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International Journal For Research in  
Applied Science and Engineering Technology



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# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

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**Volume:** 14    **Issue:** V    **Month of publication:** May 2026

**DOI:** <https://doi.org/10.22214/ijraset.2026.82258>

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# Privacy-Preserving Blockchain Framework for Academic Records Using Off-Chain Storage

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**ABSTRACT:** The process of the fast digitalization of academic record systems has brought forth important issues addressed to the sphere of data security, privacy, and efficiency of verification. Some of the weaknesses of traditional centralized systems are breach of data, unauthorized access and poor verification systems. A decentralized and immutable blockchain-based solution is an adequate solution to manage academic records securely, but it contradicts the privacy legislation, like GDPR, because of its transparent nature. This study advocates a privacy-sensitive blockchain architecture that combines off-chain storage facilities to contain scalability and privacy problems. The framework provides cryptographic hash of academic credentials that are stored on-chain and other real data are stored in secure off-chain stores. The paper assesses the presented model with respect to the security, scalability, and compliance and proves that transparency and privacy can be balanced well using hybrid blockchain architectures. The results indicate that blockchain may be used with off-chain storage to create a viable and scalable approach to contemporary academic systems.

**Keywords:** Blockchain, Academic Records, Privacy, Off-Chain Storage, GDPR, Smart Contracts

## I. INTRODUCTION

With the development of digital technologies, the field of academic records management changed considerably. Institutions have been compelled to use the electronic systems to digitally store, handle and check the student details like transcripts, diplomas and certificates. With those developments, the existing centralized systems still have critical issues such as data breach, unauthorized engagements, and an inefficient verification system [7]. Single databases run by centralized academic record systems are susceptible to security risks, and can cause a single point of failure. In addition, the verification procedure in these systems is manual, time consuming and incurs direct communication between the institutions. The result of this is delays, higher administration costs and decreased trust within the stakeholders. The blockchain technology has come up as a possible solution because of its impartiality and unalterable nature. The blockchain distributes information among a set of nodes, eliminating the need to rely on a central authority and data integrity. But in the academic application of blockchain transparency is a major issue since confidentiality of sensitive student data is required. One of the significant weaknesses of blockchain systems is the fact that data deletion cannot be provided, which does not align with the privacy laws, including the General Data Protection Regulation (GDPR).

## II. LITERATURE REVIEW

### A. Centralized Academic Systems and Their Limitations

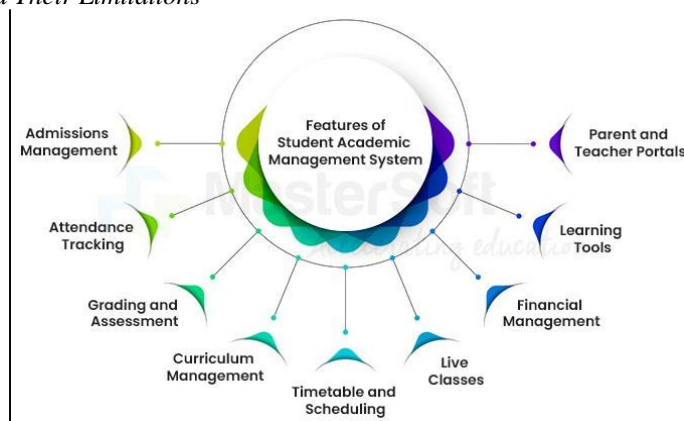


Figure 1: Academic record management systems

(Source:www.iitms.co.in)

The conventional academic record management systems mainly adhere to the centralized database structure, in which all data is maintained and managed by one authority that, in most cases is an educational organization. Although these systems are easy to manage and are simple to design, they are very limiting in security, reliability and effectiveness. Cyberattacks are very susceptible in centralized systems since once one is breached this can affect the entire database revealing sensitive student information, including personal information, grades and certifications [2]. Also, internal threats pose a risk to these systems with data being manipulated by administrative people.

**B. Blockchain for Academic Records**

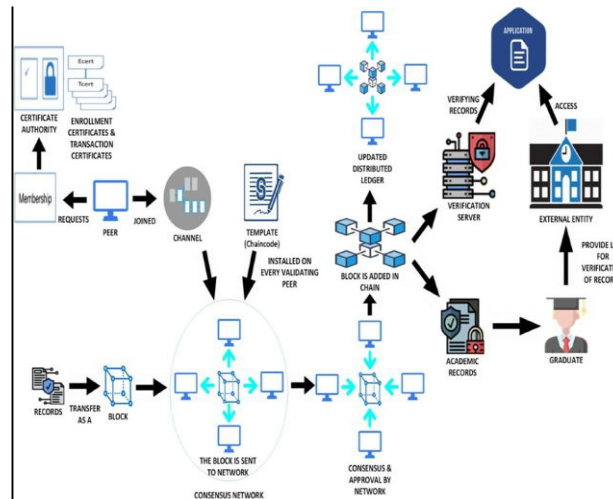


Figure2:Blockchain for Academic Records

(Source:link.springer.com)

The blockchain technology has become a revolutionary approach to solve the shortcomings of centralized academic record systems. It functions on a decentralized network with information shared among several nodes, thus, removing the central authority. The immutability is one of the major characteristics of blockchain as it guarantees the inability of the original data that is present on the ledger to be either altered or erased without the network participants consent [15]. The above property renders blockchain very capable of applications, where integrity of data and trust is important, e.g. verification of academic credentials. Blockchain could be applied in the field of academic records to store and verify credentials of students, such as degrees, transcripts, and certificates. Every record has a cryptographic hash attached to the record and which serves as a unique identifier and guarantees that any manipulation of the data is easily identified. The decentralized system of blockchain also allows emphasizing directly on credentials verification by employers or institutions, without mediators, which saves time of verification and administration costs.

**C. Privacy Challenges in Blockchain**

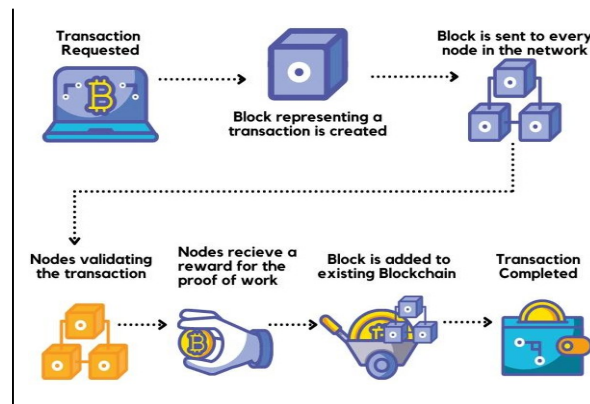


Figure3:Privacy Challenges in Blockchain

(Source:www.getastra.com)

Although blockchain technology has good security and transparency, it is also associated with serious issues of privacy, and particularly where it is used in internal areas of competency like academic records. The transparency of a blockchain is one of its natural features wherein all the transactions that go through the chain are transparent to other participants in the network[9]. As much as this feature makes business more trustworthy and accountable, it poses their own major concerns in handling personal and confidential information. Student records in academic systems hold sensitive information like identification information, academic performance and institutions. Direct storage of such data in the blockchain is likely to cause unauthorized disclosure, since even the encrypted data can be susceptible to some techniques of future disclosure[1]. Moreover, blockchain unfriendliness to privacy rules like the General Data Protection Regulation (GDPR) which provides individuals with the ability to alter or even erase their personal data is not compatible with the concept of blockchain. The fact that blockchain records cannot be destroyed or erased once stored poses a legal and ethical problem.

#### D. Off-Chain Storage Solutions

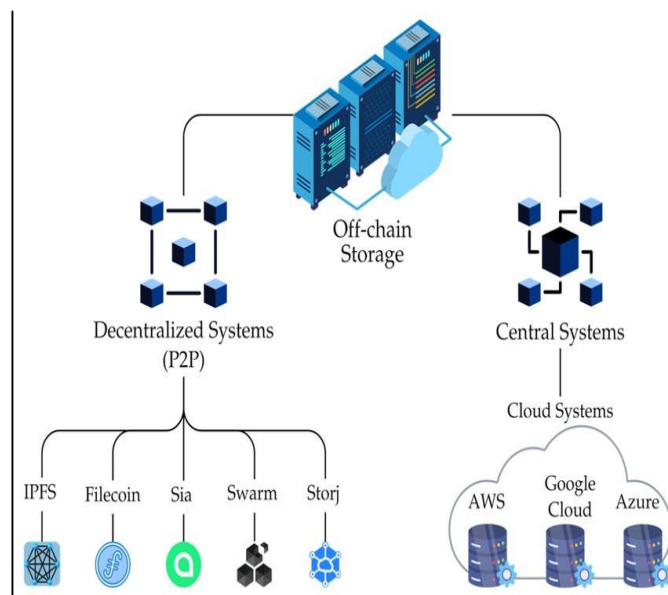


Figure4:Off-ChainStorageSolutions

(Source:www.researchgate.net)

The limitation on blockchain as far as scalability and privacy are concerned has led to the suggestion of off-chain storage solutions as the viable way to deal with these limitations. Off-chain storage enables the data to be stored externally instead of storing large amounts of data directly in the blockchain by having a reference to the actual data added to the blockchain[12]. This reference is normally a cryptographic hash which is a unique representation of the stored data and guarantees its integrity. Off-chain management of data is typically done through technologies like the InterPlanetary File System (IPFS), cloud storage systems, and decentralized networks of storage[18]. Such systems offer scalable and flexible storage systems allowing institutions to work with huge datasets without the high cost of storing them in blockchains. The technique of saving the hashes on-chain and retaining the true data off-chain guarantees that any change on the off-chain data would be revealed on the verification as the value of the hash will be different. Privacy wise, off-chain storage presents huge benefits in that the highly sensitive information is stored off-blockchain, thus reducing the chances of revealing it to unauthorized people.

#### E. Research Gap

Although the field of research investigating blockchain technology and off-chain storage solutions has expanded, there is still a critical gap in the creation of integrated frameworks that can effectively integrate the two solutions into each other in the domain of academic record management. There are numerous sources available on using blockchain to provide data integrity or using off-chain to increase scalability, but not many consider the issue of ensuring privacy compliance and performance optimization, at the same time[4].

Existing implementations of blockchain often do not take into account the challenges of dealing with sensitive academic data in accordance with legal regulations, like GDPR. Although off-chain storage has been identified as one possible solution, little has been done to study how to interlink it with blockchain smoothly to ensure the security, transparency, and convenience of verifying it. Moreover, the access control issues, institutional interoperability and real world problems of implementation are not sufficiently covered in the existing literature[10]. This paper seeks to fill this gap by proposing an integrated hybrid system which would capitalize on the advantages of both blockchain and off-chain storage. The suggested model aims at delivering the privacy preservation, efficiency in verification, and scalability, and deals with both administrative and real-life issues. In that way, it helps form a more powerful and practical solution to the recent academic record management systems.

### III. PROBLEM STATEMENT

The current solutions, regardless of the great achievements that have been made in digital academic systems, still have various fundamental problems that restrict their performance and applicability in reality. The absence of data privacy within blockchain-based infrastructure is among the key issues as the transparent aspect of blockchain may make sensitive academic data unavailable to unauthorized parties[6]. Also, direct storage in large amounts on-chain is expensive in storage and low on efficiency, which means that these systems are economically impractical to implement at scale. The final significant concern is that blockchain systems are not compatible with privacy laws, including GDPR, that acknowledge the right to modify or erase personal data, which does not align with the irreversible nature of blockchain. Moreover, existing systems tend to use inefficient verification methods based on either manual procedures or institutional relatedness, causing delay and excessive burden on administration. These constraints underscore the imperative of an effective solution that ensures confidentiality, safety, and privacy-safe management of academic records and efficiency and credibility.

### IV. RESEARCH OBJECTIVES

- To analyze privacy challenges in blockchain-based academic systems
- To design a hybrid framework using off-chain storage
- To evaluate security, scalability, and compliance of the proposed model
- To provide recommendations for real-world implementation

### V. PROPOSED FRAMEWORK

#### A. System Architecture

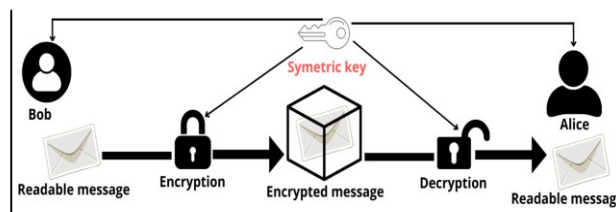


Figure 5: Blockchain technology with off-chain storage system

(Source: www.mdpi.com)

The proposed framework is developed as a hybrid solution which combines blockchain technology with off-chain storage system to provide security as well as privacy in the management of academic records. The system consists of three layers that are closely associated with each other and each deals with respective set of functionalities that collectively guard data integrity, confidentiality and effective validation [14]. The initial element is the blockchain layer that is a building block of the system. This layer is tasked with storing the cryptographic hashes of academic records instead of the information. In this way, it makes sure once a record is put on record it can never be changed without being noticed. Decentralization of blockchain also leads to transparency and trust, all the participating nodes have a matched copy of the ledger[3]. This ends the need to have a central authority and the possibility of having single points of failure. The second element is the off-chain storage layer where actual academic records, which have been stored, are stored like the transcripts, certificates and degree records. As it is not efficient and costly to store large amounts of data directly on the blockchain, the layer is an efficient and scalable alternative. To preserve these records, such technologies could be used as the InterPlanetary File System (IPFS), or secure cloud storage systems.

### B. Working Mechanism

The operating principle of the suggested framework is ordered and organized sequence of actions that guarantees safe storing of academic materials and effective validation of academic records. Once an institution creates a student record, the record will be uploaded to the off-chain storage system. This guarantees that the real data does not put unnecessary stress and demands on the blockchain with extensive storage needs. When the record is recorded off-chain, cryptographic hash of the document is computed with the help of the hashing algorithm e.g. SHA-256. This hash is a special form of the digital fingerprint of the record in such a way that any minor modification of the document will yield a totally different value of the hash [17]. The resulting hash will be added to the blockchain creating a reference that is forever and irreversible. Upon an employer or another institution, having initiated a verification request, all the smart contract does is trigger verification of the authenticity of the record. The system accesses the stored document in off-chain database and re-generates its hash. This newly-created hash is compared to the stored one on the blockchain. When the two hashes are the same, record is recognized, falsifying which will result in the record being tagged as tampered or invalid. This mechanism would guarantee quick and efficient verification without the need to have direct institution-to-institution communication.

### C. Privacy Mechanism

The privacy policy of the suggested framework will focus on reducing exposure to sensitive data and ensuring integrity and verifiability of records. The system does not store actual academic information on the blockchain, but rather, only encrypted cryptographic references in the form of hashes. This would make sure that none of the personal identifiable information is available in the blockchain network publicly. All confidential information is safely stored in the off-chain storage tier where it is secured by using an authentication and authorization process. Smart contracts are crucial in applying these access controls by defining who is allowed to access and/or verify certain records [8]. Moreover, off-chain data can be encrypted in order to make it even more confidential. This has been defined as a hybrid solution, which complies with data security standards (like GDPR) because it enables data to be changed or erased out of off-chain storage when necessary, a verifiable presence is logged on the blockchain. Subsequently, the system successfully balances transparency and privacy, which is why it would work well in the real-life academic scenario.

## VI. METHODOLOGY

### A. Research Type

The research period is conceptual and analytical research as it does not involve empirical experimentation but design and assessment of a proposed system. The study is based on comprehensive research of the current literature on the blockchain technology, record management related to academic activities, and systems designed to preserve privacy. Integrating the findings of previous research, the study will provide a systematic platform that will remove the inexistence of limitations.

### B. Data Collection

The information that is employed in this research is obtained using secondary sources like peer-reviewed journals, conferences and online databases that are considered to be credible. The existing studies concerning the implementation of blockchain, off-chain storage solutions, and data privacy regulation are examined in order to determine the major challenges and possible solutions [11]. This method will make sure that the framework proposed is founded on tested knowledge and up to date trends in technology.

### C. Evaluation Criteria

The framework is suggested and tested on several criteria to determine the level of its effectiveness and feasibility. Security is examined as a capability of the system to avoid unauthorized access and manipulations of the data. Privacy compliance assesses how the system follows the data protection rules and its capacity to protect confidential data. Scalability is measured through the ability of the system when dealing with large amounts of data and users to scale up to meet the needs. Cost efficiency is measured through the cost of storage (cost to store), transaction cost, and total maintenance cost of the system.

## VII. RESULTS AND DISCUSSION

### A. Security Analysis

The given model can be characterized by a high-security level based on the use of cryptographic hash and decentralized storage.

Hashing algorithm can be used to send any record, such that any alteration in therecordiseasilynoticed sincethehash value is modified. The blockchain is also decentralized, which helps to increase securityeven more asit doesnot have single pointsoffailureanditischallengingtoattack the system [5]. Also, blockchain records are immutable such that once information is added, it cannot be changed without consensus, thus offering a tamper-proof environment.

#### *B. Privacy Analysis*

The proposed framework greatly enhances privacy by implementing off-chain storage. Having sensitive information out of the blockchain makes it possible to avoid exposure of personal details by an unqualifiedmeans.Encryptedreferencingon theblockchainmeansthat exceptinanevent that the ledger is hacked, no valuable information can be gleaned. Moreover, the system helps to adhere to the regulations of data protection, as well as to control access and even possible modification of off-chain information. This contributes to the fact that theframeworkisapplicabletothecaseofthe environment where privacy is a vital issue.

#### *C. Scalability Analysis*

The scalability of the system can be significantlyincreasedwiththeintegrationof off-chain storage. As hash values only in small sizes are stored on the blockchain, the numberofdataloadedisconsiderably minimized.Thisresultsinincreasedspeedof transactions and performance of the system. Theoff-chainstorage layercanalsobescaled veryeasilyto handlea significant amount of data, and the framework can be adapted to accommodate institutions having a huge amount of academic data.

#### *D. CostAnalysis*

The proposed system has a hybrid architecturethatenhancesthecostefficiency ofthesystembyreducingthequantityofdata to be stored at the blockchain. This lowers transactioncostsanddatastoragecostswhich are incurred in blockchain activities. Cloud-based storage systems and other off-chain data confirmation solutions provide seaweeds with a flexible and affordable alternative to operate and handle big data. Consequently, the total cost of system operation by this approach is less than with fully on-chain solutions.

### **VIII. ADVANTAGES OF PROPOSED SYSTEM**

The suggested system has a number of key benefits in comparison to traditional and solely blockchain-based solutions. It improves the privacy of data, as it is not revealed onthe blockchain as sensitive. Off-chain storage can help to decrease storage expenses and enhance scalability, enabling thesystemtoprocesslargeamountsofdata [13].Smartcontractshavemadeitpossibleto verify academic records ina faster and more dependable manner due to the automated verification process. Also, it can be easily used in real-life applications since it aids in adhering to data protection rules. On the whole, the framework offers a moderate solution that is based on the security, efficiency, and privacy.

### **IX. LIMITATIONS**

Although the proposed system has some benefits, it also has some limitations which should be listed. The effectiveness of the securityoftheframeworkalsopartiallyrelies on the reliability of the off-chain storage system which could pose vulnerabilities in case ofpoor management. Using blockchain with available institutional systems could be involving and might demand a lot of technical skills. Moreover, lack of a unified design of protocols to support an academic blockchain system can reduce interoperability between organizations.

### **X. FUTURE SCOPE**

The advanced technologies and methodologies can be incorporated in the proposed framework as well. The use of intelligentverificationandanomalydetection can be achieved through incorporating artificial intelligence, which will ensure a better system performance. Zero-knowledge proofs can ensure much higher privacy guarantees, as they require data verification, but not informationdisclosureinactualform [16]. Also, the academic records blockchain networks across the world can be tested to enable a flawless interoperability of academic institutions, and a single and standardized system.

### **XI. CONCLUSION**

The current study outlines a privacy-aware blockchain architecture within academic recordmanagement that effectivelyusesoff-chain storage as a means of potentially managing the main issues of privacy, scalability, and costs.

The suggested model balances between transparency and confidentiality by storing sensitive data out of the blockchain and guaranteeing cryptographic integrity via on-chain reference. The framework exhibits significant possibilities of real-world application and provides a safe, effective and scaled solution to handling academic records. With digital transformation ever transforming the education sector, these hybrid architectures are bound to be an important aspect in making sure that there is trust and reliability when it comes to academic credential systems.

## REFERENCES

- [1] Alao, O., Adekeye, O.E., Adeagbo, B.T. and Oyerinde, A.T., 2025. Privacy Preserving Blockchain Architecture for Securing Cloud Based Information Systems. *Scientific Journal of Engineering and Technology*, 2(2), pp.165-171.
- [2] Ayare, A.A., Jadhav, V.A., Banatwala, M.K., Changlere, S.V., Mote, A., Joshi, P., Mr. A.A.A., Ms, V.A.J. and Banatwala, M., 2025. A systematic review on blockchain-based framework for storing educational records using interplanetary file system. *Cureus J Comput Sci*, 2.
- [3] Cruz, M.M.P., Balogo, K.M., Cofino, C.L. and Dandan, D.G., 2024, March. A proposed distributed off-chain medical health record management using blockchain technology and IPFS for HEIs. In *2024 5th International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)* (pp. 627-635). IEEE.
- [4] Eren, H., Karaduman, Ö. and Gençoğlu, M.T., 2025. Security challenges and performance trade-offs in on-chain and off-chain blockchain storage: A comprehensive review. *Applied Sciences*, 15(6), p.3225.
- [5] Fernández-Iglesias, M.J., Delgado von Eitzen, C. and Anido-Rifón, L., 2024. Efficient traceability systems with smart contracts: Balancing on-chain and off-chain data storage for enhanced scalability and privacy. *Applied Sciences*, 14(23), p.11078.
- [6] Goint, M., Bertelle, C. and Duvall, C., 2023. Secure access control to data in off-chain storage in blockchain-based consent systems. *Mathematics*, 11(7), p.1592.
- [7] Hlaing, H.H. and Asaeda, H., 2023, November. PrivOff: Secure and Privacy-Preserving Data Management for Distributed Off-Chain Networks. In *2023 IEEE 22nd International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom)* (pp. 326-333). IEEE.
- [8] Jayabalan, J. and Jeyanthi, N., 2022. Scalable blockchain model using off-chain IPFS storage for healthcare data security and privacy. *Journal of Parallel and distributed computing*, 164, pp.152-167.
- [9] Kaneriya, J. and Patel, H., 2023. A secure and privacy-preserving student credential verification system using blockchain technology. *International Journal of Information and Education Technology*, 13(8), pp.1251-1260.
- [10] Kaur, J., Rani, R. and Kalra, N., 2022. A blockchain-based framework for privacy preservation of electronic health records (EHRs). *Transactions on Emerging Telecommunications Technologies*, 33(9), p.e4507.
- [11] Kumar, A., Kumar, R. and Sodhi, S.S., 2022. A novel privacy preserving blockchain based secure storage framework for electronic
- [12] Mandinyanya, G. and Malele, V., 2025. A Hybrid Framework for Enhancing Privacy in Blockchain-Based Personal Data Sharing using Off-Chain Storage and Zero-Knowledge Proofs. *Journal of Information Systems and Informatics*, 7(2), pp.1977-2005.
- [13] Mohanta, B.K., Awad, A.I., Dehury, M.K., Mohapatra, H. and Khan, M.K., 2025. Protecting IoT-enabled healthcare data at the edge: Integrating blockchain, AES, and off-health records. *Journal of Information and Optimization Sciences*, 43(3), pp.549-570.
- [14] Li, K., Lohachab, A., Dumontier, M. and Urovi, V., 2025. Privacy preservation in blockchain-based healthcare data sharing: A systematic review. *Peer-to-Peer Networking and Applications*, 18(6), pp.1-53.
- [15] Liu, C., Hou, C., Jiang, T., Ning, J., Qiao, H. and Wu, Y., 2024. FACOS: Enabling privacy protection through fine-grained access control with on-chain and off-chain system. *IEEE Transactions on Information Forensics and Security*, 19, pp.7060-7074.
- [16] Momin, R.J.I., Rumi, A.M.S. and Reaz, R., 2026. ParikkhaChain: Blockchain-Based Result Processing and Privacy-Preserving Academic Record Management for the Complete Examination Lifecycle. *arXiv preprint arXiv:2604.16827*.
- [17] Wang, B., Jiang, R., Pu, X. and Zhang, H., 2025. An on-chain and off-chain collaborative data sharing and access control model for electronic medical records: B. Wang et al. *The Journal of Supercomputing*, 81(2), p.396.
- [18] Zhao, K., Zhang, W., Su, L., Wang, X. and Li, C., 2025. Research on blockchain-enabled consistency enhancement techniques for on-chain and off-chain interactions of privacy data. *J.COMBIN.MATH.COMBIN. COMPUT*, 127, pp.8979-8996.



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