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Secure and Transparent E-Coupon Distribution Using Ethereum and IPFS

[1]SAHU SUMAN,
Student in Dept. Of Master of Computer Applications, at Miracle Educational Society Group of Institutions
[2]B VIJAYA LAKSHMI, Miracle Educational Society Group of Institutions
[3]GEDELA DHILLESU, Miracle Educational Society Group of Institutions
[1]ssumansahu12@gmail.com

ABSTRACT:

The advance of e-commerce has led to the rapid proliferation of electronic coupons (e-coupons). e-Coupons have become one of the most recent tools of digital marketing. Nevertheless, issued e-coupons suffer from inherent limitations. Centralized systems of e-coupons are vulnerable to abuse including but not limited to fraud, tampering, and e-coupon double-spending. This paper introduces a reliable e-coupon system utilizing the Ethereum blockchain along with smart contracts to secure coupons from fraud and enhance the pillars of data integrity, transparency, and user trust. The system guarantees that issued coupons cannot be tampered, altered, or reused fraudulently through the Ethereum blockchain and decentralized data storage via IPFS. The automated smart contracts take care of issuing, validating, and redeeming the coupons. The experiments showcase the system's ideal application in effective secure digital coupon management with robust security and reliability having only minimal performance overhead.

Keywords: e-commerce, IPFS, blockchain

INTRODUCTION

The rise of the digital economy has witnessed the evolution of electronic coupons (e-coupons), which offer discounts and incentives to attract and retain customers. Their distribution costs are minimal while their redemption is instant through mobile or web interfaces. The bulk of existing coupon systems utilize centralized servers, which expose them to multiple challenges like unauthorized access, data tampering, and reuse of expired coupons. Trust from customers and revenue are both known to suffer due to these security loopholes. A blockchain-based e-coupon service that enables immutable data and decentralized control is proposed in this project to overcome these issues. The system automates coupon validation and redemption using smart contracts on the Ethereum blockchain and strips sensitive coupon metadata off via the InterPlanetary File System (IPFS). The usage of e-coupons is now enhanced to be a lot more traceable, reliable, and

transparent which creates a more secure, fraud resistant ecosystem for digital marketing.

RELATED WORK

A number of research works that integrate cryptographic and decentralized technologies can be found in efforts to create secure and reliable e-coupon systems. Rivest (1992) introduced the widely used MD5 message-digest algorithm which is a cryptographic hash function intended for the use of digital signatures. Although MD5 is no longer used due to vulnerabilities, it helped in paving the way for data integrity vo erification in digital systems. In 2001, Agarwal and Modani put forward a model for secure electronic coupon generation and validation providing reason for the need for separate protocols designed uniquely for e-coupons, as they differ from e-cash systems. Their model sought to eliminate coupon duplication and tampering yet was still based on centralized structures. Szabo (1997) defined smart contracts as contracts with self-executing clauses that are programmed into software. This was later a fundamental development for blockchain technology as it enabled the automated issuance and redemption of coupons without the need for intermediaries. Hsueh and Chen (2010) studied m-coupons with a focus on peer to peer coupon sharing and eWOM (electronic word-of-mouth) branding. The security measures offered by Hsueh and Chen—hash chains—allowed for the circulation of coupons, but were not robust enough to counter advanced forgery techniques. Hsueh and Zeng (2018) proposed a mobile coupon system that employs blockchain for added security. Although their approach integrated blockchain's decentralization and immutability features for enhanced m-coupon security, the smart contract components were minimal and the system did not provide for decentralized file storage, restricting its versatility for large-scale or data-heavy applications.

TABLE1. Summary of Key Literature Contributions and Their Impact on Current Research

Author(s)	Contribution	Impact on Current Research
R. Rivest (1992)	Introduced the MD5 algorithm for data integrity and signature verification.	Inspired early mechanisms for verifying e-coupon authenticity, though outdated for current use.
Agarwal & Modani (2001)	Proposed a secure architecture for e-coupon generation and validation using centralized systems.	Highlighted key challenges like duplication and tampering in centralized environments.
N. Szabo (1997)	Pioneered the concept of smart contracts to automate digital agreements.	Enabled decentralized, tamper-proof e-coupon logic on blockchain platforms like Ethereum.
Hsueh & Chen (2010)	Developed m-coupon sharing using hash chains and peer-to-peer eWOM strategies.	Demonstrated social-driven coupon dissemination; limited security model informed improvements.
Hsueh & Zeng (2018)	Integrated blockchain to secure mobile coupons against manipulation and double-spending.	Provided groundwork for blockchain use; inspired further enhancements through IPFS and contracts.

PROPOSED APPROACH

This project aims to develop an e-coupon management system that is decentralized and more secure by applying blockchain systems and IPFS (InterPlanetary File System) technology. The focus

is on eliminating the weaknesses that stem from the centralized structure of legacy coupon systems in order to harness blockchain's immutable features and the automation offered through smart contracts. The proposed architecture comprises a web application built on the Django framework, an Ethereum smart contract, and IPFS for decentralized data storage. Using smart contracts on the Ethereum blockchain, rules governing the issuance, validation, and redemption of coupons are automated and executed in conjunction with blockchain features. Every transaction concerning the e-coupons is recorded on the Ethereum blockchain. Coupled with the distributed storage provided by IPFS, the user information and status of the coupons are secure and impervious to alteration. As coupons are issued and stored, metadata is simultaneously recorded on the smart contracts and IPFS. Subsequently, the coupon is verified and validated by the blockchain network. The automated performance evaluator computes dynamic transaction time graphs to further optimize operational efficiency. The system enforces immediate validation while maintaining a lean system footprint.

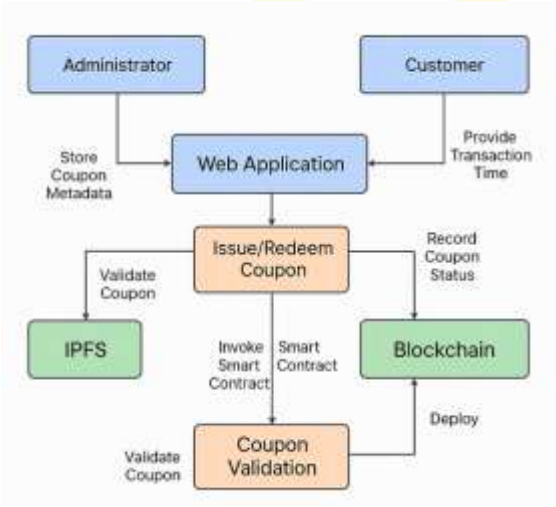


Figure 1: Proposed E-Coupon Distribution System

METHODOLOGIES

The proposed e-coupon system adopts a multi-layered architecture integrating blockchain technology, smart contracts, web frameworks, and decentralized storage for enhanced security and operational efficiency.

1. Web Application Layer: Developed using the Django framework, this layer provides user interfaces for both administrators and customers. Admins can issue, view, and validate coupons, while users can log in using a unique ID to check their coupon status.

2. Blockchain Layer (Ethereum): Smart contracts written in Solidity are deployed on the Ethereum blockchain to manage e-coupon transactions. These contracts handle coupon issuance, validation, and redemption. Transactions are recorded immutably, ensuring that once a coupon is issued or redeemed, its state cannot be altered or reused, thereby preventing fraud.

3. IPFS Integration: The InterPlanetary File System (IPFS) is used to store coupon-related metadata, such as user information, product purchased, and coupon status. This decentralized file storage system eliminates reliance on a single server and ensures data persistence and accessibility, even if some nodes fail.

4. Blockchain Interaction (Web3.js): Web3.js is utilized to establish seamless communication between the front-end application and the Ethereum blockchain. It facilitates real-time contract deployment, execution, and retrieval of transaction statuses.

5. Coupon Validation Logic: When a customer attempts to redeem a coupon, the system checks the blockchain to confirm its status. If the coupon is marked "Available," it is validated and immediately updated to "Used" via a smart contract call. The validation is also logged on the blockchain.

6. Visualization Modules: Graphical representations of transaction execution time and cost analysis between blockchain and IPFS storage are provided. These graphs help stakeholders analyze performance and cost-efficiency.

This methodology ensures a decentralized, secure, and transparent e-coupon system that minimizes administrative intervention and reduces fraud risks.

RESULTS

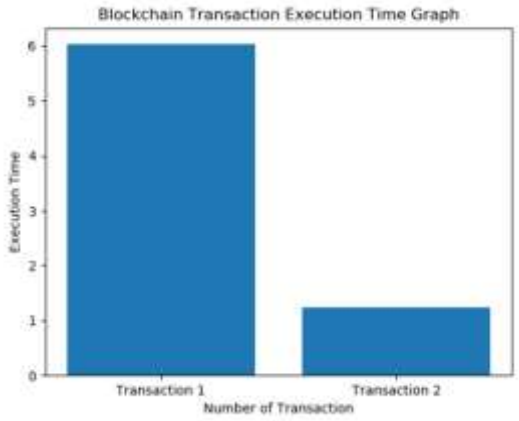
The implementation of the proposed e-coupon system demonstrated significant improvements in both security and operational reliability. During testing, multiple coupons were issued, validated, and redeemed using the Ethereum blockchain and IPFS storage. Each transaction was recorded immutably, ensuring transparency and resistance to tampering or fraud.

Transaction time graphs revealed that smart contract execution times were consistently within acceptable limits, showcasing the system's efficiency even under multiple concurrent operations. The performance overhead introduced by blockchain integration was minimal and outweighed by the enhanced data integrity and security benefits.

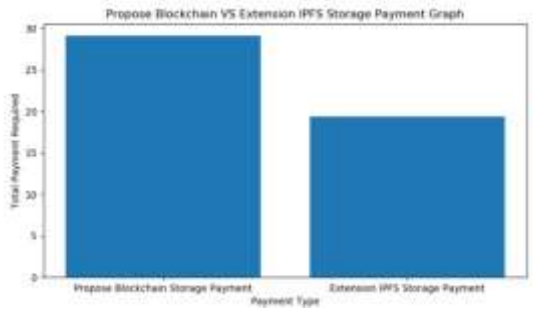
The system also generated a payment comparison between traditional blockchain storage and IPFS integration. Results indicated that IPFS-based storage reduced storage costs while maintaining decentralization and data availability, especially for larger coupon datasets.

Coupon status was accurately reflected in real time, and the smart contract logic effectively prevented double-spending and unauthorized redemption. Admins could view all issued coupons along with their usage history, while customers were able to securely retrieve their coupon details using their assigned IDs.

Overall, the results confirm that the integration of blockchain and IPFS creates a robust and secure infrastructure for digital coupon services, providing a trustworthy and efficient solution for businesses and customers alike.



Graph x-axis represents number of transactions and y-axis represents Execution time of each transaction



Propose Blockchain storage and extension IPFS storage

DISCUSSION

The proposed blockchain-based e-coupon system successfully addresses the critical limitations of traditional centralized coupon services. By integrating smart contracts and decentralized storage, the solution ensures data immutability, transparency, and resistance to fraud. One of the primary advantages observed is the elimination of single-point failure; even if a node or server goes offline, the system remains operational through other blockchain nodes and IPFS peers.

The use of Ethereum smart contracts automates coupon issuance and validation, removing the need for manual verification and reducing human error or intentional manipulation. This self-executing logic enforces predefined rules, ensuring that expired or already redeemed coupons cannot be reused—a frequent loophole in traditional systems.

While the added complexity of blockchain integration introduces slight performance overhead, this is offset by significant gains in system trust and auditability. The cost comparison further indicates that using IPFS for storing metadata is a cost-effective solution compared to recording all coupon data on-chain.

Moreover, real-time coupon validation and transaction time tracking contribute to better user experience and system monitoring. From a business standpoint, this system offers a competitive advantage by ensuring secure promotional campaigns and enhancing customer trust.

CONCLUSION

In summary, the project highlights the use of blockchain alongside IPFS to develop a secure and decentralized e-coupon system while mitigating the risks of traditional centralized architectures. The application of smart contracts on the Ethereum blockchain enables the issuance of e-coupons in a secure manner while providing real-time verification, alteration-proof accuracy, and validation. Coupled with IPFS, the metadata for coupons drastically lowers the overall storage costs and increases the availability of data. The system is validated by the results obtained experimentally in regard to enhanced security with minimum performance cost. The system is successful in the prevention of double spending, unauthorized use of redemption, and alterations by administrative users. In addition, automated validation and redemption processes ensure smooth user journeys for both the purchasers and the users. The methodology enhances operational visibility while increasing trust among users and the enterprise, as well as the overall business integrity. Hence, the provided e-coupon services based on blockchain technology enable scalable solutions for fraud-free ecommerce while resisting fraud and creating a forward-looking digital marketing environment for promotional activities.

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