

Research Article

Application of Blockchain Technologies for use of Cryptocurrency in Fees Payment Portal

Davinder Singh^{1*}, Kannadasan B.², Priyanka³, Anupama Samantaray⁴, Anil Kumar Gupta⁵ and Harpreet Singh Bedi⁶

¹Associate Professor, Department of Computer Applications, Chandigarh College of Technology, CGC Landran, India

²Assistant Professor, School of Commerce Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, India

³Assistant Professor, Kamal Institute of Higher Education and Advance Technology Affiliated to GGSIP University, India

⁴Assistant Professor, Kalka Institute for Research and Advanced Studies affiliated to GGSIP University, India

⁵Assistant Professor, Don Bosco Institute of Technology affiliated to GGSIP University, India

⁶Associate Professor, School of Electronics and Electrical Engineering, Lovely Professional University Phagwara Punjab, India

*Corresponding Author

Dr. Davinder Singh
(davinderddd@gmail.com)

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Abstract: As more digital payment solutions become commonplace, there is a need for secure, open and traceable fee management systems for educational institutions. This paper presents a blockchain solution for fee payment management that involves cryptocurrency payment in tandem with a web-based fee portal of an educational institution. The proposed solution includes a cryptocurrency wallet, smart contracts, blockchain and institution database. Payment confirmation and transaction tracking are automated via the use of smart contracts. The proposed system uses smart contracts to authenticate payment data, avoid duplicate transactions and create payment references through the blockchain. Performance analysis of the proposed method will include transaction confirmation time, gas fees and transaction success rate. Simulation of 35 transaction confirms the way the proposed methodology can be evaluated against different transaction loads. The paper also covers the aspects of security issues, limitations of implementation, cost of transactions, volatility of cryptocurrencies and wallet management.

Keywords: Blockchain, Cryptocurrency, Smart Contract, Fee Payment System, Ethereum, Digital Payment, Transaction Verification

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INTRODUCTION

The recent surge in the development of payment systems has brought about changes in how educational institutions collect various forms of tuition, examination, registration and other academic fees. Traditional payment systems for these types of fees use centralized databases and intermediaries in the form of banks and other payment gateways for carrying out transactions. Although these systems facilitate electronic transactions, they rely on many players for transactions to be carried out and records kept and verified. This can be disadvantageous in terms of transparency, traceability and independent verification of payment records.

Block-chain technology can serve as another method of maintaining transaction records through a decentralized cryptographically linked ledger. Block-chain technology in the education sector has been seen as one of the technologies that can bring changes in the handling of information both academically and financially; however, there are challenges associated with this [1]. Block-chain-based payment systems can also help in making fewer intermediaries available for transactions by authorizing transactions through cryptography [2].

Therefore, the implementation of blockchain technology and cryptocurrency can serve as an opportunity to design an alternate process for educational fee payment. Under this proposed system, a student will be able to visit the fee portal

website, link a crypto wallet, choose the desired academic fee and proceed with payment. The payment will be verified by a smart contract based on certain conditions and stored on the blockchain.

However, blockchain-based payment systems also face a number of problems. The fees charged for transactions depend upon network conditions and demand for transactions [3] and prices of cryptocurrencies may face significant fluctuations. Further-more, wallet management issues, confirmation time, privacy and vulnerabilities of smart contracts are some of the elements that have potential impact on the practical application of such systems. It has been observed from previous literature that blockchain-based smart con-tracts are prone to various security, privacy and performance vulnerabilities, making it essential to consider proper security mechanisms for their use [4]. Thus, this proposed system is mainly concerned with assessing the technical feasibility of blockchain-cryptocurrency integration in an educational fee payment portal.

Objectives

The key objectives of this study include:

- Designing a blockchain architecture to enable cryptocurrency-based payment of education fees
- Designing a smart-contract system to validate and authenticate fee transaction processes
- Implementing a cryptocurrency wallet for use on an online portal for fee payments
- Having a transaction traceability system for successful transaction processes
- Testing and evaluation of the system based on transaction time, transaction gas consumption and success rate of transactions
- Security and operational limitations of blockchain-based fee payments

Literature Review

The latest studies considered the possibility of using blockchain technologies for financial services, electronic transactions and automation of the payment process. Systematic investigation of the application of blockchain in the financial industry showed that transparency, decentralization, traceability and new opportunities for trans-actions were the most important potential advantages of this technology along with its implementation issues [5]. Also, the research of blockchain and smart contracts demonstrated how these tools could be used for the automation and decentralization of contract execution based on certain rules [6]. Furthermore, the research of blockchain and cryptocurrency payments provided information about such factors as trust, experience and regulation that could affect the usage of these payment instruments [7].

Conventional Fee Payment System

Traditional methods of fee payment systems in education are based on a centralized system architecture. Students use the institution's portal to check the unpaid fees and proceed with the payment through the payment gateway available. Payment is processed in communication with the bank or any other financial institution that processes the transaction. Post a successful payment, the result of the transaction is communicated to the institution and the payment history is recorded in the centralized database and a receipt is generated.

Despite the availability of this method being a comfortable way of making payment, it still involves several centralized systems. Verification and reconciliation of the payment will involve communication among the institution, payment gateway and the financial institution. The institution relies on centralized databases for storing payments information. This implies that verification of payment information may only be done using the information from the institution and its service providers.

Blockchain-Based Payment Systems

The technology of blockchain enables distributed systems to log transactions. Unlike traditional centralized databases, the distributed ledger is used by the blockchain network to log the transactions. Cryptography ensures the integrity of transactions logged in the distributed ledger, while consensus is used by participants in the network to agree on the correct state of the ledger (Table 1).

A cryptocurrency payment system uses blockchain transactions to enable digital assets to be transferred. A cryptocurrency wallet is used to sign transactions, while blockchain enables a transaction reference to be generated.

Role of Smart Contracts

The smart contract gives programmable capabilities to the blockchain-enabled payment system. A smart contract would establish the rules according to which payments can be accepted and processed without manual verification from an administrator on every transaction. For example, in case of a fee-payment portal, the smart contract can check the fee code, amount of payment and status of the previous transaction before recording the successful transaction.

Moreover, such smart contract can give the possibility to have an auditable relation between the institution's fee entry and its blockchain transaction.

Table 1: Comparison of Conventional and Blockchain-Based Fee Payment Systems

Parameter	Conventional Fee Payment	Blockchain-Based Fee Payment
Architecture	Centralized	Distributed
Payment Processing	Bank/Payment Gateway	Blockchain Transaction
Verification	Central Authority	Smart Contract + Blockchain
Transaction Record	Institutional Database	Blockchain Ledger
Transparency	Limited	Higher
Traceability	Depends on institutional records	Transaction Hash
Automation	Limited	Smart Contract
Cryptocurrency Support	Generally unavailable	Supported
Intermediary Dependence	Relatively high	Potentially reduced
Payment Proof	Digital Receipt	Receipt + Blockchain Transaction

Comparison of Payment Approaches

The major characteristics of conventional and blockchain-based payment approaches are summarized in Table I.

Proposed Blockchain-Based Fee Payment System

The presented research design utilizes the design-oriented and analytical approach for evaluating the possibility of implementing the use of block-chain and crypto-currency for paying educational fees. The research methodology involves design of the system architecture, defining the workflow of the payment process, implementing the validation using smart contracts and verifying the transactions performed within the blockchain. Applications based on blockchain technology in higher education revealed the potential that can be implemented using distributed ledgers and smart contracts for storing the verifiable and traceable information about the educational record [8].

The methodological approach for the study comprises four key phases: design, integration of components, payment processing and verification of transactions. The design phase encompasses the relationship among students, fee-payment portal, crypto wallet, smart-contract, blockchain environment and institutional database. Integration of components involves setting up communication between the web application and blockchain environment. Payment processing involves making the transaction once the smart-contract has been validated, whereas verification involves confirmation of the transaction made in the blockchain.

System Overview

The new approach to be adopted in the project will involve the adoption of both the blockchain technology and cryptocurrency in the payment of fees in the educational fee payment portal. This will entail viewing the fees which need to be paid, linking a cryptocurrency wallet and making payments using the blockchain transaction. The smart contract becomes the middle man in this process of making payments. It performs validation prior to successful payment.

The overall architecture for the project will include six main components which are the student, fee payment portal, cryptocurrency wallet, smart contract, blockchain and institutional database. The user interface and fee information will be managed by the portal while the blockchain components will manage payment authorization and transactions.

The distinction between the institutional data and the blockchain transaction data is a key component of the architecture. Student and academic data will remain in the institutional database while the blockchain can retain the necessary transaction reference. This kind of design has been considered in other educational blockchain systems [8].

System Architecture

The student accesses the fee-payment portal and sees the relevant fee information. After selecting a fee, the student uses a cryptocurrency wallet to connect to the portal. The wallet takes care of the secure authentication of the blockchain transaction.

The transaction request is then sent to the smart contract. The smart contract verifies if the conditions met include the right amount and if the relevant fee was paid previously. If the conditions match, the transaction is being processed on the blockchain network.

Once the transaction is confirmed by the blockchain, the transaction hash is transferred to the application. The hash with the details about the student and the fee are stored in the institutional database. It establishes a connection between the traditional institutional record and the blockchain transaction.

The designed architecture ensures that the sensitive institutional data is separated from the blockchain transactions. Information like details of students, academic information and the fee schedules can stay in the institution's database. Only the payment information can be recorded on the blockchain (Figure 1).

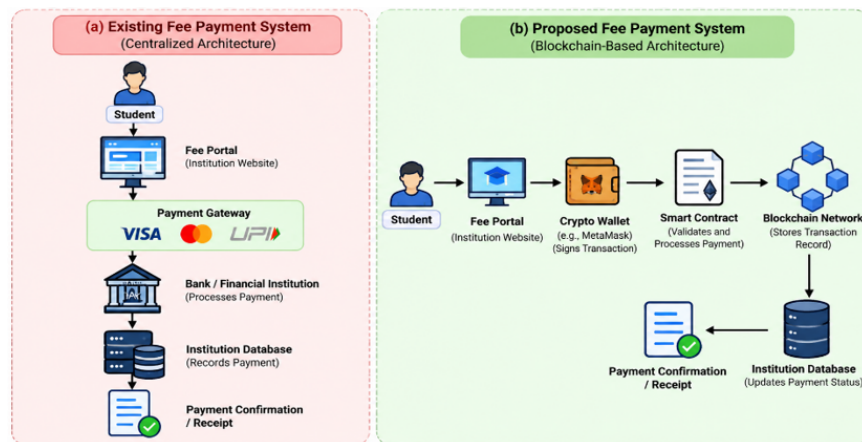


Figure 1: Proposed Blockchain-Based Fee Payment System Architecture

System Components

The major elements in the suggested system will be:

- **Student:** The student is the main user, who starts the fee payment trans-action
- **Fee Payment Portal:** The portal lets the students see the fee amount, connect the wallet, start the payment process and view the transaction status
- **Cryptocurrency Wallet:** The wallet holds the cryptocurrency of the user and gives cryptographically verified authorization to perform the payment.
- **Smart Contract:** The smart contract has the payment logic and verifies the transaction before saving the payment
- **Blockchain Network:** The blockchain holds the distributed ledger on which the confirmed payment transactions get saved
- **Institutional Database:** The database holds information about students, fee amounts, payment statuses and blockchain transaction ID correspondingly

The use of smart contracts helps implement transaction rules programmed into the smart contract automatically. In research conducted on the blockchain-based smart-contract systems, it was found that these systems could automate transaction processes using blockchain execution and predefined transaction conditions [9].

Payment Verification Mechanism

At the time when a payment is being made, the smart contract verifies if the entered value matches the required fee and if the fee has already been paid. A correct transaction is posted to the blockchain and upon confirmation creates a transaction hash.

The application gets the results of the transaction and correlates the confirmed transaction with the student and fee transaction. The status of the payment can be changed from 'Pending' to 'Paid' in the institution's system.

In case of failure of validation or rejection by the blockchain network, the status of the payment will not change and the user will be notified about the failed payment. Such an approach allows to avoid double fee payments and gives a verified proof of successful transactions.

Verification processes in educational environments using blockchain technology were also studied [10]. Blockchain records are used to provide verifiable information instead of traditional verification.

Advantages of the Proposed Architecture

The suggested architecture would have multiple benefits, which include better transaction traceability, payment verification automation, proof-of-work based transactions and lesser reliance on centralization in payment verification. Additionally, this architecture would also generate a blockchain transaction hash which can be utilized as another payment reference in addition to a traditional digital receipt.

System Workflow and Transaction Process

The workflow of the proposed system gives a sequence of the processes involved when a student uses the crypto currency to pay for educational fees. The process involves integration of the institutional database, fee portal on the web, cryptocurrency wallet, smart contract and the blockchain. The entire process is broken down into six steps starting from authentication to selection of the fee and ends in either payment confirmation or transaction failure.

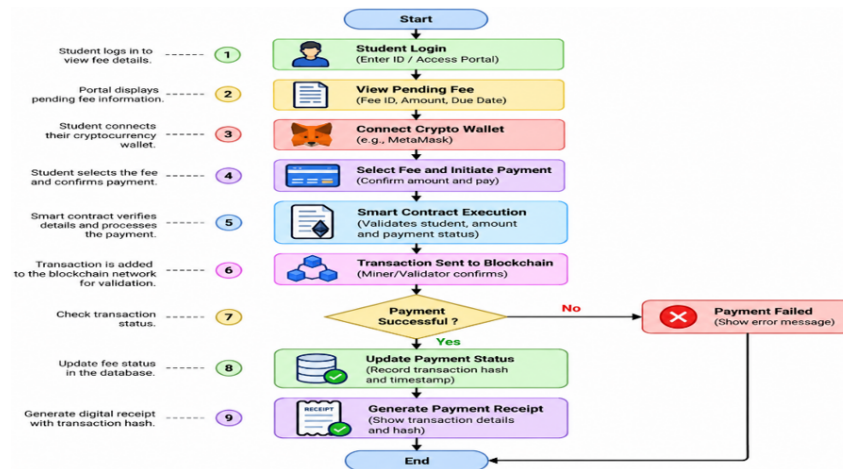


Figure 2: Proposed System Workflow

User Authentication and Fee Selection

It all starts when the student logs in to the portal of fee payment by using the credentials which are given to him by the education institute. After the authentication being completed, the portal gets the fee details of the student from the institution database. These details might have the student ID, fee type, amount and due date.

Then the student chooses which fee he wants to pay through the crypto currency payment option and the system asks the student to connect his cryptocurrency wallet.

Wallet Connection and Payment Initiation

Once the wallet has been connected, the portal gets the wallet address needed for the transaction. After that, the student checks the transaction details and confirms the transaction via the connected wallet.

Then the transaction is digitally signed by the wallet through cryptographic user credentials. The signed transaction includes the data required to call the appropriate smart contract function with the needed cryptocurrency amount. Digital signing by the wallet with the use of cryptographic credentials of the user is an essential part of the blockchain transaction [11].

Smart Contract Validation

After submitting the transaction, the smart contract applies the pre-defined logic. It validates the amount of the payment as well as whether there is the payment of the corresponding fee.

If the conditions for the payment are not met, then the transaction is refused and the fee remains unchanged. In case all the conditions are fulfilled, the smart contract uses the payment logic and creates an event with some transaction information.

Thanks to logic that are pre-defined contract, it is possible to check the payment conditions automatically without checking them manually every time. This approach fits the programmable execution logic of blockchain smart contracts [12].

Blockchain Confirmation

The valid transaction is transferred to the blockchain network. The network participants authenticate the transaction using the consensus mechanism of the block-chain. Once the transaction has been placed into the block and gets the needed confirmation, the blockchain creates the transaction hash that identifies the payment transaction. The portal may use the transaction hash to confirm the payment.

Payment Status Update and Receipt

After the success of the transaction, the institutional system updates the payment status from Pending to Paid. The transaction hash, time stamp of the payment and other pertinent data may also be recorded together with the institutional fees.

Lastly, the portal creates a receipt that includes the transaction details as well as blockchain transaction reference number. This gives the student both a traditional payment confirmation and blockchain transaction reference number (Figure 2).

Failed Transaction Handling

In case of rejection of the transaction by the smart contract, failure of the transaction during processing, or lack of required blockchain confirmation, the status of the payment will be considered unsuccessful. The portal will notify the student about the failed transaction and provide an opportunity to make a new payment transaction.



Figure 3: Smart Contract and Blockchain Transaction Flow

Table 2: Experimental Results of the Proposed System

Test	Transactions	Successful	Failed	Avg. Confirmation Time	Avg. Gas Used
T1	5	5	0	12.4 s	46,820
T2	10	10	0	13.1 s	46,910
T3	20	19	1	14.6 s	47,120
Overall	35	34	1	13.37 s	46,950

Such a process guarantees that the payment of the fee will be made only after successful processing and confirmation of the corresponding blockchain transaction.

Smart Contract Implementation, Security and Performance Evaluation

Smart Contract and Transaction Processing: In the suggested system, a smart contract developed with Solidity programming language is used in an Ethereum-like test environment of the blockchain network. The payment is made with the help of the cryptocurrency wallet that is linked to the web portal. After that, the smart contract checks if all requirements regarding the identification number of the fee, payment amount, address of the payer and payment status are met.

After the transaction has passed the verification process, the payment is recorded in the blockchain network and is assigned a unique transaction hash that allows verifying and auditing the payment. The payment status is synchronized with the database, while confidential data of students are stored outside the blockchain network.

It is important to conduct an appropriate evaluation of the smart contract as potential vulnerabilities in the logic of the contract can have negative effects on the security and integrity of the blockchain application. There exist various types of smart contract vulnerabilities on Ethereum [13] (Figure 3).

Security and Performance Evaluation

This system ensures security through transaction authorization using wallets, cryptographically signed transactions, smart-contract validation, duplicate-payment detection and transactions recorded on the blockchain. The analysis of security for such a system is especially crucial since flaws within the smart-contract code can influence transactions. This is why systematic security analysis methods have been studied to detect vulnerabilities within Ethereum smart contracts [14] (Table 2).

The total transaction success ratio comes to 97.14% which is derived from 34 successful transactions out of a total of 35 transactions. The conclusion drawn from the results is that the workflow design in discussion can process transactions with relatively uniform confirmation time and gas consumption. Yet, the presented figures are just simulated values, not actual measurements (Figure 4).

Future Scope

The cryptocurrency fee-payment system proposed in this paper can be improved in a number of ways. The use of stablecoins in place of highly volatile cryptocurrencies can be studied as an approach that would enable the determination of a more predictable fee value. The use of Lay-er-2 blockchain network can also be tested as an approach that will reduce transaction fees and confirmation time. In future works, the proposed approach can be implemented in conjunction with university ERP and student management systems in order to facilitate fee creation, reconciliation and receipt handling.

Other additional features that may be included are mobile payments, QR code wallet integration, automatic refunds, multiple currency support and improved smart-contract security testing.

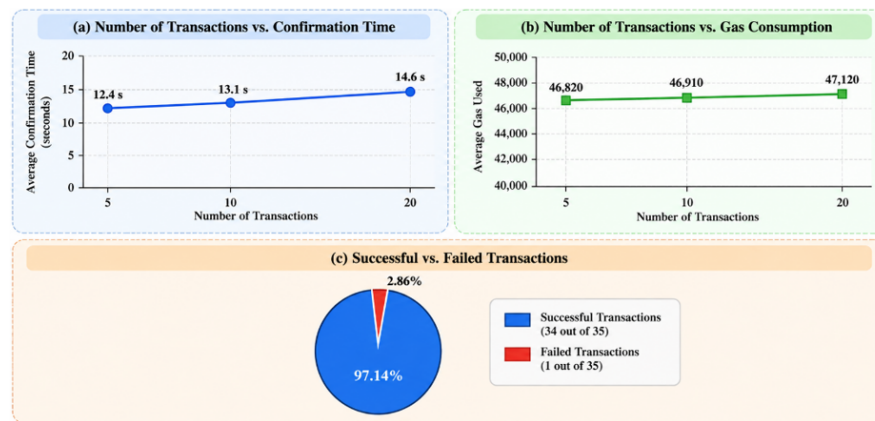


Figure 4: Experimental Performance Results

CONCLUSION

In this paper, a blockchain solution for incorporating crypto payments in an educational fee portal was discussed. The solution architecture uses a combination of a web-based fee portal, cryptocurrency wallet, smart contract, blockchain and institutional database. The smart contract automates payment validation and avoids duplication, while the blockchain acts as the traceable transaction ledger.

Performance metrics such as transaction confirmation time, gas usage and transaction success rate were used to evaluate the proposed architecture. Evaluation proves how blockchain-based transactions could be utilized to evaluate the viability of the proposed payment mechanism. Also, the system produces a hash of the transaction which could serve as an additional means of making payment along with the institution-provided digital receipt.

In spite of all the possible advantages, any implementation would need to take into account the volatile nature of cryptocurrencies, transaction fees, confirmation time, management of wallets, privacy issues, regulations and smart contracts security. In other words, this system is only a technical framework for blockchain-based fee payments rather than a substitute for current payment systems. Experimenting with other numbers of transactions and other blockchain networks will give more evidence on scalability of the proposed solution.

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