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Applications of NFT Digital Identities for Constructed Buildings and Associated Assets in Design and Construction: A Case Study

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Abstract

Digital identities, incorporating non-fungible tokens (NFTs) and blockchain technology, have gained traction in ensuring the authenticity and provenance of physical assets like art and music. However, their application in constructed assets such as commercial buildings and residential homes remains limited. This paper presents a review of employing NFTs for construction assets and provides a case study as an example. The research aims to address the effectiveness of NFT digital identities in constructed buildings, the application of digital identities to associated capital-purchased equipment, the secure and reliable transfer of these digital identities, and their ability to communicate detailed asset information. The study involves the application of an NFT digital identity to a physical residential structure and its associated assets. Through the case study, the process of asset transfer, including information from design, construction, and operations stages, was simulated between the owner and purchaser. The results confirm the successful application of NFT digital identities to constructed assets, demonstrating their potential for decentralized documentation and immutable record-keeping. The paper highlights the advantages and benefits of utilizing NFT technology compared to conventional methods. However, further research is necessary to establish its general applicability. By leveraging NFTs and blockchain, this research contributes to the growing body of knowledge on digital identities for physical assets and paves the way for wider adoption and implementation in the construction industry.

Keywords: Non-Fungible tokens; Blockchain technology; Communication and Transparency; Supply chain data; Platform-agnostic solution

Introduction

Digital identities, which incorporate non-fungible tokens (NFTs) and blockchain technology, are increasingly being utilized to ensure the authenticity and provenance of physical assets, including art and music Goldstein [1] Pierro, Sawaf, Tonelli, [2]. These digital tokens, when tied to information stores, not only serve as an additional method of decentralized documentation but also offer an immutable and permanent record that is impervious to alteration or violation. With the growing prevalence of non-fungible tokens for identity creation, possession, and transfer, their adoption and implementation are anticipated to continue to rise S Li, Chen [3]. However, the exploration of utilizing digital identities for constructed assets, such as commercial buildings and residential homes, remains limited. Therefore, this paper aims to conduct a review of the process and application of employing NFTs for construction assets, presenting a case study as an example. Furthermore, it will delve into the potential advantages and benefits of utilizing this technology in comparison to more conventional methods. The research questions to be addressed are as follows: Research Question: Can NFT digital identities be effectively applied to constructed buildings?

i. Sub-Question 1: Can digital identities be applied to the capital-purchased equipment associated with these buildings?

ii. Sub-Question 2: Can these digital identities be securely and reliably transferred?

iii. Sub-Question 3: Can these digital identities effectively communicate specific and detailed information about the assets?

Materials and Methods

This research follows a three-step methodology to study the application of the above application question:

i. Define the scope of the research.

ii. Review the literature to assist in establishing research propositions.

iii. Review the application of digital identity to a case study.

Scope of research

Digital identities have been used in certain consumer goods, credentials, and art objects. However, its application to the built environment and associated capital assets has been limited. This research explores the application of digital identities to a constructed structure and its accompanying capital assets through a case study. A comparison will be made to an identical structure without a digital identity. The objective of this research is to understand the overall suitability and feasibility of this process, as well as any potential benefits that would be realized by the Architectural, Engineering, Construction, and Facility Operations (AEC-FO) community. The case study utilized the construction of two semi-modular residential structures, built simultaneously by university students, for final use on a Native American Reservation. The exact location for installing the structures had not been determined during the construction process. The structures' simple design and limited capital assets made this case study an ideal opportunity to explore the application and use of digital identities in design and construction.

Prior Research

Prior research on this subject has been limited, with the use of applications driven to supply chain, contracting, and document management, but has not been generally applied to the specific applications of a digital identity to the constructed entity. Additionally, prior research will clarify the terminology related to this subject. The use of digital identities in construction supply chain management was reviewed by Yoon, Pishdad-Bozorrgi [4] in a review of the current state of the literature. The authors note that the use of digital identities is emerging and that it has not been comprehensively examined within the use of supply chain, but the overall benefit appears to be widespread in promoting better communication and transparency. Similarly, Wen and others [5] in their case study of using sensor integration with digital identities for better supply management coordination. Hijazi and others Hijazi, Perera, Calheiros, & Alashwal, [6] use a comparable process in establishing a process to integrate BIM project designs and digital identities to provide immutable and traceable documents for the use of supply chain data delivery. Similarly, Naderi et al. [7] reviewed the use of smart contracts for safety incentives via a proposed traceable and immutable decentralized application. Li and Kassem [8] reviewed applications of smart contracts within construction and noted thematic applications in a variety of construction management functions including contracting and operations, but not that of the build entity itself. Darabseh and Martins [9] also reviewed the possible applications of smart contracts and highlighted possible uses and organizations of the application of NFT's in design, construction, and operations.

Terminology and concepts

i. **Distributed Ledger Technology/ Blockchain**: Decentralized and distributed ledger comprising connected and enumerated transactions that are resistant to alteration and manipulation. Each information block is linked to previous blocks by a cryptographic link, where network peers create and exchange approved transactions Buccafurri, Lax, Russo & Zunino [10] J Li & Kassem [8] Wust & Gervais [11].

ii. **Ethereum:** A platform, with blockchain as the underlying technology, to encode scripts or rules for processing transactions and smart contracts. Smart contracts are a Turing-complete program within the Ethereum platform that uses blockchain to ensure the correct execution Chen, et al. [12].

iii. **Digital Identity:** An asset's information used by computer/web-based systems to provide information based on a set of defined attributes Buccafurri, et al. [10].

iv. **Fungible Tokens:** Representative of an identical asset that can be replicated and interchanged Hasan, et al. [13]; Pierro, et al. [2].

v. **Non-Fungible Tokens (NFTs):** Representative of unique assets with unique identifiers and attributes that cannot be divided, or their history altered. NFTs have a hierarchical deterministic wallet that allows for near-unlimited file storage, based on access and control from the NFT owner. NFTs are stored in a digital wallet, where ownership can be transferred to another wallet. Wallets can have group approval to allow for greater accountability, transparency, and control of these digital assets. These digital assets are implemented on top of the Ethereum blockchain using their own smart contracts and are different than Ether crypto Hasan, et al. [13] Pierro, et al. [2] Popescu [14].

Application of Digital Identities to a Case Study

As mentioned in part I, the chosen case study involved the construction of two identical, semi-modular residential buildings (approx. 950sf) simultaneously built for final use on a Native American Reservation. This study utilized the reference number that was assigned by the university. The buildings were wood-framed and followed conventional residential construction methods. The design of each structure was completed using BIM, with input and approval from the sponsoring organization. Materials for both structures were procured in bulk, following US Government procurement requirements. As mentioned, labor was provided by university students and mentors. Therefore, this case study simulated material procurement and delivery processes from vendors/contractors to building owners. This simulation will have little to no impact on the results since the process of assigning digital identities will remain unchanged and will be handled by the originating entities. Creating individual identities involved a multi-part process that utilized multiple platforms. This process facilitated the creation of identities based on a designed hierarchy, where information was created and/or nested according to the type and location of the physical asset. It is important to note that the specific process of creating digital identities involves specific programming processes beyond this paper's scope.

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The digital identity creation process utilized a web-based platform (BLDX), which used a domain naming service (Butterfly Protocol) to issue NFT domains and establish ownership (Figure 1). These protocol domains are incorporated into the digital identities' names to establish security keys and channels for further privacy control. The data can then be stored and indexed within a unique, searchable, and verifiable digital identity. The structure of this process is based on the following levels (Figure 2):

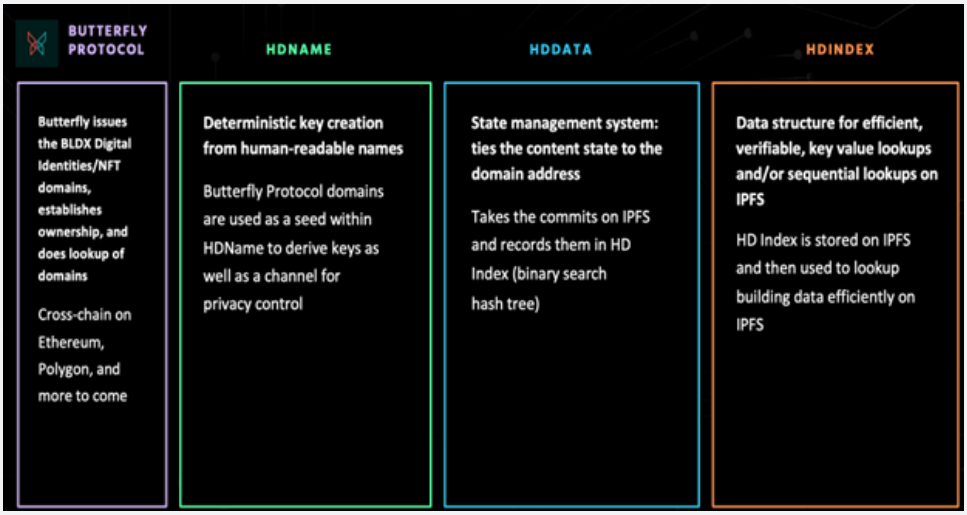

Figure 1: Creation Hierarchy and Data Storage.

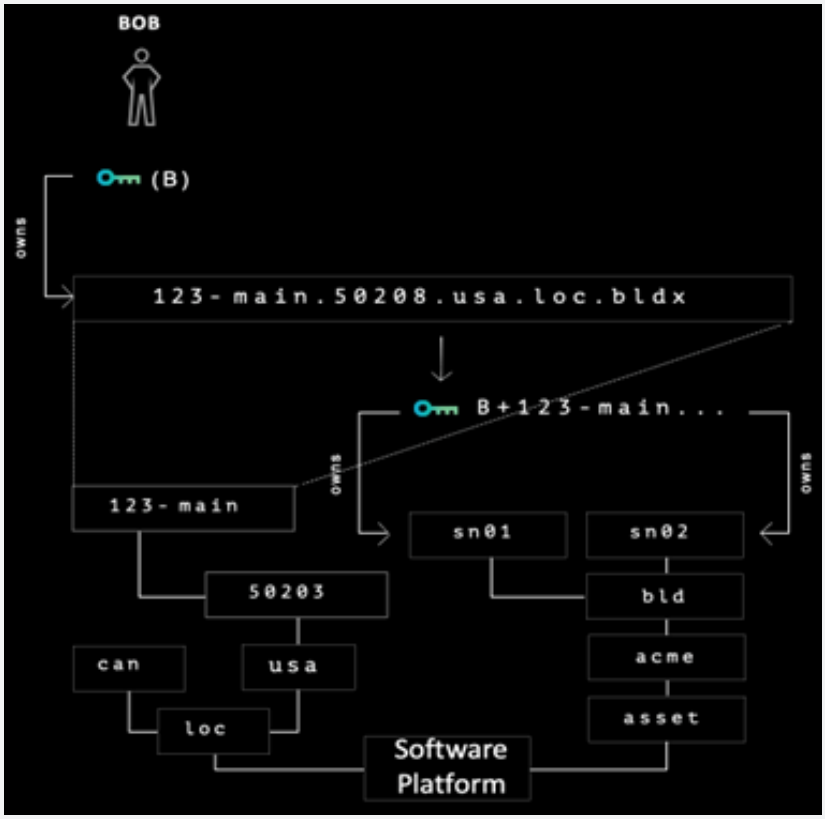

Figure 2: Level Hierarchy of NFT Digital Identity.

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i. Level 1: Building Name/Location The digital identities were created and named based on the physical location of the building, including the street address, postal code, and country name. This identity provides the digital shell where the subsequent information is stored.

ii. Level 2: Physical Building Assets The identity is further broken down into physical building assets, including BIM files, relevant construction documents, and other custodial documents.

iii. Level 3: Physical Assets of Each Building The final layer is used to store information about capital assets that are located within each building, as well as other digital identities. This could include large building infrastructure items such as chillers and boilers, as well as assets specific to the purpose of each building, such as MRI machines and athletic infrastructure.

Using the above reference method and structure, this research was able to observe the application of digital identities to buildings and the associated building assets.

Results

Results provided information specific to the stated research questions. The limited case study offered an opportunity to test the general application of digital identities to constructed building assets.

Research Question: Can NFT digital identities be effectively applied to constructed buildings?

A digital identity was successfully created for one of the constructed residential entities. The NFT was created with the capability to digitally store BIM models, product data, building warranties, construction receipts, inspection records, and more. The digital identity contained publicly searchable information, as well as information that the NFT owner (and building owner) could secure behind a protected file system. For the other constructed residential entity, the same information was either included with the building itself (in an envelope) or sent via email to the sponsoring organization.

Sub-Question 1: Can NFT digital identities be applied to associated capital-purchased equipment?

Upon creating the NFT for the construction of the residential entity, separate NFTs were also created for certain capital assets, such as the kitchen oven and domestic water heater. This was done to test further the application of creating these digital identities. The relevant production information and warranty information were nested within these NFTs. The NFTs were successfully incorporated within the residential building NFT.

Sub-Question 2: Can these digital identities be securely transferred?

In testing the created digital identities, as demonstrated in other case studies Ho [15] Murray, [16], the digital identities can be securely transferred to individuals or legal entities. This process was successfully tested for the NFTs associated with the constructed residential building to verify the digital asset transfer.

Sub-Question 3: Can these NFT digital identities communicate certain information to interested parties?

This question was successfully tested using the file structure created for the NFTs. Interested parties could access relevant information from the public folder structure.

Discussion

The concept of digitally storing documents and relevant information for a constructed asset is not new, and neither is associating an NFT with an asset. However, the innovation lies in linking ownership of an NFT with a constructed asset. This application offers a platform-agnostic solution for storing documents and information related to a facility's design, construction, and operations. Ideally, it would include the BIM model, construction tests and observations, and commissioning of the structure. Although not tested in this study, the ability for asset owners to search for relevant information such as warranty information and proof of purchase would be better facilitated in a searchable, central repository compared to more traditional storage alternatives. The suggested and tested NFT format provided a searchable platform for the building and asset holder, and potentially for the manufacturer. Interested parties, including manufacturers, could pull and/or push information to these NFT owners and capture valuable insights. This information could include the number of units still in use, operational issues, energy use/efficiency, etc. These points are beyond the scope of this research but provide an interesting secondary use for NFTs.

Conclusion

This paper reviewed the process and application of employing NFTs for construction assets. A case study was presented as an example to test this process. The case study confirmed the application of an NFT digital identity to a physical residential structure and associated assets. This case study allowed for a simulation of asset transfer between owner and purchase, including information from the residential entity's design, construction, and operations. The potential advantages and benefits of utilizing this technology in comparison to more conventional methods were discussed, but more research is needed to confirm general application.

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