Base Fee Manipulation In Ethereum’s EIP-1559 Transaction Fee Mechanism

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Ethereum

market capitalization:
US$ 200 billion
Ethereum

market capitalization: US$ 200 billion

leading smart contract and DeFi platform
Ethereum

- Market capitalization: US$ 200 billion
- Leading smart contract and DeFi platform
- Daily transaction fees: US$ 3 million
History of Ethereum transaction fees

genesis
30 July 2015
History of Ethereum transaction fees

- First-price auction

Genesis:
30 July 2015
First-price auction
First-price auction
First-price auction

$T_4$

$T_5$

$T_3$

$T_6$

$T_1$

$T_2$
First-price auction
First-price auction

\[ T_4 \quad T_5 \]

\[ T_3 \quad T_4 \quad T_5 \quad T_6 \quad T_1 \quad T_2 \]

transaction fees

block reward
History of Ethereum transaction fees

- first-price auction
- genesis: 30 July 2015
- EIP-1559 proposed: 13 April 2019
History of Ethereum transaction fees

- first-price auction
- genesis 30 July 2015
- EIP-1559 proposed 13 April 2019
- EIP-1559 shown to be incentive compatible for myopic miners 1 December 2020
Myopic vs. non-myopic miners

Myopic miners

Non-myopic miners
Myopic vs. non-myopic miners
Myopic vs. non-myopic miners

**Myopic miners**

- Myopic miner (eye) looking forward (to the left)
- Block diagram with gray and blue boxes

**Non-myopic miners**

- Non-myopic miner (eye) looking forward (to the left) and backward (to the right)
- Block diagram with gray and blue boxes, and a dashed box indicating additional structure
History of Ethereum transaction fees

First-price auction

- genesis
  - 30 July 2015

- EIP-1559 proposed
  - 13 April 2019

- EIP-1559 shown to be incentive compatible for myopic miners
  - 1 December 2020

- EIP-1559 deployed
  - 4 August 2021
History of Ethereum transaction fees

- genesis: 30 July 2015
- EIP-1559 proposed: 13 April 2019
- EIP-1559 deployed: 4 August 2021
- EIP-1559 shown to be incentive compatible for myopic miners: 1 December 2020

first-price auction

EIP-1559
EIP-1559 transaction fee mechanism

base fee: $$
EIP-1559 transaction fee mechanism
EIP-1559 transaction fee mechanism

- **Base fee**: $\$, $\$
- **Tip**: $\$
- **Block reward**: $\$, $\$\$

Diagram showing the transaction fee mechanism with different fee levels and a figure representing a user.
EIP-1559 transaction fee mechanism

Base fee is burned and not received by the miner.
EIP-1559 transaction fee mechanism

base fee is dynamically adjusted
EIP-1559 transaction fee mechanism

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EIP-1559 transaction fee mechanism

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EIP-1559 transaction fee mechanism

base fee is dynamically adjusted
EIP-1559 transaction fee mechanism

base fee is dynamically adjusted
Is EIP-1559 incentive-compatible?
Model

user

miner
User
User

\[ tx \]

\[ $$$ \]
Miner
Miner

$p_x$: proportion of mining power
Miner

\( p_x \): proportion of mining power chosen with probability \( p_x \) to mine the next block
Buyer-seller interaction
Buyer-seller interaction

users collaborate with miners if it benefits them both
Steady state
Steady state

only assumption on demand curve is that it is a decreasing function
Steady state

only assumption on demand curve is that it is a decreasing function
Steady state

only assumption on demand curve is that it is a decreasing function

\[ s^* : \text{target block size} \]
Steady state

Only assumption on demand curve is that it is a decreasing function.

$b^* + \varepsilon$: transaction fee

$s^*$: target block size

$b^*$: target base fee

$\varepsilon$: average tip
Steady state

only assumption on demand curve is that it is a decreasing function

\( b^* + \varepsilon \): transaction fee

\( b^* \cdot s^* \): burned

\( s^* \): target block size
\( b^* \): target base fee
\( \varepsilon \): average tip
Steady state

only assumption on demand curve is that it is a decreasing function

\( b^* + \epsilon \): transaction fee

\( b^* \cdot s^* \): burned

\( \epsilon \cdot s^* \): received by miner
Honest strategy in steady state

\( p_x \): proportion of mining power
Honest strategy in steady state
Honest strategy in steady state

tip
base fee
A Miner’s Deviation from the Honest Strategy
Deviation from honest strategy

$p_x$: proportion of mining power
Deviation from honest strategy
Deviation from honest strategy
Deviation from honest strategy
Deviation from honest strategy

- tip
- base fee
Profitability of deviation

users and miners profit from collaboration
Profitability of deviation
Effects on other miners
Effects on other miners

Joining the attack

honest strategy

deviation from honest strategy

it can be rational for a smaller miner to join the attack it observes
Effects on other miners

Joining the attack

- honest strategy
- deviation from honest strategy
- it can be rational for a smaller miner to join the attack it observes

Starting the attack

- honest strategy
- deviation from honest strategy
- it can be rational for a smaller miner to start the attack it knows is coming
Mitigating the Problem
Mitigation

decrease adjustment parameter
Mitigation

decrease adjustment parameter

reacts to slowly too
changes in demand
Mitigation

decrease adjustment parameter

reacts to slowly too
changes in demand

instead of burning base fee,
divert base fee to a special pool
Mitigation

- Decrease adjustment parameter: reacts to slowly too changes in demand
- Instead of burning base fee, divert base fee to a special pool: does not tackle the issue
Mitigation

decrease adjustment parameter

reacts to slowly too changes in demand

instead of burning base fee, divert base fee to a special pool

does not tackle the issue

use average of $W$ previous block sizes instead of only previous block
Mitigation

decrease adjustment parameter

- reacts to slowly too
- changes in demand

instead of burning base fee,
divert base fee to a special pool

- does not tackle the issue

use average of $W$ previous block sizes instead of only previous block

- exacerbates problem
Mitigation

decrease adjustment parameter

- reacts to slowly too changes in demand

instead of burning base fee, divert base fee to a special pool

- does not tackle the issue

use average of $W$ previous block sizes instead of only previous block

- exacerbates problem

use a geometric sequence as weights to average the history of block sizes
Mitigation

decrease adjustment parameter

reacts to slowly too changes in demand

instead of burning base fee, divert base fee to a special pool
does not tackle the issue

use average of $W$ previous block sizes instead of only previous block

exacerbates problem

use a geometric sequence as weights to average the history of block sizes

our approach
Mitigation

\[
\frac{1 - q}{q} q^4 \rightarrow \frac{1 - q}{q} q^3 \rightarrow \frac{1 - q}{q} q^2 \rightarrow \frac{1 - q}{q} q
\]
Mitigation
Mitigation

our proposed mitigation adjusts to new demand almost as quickly as EIP-1559
Mitigation
Mitigation

our proposed mitigation prevents the attack in a significant part of the parameter space
Conclusion

it can be rational to deviate from the honest strategy under conservative assumptions
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without assuming collaboration, it can be rational for smaller miners to join or even start an attack
Conclusion

it can be rational to deviate from the honest strategy under conservative assumptions

without assuming collaboration, it can be rational for smaller miners to join or even start an attack

we proposed mitigation reduces the profitability and often even prevents the attack altogether
Open problems

finding the optimal attack
Open problems

- finding the optimal attack
- in-depth analysis of proposed mitigation
Open problems

- Finding the optimal attack
- In-depth analysis of proposed mitigation
- Differences between proof-of-work and proof-of-stake
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