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Enhancing the Reputation System in Ridesharing: A Blockchain-Based Mutual Escrow and Cool-Off Period Approach

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Abstract

Traditional and decentralized ride-sharing platforms face significant challenges in ensuring trust between drivers and riders due to rating manipulation and biased reputation systems. Our research addresses these issues by introducing mutual escrow, bidirectional dynamic rating, and a cooldown period to enhance fairness and prevent manipulation. Mutual escrow discourages dishonest feedback by assigning a default rating to users who fail to submit a rating within the specified time frame. Bidirectional dynamic rating adjusts reputation scores based on rating consistency, ensuring a more secure and trustworthy system. A cooldown period delays rating submissions, reducing impulsive or retaliatory feedback. Our system strengthens trust and fairness in decentralized ride-sharing by addressing rating manipulation, biased feedback, and reputation attacks. Unlike traditional single-dimensional systems, our approach dynamically adjusts reputation scores based on historical consistency, reducing the impact of unfair ratings. This research contributes to developing fair and decentralized reputation systems, ensuring trust and transparency in ride-sharing by preventing fake ratings, biased feedback, and reputation fraud. Ultimately, this approach fosters a more secure, transparent, and reliable ride-sharing ecosystem.

Keywords: Mutual Escrow Rating, Peer-to-Peer Trust Model, Multidimensional Reputation Scoring, Cooling-Off Period for Ratings, Feedback Token Mechanism

1.Introduction

The emergence of ridesharing platforms has revolutionized urban transportation, creating a peer-to-peer economy that connects drivers with passengers through mobile applications. While these platforms have gained widespread. By implementing mutual escrow rating and bidirectional dynamic rating, we ensure that reputation scores are more reliable and resistant to manipulation. Unlike traditional single-dimensional systems, our approach dynamically adjusts reputation scores based on historical consistency, reducing the impact of unfair ratings. This research contributes to the development of fair and decentralized reputation systems, ensuring trust and transparency in ride-sharing by preventing fake ratings, biased feedback, and reputation fraud. By integrating mutual escrow and bidirectional dynamic range, our system promotes honest feedback, minimizes manipulation, and strengthens the integrity of decentralized ride-sharing. Ultimately, this approach fosters a more secure, transparent, and reliable ride-sharing ecosystem adoption; however, the traditional centralized reputation systems they employ face several limitations in ensuring trust, transparency, and reliability. This research explores the potential of blockchain technology to address these challenges and create a more robust, decentralized reputation system for ridesharing services. Traditional ridesharing platforms typically implement reputation systems based on user ratings and reviews stored in centralized databases. These systems allow passengers to rate their drivers (and vice versa) on various aspects such as punctuality, safety, and overall service quality. However, these conventional approaches suffer from several drawbacks. First, the centralized nature of data storage makes them vulnerable to manipulation and single points of failure. Second, the opacity of ranking algorithms and potential bias in review aggregation can lead to unfair evaluations.

Blockchain technology offers promising solutions to these limitations through its inherent characteristics. The decentralized nature of blockchain ensures that reputation data is distributed across multiple nodes, making it resistant to manipulation and unauthorized modifications. Smart contracts can implement transparent and immutable ranking algorithms, ensuring fair and consistent evaluation of service quality. Furthermore, the cryptographic mechanisms underlying blockchain technology can verify the authenticity of reviews while maintaining user privacy. The immutable ledger also creates an audit trail of all interactions, enabling the detection of fraudulent behavior and malicious actors. The integration of blockchain in ridesharing reputation systems introduces several innovative features:

1. Immutable Review Records: Once recorded on the blockchain, reviews, and ratings cannot be altered or deleted, ensuring the integrity of historical reputation data.

2. Repeated interaction: Our approach reduces the chances of repeated reviews through that same client again and again.

3. Multi-dimensional range: With a multi-dimensional range, it becomes possible for the user and driver to review the other more accurately.

4. Feedback Mechanism: It prevents fake reviews and non-actors, who are not involved in this ridesharing. Only real Drivers or Riders who completed a transaction receive feedback tokens, preventing unrelated users from leaving feedback

This research paper examines the technical architecture, implementation challenges, and potential benefits of a blockchain-based reputation system for ridesharing platforms.

2.Literature Review

Online reputation systems play a crucial role in peer-to-peer (P2P) platforms by fostering trust among participants. Traditional reputation models primarily focus on credibility and user participation, but they often suffer from biased ratings, feedback reluctance, and manipulation risks. To address these issues, various enhancements, such as verification mechanisms, gamification strategies, and review anonymity, have been explored. However, existing models predominantly rely on static, single-dimensional rating systems, limiting their ability to ensure fairness and prevent reputation manipulation [1].

Decentralized reputation systems leveraging blockchain technology have been proposed to enhance transparency and security in multiple domains, including P2P car-sharing, e-commerce, and decentralized federated learning. Blockchain ensures immutability, authenticity, and protection against manipulation by storing reputation scores on a tamper-proof ledger. Some systems integrate feedback tokens, identity verification, and time-limited reviews to prevent whitewashing and unfair scoring. Others utilize multiple blockchains, IPFS, and incentive structures to securely store and process reputation data while mitigating collusion and model poisoning attacks [2, 3].

For instance, distributed ledger-based reputation systems have demonstrated effectiveness in mitigating model poisoning attacks and defending against direct reputation system attacks. While these systems offer strong security guarantees, they introduce trade-offs in resource utilization and scalability [4]. Similarly, blockchain-based reputation frameworks for e-commerce and car-sharing use smart contracts for automated reputation evaluation and monetary incentives to encourage genuine feedback. Reputation scores in such models dynamically adjust based on transaction attributes such as time, amount, and historical scores, improving resistance to unfair ratings and collusion [5, 6].

Hybrid approaches combining permissioned blockchain and verifiable credentials have also been explored to enhance reputation authenticity. Systems utilizing Hyperledger Indy and Hyperledger Fabric provide verifiable credentials with privacy-preserving features while implementing smart contracts for secure and transparent feedback processing [6]. Additionally, blockchain-based electric car-sharing systems leverage IOTA technology and escrow-based smart contracts to ensure trust, cost transparency, and fraud prevention [7].

Despite these advancements, existing reputation systems lack mutual escrow mechanisms, where both parties commit stakes before submitting ratings to ensure accountability. Furthermore, most models are static and single-dimensional, failing to adapt to multi-criteria, and dynamically evolving reputation scores. Additionally, existing models do not address the issue of repeated interactions between the same driver and rider. This creates a vulnerability where a driver or rider can intentionally form repeated connections to manipulate ratings—for instance, a driver might befriend a rider and offer regular rides in exchange for high ratings, or a rider might request the same driver for preferential treatment.

To prevent such manipulation, we propose a cool-off period in which both the driver and rider must wait a set duration (e.g., 7 days) before submitting ratings if they meet again within that time frame. This mechanism prevents immediate influence from repeated short-term interactions, ensuring that ratings remain fair and unbiased.

This gap underscores the need for a mutual escrow-backed, bidirectional rating framework that evaluates users across multiple criteria—such as trustworthiness, ride quality, reliability, and dispute history—while incorporating a cool-off period to prevent rating manipulation through repeated interactions, ensuring a fairer and more resilient decentralized ecosystem.

3.Proposed Methodology

This research proposes a decentralized reputation system for peer-to-peer ride-sharing platforms to mitigate biased ratings, reputation fraud, and Sybil attacks and fake reviews. By leveraging blockchain technology, smart contracts, mutual escrow rating mechanism, and feedback token mechanism our system ensures trust, transparency, and fairness in reputation management. The bidirectional dynamic rating algorithm further refines the evaluation process, making ratings more accurate and resistant to manipulation.

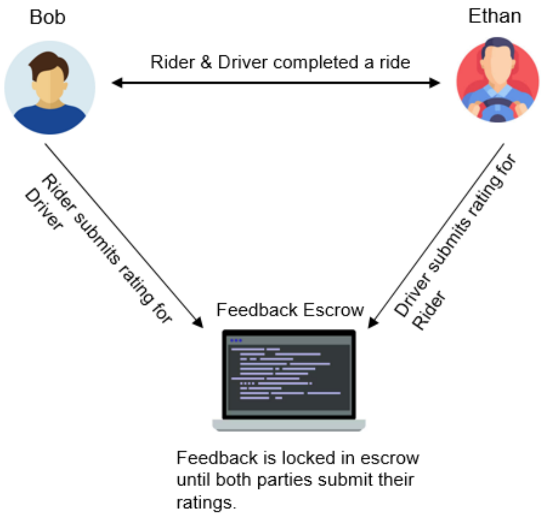
1. Mutual Escrow Rating System

To prevent dishonest ratings, both parties must stake a deposit in an escrow smart contract before submitting feedback. This mechanism ensures:

Rating Fairness: Ratings remain hidden until both parties submit, preventing retaliation.

Escrow Enforcement: If only one party submits a rating, the default rating is provided automatically to the compliant party, discouraging rating fraud.

Eliminating Asymmetry: The system eliminates rating asymmetry, ensuring fairness.



2. Feedback token Mechanism

To prevent fake reviews and non-actors, who are not involved in this ridesharing. Only real Drivers or Riders who completed a ride receive feedback tokens, preventing unrelated, unauthorized users or bots from manipulating ratings.

Token Generation: A unique feedback token is generated at the beginning of each ride.

Verification & Usage: Only users possessing a valid token can submit feedback.

Expiration Mechanism: Tokens have a time-limited validity, ensuring timely submission and preventing outdated submissions.

One-Time Use: Once a feedback token is used, it becomes invalid, preventing duplicate or fake feedback submissions.

Feedback Tokens Workflow:

1) When the ride starts, a unique feedback token is assigned to both the rider and driver.

2) After ride completion, users can submit feedback using their tokens.

3) The system verifies the validity and expiration of the token before allowing feedback submission.

4) Expired or duplicate tokens are automatically rejected.

3. Bidirectional Dynamic Rating Mechanism

Unlike traditional single-dimensional rating systems, our model updates reputation scores dynamically based on rating consistency. Key features include: The reputation system adopts a multi-dimensional scoring approach, evaluating users on factors such as reliability, communication, and safety compliance. To ensure relevance over time, a decay mechanism gradually reduces the influence of older ratings. Additionally, the system incorporates consistency checks that adjust scores when noticeable fluctuations in user behavior occur, helping maintain a fair and accurate reputation profile.

4. Cooldown Period for Fair Feedback

To prevent rating inflation and manipulation from frequent rider-driver interactions, we implement a cooldown period that restricts users from submitting ratings too frequently for the same party. To promote fair and thoughtful feedback, the system introduces a cool-off period that temporarily delays users from rating the same person again within a short timeframe (e.g., 24 hours). This brief pause helps reduce impulsive or emotionally driven responses, encouraging users to reflect on the overall ride experience before submitting their ratings.

Cooldown period Workflow:

1) If a rider and driver interact again within 1 day, they cannot submit a new rating.

2) The system verifies the last interaction timestamp before allowing feedback submission.

3) After the cooldown period expires, normal feedback mechanisms resume.

5. Smart Contract and Blockchain Integration

All ratings and transactions are stored on Ethereum smart contracts, ensuring that the system ensures tamper-proof reputation tracking by storing feedback on a secure, immutable ledger, making it resistant to manipulation. Its transparent and decentralized nature allows all participants to verify ratings without relying on a central authority, fostering trust in the platform.

6. Security and Integrity:

The system verifies each token's validity one-time through the Verifiable Credentials Subsystem (VCS) on the blockchain, ensuring that no tampering or unauthorized access takes place. This mechanism helps maintain the integrity of the feedback process by effectively preventing fake or fraudulent submissions.

4.Implementation

1. System Architecture

This research proposes a decentralized reputation management system that integrates blockchain with a ridesharing platform. The system is built using a combination of blockchain technology for security and transparency, along with a traditional web stack for user interaction. The key components of the architecture include:

Frontend: A React.js-based interface integrated with Web3.js to interact with the blockchain.

Backend: A Node.js and Express.js server to facilitate user interactions with the blockchain, ensuring feedback token validation and enforcing the cool-off period authentication.

Database: MongoDB for off-chain storage of non-critical user information.

Blockchain: Ethereum-based smart contracts implemented in Solidity to manage escrow, and reputation ratings.

2. Cool-Off Period Implementation

To prevent rating inflation and manipulative rating exchanges, a Cool-Off Period is enforced. This mechanism restricts how frequently the same rider and driver can rate each other within a given timeframe, ensuring more balanced and fair reputation assessments. The Cool-Off Period mechanism follows these steps:

Tracking: The system records the timestamp of the last rating exchanged between a specific rider and driver.

Enforcement: If a new rating is attempted within the Cool-Off Period (e.g., 24 hours), the system rejects the submission, preventing frequent rating loops.

Expiration: Once the Cool-Off Period elapses, users.
Regain the ability to rate each other for subsequent rides, maintaining fairness in the rating process.

The cool-off period enforcement follows **Algorithm 1**, which outlines its implementation in the rating submission process:

ALGORITHM 1: ENFORCE COOL-OFF PERIOD

Ensure: Prevent frequent rating exchanges between the same Rider (R) and Driver (D) within a defined time frame.
Require: R and D have completed a ride and attempt to submit a rating.

If (R & D exchanged rating within 24 hrs):
    Reject the new Rating submission
Else If (R & D exchanging rating for the first time in last 24 hrs):
    Allow the rating
    Update the previous_Rating_Time with the current time
Else:
    Reject feedback submission

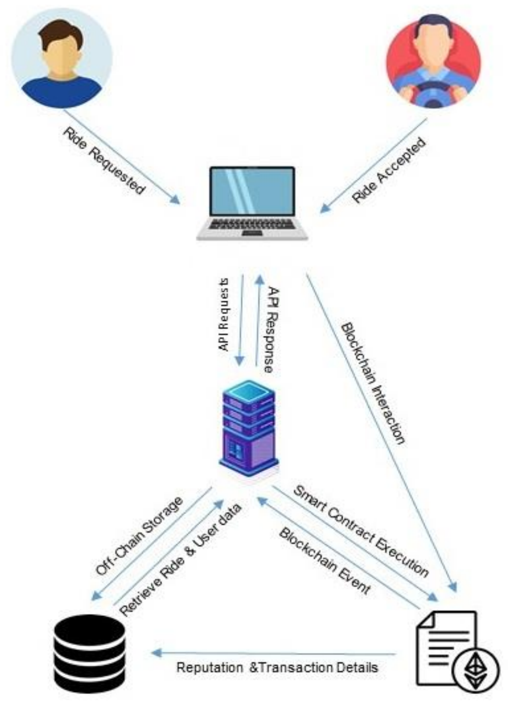


Figure 2: System Architecture for Secure & Transparent Rating System

3. Smart Contract Implementation

The reputation system is governed by smart contracts, ensuring trustless and tamper-proof interactions. The core smart contract functionalities include:

Mutual Escrow Mechanism: Before submitting feedback, both rider and driver are required to stake a deposit, which is held in escrow. If only one party submits feedback, the escrowed amount is refunded only to the compliant user, discouraging rating manipulation.

Feedback Submission with Cooldown Period: To prevent impulsive or retaliatory feedback, the system enforces a cooldown period. Feedback can only be submitted after a pre-defined period (e.g., 7 days).

ALGORITHM 2: ESCROW-BASED FEEDBACK

Ensure: Mutual Escrow is established between
Require: The ride is successfully completed, and both have feedback tokens

If (Feedbacksubmit_time > FT
    Feedback stored on the blockchain
If (only one user submitted feedback):
    The user who didn't submit feedback receives a default rating
Else If (no feedback from either side)**:**
    Both will get a default rating.

4. Feedback Token System

To ensure authenticity in the feedback mechanism, a tokenized approach is implemented. The system generates unique feedback tokens for each completed ride, preventing fake reviews and unauthorized feedback. The feedback token mechanism follows these steps:

Generation: A unique feedback token is created when the ride starts and shared between the rider and driver.

Validation: Only a valid token allows feedback submission, ensuring that only participants of a completed ride can rate each other.

Expiration: Tokens expire after a pre-defined period, preventing delayed or manipulated feedback.

The feedback token follows **Algorithms 3 and 4**, which detail the use of feedback tokens in the submission process.

ALGORITHM 3: ISSUE FEEDBACK TOKEN

Ensure the ride completed successfully between Driver (D) and Rider (R).

Require: R has started a Ride with Driver D.
If (ride_Status > completed):
    Feedback Token issued to both D and R
    R and D use this token to rate each other
Else :
    Ride is canceled

ALGORITHM 4: VALIDATE FT AND EXPIRY

Ensure: Feedback Token (FT) is valid and not expired before submission.

Require: R and D must possess a valid FT.
If (current_time > FT Expiration_time):
    Reject the new Rating submission
Else If (FT == valid && ride_Status == completed):
    Allow the rating
    Update the last rating time to the current time
Else:
    Reject feedback submission

5. Data Storage and Security

- **On-Chain Storage**: Reputation scores, escrow amounts, and feedback token transactions are stored on the Ethereum blockchain for immutability.

- **Off-Chain Storage**: User information and ride details are stored in MongoDB to optimize performance.
- **Security Measures**: To maintain the integrity of reputation data, the system ensures that all entries are immutable and tamper-proof. This is achieved through smart contract-based verification, which prevents any unauthorized manipulation or alteration of feedback records.

6. User Flow

The proposed system ensures a structured and secure feedback process. The workflow follows these steps:

- **Ride Initiation**: The rider and driver agree on a ride.
- **Feedback Token Issuance**: The system generates a unique feedback token for both parties.
- **Ride Completion**: The escrow deposit is locked, and both parties must submit feedback.
- **Cooldown Period Enforcement**: Users cannot rate the same party again for a fixed period.
- **Feedback Validation**: Both cannot rate without a feedback token.
- **Mutual Escrow**: Ratings are stored only if both parties submit feedback.

5.Result

1.Cool-off Period Experiments and Results

1.1. Experimental Setup

To quantify the effectiveness of the Cool-Off Period, we experimented with two user-driver pairs under different conditions:

- Case 1 (Without Cool-off Period):

A single user-driver pair completed 10 rides within a 24-hour period, providing feedback immediately after each ride. Since no restrictions were imposed, multiple ratings were submitted by the same pair on the same day.

- Case 2 (With Cool-off Period):

Another user-driver pair completed seven rides within a 24-hour span, but due to the enforced Cool-Off Period, they were allowed to rate each other only once during that time. The system automatically blocked any additional ratings between the same pair within the 24-hour window to maintain fairness.

1.2. Data Collection and Processing

To analyze rating frequency, we queried the number of ratings recorded within 24 hours for both cases using MongoDB aggregation:

Ratings without Cool-Off Period

```
db.userratings.countDocuments({ userId: ObjectId("user1_Id"),  captainId:
ObjectId("driver1_Id"),  createdAt: {    $gte: ISODate("2025-03-24T00:00:00Z"),    $lt:
ISODate("2025-03-25T00:00:00Z") }  });
```

Ratings with Cool-Off Period

```
db.userratings.countDocuments({ userId: ObjectId("user_2Id"), captainId:
ObjectId("driver2_Id"), createdAt: { $gte: ISODate("2025-03-24T00:00:00Z"), $lt:
ISODate("2025-03-25T00:00:00Z") } });
```

1.3. Result and Observations

Experiment	**Rider-Driver Pair**	**No. of Rides**	**No. of Ratings recorded**
Without Cool-off Period	User1-Driver1	7	7
With Cool-Off Period	User2-Driver2	7	1

• In Case 1, the user and driver rated each other after every ride, leading to 7 ratings in a single day.
• In Case 2, the Cool-Off Period successfully restricted users to only 1 rating per day, ensuring fairness and preventing unfair reputation boosting.

2.Feedback Token Mechanism Experiment and Results

2.1. Experimental Setup
To assess the effectiveness of Feedback Token, we conducted experiments under two conditions:

• Case 1 (Without Feedback Token Authentication):
In the absence of validation, both riders and drivers could submit feedback freely, which opened the door for unauthorized users to submit ratings. This lack of control made the system vulnerable to fake or misleading feedback.

• Case 2 (With Feedback Token Authentication):
Both the rider and driver could only submit a rating if they had a valid feedback token. If the token was either invalid or had expired, the system blocked the rating submission, ensuring only authorized and timely feedback was accepted.

2.2. Data Collection and Processing
The following MongoDB queries were used to track feedback token authentication and expiry:

Rating with valid feedback token

```
db.rides.countDocuments({ feedbackToken: { $ne: null } , captainRated: true,
userRated: true });
```

Rating without invalid or null feedback token

```
db.rides.countDocuments({ feedbackToken: null , captainRated: true, userRated: true });
```

Rating before expiry

```
db.rides.countDocuments({ captainRated: true, userRated: true, userRatingExpired:
false, captainRatingExpired:
false });
```

Rating after expiry:

```
db.rides.countDocuments({ userRatingExpired: true, captainRatingExpired: true });
```

2.3. Results and Observations

Experiments	Total Rides	No. of Invalid Ratings	No. of Valid Ratings	No. of Ratings after Expiry	No. of Ratings before expiry
Without token authentication	22	18	N/A	16	N/A
With token authentication	61	0	34	N/A	52

- 18 ratings were submitted without a feedback token before authentication was enforced.
- 34 ratings were using valid feedback tokens.
- 8 ratings were attempted after token expiry, but they were blocked by system.
- 52 ratings were successful which are within the expiry of the token.

3.Mutual Escrow Rating Experiment and Results

3.1. Experimental Setup

To assess the effectiveness of the Mutual Escrow Rating System, we conducted experiments under two conditions:

Experiments	Total Ratings	Ratings before Mutual Submission	Default Ratings	Finalized Ratings
Without Escrow	10	10	N/A	10
With Escrow	10	0	4	6

- Case 1(Without Escrow Rating)

In the traditional system, riders and drivers could submit their ratings independently, without waiting for the other party. Once submitted, the ratings became visible immediately. This approach also allowed feedback to be given even if the other party chose not to respond.

- Case 2(With Escrow Rating)

To ensure fairness, individual ratings were kept private until both the rider and driver submitted their feedback. The system only disclosed the ratings once both sides had responded or when the escrow period expired. In cases where one party didn't submit feedback, a neutral default rating was applied to maintain balance and prevent misuse.

3.2. Data Collection and Processing

The following methods were used to track ratings under escrow and non-escrow conditions using Remix IDE and smart contract event logs:

• Ratings submitted before the other party (non-escrow): Observed immediate storage of ratings when submitted by one party.

• Ratings submitted but hidden until mutual submission (escrow): Monitored smart contract storage where ratings were held privately until both users rated.
• Default ratings assigned after escrow expiration: Identified cases where one party failed to submit, leading to a default neutral rating after the deadline.

• Finalized ratings with escrow vs. ratings without escrow: Compared the no. of ratings stored instantly (non-escrow) vs. ratings only finalized when both users submitted (escrow).

3.3. Result and Observations

• In the non-escrow systems, all 10 ratings were visible immediately upon submission, leading to potential bias or retaliation.
• In the escrow system, ratings were hidden until both users submitted, ensuring fairness.
• 3 ratings were assigned a default neutral score due to one party failing to submit within the escrow deadline.
• Finalized ratings in escrow were 17, meaning most participants successfully submitted within the timeframe.

3.4. Gas Fee Analysis

To assess the economic feasibility of the proposed mutual escrow and dynamic bidirectional rating system, we conducted a gas fee analysis for various smart contract operations. Gas fees represent the computational cost required to execute operations on the Ethereum blockchain. The following experiments were performed using the Remix IDE, and gas consumption was measured for each transaction.

6.Methodology:

We deployed the smart contract on a test environment and executed key functions while recording the gas used. The primary operations analyzed included:
• **Escrow Creation (createEscrow):** Initiates an escrow agreement between the rider and driver.
• **Rating Submission (submitRating):** Allows users to submit ratings which are stored securely until mutual submission.

• **Escrow Finalization (finalizeEscrow)**: Releases the ratings after both parties submit feedback or after expiration.
• **Fetch Rating Status (getRatingStatus)**: Queries the current status of a rating under escrow (read function, which typically has no cost).

Gas Usage and Cost Analysis:

To estimate costs, the recorded gas values were multiplied by a sample gas price of 20 Gwei and converted to USD based on the current Ethereum exchange rate of $2,088 per ETH. The gas fee for each transaction was calculated using the following formulas:

1.Gas cost in Gwei:
Gas Used * Gas Price (Gwei)

2.Gas Cost in ETH:
Gas Cost in Gwei/1,000,000,000

3.Gas Cost in USD:
Gas Cost in ETH * ETH Price (USD)

The following table presents the gas consumption for each smart contract function:

Operation	**Gas Used**	**Cost(ETH)**	**Cost(USD) (@$2,088/ETH)**
Escrow Creation (createEscrow)	114459 gas	0.00228918 ETH	$4.78
Rating Submission (submitRating)	117836 gas	0.00235672 ETH	$4.92
Escrow Finalization (finalizedEscrow)	54195 gas	0.0010839 ETH	$2.26
Fetch Rating Status (getRatingStatus)	N/A (Read-only)	0 ETH	$0.00

7.Conclusion

This research introduced a mutual escrow and dynamic bidirectional rating system for ridesharing. The system successfully addresses critical challenges such as ratings manipulation, unfair feedback exchange, and rating inflation. The Feedback Token Mechanism ensured that only authorized users could submit ratings, mitigating fraudulent feedback submissions. The Cool-Off Period effectively prevents frequent rating exchanges between the same rider and driver, reducing bias and ensuring fairer evaluations.

Experimental results validate the effectiveness of these mechanisms. The Feedback Token Authentication system successfully differentiated between valid and invalid token usage, preventing unauthorized ratings.

The Feedback Token Expiry mechanism discouraged delayed or manipulated feedback submissions. Additionally, the comparative analysis demonstrated a significant reduction in rating inflation when the cool-off period was enforced. Graphical analysis further illustrated the valid vs. expired feedback tokens, reinforcing the system's reliability.

Future enhancements could focus on optimizing gas efficiency by refining smart contract login and exploring Layer-2 scaling solutions to reduce transaction costs. Automating data collection through smart contract event listeners and off-chain aggregation can improve large-scale validation. The model's adaptability could be tested in other decentralized platforms, such as peer-to-peer marketplaces.

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