Blockchain Enabled E-Commerce Platform with Secure Cryptocurrency Transactions

Muralidharan B.[1], Adaikalaraj S.[2], Bharath Kumar V.[3], Cibi Raj C.[4]

[1]Assistant Professor, [2,3,4]Student, Department of Computer Science and Engineering, NPR College of Engineering and Technology, Natham, India.

E-mail: [1]muralidharanb@nprcolleges.org, [2]adaikalarajs920822104002@nprcolleges.org, [3]bharathkumarv920822104019@nprcolleges.org, [4]cibirajc920822104021@nprcolleges.org

Abstract

Blockchain technology plays a key role in enhancing the security, transparency, and reliability in e-commerce processes. This research work proposes a blockchain-based e-commerce system by integrating traditional web technologies and the ethereum smart contracts for performing cryptocurrency transactions. In the proposed solution, a combination of Web2 and Web3 will be used: the application services such as product management and user transactions will run off-chain, whereas the payment process, escrow service and transactions settlement will run by executing transactions through Solidity smart contracts on the Ethereum Sepolia test network. In order to implement the platform, ReactJS, Node.js, Web3.js, MetaMask and Remix IDE frameworks will be used. The experimental evaluation covers smart contract deployment, latency measurement, transaction cost measurement, function validation and security testing. The obtained outcomes confirm successful transaction execution, consistent confirmation latency, reliable smart contract execution and payment security through the wallet.

Keywords: Blockchain, E-Commerce, Ethereum, Smart Contracts, Cryptocurrency, MetaMask, Sepolia Testnet, Decentralized Payments.

1. Introduction

1.1 Background

Electronic commerce (E-commerce) has revolutionized the businesses processes and user interaction with fast digital transactions. However, the current digital transactions platforms use

DOI: https://doi.org/10.36548/jaicn.2026.3.008
Extended version of article received from **International Conference on Smart Innovations in Engineering & Technology (ICSIET 2026)**
Received: 14.06.2026, received in revised form: 17.07.2026, accepted: 10.08.2026, published: 19.08.2026

a centralized architecture for managing the users, enabling transactions and verifying payments. Although the current platforms are convenient and scalable, they suffer from vulnerability to security threats, data manipulation, failure points identification and dependence on a trusted third-party service provider of payment. In order to resolve these issues, there is a need to develop an innovative blockchain based model. Blockchain provides a decentralized transaction processing framework, tamper-proof data storage and cryptography-based validation. In contrast to traditional payments, blockchain allows for p2p transactions without relying on central bodies but still provides a transparent and tamper-proof ledger. Additionally, Ethereum uses blockchain for running smart contracts that automatically perform transactions based on certain conditions.

1.2 Problem Statement

The existing e-commerce payment processing systems depend upon centralized financial intermediaries for the authorization and transaction management. This creates increased delay, transaction cost, and system insecurity and decreases the transparency of financial transactions. Another problem with the existing system is that the maintenance of trusted transaction logs and ensuring the legitimacy of transactions becomes difficult due to the storage of financial information in a centralized database. Hence, there is a need to enable decentralized e-commerce payment processing system along with the existing web technologies.

1.3 Research Gap

Several research studies highlight the possibilities of using blockchain technology for decentralized payment processing, automated execution of smart contracts, and secured transactions on the digital platform. Nevertheless, most of the studies tend to concentrate on the blockchain architecture, or the consensus mechanism, or the conceptual model of payment, but there has not been enough study on the blockchain based payment technology in real-time e-commerce system. Also, there are only fewer studies that describe the experimentation of such e-commerce systems through public Ethereum test network including wallet-based authentication, deployment of smart contract, decentralized payment processing, and integration at application level.

1.4 Research Objectives

The main purpose of this research is to develop an e-commerce platform using blockchain technology that allows the integration of decentralized cryptocurrency payments with existing web shopping services. To achieve this objective, the study aims to:

- Deliver a hybrid Web2-Web3 solution combining ReactJS, Node.js, Ethereum, and Solidity smart contracts for decentralized transaction processing.
- Implement the payment processing with the help of MetaMask wallets and Ethereum smart contracts.
- Automate the process of payments verification, escrow handling, funds transfer, and refund processing using the mechanism of smart contracts.
- Improve the transparency of transactions and increase data integrity with the help of blockchain.
- Conduct a prototype validation experiment on the Ethereum Sepolia network.

1.5 Key Contributions

The major contributions of this research are summarized as follows:

- A hybrid system comprising of Web2–Web3-based e-commerce framework, which splits traditional application functionalities from blockchain-based payment settlement functionality in order to minimize storage requirements on-chain while retaining transaction integrity.
- Design and implementation of Solidity-based smart contracts for supporting escrowed payment settlement, automation of payment, refund management, and transaction immutability.
- Creation of an integrated prototype utilizing technologies such as ReactJS, Node.js, Web3.js, MetaMask, and the Sepolia blockchain of Ethereum for demonstrating decentralized payment execution.
- Experimental validation of the developed platform by deploying smart contracts, latency testing, transaction cost analysis, functionality validation, and security validation.
- Simulation of the possibility of incorporation of blockchain in e-commerce payment solutions through a public Ethereum test network.

2. Literature Review

The blockchain technology enables decentralized digital transactions due to its ability to provide distributed trust, cryptography, and verification. Nakamoto [1] presented the peer-to-peer cash transaction model, where it has shown how transactions could be validated without any centralized financial intermediaries. The approach gave rise to the concept of decentralized payments, while the original architecture of Bitcoin allows only the minimal implementation of complex e-commerce logics. Further development of the idea was done by Antnopoulos [2], who presented Ethereum as a programmable blockchain to perform smart contracts and applications.

Blockchain technology has become the focus of recent academic research regarding e-commerce platforms. Zhang et al. [3] have suggested the implementation of the PBTMS system, a blockchain-based privacy preservation system, which can increase efficiency and reliability in an e-commerce environment. This study revealed the existing need for preservation of transaction privacy alongside the maintenance of trustworthiness in records, which is especially important when the public ledgers are used in commercial transactions. Muravev et al. [4] stressed that blockchain technology could significantly enhance transparency and security in digital transformation processes through immutable records and verification.

From the architecture perspective, Zheng et al. [5] investigated the basic elements of blockchain technology like distributed ledgers, consensus algorithms, cryptography systems, and scalability challenges. The research offers the systematic foundation for selecting the appropriate blockchain architecture based on the application requirements. Aste et al. [6] investigated the wide industrial implication of the blockchain technology and found decentralization and programmable trust as the major factors that contribute to its adoption, together with the scalability challenges.

A study into privacy-preserving design of smart contracts was conducted by Xu et al. [7], showed that there exist ways to conduct contract activities within the public blockchain architecture while maintaining the privacy. In terms of protocol, Wood [8] proposed a formal definition of the Ethereum architecture, consisting of the Ethereum Virtual Machine, transactions, state transitions, and computations based on gas. Recent implementation-oriented studies illustrate the progression of blockchain design concepts into actual payment platforms. Gondi [9] proposed a blockchain-powered mobile application for decentralized payments and shows how the integration of applications with blockchain technology can be implemented in practice. Similarly, Sakthimurugan et al. [10] studied the secure blockchain-based payment systems dedicated to e-commerce with a focus on transaction security and decentralized settlement. However, there is still a need for blockchain integrated e-commerce prototype, which would include integration of wallet authentication, smart contract-controlled escrow system, transactions logging and security validation.

3. System Architecture and Methodology

The proposed blockchain-based e-commerce solution is designed using a layered architecture that combines the traditional web-based technology together with the Ethereum smart contract to enable decentralized payment processing.

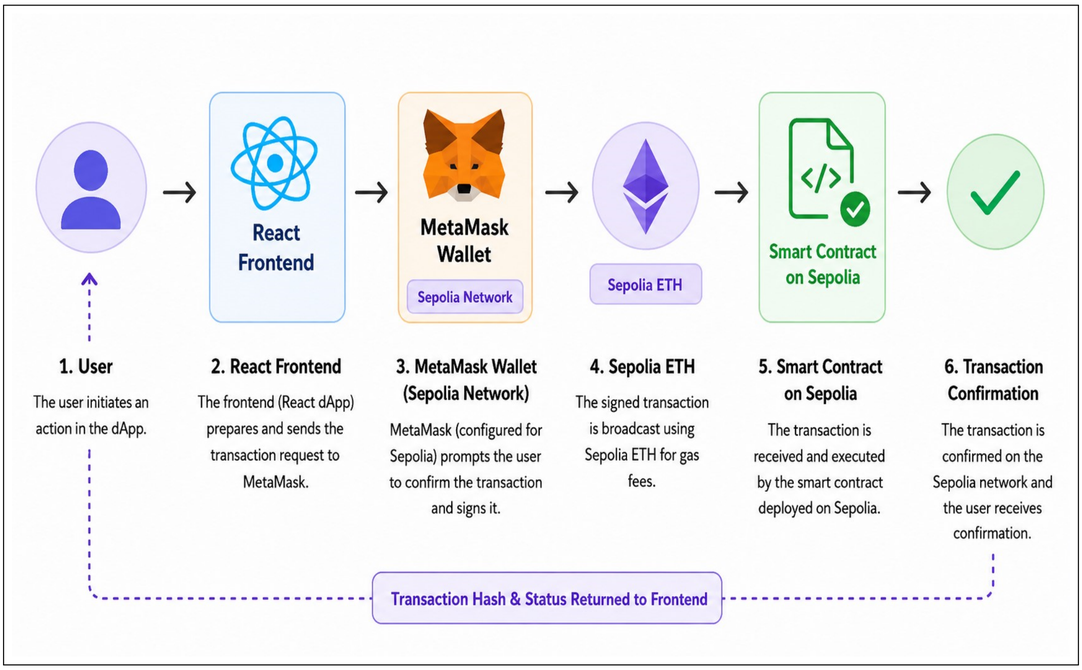

Figure 1. Transaction flow using Sepolia testnet and MetaMask integration

As depicted in Figure 1, the proposed framework segregates business logic from transaction management by retaining the product details, session, and application services off-chain but performing the payments operation via smart contract on the blockchain.

The system's architecture, illustrated in Figure 2, is composed of five layers: user layer, presentation layer, application layer, blockchain layer, and ledger layer. Users and customers engage with the application by means of ReactJS-based user interface, which was developed with the help of TypeScript and Tailwind CSS. Application layer is designed based on Node.js and Express.js, controls the business logic, REST APIs, and interactions with blockchain services with the help of Web3.js. Solidity smart contracts run on the Ethereum Sepolia and are used for transaction settlement.

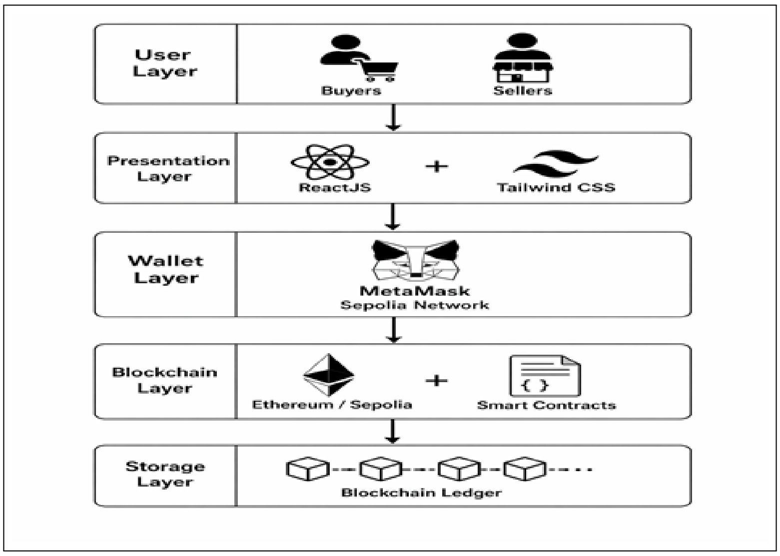

Figure 2. Architecture of the proposed blockchain- enabled e-commerce platform

The network configuration used during development is summarized in Table 1, while the implementation technologies are presented in Table 2.

Table 1. Sepolia network configuration parameters

Parameter	**Value**
Network Name	Sepolia
Chain ID	11155111
Currency Symbol	SepoliaETH
Block Time	12–15 seconds
MetaMask Support	Native
Faucet Available	Yes (multiple sources)

Table 2. Software requirements

Component	**Technology**
Operating System	Windows 10/11 or Linux
Frontend	ReactJS with Tailwind CSS, TypeScript

Backend	Node.js with Express.js, Next.js
Blockchain Platform	Ethereum (Sepolia Testnet)
Smart Contract Language	Solidity
Development Tools	VS Code, Git, Hardhat/Truffle
Wallet Integration	MetaMask
Web3 Library	Web3.js or Ethers.js

The proposed payment method utilizes a state transition model controlled by a smart contract. Each order goes through several predefined states within a transaction process such as order creation, locking of the payment, settlement, refund, and completion. The state transition is allowed only after confirming transaction ownership, payment value, and current order status.

Smart contracts were designed using Solidity version 0.8.x and deployed on the Ethereum Sepolia network. Execution of the smart contracts occurs based on the transaction mechanism of Ethereum where each state change request is verified by the blockchain prior to updating the ledger. Communication between application and blockchain occurs via MetaMask and Web3.js, with MetaMask doing the local transaction signing while Web3.js handles invoking and fetching responses from the contract.

4. Implementation

The developed prototype is implemented using MERN and Ethereum blockchain services. For the purpose of developing the frontend, the ReactJS framework was used, whereas Node.js and Express.js helped in creating the backend services for users, products, and application management. Solidity was used to code the decentralized payment mechanism, while Remix IDE was used as the main development tool (refer to Figure 3).

After successful compilation, ABI was embedded into the frontend side to allow the web app and the smart contract to communicate with each other. Deployment of the contract was done in the Ethereum Sepolia network via MetaMask Injected Provider.

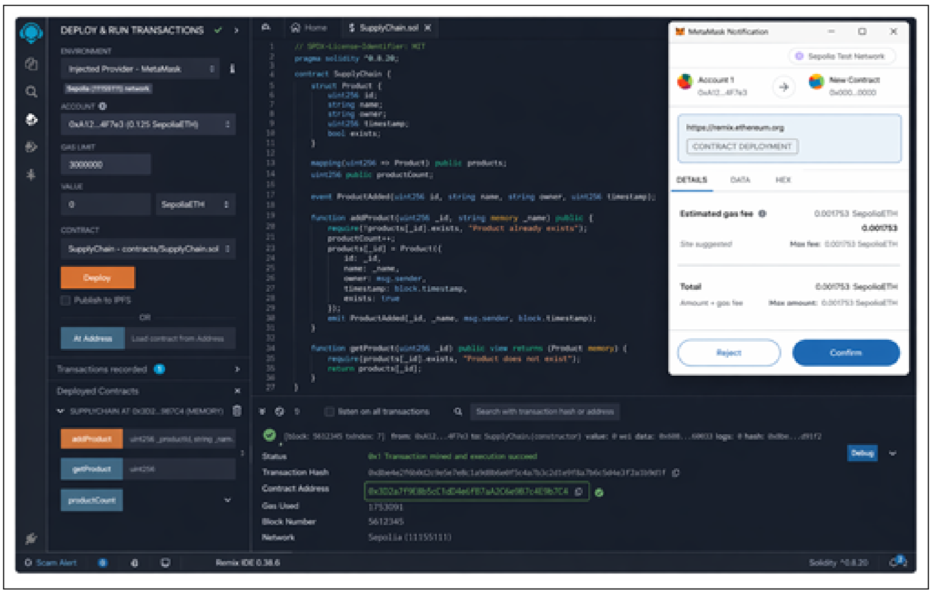

Figure 3. Smart contract deployment using Remix IDE and MetaMask on the Ethereum Sepolia test network

The blockchain interface was accomplished using the Web3.js technology that facilitated the ability for the app to call smart contract functions, get transaction receipts, and listen to blockchain events. The user authentication and transaction authorization were done using MetaMask that allowed the creation of a connection between the wallet and the application securely by generating signatures without having to expose any private keys.

System validation was conducted through four complementary testing stages.

- Unit testing verified the correctness of smart contract functions and application modules.
- Integration testing evaluated communication between the frontend, backend, wallet, and blockchain network.
- End-to-end testing reproduced complete buyer and seller transaction workflows to verify application interoperability.
- Blockchain-specific testing focused on transaction execution, access control, gas optimization, and smart contract reliability.

5. Results and Discussion

The proposed blockchain-enabled e-commerce platform was experimentally evaluated on the Ethereum Sepolia test network to validate its functional correctness, transaction performance, security, and operational feasibility. Evaluation mainly concentrated on smart contract deployment, transaction latency, transaction cost behavior, functionality verification, and security strength. The experiment process was conducted according to the implementation approach that was discussed in Section 4, where smart contracts were deployed via Remix IDE and accessed with MetaMask wallets.

5.1 Smart Contract Deployment

The smart contract was successfully deployed on the Ethereum Sepolia network after compilation using Solidity version 0.8.25. The deployment parameters are summarized in Table 3.

Table 3. Smart contract deployment details on Sepolia

Parameter	Value
Network	Sepolia Testnet
Chain ID	11155111
Deployment Gas Used	2,345,678 Gwei
Deployment Cost	0.0234 SepoliaETH
Contract Verification	Verified on Sepolia Etherscan
Solidity Version	0.8.25

The deployment confirms the accuracy of the implemented smart contract and demonstrates compatibility with the Ethereum Virtual Machine (EVM). The contract has been verified using the Sepolia blockchain explorer which makes the process more transparent as each transaction made by the application can be individually verified using its transaction hash. Since the Sepolia network is a proof of stake public test network, it mimics the exact functioning of Ethereum Mainnet without any financial risks.

5.2 Transaction performance analysis

Transaction latency represents the elapsed time between transaction submission and blockchain confirmation. The experimental observations are presented in Table 4.

Table 4. Transaction latency results on Sepolia network

Transaction Type	Avg Latency (s)	Std Dev (s)
Order Creation (Payment Lock)	14.2	2.3
Order Confirmation (Release)	13.8	1.9
Order Cancellation (Refund)	14.5	2.1
Product Listing (Write)	13.5	1.8
View Functions (Read)	0.05	0.01

From the experimental results, it is seen that write operations on the blockchain needed one confirmation per block, having confirmation times of 13.5 to 14.5 seconds on average. Low standard deviations in network behavior are seen from the experiment conducted. Order creation and refunds took longer for confirmation due to extra state modifications. On the other hand, read transactions required a mean execution time of only 0.05 seconds since they call Ethereum RPC locally without being involved in blockchain consensus protocol. It is evident that there exists a significant computational difference between state changing transactions and read queries.

5.3 Transaction Cost Analysis

Table 5. Cost comparison with traditional systems

Payment System	Cost	Processing Time
Blockchain (Sepolia)	~0.001-0.002 ETH	12-15 seconds
Credit Card	2-3% ($2-$30)	1-3 days
Bank Transfer	$5-$50 + FX	2-5 days
PayPal	2.9% + $0.30	Instant-24 hours
Wire Transfer	$25-$50	3-7 days

The comparative transaction costs are summarized in Table 5. Unlike traditional payment infrastructures that involve banks or centralized payment gateways, blockchain settlement eliminates intermediary processing fees. Consequently, transaction confirmation occurs within a single blockchain confirmation interval instead of requiring multi-stage financial settlement.

Although the observed transaction costs on Sepolia are represented using test ETH and therefore cannot directly represent production expenses, the results illustrate the economic characteristics of decentralized payment systems. Actual deployment on Ethereum Mainnet or Layer-2 solutions would depend on prevailing network gas prices and congestion.

5.4 Functional validation

The functional validation results presented in Table 6 demonstrate that all major modules of the proposed platform operated successfully throughout the testing process.

Table 6. Functional validation results of the proposed blockchain e-commerce platform

Functional Module	Test Scenario	Expected Outcome	Observed Result
Wallet Authentication	Connect MetaMask wallet	Wallet address retrieved successfully	Successful authentication with account recognition
Network Validation	Switch to Sepolia network	Correct blockchain network selected	Automatic network detection and switching
Product Management	Browse and retrieve product catalog	Product details loaded without errors	Product information displayed correctly
Order Creation	Create blockchain-backed purchase order	Order recorded and payment escrow initiated	Order successfully created with transaction hash
Payment Verification	Verify transferred cryptocurrency amount	Smart contract validates payment	Correct payment accepted and confirmed
Escrow Settlement	Seller confirms product delivery	Escrow amount released to seller	Funds transferred after successful verification
Refund Processing	Cancel order before completion	Escrow returned to buyer	Refund executed successfully
Blockchain Traceability	Verify transaction on Sepolia Explorer	Transaction publicly traceable	Transaction hash verified successfully

5.5 Security Evaluation

Security analysis was performed to determine the vulnerabilities that are common to blockchain implementations like re-entrancy attacks, unauthorized access, arithmetic overflow, and wallet vulnerabilities.

The developed smart contract uses the Checks-Effects-Interactions execution pattern which greatly minimizes the chances of encountering reentrancy attacks. The current version of Solidity (0.8.x) automatically prevents overflow and underflow of integers through arithmetic validation at the level of compilation. Role-based access control guarantees that only authorized users are able to perform administration actions and change transaction statuses.

Private keys remain within the MetaMask wallet and are never communicated to the application server, thereby ensuring that the users will retain ownership of their cryptographic certificates. Altogether, the above facts confirm that the proposed platform can provide a secure execution environment.

6. Conclusion

This study has proposed the design, development, and evaluation of a blockchain-supported e-commerce solution with integrated decentralized cryptocurrency payment systems and traditional web-based shopping services. A hybrid Web2/Web3 system architecture was used to perform application-specific activities and the blockchain-specific payment process was used to minimize the on-chain storage space and ensured transparency and tamper-resistance in the transaction records. The Ethereum-based smart contract framework was used to automate the entire payment and escrow process along with MetaMask for wallet-based transaction authorization. The prototype was successfully implemented on the Ethereum Sepolia test network, and experimentally verified through deployment verification, transaction latency, transaction cost, functionality, and security analyses. The results confirm that the proposed platform has enabled reliable payment processing in a decentralized manner, and ensured the seamless integration of web technologies with the blockchain infrastructure. In the future, the implementation of the proposed platform will be carried out on Ethereum Mainnet or Layer-2 networks.

References

[1] Nakamoto, Satoshi, and A. Bitcoin. "A Peer-to-Peer Electronic Cash System." 2008, pdf 4, no. 2, 15. [Online]. Available: https://bitcoin.org/bitcoin.pdf.

[2] Antonopoulos, Andreas M., and Gavin Wood. Mastering Ethereum: Building Smart Contracts and Dapps. O'reilly Media, 2018.

[3] Zhang, Ruochi, Yi Li, and Li Fang. "PBTMS: A Blockchain-Based Privacy-Preserving System for Reliable and Efficient E-Commerce." Electronics 2025, vol. 14, no. 6, 1177.

[4] Muravev, Maksim, Artiom Kuciuk, Viacheslav Maksimov, Tanzeem Ahmad, and Ajay Aakula. "Blockchain's Role in Enhancing Transparency and Security in Digital Transformation." Journal of Science & Technology 2020, vol. 1, no. 1, 865-904.

[5] Zheng, Zibin, Shaoan Xie, Hongning Dai, Xiangping Chen, and Huaimin Wang. "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends." International Congress on Big Data (BigData congress), IEEE, 2017, 557-564.

[6] Aste, Tomaso, Paolo Tasca, and Tiziana Di Matteo. "Blockchain Technologies: The Foreseeable Impact on Society and Industry." Computer 2017, vol. 50, no. 9, 18-28.

[7] Xu, Lei, Nolan Shah, Lin Chen, Nour Diallo, Zhimin Gao, Yang Lu, and Weidong Shi. "Enabling the Sharing Economy: Privacy Respecting Contract Based on Public Blockchain." In Proceedings of the ACM Workshop on Blockchain, Cryptocurrencies and Contracts 2017, 15-21.

[8] Wood, Gavin. "Ethereum: A Secure Decentralised Generalised Transaction Ledger." Ethereum Project Yellow Paper 2014, vol. 151, no. 2014, 1-32.

[9] Gondi, Madhuri Latha. "Design and Implementation of a Blockchain-Backed Mobile App for Decentralized Payments." 4th International Conference on Automation, Computing and Renewable Systems (ICACRS), IEEE, 2025, 1294-1300.

[10] Sakthimurugan, S., K. Ragini, K. Priyadharsini, Varanasi Srinivas, Zaid Ajzan Alsalami, and Prashant Gupta. "Blockchain-Based Secure Payment Systems for E-Commerce." International Conference on Intelligent Control, Computing and Communications (IC3), IEEE, 2025, 1256-1260.