Blockchain for Long-Term Digital Archiving in Academic Libraries: Preserving Authenticity and Accessibility

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Abstract

This paper explores the application of blockchain technology in digital archiving, emphasising its potential to preserve the authenticity and accessibility of digital records in academic libraries. Blockchain's inherent immutability and decentralised structure in academic libraries offers a secure foundation for archiving, enabling enhanced protection against unauthorised alterations and facilitating trust in long-term digital preservation. It highlights critical advantages of integrating blockchain with archival practices, such as the reinforcement of data integrity through cryptographic protocols and distributed validation mechanisms. Additionally, case studies demonstrate blockchain's capability to support secure data sharing across borders and institutions, addressing common archival challenges. Despite its promise, the technology poses regulatory and legal obstacles, especially regarding data privacy and compliance with laws like the GDPR. This paper argues that while blockchain provides an innovative solution for digital archiving, a cautious approach is needed to balance its benefits with regulatory compliance. Future research should focus on refining blockchain-based archival frameworks to overcome these challenges and enhance usability for diverse stakeholders.

Keywords: *Blockchain; Digital archiving; Data immutability; Decentralisation; Data privacy; Academic libraries and long-term preservation.*

Introduction

A digital archive is a repository designed to preserve digital records of enduring cultural, historical, or evidentiary significance. These records can encompass a wide array of digital objects, including texts, images, videos, and audio files. The primary objective of a digital archive in the library is to safeguard valuable information and artifacts in a format that facilitates easy access, search ability, and sharing across digital platforms (Ashikuzzaman, 2024). In academic libraries, the establishment, management, and sustainability of its digital archive involve several critical considerations which include:

Long-Term Preservation: Digital archives are susceptible to technological obsolescence due to the rapid evolution of storage media—from floppy disks to cloud storage. Ensuring that

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digital artworks remain accessible over extended periods requires strategies that address legal, regulatory, operational, and historical factors.

Metadata Management: Each item in a digital archive must be accompanied by comprehensive metadata, including descriptive, structural, and administrative information. Authorized personnel must regularly update this metadata to maintain transparency and ensure that all archival operations are documented in an open and verifiable manner. Additionally, robust metadata supports anti-counterfeiting efforts by safeguarding artworks against forgery and aiding in their identification if lost and subsequently recovered.

Format Accessibility: Digital records are stored in various media formats, each associated with specific software and hardware requirements. A digital archive must ensure the ongoing availability and retrievability of these formats, facilitating efficient and accurate access to artworks.

Integrity and Protection: Safeguarding digital descriptions of artworks against unauthorized alterations is paramount. Integrity measures ensure that records remain unaltered without proper authorization. Protection strategies are essential to defend against data corruption, loss due to natural disasters, or cyber-attacks. While digital tools cannot protect physical artworks, they play a crucial role in preserving their digital representations.

Traceability: Implementing mechanisms to track all movements and modifications of individual artworks within the archive enhances accountability and aids in provenance research. A significant challenge in digital archiving is the inconsistency in description practices across different repositories, which can hinder the discovery and accessibility of records. The General International Standard Archival Description (ISAD(G)) addresses this issue by providing guidelines for creating effective archival descriptions. ISAD(G) promotes a hierarchical approach to metadata, facilitating the organization and retrieval of archival materials. The InterPARES (International Research on Permanent Authentic Records in Electronic Systems) project has been instrumental in developing policies and guidelines for the creation and maintenance of digital records. This international collaborative initiative focuses on ensuring the authenticity and long-term preservation of digital records. InterPARES has translated digital preservation theories and methods into concrete action plans for existing records, particularly benefiting archives and records units with limited resources (InterPARES 3 Project).

Digital preservation in academic libraries

Digital preservation is an indispensable function of academic libraries, ensuring the longevity and accessibility of scholarly content, supporting research and education, and safeguarding cultural heritage. Despite the challenges involved, implementing sustainable preservation strategies is essential for academic libraries to fulfil their mission in the digital age. Through collaborative efforts, robust policies, and on-going staff capacity building, libraries can

effectively navigate the complexities of digital preservation and continue to serve as vital hubs of knowledge and learning (Anuradha & Chand, 2024).

Academic libraries serve as pivotal repositories of knowledge, providing access to a vast array of resources that support research, teaching, and learning. With the advent of digital technologies examples digital and institutional repositories; integrated library systems Koha, Aleph, Sierra; digital library platforms CONTENTdm, Omeka and Greenstone; electronic resource management Coral ERM; Digital preservation tools Archivematica, Preservica, a significant portion of scholarly content is now produced and stored in digital formats. While this transition offers numerous advantages, it also presents challenges related to the longevity and accessibility of digital materials. Digital preservation ensures continued access to digital materials over time and has thus become a critical function of academic libraries.

The importance of digital archiving in academic libraries

Ensuring Long-Term Access to Scholarly Content: Digital archiving guarantees that valuable academic resources, including e-books, online journals, and research data, remain accessible despite technological changes and potential obsolescence. Without proactive preservation efforts, there is a risk of losing significant scholarly work due to hardware failures, software incompatibility, or data corruption. As noted by the University Libraries' digital preservation policy, meticulous, large-scale planning is essential to curate and maintain digital scholarly content across technological changes over time.

Supporting Research and Education: Reliable access to preserved digital resources is fundamental for ongoing research and educational activities. Researchers and students depend on the availability of digital materials for literature reviews, data analysis, and the development of new knowledge. Effective digital preservation ensures that these resources remain intact and usable for future academic endeavors.

Safeguarding Cultural Heritage: Academic libraries often house unique digital collections that reflect cultural, historical, and scientific heritage. Preserving these digital artifacts is vital for maintaining the cultural record and providing future generations with access to primary sources. Digital archiving serves as both a technical challenge and a social and cultural responsibility for libraries.

Challenges faced by academic libraries in digital archiving

Despite its importance, digital achieving in academic libraries faces several challenges:

Technological Obsolescence: Rapid advancements in technology can render hardware and software obsolete, posing a threat to the accessibility of digital materials.

Resource Constraints: Implementing comprehensive digital preservation strategies requires significant financial and human resources, which may be limited in academic institutions.

Legal and Ethical Issues: Navigating copyright laws and intellectual property rights can complicate preservation efforts, especially when dealing with digital content that has usage restrictions.

The role of blockchain in enhancing digital archiving in academic libraries

Blockchain technology, renowned for its decentralized and secure data management capabilities, is increasingly being explored for its potential applications in academic libraries. The role of blockchain in enhancing library operations, focusing on areas such as resource sharing, circulation control, and user data security. Academic libraries are pivotal in supporting education and research by providing access to a vast array of information resources. As digital transformation accelerates, these institutions face challenges related to data security, resource sharing, and operational efficiency. Blockchain technology offers promising solutions to these challenges by enabling decentralized, transparent, and secure information management such as:

Enhancing Resource Sharing and Inter-Library Loans: Traditional inter-library loan (ILL) systems often encounter issues such as delays, high operational costs, and data management inefficiencies. Integrating blockchain technology can streamline these processes by creating a secure and transparent platform for managing resource requests. Smart contracts—self-executing agreements encoded on the blockchain—can automate lending procedures, reducing human intervention, and minimizing errors. This approach not only expedites transactions but also ensures data accuracy and enhances collaboration among libraries (Savatagi & Naik, 2024).

Improving Circulation Control: Effective circulation control is essential for tracking the borrowing and returning of library materials. Blockchain's immutable ledger can record every transaction, providing a reliable and tamper-proof system for monitoring circulation activities. This ensures accountability and reduces the risk of data manipulation. A study by Obim, Ukwueze, and Nwadike (2023) highlights the potential of blockchain to enhance circulation control in university libraries by facilitating accurate record-keeping and quick tracking of transactions.

Ensuring Data Security and User Privacy: Protecting user data is a critical concern for academic libraries. Blockchain's decentralized nature enhances data security by eliminating single points of failure and reducing vulnerability to cyber-attacks. Additionally, blockchain can provide users with greater control over their personal information, thereby enhancing privacy. Jha (2023) emphasizes that blockchain technology can safeguard user records and improve the privacy of research data, fostering trust between libraries and their patrons.

Blockchain technology offers a transformative approach to digital archiving by ensuring the authenticity and accessibility of records. Its inherent characteristics, such as immutability and decentralisation, provide a robust framework for preserving digital assets over the long

term. For instance, Stančić & Bralić highlight the importance of blockchain in overcoming challenges related to data immutability, which is crucial for maintaining the trustworthiness of digital records (Stančić & Bralić 2021). Furthermore, Zhang emphasised that blockchain's cryptographic algorithms and distributed databases create a secure environment for archiving digital data, making it impossible for unauthorised parties to alter records (Zhang 2024). Additionally, Cao discussed how blockchain can enhance digital archive management systems, facilitating better creation and preservation practices (Cao, 2023). The integration of blockchain with existing digital preservation standards can lead to more reliable archival processes, as noted by Bralić, Stančić, & Stengård (2020) who proposed a model that combines blockchain with digital signature certification for long-term preservation. Overall, the application of blockchain technology in digital archiving not only preserves the integrity of records but also enhances their accessibility for future generations.

The problem of authenticity and accessibility in digital archiving in academic libraries

The preservation of authenticity and accessibility of digital archiving in academic libraries presents significant challenges that must be addressed to ensure the long-term viability of digital records. One primary concern is the integrity of digital records over time. As noted by Conway (2011) the quality and usefulness of digital surrogates can diminish if the preservation processes are not rigorously validated. This issue is compounded by the rapid evolution of technology, which can render certain digital formats obsolete, as highlighted by Fischer, Lundell & Gamalielsson (2021) who emphasized the need for digital file formats specifically designed for long-term archival. Furthermore, the lack of standardised metadata across different digital archives can hinder the ability to connect and retrieve records effectively, as pointed out by Kim, who discussed the isolation of records within distinct archival systems (Kim, 2023).

Existing digital archiving methods also face limitations that exacerbate these challenges. For instance, many digital archives are plagued by inadequate infrastructure and out-dated legislation, particularly in regions like Southern Africa, where Ngoepe & Saurombe (2016) argued that the absence of comprehensive archival frameworks significantly hampers the management of electronic records. Similarly, Katuu & Ngoepe (2015) highlight the difficulties faced by public sector institutions in systematically transferring digital records into archival custody due to poor management practices and a lack of skilled personnel. Additionally, Burke & Zavalina (2019)'s research on language archives reveals that the confusing design and inadequate metadata quality often lead to underutilisation of valuable linguistic data, further illustrating the accessibility issues inherent in current digital archiving practices.

Moreover, the reliance on traditional methods of recordkeeping in the face of technological advancements can create barriers to effective digital archiving. According to Lampert (2017) the pressure to digitise materials efficiently necessitates a re-evaluation of staffing and resource allocation in digital libraries, which can impact the overall effectiveness of

archiving efforts. The challenges of managing grey literature and ensuring digital accessibility are also underscored by Robinson, Saddler, Kerr-Campbell, Patrickson-Stewart, and Walker (2020), argued that digitisation must be accompanied by strategic planning to enhance the visibility and usability of collections. Thus, while digital archiving holds exciting potential for preserving records, the current methodologies and frameworks often fall short in ensuring both authenticity and accessibility over time.

Blockchain technology for authenticity

Blockchain technology provides a revolutionary approach to ensuring the authenticity and integrity of digital archives in libraries through its immutable record-keeping and cryptographic security features. At the core of blockchain's functionality is its use of cryptographic techniques, which secure data and verify transactions across a decentralised network. Each transaction is recorded in a block, which is linked to the previous block through a unique hash value, creating a chain that is resistant to tampering. This structure makes it impossible for any unauthorised party to alter the data without detection, as highlighted by Zhang (2024) who notes that the cryptographic algorithms employed in blockchain ensure the transparency and security of digital records. Furthermore, Lemieux (2016) discussed the potential of blockchain technology in supporting the principles of recordkeeping and digital preservation, although it also emphasises the need to critically assess its limitations and risks. The integrity of archives is supported by blockchain's decentralised nature, which eliminates the need for a central authority.

This decentralisation allows multiple nodes in the network to validate transactions, ensuring that all copies of the record are consistent and trustworthy. Kernahan, Bernskov & Beck (2021) note that the distributed ledger technology (DLT) underlying blockchain provides a robust framework for maintaining data integrity across various applications, including archival systems. Additionally, the use of cryptographic signatures in blockchain allows for the authentication of users and systems, facilitating secure access control and ensuring that only authorised individuals can modify or access sensitive archival data (Xia, Sifah, Smahi, Amofa & Zhang (2017). This aspect is particularly crucial in archival science, where the authenticity of records must be preserved over time to maintain their historical value. Moreover, blockchain's ability to create a transparent and auditable trail of transactions enhances the accountability of digital archiving processes. Cao (2023) view the implementation of blockchain in digital archives can lead to improved management practices, enabling better tracking of changes and access to records. This transparency not only fosters trust among stakeholders but also simplifies compliance with legal and regulatory requirements concerning data integrity and authenticity. As a result, blockchain technology emerges as a powerful tool for enhancing the reliability of digital archives, ensuring that they remain authentic and accessible for future generations.

Ensuring accessibility through blockchain technology

Blockchain technology plays a pivotal role in enhancing accessibility within digital archiving systems through its distributed ledger capabilities and decentralised architecture. The fundamental characteristic of blockchain is its ability to maintain a shared, immutable ledger that is accessible to all participants in the network. This decentralisation ensures that no single entity controls the data, thereby promoting transparency and trust among users. Liu (2022) is of the opinion that blockchain's decentralised nature allows for the secure sharing of information across various stakeholders without the need for a central authority, which can often be a bottleneck in traditional systems. This feature is particularly beneficial in the context of digital archiving, where multiple parties may need to access and verify records. Moreover, the implementation of Distributed Ledger Technologies (DLT) facilitates enhanced record access by allowing multiple nodes to participate in the verification and validation of transactions.

This collective approach not only increases the resilience of the system against data tampering but also ensures that all users have access to the most up-to-date information. Drosatos & Kaldoudi (2019) are of the opinion that the blockchain can safeguard transactions and maintain the integrity of databases, which is crucial for ensuring that archived records remain accurate and accessible over time. The ability to track changes and access records in real-time enhances the usability of digital archives, making it easier for researchers and stakeholders to retrieve necessary information. In addition to improving access, blockchain's decentralised architecture supports the development of innovative archiving systems that can operate independently of traditional centralised frameworks. Gencer, Basu, Eyal, Renesse & Sirer (2018) note that blockchain enables services such as land record management and voting systems to function without relying on trusted authorities, thus democratising access to information.

This decentralisation can be applied to digital archiving, where users can interact with the archive directly, ensuring that access is not limited by bureaucratic processes or centralised control. Furthermore, the use of smart contracts within blockchain systems can automate various archival processes, such as permissions and access rights, thereby streamlining user interactions and enhancing overall accessibility Jin, Eom & Lee (2019). Overall, blockchain technology offers a robust solution for ensuring accessibility in digital archiving systems through its decentralised and distributed nature. By facilitating secure, transparent, and real-time access to records, blockchain not only preserves the integrity of archived materials but also empowers users to engage with these resources more effectively.

Legal and Regulatory Challenges of long-term digital archiving in academic libraries

The integration of blockchain technology into libraries' digital archiving systems presents various legal and regulatory challenges, particularly concerning data privacy and compliance

with existing laws. One of the primary legal implications of using blockchain in archives is the difficulty in reconciling the immutable nature of blockchain with data protection regulations, such as the General Data Protection Regulation (GDPR) in the European Union. As noted by Hofman, Lemieux, Joo & Batista (2019) the GDPR imposes strict requirements on data erasure and user consent, which can conflict with the permanent and unalterable records, maintained on a blockchain. This paradox raises significant questions about how organisations can comply with legal mandates while leveraging the benefits of blockchain technology.

Moreover, the decentralised nature of blockchain complicates the enforcement of data privacy laws. Xu & Zhang (2023) highlight that while blockchain can enhance privacy through its distributed ledger system; it also poses risks related to data de-anonymisation and the potential for unauthorised access to sensitive information. The challenge lies in ensuring that personal data is adequately protected while still allowing for the transparency and traceability that blockchain offers. This issue is further compounded by the lack of clear regulatory guidelines on how blockchain systems should be designed to comply with data protection laws, as emphasised by Ahmed, Yayilgan, Nowostawski, Abomhara, Ramachandra & Elezaj (2020) who discussed the need for frameworks that align blockchain functionalities with GDPR requirements. In addition to data privacy concerns, regulatory compliance issues arise from the need for organisations to navigate a complex landscape of laws and regulations that vary by jurisdiction. Nisar (2023) points out that regulatory compliance is a significant barrier to the adoption of blockchain technology, particularly in regions like China, where the government plays an active role in shaping the technology landscape.

Organisations must ensure that their blockchain implementations adhere to local laws, which can be challenging given the rapidly evolving nature of both blockchain technology and regulatory frameworks. Furthermore, the use of smart contracts, which are integral to many blockchain applications, introduces additional legal complexities. These self-executing contracts can automate compliance processes but also raise questions about liability and accountability in the event of a failure or dispute. Farouk (2023) state how the legal landscape surrounding blockchain in healthcare highlights the importance of understanding the implications of smart contracts for compliance and liability. As blockchain technology continues to evolve, organisations must remain vigilant in addressing these legal and regulatory challenges to ensure that their digital archiving practices are both effective and compliant. While blockchain technology offers promising solutions for enhancing the authenticity and accessibility of digital archives, it also presents significant legal and regulatory challenges. Organisations must navigate the complexities of data privacy laws, compliance requirements, and the implications of decentralised systems to effectively implement blockchain in their archival practices.

Case studies and existing blockchain applications

Several institutions have begun to explore and implement blockchain technology for digital archiving, showcasing its potential to enhance the authenticity, integrity, and accessibility of archived records. One notable case is the European Blockchain Services Infrastructure (EBSI), which aims to provide a secure and efficient way to verify education credentials across borders. Tan, Lerouge, Caju & Seuil (2023) described a cross-border use case between Belgium and Italy, where blockchain is employed to streamline the verification process, thereby enhancing trust and reducing fraud in educational records. This initiative highlights how blockchain can facilitate collaboration between institutions while ensuring the authenticity of digital credentials.

Another significant example is the Trust Chain Model developed by Stančić & Bralić (2021) which integrates blockchain technology into digital archiving to address the challenges of data immutability. Their research emphasises the importance of maintaining the validity of digital signatures over time, allowing institutions to preserve the authenticity of archived documents even after the expiration of signing certificates. This model has been proposed as a solution for various archival institutions seeking to enhance their digital preservation strategies. In the context of higher education, Aini, Lutfiani, Lestari Santoso, Sulistiawati & Astriyani (2021) discussed the application of blockchain for managing educational certificates. They claimed that by utilising blockchain technology, institutions can create tamper-proof digital records that verify the authenticity of diplomas and other academic credentials. This approach not only protects against forgery but also simplifies the verification process for employers and educational institutions. Furthermore, the development of the Archain system, as presented by Galiev, Prokopyev, Ishmukhametov, Stolov, Latypov & Vlasov (2018) illustrates a novel blockchain-based archival system designed to provide a decentralised, transparent, and secure method for managing personal archives.

This system aims to leverage blockchain's strengths to create a more reliable archival framework that can adapt to the needs of users while ensuring data integrity. Cao's research emphasises the role of blockchain in enhancing information security for digital archives. By employing cryptographic methods and a distributed ledger, blockchain can facilitate better management and preservation of digital records, thereby addressing shared challenges faced by archival institutions Cao (2023). This comprehensive approach to digital archiving demonstrates the potential of blockchain to revolutionise how institutions manage and preserve their records. Overall, these case studies illustrate the growing interest and practical applications of blockchain technology in digital archiving across various sectors, particularly in education and institutional records management. As more organisations adopt blockchain solutions, the potential for improved authenticity, security, and accessibility in digital archives will continue to expand.

Challenges and barriers to blockchain adoption in academic libraries in Nigeria

Despite its potential benefits, in Nigeria the adoption of blockchain in academic libraries faces several challenges such as:

Cost of Implementation**:** The financial investment required for blockchain infrastructure can be substantial, posing a barrier for institutions with limited budgets (Akintunde & Amuda, 2024).

Technical Expertise: A lack of understanding and technical skills among library staff can hinder effective implementation and utilization of blockchain technology (Mondal, 2021).

Privacy Concerns: While blockchain enhances security, concerns about data privacy and the handling of sensitive information remain, necessitating the development of comprehensive policies and frameworks.

Strategies for successful implementation into academic libraries in Nigeria

To overcome these challenges, academic libraries can consider the following strategies:

Staff capacity building and development: Investing in training programs to equip library personnel with the necessary skills to manage and operate blockchain systems effectively.

Collaborative initiatives: Partnering with other institutions to share resources and knowledge can reduce costs and facilitate the exchange of best practices.

Policy formulation: Developing clear policies and guidelines to address privacy concerns and ensure compliance with legal and ethical standards.

Conclusion

In the academic libraries, the potential for blockchain technology in digital archiving is substantial, with its decentralised and immutable nature offering innovative solutions for records management. As institutions increasingly recognise the benefits of blockchain, its adoption is expected to grow, particularly in enhancing the authenticity and accessibility of archived materials. Its integration can elevate libraries and archives by addressing gaps in collections and fostering community trust through transparent record-keeping.

Blockchain technology in digital archiving practices can facilitate compliance with legal and regulatory frameworks in the academic libraries. As academic libraries continue to explore blockchain applications, the future of digital archiving may see a shift towards more decentralised systems that empower library users, enhance collaboration, lead to improved practices and greater accessibility for future generations.

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