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Leveraging the Polygon Blockchain for a Secured and Transparent Payment Gateway

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***Abstract* - As digital commerce continues to expand, the need for more secure, transparent, and cost-effective payment systems has never been greater. Payment gateways often struggle with issues like centralized control, data breaches, and high transaction fees-challenges that can erode user trust. This study explores a more modern solution by integrating blockchain technology into payment processing through a system called HappyPay, built on the Polygon network. By tapping into the power of decentralization, smart contracts, and immutable ledgers, HappyPay enhances both the security and efficiency of digital transactions. Developed using the Waterfall model and deployed on the Polygon Mumbai Testnet, the system supports MetaMask and WalletConnect for seamless wallet integration and real-time transaction tracking. With fees as low as 0.70 Nigerian Naira per transaction and processing speeds averaging just 4 seconds, the results highlight how blockchain can make digital payments not only faster and cheaper but also more trustworthy. This work presents a compelling case for reimagining the future of payments with blockchain at its core.**
***Keywords:* Blockchain Technology, Payment Gateways, Decentralization, HappyPay, Polygon Network**

I. INTRODUCTION

The creation of digital payments has significantly changed the financial and commercial sectors, enabling fast, secure, and borderless transactions. Payment gateways act as intermediaries between customers and merchants and are essential to the success of digital commerce. They ensure secure processing by employing advanced encryption techniques to protect sensitive financial data and facilitate seamless interactions between users and financial institutions [1]. However, despite their vast role, payment gateways face issues, including data breaches, fraudulent activities, and limited transparency between customers and merchants. Centralized systems are particularly vulnerable to cyberattacks, which undermine trust and compromise sensitive information [2].

Blockchain technology has emerged as an efficient solution to the challenges faced by traditional payment gateways. Introduced by Satoshi Nakamoto in 2008, blockchain operates as a decentralized, distributed ledger that records transactions in a secure, immutable, and transparent manner. Its decentralized nature removes the need for a central authority, reducing single points of failure and enhancing security. The technology also fosters transparency by enabling participants to access real-time transaction records on a shared ledger, thus improving accountability and trust [3]. In the context of payment gateways, Polygon's ability to reduce transaction costs and process payments quickly is crucial for facilitating real-time transactions across a wide range of platforms. In traditional payment systems, intermediaries such as banks and payment processors often lead to high transaction fees, delays, and a lack of transparency. By utilizing blockchain technology, particularly through Polygon's Layer 2 scaling, payments can be processed directly between parties without the need for intermediaries, thus lowering costs and increasing efficiency [4].

This scalability is particularly important for businesses and developers looking to create payment gateways with blockchain integration. For example, small businesses that may have previously been excluded from blockchain-based payment systems due to the high costs of transactions on Ethereum can now take advantage of Polygon's low fees, making decentralized payments more accessible [5]. In recent years, the integration of blockchain technology into the education sector has gained attention for its potential to address long-standing issues related to credential fraud and verification inefficiencies. This project explores the implementation of NFT-based academic certification systems utilizing blockchain platforms such as Ethereum and Polygon. While Ethereum is widely adopted due to its established standards like ERC721, it is often limited by high transaction costs. Conversely, Polygon, a Layer 2 scaling solution, offers lower fees and enhanced scalability, making it more practical for large-scale deployments [6].

By leveraging these technologies, the project aims to develop a system that ensures the secure, tamper-proof issuance and verification of academic credentials. This approach not only enhances trust in academic records but also promotes cost-effective and efficient verification processes, particularly beneficial for institutions and employers globally. The evolution of blockchain technology has significantly impacted various industries, enabling decentralized, secure, and transparent systems. In the realm of cryptocurrencies, Bitcoin (BTC) was the pioneer, introducing the concept of a decentralized digital currency. However, it was Ethereum (ETH) that showcased the broader capabilities of blockchain through the introduction of smart contracts. Proposed by Vitalik Buterin in 2013 and launched in 2015, Ethereum allowed developers to build decentralized applications (dApps), giving rise to entire ecosystems such as decentralized finance (DeFi), non-fungible token (NFT) marketplaces, and play-to-earn (P2E) gaming platforms [7]. Unlike Bitcoin, which primarily serves as a store of value, Ethereum's programmable blockchain supports a growing range of real-world applications.

Despite its versatility, Ethereum faces challenges related to transaction speed and cost, which have led to concerns over scalability. To address these limitations, Polygon (MATIC) was introduced in 2017 (initially as the Matic Network) as a Layer 2 scaling solution that offloads part of Ethereum's computational workload to its own network. This allows for faster and cheaper transactions while maintaining compatibility with Ethereum's ecosystem. Polygon now offers a variety of scaling technologies, including zkEVM and Polygon CDK, aimed at improving performance without compromising decentralization [7]. These developments provide a strong foundation for blockchain-based applications, including secure and efficient academic certification systems.

Furthermore, smart contracts, which are self-executing agreements that automate transactions based on predefined conditions, streamline processes and significantly reduce operational costs [8]. This study aims to examine how the Polygon blockchain can enhance security and transparency in payment gateways. It will explore the benefits of decentralization, immutable ledgers, and smart contracts in addressing the challenges faced by traditional payment systems.

Additionally, the research will assess the potential obstacles to blockchain adoption, including regulatory concerns and technical complexities, while emphasizing its transformative impact on the digital payment landscape. The objectives of this research are to examine the challenges faced by payment gateways, explore the potential of blockchain technology in addressing these challenges, and develop a Polygon-based payment gateway that solves the issues of transparency and security. This study introduces the use of the Polygon blockchain to improve payment gateways by enhancing security, transparency, and efficiency.

II. LITERATURE REVIEW

This section reviews key concepts about blockchain technology and payment gateways; it also examines related research on blockchain-based payment systems. This review aims to identify the existing gaps within the domain and how the proposed model will bridge those gaps.

A. Related Works

Dutta *et al.,* (2024) introduced a user-friendly, decentralized blockchain payment gateway. The methodology involved implementing the MetaMask wallet for interaction with Ethereum, Solidity smart contracts, and Quick Response (QR) code authentication. Experimental evaluations of the system demonstrate a 95% performance rate, 100% accessibility, and an SEO (Search Engine Optimization) score of 80% based on Google Page Speed Insights. The results highlight high performance, accessibility, and security in payment transactions. However, the research identifies limited real-world adoption, scalability issues, and potential regulatory concerns as challenges.

Atsina (2023) addresses cross-border payment challenges and high transaction costs by developing a blockchain-driven payment system that makes use of digital currencies (cryptocurrencies), which can reduce or even eliminate the need for merchants to deal with multiple currencies, ultimately lowering transaction costs and mitigating security risks, especially in cross-border payments. The study finds that blockchain reduces reliance on multiple currencies, lowers transaction costs, and enhances security. However, the paper highlights implementation complexity and regulatory barriers as limitations.

Naranjo *et al.,* (2024) examined the security benefits of blockchain technology in Ecuador's payment gateways. The study highlights key blockchain features-immutability, decentralization, authentication, and transparency-as critical tools for enhancing transaction security and combating fraud. Digital signatures and smart contracts ensure authorized access, while real-time auditing supports regulatory compliance. The study assesses blockchain's security features and regulatory aspects. Findings reveal improved transaction security, fraud prevention, and compliance support. However, infrastructure limitations and adoption challenges remain significant obstacles.

Mohanty *et al.,* (2022) explore blockchain interoperability for decentralized financial systems. The research analyzes atomic swaps and cross-chain transactions, finding that interoperability reduces transaction costs and reliance on centralized systems. It also explains how it can reduce costs and reliance on central systems. However, unresolved challenges in scalability and cross-chain communication hinder widespread adoption.

B. Review of Key Concepts

With the increasing demand for secure and transparent digital systems, blockchain technology has emerged as a promising solution for decentralizing data and eliminating trust-based vulnerabilities. In particular, the use of smart contracts has proven effective in ensuring that user credentials and transactions remain tamper-proof and verifiable. [13] demonstrated how decentralized authentication, built on the Ethereum blockchain, could enhance data security by removing the risks associated with centralized control. Their work provides a strong foundation for blockchain-based systems that require robust identity and transaction verification mechanisms. Drawing from this model, the present project focuses on leveraging the Polygon blockchain to design a secure and transparent payment gateway. This system aims to facilitate trustless digital transactions by ensuring that payment records are immutable, cryptographically secure, and accessible, aligning

C. Polygon Blockchain

Polygon (formerly known as Matic Network) is an innovative Layer 2 scaling solution designed to address the limitations of Ethereum, such as high transaction costs and slow processing speeds. It has quickly become one of the most widely used and recognized blockchain projects, offering a scalable and efficient alternative for decentralized applications (dApps) and decentralized finance (DeFi) protocols. This review explores the strengths and weaknesses of the Polygon blockchain, its core technologies, its applications, and its role within the broader blockchain ecosystem [5]. One of the primary reasons Polygon has gained popularity is its ability to enhance Ethereum's scalability. Ethereum, while decentralized and highly secure, faces significant issues with transaction speed and gas fees, particularly during periods of high demand [14]. Polygon solves this problem by providing a Layer 2 framework, including sidechains, Plasma, and Optimistic Rollups, which process transactions off the main Ethereum chain, thus reducing congestion and enabling faster, cheaper transactions [5] Polygon's use of sidechains, in particular, allows it to process transactions independently of Ethereum, periodically committing results back to Ethereum for security [4]. This method significantly improves throughput while preserving Ethereum's decentralized nature.

D. Overview Payment Gateway

Payment gateways are digital platforms that facilitate financial transactions between customers and merchants, playing a crucial role in e-commerce and online payment systems. These gateways authenticate and authorize payments, ensuring secure fund transfers. A payment gateway can authenticate and route payment details in an extremely secure environment between various parties and related banks. The payment gateway functions, in essence, as an "encrypted" channel, securely passing transaction details from the buyer's personal computer (PC) to banks for authorization and approval. Upon gaining approval, the payment gateway sends back the information to the merchant, thereby completing the "order" and providing verification [14]. A payment gateway is immensely justifiable due to the multiple benefits it offers, including: real-time authorization of credit/debit cards, rapid and efficient transaction processing, multiple payment options, secure flow of transaction details among buyers, sellers, and financial institutions, flexible and powerful real-time report generation, multi-currency settlements (if needed), the facility for customer refunds, merchants can eliminate large databases, extensive processing, and complex software, CA (certifying authority) authenticated secure servers, collection of bulk data in a cost-efficient manner (with the additional benefit of card validity checks), access to card "hot-lists" to filter out fraudulent transactions, the ability to provide value-added services to merchants, acquiring and issuing banks, provision for multiple host interfaces, comprehensive and simple administrative control, and stringent security measures to gain customer and merchant trust. However, centralized payment gateways often face challenges such as limited transparency, high transaction costs, and susceptibility to fraud [15].

III. METHODOLOGY

This study adopts a waterfall model for the development and integration of the system. The model is suitable because it ensures a systematic development process that allows for clear planning, design, implementation, and testing. The methodology includes system design, user interface design, and system implementation.

A. System Design

The system leverages the Polygon blockchain, which is known for scalability and low transaction fees. It also ensures transparency, security, and immutability. Using the Polygon blockchain is better because it offers lower transaction fees compared to the Ethereum blockchain. The system also uses MetaMask for user authentication and transaction management. The Wallet Connect option serves as an alternative connection method for mobile users, allowing them to connect using a QR code. The smart contract was developed using Solidity to automate transactions, ensuring a secure, tamper-proof agreement between users without the need for a third party. The user interface was designed using HTML, CSS, and JavaScript to create a responsive, user-friendly experience where users can connect their wallet, view their balance, send and receive payments, and view transactions on the interface.

B. User Interface

Built with HTML, CSS, and JavaScript for seamless user interaction, the user interface contains the login page with WalletConnect integration and a dashboard section that displays the user balance, live transaction viewer, and send and receive buttons for fund transfers. The interaction flow starts when the user logs in and connects their wallet. Then the user selects the payment method, and after paying, they view their transaction in real time.

C. Implementation

The system was implemented on the Polygon Mumbai Testnet, a testing environment that mimics the Polygon Mainnet but differs by using tokens for risk-free transactions. The development for this research involved several tools and technologies.

Visual Studio was used for writing and managing the frontend code, while Remix IDE served as a platform for developing and testing the smart contracts. MetaMask was utilized for wallet management, enabling secure user interaction with the blockchain. Solidity was used to develop the smart contract, alongside HTML, CSS, and JavaScript for designing a responsive user interface. Additionally, wallet integration was achieved using both MetaMask and WalletConnect to ensure seamless and secure user authentication.

IV. RESULTS AND DISCUSSION

A. System Workflow and Design

1. Data Flow Diagram

The data flow begins with a user initiating a payment via a web or mobile interface. The frontend communicates with a backend server integrated with Polygon nodes.

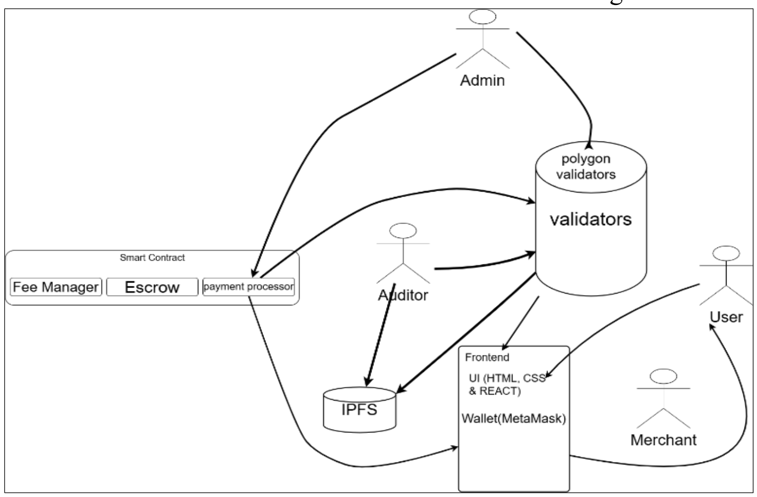

Fig.1 Data Flow Diagram

Smart contracts, written in Solidity and deployed on the Polygon Mumbai Testnet, validate transaction parameters. Validated transactions are broadcast to the Polygon network, where validators confirm and add them to blocks. Transaction metadata, e.g., invoices, is stored off-chain on InterPlanetary File System (IPFS), with content identifiers (CIDs) recorded on-chain for transparency.

2. Use Case Diagram

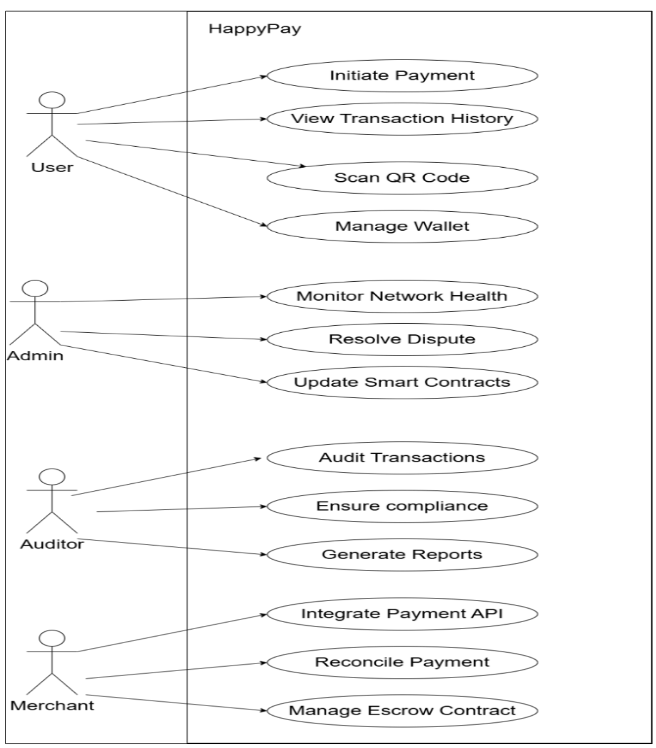

Fig.2 Use Case Diagram

Key factors include users, whose duties are to initiate payments, check balances, and view history; admins, who monitor network health to ensure safety at all times and resolve disputes; auditors, who verify transaction integrity;

and merchants, who confirm and validate transactions done by users. Use cases span payment initiation, automated escrow releases via smart contracts, real-time status updates, and dispute resolution. For example, a user initiating a payment triggers a smart contract that locks funds until predefined conditions (e.g., product delivery) are met, ensuring trustless execution.

3. Activity Diagram

This shows the flow of activities in the system and how each actor plays a part. The user starts the flow by initiating a payment. They can also check their balance and perform other essential tasks on the system. The system then validates the transaction through the Polygon blockchain and updates the ledger. The admin monitors the node to check for vulnerabilities, and finally, the auditor generates a complaint report.

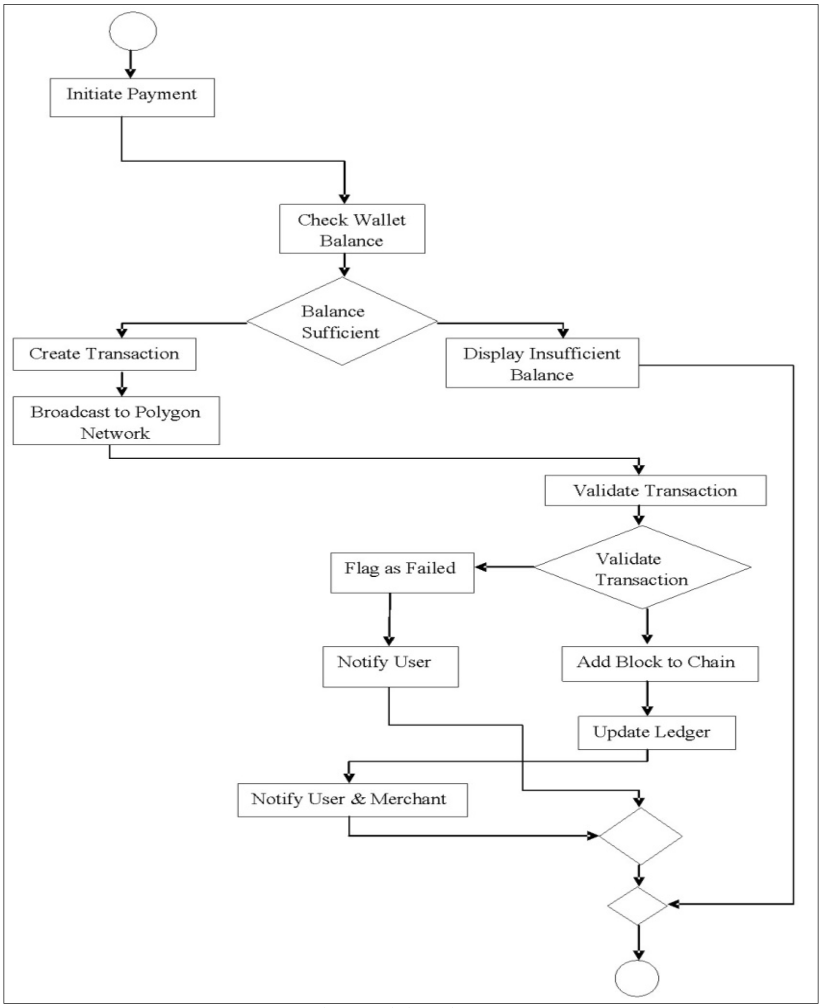

Fig.3 Activity Diagram

4. User Interface and Wallet Integration

MetaMask serves as the primary wallet provider for direct interaction with the Polygon blockchain. It is a browser extension and mobile application that allows users to store, manage, and transact cryptocurrencies securely. When a user attempts to access the payment gateway, they will be prompted to connect their MetaMask wallet. Upon successful connection, MetaMask will provide the user with access to their account balance and transaction history, ensuring that they can verify their funds before proceeding with any payment. Once connected, the payment gateway requires the user to sign a verification message. This message is used to authenticate the user and confirm their intent to interact with the platform. By approving this sign-in message, the user grants access to initiate transactions using their wallet.

This process ensures that transactions are only carried out with the user's consent, enhancing security and preventing unauthorized access to funds. After approval, the user balance is updated on the payment gateway interface, allowing them to proceed with their payments. WalletConnect is an alternative wallet connection method that enhances accessibility by providing QR code-based authentication. Unlike MetaMask, which operates as a browser extension, WalletConnect allows users to connect to decentralized applications using their mobile wallet by simply scanning a QR code. It will redirect the user to

MetaMask to complete the transaction seamlessly. This is particularly useful for users who prefer transacting on a mobile device rather than through a browser extension. The WalletConnect feature works by generating a QR code that the user can scan. Once scanned, the user is directed to MetaMask, where they will approve the connection request.

This establishes a secure link between the payment gateway and the user's wallet, allowing for seamless interaction. The QR code ensures that the user can securely access the payment platform without the need for a browser extension, making it compatible and feasible for all users. After the wallet has been successfully connected, the user can proceed with transactions. The payment gateway ensures that all payments are validated on the Polygon blockchain, confirming the transparency of each transaction. Once a transaction is completed, users have the option to disconnect their wallet from the payment gateway to enhance privacy and security. However, they may also choose to leave their wallet connected for future transactions, reducing the need for repeated authentication.

5. Performance Evaluation

TABLE I PERFORMANCE EVALUATION

Aspect	Metrix	Results	Performance
Security	Smart Contract Security Encryption Verification Access Control	No Vulnerability Https, Secured Wallet Connection Unauthorized Access Blocked	Good Good Good
Transaction Efficiency	Transaction Speed Gas Fee Scalability	4seconds Average Matic (0.7NGN) >500 User	Good Good Good
User Experience	UI Responsiveness User Auth Speed Ease Of Use	65% For Desktop <2 Seconds 3.5/5	Fair Excellent Fair

6. Smart Contract Deployment

Smart contracts are the backbone of this work, serving as autonomous, trustless agreements that execute predefined rules without intermediaries. Their role is critical for achieving the project's goals of security, transparency, and efficiency. The purpose of developing smart contracts is to eliminate the need for intermediaries, enhance security in agreements, and enable trust-based transactions. The key functions of smart contracts in this study include processing payments, resolving disputes between the gateway and users, providing escrow services, and managing and reducing transaction fees. The smart contract was developed with Solidity, an object-oriented programming language that supports the Ethereum Virtual Machine, and it was deployed on the Polygon blockchain to help validate and ensure transactions are carried out in an organized manner. The smart contract was deployed on the Mumbai Testnet network using Remix IDE.

V. CONCLUSION AND RECOMMENDATIONS

The successful implementation of this study demonstrates the practical potential of blockchain, especially the Polygon network, for a digital payment solution. By harnessing its scalability, low transaction fees, and EVM compatibility as a layer-2 solution, we created a system that meets modern demands for security, transparency, and efficiency. Throughout this study, we ensured adherence to best practices in smart contract development, cryptographic security, and user privacy. This payment system can serve purposes beyond payments; it can also function as a foundational layer for other blockchain-based financial services. This project underscores the relevance and readiness of decentralized finance (DeFi) tools in solving real-world transaction issues. In the future, we hope to improve the current functionalities of the system to increase efficiency and add more features. Some of the future recommendations were made due to time constraints, which the study aims to implement later:

A. Regulatory Compliance

Depending on the target market, it is important that this system complies with financial regulations and data protection laws to avoid being flagged as fraudulent and banned in the global market.

B. Token Integration

We should consider incorporating stablecoins like Bitcoin or native coins like Ethereum to offer flexibility in pricing, rewards, and liquidity within the payment system.

C. UI/UX Improvements

A user-friendly and intuitive interface can significantly enhance user trust and adoption, especially among non-technical users.

D. Scalability Enhancement

Future improvements could integrate other layer-2 solutions to test how the system operates across multiple blockchains, improving interoperability and expanding usability.

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