



Decentralized Ecosystem for Secure Question Paper Distribution

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Abstract

This paper introduces a decentralized system driven by blockchain technology that guarantees safe, transparent, and impenetrable question paper creation and dissemination. Conventional exam systems face issues such as lack of accountability, centralized control, and paper leaks. Through a crowdsourced model, the proposed system allows verified educators to submit questions that are validated by subject-matter experts and recorded immutably on the blockchain. Based on syllabus topics and difficulty levels, Natural Language Processing (NLP) algorithms automatically generate diverse and balanced question papers. InterPlanetary File System (IPFS) is used to store and distribute encrypted documents, ensuring end-to-end security. Experimental findings show that the proposed system enhances exam security, reduces manual workload, and restores trust in the evaluation process.

Keywords: Blockchain, IPFS, Crowdsourcing, NLP, Smart Contracts, Encryption, Question Paper Creation.

1. Introduction

Traditional exam systems rely on centralized paper creation and distribution, leading to inefficiencies, human bias, and the risk of paper leaks. Incidents such as NEET and UPSC leaks expose these vulnerabilities. Manual verification and restricted content review limit transparency and scalability. The proposed system offers a decentralized, AI-assisted approach that leverages blockchain for immutability and traceability and NLP for smart question generation. Verified educators contribute to a shared question bank, while smart contracts on Ethereum validate users and record every action securely. Generated papers are encrypted using XChaCha20-Poly1305 and stored on IPFS. The system aims to redefine academic integrity through automation, transparency, and decentralization. By integrating blockchain, artificial intelligence, and decentralized storage, the system ensures end-to-end security and accountability at every stage of the examination process. Each question submission, validation, and paper generation event is recorded immutably, preventing unauthorized access or manipulation. This not only enhances trust among educators and administrators but also minimizes manual intervention, reduces operational delays, and

establishes a transparent framework for fair and efficient exam management [1-4].

1.1 Methodology Overview

- **Contributor Registration:** Verified educators register on the platform and receive authentication through blockchain-based smart contracts. Question Submission Contributors upload questions along with details such as subject name, topic, and difficulty level. Each submission automatically generates a Unique Question ID, IPFS Hash, and Blockchain Transaction Hash confirming successful registration on the blockchain.
- **Expert Validation:** Subject-matter experts review the submitted questions for accuracy, relevance, and alignment with the syllabus. The approval status (Pending / Approved) is transparently recorded on the blockchain.
- **AI-Assisted Paper Generation:** Validated questions are processed by the AI module, which uses Natural Language Processing (NLP) algorithms to automatically generate balanced and diverse question papers based on syllabus coverage and difficulty distribution.
- **Encryption and Storage:** Generated question papers are encrypted using the XChaCha20-

Poly1305 algorithm to maintain confidentiality and are stored securely on the InterPlanetary File System (IPFS) for decentralized, tamper-proof storage [5-10].

- **Admin Access and Distribution:** Authorized administrators retrieve and decrypt the encrypted question papers from IPFS through verified blockchain transactions. This ensures secure, traceable, and transparent paper distribution for examination scheduling.

2. Experimental Setup and Testing

The core experimental environment was built to ensure the immutability, decentralization, and secure communication required by the system's objectives.

2.1 System Architecture Overview

The system employs a decentralized application architecture, separating the immutable ledger, the

large file storage, and the secure client interface. This structure is essential for achieving the security and transparency objectives of the project. The Ethereum environment was simulated locally using Ganache (Test RPC Client). All Smart Contracts were written in Solidity (v0.8.x) and deployed to this local network, Shown in Figure 1 & Table 1.

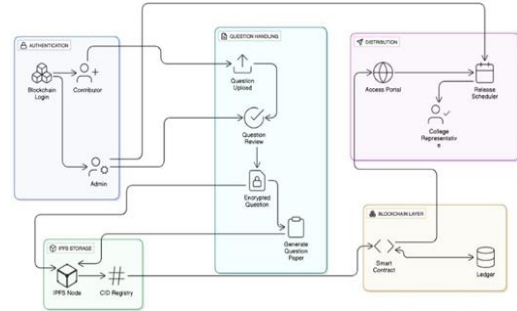


Figure 1 System Design

Table 1 Unit Testing

Test	Test Data	Result
1. Submit Empty Question Form (Critical Validation)	Empty form submitted without data	Validation error message shown — "Please fill all required fields"
2. IPFS Hash Format Check	Attempt to register a question with an invalid-length IPFS hash (e.g., a short string).	Smart Contract function reverts (fails) with a specific error message (e.g., "Invalid IPFS Hash length").
3. Unauthorized Write Attempt (Security)	A non-admin wallet attempts to call a restricted Smart Contract function (e.g., approveQuestion()).	The smart contract transaction reverts (fails) with a specific error (e.g., "Caller is not authorized/Admin").
4. Encryption Reversibility (Security)	Encrypt a known string (e.g., "Test Question Body") using the XChaCha20-Poly1305 function.	Decrypting the ciphertext using the same key/IV yields the original string ("Test Question Body").
5. Difficulty Boundary Check (Integrity)	Submit a question with difficulty set to 6 (assuming 1-5 scale).	Smart Contract transaction reverts (fails) with error: "Difficulty score out of range."

The Truffle Suite was used for compilation and deployment management. The blockchain serves as the source of truth for all metadata, audit logs, and access permissions. IPFS was run locally to simulate the off-chain storage layer for the large question and

encrypted paper files. Only the immutable content hash is stored on the blockchain. The user interface was developed using Next.js/TypeScript (Frontend) and connected to the blockchain via the ethers.js library and MetaMask. The backend API, responsible



for XChaCha20-Poly1305 encryption/decryption and NLP question generation/vetting logic, was developed using Python, shown in Table 2.

Table 2 Integration Testing

Test	Test Data	Expected Result
1. Frontend ↔ Blockchain Integration	Submit valid question from UI	Data sent from frontend to smart contract; transaction confirmed
2. Blockchain ↔ IPFS Integration	Store encrypted question paper	IPFS hash successfully stored and linked in blockchain
3. IPFS ↔ Decryption Module	Retrieve encrypted hash from IPFS	File fetched and decrypted correctly using XChaCha20 key
4. Web3 ↔ MetaMask Wallet Connection	Connect wallet from UI	Wallet connects successfully; user address displayed

Validation was performed using a mixed methodology. Unit Tests verified individual function logic (e.g., Smart Contract reverts, encryption reversibility), while Integration Tests ensured successful communication between the frontend, blockchain, and IPFS layers. System Tests verified role-based access control and the end-to-end security workflow. The core input parameters used across the testing phases, specifically for the Smart Contract (SC) functions, are summarized below. These parameters define the nature and security requirements of the data being handled.

3. Results and Discussion

3.1 Results

The project's decentralized architecture was implemented and successfully validated across key functional and security components. The rationale centered on mitigating the lack of transparency,

security vulnerabilities (like paper leaks), and manual inefficiencies inherent in traditional centralized examination systems. The experimental design focused on testing the core functional units, their integration, and the security of the blockchain-based operations. The implementation successfully utilized a local Ethereum-compatible network (Ganache) to deploy the QuestionRegistry smart contract. Test cases confirmed that question submission and reviewer approval transactions were successfully executed, mined, and immutably recorded on the blockchain. The system correctly linked the unique Question ID on the blockchain to the content's metadata hash (stored on IPFS), ensuring tamper-proof traceability of content provenance. The system integrates IPFS (InterPlanetary File System) for decentralized storage of question content and encrypted final papers. The algorithms successfully implemented hybrid encryption (XChaCha20-Poly1305) before distribution, ensuring that only authenticated personnel with the correct private keys can decrypt and access the papers just before the exam. The project incorporates NLP algorithms to automatically generate balanced question papers based on configured parameters like subject, difficulty distribution, and syllabus coverage, as shown in the system design. The initial AI/ML checks are also designed to filter for duplicates and perform quality assessment before expert review. The system successfully implemented role-based access control (RBAC) across the Contributor, Admin, and College Representative interfaces. The Admin Dashboard provides system health metrics (Blockchain, IPFS, AI Services status) and quick actions for review and generation, minimizing manual intervention. Integrated testing identified critical flaws. Specifically, one test failed because the system accepted empty question forms, leading to wasted blockchain transaction attempts (gas costs). Another failure revealed a critical synchronization issue where a Reviewer's approval updated the frontend status but failed to execute the immutable transaction on the blockchain. These failures necessitated immediate rectification to improve front-end/back-end validation and asynchronous transaction error handling, confirming the testing

approach's value.

3.2 Discussion

The results strongly validate that the proposed decentralized framework effectively addresses the primary challenges of traditional examination systems: security, transparency, and centralization. The immutability provided by the Blockchain Layer is the core functional advantage. Every critical step—question submission, expert approval, and paper finalization—is permanently logged via smart contracts. This contrasts sharply with legacy systems where a lack of version control and auditability makes tracing accountability difficult in case of leaks or disputes. The combination of Crowdsourcing and AI/NLP (as designed in the Results section) significantly enhances content diversity and reduces subjective human bias that occurs in centralized manual creation. By automating question selection based on curriculum metrics, the system ensures a balanced exam paper, fulfilling the goal of improving fairness in academic assessments. Furthermore, utilizing IPFS for storage and XChaCha20-Poly1305 for encryption before distribution provides a robust defense against paper leaks and unauthorized access, which is a major systemic weakness in traditional physical and email-based distribution, Shown in Figure 2 [11-15].

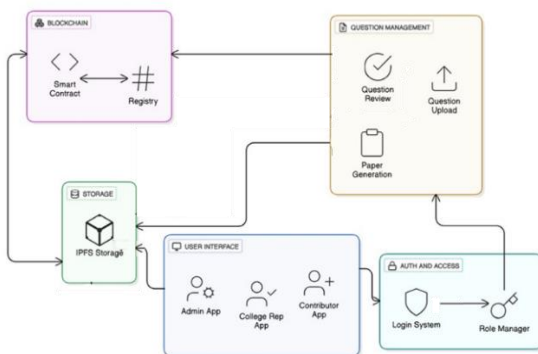


Figure 2 Project Overview

The system moves away from vulnerable centralized servers to a tamper-proof decentralized delivery model. The initial test failures, while setbacks, are essential to the discussion as they highlight the complexity of synchronizing off-chain application logic (like UI state updates and form validation) with

on-chain, asynchronous, gas-dependent transactions. This underscores that robust error handling and redundancy mechanisms are crucial for the practical deployment of decentralized applications (dApps) in mission-critical environments like examination systems. The project successfully demonstrates the foundational technology to redefine secure content management.

Conclusion

The project successfully designed, implemented, and validated a Decentralized Crowdsourcing Platform for Question Paper Generation that directly addresses the problem of insecurity, centralization, and lack of transparency in traditional examination systems. By integrating a Solidity Smart Contract on a blockchain, the system confirms the problem analysis by ensuring all question submission and approval actions are immutable, auditable, and traceable. The use of IPFS and strong hybrid encryption secures the final exam paper, effectively eliminating the risk of unauthorized pre-release and paper leaks which compromise the fairness and credibility of assessments. Overall, the project demonstrates a transformation of the question paper curation process, guaranteeing content integrity and restoring trust in the academic evaluation lifecycle through the power of decentralized technologies and AI-driven automation.

Acknowledgements

The knowledge and satisfaction that accompany the successful completion of any task would be incomplete without acknowledging the people who made it possible. Their guidance and encouragement have crowned our efforts with success. We would like to profoundly thank the Management of Bangalore Institute of Technology for providing such a healthy environment for the successful completion of our project work. We would like to express our thanks to the Principal, Dr. J. Prakash, for his encouragement that motivated us for the successful completion of our project work. It gives us immense pleasure to extend our heartfelt gratitude to Dr. Kempanna M., Associate Professor & Head, Department of Artificial Intelligence & Machine Learning, for his encouragement that motivated us towards the successful completion of this project. We extend our



heartfelt gratitude to Prof. Nagabushan P, Assistant Professor, Department of AI&ML, BIT, for his invaluable guidance, continuous support, and insightful feedback throughout the development of this Project. We would not forget to remember Dr. Jyothi D.G., Professor and Dr. Shruthiba A, Assistant Professor, Project Coordinators, Department of AI&ML, BIT, for their encouragement and more over for their timely support and guidance till the completion of the Project work. We are also very much pleased to express our sincere gratitude to all the staff members of the AI&ML Department, BIT. Lastly, we would like to take this opportunity to thank our friends and family for their support throughout the completion of the project.

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