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LEVERAGING BLOCKCHANE TECHNOLOGY TO ENHANCE LIBRARY SERVICES IN THE DIGITAL AGE

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ABSTRACT

This paper explores the potential of blockchain technology to enhance library services in the digital age. As libraries adapt to the challenges of digital content management, intellectual property protection, and user privacy, blockchain presents an innovative solution. By offering decentralized, transparent, and immutable record-keeping, blockchain can address key library challenges such as digital rights management, resource sharing, and ensuring data integrity. Key features like smart contracts, tokenization, and enhanced security allow for more efficient operations, while also promoting trust and transparency. However, the adoption of blockchain in libraries presents challenges related to scalability, interoperability with existing systems, legal compliance, and the need for user education. Despite these challenges, blockchain's ability to improve digital resource management, enhance user privacy, and streamline administrative processes makes it a promising tool for the future of library services. Further research, pilot projects, and case studies are necessary to assess its practical applications, costs, and legal implications for libraries seeking to integrate this technology

Keywords: Blockchain Technology, Library Services, Digital Libraries, Digital Rights Management (DRM), User Privacy and Data Security

Introduction

As libraries continue to adapt to the digital age, they face increasing pressure to meet the demands of a rapidly evolving information landscape. The digital transformation has introduced new opportunities for libraries to expand their services, streamline operations, and provide users with more accessible and secure information. However, it has also brought about significant challenges, such as the management of digital content, preservation of intellectual property, verification of data authenticity, and safeguarding user privacy (Kuhlthau, 2004; Tammaro, 2015). Blockchain technology, originally designed to underpin cryptocurrency systems (Nakamoto, 2008), has emerged as a promising solution to address these concerns in library environments.

Blockchain is a decentralized, distributed ledger system that ensures secure, transparent, and immutable record-keeping. Transactions are verified by a network of participants, making blockchain resistant to tampering and fraud, which is especially valuable for libraries where the integrity of information and intellectual property protection is critical (Tapscott & Tapscott, 2016). By integrating blockchain, libraries can improve the management of digital resources, enhance copyright management, and bolster data security. Additionally, blockchain can provide a verifiable record of transactions, supporting the authentication and provenance of digital content, ensuring the reliability of information for library users (Tudor et al., 2020).

This analysis explores the potential of blockchain to enhance library services in the digital age, examining its applications, potential to reshape library practices, and the benefits and challenges of adoption. It provides insights into how libraries can strategically use blockchain to improve service delivery, promote data integrity, and facilitate access to knowledge in an evolving digital environment.

Overview of blockchain technology

Blockchain technology, first introduced by Satoshi Nakamoto in 2008 as the foundation for Bitcoin, has evolved to impact diverse sectors beyond finance, such as supply chain management, healthcare, and intellectual property (Tapscott & Tapscott, 2016). It is a decentralized, distributed ledger that enables secure, transparent, and immutable data recording. Transactions are grouped into blocks, each linked by cryptographic hashes, forming a chain that ensures data integrity (Narayanan et al., 2016). Altering any block's data would require changing all subsequent blocks, making such modifications computationally infeasible.

Blockchain operates through consensus mechanisms like Proof of Work or Proof of Stake, ensuring security and eliminating single points of failure (Buterin, 2014). Its immutability guarantees that once data is recorded, it cannot be altered or deleted without detection, which is vital for applications involving trust and verification (Tapscott & Tapscott, 2016).

In addition, blockchain supports smart contracts self-executing agreements coded with predefined terms that automatically execute actions, such as payments or access control, when conditions are met. This eliminates intermediaries, enhancing efficiency and reducing the risk of errors or fraud (Szabo, 1997). Blockchain's potential to ensure data integrity, eliminate middlemen, and automate processes could be leveraged to transform library services, particularly in resource management, intellectual property protection, and improving access to knowledge in the digital age.

Relevance to library services in the digital age

The digital transformation of libraries has redefined how information is managed, shared, and accessed, with blockchain technology offering solutions to key challenges such as data integrity, resource management, and copyright protection. In the digital age, libraries face the growing issue of ensuring the authenticity and security of digital resources. Blockchain's immutability and transparency make it an ideal tool for safeguarding digital assets, ensuring that materials like e-books, articles, and archival content are authenticated and traceable (Tudor et al., 2020). This is particularly important in academic contexts where the credibility of research materials depends on their provenance (Anderson, 2021).

Blockchain also provides a solution for managing digital rights and intellectual property, automating copyright transactions through smart contracts, and ensuring fair compensation for creators and publishers (Li & Hu, 2023). It can also help libraries comply with licensing terms and protect intellectual property more effectively. Furthermore, blockchain supports user privacy by allowing decentralized control over personal data, reducing the risk of breaches and enhancing trust in library services (Chen & Wang, 2022). Blockchain can also streamline interlibrary collaborations and digital resource sharing, offering a secure, transparent method for tracking resource loans and reducing administrative tasks. It could even facilitate decentralized library networks, expanding equitable access to

Blockchain technology has the potential to enhance library services by improving operational efficiency, ensuring data integrity, and offering secure, transparent services that align with the evolving needs of modern libraries

Key Features of Blockchain Technology

Blockchain technology, initially developed as the foundation for cryptocurrencies like Bitcoin, has evolved into a highly versatile tool with a wide range of applications across various industries. Its unique attributes decentralization, immutability, transparency, and security make it especially relevant for addressing challenges in the digital age, including those faced by libraries in managing and securing digital resources. Below are some of the key features of blockchain technology that are particularly valuable for enhancing library services.

Blockchain technology offers several key features that are highly beneficial for libraries in the digital age:

- 1. **Decentralization**: Blockchain operates on a distributed network of nodes, eliminating the need for a central authority. This allows libraries to share control over digital content and data management, reducing the risk of breaches and enabling collaborative resource sharing without intermediaries (Zhang et al., 2021). It also ensures user control over personal data (Chen & Wang, 2022).
- 2. **Immutability**: Data recorded on the blockchain is permanent and tamper-proof, ensuring the authenticity and integrity of digital resources like research articles and e-books. This feature is crucial for maintaining the reliability of scholarly materials (Patel, 2022).
- 3. **Transparency and Traceability**: Blockchain provides full visibility of transactions, making it

easy for libraries to track digital resources, verify provenance, and manage interlibrary loans. Transparency also ensures that creators and publishers are fairly compensated for their work (Tudor et al., 2020; Li & Hu, 2023).

- 4. **Smart Contracts**: These self-executing contracts automate processes like licensing and subscription management. For libraries, this could streamline digital rights management, ensuring compliance with usage terms and reducing administrative tasks (Gustafsson & Ahlberg, 2021).
- 5. Security and Encryption: Blockchain's cryptographic algorithms ensure high security for user data and digital resources. The decentralized nature eliminates a central point of failure, providing strong protection against unauthorized access and tampering (Narayanan et al., 2016; Chen & Wang, 2022).
- 6. **Tokenization**: Tokenization creates digital tokens that represent digital content or access rights. Libraries could tokenize resources like ebooks, allowing secure, verifiable borrowing and streamlining resource sharing through interlibrary loans (Zhang et al., 2021).

Blockchain's decentralization, immutability, transparency, security, smart contracts, and tokenization make it a powerful tool for enhancing library services. By leveraging these features, libraries can improve operational efficiency, protect intellectual property, and provide secure, equitable access to digital resources.

Blockchain technology offers transformative applications for libraries, enhancing efficiency, security,

and user services while addressing challenges in the digital age, such as resource management, intellectual property protection, and data privacy. Here are some key applications:

- 1. Digital Rights Management and Copyright Protection: Blockchain helps manage and track digital rights transparently and securely, ensuring content creators and publishers are fairly compensated. Smart contracts can automate licensing agreements, while blockchain ensures the authenticity and provenance of digital resources, essential for maintaining academic integrity (Li & Hu, 2023; Patel, 2022).
- 2. **Resource Management and Interlibrary** Loans: Blockchain improves the management of interlibrary loans (ILLs) by providing a decentralized ledger to track resources securely and transparently. Tokenization of digital assets allows for efficient lending and tracking of digital content, reducing administrative burdens and enhancing resource sharing between libraries (Zhang et al., 2021; Tudor et al., 2020).
- 3. Improved User Privacy and Data Security: Blockchain's decentralized nature enhances user privacy by preventing data from being stored in a single vulnerable location. Blockchain-based identity management systems can give users control over their personal data, ensuring secure access to library services without relying on centralized databases (Chen & Wang, 2022; Tudor et al., 2020).
- 4. Archival and Digital Preservation: Blockchain's immutability ensures that digital

materials are preserved and remain unaltered over time. This feature is critical for digital archives, allowing libraries to verify the authenticity and integrity of digital records (Narayanan et al., 2016; Patel, 2022).

- 5. Decentralized Knowledge Sharing: Blockchain enables decentralized platforms for resource sharing, allowing libraries to collaborate directly without relying on intermediaries. This promotes open and collaborative knowledge exchange, particularly in public-domain content, scholarly research, and educational resources (Zhang et al., 2021).
- 6. Enhanced Transparency in Library
 Operations: Blockchain's transparency allows
 libraries to maintain verifiable records of transactions, acquisitions, donations, and resource usage, enhancing accountability. It can also improve financial transparency by tracking budgets and expenditures, ensuring responsible resource management (Tudor et al., 2020).

Efficient cataloging and metadata management, Secure digital rights management for e-resources, Enhanced interlibrary loan systems, Transparent record-keeping for user transactions, Benefits for Libraries, Improved trust and accountability, Reduced operational costs, Streamlined resource sharing across institutions

Blockchain technology offers transformative solutions for modern libraries, addressing challenges in cataloging, metadata management, digital rights management (DRM), interlibrary loan systems, and record-keeping. By integrating blockchain, libraries can enhance efficiency, security, and transparency in their operations. Key applications include:

- 1. Efficient Cataloging and Metadata Management: Blockchain provides a decentralized and immutable platform for storing metadata, ensuring accurate and permanent records. It can also automate cataloging through smart contracts, reducing errors and improving resource discovery across libraries (Narayanan et al., 2016; Li & Hu, 2023).
- 2. Secure Digital Rights Management (DRM): Blockchain enables secure and transparent DRM by using smart contracts to manage licensing agreements and enforce access rights. It ensures compliance with licensing terms, reduces intermediaries, and offers transparent tracking of digital resource usage (Gustafsson & Ahlberg, 2021; Li & Hu, 2023).
- Enhanced Interlibrary Loan (ILL) Systems: Blockchain improves ILL by providing real-time, secure tracking of resources between libraries. It reduces administrative burdens and fosters equitable resource sharing through decentralized, tokenized systems (Tudor et al., 2020; Zhang et al., 2021).
- 4. Transparent Record-Keeping for User Transactions: Blockchain's transparency allows libraries to track user transactions—such as borrowing history and payments—in a secure, immutable way. This enhances accountability, promotes trust, and provides valuable insights into resource usage (Patel, 2022; Chen & Wang, 2022).

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5. Benefits for Libraries:

- Improved Trust and Accountability: Blockchain ensures transparency and prevents data manipulation, enhancing trust between libraries, content providers, and users (Tudor et al., 2020).
- Reduced Operational Costs: Automating processes and eliminating intermediaries reduces administrative costs and increases efficiency (Li & Hu, 2023).
- Streamlined Resource Sharing: Blockchain facilitates more efficient sharing of physical and digital resources between libraries, ensuring fair access and real-time tracking (Zhang et al., 2021).

Blockchain can significantly improve library services by addressing challenges in digital rights management, resource sharing, transaction tracking, and operational efficiency, ultimately enhancing user trust and library collaboration in the digital age.

Challenges and Considerations in Adopting Blockchain Technology in Libraries

While blockchain technology offers promising benefits for libraries, its integration presents several challenges that must be addressed for successful adoption. These challenges are technical, organizational, and legal in nature:

1. Scalability Issues: Blockchain networks, especially those using proof-of-work mechanisms, can face slow transaction speeds and congestion as the number of users and transactions grows. Libraries, particularly large institutions, may struggle with the volume of data generated by cataloging, lending, and tracking usage. Exploring alternative blockchain solutions, like proof-of-stake or Layer 2 technologies, may help mitigate scalability concerns.

- 2. Interoperability: Libraries rely on various existing systems (e.g., integrated library systems, digital asset management). Integrating blockchain with these legacy systems can be challenging and may require significant modifications to ensure compatibility, data synchronization, and avoid duplication.
- 3. Legal and Regulatory Concerns: Blockchain's use in libraries raises legal issues, especially around digital rights management, intellectual property laws, and compliance with privacy regulations like GDPR. The immutability of blockchain may conflict with data protection requirements, necessitating careful consideration of how data is handled.
- 4. **Cost and Resource Requirements**: Implementing blockchain is costly, requiring investment in infrastructure, staff training, and ongoing maintenance. Smaller libraries or those with limited budgets may find blockchain adoption prohibitive, and specialized expertise may be necessary for successful integration.
- 5. Energy Consumption: Blockchain networks using proof-of-work consensus mechanisms consume significant amounts of energy, raising environmental concerns. Libraries may need to

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explore more energy-efficient alternatives to align with sustainability goals.

- 6. User Adoption and Trust: Library users may be unfamiliar with blockchain technology and concerned about the irreversible nature of transactions. Educating users, ensuring transparency, and providing user-friendly interfaces will be crucial for fostering trust and encouraging adoption.
- 7. Data Storage and Governance: Blockchain is not well-suited for storing large files like digital books and images due to its limited capacity. Libraries will need to rely on traditional storage systems and establish clear governance structures to manage data access and security.

While blockchain technology offers significant potential to enhance library services, its adoption is complex and requires addressing challenges related to scalability, interoperability, legal issues, costs, energy use, user trust, and data governance. Careful planning, investment in infrastructure, and user education will be key to successfully integrating blockchain into library operations. As the technology evolves, libraries may discover new ways to leverage blockchain for improved services.

Challenges of Blockchain Integration in Libraries

Technical Complexity and Implementation Costs:

Technical Complexity: Blockchain's decentralized nature contrasts with traditional centralized library systems, making integration difficult. Libraries need

workflows to adapt current to accommodate blockchain's distributed ledger, and must deal with the complexities of selecting suitable consensus mechanisms and cryptographic infrastructures.

- Implementation Costs: Blockchain adoption involves significant upfront costs, including investments in infrastructure, specialized hardware, and blockchain development tools. Libraries may also need skilled developers for custom applications and integration with existing systems, further driving up costs. Ongoing costs include system maintenance, security updates, and potential transaction fees for public blockchains.
- Training and Capacity Building: Library staff must be trained to manage and operate blockchain systems, and patrons need education on how blockchain affects services like digital rights management and privacy.
- Sustainability: Blockchain technology evolves rapidly, so libraries need to plan for future upgrades to avoid obsolescence. Switching platforms in the future could incur additional costs.
- Alternative Solutions: Libraries should consider whether blockchain is the most cost-effective solution, or if alternatives like distributed ledger technologies or cloud-based solutions might provide similar benefits at a lower cost.

Blockchain offers promising benefits for libraries, such as decentralization, transparency, and security, but its integration is complex and costly. Libraries need to assess their specific needs and resources carefully before adopting blockchain technology. Strategic planning, pilot projects, and ongoing staff training are essential for successful and sustainable blockchain adoption.

The Potential and Need for Further Research on Blockchain in Libraries

- 1. Potential of Blockchain to Transform Library Services:
 - Digital Rights Management (DRM): Blockchain offers a decentralized way to manage and track digital rights, simplifying licensing agreements and ensuring transparency in resource access.
 - Interlibrary Loan (ILL) Systems: Blockchain can enhance ILL systems by enabling real-time tracking and reducing intermediaries, leading to faster and more transparent resource sharing.
 - Cataloging and Metadata Management: Blockchain can improve cataloging accuracy and transparency by providing immutable, verifiable records of materials, facilitating collaboration between libraries.
 - User Transactions: Blockchain's tamperproof nature can secure and automate user transactions (e.g., borrowing books), improving trust and efficiency.

Patron Control and Privacy: Blockchain can empower patrons by giving them greater control over their personal data, enhancing privacy while maintaining transparency.

2. Need for Further Research and Pilot Projects:

- Practical Applications: Despite interest, there is limited empirical research on blockchain's real-world applications in libraries. More case studies are needed to assess how blockchain can integrate with existing systems like Integrated Library Systems (ILS) and DRM tools.
- Pilot Projects: Libraries should launch pilot projects to test blockchain in areas such as cataloging, DRM, and resource sharing, helping identify scalability, interoperability, and cost challenges.
- Cost-Benefit Analysis: Research is needed to evaluate whether blockchain's benefits (e.g., efficiency, security) justify its high upfront and ongoing costs, and to assess which blockchain platforms are most costeffective for libraries.
- Ethical and Legal Considerations: Blockchain's immutability raises legal concerns, particularly regarding data privacy laws (e.g., GDPR) and copyright issues related to DRM. Further research is needed to address these challenges.
- Stakeholder Engagement: Engaging all stakeholders—libraries, users, policymakers, and tech providers—is essential for successful blockchain

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adoption. Research should focus on how to meet the needs and concerns of these groups.

Conclusion: Blockchain has the potential to revolutionize library services by improving transparency, security, and efficiency. However, significant research and pilot testing are required to assess its practical, legal, and financial implications. By conducting research and initiating pilot projects, libraries can build a strong foundation for blockchain adoption and align it with their goals of advancing services in the digital age.

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