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Secure Pay-Blockchain based UPI Payment System

Mr.VSSPLN Balaji Lanka[1], G. Jhansi[2], M. Dheeraj Kumar[3], Shaik Lutfiyah[4], K. Uday Kiran[5]
[1]*AssistantProfessor,* [2,3,4,5]*UGStudent, DepartmentofCSE,VignanInstituteofTechnologyand Science, Deshmukhi, Hyderabad*

Abstract- Due to the popularity of the digital payment system, there has been an increase in the need to adopt frameworks of secure and reliable transaction systems, especially in Unified Payments Interface (UPI) systems. This paper will overcome the issue of security, transparency, and trust by offering a Blockchain-Based UPI Payment System, a decentralized system that will provide security to financial transactions and user data. The proposed system provides blockchain technology which guarantees integrity of the data and prevents unauthorised modifications because it stores the UPI transactions inadecentralized form andin animmutable way. Smart contracts are also used to automate the procedure of validating and processing transactions and reduce the required number of intermediaries. In the proposed system, cryptography techniques are merged to enhance authenticity, confidentiality and security of the system against fraud. The system that is proposed will enable the real-time tracking of transactions without the impact of user privacy. The transactions can also be traced with the system and this will assist in detection of suspicious transactions at an early stage. Overall, theUPI system based on blockchain is a safe, open, and reliable digital payment system that may be appliedin the modern financial landscape.
Index terms—Blockchain,Smartcontracts,securepayment

I. INTRODUCTION

The online payment services have become popular in the current digital economy, due totheconvenience it offers to the users. One such widely used online payment service is UPI and it is utilized in financial transactions. However, due to the growing usage of online payment services, the risks of fraud, data breach, and unauthorized access arealso growing, especially when the services are stored on a centralized control. The weaknesses of the system giveway to cyber attackers who may interfere with the data of transactionsor exploittheusercredentialsor lossofmoney or loss of confidence among the users.

In order toresolve these concerns, this paper will present a proposal of a Blockchain-Based UPI Payment System that willharnessthestrengthofdecentralisedledger technology to improve the security and authenticity of UPI transactions.The proposed system, based on blockchain technology, cryptographic security, and use of smart contracts, however, stands in contrast with traditional payment systems, which require a single entity to accomplish their work successfully. This makes the transaction details tamper-proof, transparent, and viewable by all the parties that have the authority to do so and therefore any form of fraud or alterations is avoided.

The greatest advantage of the suggested system is the opportunity to guarantee the integrity of transactions and make real-time payments. It can track the operations of the transactions among the distributed nodes and as such, it can identify any kind of suspicious activity that can be the signifier of fraud. The blockchain also follows the principle of making sure that once the records are stored in the system they cannot be changed.

The paper explains how and what the blockchain-based UPI payment system looks like and how it works alongside the major elements of the system such as smart contracts and cryptographic validation procedures. It also provides the importance of incorporating transaction details, user identification details and network validation processes to augment the securityof the payment system. The results of the given research allow stating that the offered system can help to reduce the threat of fraud, increase the level of transparency, and address the changing risks of digital payments.

II. EASEOFUSE

The UPI payment system is easy to use in blockchain since the payment system follows the same easy procedure just like other UPI applications allowing any user tomake payment byscanningthe QRcode or typing the UPI ID without any understanding of the blockchain technology. The entire complicated procedures such as encryption, verification and secure storage take place in the background thus making transactions run smoothly with a couple of clicks. The system is usable since it is familiar, prompt confirmation of payments, and the history of transactions can be easily obtained, and blockchain technology enhances the level of security and transparency of the system without the user making any additional effort.

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A. Existing System

In the existing system, a transaction of UPI is processed without blockchain technology. The transaction relies on centralized servers, and rules and authentication procedures that are provided by banks to ensure the security of the transaction. In spite of the fact that this system is effective in terms of payment and familiar frauds, itis lackingtransparencyand flexibilitytoaddress emerging security threats.

B. Proposed System

The proposed UPI payment system based on the blockchain and designed on the Ethereum platform with the help of Ganache will allow creating a controlled and safe testing environment. The transactions will be processed using the smart contracts and automatically verified and stored in the blockchain.

III. LITERATURE SURVEY

A number of researchers have tried to improve the safety and confidence that comes with digital payment systems like UPI using the blockchain technology. Li et al. (2020) created a decentralized system of storing transactions with a secure payment system through blockchain and smart contracts. Their study showed that fraud resistant records and distributed consensus could be used to increase trust. Their solution was however generic to digital payments and not specific to the needs of real-time and high volume payment systems like UPI.

Singh and Sharma (2021) have explored how blockchain technology can be used to ensure online transactions are secure since there is no central authority involved. The researchers came to a conclusion that blockchain technology contributes to a significant increase in transparency and prevents the risk of central control. The study has shown the advantages of the blockchain technology use, but still, made no comments on the necessity to protect privacy of the users and quick processing of the transactions needed in the UPI transactions.

The authors use the review of the application ofblockchain in financial technology to examine how blockchain is used to enhance security, traceability, and reliability (Movva and Dasarraju, 2024). Although they mentioned theutilityof decentralized systems in payment, their research was theoretical and it did not include any models and experiments of the working UPI integration.

Tyagi and Beri (2025) came up with a proposal of digital payment systems that were integrated with blockchain to promote trust and transparency. It was a research on how distributed ledgers can be used to eliminate centralized serverstosecurepayments.Nevertheless,thepaperdidnot dwell on thefunctionalityanalysisandpracticalevaluation of the suggested model, which would have contributed to the evaluation of its capabilityto replicatereal UPI traffic.

Lastly, Lin et al. (2025) developed a payment processing system that was based on blockchain technology, which combined decentralized technology and a secure verification system. In terms of security, the research indicated improved security and reduced chances of manipulation of transactions. Nonetheless, the interoperability challenges of compatibility between the current banking structureand regulatoryprovisions of UPI systems were not discussed in the study.

Collectively, these studies indicate that despite the potential of blockchain to offer the digital payment security, there is hardly any literature that specifically covers the needs of the UPI systems i.e. the real-time processing, scalability, privacy, and easy integration with existing banking infrastructure. This shows that the UPI payment systems require tailored blockchain solutions.

The importance of smart contracts to blockchain payment systems has alsobeen mentionedrecently. Smart contracts can be used to enable transactions validation to be automated, transaction rules enforced, includingtransaction limits, and disputes resolved without human intervention.

Such contracts that are optimized are of great significance in the UPI network setting where the transactions occur in real time, and that they involve a huge number of users. Unless such contracts are optimized, there arepossibilities of performance problems or errors.

The other specific focus of recent research is the decision on the type of blockchain. Public blockchains are extremelytransparentand,however, theymaybeslower in processing as they have to reach consensus, whereas permissioned or hybrid blockchains are faster inprocessing and alsoprovidemorecontrol on whoisableto access the data. Hybrid blockchains tend to be more acceptable in the UPI transactions.

By filling these gaps, future research can come up with secure, fast, scalable, andcompliantblockchain-basedUPI systems to present areliable solution to the existing digital payment system and nullify the threats posed by the centralized one.

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IV. ARCHITECTUREAND METHODOLOGY

The UPI payment system architecture design based on blockchain is designed to provide secure, transparent, and real-time transactions, including banks and users. The design is a modular type, where each unit is concernedwith a specific task.

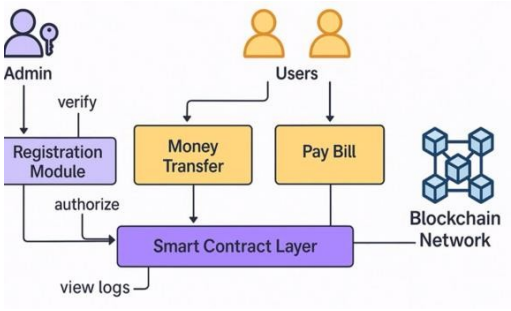


Fig1:System Architecture

A. UserInterfaceLayer

This layer will provide a web interface that is interactive where users are able to register, log in and in the process carry out payment transactions. The interface is designed with the help of standard web technologies which also offer a smooth means of interaction with the blockchain network.

B. ApplicationLayer

Application layer provides an interface between the blockchain network and the user interface. It is based on Web3 libraries to interact with the deployed smart contracts on the network. Application layer is also to handle the request of transactions, get account details and display status of transactions to the user in real time.

C. SmartContractLayer

The Smart contracts written in Solidity programming language are the implementation of the business logic of the system. The smart contract is what takes care of user account management, validation of transactions and automatic transfer of funds. Once deployed, the smart contract is executed on blockchain environment

D. BlockchainNetworkLayer

The Ethereum platform forms the basis of the blockchain layer. All the transactions are cryptographicallysigned and time-stamped, and stored in the distributed ledger. This gives mutability, transparencyand fault tolerance. The development and testing is done in a local Ethereum test environment(Ganache).

V. METHODOLOGY

The system of the proposed system is developed in a systematic methodology to guarantee that it is right, secure and scalable.

1) Step1:RequirementAnalysis

The Identification ofthe system requirementshas been carried out through the analysis of the flaws of the traditional centralized UPI payment system, including the use of third-party servers and vulnerability tosingle points of failure. The primary objective will be to provide a safe payment service.

2) Step2:SmartContract Development

Smart contracts were also meant to establish the guidelines on how to address user registration,balances and fund transfers. Validation checks arealso added to prevent transactions of unauthorized people and to have a enough balance to make the transaction.

3) Step3:BlockchainEnvironment Setup

The development was done on a local Ethereum blockchain environment (Ganache) that wasconfigured as a private network using local testing tools. A blockchain development framework was used to compile and deploy smart contracts and frontend interfaces were developed.

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4) Step4:FrontendandBlockchainIntegration

Web3.js were used to connect the web application to the blockchain network. The user must log in and authenticate transaction using a digital wallet that will enable the user to sign a transaction in a secure way without exposing his / her private keys.

5) Step5:TransactionProcessing

Upon a user paying, a payment is handled to receive validation via the smart contract. After validation, the transfer is made and the transaction is stored in the blockchain. The transaction status is then updated in user interface.

6) Step6:TestingandPerformanceEvaluation

The system was put towards functional accuracy, transactionintegrity,andsecurity.Differenttransaction situations were performed to test the immutability and transparency of payment system based on blockchain.

VI. IMPLEMENTATION

A. BlockchainbasedUPIOverview:

Blockchain-based UPI Payment System: It is a decentralized digital payment system which is basedon blockchain technology to support peer-to-peer transactions without having centralized banking servers.Theproposedsystemusessmartcontractsona blockchain network to automatically validate and process transactions.

Unlike the traditional system where the UPI payment system requires theintermediaries ofthe banks tovalidate and process transaction.

Theproposed system issecure,transparentandimmutable in its transactions.The system will join UPI-like handles with blockchain wallet addresses so that, the users can send andreceive payments in a manner similar to the UPI apps but with the added benefit of decentralization.

1) LocalBlockchainSetup

The initial stage of the UPI system based on blockchain implementation istheconfigurationofthelocal blockchain with the help of Ganache. Ganache is a simulator that is a local blockchain, and it allows development and testing to bedonein controlled environment. When an installation is made a new workspace is created to configure the project. Ganache will automaticallycreate a test ten accounts, with each account loaded with 100 Ether in it, together with a private key. These are the accounts that are used to simulate users and carry out blockchain transactions in the process of development and testing.

2) MetamaskIntegration

The MetaMask browser extension is then set andlinked to the Ganache local blockchain network. In MetaMask, a custom network is added with the network name of Ganache, the RPC URL of http:127.0.0.1:7545 and the relevant chain ID (1337 or 5777). The Ganache generated test accounts are then imported into the MetaMask with their individual private keys. This can be integrated to allow the user wallet interface to interact and test the transactions on the local blockchain environment in a seamless manner.

3) SmartContract Implementation

Smart contracts are executable computer programs which have predefined rules and conditions to perform transactions like user registration, balance checking, fund transfer activities etc.Thelogicspecified in such contracts automatically makes sure that the specified logic is enforced without the need of any manual intervention, which means that the transactions are executed securely and reliably.

4) TransactionValidationLogic

The smart contract authenticates a transaction before a payment is made depending on some conditions.

Let: Bs= Sender Balance Br=ReceiverBalance A= Transfer Amount

A transaction is valid if: Bs>=A^A>0^S!=R

In case the requirements are satisfied, the transaction will be valid and will be automatically processed.

5) PaymentExecutionandLedger Update

Onceanalyzed,thebalancesofthetwouserswillbe updated by the smart contract as follows:

$$Bs^{new}=Bs-A \quad Br^{new}=Br+A$$

Thisisthen permanentlywritteninthe blockchainledger.

6) SmartContractDeployment

Once the smart contract logic and rules of transaction are defined, the contract is implemented to the blockchain network. Deployment The smart contract source code is compiled and sent to blockchain as a transaction.

After an deployment, thecontractreceives a different address on the blockchain that is used as a permanent identifier to address its functions.

The blockchain authenticates the code of the contract and logs it in a block during deployment, which imposes an immutable and tamper-resistant contract. This makes sure that the rules that have been set up, which govern user registration, balance inquiry and transfer of funds can not be changed once they are deployed. The implemented smart contract is then a trusted backend that performs several transactions automatically under the given conditions.

B. WebApplicationandUserInteractionModel

The web application is a significant element that interacts with the blockchain network with the users. The network of blockchain carries out the transactions and security, whereas the web application carries out the ease of use by hiding the complexities of technicalities. The web application is coded in a modular manner in which each user action is synthesized into a blockchain operation through engaging with smart contracts.

1) PaymentRequestFormation

The web application constructs a request of payment when the user makes a transaction that comprises ofthe sender address, receiver address, the value being transferred and the transaction details. The request is structured in the interface requirements of the smart contract. At this stage, the web application only processes non sensitive data and the private keys are held safe.

The payment request is an input to the smart contract and this is not executed until the user approves it.

2) SmartContractInteraction

After the payment request is created, the web application makes an invocation of the transferfunction of the deployed smart contract. This is achieved by having a secure blockchaincommunication layer which sends the details of the transaction to the blockchain network.

The smart contract independentlyvalidates therequest checking account balances, sender address, receiver address and amount of transaction. This is to makesure that the application will not modify the rules ofthe transaction because all the rules are imposed in the blockchain.

3) TransactionAuthorizationandExecution

After the transaction request has been sent to the blockchain, authorization is performed using cryptographicsignatures.Thesignedtransaction issent to the network in which it is decentrally verified. The transaction is validated by a number of blockchain nodes before being passed.

After the validation is successfully completed, the smart contract carries out the transfer of funds and leaves the required entries in the ledger.

4) Real-TimeTransactionStatusMonitoring

The web application waits to have the blockchain transaction confirmed. Once the transaction is part of a validated block it is responded to with a confirmation message by the web application.

The feedback mechanism can be used to help the user track the transaction status on a real-time basis as was the case with traditional UPI payments.

5) TransactionLoggingandAuditability

Every transaction gets registered on the blockchain automatically having a transaction hash. With the help of thetransactionhash,theapplicationretrievesthedetailsof the transaction and presents it to a user.

The transaction logs are immutable due to theimmutability of the blockchain records, and hence they cannot be altered or deleted. The latter allows having complete auditability and gives increased confidence tothe payment system.

6) HandlingTransactionFailures

The smart contract will also not accept the transaction in case of a failed transaction because of lack of balance, incorrect address or any network problems. The cause of the failure will be re-sent back to the application and displayed to the user.

This simple failure management system will allow theuser to know about the issue and rectify it respectively.

7) ScalabilityandUserLoadHandling

The web application is designed in such a way that it supports several users and concurrent requests of transactions. The transactions are processed asynchronously by the system to maintain the responsiveness of the interface during the peak network traffic.

The system can be scaled up easily and does not impact the user experience.

8) CompatibilitywithExistingUPIWorkflow

The backend is blockchain-based but user flow is nearly equivalent to the conventional UPI system. Similar functions such as typing in the details of the recipient, choosing the amount, and authorizing the payment are performed by users.

9) PrivacyPreservation

The system keeps the privacy of the user who does not keep any personal or banking details. The system merely captures wallet addresses and transaction data on the blockchain. No sensitive identity information is disclosed or shared.

CODESNIPPET

```
contract MoneyTransferBank {
    /**
     */
    function sendMoney(address payable _to) public payable {
        require(s_isRegistered[msg.sender], "MoneyTransferBank: Sender is not a registered user."
        require(s_isRegistered[_to], "MoneyTransferBank: Recipient is not a registered user.");
        require(msg.value > 0, "MoneyTransferBank: Amount must be greater than zero.");
        require(s_balances[msg.sender] >= msg.value, "MoneyTransferBank: Insufficient balance.");

        s_balances[msg.sender] -= msg.value;
        s_balances[_to] += msg.value;

        // Record transaction
        s_allTransactions.push(Transaction(msg.sender, _to, msg.value, block.timestamp));
        uint transactionId = s_allTransactions.length - 1; // Get the index of the newly added tr
        s_userTransactionIds[msg.sender].push(transactionId);
        s_userTransactionIds[_to].push(transactionId);

        emit Transfer(msg.sender, _to, msg.value);
    }
```

Fig2:Samplesmartcontractfunction

VII. RESULTS AND OUTPUT

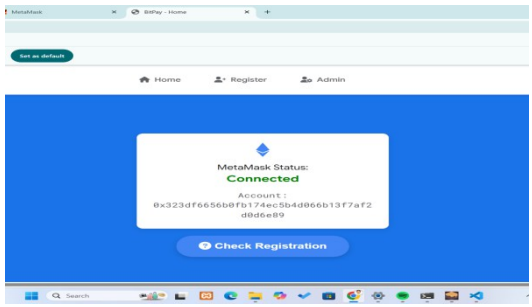


Fig3:MetamaskWalletConnection

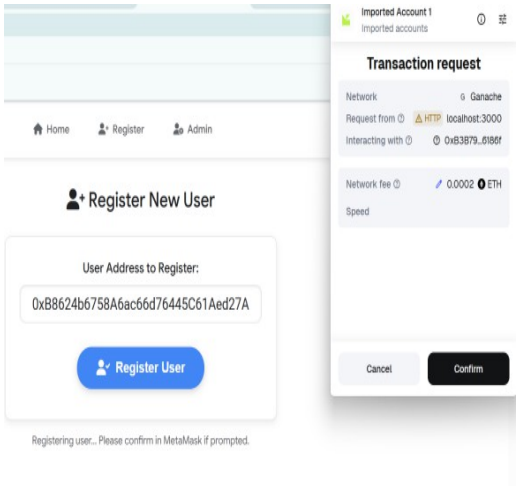


Fig4:RegisternewuserandConfirmation

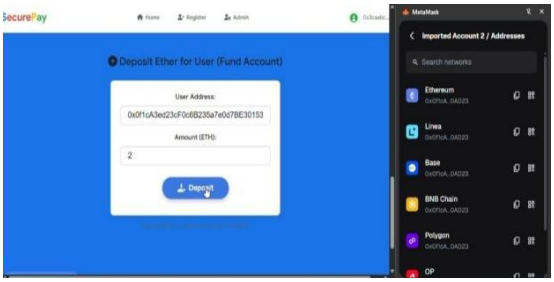


Fig5:FunddepositInterface

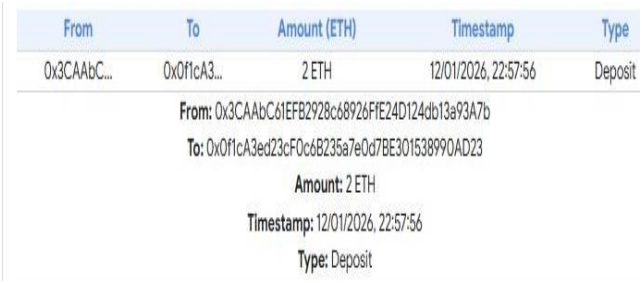


Fig6:Blockchaintransactionrecord

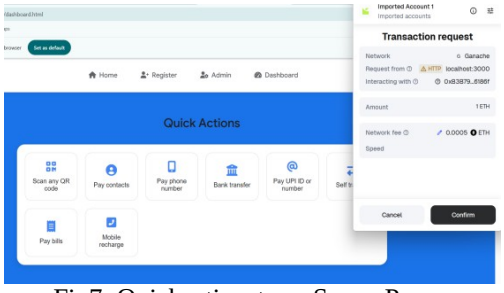


Fig7: QuickactionstouseSecurePay

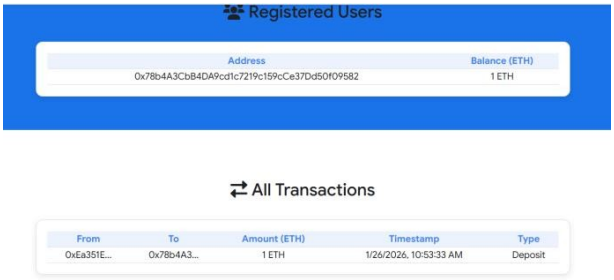


Fig8:UpdatedUser Balance

VIII. CONCLUSION

The suggested UPI payment system based on blockchain has shown that blockchain technology can be used successfully to enhance the security, transparency, and dependability of blockchain-based payments. The suggested system is developed based on blockchain technology and smart contracts to manage transactionsand is entirely independent of central servers, which guarantees the secure transactions, proper balance update, and immutable records of transactions. The test outcomes confirm that the suggested system can handle payments effectivelyand stop unauthorizedandinvalidtransactions, as well as an experience that a user can experience due to the current UPI apps. As this paper establishes, the blockchain technology has the potential to be adependable substitute in thenext generation UPI payment systems.

IX. FUTURE SCOPE

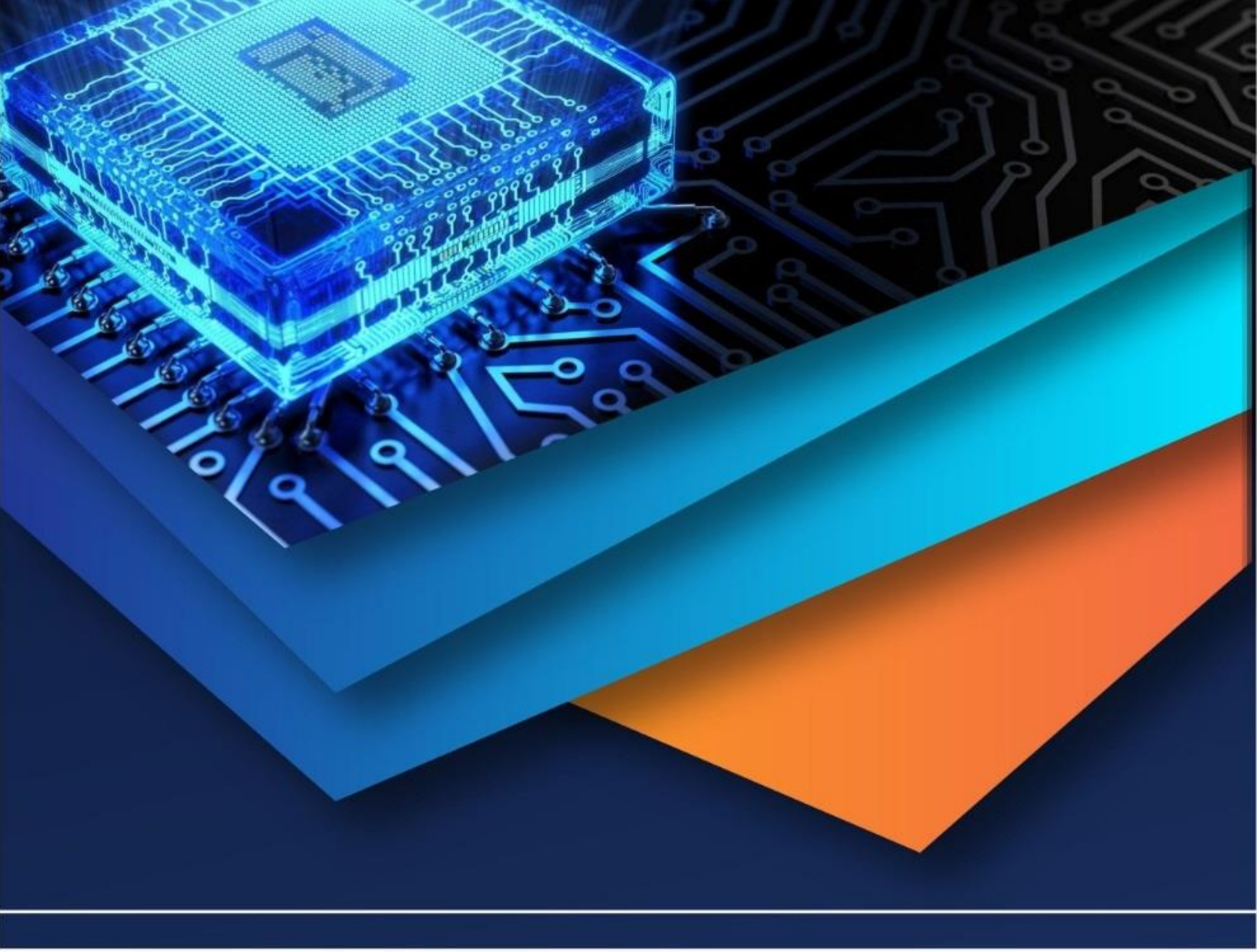
To enhance the UPI payment system based on the SecurePay blockchain computing, one may introduce the deployment of the system on a real blockchain instead of on a local test system. Users can be enabled to pay by use of a simple identifier like mobile numbers or UPI IDs linked to their blockchain wallets in the future. Thesystem can also be made easier with the help of QR code payments and mobile app support. Basic security verification andtheuser authentication can alsobeused to make the system more credible. Scalable blockchain networks or layer 2 scale solutions can be used to exploit more users and transactions, ensuring cost and latency is minimized.Thesechangescan beusedtomakeSecurePay a more practical digital payment system.

The other possible future development of SecurePaywould be the integration of advanced monitoring and control capability to the advantage of the users and the administrators. To increase the security of the system and educate users, it is possible to introduce live transaction notifications, expense reports, and simple fraud filters.The transaction restrictions and self recovery can also be developed into the smart contracts in order to reduce abuse. SecurePaycan beincorporatedtooperatealongside the existing digital payment systems with sufficienttesting and incremental improvements thus becoming a potential solution to reliable digital transactions in future.

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