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# Dissecting EIP-1559

An Important Revision for the Ethereum Gas Fee Model

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**Research and Insights**

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# Content

# Executive Summary

## Key Takeaways

- The Ethereum network currently allocates computing resources to transactions with a first-price auction method: Transaction senders submit their bids to compete for the computing resources, and the sender who submits the highest bid wins and pays his or her bidding price.

- The first-price auction tends to suffer economic inefficiency and suboptimality. Whether a sender can win or gain the most highly depends on other competitors' valuations and strategies. It also contributes to the volatility of the transaction fees on the network.

- The EIP-1559 proposal aims at mitigating the above economic defects and improving the user experience. The bidding method and fixed block size in the current model are replaced by a compulsory base fee and an optional tip, and variable block size. The new model can attain economic efficiency easier than before, and potentially mitigate the volatility in transaction fees.

- The new model cannot significantly reduce the transaction fees on its own, since they are determined by the demand and supply, which cannot be substantially altered by an improvement in the allocation design.

- As the base fee would be burnt, the new model could bring deflation to Ether. This might also slash the revenues earned by miners, as the base fees are destroyed instead of paying to them.

# Introduction

Being the leading financial infrastructure in the digital asset space, the Ethereum network now handles more than a million transactions every day. The heavy network traffics has aggravated the congestion issue of the network, and hence users often pay hefty transaction fees and suffer from delayed transactions. Vitalik Buterin, the founder of the Ethereum network, has made a proposal, EIP-1559, on improving the current transaction fee model. In what follows, we try to dissect the design of the transaction fee models from an economic perspective: First, we illustrate the current model and its economic defects; Second, we explore how the new proposal can potentially fix the existing flaws; Third, we highlight some other potential impact brought by the new model.

# Current Fee Model and Economic Defects

### Ethereum Transaction and Gas Fee

Broadly speaking, a transaction in Ethereum is any action conducted by an externally-owned account (i.e., controlled by humans instead of codes), and this action instructs the Ethereum virtual machine (EVM) to alter the “state”, which describes the current status of all accounts and balances on the network. A common example is a simple transfer of tokens: Bob sends Alice 1 ETH, and this transfer requires Bob's account to be debited and Alice's account credited.

Then here comes the concept of **gas fee**. The sender of the transaction needs to submit a **gas limit** and a **gas price** for the transaction to be executed. The gas limit measures the computing costs required to execute the transactions on the network. It requires a minimum of 21,000 units of gas to proceed a transaction, and more complicated transactions require more computational effort, and hence more gas to proceed. The gas price is the maximum amount a sender is willing to pay per unit of gas. It is measured in the unit of gwei (one gwei equals to $10^{-9}$ ETH). It essentially reflects the current demand for conducting computations on the network. Thus, the total gas fee paid by a sender is the product of the gas price and the gas limit.

$$\boldsymbol{Total\ Gas\ Fee = Gas\ Limit\ \times Gas\ Price}$$

Say, the average gas price is around 178 gwei on Feb 15, 2021, and you are willing to pay this average price for the minimum gas required for a transaction. Then the total gas fee for this transaction equals 178 × $10^{-9}$ × 21000 = 0.003738 ETH, equivalent to 6.73 USD (suppose 1 ETH = 1800 USD).

Where do these gas fees go to? They are paid as compensations to the miners, who undertake to write transactions to a new block. Blocks are batches of transactions and associated metadata. Each block has a **block gas limit**: the total amount of gas spent by all transactions in a block must be less than the block gas limit. The block gas limit has expanded over time, and it currently weighs around 12.5M gas.

A miner has the power to determine which transactions to include and their ordering within the block. A block confirmation is therefore the act of the transaction being included in a block on the blockchain. It is not hard to imagine how the miner would behave in this setting: in order to earn the most from creating a block, a miner naturally places higher priorities on transactions with high gas fees. This illustrates how Ethereum allocates the computing resources, i.e., gas, to the transactions. Using the terminology of economics, this way of allocating resources is classified as a **first-price auction.**

### First-Price Auction and Economic Defects

In a traditional first-price auction, the potential buyers submit their sealed bids for an object. The bidder with the highest bid is awarded the object and pays his/her bidding price. In the case of Ethereum network, the transaction senders are the bidders, and they compete for gas to get their transactions included in a block. This method of allocation may look fair and efficient at first glance as the winner is the one who pays the most. **Though maybe counterintuitive, an allocation of first-price auction tends to be economically inefficient and the bidder's strategy is usually suboptimal.**

We define an efficient allocation and an optimal bid as follows:

**Efficient Allocation:** From an economic perspective, an allocation is efficient whenever the resources are allocated to those who value the resources most.

**Optimal Bid:** A bidder tries to obtain the greatest gain from the auction. If the bidder wins the bid, the net gain is the difference between his/her own valuation of gas and the bidding price. For the winner, his/her bid is optimal if it can maximize the net gain.

Let us check why an allocation resulting from a first-price auction usually fails these two conditions.

Consider a block which can only include one more transaction. Assume there are five transaction senders competing for the final slot. The five senders' valuations are listed in the table below: Sender A is the highest-valued user while Sender E is the lowest-valued user. Thus, the allocation is efficient if the gas is allocated to Sender A. We now have two cases:

**Case 1: All the senders bid at a price lower than their own valuation by 10.**
Everyone aims at getting a net gain of 10. Sender A gets the slot as he/she submits the highest bid, 100. It is thus an efficient case. Nevertheless, it is not the optimal bid for Sender A. If Sender A lowers the bid to 91, he/she can still win the bid while raising the net gain from 10 to 19 (=110-91). As a result, Sender A would find his/her own bid overpriced after knowing others' bids afterwards.

**Case 2: Senders A to D try to earn higher net gains by bidding lower; Sender E acts more conservatively and bids higher.**
Sender E wins the bid as 60 is the highest bid, and this allocation is economically inefficient as the resource is allocated to the lowest-valued user. In other words, the social gain is lower as compared to assigning the resource to the highest-valued user. Interestingly, Sender E's bid is also not the best one by hindsight, as he/she can further enlarge the net gain by setting a bid in between 41 and 59.

**Examples of inefficient allocations and suboptimal bids**

| Senders' Valuations and Bids | | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Valuation | 110 | 100 | 90 | 80 | 70 |
| Case 1 | | | | | |
| Bid | 100 | 90 | 80 | 70 | 60 |
| - Efficient in the sense that the highest valued bidder A wins the bid<br>- Sender A's bid is suboptimal | | | | | |
| Case 2 | | | | | |
| Bid | 40 | 30 | 30 | 20 | 60 |
| - Inefficient in the sense that the lowest-valued bidder E wins the bid<br>- Sender E's bid is also suboptimal | | | | | |

In short, it is common that we can lose in such auction even if we are the highest-valued bidders, and our bids are usually far from optimal in terms of maximizing gains. **The culprit is that the final auction outcome highly depends on the competing bidders' valuations and strategies.** In practice, we can hardly make perfect guesses about the competitors' valuations and strategies. Hence, we often regret bidding too high if we win, and too low if we lose.

Besides, as different bidders can have substantially different valuations and strategies, the bidding prices, i.e., gas prices, can be extremely volatile. It is not rare that the gas price suddenly goes up by tens of times with surging demand. In principle, the computing costs involved in proceeding different transactions should not be as volatile as the gas prices suggest. This leads to significant mismatch between the gas fees and the computing costs and, hence, uncertainty in fee estimation.

Now we move on to see whether the new mechanism specified in EIP-1559 can fix these issues.

# Improvement of the New Model

Let us go over the new model proposed in EIP-1559, which revolves around three concepts, namely, base fee, variable block size and tips to miners.

### Base Fee

- Instead of bidding gas prices, transaction senders need to pay a basic fee to get their transactions included in a block. The basic fee is determined by the preceding blocks only, and not impacted by the transactions included in the current block.
- The base fee is adjusted up and down by the protocol according to the level of network congestion.
- All base fees paid are burnt. In other words, the Ethereum paid as base fees are removed from the circulating supply of Ethereum.

### Block Size

- The current block gas limit (12.5M gas) is replaced by two values: a **long-term average target**, and a **per-block hard cap.** The long-term average target equals the current block gas limit, while the per-block hard cap doubles the target.
- If the gas usage exceeds the per-block target, the base fee adjusts slightly upward; if it is below the target, it adjusts slightly downward.
- According to the specifications in the proposal, the base fee increases by 12.5% if the previous block hit the hard cap and decreases by 12.5% if the previous block is empty, i.e., zero gas usage.

- Therefore, in comparison to the block size, the base fee adjusts to a smaller extent in response to changing demands.

### Tips to Miners

- On top of the base fee, a transaction sender can pay an addition tip. While the base fee is burnt, the tip goes to the miners.

- In case of surging demands for transactions, the tips can motivate the miners to prioritize transactions. It can also compensate miners for uncle risk (i.e., the risk that their block will not be added to the main chain).

These changes can potentially fix the economic defects of the current model:

### Improving Economic Efficiency

The new model can attain economic efficiency more easily than the current one. If we ignore the optional tips paid to the miners, it is the same as selling and buying products at stipulated prices in a supermarket. Buyers only need to compare their valuation against the base fee: they will pay if their valuations outweigh the costs, and vice versa. The allocation is efficient because those who choose to pay the base fee must have higher valuations than those who are unwilling to pay. In the example below, only the highest valued bidder Sender A is willing to pay the base fee. Also, the rule of the game is more straightforward than an auction. People do not need to guess other competitors' valuation and strategies, and the allocations naturally maximize their net gains. That said, in case of surging market demand for transactions, senders can still compete for gas by giving extra tips, which would make the allocation partially a first-price auction.

**An Example of Base Fee Mechanism**

| Senders' Valuations and Base Fee | | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| Valuation | 110 | 100 | 90 | 80 | 70 |
| Base Fee | | | 105 | | |
| - Only Sender A pays the base fee | | | | | |
| - The gas is allocated to the highest valued bidder A | | | | | |
| - The allocation is naturally optimal | | | | | |

### Mitigating Volatility in Gas Fees

The following example illustrates how the new model can potentially smooth the volatility in gas fee.

Suppose the usage of gas originally hovers around the long-term target, i.e., 12.5M per block. And then the launch of a new token leads to a sudden spike in the demand for transactions on the network. In the current model, many new transaction senders would join and bid at higher prices. As the block size is limited at 12.5M, these new senders tend to displace those who submit the bids earlier but at lower prices, resulting in delayed transactions of the latter group.

Now the maximum block size is doubled, so more senders can now get their transactions included without much delay. Meanwhile, the base fee of the next block adjusts slightly upward in response to the congestion. The base fee gradually increases until it is high enough to drive away some of the senders and bring the block usage down to the long-term target. We can see that the volatility in gas fee is constrained by the pricing mechanism of the new protocol, and it is, in fact, partially transferred to the variability in the block size.

### Simple Simulation

Using the following naïve assumptions, we can simulate the changes in gas fee and block size in the new model as compared to the current model.

1. There are two demand conditions: high demand and low demand. Technically speaking, they are represented by linear demand curves in our studies:
   Low demand condition: gas demanded = 17500000 – 100000 × gas fee
   High demand condition: gas demanded = 30000000 – 100000 × gas fee
   We also assume that the tips to miners are eligible in our case.

2. The settings of the block size supply are different in the two models:
   Current Model: The block size is fixed at 12.5M gas per block
   EIP-1559 Model: The block size adjusts according to a specific rule stipulated in the proposal

The following two charts illustrate how the gas fees and block size change in response to the changes in demand for transactions.

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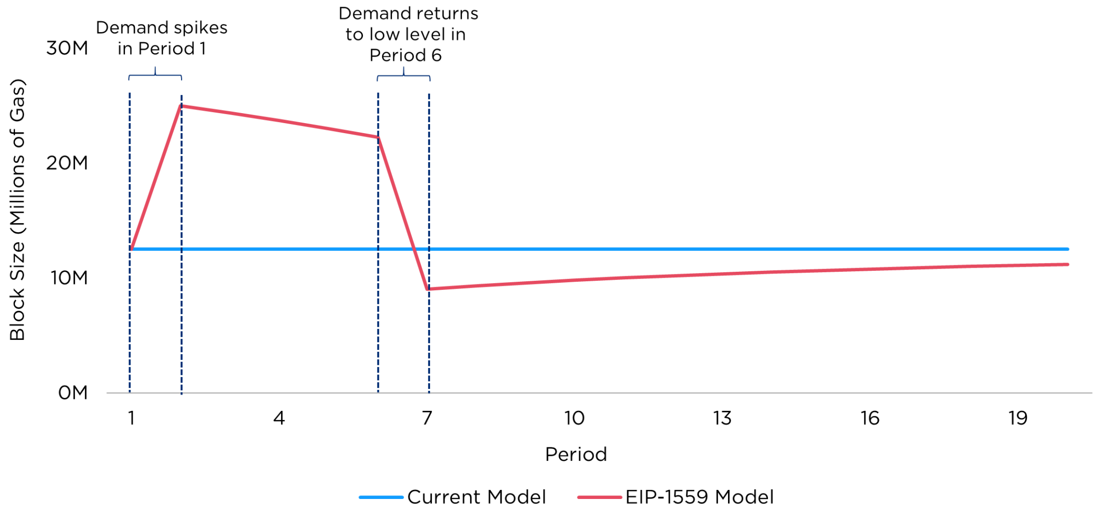
## Changes in Block Size in Response to Changes in Demand for Transaction

*As compared to the current model, the changes in block size are more volatile in the EIP-1559 model*




*Source: Crypto.com Research*

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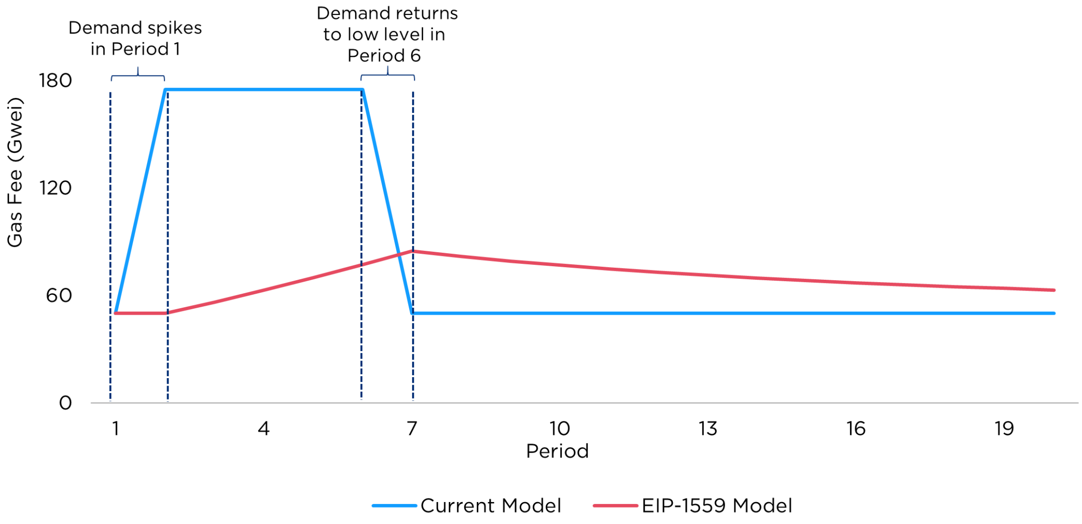
## Changes in Gas Fee in Response to Changes in Demand for Transaction

*As compared to the current model, the changes in gas fee tend to be smoother in the EIP-1559 model*




*Source: Crypto.com Research*

In Period 1, the demand is low. The gas fee is 50 gwei and the block size is 12.5M. This is also the long-term target in our case.

In Period 2, there is a sudden spike in demand for transactions. In the current model, the gas fee surges to 175 gwei as the block size is fixed at 12.5M. In the new model, the gas fee stays at 50 gwei since the gas fee depends on the preceding block size; the current block size reaches the maximum 25M.

From Period 2 to Period 6, the demand stays high. The gas fee stays high with fixed block size in the current model. In the new model, the gas fee gradually increases from 50 gwei to 77.3 gwei, and the block size decreases from 25M to 22.3M.

In Period 6, the demand falls back to the low level. The gas fee immediately retraces to 50 gwei in the current model. In the new model, the gas fee increases slightly as the preceding block size is above the target level; the current block size sharply pungles below the long-term target 12.5M.

Since Period 7, the demand remains low. In the current model, the gas fee and the block size respectively stay at 50 gwei and 12.5M. In the new model, both the gas and the block size slowly converge to the long-term levels.

In short, this simulation illustrates our former intuitive explanation: the new model makes the transaction fees less volatile by allowing a higher flexibility in the block size.

# Other Potential Impact of the New Model

### Impact on Transaction Fees

While the new model can mitigate the price spikes in the existing model to a certain extent, it cannot significantly reduce the gas fees on its own. As everyone knows, market prices fundamentally depend on demand and supply. As for Ethereum, the transaction fees are often unreasonably high since the network capacity cannot effectively catch up with the growing demand for transactions. This is basically the scalability issue of the Ethereum network. For example, if the transaction throughput is enhanced (i.e., an improvement in the supply of computing resources), the transaction fees naturally shrink. Meanwhile, an improvement in the allocation mechanism only streamlines the process of handling transactions, and it cannot significantly alter the underlying supply and demand that determine the transaction fees.

### Monetary Effect of Burning Base Fees

Another main concern revolves around the impact of burning base fees on the value of Ether. Since the base fees paid for transactions are burnt, the value of the existing Ether naturally increases due to a reduction in the monetary quantity. Thus, the burning rule implicitly refunds all the Ether holders. If the base fees burnt significantly exceed the new Ether created in block mining, Ether will experience deflation. There would be more uncertainty about the inflation rate over a short period of time, but the long-term inflation could be capped at around 0.5%-2.0% with the full transition to Ethereum 2.0.

### Impact on Miners' Revenue

The proposal remains controversial, not least because it could slash the revenues of miners. Flexpool, a minority Ethereum mining pool, slammed the proposal for paying "the miners significantly less for the same work". This is probably true as miners are considered overpaid in EIP-1559. The transaction fee is currently fully pocketed by the miners. Under the new model, the base fee, the compulsory payment, would be burnt and the miners would probably lose most of it (they might still indirectly gain from the increase in the overall Ether value); the optional tips are expected to be quite trivial for most of the time.

# Summary

## Key Takeaways

- The Ethereum network currently allocates computing resources to transactions with a first-price auction method: Transaction senders submit their bids to compete for the computing resources, and the sender who submits the highest bid wins and pays his or her bidding price.
- The first-price auction tends to suffer economic inefficiency and suboptimality. Whether a sender can win or gain the most highly depends on other competitors' valuations and strategies. It also contributes to the volatility of the transaction fees on the network.
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