between RI systems by utilizing the blockchain technology to track and validate changes within the records. By utilizing the blockchain technology's proof of work transactions to secure the metadata record changes into the ledger system, this study addressed the validation and accountability of changes to the MARC authority metadata records. The testing process that was this study implemented for testing involved a small restricted network to validate and account for changes to the MARC metadata authority records.

Methodology

This study utilized a single metadata record, which was obtained curtsy Ferris's Fir database. Woodbridge Ferris's MARC metadata authority record was selected as a convince sample.

Figure 2 is the start of Ferris's MARC metadata authority record. Ferris's MARC record is a single line file that contains the indicator signposts for cataloging the record. These indictor signposts are composed of integers, spaces, and character strings. These strings create the signposts that help direct the RI's to classify and store the MARC authority record, however direct interpretation and understanding of these string signposts are outside of this study's scope. This study's scope is restricted because the understanding and interpretation of the MARC authority record's signposts is not inherently relevant for the blockchain data processing. Figure 3 shows Ferris's MARC record was modified to include lines 2 and 3. Lines 2 and 3 are significant for testing input for multiple lines of text, in the instance that a record contained multiple lines.

The lines ‘tester changed”, ‘123’ were added in notepad and then modified file was saved as a .txt file type. Figure 4 details the saved MARC authority records. The original file named is named “Woodbridge Ferris Authority Record”, while the new modified file is “Woodbridge Ferris Authority Record mod”. Each file is roughly 1kilobyte worth of data stored in that compose all of Woodbridge Ferris’s MARC authority record.

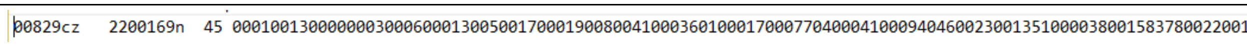


Figure 2: Ferris’s Original Authority Record (Before Modification).

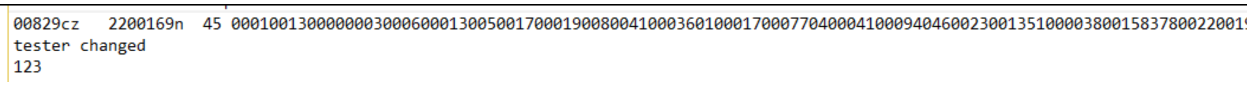


Figure 3: Sample of Ferris’s Modified Authority Record (After Modification).

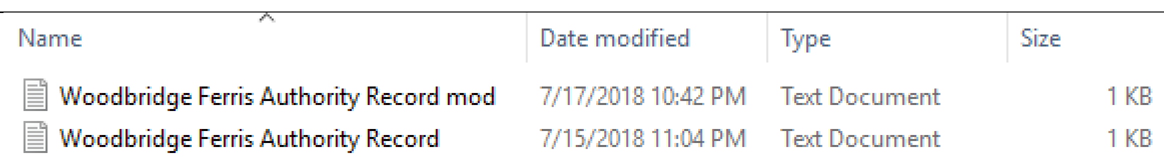


Figure 4: Saved Files.

Prior to development, in addition to obtaining a MARC record for testing, this study also needed to decide on a medium for developing the blockchain process. After researching and exploring the complexity and knowledge required to fork preexisting code bases from well-known blockchains such as Bitcoin and Ethereum, this study concluded that building a blockchain application from scratch would involve less overhead and allow for better customization for later expansion (Unchained, 2018). The decision to not fork the current opensource code from the well-known cryptocurrencies involved, complexity, unnecessary overhead in the form of wallets and pay transactions, intensive maintenance, and unmaintainable legacy code (Unchained, 2018).

Another reason that the existing code was not acceptable for this research purpose is because most systems involve a two-party contract, where one is exchanging goods with another. The RI blockchain does not necessarily require two users to agree to terms of payment, instead the RI blockchain is looking to commit and track single user edits the record.

Tools

Eclipse Photon Release (4.8.0) was installed on the host machine along with the Java development kit (SDK). Additional tools that were installed were standard java libraries and Gson libraries for coding and development of the blockchain; Google Cloud Plugins, Maven Integration of Eclipse, and MercurialEclipse for the development of an Application Programing Interface (API), for distributing the ledger and application across the network, and Amazon Web Services was utilized to create virtual machines to network three nodes together for distributing the application and tracking changes.

Development and Testing

The blockchain that this study implemented relies on encryption within the block class. In Figure 5 the encryption of SHA 256 algorithm encrypts the prior hash code, the exact timestamp that is unique to the record submission, the block number, and the entire metadata record into a block for storage.

```
Create public function to create hash
{
Encrypt string variable passing variables (prior hash + timestamp + counter + metadata record);
Return encrypt string variable;
}
```

Figure 5: Code Sample Encryption Hash.

The returned encrypt string variable hash value is significant because the returned data is the encrypted data that is being committed as mined block transaction permanently to ledger. The ledger block contains the editor's name, the entire encrypted hash value, and the prior blocks hashed value for validation and accountability that the change to the MARC metadata authority record occurred.

In Figure 6, the entire first record block, including hashed value, being displayed. The very first transaction on a block is referred to as a genesis block and has a prior hashed value of zero. For testing purposes, the entire metadata record is also being displayed below the hash value, along with the editor's signature, unique timestamp, and the counter sequence.

```
Blockchain is Valid: true

The block chain:
[
  {
    "hash": "0000030eacd224cf88d105f3ef3f7ebc96778b19285fa3489197607994009638",
    "previousHash": "0",
    "metadata": "00829cz   2200169n  45 000100130000000030006000130050017000190080041000
    "editor": "tester1",
    "timeStamp": 1533089545581,
    "counter": 1123361
  },
  {
    "hash": "00000c92f0621bcf3712e8ed36866ecd5845056488cf004ce6c3fe889d42fe15",
    "previousHash": "0000030eacd224cf88d105f3ef3f7ebc96778b19285fa3489197607994009638",
    "metadata": "00829cz   2200169n  45 000100130000000030006000130050017000190080041000
    "editor": "tester2",
    "timeStamp": 1533089590500,
    "counter": 602112
  }
]
```

Figure 6: Sample Same Record Blockchain Contents.

Figure 6 also includes the second test, where Ferris's unmodified metadata record was submitted to the blockchain. This still resulted in a different block-hash value due to different time, counter, and editor data being unique to the block. These blockchain features assist in verifying the validity of the record and assists in holding the user accountable to editing the record as the information is stored in the unique block.

Figure 7 displays a test utilizing Ferris's unmodified record as the genesis block. The second block is submitted using the modified record with a new user's name. The hashed-block values are still different due to time stamps, user information, and record contents. Figure 8, outlines that the changes to the record where noted and accepted into the blockchain holding tester 2 accountable for the change. The changes are denoted on the second line of metadata, before the "editor" tag.

```
Username?
tester1
What is the full file path and name?
C:\Users\Snow\Desktop\MISI 700\metadata record\Woodbridge Ferris Authority Record.txt
Your name is: tester1
Metadatarecord is: 00829cz   2200169n  45 0001001300000003000600013005001700019008004100003
Trying to Mine block 1...
Block Mined: 000002b1cc3e8feb7b7198344ce8d0c0899a4c1a6a8dd3a643cc48d207fd4cd0
Username?
tester2
What is the full file path and name?
C:\Users\Snow\Desktop\MISI 700\metadata record\Woodbridge Ferris Authority Record mod.txt
Trying to Mine block 2...
Block Mined: 0000030ac08ef4010e05ce83d08722bb3a674647c659fd89e494c2cb74d7ed85

Blockchain is Valid: true

The block chain:
[
  {
    "hash": "000002b1cc3e8feb7b7198344ce8d0c0899a4c1a6a8dd3a643cc48d207fd4cd0",
    "previousHash": "0",
    "metadata": "00829cz   2200169n  45 0001001300000003000600013005001700019008004100036O
    "editor": "tester1",
    "timeStamp": 1533093976628,
    "counter": 744384
  },
  {
    "hash": "0000030ac08ef4010e05ce83d08722bb3a674647c659fd89e494c2cb74d7ed85",
    "previousHash": "000002b1cc3e8feb7b7198344ce8d0c0899a4c1a6a8dd3a643cc48d207fd4cd0",
    "metadata": "00829cz   2200169n  45 0001001300000003000600013005001700019008004100036O
    "editor": "tester2",
    "timeStamp": 1533094000837,
    "counter": 893203
  }
]
```

Figure 7: Sample Output Old and Modified Record.

```
Username?
tester1
What is the full file path and name?
C:\Users\Snow\Desktop\MISI 700\metadata record\Woodbridge Ferris Authority Record.txt
Your name is: tester1
Metadatarecord is: 00829cz   2200169n  45 00010013000000030006000130050017000190080041000036
Trying to Mine block 1...
Block Mined: 0000009a11a33c6e9b1df127cc7074de4a137f829ad37ef9a9b0c12371905735
Username?
tester2
What is the full file path and name?
C:\Users\Snow\Desktop\MISI 700\metadata record\Woodbridge Ferris Authority Record mod.txt
Trying to Mine block 2...
Block Mined: 0000042166af96515c205ed0a60f229b52bcfe00c46cb9093839c79acf63cd52

Blockchain is Valid: true

The block chain:
[
  {
    "hash": "0000009a11a33c6e9b1df127cc7074de4a137f829ad37ef9a9b0c12371905735",
    "previousHash": "0",
    "metadata": "00829cz   2200169n  45 00010013000000030006000130050017000190080041000003601
        Jan. 6, 1853; d. in Washington, D.C., Mar. 23, 1928)\u001e\u001d",
    "editor": "tester1",
    "timeStamp": 1533528067068,
    "counter": 161548
  },
  {
    "hash": "0000042166af96515c205ed0a60f229b52bcfe00c46cb9093839c79acf63cd52",
    "previousHash": "0000009a11a33c6e9b1df127cc7074de4a137f829ad37ef9a9b0c12371905735",
    "metadata": "00829cz   2200169n  45 00010013000000030006000130050017000190080041000003601
        Jan. 6, 1853; d. in Washington, D.C., Mar. 23, 1928)\u001e\u001dtesterchanged123",
    "editor": "tester2",
    "timeStamp": 1533528090402,
    "counter": 426429
  }
]
```

Figure 8: Metadata Record Differences

Summary

This study's application development started in late May and spanned the entire length of the study until July 29th. This study's purpose was to answer the two questions: 1) Can the blockchain technology distributed ledger be used to validate changes to the MARC metadata authority record; and 2) Can blockchain technology be used to hold users accountable by tracking who is making editorial changes to the metadata authority records?

While this study was able to create a blockchain and verify that changing data inside a metadata record does result in modify the block's hashed value, this study was unable to conclude that there was a change to a distributed ledger. This study was unable to utilize the distributed ledger feature as this blockchain ledger was localized to the single machine only.

Additionally, this study was also able to provide a reasonable ability to validate changes to the MARC metadata authority record by providing encrypted hashed values to account for any and all changes to the metadata records, along with a timestamp and the name of the user committing the record to the blockchain. In summary, this study is inconclusive because the development of an Application User Interface (API) to distribute the ledger system to other nodes was not completed. However, there is reasonable cause to believe that blockchain technology will be a suitable vehicle for MARC records from the standpoint of validation and accountability.

Further Study

The general hypothesis of this study is that the blockchain technology is a feasible vehicle for RI's to continue to explore, however further exploration is required. Further study that can be explored and elaborated on in testing is a creation of on API to distribute the application to multiple machines, private-public key user authentication, and the distributed ledger system.

Chapter 5

Conclusion

According the American Library Association (2006), 1.5 billion people visited RI across the United States in 2012 alone. These statistics only continue to grow as the local communities expand and grow, but RI’s are dealing with ever increasing constraints as state, federal, and local governments cut back on funding (Grimes et al., 2012). These increasing constraints force RI’s into collaborative partnerships to assist in alleviating costs while reducing operational overhead, these partnerships also assist in expanding the resources at the RI’s disposal (Grimes et al., 2012; Library of Congress, n.d.-a). However, because of these partnerships there are multiple systems that share similar resources, these disjointed systems are united by the MARC metadata records that are used for resources distribution and tracking (Library of Congress, n.d.-a).

These MARC records that create the backbone of the resource’s publication information originates from 1968 and is posing multiple issues with integration with today’s technologies (Gardner, 2012). Some of the problems with MARC are readability, fuzzy logic, and no single database tracks the changes to the MARC records as authoritative sources (Gardner, 2012; Steverman, 2017). To assist RI in their ability to disseminate scholarly works to their communities, the MARC records need to be unified and accounted for. To assist in the unification and accountability of MARC metadata records, the American Library Association (2017), believes that RI and their partners need to develop a way to distribute information and resources in a tamper-resistant setting.

RI are turning their attention to investigate the probability of utilizing a new and emerging technology known as blockchain to assist in unifying the MARC metadata records, distribution of resources, and track resource usage (American Library Association, 2017; Davis, 2016; Hoy, 2017; Van Rossum, 2017). The research problem that this study worked to address is the validation and accountability of MARC authority metadata records when transferred between systems. This study’s purpose was to enhance authoritative MARC records by utilizing the blockchain technology to develop an immutable, sequential, chain of records that can assist in the validation and unification of metadata authority records. The study attempted to answer if (1) the blockchain's distributed ledger technology could be used to validate changes to the MARC metadata authority records, and (2) if the blockchain technology could be used to track who is making editorial changes to the metadata authority records.

This study used an explorative design science using quantitative data collect to support if the blockchain can assist in creating accountability and validation when submitting changes to a MARC metadata authority record. While the results were inconclusive, due to this study being unable to accurately test the blockchain on a distributed network to verify the ledger, the application has code developed to track who is submitting the changes to the record. This study did manage to review changes to the MARC metadata authority record as it displayed in a blockchain's proof of work output. The study reviewed changes to the MARC metadata authority record by reading in user's input in the form of a MARC metadata authority record and username. The username and the MARC metadata authority record were combined with a timestamp and the prior hash value and then encrypted to be used in the next sequence. This allowed for changes to the recorded and acknowledged as the result in a different hash-value, as well as the whole MARC metadata authority record that was read into the system.

While this study was able to display and account for changes to the MARC metadata authority records, the RI blockchain application requires further refinement and expansion. The hypothesis still stands that blockchain could be used to validate and create accountability within RI systems because other blockchain applications, such as Bitcoin, use similar system requirements to track and account for who has money and has made which transactions in the system.

As Bitcoin, and other financial applications utilize the blockchain technology, the hypothesis still stands that blockchain could be used to validate and create accountability within RI systems (Greenspan, n.d.; Nakamoto, n.d.). As financial systems are thriving off blockchain and are used to validate and transfer funds between users using a distributed ledger system, RI should still investigate the relationship and blockchain technology.

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