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Chain Your Loot: Implementing Blockchain into Gaming Loot Box Markets

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***Abstract*—Concerns regarding loot box fairness, along with increased exploitations of video game players and a lack of trustworthiness in video games and their merchandise, continue to rise, yet these issues have received limited attention and research. In response, this study introduces an Ethereum blockchain-based solution aimed at addressing the lack of transparency and fairness in loot box markets. Emphasizing transparency, fairness, and player trust, our model employs smart contracts to disclose reward probabilities to players, promoting informed decision-making. Central to our approach is the integration of a Random Number Generator (RNG) within the smart contract to ensure impartial outcomes. Deployed on the Sepolia testnet, designed to closely replicate the real Ethereum mainnet, our evaluation highlights improved transaction transparency and fairness. Analysis of Sepolia testnet's performance provides valuable and positive insights into blockchain operational dynamics. This paper contributes to ethical gaming practices by proposing a framework that could reshape how virtual rewards are managed, advocating for blockchain adoption to enhance gaming equity.**

***Index Terms*—Blockchain, Smart Contract, Ethereum, Gaming, Player, Video Games, Loot Box, In-Games Purchases, Solidity, Reward, Transparency, Fairness, Security, RNG, Probabilities**

I. Background and Introduction

A. In-Games Purchases and Loot Box Market

In recent years, the gaming industry has experienced a surge in in-game purchases, especially loot boxes, which are virtual items containing random assortments like cosmetic enhancements, weapons, or characters. The loot box market has expanded significantly, evolving into a multi-billion-dollar industry globally [1].

The economic impact of loot boxes is significant, with major game developers using them to sustain revenue streams. Games like Fortnite, FIFA, and Overwatch have generated billions through in-game purchases, including loot boxes [2]. The "FIFA Ultimate Team" mode, where players buy virtual card packs, has been especially profitable, contributing to EA Sports' annual revenue. In 2020, EA earned over $1.49 billion from its Ultimate Team modes [3].

The loot box model has evolved over time. Initially, they were designed to provide excitement and surprise for players. However, the growing reliance on loot boxes for progression and competitive advantage has sparked widespread criticism. For example, Star Wars Battlefront II faced backlash for its loot box system, which was seen as pay-to-win, leading EA to make significant adjustments to the game's progression system after public outcry [4].

The randomized nature of loot boxes has sparked ethical concerns, with some countries classifying them as gambling. In 2018, Belgium banned loot boxes, citing harm to minors, while the Netherlands fined developers for failing to obtain proper gambling licenses [5] [6]. Furthermore, Loot boxes can trigger gambling-like behaviors, leading to addiction risks, particularly among young players. The UK's Royal Society for Public Health has called for them to be classified as gambling due to these mental health concerns [7] [8].

The lack of transparency in loot box probabilities has raised concerns about consumer rights. Many players are unaware of the odds of receiving rare items, leading to frustration. In response, countries like China and Japan now require developers to disclose loot box probabilities, aiming to protect players from deceptive practices [9].

Overall, while loot boxes are highly profitable for the gaming industry, they have sparked controversy and regulatory scrutiny. The challenge lies in balancing monetization with ethical considerations and player protection, ensuring a fair and transparent gaming environment.

B. Problem Motivation

Loot box systems fundamentally suffer from opacity issues. As demonstrated in Fig. 1, players make significant financial investments without clear probability disclosures, leading to potential harm [10]. This lack of transparency, combined with randomized rewards and high spending potential, raises ethical concerns due to its similarities to gambling mechanics.

Below, we discuss the essential problem motivations that highlight the need for a more transparent and fair approach to loot boxes:

1) ***Lack of Transparency****:* Limited transparency in loot box odds leads to uninformed spending and player frustration, particularly in popular games like FIFA and Overwatch, where players often receive common items instead of desired rare rewards [11].

2) ***Financial Exploitation****:* Loot boxes with random rewards can lead to excessive spending, especially among young players [12]. Stricter regulations and transparency are needed to protect vulnerable users.

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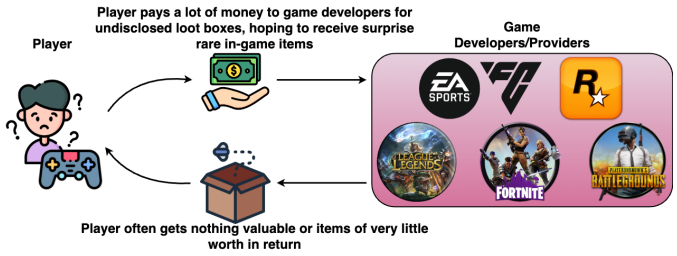

Fig. 1. Player pays game developers for mystery loot boxes, expecting to obtain rare and surprise in-game items, but frequently ends up with items of negligible value or nothing worthwhile.

*3) **Ethical Concerns and Regulatory Scrutiny**:* Loot boxes are increasingly seen as gambling, raising concerns about underage users. Countries like Belgium have banned them, while others are pushing for stricter regulations [5].

*4) **Trust and Fairness**:* The perceived unfairness of loot boxes can damage a game's reputation, as seen with EA's Star Wars Battlefront II [13]. Transparency in odds can improve player trust and satisfaction.

*5) **Data Integrity and Security**:* Proprietary probability systems in loot boxes raise concerns about data integrity, as seen in the 2019 class-action lawsuit against Apple and Kabam regarding "Marvel Contest of Champions" [14]. Consistent and verifiable probabilities are crucial for maintaining player trust.

C. Why Blockchain for Gaming Loot Box Markets?

Blockchain technology, especially on Ethereum [15], offers a robust framework to address loot box challenges. As a decentralized and immutable ledger, blockchain ensures secure and transparent transactions [16]. Ethereum's smart contracts, self-executing contracts with predefined rules, can automate and enforce the terms of loot box agreements [16]. This provides transparency, security, and reliability, making blockchain an ideal solution for managing loot box probabilities and enhancing player trust.

Below, we discuss the essential reasons why blockchain is suitable for addressing the issues with loot boxes:

*1) **Enhanced Transparency through Immutable Records**:* Ethereum's immutable blockchain ensures transparent loot box transactions, allowing players to verify probabilities and inspect the smart contract for accuracy [17].

*2) **Decentralization to Prevent Manipulation of Loot Box Probabilities**:* Ethereum's decentralized network ensures loot box fairness by preventing unilateral changes to odds. Any modifications require consensus from the network [16], [17].

*3) **Smart Contract Automation for Trustworthy Execution of Loot Box Mechanics**:* Ethereum's smart contracts automate loot box transactions based on predefined rules, reducing human error and fraud. These contracts ensure transparent distribution of rewards according to set probabilities, guaranteeing adherence to agreed terms [16], [17].

*4) **Auditable and Verifiable Transactions in Loot Box Operations**:* Ethereum transactions are securely recorded and transparent, enabling verification of loot box outcomes. Auditors can review blockchain records to ensure fairness and integrity [18], [19].

*5) **Integration of Cryptographic Security Measures for Loot Box Integrity**:* Ethereum uses cryptographic protocols to secure transactions and smart contracts, protecting loot box mechanisms from fraud and data breaches. Cryptographic hashing ensures the confidentiality and integrity of data, boosting player trust [20].

II. Existing Studies and Literature Review

In this section, we explore existing research on the application of blockchain technology in gaming, with a focus on smart contracts and loot boxes.

The author of paper [17] explores the potential of blockchain and smart contracts to enhance transparency and trust in loot box mechanisms within video games. The author discusses how blockchain technology can mitigate exploitations by ensuring the integrity and fairness of loot box outcomes. The study also highlights the benefits of using smart contracts to manage and display loot box probabilities, thus promoting a more player-centric approach in gaming. However, while the paper demonstrates the theoretical benefits of blockchain, it does not extensively cover the practical challenges and scalability issues that may arise during real-world implementation.

Similarly, in paper [21], the authors provide a comprehensive economic analysis of loot box markets within blockchain games. They utilize various economic models to assess the impact of blockchain integration on loot box dynamics, focusing on market efficiency and player behavior. The study concludes that blockchain can introduce significant improvements in transparency and trust, potentially altering player engagement and economic outcomes in gaming environments. Nevertheless, the paper primarily focuses on theoretical economic models and lacks empirical data from actual blockchain-based games to support its conclusions.

Furthermore, CoinsLoot [22] is another pioneering project that combines cryptocurrencies with loot boxes to encourage broader participation in the cryptocurrency market. It simplifies the process of acquiring cryptocurrencies by allowing users to open loot boxes containing a mix of cryptocurrencies and real-life items, thus making the entry into the crypto market more accessible and engaging. While this approach is innovative, it raises questions about the randomness and fairness of loot box contents, as well as the potential for encouraging gambling-like behavior among users. Furthermore, the reliance on the platform's native currency, Loot Tokens, introduces an additional layer of complexity for users new to cryptocurrencies [23].

In the same way, Pandora's Loot Box [24] is another project by in the same domain, which attempts to offer a transparent and secure loot box experience using blockchain technology. This project focuses on ensuring that the contents of each loot box are verifiable and fair, aiming to address the common criticisms of traditional loot box systems. However, detailed

empirical studies on its effectiveness and user reception are still limited, highlighting the need for more extensive research and real-world testing to validate its claims and performance.

III. Methodology

A. System Architecture and Process Overview

Our system architecture integrates as shown in Fig. 2 blockchain technology with in-game loot box mechanisms to enhance transparency, trust, and fairness. This section outlines the sequential steps involved in a player's interaction with the loot box system, detailing the roles of smart contracts and blockchain technology in verifying and executing transactions.

*1) **Player Initiation**:* The process starts when a player purchases a loot box, triggering interactions between the game application, smart contracts, and the blockchain network.

*2) **Game Application Interface**:* The game application provides players with loot box details, including items, probabilities, and costs, allowing for informed decisions.

*3) **Smart Contract Verification**:* The game application interacts with a smart contract to authenticate the transaction, ensuring it follows predefined rules and verifies the loot box contents

*4) **Smart Contract Execution**:* After verification, the player calls a smart contract function to draw an item, with the blockchain ensuring a secure, transparent, and tamper-proof transaction.

*5) **Transaction ID Assignment**:* The draw result and a unique transaction ID are recorded on the blockchain, ensuring transparency and traceability.

*6) **Display of Results**:* Finally, the drawn item and transaction ID are displayed to the player, providing immediate feedback and reinforcing trust in the system.

Game developers/providers deploy a smart contract that connects to the loot box market via an API [25]. This contract allows players to view potential items, their probabilities, and loot box costs. Players also have access to the algorithms, including the RNG in the *drawItem()* function, ensuring fairness in item distribution [26].

Players must register their crypto wallets to a blockchain address to interact with the loot box market [27]. Once registered, they can make informed purchase decisions based on the provided information, allowing them to evaluate transactions independently. When a player makes a purchase, the smart contract executes the transaction, and the item is recorded on the blockchain with a unique transaction ID. This ID ensures transaction integrity and transparency, allowing verification by both the player and auditors.

The integration of blockchain technology and smart contracts in the loot box system enhances transparency, trust, and fairness. Players are equipped with all the necessary information to make informed decisions, and the blockchain ensures that all transactions are secure, verifiable, and immutable.

B. Dataset

Our study uses a custom dataset to analyze and validate the smart contract-based loot box system, filling a gap in data on blockchain-based loot box transactions. The dataset includes

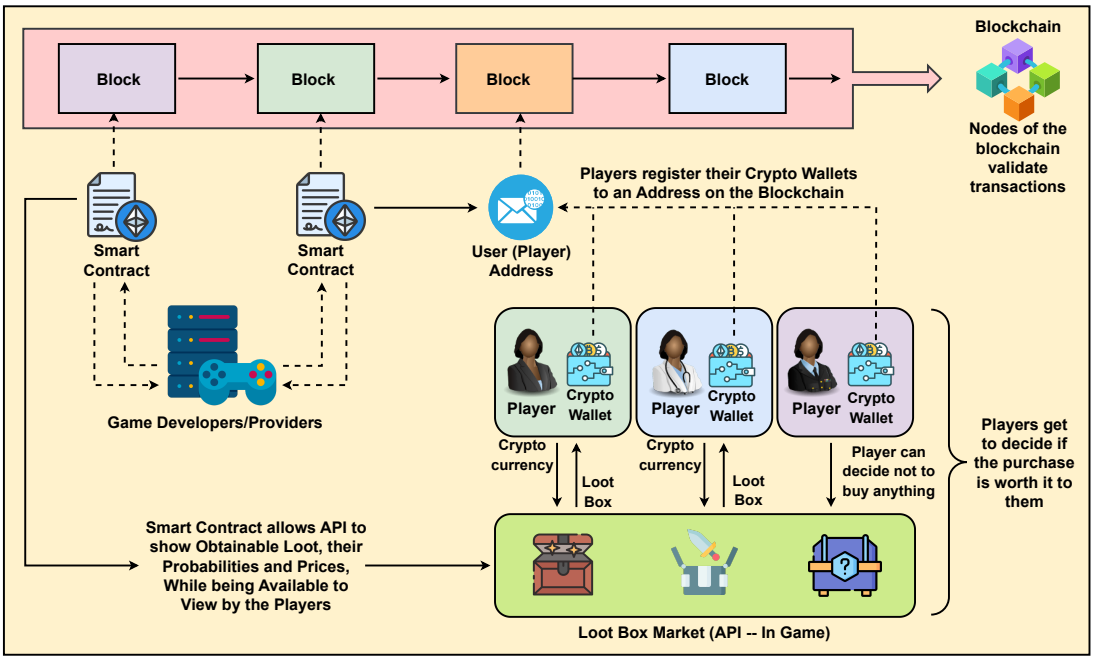

Fig. 2. This figure illustrates the overall system architecture of our loot box management framework. It highlights the interactions between players, game developers, and the blockchain. Players use their crypto wallets to interact with the smart contract, which manages the probabilities and prices of obtainable loot in the game. The blockchain nodes validate transactions, ensuring transparency and trust. Game developers provide the loot box market API that integrates with the smart contract to display the loot details and their probabilities, enabling players to make informed decisions about their purchases.

100 unique entries, each representing a loot box transaction across 16 detailed columns. Key fields include Gaming User ID (unique player identifier), Game (associated game), Item Acquired (item awarded), Item Rarity (rarity category), and Probability (%) of item acquisition. We selected popular games like Apex Legends, PUBG, and League of Legends [28] and included iconic items like Pathfinder's War Machine Skin and Desert Eagle, covering a spectrum of rarity levels to reflect real gaming conditions [29]. For each transaction, the dataset records details such as Date of Acquisition, Transaction Hash, and Txn.Fee in both ETH and Gwei [30], ensuring precise tracking and credibility. The probability percentages are balanced with item rarities to simulate authentic gameplay conditions, and varied player behaviors such as total loot boxes purchased and transaction frequency are also factored in [31]. For example, the DJ Sona item from League of Legends has a 15% acquisition probability and required nine loot boxes on average for acquisition [28]. Usernames were generated using an AI model to mimic real player interactions [32], and item probabilities were assigned accordingly [33].

This custom dataset provides a comprehensive framework for testing the effectiveness of blockchain smart contracts in promoting transparency and fairness in loot box transactions, with data that supports an analysis of player spending patterns and in-game purchase dynamics. It not only aids in validating our system but also sheds light on the broader impact of blockchain on ethical gaming practices.

C. *Ledger Structure*

Our Ethereum-based loot box system leverages the blockchain ledger to ensure transparency and traceability by recording all player interactions and transactions [15]. Illustrated in Fig. 3, this structure uses blockchain's immutability to maintain accurate, verifiable records of essential user information. Key elements include:

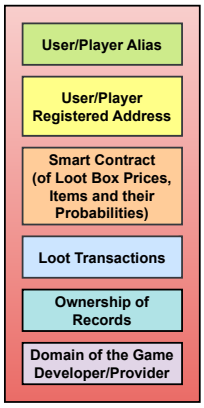

Fig. 3. Ethereum blockchain ledger storing necessary information such as player alias, address, loot box prices, item probabilities, loot transactions, ownership records, and game developer domain.

1) ***User/Player Alias****:* The player's alias, often identical to their in-game username, identifies and tracks their interactions within the game environment.

2) ***User/Player Registered Address****:* The player's blockchain address, tied to their crypto wallet, uniquely links their in-game activities to blockchain transactions.

3) ***Smart Contract Records****:* The ledger documents key details of the loot box smart contract, including the game developer's address, user ID, loot box ID, item list with probabilities, a random seed for fair distribution, and a timestamp to track transaction timing.

4) ***Loot Transaction Records****:* Each loot box transaction is logged with a unique ID, player ID, smart contract source, loot box details, cost, timestamp, and block number, ensuring transparency and traceability.

5) ***Ownership Records****:* The ledger logs item ownership with the item ID, player account address, and fund recipient address, ensuring transparency and traceability.

6) ***Domain of Game Developer/Provider****:* The ledger also records the game developer's domain, linking the service provider to the blockchain loot box system and ensuring transparency in financial transactions.

D. *Roles and Interaction*

In our loot box system, three main roles are involved: the player, the loot box market, and the Ethereum blockchain. As illustrated in Fig. 4 and Fig. 5, the process starts when a player accesses the loot box market through a game app, connecting to the game developer's domain. Using a unique Ethereum address, the player interacts with the smart contract to view blockchain records and item information, ensuring authenticity and informed purchasing decisions.

In Fig. 5, the player, loot box market API, and Ethereum blockchain interact to facilitate loot box purchases. The player is authenticated through their crypto wallet and Ethereum address. The smart contract provides transparency by displaying loot items, probabilities, and prices. When the player buys a loot box, the *drawItem()* function is triggered, generating a transaction and record ID. The player receives the item, and funds are transferred to the game developer, ensuring secure and transparent transactions.

E. *Smart Contract*

A smart contract on the Ethereum blockchain is a self-executing program with predefined rules written in code [34], [35]. It automatically enforces agreements or transactions when specific conditions are met, removing intermediaries and ensuring transparency, security, and efficiency in decentralized applications (dApps) and transactions [36]. Below we discuss the key aspects and features of our smart contracts in detail.

1) ***Inputs to Smart Contract****:* The smart contract for loot boxes uses inputs like user transactions, payment methods, and usernames to seed the Random Number Generator (RNG) for loot outcomes. Access controls manage security via user addresses, while game data such as player profiles and inventories validate transactions and manage assets.

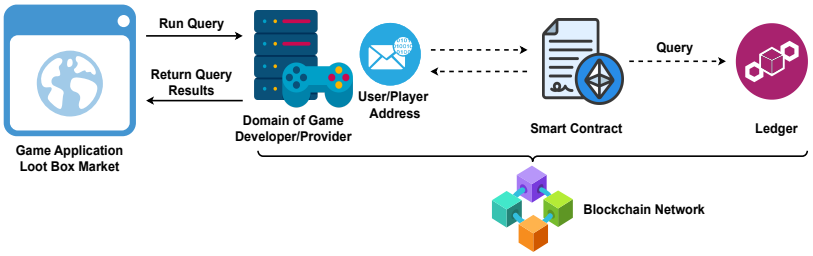

Fig. 4. This event flow figure illustrates the roles and interactions of various entities, including users, smart contracts, and game developers, within the blockchain-based loot box ecosystem.

*2) **Key Functions of Smart Contract**:* To facilitate the management of loot boxes in gaming applications effectively, our smart contract incorporates several critical functions:

- ***drawItem()***: The *drawItem()* function opens a loot box and uses the RNG to determine the item based on predefined probabilities.
- ***getItemProbability()***: This function displays item probabilities for each loot box, promoting transparency and fostering trust by clearly showing the chances of obtaining specific items.
- ***getRandomNumber()***: The *getRandomNumber()* function generates and displays the random number used to determine the loot box outcome, ensuring fairness.
- ***getPlayerItem()***: The *getPlayerItem()* function retrieves and displays the item received from a loot box, ensuring transparency by allowing players to verify the authenticity of the item based on the RNG result.
- ***RNG()***:Keccak256, a cryptographic hash function from SHA-3, generates secure 256-bit outputs from inputs like timestamps and player aliases. In gaming applications, it powers the RNG function to produce random, verifiable numbers for loot box outcomes. This ensures fairness, transparency, and trust in blockchain-based transactions [17].

These functions enable the smart contract to efficiently manage loot box mechanics, ensuring transparency, fairness, and user satisfaction in the gaming ecosystem.

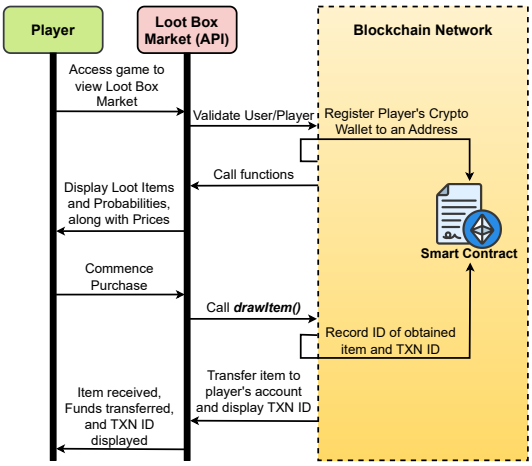

Fig. 5. The sequence diagram depicts the interaction between the player, the loot box market API, and the Ethereum blockchain. It shows the authentication process, viewing of loot items, purchase execution through the *drawItem()* function, and the secure transfer of items and funds, ensuring transparency and trust.

IV. Results and Discussion

A. Average Number of Loot Boxes Purchased by Item Rarity

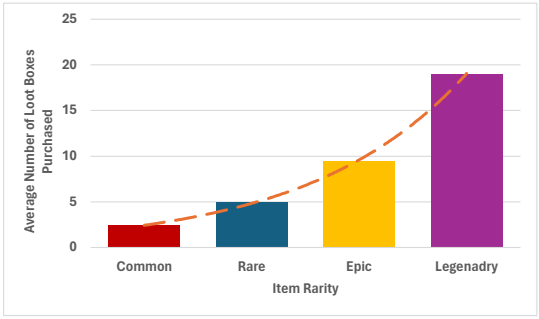

Fig. 6. The graph shows that players need to spend more to acquire rarer items, a detail often not disclosed upfront. This lack of transparency can lead to uninformed spending, as players may not realize the number of purchases required to obtain specific items.

The bar graph in Fig. 6 shows that players must purchase more loot boxes on average to obtain higher rarity items, such as Epic and Legendary, compared to lower rarity items like Common and Rare.

In gaming, item rarities typically fall into the following categories [37]:

- **Common**: These are the most common items, with low rarity, lower power, and accessibility.
- **Rare**: These items are rarer than common ones, offering better attributes or unique appearances, making them more desirable.
- **Epic**: These items are rarer, with enhanced qualities that improve gameplay or offer significant aesthetic value.
- **Legendary**: These are the rarest, most coveted items with top attributes and effects, and are the hardest to obtain.

Fig. 6 highlights the lack of transparency in loot boxes, where players spend more for rarer items without clear odds. It emphasizes the need for better disclosure of probabilities and costs.

B. *Reliability of RNG Function in Loot Box Smart Contract*

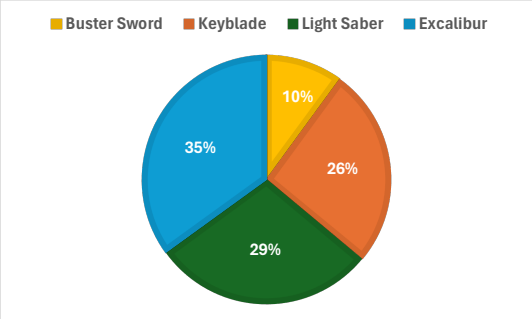

Fig. 7. This pie chart displays the relationship between the outcomes of our RNG function and the assigned probabilities for each item in the loot box smart contract. The percentages of items received in 100 transactions closely match the assigned probabilities, establishing a reliable baseline.

The pie chart in Fig. 7 displays the results of 100 loot box transactions on the Sepolia testnet, showing that the item distribution aligns with the assigned probabilities. This confirms the transparency and reliability of the RNG function, with outcomes such as the Buster Sword, Keyblade, Light Saber, and Excalibur reflecting 10%, 26%, 29%, and 35% of the transactions, respectively.

The alignment between expected and actual probabilities confirms the smart contract's reliability, ensuring consistent odds and fostering trust in its fairness. This enhances transparency in loot box markets.

C. *Transaction Time Analysis in the Sepolia Testnet*

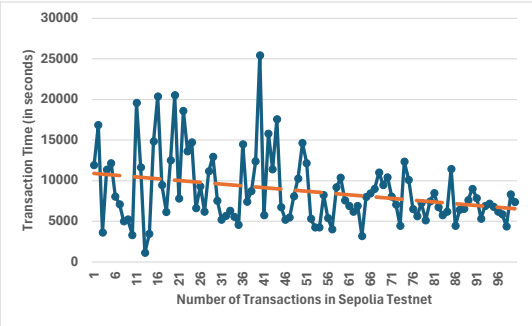

Fig. 8. This graph depicts the relationship between the number of transactions and transaction time on the Sepolia testnet. On average, the transaction time tends to decrease as the number of transactions increases.

Fig. 8 shows the relationship between transaction time and the number of transactions on the Sepolia Testnet, using 100 transactions to evaluate the smart contract's performance. Fig. 8 illustrates that while transaction times fluctuate with increased transactions, the average time decreases as the number of transactions grows on the Sepolia testnet.

The variability in transaction times on the Sepolia testnet, as shown in Fig. 8, is influenced by network congestion, contract complexity, and consensus delays [38]. Despite fluctuations, the trend shows improved efficiency with higher transaction volume, highlighting the need for optimization in high-demand environments.

D. *Transaction Cost Analysis in the Sepolia Testnet*

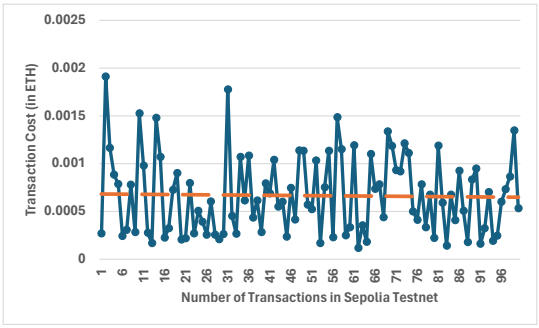

Fig. 9. This graph shows the transaction costs in ETH against the number of transactions on the Sepolia testnet. Despite fluctuations in transaction costs, the trend line indicates that the average transaction cost remains relatively low and not overly expensive.

The graph in Fig. 9 shows the relationship between the number of transactions and their cost (in ETH) on the Sepolia testnet, covering 100 transactions. As the number of transactions increases, transaction costs fluctuate, showing a range of values. Some transactions incur higher costs, while others remain low.

Despite fluctuations, the average transaction cost remains relatively low, as shown by the trend line, which is beneficial for users and developers on the Sepolia testnet.

A notable observation is the lack of a clear trend in transaction costs, indicating that factors beyond transaction volume, such as network congestion, gas prices, and smart contract complexity, influence costs [38]. Higher gas prices during peak network activity lead to increased transaction costs, while lower costs occur during less congested periods.

This pattern highlights the impact of real-time network conditions and transaction complexity on costs. The Sepolia testnet, simulating the Ethereum mainnet, underscores the importance of understanding these fluctuations for efficient blockchain interactions.

V. Challenges, Future Work and Conclusion

While our study demonstrates the potential of an Ethereum blockchain-based loot box system, further exploration is needed. Due to the absence of relevant datasets, we used a simulated dataset for testing in a controlled environment, providing foundational insights. This initial work paves the way for future research using real-world gaming data. Additionally, the Sepolia testnet, resembling the Ethereum mainnet, allowed us to test the model under varying real-world conditions.

Future work will involve deploying and testing the model on the Ethereum mainnet, gathering real player data from diverse gaming platforms to refine its performance. Advanced machine learning techniques will improve the RNG function and predict player behavior more accurately. Integration with existing game economies and virtual asset markets will enhance trust

and fairness in the gaming industry, with a better dataset and real-world application strengthening the system's robustness [39].

In conclusion, our research presents an innovative Ethereum blockchain-based model for addressing loot box exploitation in video games. The model prioritizes player transparency by displaying item probabilities and incorporates a fair RNG function within the smart contract to foster trust and security. Our findings indicate that blockchain-based smart contracts can enhance trust, fairness, and security in loot box markets, promoting a more equitable gaming experience. Further research and real-world application will continue to validate and expand upon these promising results.

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