Blockchain-based Continuous Timestamps Tracking System: Towards Ownership Information Believability

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Abstract

Ownership information of high value assets such as property is often concealed and fragmented, adversely affecting information believability. Following the design science research approach, we conceptualize believability as a data quality dimension that supports ownership traceability. We then investigate how blockchain technology might improve information believability in ownership traceability systems. We represent and address our findings via the development of a blockchain-based continuous timestamps tracking system model, framework and implementation for property ownership. A use case of banking transactional data for property ownership traceability is introduced to illustrate our workflow and system design. The proposed system takes advantage of blockchain technology such as traceability and irreversibility to support information believability in the design, management, and use of information systems.

Keywords: Blockchain, Continuous tracking, Timestamps, Information believability, Property ownership.

1. Introduction

Information systems often refer to data manufacturing systems using raw data input to produce data output or data product (Wang and Strong, 1996). Data quality thus is vital for any system in avoiding garbage in–garbage out, and maintaining accuracy and consistency. Intrinsic data quality has been argued that it includes not only accuracy and objectivity, but also believability and reputation of the data source (Tseng and Fogg, 1999). The attention to believability is on the rise in recent years. Several scholars argue that believability is even a more important dimension of data quality than accuracy due to the existence of gaps between data as input and information as output (Wang and Yang, 1996; Pradhan, 2005). In that context, existing continuous-time tracking systems seem to ignore the existence of believability as an important dimension of both input and output data quality. This phenomenon accretes problems of synchronization and control of chaotic systems with uncertain performance criteria, which are considered great challenges for continuous-time tracking systems (Reddy and Pavan, 2007). Several methods have been proposed for the design of controllers for multivariable continuous-time tracking systems, such as research by Davison and Smith (1971) and Reddy and Pavan (2007). These methods require open-loop tracking systems to be completely controllable (Bradshaw and Porter, 1975; Shaked and De Souza, 1995). However, believability, as a dependent variable that relies on other factors to be determined, is possibly unable to control.

Since the last decade, the use of timestamps properties of blockchain technology has been considered an advanced method for continuous-time tracking systems, so-called traceability systems (Chee et al., 2014). Those blockchain-based traceability systems can achieve significant performance in terms of information traceability, irreversibility, and security under the control of user groups within a decentralized network. However, extant research is silent on how to extend the tracking performance in the mode-controllability structure of open-loop tracking systems to include believability as well as how to connect the properties of believability and blockchain-based continuous-time tracking systems. These issues reflect a gap in current continuous-time tracking system designs. We put our effort into fulfilling this research gap. Our research purpose thus revolves around finding the answer to the question *"how to improve information believability of traceability systems?"* A design science research approach with a goal of delivering problem presentation structures and developing solutions would be a good fit for our research purposes. In this paper, we focus on property ownership domain as a working example for the following reasons. Firstly, property ownership tracking has been a great challenge under privacy protection, where the ownership information can be unpublished. The fragmentation of property

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ownership information is a vital issue that needs to be addressed (Fernando and Ranasinghe, 2019; Krishnapriya and Sarath, 2020). Secondly, property ownership information, despite being accurate, might not satisfy properties of believability when the input data is intentionally covered with concealed motivations (Yang et al., 2004; Pradhan, 2005). In addition, there is an outstanding gap in the literature regarding property ownership tracking systems that consider believability as an element of system design. From the above outlines, property ownership would be a worthy example to carry out further investigations.

The rest of the paper proceeds as follows. The second section reviews conceptual definitions and the application of believability as a dimension of data quality. This section also discusses blockchain technology in supporting ownership traceability. Next, we will provide a brief description of the design science research methodology in the third section. The concept model of the blockchain-based continuous timestamps tracking system is presented in the fourth section following by the system development in the fifth section. We then present a use case of the blockchain-based property ownership tracking system using banking transactions in the sixth section. The contribution, constraints, and an evaluation plan of the proposed system framework will be discussed in the seventh section before we conclude.

2. Related work

2.1. Believability

Believability in information systems and computer science is generally classified as content believability and procedural believability. Each believability type has its functional implications for the design, maintenance, and use of information systems (Stupple et al., 2011). Content believability generally refers to believability corresponding to data or information for support or against it. Procedural believability means the believability attached to information as a result of the process by which such information was produced (Pradhan, 2005). Wang and Strong (1996) propose that the accuracy category of data quality includes accuracy, objectivity, believability, and reputation. In other words, believability is one category of accuracy dimension of data quality. Pradhan (2005) argues that a better definition of believability might be able to connect believability to the property of being worthy to believe by rational and informed users. Chee et al. (2014) agree that output information believability refers to the reference to a group of users. In particular, to consider that information is believable to an individual user means the information acquires a set of properties, which references that information is believable under such user's judgment. When believability refers to a group of users, there are subsets of properties where different users regard them as relevant to determine whether some information is believable. In this circumstance, believability is an intersection of all the members' judgments accordingly. It is noteworthy that intrinsic data quality refers to not only accuracy and objectivity but also believability and reputation. Such perspective suggests that the accuracy and objectivity of data are insufficient to define a data set or a piece of information as high quality. This phenomenon can be explained using an example of property ownership. When the property ownership is correctly entered into the system but cannot gather full ownership data from history to the most recent updates, the output information might not be qualified as believable or might violate the timeliness principle. From the system approach, accuracy can be described as correspondence with reality in terms of mapping (Pradhan, 2005). In particular, the information is considered accurate if components of the data or information match components of reality or facts (Wand and Wang, 1996). However, these components might not match precisely or might miss out on a set of facts that cannot be read by information systems. This issue steers to a need for information systems that are designed to enhance procedural believability. The gaps between accuracy and believability suggest that the design, development, and use of an information system should consider improving the procedural believability, in other words, the traceable believability of the information. We will put effort into including believability as a pivotal element in the design and development of our solutions.

The concept of believability is popular in the Computer Science discipline. Stupple et al. (2011) use response time to test the selective processing model, which views information believability as belief-bias effects arising from the interplay between superficial heuristic processes and more rigorous analytic processes. Kalincik et al. (2017) use believability as an indicator for data quality and system evaluation. Believability is also considered a performance target in agent-based systems designed by Riedl and Young (2005), Gorman et al. (2006), Bogdanovych et al. (2016), and Dogan (2016). In another approach, Raj and Balakrishnan (2011), Umarov et al. (2012), Bevacqua et al. (2017), and Sutoyo et al. (2019) have tested believability as a KPI performance of AI agents design. Mezzanzanica et al. (2015) and Karuna et al. (2021) discover that believability consists of corrective interventions, thus simplifying the process of developing data cleaning activities. In recent years, believability has been used as meta-analysis data (Chee et al., 2014; Duncan and Sparks, 2020). Tseng and Fogg

(1999) discuss challenges of credibility and computing technology from users' point of view, showing that trust is undermined for an infinite term when the system delivers erroneous information. However, there is a literature gap regarding the determination of which properties of information make it worthy of being believed by rational and informed users. Scholars such as Laaksolahti et al. (2003) and Martinho et al. (2003) have been putting efforts into building and enhancing the believability of information systems. Notably, Yang et al. (2004) argue that classical iterated belief revision methods rarely take into account the impact of uncertain information. Thus, there is a need for a belief revision in the multi-agent system to support the believability of information. They also extended the Dempster-Shafer theory of evidence and believability function formalism to obtain believability of information. The revised belief set by believability-based iterated belief revision, is dependent on the history of revision on the information received prior to the current belief set. Yang et al.' (2004) work has laid the foundation for conceptualizing believability as an important element of information systems. Chee et al. (2014) consider believability as an individual data quality dimension of decision-making systems. They use design science research to propose and develop an integrated framework of the business intelligent product and meta content map to facilitate the traceability and accountability of these products. In their system, the accountable level of traceability performance has to rely on the level of information believability. From the above system design perspective, information believability is defined by users. Thus, believability is implicitly referential considering it always contains a reference to some users' judgments. How to include such references to the design, implementation, and use of information systems remains unknown.

2.2. Ownership traceability using blockchains

Blockchain has been acknowledged as an effective technology in delivering transparency, immutability, traceability, trust, and performance of traceability systems (Lazuashvili et al., 2019). Several studies conclude that blockchain-based systems improve ownership traceability, particularly in supply chain management (Islam et al., 2018; Islam and Kundu, 2019; Sund et al., 2020) as well as in areas where traceability is often the most challenging for intangible items such as the origin of products and ownership (Hasan et al., 2020; Cu et al., 2021). One of the relevant works to our paper that should be mentioned is the study by Lazuashvili et al. (2019) on the integration of blockchain technology into a land registration system for immutable traceability. They argue that using blockchain technology in land registries leads to achieving a disruptive transformation of public-service provision systems. They use a case study approach to ascertain how blockchain technology resolves issues concerning contemporary land registry systems and determinants for a successful application of the digital novelty. However, Lazuashvili et al.'s (2019) theoretical approach might not be sufficient to provide practical evidence or further information technology solutions. Cu et al. (2021) suggest the use of blockchain for fractional ownership traceability could enhance trust among transactional participants. Scholars such as Koirala et al. (2019) and Qiu and Zhu (2021) have proposed blockchain-based solutions for ownership management. Nevertheless, the practical evidence of blockchain application in property ownership traceability is missing while existing studies are mostly theoretical approaches, lack practical support, and systems development for tracking items in supply chains. Only a few studies have addressed the issues of property ownership traceability with dependence on existing blockchain-based frameworks for land registry, which have been introduced and implemented by officials around the globe. Extant research has not explicitly addressed how to include the believability of both input data and output information in blockchain-based traceability systems for high value assets such as property. The purpose of our research is to address these gaps.

3. Design science research approach

We follow the design science research (DSR) approach (Hevner et al., 2004) to represent and address the identified gaps and problems outlined in the earlier section. The choice of our research approach is appropriated because DSR is an approach that facilitates studies with the primary goal of delivering problem presentation structures and developing solutions for real world problems. DSR guidelines enable us to realize the creation, evaluation, and presentation of the conceptual artefacts such as concepts, models, frameworks, and the system artefact. Specifically, the process of developing a continuous timestamps tracking system for high value assets such as property.

In our research, conceptual artefacts enable us to conceptualize believability (as an intangible element) to be an entity that contains its attributes in a system model, where we can use information tools to address the corresponding practical problems. The system artefact is a resulting IT artefact that provides a proof-of-concept for the inclusion of believability as a dimension of data quality in the design, implementation, and use of information systems. Using blockchain's core features, our system artefacts will deliver a consistent, transparent, and continuous timestamps tracking system that can reduce information fragmentation and information asymmetry via traceable, transparent, and believable output information. These artefacts will be evaluated aligning with the development of our research. As such, we intertwine the relevance of research, our design, and knowledge base following three cycles of design science outlined by Hevner et al. (2004).

4. A model of a continuous-time tracking system with referenced believability properties

The observation and definition of existing problems in previous sections have led this research to the development of conceptual artefacts to represent and address these problems. Aiming to include believability and its corresponding users' references to be an element of the information system design, we first review relevant models of existing systems. We found that the continuous-time tracking system model denoted by Crossley (1977) and Wang and Strong (1996) would enable us to conceptualize the traceability of believability. Combining with Pradhan's (2005) perspective of believability, we conceptualize believability in a continuous-time traceability model as follows.

Let x be a user of the continuous-time tracking system.

$X = \{x_{1,} x_{2,} \dots, x_n\}$ is a group of users.

Pradhan's (2005) assumes that each user has a set of properties px_i that references believable information. When believable information relates to a group of users, there are subsets $\{px_{1,} px_{2,} \dots, px_n\}$, where the properties set p is an intersection of all the members' judgements:

$$p = \cap \{px_{1,} px_{2,} \dots, px_n \mid x \in X\} \quad (1)$$

Let $W(t)$ be an input command vector at time t, following Crossley (1977) continuous-time tracking model, the system is required to track command inputs of the form:

$$W(t) = [w_1(t)_, \ w_2(t), \dots \ , w_i(t) \dots, w_q(t)] \quad (2)$$

where the coordinates of a random point on vector W_t can be measured as:

$$w_i t_j = \sum_{j=0}^{s_i} w_{ij}\, t_j \quad (3)$$

with s_i is the upper limit of the vector direction.

Crossley (1977) considers the mode-controllability structure of tracking system which consists of a linear multivariable n^{th}-order plant governed by state is presented in a vector-matrix system form:

$$\dot{x}(t) = Ax(t) + Bu(t) \quad (4)$$

and output equations of the respective forms:

$$y(t) = \ Cx(t) = [c_1, c_2, \dots, c_q]' x(t) \quad (5)$$

Combining from (1) to (5), we can include a component p_{ij} that represents believable quality for each $w_i t_j$, the system output of believability then can be represented as:

$$Y(t) = \ Cp(t) = [c_1, c_2, \dots, c_q]' p(t) \quad (6)$$

The equation (6) indicates that each tracking output produced by system ran by x_i member will be associated with a respective property set p_{ij} that represents the data is verified and trustable at the time it was input. The equation (6) has several implications. Firstly, it reiterates the principle garbage in–garbage out via the operation of quality in–quality out. Secondly, it makes sense that not only the data is continuously trackable, sets of properties regarding information believability are also associated with each input time point. Lastly, as users' sets of believability properties change over time, the knowledge body of properties builds up showing which properties that users regard as believable and which are not. Tracking those sets of believability properties matters in terms of (i) assessing believability by systematically capturing users' perspectives of believability overtime, and (ii) using decentralized technology such as blockchain to make information of high value assets, such as property ownership records, available is beneficial for everyone with scrutiny purposes. This finding thus is an important artefact that guides us to the design of a decentralized tracking system that will take on consensus of its network members to verified trusted source for the input data, which may improve the believability of the output information. As information believability is also an endogenous element (Pradhan, 2005), we follow Wang and Strong (1996) intrinsic data quality, which include four dimensions of objectivity (O), accuracy (A), believability (B), and reputation (R) (of published sources) to draw a corresponding reference framework for users' sets of believability properties (Figure 1).

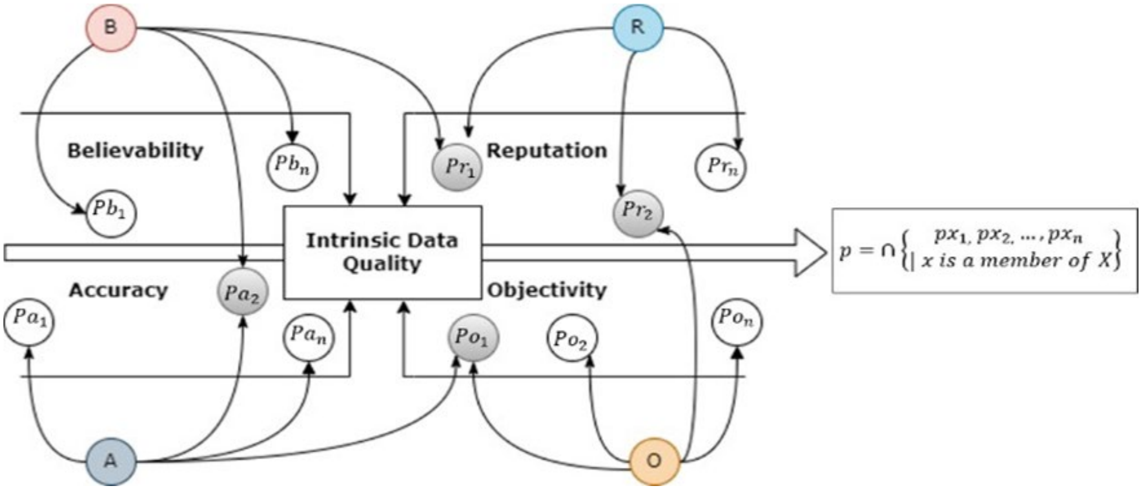

Figure 1. Intrinsic data quality properties reference framework.

5. Blockchain-based continuous timestamps property ownership tracking system framework

The establishment of conceptual artefacts in the earlier section facilitates us to develop a continuous timestamps tracking system for property ownership that includes believability as a dimension of data quality. In this system, believability is presented in the form of users' reference sets at a specific point in time. We expect to include believability as an important indicator for both input data and output information.

Considering the applicability of blockchain to traceability tracking systems, we propose that the construction of the continuous timestamps tracking system should base on a consortium blockchain with possible paths to the public blockchain. With this design, we aim to reduce property ownership records that are operated in a closed network environment for privacy reservations that might be invisible and impossible to track. Varied from private blockchain, consortium blockchain can have more than one organization or entity to act as nodes on the chain (Ethereum, 2022). The choice of consortium blockchain is based on the working example of this paper – a large amount of property ownership information, which usually needs to be handled by organizations. It is thus necessary to establish a consortia blockchain network that (i) has great potential for integration with enterprise systems, (ii) enables organizations to keep internal permissions for users, and (iii) remain paths of connection to the public blockchain. By embedding consortium blockchain as a semi-decentralized network, we will be able to introduce user entities that can verify and record ownership data with the corresponding believability attributes before sending transactions to mining nodes of the blockchain. We represent the design of system architecture in Figure 2.

Figure 2 is the architecture of a blockchain-based continuous timestamps tracking system based on a decentralized network. This system architecture includes three layers. In the user layer, authorized users can input property ownership data via virtual apps installed on their devices. The input data will be stored in the cloud-based database with an offline backup version. Before the input data is put forward to the blockchain cloud's mining nodes, the data will need to get through a set of property filters to be verified as qualified. Once such data is approved, it will be encrypted to be a new block of information with a unique timestamp in the blockchain's multichain. Users then can access this verified information via a virtual table to perform queries. We will present details of a workflow design and system prototype via a use case in the next section.

The uniqueness of the proposed system could be found in the inclusion of believability (and its corresponding properties) as one of the key dimensions of the input data quality to improve the believability of the output information. In the following section, we will use a use case to illustrate a property ownership traceability system using bank transactions.

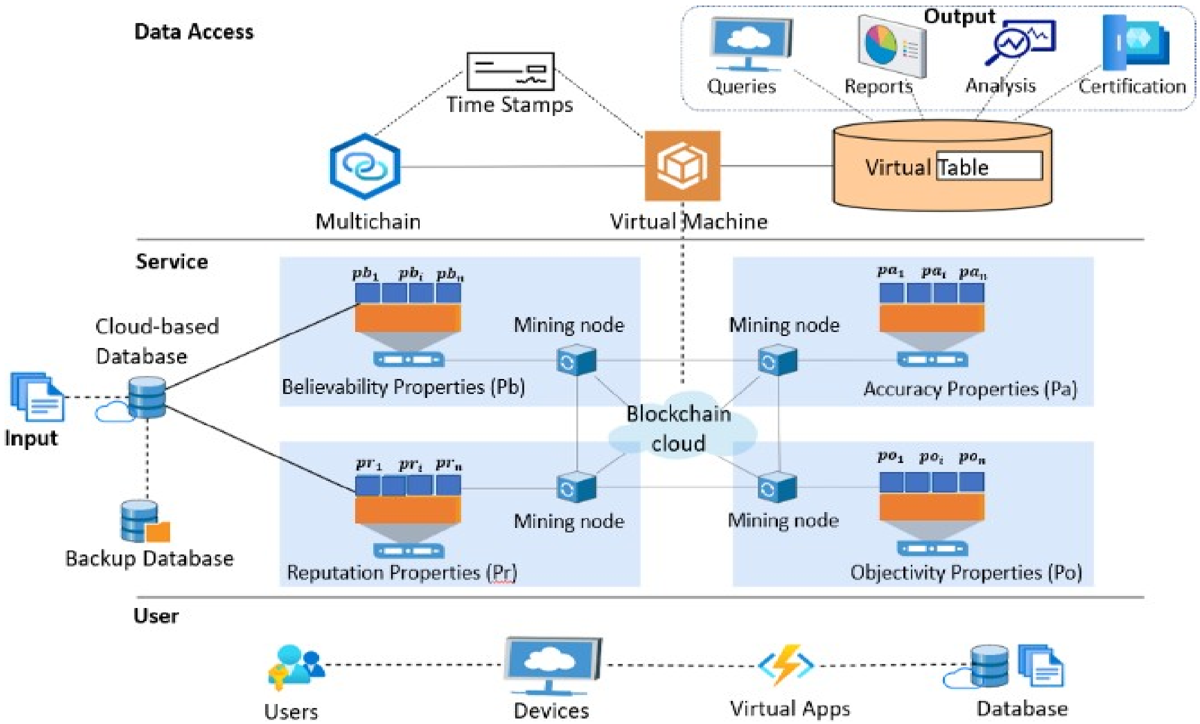

Figure 2. Blockchain-based continuous timestamps tracking system architecture

6. Implementation of a property ownership traceability system using bank transactions

The role of the bank is irreplaceable in real estate transactions despite the emergence of various types of decentralized financial payment methods such as cryptocurrency and non-fungible tokens (NFT) (Veuger, 2018). Because the proposed traceability system furthers the accuracy dimension of data quality to the believability dimension. We argue that using land registry data at government departments might not be sufficient to help understand the believability of information. Instead, banking transactional records for purchasing high value items, such as houses, might contain further insights and thus are worthwhile to be selected as a use case of the blockchain-based property ownership traceability system. In this use case, we restrict the use of blockchain as a technology for ownership records and traceability. Cryptocurrency is excluded from this use case. This means blockchain cryptocurrencies such as Bitcoin, although a popular payment method, might not be able to replace traditional banking at this stage. We will use non-fungible tokens such as NFT with Ethereum Request for Comment 20 (ERC-20) for the sole purpose of encrypting property ownership data.

To illustrate the system for the use case, we used a simulated set of data regarding real estate transactions across banks. Such a dataset would categorize the transactions with any amount larger than US$100,000 on the basis of narrations. We also can extract types of payment (cash, debit, credit, etc.), remittance and receiver account numbers and account names, and the bank names or the short form of the bank names using the financial system code. For this use case, we focus on the total value of transactions and tentatively exclude weekly mortgage payments. We apply the blockchain-based property ownership tracking system for this use case as an adaptive system that works parallel with traditional banking systems to analyze transactional data following the proposed workflow (Figure 3). The workflow starts with analyzing the banking transactions. The transaction will firstly be filtered in amount. For each amount that is lesser than US$100,000, the transaction will be excluded from the workflow. Transactions that exceed such threshold will be stored in a separate web-based in-memory database. There will also be a backup database as a digital twin of the in-memory database to improve data security. We then use a predetermined property filter to evaluate the believability of the transaction. This predetermined property filter consists of sets of believability properties that have been primarily defined by experts and will be updated on a regular basis.

Once the transaction meets standards of believability properties, its details will be taken to the blockchain and encrypted as a block of information with a unique timestamp. Suppose the transaction does not meet the criteria, in that case, the system will carry on special learning based on cluster analysis and association detection to extract data such as clusters of origin of locations, transactions, tax records, account history, connection to money laundering suspects, etc. The system might perform further learning to extract data from other adaptive enterprise systems. Learning results will provide insights to determine whether the transaction meets believability properties to be certified. Transactions that fail to meet believability properties after special learning will be labelled as uncertified property ownership status when they are encrypted in the blockchain network.

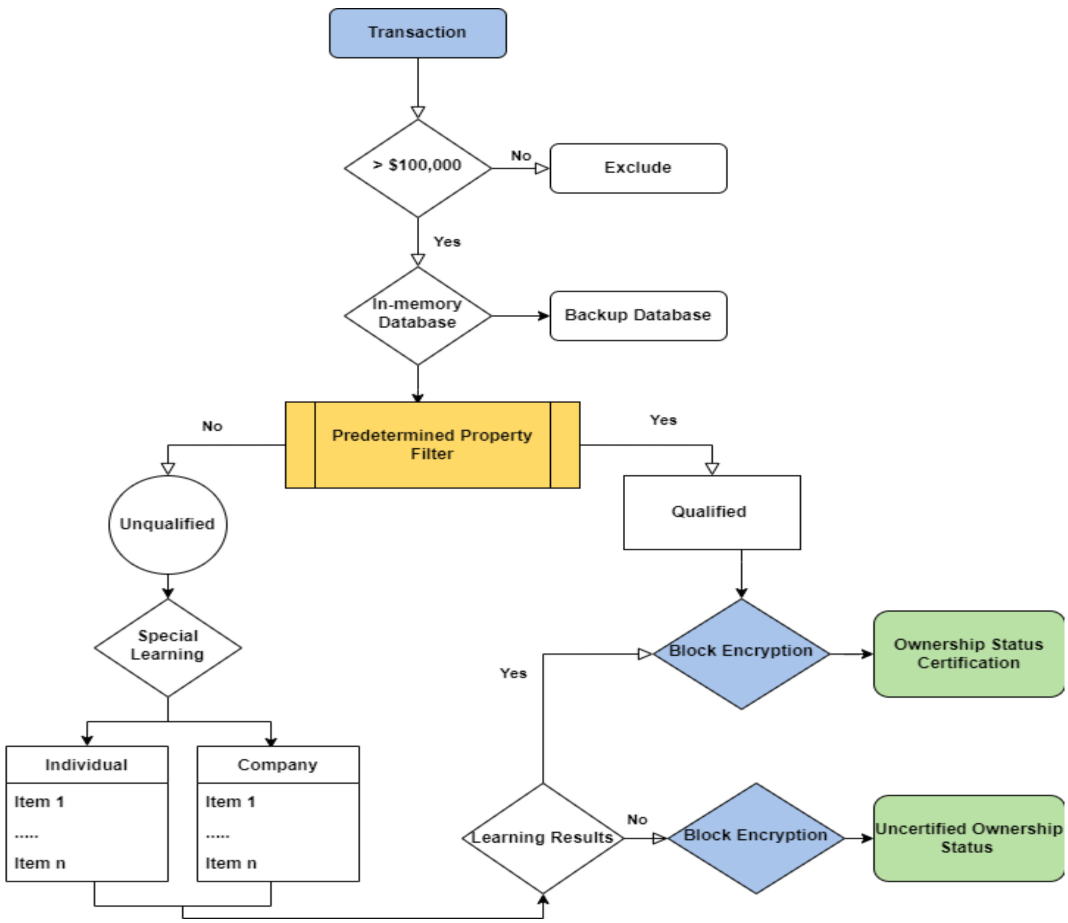

Figure 3. Workflow of the blockchain-based property ownership timestamps tracking system using bank transactions.

While existing systems record and encrypt land ownership information, their workflows have skipped filtering properties of information believability. In such operational manners, information accuracy and validation might be qualified while information believability status of property ownership is dismissed. The proposed workflow would help fulfil this gap. The novelty of the proposed workflow compared to existing blockchain-based land registry flows lies in the information property filter that underlying the classification of ownership information believability during the block encryption process. We have deployed a blockchain network and set up a node to illustrate the block creation of the use case (Figure 4).

In the Microsoft blockchain cloud, we set up a Believability Traceability consortia network running on Hyperledger Besu - an Ethereum alliance designed to be enterprise-friendly for both public and private blockchain networks. Which means our Believability Traceability consortia network will run on a shared infrastructure that can connect to the public blockchain while maintaining organizational network permissions at the same time. In the Believability Traceability consortia blockchain, we deploy the Block Creation node typically for property ownership's believability traceability. The function of the Block Creation node is to encrypt information blocks that contain believability properties and seal them with blockchain's unique timestamps on the chain. In other words, we can consider the Block Creation node as a mining node that functionally mines new blocks of the blockchain.

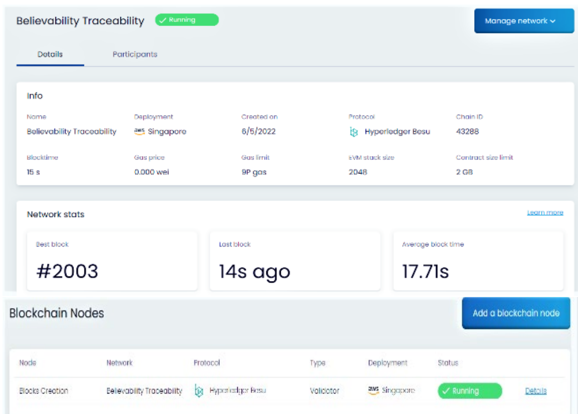

Figure 4. Believability traceability blockchain consortia network.

For encrypting property ownership information, we create a smart contract and deploy it to the blockchain cloud middleware, then integrate such contract into the user interface of the enterprise system using an integration studio that is available on the blockchain cloud. This smart contract will perform the following tasks: (i) gets ownership information input by users, (ii) encrypts the information into a non-fungible token (which serves as an information tag), (iii) sends the information tag to the mining node, (iv) creates timestamps and integration of the block to the multichain, and (v) returns the report that contains information such as block ID, contract address, property owner name, number of ownership certificates, ownership status (certified or uncertified), and attached believability properties (appears as an identifier or keyword) after mining completion. Highlights of the smart contract code can be seen in Figure 5.

It is notable that while the smart contract encrypts property ownership information to be an information block of the blockchain's multichain, it has included the results of properties filter on data quality. Thus, the contract defines whether the ownership information is qualified to believe and releases property ownership certification. This is one of the critical contributions of this paper – to deliver a smart contract that moves beyond its current use to serve innovation purposes.

This design will provide continuous records of ownership status with specified timestamps and thus will support traceability for forensic audit purposes, clearing house, ownership management, and prevention of money laundering.

```
pragma Solidity ^0.8.0;

import '../_library//tokens/// https://eips.ethereum.org/EIPS/eip-20
// SPDX-License-Identifier: MIT
pragma solidity >=0.5.0 <0.8.0;

/* ERC20 tokens for believability filtered property ownership blocks creation.*/
contract ownershipCertification is Token {

    /* NOTE:
    The following variables are to support ownership believability.
    Onweship properties are included to support information believability.
    These variables are to customise the token contract & in no way influences the core functionality.
    Wallets/interfaces will not be impacted by the attached information.
    */
    string public name;                 //Owner name: e.g. John Smiths
    uint8 public decimals;              //How many ownership certificates/ID to show.
    string public symbol;               //An identifier: e.g. PoB (property of believability)

    constructor(
        uint256 _initialAmount, string memory _name, uint8 _decimalUnits, address gatekeeper,
        string  memory _symbol;
        string  memory uifieldDefinitionHash) {
        ERC20Token(name, decimals, gatekeeper, symbol, uifieldDefinitionHash){}
    }

    function getDecimalsFor(
        bytes memory /*field name*/
    ) Public view override returns(uint256){
        return _decimals;
        require(symbol >= _value, "block encryption without ownership certification");
    }
```

Figure 5. Smart contract for believability filtered property ownership creation.

7. Discussion

In the earlier sections, we proposed conceptual artefacts which became the foundation for the creation of system artefacts, namely, the blockchain-based continuous timestamps tracking system (Figure 2), system components, prototypes, and implementations. The uniqueness of our solution compared to existing blockchain traceability systems can be seen in the inclusion of sets of properties that regard intrinsic data quality in system architecture. In particular, input data is checked for quality before it gets approved to be encrypted. We thus deliver a quality-in quality-out system that increases the believability of the output information. In addition to the advantage of including a properties reference framework in the system (as discussed in section 4), each input information will be entangled to a set of properties at a unique timestamp, which will benefit not only tracking property ownership timelines but also understanding the evolution of input data's properties over time. This research delivers to academic audiences a novel perspective of system design in terms of proposing an information system architecture that includes intangible elements, such as intrinsic data quality and information believability, to be a part of the system architecture. We also contribute to the knowledge base a further understanding and application of believability as a dimension of data quality. For industry audiences, we provide advanced tracking tools for property ownership built on blockchain technology, which will take on advantages of blockchain such as traceability, immutability, and irreversibility. Together with the intrinsic data quality reference framework (Figure 1), a novel workflow (Figure 3), and a system design that potentially delivers better business intelligence and information believability. Despite property ownership tracking, the proposed design could be generalized to a broader area of high value assets ownership such as high value multi owned assets, intellectual assets, and others. In the scope of this paper, we have not completed the full-fledged system prototype creation. The proposed system artefacts will also need to be evaluated. According to Peffers et al. (2007), the evaluation of artefacts is an iterative process that requires multiple episodes. In future research, we intend to build a full-fledged system prototype and test its workflows by various evaluation methods such as black box testing, white box testing, feedback analysis, and interviewing experts.

8. Conclusion

To improve ownership information believability about high value assets such as property, we need to design a system that performs beyond the accuracy of input data and output information. Intrinsic data quality, of which believability is a major part, should be included in the system design to improve the believability of output information. We present such a perspective in the design, implementation, and use of information systems via the development of a set of conceptual artefacts upon which the system artefact is constructed. The proposed system is a blockchain-based continuous timestamp tracking system running on a shared network infrastructure. Notably, the system architecture includes four dimensions of intrinsic data quality, namely, believability, accuracy, reputation, and objectivity. These four dimensions exist in the system architecture as individual entities that contain their unique attributes to reference relevant properties of input data before such data will be encrypted to be a block on information with a unique timestamp in the blockchain network. This design takes advantage of blockchain technology such as traceability, immutability, and irreversibility to build up believability and trust in information. Furthermore, this design assists observing and understanding the evolution of ownership data properties over time. This paper contributes to both academia and industry a novel perspective to improve data quality and information believability in design, management, and the use of information systems. The proposed solution could be generalized to a broader area of continuous tracking such as product authenticity, high value asset ownership, intellectual property ownership, and others.

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