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Utilizing Blockchain Technology to Ensure the Authenticity of Diplomas

Hasan Wijaya, Adam Sekti Aji
Universitas Teknologi Yogyakarta

ABSTRACT

A diploma management system presently utilized in Indonesia remains a manual, paper-based approach. This system exhibits multiple deficiencies, including diploma forgery, lost diplomas, damaged diplomas, hand-written diplomas, data transparency difficulties, and challenges in diploma verification. A software application named e-Jazah was created to administer digital diplomas utilizing blockchain technology to resolve these challenges. The construction of this new system seeks to mitigate the issues that emerged in the prior manual system. Blockchain technology is employed to ensure data integrity. The solution is designed to utilize a fundamental characteristic of blockchain technology—its tamper-resistant quality—which protects data integrity from alteration or corruption attempts. The system is decentralized, comprising numerous peers that operate the blockchain network. The blockchain network is constructed using Hyperledger Fabric technology. Hyperledger Fabric was selected due to its status as a permissioned blockchain and its user-friendly smart contract development features. The system consists of a frontend component serving as the user interface, a backend component linking the frontend to the blockchain network, and the blockchain network itself, with the update aimed at enhancing the UI/UX to improve user experience. The established system streamlines the fundamental procedure of diploma issuance via its functional specifications. The technology may authenticate diplomas using two methods: the diploma number and a PDF document.

Keywords: *Blockchain, Decentralization, Hyperledger Fabric, Diploma Authenticity*

Corresponding author
Name: Hasan Wijaya
Email: hasan.5210411075@student.uty.ac.id

INTRODUCTION

A diploma is an official certificate verifying that an individual has fulfilled their formal education requirements (Rahardja et al., 2020). Academic transcripts and diplomas function as proof of an individual's educational accomplishments and skills (Kiiskilä et al., 2023). The possession of a diploma is essential, since it constitutes a fundamental requirement for obtaining satisfactory employment. An individual's educational attainment can enhance prospects to obtain superior job positions commensurate with their skills and abilities. The reputation of the educational institution that issues the diploma is frequently a critical factor in the recruiting process, since it is perceived to indicate the quality and credibility of its graduates (Caramihai & Severin, 2023). The substantial demand for

diplomas in society indicates that these papers possess considerable importance in both educational and employment sectors.

Currently, diplomas in Indonesia are predominantly issued in physical or paper format. This circumstance renders the verification of diploma legitimacy susceptible to falsification (Saramago et al., 2021). Moreover, the traditional diploma verification process is conducted manually by the granting institution, necessitating considerable time and expense (Rustemi et al., 2024). Moreover, traditional diplomas, existing as physical documents, exhibit a considerable susceptibility to damage and loss. In the event of a lost diploma, the holder must navigate a protracted set of administrative processes to secure a replacement from the appropriate educational institution. This procedure entails submitting a loss report to the local police as administrative proof, which is thereafter forwarded to the diploma-issuing institution as a requisite for the reissuance of the academic document.

As a result, in order to reduce the risk of academic credentials being damaged, lost, or forged, technology is necessary to guarantee the security, validity, and authenticity of diplomas. The selection of blockchain technology was based on its exceptional security and comprehensiveness. Decentralized data storage is facilitated by blockchain technology, which ensures that all authorized entities can transparently monitor and validate modifications to the data (Lemieux, 2017).

The utilization of blockchain technology in the verification of academic documents has been the subject of numerous studies, with the objective of reducing the risk of diploma forgery and enhancing security (Rahardja, 2020; Samarago, 2021). Nevertheless, there has been a dearth of research on the development of software that includes a user-friendly, intuitive, and interactive interface for both the general public and educational institutions. The objective of this investigation is to create blockchain-based e-Diploma software that not only serves as a storage medium for digital diploma data but also offers features that facilitate the rapid, secure, and transparent verification of diploma authenticity by optimizing UI/UX aspects. It is anticipated that this investigation will enhance the efficacy of academic document validation while simultaneously reducing the prevalence of diploma forgery.

METHOD

Blockchain is a type of Distributed Ledger Technology (DLT) that consecutively records transactions in blocks. In a blockchain system, data cannot be erased or modified; it can only be appended by a consensus procedure across the network. Data on the blockchain can solely be appended via a consensus mechanism. This approach guarantees that data on the blockchain maintains a high degree of security and integrity, rendering it exceedingly challenging to alter or counterfeit (Yang, 2019).

In 2009, the Bitcoin blockchain was the first implementation of blockchain technology that employed ledger technology. Nevertheless, its applications were still restricted at that time. Smart contracts have the potential to broaden its implementations, particularly in the areas of government, healthcare, science, and IoT (Zhao & Yan, 2016). A

smart contract is a computer program that is coded and embedded within a blockchain network to execute, enforce, or facilitate an agreement or contract. The primary function of a smart contract is to automatically execute predetermined contract terms once specific conditions are met.

The system's security is ensured by rendering data tampering very impossible through the spread of data over numerous interconnected nodes. This data dispersion renders the system exceptionally resilient to cyberattacks and technical faults. This is due to the absence of a singular point of failure that could result in the complete loss of data. Each transaction is documented in a block that is cryptographically connected to preceding blocks. Every block constitutes a chain that cannot be modified without the agreement of the majority of nodes within the network (Mohsin et al., 2019).

This study proposes a blockchain-based application, e-Jazah, which utilizes the Hyperledger Fabric framework as its core platform for the management and verification of digital diplomas. The Hyperledger Fabric design facilitates the utilization of container technologies and smart contracts that encapsulate application rules and logic. Hyperledger Fabric is regarded as proficient in establishing a blockchain system characterized by elevated security, transparency, and accountability (Ghani et al, 2022). This is substantiated by the characteristic of Hyperledger Fabric, which is a permissioned network, supports confidential transactions, and programmability, enabling customization to meet the requirements of the established system.

In this study, the author collected data through a literature review. The author read and analyzed written documents related to the research topic. These documents may include books, journals, articles, papers, theses, dissertations, and other sources. When conducting a literature review, the author must pay attention to matters such as selecting relevant sources, reading the sources carefully, and analyzing the information.

Meanwhile, Figure 1 illustrates the phases of system development that will be implemented in this investigation. The first step in building the e-Jazah system is to perform a comprehensive examination of issues pertaining to diploma management and verification. During the problem analysis phase, the researcher identified several challenges commonly encountered by the public and educational institutions, including the prevalence of diploma forgery, the manual verification process for diplomas, the risk of damage to and loss of physical documents, and the protracted duration of academic document validation. These challenges engender confusion concerning the legitimacy of educational papers and may adversely affect several stakeholders, including educational institutions, corporations, and the general populace.

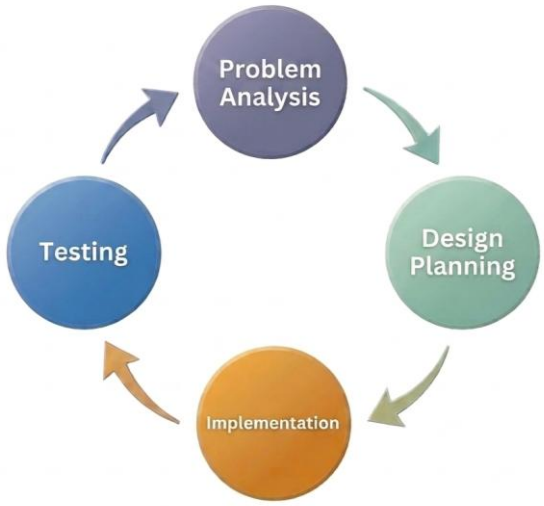

Figure 1: Research Phase

The following phase of the development process is design planning, which entails the specification of the database design. A crucial element of this design is the creation of the smart contract, which will provide the foundation of the system's functionality. This smart contract is meticulously crafted to guarantee that all facets of decentralised transactions are documented and executed effectively on the blockchain network. The subsequent stage in the development process is the implementation phase, whereby the system is programmed. The author will employ Hyperledger Fabric as the blockchain framework, Express.js for the RESTful API, React.js for the user interface, and JavaScript for the smart contract programming language. The implemented system will thereafter be tested using the black-box testing method. The main aim of this testing is to assess if the system's operations, inputs, and outputs conform to the established standards. This testing will aid in identifying and rectifying potential flaws or problems with the specifications, hence ensuring the system's reliability and consistency.

FINDING AND DISCUSSION

RESEARCH RESULT

This research resulted in the development of digital diploma software (e-Jazah) that implements blockchain technology to address the issues of diploma forgery and damage. Before detailing the frontend functionality, this section first explains the architecture of the system that was built. This architecture is designed to integrate application components with the blockchain network and facilitate interactions among various user actors. The component structure and inter-layer relationships within the system are shown in Figure 2.

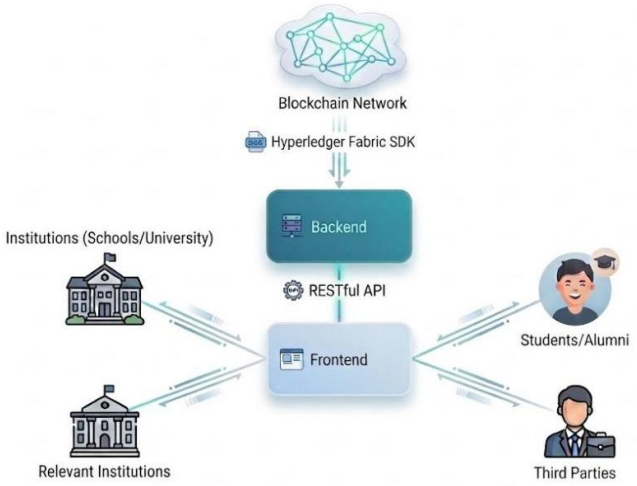

Figure 2: Architecture of the Blockchain-Based e-Jazah System

Structurally, the e-Jazah system architecture is divided into three main, mutually integrated layers. The top layer is the core blockchain network built using Hyperledger Fabric. This layer functions as a distributed ledger that stores transaction data and diploma histories securely, transparently, and in a tamper-proof manner. Interactions and function execution on this blockchain network are controlled by smart contracts via the Hyperledger Fabric SDK. Below this lies the backend layer, which acts as the business logic provider and intermediary between external applications and the blockchain network. This backend component processes requests from the interface layer, translates them via the Hyperledger Fabric SDK, and sends them to the blockchain nodes. The two-way communication between the backend and frontend components is facilitated by RESTful API-based services. Meanwhile, the lowest layer consists of the frontend component, which serves as the web interface for the e-Jazah application and interacts directly with users. This frontend layer sends data requests or diploma verification requests to the backend via the RESTful API and then visually displays the results to the user.

The frontend layer of this system is designed to be inclusive, meeting the needs of four key actors or stakeholders in the digital diploma ecosystem. The first actor is educational institutions, such as schools or universities, which have full authority to enter graduation data and issue digital diplomas within the system. Next, there are relevant institutions that act as supervisory authorities for educational institutions. The third stakeholder is students or alumni, as the rightful owners of the documents, who use the system to view their personal academic records, download their diplomas, and manage public links for legalization purposes. Finally, this system also facilitates third parties, such as companies or recruitment agencies, which require instant verification features to check the validity of diploma numbers and PDF files.

Based on the implementation of the designed system architecture, the development of the e-Jazah application resulted in several interface components and functional features that support the issuance and verification of blockchain-based digital

diplomas. Figure 3 shows the diploma verification interface, which offers two methods: entering the diploma number and uploading a PDF document. Users can manually enter the diploma number or upload a PDF file so the system can automatically verify the document's authenticity.

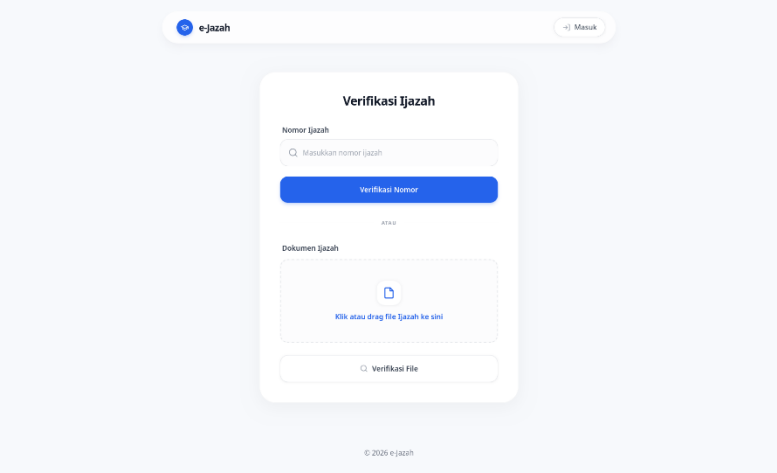

Figure 3: Diploma Verification Interface

Figure 4 shows the validation confirmation message displayed by the system when the diploma data has been successfully verified and deemed valid. Conversely, Figure 5 shows the validation failure page that appears when the diploma number cannot be found or the PDF document has been altered. In such cases, the system will display a "Verification Failed" message along with a warning indicator indicating data tampering.'

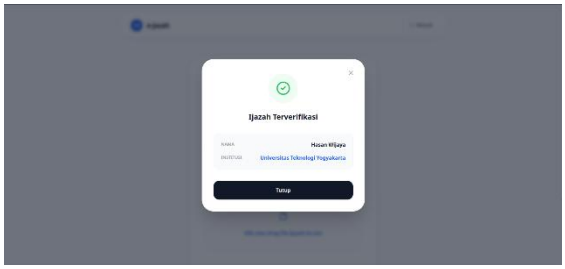

Figure 4: Validation Confirmation Message

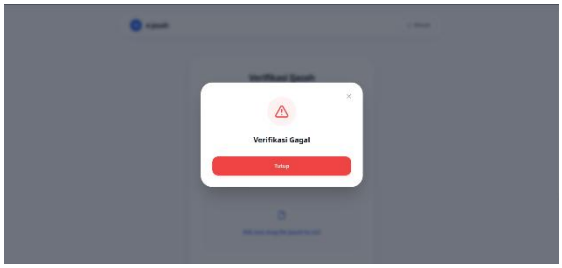

Figure 5: Validation Confirmation Failed

Next, Figure 6 shows the diploma list page, which serves as a dashboard for displaying the history of digital diplomas recorded in the system. This page contains academic information, such as the diploma number, the holder's name, the educational institution, the region of origin, the graduation date, and the academic degree. Additionally, there is a toggle feature that allows users to control public access to the diploma sharing link.

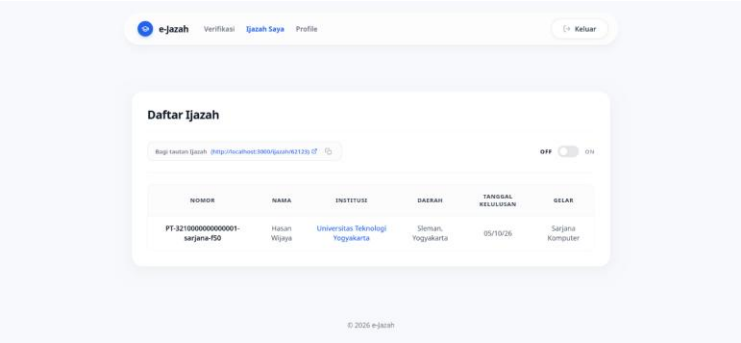

Figure 6: Diploma List Page

Figure 7 shows a preview page of a digital diploma that displays a complete visual representation of the academic document. The information included covers the National Identification Number, Student ID Number, program of study, graduation date, graduation status, and the official signature of the relevant educational institution.

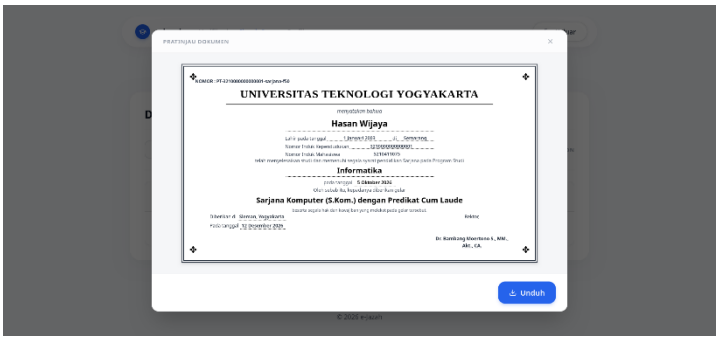

Figure 7: Diploma Preview

Figure 8 illustrates the institutional account creation page, utilized for registering educational institutions in the system by uploading a CSV file that adheres to the specified template. Figure 9 illustrates a comparable procedure, showcasing the student account creation page utilized for registering the data of diploma recipients.

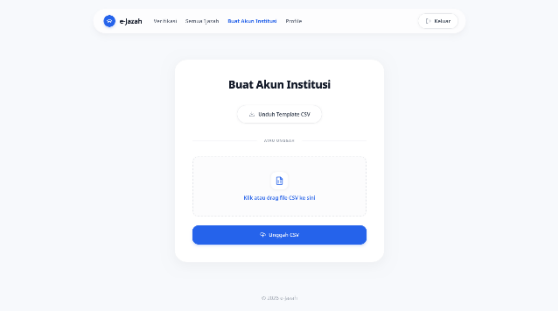

Figure 8: Institution Account Creation Page

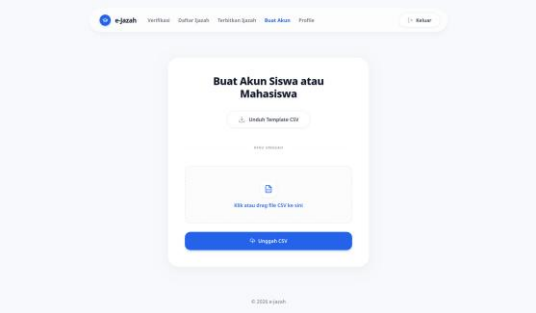

Figure 9: Student Account Creation Page

Finally, Figure 10 shows the diploma issuance page used by educational institutions to record digital diploma data onto the blockchain network via a CSV file upload process. This page includes a “Download CSV Template” feature to ensure that the structure of the uploaded data conforms to the format required by the system.

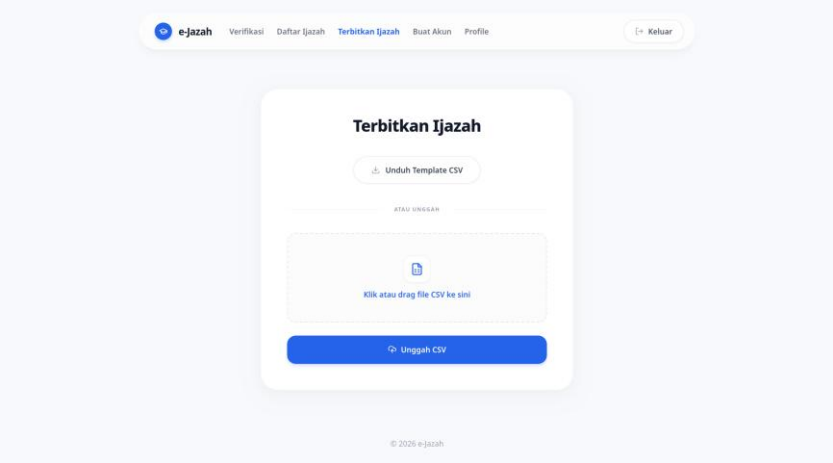

Figure 10: Diploma Issuance Page

To ensure that all functionalities of the blockchain-based e-Jazah system operate in accordance with user requirements and the designed architectural framework, an evaluation phase was conducted using the Black-Box Testing method. This testing focuses on evaluating the application’s external functionalities without needing to examine the internal program code structure privately. This testing involves all stakeholders within the system’s ecosystem, namely Students, Institutions (Schools/Universities), Relevant Institution (Regulators/LLDIKTI), and Third Parties (the Public/Recruitment Firms).

The test scenarios were comprehensively designed to evaluate authentication mechanisms, role-based access control (RBAC), digital document management, and backend interactions with smart contracts (chaincode) on the Hyperledger Fabric

distributed ledger network. A detailed matrix of the test scenario execution and the actual results is summarized in Table 1 below.

Tabel 1: System Testing

No	Test Scenario	Expected Results	Status
1	Users log in to the system using a combination of a username and password.	The system successfully validated the credentials, generated a session token, and redirected the user to the dashboard page based on their respective access rights (role).	Passed
2	Authenticated users in the system can change their passwords.	The system successfully updated the encrypted password data in the database and displayed a success notification.	Passed
3	The Student user accesses the diploma list menu to view all of their digital diplomas.	The system retrieves the relevant student's academic records and displays them in a neat list of diplomas.	Passed
4	Students can toggle the switch to enable or disable the link for sharing their diploma.	The system updates the access visibility status in real time within the database and changes the public validity of the diploma.	Passed
5	Students click the download button to download their digital diploma.	The system successfully generated the PDF diploma file and automatically downloaded it to the student's local device.	Passed
6	Third parties can access the diploma URL/link shared by students when the link status is active (ON).	The system successfully displays detailed information about students' diplomas in a transparent manner without requiring login credentials.	Passed
7	A third party verifies the diploma number or uploads a PDF copy of the diploma on the public verification page.	The backend service recalculates the hash of the PDF file, matches it with the blockchain ledger via a smart contract, and then displays a confirmation of the diploma’s authenticity.	Passed
8	The institution fills out the graduation form and clicks the button to issue a new digital diploma for the student.	The smart contract (chaincode) is executed, and the system generates a new block on the blockchain network to record the certificate hash.	Passed
9	Institutions can access the document history menu to	The system displays a list of all diplomas issued by that institution.	Passed

No	Test Scenario	Expected Results	Status
	review all previously issued diplomas.		
10	The institution registers new students' data using the student account creation form.	The system successfully created a new account with the role “Student.”	Passed
11	The relevant institutions (regulator) enters data on new schools or colleges into the system.	A new institutional account has been successfully created with the “Institution” role, granting the institution the legal authority to manage and issue diplomas on the platform.	Passed
12	Relevant institutions access the monitoring dashboard to view and monitor all diplomas issued by the institutions under their jurisdiction.	The system displays a detailed table of all diploma issuance transactions across institutions.	Passed

DISCUSSION

The application of blockchain technology in diploma verification is considered effective in reducing the risk of diploma forgery and improving the efficiency of the academic document validation process. According to the research findings, blockchain offers a decentralized framework that enables the secure, transparent, and tamper-resistant storage of diploma data. This discovery corresponds with the study by Rahardja et al. (2020), which asserts that the implementation of Blockchain in education can reduce diploma forgery and improve the validation of academic documents. In traditional systems, the diploma verification procedure is performed manually by the granting institution, necessitating considerable time and substantial administrative expenses.

The implementation of blockchain is propelled by the increasing demand for secure and reliable management of digital academic materials. Physical diplomas are susceptible to damage, loss, or forgery, necessitating a digital verification mechanism to protect the authenticity and integrity of academic records. This discovery corresponds with the study by Saramago et al. (2021), which elucidates that conventional academic qualifications are susceptible to counterfeiting and ineffective verification procedures. Utilizing Blockchain technology enables the expedited and precise verification of diploma legitimacy via a distributed ledger system.

Furthermore, a study utilizing Hyperledger Fabric by Alfikri & Munir (2022) revealed that data integrity is preserved, as data cannot be modified without conforming to the consensus mechanism of the blockchain network. However, the deployment of blockchain for diploma verification encounters numerous hurdles, including the adequacy of technological infrastructure, connection with current academic systems, and a limited comprehension of blockchain technology among educational institutions. Consequently,

additional development and cooperation from several stakeholders are essential for the optimal deployment of a blockchain-based diploma verification system.

CONCLUSION

The deployment of a digital diploma system in Indonesia is deemed effective utilizing Hyperledger Fabric, as it operates as a permissioned blockchain, requiring explicit access authorization for each network participant. This method facilitates enhanced network security and improved resource efficiency relative to permissionless blockchains. The system development process is further enhanced by the deployment of smart contracts that are interoperable with multiple high-level programming languages, including Go, Java, Python, and JavaScript. The system architecture comprises three primary components: the frontend, backend, and blockchain network. This study also concentrated on improving user interface and user experience (UI/UX) elements to create a more intuitive, responsive, and user-friendly system interface. The system can validate documents through two methods: verification via the diploma number and examination of the PDF file. The system will indicate the status "Verified" if the document is valid; conversely, the status "Verification Failed" will be shown if the diploma number is unregistered or if alterations are identified in the uploaded PDF document.

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